RESEARCH ARTICLE



Anatomical and morphological spine variation in Gymnocalycium kieslingii subsp. castaneum (Cactaceae)

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Abstract

Although spine variation within cacti species or populations is assumed to be large, the minimum sample size of different spine anatomical and morphological traits required for species description is less studied. There are studies where only 2 spines were used for taxonomical comparison amnog species. Therefore, the spine structure variation within areoles and individuals of one population of Gymnocalycium kieslingii subsp. castaneum (Ferrari) Slaba was analyzed. Fifteen plants were selected and from each plant one areole from the basal, middle and upper part of the plant body was sampled. A scanning electron microscopy was used for spine surface description and a light microscopy for measurements of spine width, thickness, cross-section area, fiber diameter and fiber cell wall thickness. The spine surface was more visible and damaged less in the upper part of the plant body than in the basal part. Large spine and fiber differences were found between upper and lower parts of the plant body, but also within single areoles. In general, the examined traits in the upper part had by 8-17% higher values than in the lower parts. The variation of spine and fiber traits within areoles was lower than the differences between individuals. The minimum sample size was largely influenced by the studied spine and fiber traits, ranging from 1 to 70 spines. The results provide pioneer information useful in spine sample collection in the field for taxonomical, biomechanical and structural studies. Nevertheless, similar studies should be carried out for other cacti species to make generalizations. The large spine and fiber variation within areoles observed in our study indicates a very complex spine morphogenesis.

Keywords

Areole, fiber, minimum sample size, spine cross-section, spine morphogenesis, spine surface

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Introduction

Spines may be considered one of the most characteristic morphological structures of the *Cactaceae* family. Cactus spines are the modified bud scales of an axillary bud, originating from primordia which are morphologically indistinguishable from the leaf primordia (Mauseth 2006). Spines contain just two cell types, which never occur in long-shoot leaves of cacti: libriform fibers and sclerified epidermis cells (Mauseth 2006). The cactus spine epidermis lacks stomata. In a few species, some spine epidermis cells elongate outward as trichomes (Sotomayor and Arredondo 2004, Mauseth 2006, Řepka and Gebauer 2012). The epidermis can be continuous, divided into single cell elements or transversely fissured, and such fissures extend deeply into the underlying sclerenchyma (Barthlott 1979).

Spines are not only a lifeless part of the plant body but have several important functions. They provide defense against herbivores (Norman and Martin 1986, Gibson and Nobel 1986), protect the sensitive meristems from freezing temperatures (Loik and Nobel 1993, Mauseth 2006) and shade the plants to avoid temperature stress (Gibson and Nobel 1986, Mauseth 2006). Consequently, each cactus must evolve its spine coverage pattern in order to maximize its photosynthetic efficiency within its own habitat (Menezes et al. 2015). The spine surface of *Opuntia* is also constructed as an efficient system to collect fog and to drive water droplets towards the spine base, where they are absorbed (Ju et al. 2012). Moreover, the areole position on the plant body may reveal past physiological and climatic variation since new spines develop on the top of the cactus body whereas the oldest spines are situated in the basal part (English et al. 2007). The exception are tree-like species of *Opuntia* and *Quiabentia*, which continue producing spines from their lower areoles even in old age (Rowley 2003).

The spine diversity within the family is truly spectacular and spine anatomical and morphological traits are useful tools for taxonomists (e.g. Hunt et al. 2006, Mosco 2009, Řepka and Gebauer 2012). Although, there is evidence that spine development is influenced by genetic (Mihalte and Sestras 2012) and environmental conditions as water availability or solar radiation can modified spine growth (e.g. Peharec et al. 2010, Menezes et al. 2015). Nevertheless, to the best of our knowledge, there is no prior study analyzing spine and fiber structure variation within areoles, individuals or populations, with the exception of variation in spine number and length (e.g. Schmalzel et al. 2004, Hunt et al. 2006, Baker and Butterworth 2013, Menezes et al. 2015). Although the variation in spine anatomical and morphological traits within a population or species is assumed to be large (Mauseth 2006), there are studies where only 2 spines were used for *Turbinicarpus* species comparison (Mosco 2009) or for the assessment of spine stiffness (Schlegel 2009).

Spine and fiber variation within areoles and individuals was studied in one *Gymnocalycium kieslingii* subsp. *castaneum* (Ferrari) Slaba population with the intent to solve three questions: (1) does areole position on the plant body play an important role in spine and fiber variation?; (2) are spine and fiber traits less variable within an

areole than between areoles and individuals?; (3) how many spines need to be collected for an analysis of specific traits? Our results will provide useful information for spine sample collection in the field for taxonomical, biomechanical, physiological or structural studies.

Methods

Plant material

A single representative of the nominate subgenus of *Gymnocalycium*, *G. kieslingii* subsp. *castaneum* was chosen for the study. This is an endemic taxon of the Argentinian province of La Rioja, which is taxonomically clear with relatively low morphological variability. It grows in 13 populations occupying fairly narrow ecological niche. It grows on the poor and highly permeable sandy soils without humus, blended with skeleton basement rock, generated by the disintegration of granitoids on the slopes of the Sierra de Velasco Mts. The climate is semi-arid and the mean annual precipitation is 360 mm. The mean annual temperature is 20 °C with 2,800 hours of sunshine (http://www.arquinstal.com.ar/atlas/datos/larioja.html). Plants are uniformly found under/or outsides of *Larrea cuneifolia* Cav. in the phytogeographical district Monte (Cabrera 1976) at altitudes of 1250–1550 m. Distribution area is relatively small (cca 760 km²) compared to other species of the subgenus. It lies between city of Aimogasta in the north and city of Villa Sanagasta in the south.

The plant usually forms flattened spherical bodies 60–90 mm in diameter. It rarely achieves a greater height than width (Till 1990). The plant material was collected from one population at the sandy depression of Bolsón de Huaco, SSW of the village of El Huaco in the northern part of the La Rioja Province, at altitude of 1260 m (67°07'S; 29°22'W). Fifteen plants were randomly selected on a ca. 700 m line along the road (north-south), at distances of 50 m from each other. From each plant, one areole from the basal, middle and upper part on the northern face of the plant body were sampled (i.e. 45 areoles in total). Additional areoles were sampled from 5 plants at each examined position for scanning electron microscopy (i.e. 15 areoles). Only fully developed areoles were collected.

Scanning electron microscopy (SEM)

The whole areole was mounted on specimen stubs, sputter-coated with gold, and observed with high-vacuum SEM using a VEGA TS 5130 instrument (Tescan, Czech Republic) operating at 15 kV. Images of the whole areole and detailed images of the spine surface in the middle and top spine parts were made. From these images, epidermis characteristics, shape of epidermis cells, presence and type of trichomes and presence of fissures were determined.

Light microscopy

A 5% solution of hydrochloric acid was used to soften spines before sectioning. In this solution, two days of soaking was sufficient to soften the spines for anatomical analysis. The spine length (S_1) was measured before making cross-sections. Handmade cross-sections were taken from the spine base and were examined under a bright field microscope (Olympus BX51, Olympus Czech Group, Czech Republic) at magnifications up to 400× and were photographed using a digital camera (Olympus E-330, Olympus Czech Group, Czech Republic) connected to a computer with the QuickPhotomicro 2.3 software (Promicra, Czech Republic). Spine width (S_w), spine thickness (S_{th}), spine cross-section area (S_a), spine circumference (S_c), fiber maximum and minimum diameter (F_{max} and F_{min}), and cell wall thickness (CW_{th}) were measured using the ImageTool 3.00 software (UTHSCSA, USA) (Fig. 1). Ten fibers were measured in each spine. Only the largest fibers were measured as fibers at the end taper. Spine and fiber roundness (S_r and F_r , respectively) were defined as the S_w/S_{th} and F_{max}/F_{min} ratio, respectively, with a ratio of 1 denoting a perfectly round cross-section and larger ratios indicating a more ellipsoidal shape. In total, 245 spines were examined.

Statistical analysis

The first step was the calculation of fundamental descriptive characteristics using linear mixed effect models (LME). In these models, all of the traits come from a nested design; therefore, we used LME to avoid the problem of pseudoreplication (Hurlbert 1984; Pekár 2012). In the LME analyses, traits were treated as factors with fixed effects, and individuals and areoles were treated as factors with random effects. LMEs were fitted using the LME function in the NLME library of the R statistical program (R Development Core Team 2015). Results from the first step were used for other calculations. The influence of spine position on the plant body was analyzed using one-way nested ANOVA. Plant position was treated as a factor with fixed effects, and individuals and areoles were treated as factors with random effects. In the second step, minimal sample size (N) was calculated according to the following equation:

$$N = \frac{\sigma^2 (t_{1-\alpha/2}(n-1))^2}{D^2}$$

where σ is the assumed standard deviation (SD) for the group, the $(t_{1-a/2}(n-1))$ value is the quantile of the Student's *t*-distribution for n-1 degrees of freedom and D is the desired margin of error. The interval limits for minimum sample size were taken as 10, 15 and 20% differences of the mean. Only spines sampled from the middle part of plant body were used for minimum sample size calculation. Calculations were performed in the R software environment (R Development Core Team 2015) and STATISTICA v. 10 (StatSoft, USA).

All acronyms, abbreviations and symbols are defined in Table 1.



Figure 1. Measured spine traits: spine width (S_w) and spine thickness (S_{th}) . Fibers are shown in the detailed picture.

Trait Explanation		Unit				
	Spines					
S ₁	Spine length	mm				
S _w	Spine width	mm				
S _{th}	Spine thickness	mm				
S _a	Spine cross-section area	mm ²				
S _c Spine circumference		mm				
S _r	Spine roundness	-				
Fibers						
F _{max}	Fiber maximum diameter	μm				
F _{min}	Fiber minimum diameter	μm				
CW _{th}	CW _{th} Cell wall thickness					
F _r Fiber roundness		-				

Table 1. Spine and fiber traits, their abbreviations and units, examined throughout the study.

Results

Spine surface structure in SEM

Spines in the basal part of the plant body were either completely covered with mineral deposition so that the surface structure was not recognizable or the surface was only



Figure 2. SEM images of upper, middle and basal part of *Gymnocalycium kieslingii* subsp. *castaneum*. **a** surface of spine from basal part covered with mineral deposition **b**, **c** surface of spine from basal part with a few epidermal cells **d** damaged, bent and deformed tip of spine from basal part **e** surface of spine from middle part with clearly visible epidermal cells sharply bent upward in upper part **f** surface of spine from upper part with very clearly visible and undamaged epidermal cells **g** undamaged top part of spine from upper part **h** epidermal cells of spine from upper part, bent lengthwise in its central part. Scale bar = 200 µm.

partially visible (Fig. 2a, b). In rare cases, epidermal cells were still obvious (Fig. 2c). Spine tips were usually damaged, bent and deformed (Fig. 2d).

In the middle part of the plant body, the spine surface was only slightly damaged. The epidermal cells were clearly visible (Fig. 2e) and were only missing in a few cases. They were generally rectangular in shape (major to minor axis diameter ratio 2:1). Epidermal cells were usually sharply bent upward in the upper part (Fig. 2e) and arranged in regular transverse rows with different directions. In rare cases, deep fissures were observed.

Epidermal cells of spines in the upper part of plant body were very clearly visible and undamaged (Fig. 2f, g). Epidermal cells were irregular in both shape and size. They were flat on the spine tips and started to bend slightly to sharply at some distance from the spine tips (Fig. 2g). In some cases, they were also bent lengthwise in their central part (Fig. 2h). They were usually arranged in regular rows. The rows were wavy in shape and ran slightly upwards. No fissures were observed.

Spine variation between individuals

Spine length (S_1) ranged from 3 to 16 mm and spine cross-section area (S_a) from 0.21 to 2.81 mm² (Table 2). S_1 and S_a had the largest coefficient of variation (CV) between individuals (Table 3). In contrast, spine roundness (S_r) had the lowest CV (Table 3). In most cases, the shape was near-circular, as the mean S_r was 1.25 (Table 2). The mean fiber maximum diameter (F_{max}) and fiber minimum diameter (F_{min}) were 13.7 and 10.03 µm, respectively (Table 2). The studied fiber traits were less variable than spine traits between individuals (Table 3). Fiber roundness (F_r) was the least variable

Trait (unit)	Trait (unit) mean±SD min max		mean±SD	mean±SD	
	All sj	Individuals	Areoles		
		Spi	nes		
$S_1(mm)$	8.7±1.6	3	16	8.7±6.4	8.7±4.5
S _w (mm)	1.05±0.14	0.58	2.21	1.05±0.5	1.05±0.4
S _{rb} (mm)	0.85±0.10	0.43	1.63	0.85±0.4	0.85±0.3
$S_a (mm^2)$	0.73±0.16	0.21	2.81	0.72±0.6	0.73±0.5
S _c (mm)	3.05±0.37	1.69	6.16	3.05±1.4	3.07±1.1
S	1.25±0.17	1.01	2.08	1.25±0.3	1.25±0.2
		Fib	bers		
F _{max} (μm)	13.72±2.6	8.1	20.8	13.7±5.5	13.8±3.9
F _{min} (μm)	10.05±1.8	5.9	15.9	10.03±3.9	10.08±2.8
CW _{th} (µm)	3.82±0.99	1.5	6.6	3.8±2.2	3.8±1.5
F	1.38±0.14	1.1	2.3	1.38±0.15	1.38±0.15

Table 2. Mean $(\pm SD)$, minimum and maximum values for all sampled spines (n=245), and mean values $(\pm SD)$ for individuals (n = 15) and areoles (n = 45) of *Gymnocalycium kieslingii* subsp. *castaneum*. See Table 1 for explanation of spine and fiber traits.

Trait	CV (%)				
(unit)	All spines Individuals		Areoles		
		Spines			
S ₁ (mm)	18	74	52		
S _w (mm)	13	48	38		
S _{th} (mm)	12	47	35		
$S_a (mm^2)$	22	83	68		
S _c (mm)	12	46	36		
S _r	10	24	16		
Fibers					
F _{max} (μm)	19	40	28		
F _{min} (μm)	18	39	28		
CW _{th} (µm)	26	58	39		
F	10	11	11		

Table 3. Coefficient of variation (CV) for spine and fiber traits between all sampled spines, individuals and areoles. Values of CV above 40% are shown in bold. See Table 1 for explanation of spine and fiber traits.

trait (Table 3). The mean F_r value was 1.38 (Table 2), indicating fibers with a slightly ellipsoid shape. On the other hand, cell wall thickness (CW_{th}) had the highest CV of the fiber traits (Table 3), ranging from 1.5 to 6.6 µm (Table 2).

Spine variation between areoles and within the plant body

The fiber traits were less variable than spine traits between areoles (Table 3). Although the CV of spine and fiber traits between areoles was lower than that between individuals, it was higher than 30% in most cases (Table 3). The most and the least variable spine and fiber traits between areoles were the same as between individuals. The CV of S_a and S_l was the highest, whereas the CV for S_r and F_r was the lowest (Table 3). Spine and fiber traits were similar in the base and middle part of plant body. However, the upper part was significantly different from the other parts for almost all studied spine and fiber traits (except S_l , S_r an F_r) (Table 4). In general, studied traits were by 8–17% higher in the upper part than in the lower parts (Table 4).

Spine variation within areoles

The CV of spine traits within an areole was lower than between areoles and individuals (Table 3 and Suppl. material 1). Nevertheless, a CV value higher than 15% was observed for S_a (91% of sampled areoles) and for S_1 (60% of sampled areoles) (Suppl. material 1). The most and the least variable spine traits within an areole were almost the same as those between the areoles. On the other hand, the variation in fiber traits

Table 4. Influence of areole position on the plant body on spine and fiber traits. Bold letters show statistically significant differences between upper and basal part. See Table 1 for explanation of spine and fiber traits.

T		D				
Irait (unit)	basal part	middle part	upper part	I'-value		
Spine						
S ₁ (mm)	8.3±0.28	8.8±0.21	9.2±0.29	0.12		
S _w (mm)	1.02±0.02	1.03±0.02	1.11±0.03	0.01		
S _{th} (mm)	0.82±0.01	0.84±0.02	0.89±0.03	0.03		
$S_a (mm^2)$	0.68±0.03	0.70±0.03	0.81±0.05	0.01		
S _c (mm)	2.98±0.06	3.00±0.06	3.28±0.09	0.01		
S _r	1.26±0.02	1.22±0.01	1.21±0.02	0.45		
Fiber						
F _{max} (µm)	13.0±0.3	13.6±0.4	14.7±0.3	0.01		
F _{min} (μm)	9.5±0.3	10.06±0.4	10.7±0.6	0.01		
CW _{th} (µm)	3.5±0.3	3.87±0.2	4.20±0.3	0.01		
F,	1.4±0.04	1.37±0.04	1.4±0.11	0.38		

within an areole differed from the variation of fiber traits between the areoles. Contrary to the variation between areoles, F_r was the most and CW_{th} the least variable trait within an areole. A CV value higher than 15% was found in most cases for F_r (62% of sampled areoles) and for F_{max} (44% of sampled areoles). On the other hand, a CV of CW_{rb} higher than 15% was only found for 7% of the sampled areoles.

Spines within an areole were distributed only marginally with radial arrangement (Fig. 3). All spines were straight or slightly curved to the body. The lower one pointing downward The number of spines per areole range from 3 to 7 spines and the most frequent number of spine per areole was 5 (51% from all areoles) (Suppl. material 1). Only 11% from all areoles had 3 and 4 spines.

Minimum sample size

In general, calculated minimal sample sizes corresponded with the CVs of the studied traits. To study spine traits with 10% differences in the mean value, we should measure at least 52 spines (Table 5). However, if we studied only S_a or S_c , 25 spines would be needed and even fewer spines would be needed for S_r (Table 5). In the case of fiber traits, the most variable trait was CW_{th}, for which 70 spines should be used to obtain results within 10% differences in the mean value (Table 5). To study fiber diameter, 43 spines should be used and no more than 6 spines are needed for F_r . The minimal sample size for the studied parameters would be on average 3.7 times lower, if 20% differences in the mean value were used (Table 5).

T	sample size					
Irait (unit)	mean ±10%	mean ±15%	mean ±20%			
	Sp	ines				
S ₁ (mm)	52	23	13			
S _w (mm)	40	18	10			
S _{th} (mm)	34	15	9			
$S_a (mm^2)$	23	11	6			
S _c (mm)	25	11	7			
S _r	1	1	1			
	Fibers					
F _{max} (μm)	43	19	11			
F _{min} (µm)	40	18	10			
CW _{th} (µm)	70	31	18			
F	6	2	2			

Table 5. Minimum sample size required to study specific spine and fiber traits. The interval limits were taken as 10, 15 and 20% differences of the mean.



Figure 3. Typical radial arrangement of spines within an areole of *Gymnocalycium kieslingii* subsp. *castaneum*. All spines are straight or slightly curved to the body. The lowest spine is pointing downward. Scale bar = 5 mm.

Discussion

Spine surface

In the present study, the spine epidermal cells were usually bent upward, but flat shapes were also observed. Epidermal cells were usually arranged in regular transverse rows. The spine epidermis and mesophyll of several cacti have deep fissures, created during normal development (Mauseth 2006). These fissures are believed to play an important role in water absorption, but it has not yet been investigated what effect this process may have on the overall water balance of the plants (Mosco 2009). In G. kieslingii subsp. castaneum such fissures had only 9% of observed spines. Trichomes observed in other cactus species (Mauseth 2006, Řepka and Gebauer 2012) were also absent in G. kieslingii subsp. castaneum. It has been reported that differences in surface structure are related to age: young spines (situated in the upper part of the plant body) of *Mammillaria scrippsiana* var. armeria and Echinopsis sp. have a smooth surface, whereas older spines (situated in the lower parts of plant body) show a broken surface. We did not observe such differences, which may be specific characteristics of a particular genus of cacti. However, there were differences in spine surface damage and visibility. The spine surface was more visible and less damaged in spines from the upper part than in the lower parts. In the basal part, the spine surface was almost completely covered with mineral deposition (Fig. 2a). Thus, spines situated in the upper part of plant bodies are the most appropriate for surface analysis and taxonomic use.

Spine variation between individuals and areoles

Spines develop from lateral buds (areoles) and vary considerably across species in number, length, width and thickness (Mauseth 2006, Mosco 2009). This is an extreme form of leaf modification (Mauseth 2006). The number of spines per areole of G. kieslingii subsp. castaneum is described as ranging from 5 to 7 (Ferrari 1980). In the present study, areoles with 3 and 4 spines were also found in 11% from all areoles. The spines shape was the least variable trait and it was mostly circular. This is in accordance with Mauseth (2006), who mentioned that cactus spines are frequently circular in crosssection. On the other hand, S₁ and S₂ were the most variable spine traits. In another study, spine length was also found to be the most variable trait in 30 Aylostera and Rebutia (Cactoideae) hybrids (Mihalte and Sestras 2012). It has already been found that spine variation occurs even within a single species, reflecting environmental conditions during cactus growth (e.g. Nobel 1988, English et al. 2007, Menezes et al. 2015). For example, S₁ was found to be positively correlated with rainfall (Menezes et al. 2015). It is obvious that longer and thicker spines will require more photosynthates for its development. On the other hand, such a spine increment would reduce the interception of photosynthetic active radiation, which would then reduce photosynthetic productivity (Nobel 1983). However, abundant spines shade the photosynthetic cortex from intense insolation and UV radiation to avoid high-temperature extremes (Loik 2008). Thus,

the large variation of S_1 and S_a found in our study may be partly explained by a sensitive plant regulation system that balances between positive and negative spine functions. However, the factors controlling morphogenesis in the basal meristems of spines are still unknown (Mauseth 2006) and the identification of genes and their expression will be an important step towards our understanding of the spine development.

Two main fiber shapes in spine cross-sections (i.e. folded and pillar) were described by Schlegel (2009). Fibers of *G. kieslingii* subsp. *castaneum* were mostly oval and had a pillar structure. In our study, the mean fiber maximum and minimum diameters were in the range reported for *Echinocactus grusonii* (Huang and Guo 2013), *Opuntia ficusindica* (Vignon et al. 2004) and *Turbinicarpus* sp. div. (Mosco 2009), which had spines composed of fibers with diameters of 5–15, 6–10 and 6–18 µm, respectively. There are only two studies including measurements of cell wall thickness of fibers (CW_{th}). *Turbinicarpus* species had a mean CW_{th} of 0.7 to 5.9 µm (Mosco 2009), and *Escobaria* species had a mean CW_{th} of 3.3–4.0 µm (Řepka and Gebauer 2012). These values are slightly lower than for *G. kieslingii* subsp. *castaneum*.

Spine variation within areoles

Although a large variation of spine traits within single species has been described (Peharec et al. 2010), there is no extant report describing spine variation within an areole. Since the spines grow from the same lateral bud, low variation of anatomical and morphological parameters would be expected. This hypothesis was only partly supported in our study, as the spine and fiber variation within areoles was lower than between areoles, but the CV for different studied traits within an areole was still high. For example, the CV for S_a was even higher than 40% in a few cases (Suppl. material 1). Thus, it seems that even within a single areole, the function of the basal meristem of the spine is very sensitive to environmental and internal stimuli.

Spine variation on the plant body

The areole position on the plant body could be related to age, since new spines develop on top of the cactus body, whereas the oldest spines are situated in the basal part. Thus, variation in spine traits from different positions on the plant body can be expected due to different environmental conditions during spine development. For example the stable isotope composition of spines produced serially from the apex of the long-lived columnar species *Carnegiea gigantea* revealed the past physiological and climatic variation (English et al. 2007). This corresponds with our results, as almost all spine and fiber traits (except for S₁, S₁ and F₂) had different values in the lower parts than in the upper part of the plant body. Nevertheless, the growth of cacti is very slow, and determination of their age without direct observation is difficult (Martinez del Rio et al. 1995).

Minimum sample size

Although spine variation is known even in single species, spine sample sizes used by different authors are very variable. For example, anatomical studies use 2 spines (Mosco 2009), morphological studies use 17 spines (Peharec et al. 2010), and mechanical studies usually use 2-22 spines (Schlegel 2009, Huang and Guo 2013). In our study, we found that the minimum sample size was largely influenced by the studied spine and fiber traits, and ranged from 1 to 70 spines, if 10% difference in the mean value was taken in account. Thus, for spine sample collection, the spine/fiber trait to be studied is crucial. In our case, fewer spines (taken from the middle part of the cactus body) would be needed to describe S_r (1 spine), F_r (6 spines), S_2 (23 spines) and S_c (25 spines). In contrast, more spines should be collected to study CW_{tb} (70 spines), S_1 (52 spines), F_{max} (43 spines) and S₂ (40 spines). These sample sizes may, however, only apply to spines collected from different plants within a single population. We should note that more similar studies on other cactus species or on the same species, but growing in different environment conditions are needed to make generalizations for spine sample collection in the field. This is important task for the correct delimitation and identification of cactus species especially if cultivated specimens were used as sources of evidence in taxonomy (e.g. Schmalzel et al. 2004).

Conclusion

Our study of 15 cactus individuals, 45 areoles and 245 spines showed that spine and fiber traits are highly variable. The areole position on the plant body was an important factor in most of the studied spine and fiber traits (Question 1). The spine and fiber variation within an areole was lower than between areoles, but the variation was still high (Question 2). The minimum sample size was largely influenced by the examined spine and fiber trait, ranging from 1 to 70 spines (mean \pm 10%) (Question 3). The large spine and fiber variation between individuals and even within single areoles observed in this study indicates a very complex spine morphogenesis. We encourage a further research focus on the spine and fiber variation in other cacti species, but also on the factors controlling the basal meristem function and gene expression in spines.

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Supplementary material I

Table S1. Coefficient of variation (CV) of spine and fiber traits within areoles.

Authors: Roman Gebauer, Radomír Řepka, Radek Šmudla, Miroslava Mamoňová, Jaroslav Ďurkovič

Data type: specimens data

- Explanation note: The number of spines within an areole is given in brackets (n). Depicted are CV values above 15%. See Table 1 for explanation of spine and fiber traits.
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RESEARCH ARTICLE



Jasminanthes xuanlienensis (Apocynaceae, Asclepiadoideae), a new species from Vietnam

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Abstract

Jasminanthes xuanlienensis (Apocynaceae, Asclepiadoideae), a new species from Vietnam is described, illustrated and compared with its five congeners. *Jasminanthes xuanlienensis* differs distinctly from congeners by the longer peduncles (14–18 cm vs. 4 cm at most in *J. pilosa* and *J. saxatilis*, salmon-pink color of the inner corolla lobes (white or greenish in the other species), and corolla tube length (12.0–14.5 mm vs. shorter or longer in congeners).

Keywords

Marsdenieae, China, Xuan Lien National Park

Introduction

Jasminanthes Blume (Apocynaceae, Asclepiadoideae, Marsdenieae) is a small Old World genus of six species (Endress et al. 2014). Its type species, *Jasminanthes suaveolens* Blume, is from Java. However, the centre of diversity of *Jasminanthes* is mainland Asia, particularly China, where the remaining congeners are found (Gilbert et al. 1995, Li et al. 1995). *Jasminanthes* was considered to be a large-flowered *Marsdenia* R.Br. by Forster (1995). However, the very broad circumscription of *Marsdenia* adopted by Forster is not based on phylogenetic evidence and has not been generally accepted

in later works. For instance *Gymnema*, also considered congeneric with *Marsdenia* by Forster (1995), was retained in floristic works such as Jagtap and Singh (1999) and Watson (1999). The phylogeny of Surveswaran et al. (2014) does not address whether *Gymnema* should be merged with *Marsdenia*. The purpose of the present paper is limited to validate a new taxon and we believe that its correct placement is in *Jasminan-thes. Jasminanthes* is separated from *Marsdenia* based on its large flowers (>15 mm long) with salverform corolla and by its inconspicuous to absent staminal corona. In contrast, *Marsdenia* usually has much smaller flowers (<10 mm long) with urceolate or rotate corolla and conspicuous staminal corona. If molecular evidence later proves that *Jasminanthes* is indeed to be considered within a broadly circumscribed *Marsdenia*, a new combination will be required.

In Vietnam, no species of *Jasminanthes* have been recorded to date (Ho 1993, Tran 2005). However, recent fieldwork in Xuan Lien National Park, Vietnam, yielded a collection of *Jasminanthes* that was identified as a new species based upon comparison with the known species in the literature and specimens at BK, BKF, BM, HN, HNU, HNPM, IBK, IBSC, K, KUN, KYO, P, SING, TI, TO, TUT, and VNM. Here we describe the new species and provide a detailed table of character differences among the species along with a key to the species of *Jasminanthes*.

Species treatment

Jasminanthes xuanlienensis **T.B.Tran & Rodda, sp. nov.** urn:lsid:ipni.org:names:60472843-2 Fig. 1

Type. Vietnam. Thanh Hoa province: Xuan Lien National Park, 720 m, N19°59'14.6", E104°59'49.1", 22 April 2013, *Do Van Hai et al. XL 904* (HN, holotype; HN, isotype).

Description. *Liana* large, up to 10 m long. *Stems* glabrous, 1.7–2 mm in diameter; *internodes* 21–23 cm long. *Leaves* opposite; *petiole* 1.6–2.6 cm long, 1.5–2 mm in diameter, pubescent with spreading trichomes, *lamina* variable in shape, elliptic (ovate), 11–15 × 4.1–6.8 cm, with many black spots when dry; adaxial surface glabrous except sparsely pubescent base with spreading trichomes, basal colleters 1–3 each lamina base, ovoid; abaxial surface pubescent, with spreading trichomes; base round to acuminate; apex acuminate with a caudate tip 0.8–1.5 cm long; lateral veins 9–13 pairs. *Inflorescences* extra-axillary, simple or dichotomous, umbelliform, up to 30-flowered; *peduncle* 14–18 cm long, 1.3–1.7 mm in diameter, pubescent, trichomes spreading to retrorse. *Pedicel* 8.5–11.0 mm long, 0.2–0.5 mm in diameter, pubescent with spreading trichomes. *Flower bud* just before anthesis fusiform, 10.7–13.0 mm long, 1.9–2.9 mm in diameter, apex acuminate, base bulbous. *Calyx* sepals 5, free; *lobes* triangular-linear, apex acuminate, 2.5–2.6 × 0.6–1.0 mm, adaxial surface glabrous, abaxial surface pubescent with spreading trichomes; *colleters* occurring singly between the sepals, ovoidconical, 0.2–0.3 × 0.1–0.2 mm. *Corolla* salverform, tube 12.0–14.5 mm long, adaxi-



Figure 1. *Jasminanthes xuanlienensis* T.B.Tran & Rodda. **A** Flowering branch in the habitat of the type locality (22 April 2013) **B** Inflorescence **C** Flower, top view **D** Pollinarium **E** Gynostegium and staminal corona. aa: anther appendage; ca: caudicle; cl: corona lobe; co: corpusculum; gr: guide rail; p: pollinium; sh: style head . (Photographs by T.B. Tran, photo edit by M. Rodda).

ally with 5 pairs of longitudinal lines of retrorse trichomes, abaxially glabrous, throat pubescent, eglandular trichomes 0.36-0.70(-1.34) mm long, lobes elliptic-ovate to triangular, $7.0-8.0 \times 3.0-3.6$ mm, adaxial surface salmon-pink, abaxial surface green-ish-white. *Corona* staminal; corona lobes arrow-shaped, much reduced and attached to gynostegium lengthwise, c. 1.8 mm high, c. 0.8 mm wide, glabrous. *Guide rails* 1.7-2.0 mm long. *Gynostegium* 3.5-4.0 mm tall, 1.8-2.0 mm wide. *Pollinia* erect, oblong, 0.49-0.58 mm $\times 0.2-0.23$ mm; *caudicle* 0.12-0.13 mm $\times 0.05-0.06$ mm; *corpusculum* rhomboid, $0.2-0.23 \times 0.10-0.11$ mm. *Anther appendages* erect, covering the style head, $1.0-1.2 \times 0.7-0.9$ mm. *Style head* conical with a round tip, 0.8-1.0 mm high. *Ovary* bi-carpellate, carpels ovoid, c. 1.60 mm long, 1.10 mm wide at the base. *Fruits* and *seeds* not observed.

Etymology. The species is named after the type locality, Xuan Lien National Park, Thanh Hoa province, in northern Vietnam.

Characters	J. xuanlienensis	J. chunii	J. mucronata	J. pilosa	J. saxatilis	J. suaveolens
Lamina shape	elliptic (ovate)	ovate	ovate-oblong	oblong- ovate	elliptic- lanceolate	elliptic- lanceolate
Lamina base	acuminate	cordate- subcordate	cordate- subcordate	cordate	acute	acute to round
Lamina apex	caudate	acute- cuspidate	acuminate- short caudate	shortly acuminate	acuminate- caudate	acuminate- cuspidate
Lateral veins (pairs)	9–13	4–7	5–7	7–10	5–6	5–8
Length of petiole (cm)	1.6–2.6	1-1.5(-2)	1.5–3	1-4.5	1.3–1.8	0.7–1.2
Number of flowers	up to 30	up to 12	2-4(-9)	5–10	c. 10	c. 10
Length of peduncle (cm)	14–18	(0.5–)1– 1.5 cm	1–2	2–4 cm	3-4	0.5–1
Length of pedicel (cm)	0.85–1.1	1–1.3	1–3	0.7–1	0.8–1	0.7–1
Shape of sepal	triangular	oblong	elliptic-oblong	oblong- lanceolate	triangular	triangular
Size of sepal (mm)	2.5–2.6 × 0.6–1	5–6 × c. 2	7-8 × 3-4	18–30 × 4–8 mm	c. 3 × 1	5.5–8 × 2–3.5
Corolla lobe colour	adaxially salmon- pink, abaxially greenish-white	white	white	white	greenish	white
Length of corolla tube (mm)	12.0–14.5	7–9	c. 15	40–50	6–8	9–11
Size of corolla lobe (mm)	7.0–8.0 × 3.0–3.6	6–8 × 4–5	15–17 × 6–8	25–30 × 6–8	c. 10 × 3	7.0–9.0 × 1.0–1.5

Table 1. Morphological comparision of Jasminanthes species.

Distribution and ecology. Jasminanthes xuanlienensis was found growing in primary evergreen forests on limestone soil of Xuan Lien National Park. It was collected in flower in April. Plants observed growing in the vicinity include *Piper acreanum* C.DC., *Beccarinda tonkinensis* (Pellegr.) B.L.Burtt, *Sarcosperma kachinense* (King & Prain) Exell, *Hoya vercillata* (Vahl) G.Don, and *Alangium salviifolium* (L.f.) Wangerin.

Conservation status. *Jasminanthes xuanlienensis* is known only from the type locality, an area still poorly known botanically; its preliminary conservation status is therefore Data Deficient (DD; IUCN 2014).

Notes. The six species of *Jasminanthes* are clearly distinguishable from one another based on morphological characters (Table 1). The new species can be easily separated from all *Jasminanthes* species as it has very long peduncles (14–18 cm long), while the longest peduncles observed in other species are those of *J. pilosa* (Kerr) W.D.Stevens & P.T.Li and *J. saxatilis* (Tsiang & P.T.Li) W.D.Stevens & P.T.Li), which reach 4 cm long. *Jasminanthes xuanlienensis* has unique pink corolla lobes whereas the other species have white corollas, or greenish corollas in *J. saxatilis*.

Key to the species of Jasminanthes

1	Peduncle >10 cm long; corolla salmon, pink adaxiallyJ.	xuanlienensis
_	Peduncle <5 cm long; corolla white or greenish adaxially	2
2	Sepals >15 mm long; corolla tube >35 mm long	J. pilosa
_	Sepals <10 mm long; corolla tube >10 mm long	
3	Corolla tube >13 mm long, lobes >14 mm long	.J. mucronata
_	Corolla tube <11 mm long, corolla lobes <10 mm long	
4	Lamina ovate, base cordate or subcordate	J. chunii
_	Lamina elliptic-lanceolate, base acute to round	5
5	Sepals <3.5 mm long; peduncle >3 cm long	J. saxatilis
_	Sepals >5 mm long; peduncle <1.5 cm long	J. suaveolens

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RESEARCH ARTICLE



Lithocarpus dahuoaiensis (Fagaceae), a new species from Lam Dong Province, Vietnam

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Abstract

Lithocarpus dahuoaiensis Ngoc & L. V. Dung, a new species from the Central highland of Vietnam, is described and illustrated. The new species is morphologically similar to *Lithocarpus macphailii* (M. R. Hend.) Barnett or *Lithocarpus encleisocarpus* (Korth.) A. Camus in having completely entire leaf margin, solitary cupule, long stalks of fruits, deeply cup-shaped or turbinate cupules, with a number of horizon-tal filiform lines. The species differs in its nut enclosure ca. 1/2 - 2/3 of the nut, adaxially glabrous leaf blades, secondary veins 11-12 pairs and faintly to very faintly visible hairs on the outside of the cupule. A table showing the morphological comparison of *Lithocarpus dahuoaiensis* with *Lithocarpus macphailii* and *Lithocarpus encleisocarpus* is also provided.

Keywords

Da Huoai, Fagaceae, Lam Dong Province, Lithocarpus, Lithocarpus dahuoaiensis, Vietnam

Introduction

Lithocarpus Blume is the second largest genus of the family Fagaceae, comprising 341 species (The Plant List 2013). The genus is commonly known as Stone Oaks and widely distributed throughout the tropical and sub-tropical broad-leaved evergreen forests in East and Southeast Asia, extending to New Guinea (Cannon 2001, Phengklai 2008). In North America, one species of *Lithocarpus*, *L. densiflorus* (Hook. & Arn.) had been known, but has recently been treated as a member of a new monotypic genus *Notholithocarpus* (Manos et al. 2008). The center of diversity is in East to Southeast Asia, where 123 species are enumerated in China (Huang et al. 1999), 58 species in Thailand (Phengklai 2008, Strijk et al. 2014) and 115 species in Vietnam (Ho 2003, Ban 2005).

In Vietnam, the species of Fagaceae are highly diversified and can be seen in various forest types, from dry evergreen forest at lowland to montane evergreen forest at high mountains. A total of 216 species and two varieties in six genera have been recorded in the country (Ho 1999, Ban 2005, Linh et al. 2013, Vuong and Xia 2014), which represents 66% of the total world genera and 24% of the total world species diversity in this family. One species of *Fagus* L., two species of *Castanea* Mill., 54 species of *Castanopsis* (D. Don) Spach., 43 species of *Quercus* L., one species of *Trigonobalanus* Forman and 115 species with two varieties of *Lithocarpus* have been found, indicating that *Lithocarpus* is the largest and most diversified genus of the family in Vietnam. Recently, several taxonomic works on Fagaceae of Vietnam were published (Deng et al. 2010, Linh et al. 2013, Vuong and Xia 2014), indicating that taxonomic studies of the family Fagaceae in Vietnam are still required.

Lam Dong Province is located in Central highland of Vietnam (Fig. 1) and has long been known as one of the biodiversity hotspots in Vietnam. In June 2015, the International coordinating Council of UNESCO's Man and the Biosphere Program added 20 new sites to the World Network of Biosphere Reserves, among which Langbiang biosphere reserve in Lam Dong Province was one of the sites selected (UNESCO 2015). In the region, 3,490 species of vascular plants have been recorded, including 131 and 45 threatened species which are listed in Vietnam's Red Book and IUCN Red List Categories, respectively (Ban et al. 2007, IUCN 2012). As for Fagaceae, 90 species, including 30 species of *Lithocarpus*, are recorded from Lam Dong Province (Ho 2003, Ban 2005, Dung 2005).

During our floristic inventory in Lam Dong Province in 2015, we discovered several individuals resembling species of the genus *Lithocarpus*. Further study revealed that these did not resemble any species described previously. Here, these are described and illustrated as *Lithocarpus dahuoaiensis* Ngoc & L. V. Dung, sp. nov.

Material and methods

The new species was discovered through literature review, as well as a thorough examination of specimens in the herbaria at ANDA, BKF, DLU, FU, HN, K, KYO, L, P, VNM and digital images of specimens on JSTOR Global Plants (https://plants.jstor. org/), Herbier National de Paris, Muséum National d'Histoire Naturelle (P).



Figure 1. Distribution map of *Lithocarpus dahuoaiensis* Ngoc & L. V. Dung. Black triangle, Da Huoai, Lam Dong Province (Type locality); White triangle, Dong Nai Culture and Nature Reserve, Dong Nai Province.

Taxonomy

Lithocarpus dahuoaiensis Ngoc & L. V. Dung, sp. nov. urn:lsid:ipni.org:names:60472844-2

Figs 2, 3

Diagnosis. *Lithocarpus dahuoaiensis* is morphologically similar to *Lithocarpus macphailii* (M.R.Hend.) Barnett and *Lithocarpus encleisocarpus* (Korth.) A. Camus in having a completely entire leaf margin, solitary cupule, long stalks of fruits, deeply cup-shaped or turbinate cupules with the number of horizontal filiform lines. But *L. dahuoaiensis* is

distinct by its cupules enclosing ca. 1/2–2/3 of the nuts (vs. cupules almost completely covering the nut in *L. macphailii* and *L. encleisocarpus*), surface of the cupule densely tomentose inside and subtle hairy to very subtle hairy outside (vs. outside densely fulvous tomentose in *L. macphailii* and outside densely fulvous tomentose by stellate hairs in *L. encleisocarpus*), leaf blades glabrous adaxially, undersides covered with very short soft hairs and subtle (vs. densely glaucous tomentose with adpressed, stellate hairs abaxially in *L. macphailii*, pubescent then glabrescent abaxially in *L. encleisocarpus*), secondary veins 11–12 pairs (vs. 12–16 pairs in *L. macphailii* and 8–10 pairs in *L. encleisocarpus*).

Type. VIETNAM. Lam Dong Province, Da Huoai, along the 20 National Highway, in the lowland evergreen forest, alt. 225 m, 11°23'32.5"N, 107°33'56.3"E, 14 June 2015, *N. Nguyen, D. Luong, B. Hoang, T. Nguyen V3194* (holotype: KYO!; isotypes: DLU!, FU!, HN!, K!, P!, VNM!).

Description. Evergreen tree, up to 35 m tall; young branchlets pubescent with white hairs, soon glabrous, greyish green in vivo and blackish brown in sicco; terminal buds ca. 10-12 mm long, bud scale 4-6 mm long, densely covered with whitish hairs. Stipules not seen. Leaves alternate, blades broadly elliptic to slightly obovate, ca. $15-27 \times 6-11$ cm, thickly coriaceous, base cuneate, margin entire, slightly recurved, apex acuminate or caudate, acumen ca. 5-10 mm long, glabrous adaxially, subtle short soft hairs abaxially; midrib slightly raised above, distinctly raised below glabrous, greenish yellow in vivo, reddish brown in sicco; secondary veins 11-12 pairs, clearly visible on both sides, flat to slightly prominent adaxially, prominent abaxially, veins curving smoothly and disappearing near margins, at an angle of 55-65 degree from the midrib, tertiary veins scalariform, invisible to faintly visible on both surfaces; petioles ca. 10-15 mm long, rounded, thickened, pubescent when young, glabrescent later. Flowers not seen. Infructescences erect, woody, 25 cm long, rachis densely adpressed hairy. Acorn solitary, ovoid or turbinate, 13-15 mm in height, 20-23 mm in diam. (including cupule); fruiting stalk 3-5 mm long, densely fulvous tomentose hair. Cupules, turbinate, base a little broader than the upper part, densely tomentose inside and invisible or subtle hairy outside, lamellate, wall woody, sometimes crackled, enclosing ca. 1/2-2/3 of the nut, 12-14 mm in height, 19-22 mm in diam., bractlets triangular, obscure, forming 6-7 dimly concentric flanges. Mature nut 19-22 mm in height, 20-23 mm in diam., densely white tomentose; scar created by cupule at the base is deeply concave, ca. 13-15 mm in diam.; wall woody, crackled; apex abruptly acuminate, ca. 1.5–2 mm in height.

Phenology. Mature fruits were collected in June.

Distribution and habitat. Vietnam (so far known from Lam Dong Province and Dong Nai Province split by a boundary along National highway 20). (Figure 1)

Etymology. The specific epithet is derived from the type locality, Da Huoai, Lam Dong Province, Central Highland Vietnam.

Conservation status. Data Deficient (DD). Three fruiting individuals were found at the type locality, along the Chuoi pass of the 20 National highway. In addition, a



Figure 2. *Lithocarpus dahuoaiensis* Ngoc & L. V. Dung. **A** Leafy twig **B** Buds **C** Petiole **D** Abaxial surface of mature Leaf **E** Infructescence **F** Mature fruit **G** Cupule (left) and bottom of nut (right) **H** Vertical sections of nut.



Figure 3. Line drawing of *Lithocarpus dahuoaiensis* Ngoc & L. V. Dung. **A** Leafy twig **B** Infructescence **C**, **D** Cupule **E** Vertical section of mature nut **F**, **G** Mature nut. Scale bars **A**, **B** = 5 cm; **C**–**G** = 10 mm.

Table 1. Morphological comparison between *Lithocarpus dahuoaiensis* Ngoc & L. V. Dung, sp. nov. with *Lithocarpus macphailii* (M.R.Hend.) Barnett and *Lithocarpus encleisocarpus* (Korth.) A.Camus. (The measurements of *L. macphailii* and *L. encleisocarpus* derive from Soepadmo 1972)

Characters	racters L. dahuoaiensis L. macphailii		L. encleisocarpus
Leaf margin	Entire	Entire	Entire
Leaf surface	Glabrous above, very	Densely glaucous tomen-	Subglabrous on upper
	short soft hairs and sub-	tose with adpressed, stel-	surface, densely glaucous
	tle beneath	late hair on lower surface	adpressed stellate-hairy
			on lower surfaces
Leaf size (cm)	15–27 × 6–11	15–22 × 6–8	12–15 × 4–6
Length of petioles	10–15 mm long	10–17 mm long	5–15 mm long
Number of second-	11–12 pairs	12–16 pairs	(7–)8–10(–12) pairs
ary veins			
Length of fruit stalk	3–5 mm long	Up to 5 mm long	10–15 mm long
Acorn size (in diam.)	20–23 mm	20–25 mm	20–27 mm
Cupule size	12–14 mm high × 20–23	7–15 mm high × 20–30	N/A
	mm across	mm across	
Cupule outside	Faintly or very faintly	Densely fulvous-tomen-	Densely fulvous tomen-
	visible hairs	tose	tose by stellate hairs
Horizontal rings in	6–7, dimly concentric	5–8, thin, more or less	5–7, more or less con-
cupule	flanges	concentric	centric
Nut enclosure	Enclosing ca. 1/2-2/3 of	Almost completely cover-	Completely enclosing
	the nut	ing the nut	the nut
Infructescence length	15–25 cm long	10-25 cm long	8-20 cm long

staff member of Dong Nai Culture and Nature Reserve has collected this species at Ma Da, Vinh Cuu, Dong Nai Province, indicating its wide distribution around the type locality. However, at present we have no reliable information on its population size. Further investigations are needed to determine the conservation status and actual population size in its natural habitat.

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RESEARCH ARTICLE



Diplycosia platyphylla (Ericaceae), a new species from Mindanao, Philippines

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Abstract

Diplycosia platyphylla P.W.Fritsch, a new species from Mindanao Island, Philippines, is described and illustrated. This species is most similar to the Bornean *D. urceolata* but differs by its green or slightly flushed pink petioles 4–7 mm long, wider leaf blades, acute calyx lobe apices, and lavender mature fruiting calyx. The new species is known only from a single collection made from Mount Apo in North Cotabato Province, southern Mindanao.

Keywords

Diplycosia, Ericaceae, Gaultherieae, Mindanao, Mount Apo, new species, Philippines

Introduction

Diplycosia Blume (Ericaceae: Vaccinioideae: Gaultherieae) comprises about 116 species distributed throughout Southeast Asia and New Guinea (Sleumer 1967; Argent 1982, 1989, 2002; Ferreras and Argent 2011; Argent 2013, 2014; Fritsch and Amoroso in press; Fritsch and Bush in press). The genus can be delimited from other genera of the tribe by a base chromosome number of x = 18 (vs 11), and a combination of (usually) entire leaf margins, fasciculate inflorescences, paired bracteoles borne at the apex of the pedicel, anthers with terminal tubules but with neither spurs nor disintegration tissue, and a capsule surrounded by an accrescent, fleshy calyx, or rarely a berry. Molecular studies strongly support the monophyly of the genus, and place it as phylogenetically nested within *Gaultheria* Kalm ex L. in the Wintergreen Group clade (Powell and Kron 2001; Bush et al. 2009; Fritsch et al. 2011).

Nine species of *Diplycosia* are currently recognized in the Philippines, three having been described since the taxonomic treatment of Ericaceae for the *Flora Malesiana* (Sleumer1967; Ferreras and Argent 2011; Argent 2013; Fritsch and Amoroso in press). Because species of *Diplycosia* are often restricted to a single mountain or very few locations, more Philippine species of this genus likely await discovery (Argent 2013). Five species of *Diplycosia* have been documented from the island of Mindanao (Pelser et al. 2011 onwards; Fritsch and Amoroso in press), the southernmost major island of the Philippines. In April–May 2014 a joint botanical expedition was undertaken by the California Academy of Sciences and the CEBREM Office of Central Mindanao University to mountain peaks in the central part of Mindanao. Several individuals of *Diplycosia* were observed on Mt. Apo, the highest peak in the Philippines at 2954 m a.s.l. These plants appeared not to match any other Philippine species of the genus, according to the key in Argent (2013). Further study of a collection and photographic images made from these plants confirmed that these individuals represent a species new to science, which is here described and illustrated.

Methods

Plants here described as a new species were dried as herbarium specimen vouchers. Macromorphological characters derived from both the specimens and photographic images of the living material were compared with those from the relevant literature sources (Sleumer 1967; Argent 1982, 1989, 2002, 2013, 2014; Ferreras and Argent 2011), specimens that are available at BRIT, CAS, and E, and online type images accessed from JSTOR Global Plants (https://plants.jstor.org/). We focused in particular on the characters used for the most recent key to Philippine *Diplycosia* in Argent (2013). Acronyms of herbaria follow Thiers (2016). Conservation status was assessed in accordance with IUCN Standards and Petitions Subcommittee (2016) criteria. The mature fruit was lost in transit between collection and deposition, and thus was not preserved; its description is based on a poor-quality photograph where only the general features were documented.

Taxonomy

Diplycosia platyphylla P.W.Fritsch, sp. nov.

urn:lsid:ipni.org:names:60472845-2 Figs 1, 2

Diagnosis. Haec species *Diplycosiae urceolatae* simillima, sed ab eo petiolo viridi vel viridi ex roseo 4–7 mm longo, lamina 7–7.5 cm lata, lobis calycis acutis, calyce fructus maturo lavandulo differt.

Type. PHILIPPINES. Mindanao Island, North Cotabato Province, Barangay Ilomavis, Mount Apo Natural Park, Matingao River Watershed, road from Site C to Site H at Energy Development Corporation (EDC), 1718 m, 6°59.88498'N, 125°14.86668'E, 29 Apr 2014, *D.S. Penneys 2302* (holotype: PNH!; isotypes: CAS-1196249!, CMUH-00010804!).

Description. Terrestrial erect shrublet to 0.6 m tall with ascending-erect branchlets. Young branchlets not observed; old branchlets gray, stout (3.5-4.5 mm wide), subterete, with non-peeling epidermis, glabrous. Leaves spirally arranged, with distinct wintergreen odor when crushed (fresh leaves), ascending; petiole green or slightly flushed pink, 4–7 × 2.5–2.9 mm, grooved above, glabrous; lamina broadly obovate to subrotund, the larger $8.3-9.7 \times 7-7.5$ cm, 1.2-1.7 times as long as wide, coriaceous, abaxially glossy and evenly dark red-dotted over the surface, adaxially shiny and glabrous; major veins prominent abaxially, sulcate adaxially, major secondary veins originating on proximal half, 1 to 3 on each side of midvein, arching-ascending, alternate, occasionally 3 on one side and only 2 on the other; base broadly cuneate, margin entire, revolute, glabrous, apex rounded or strongly emarginate, the very tip with a thick protruding dark gland to 0.8 mm long. Inflorescences axillary or on older sections of defoliated branchlets proximal to the leaves, fasciculate, 3- to 6-flowered, often with up to 7 additional old fruiting pedicels; bracts ovate-deltoid, $1.5-2 \times 1.2-1.7$ mm, appressedpuberulent. Pedicels slightly dilated distally, $4-7 \times 0.5-0.8$ mm, muriculate with short (to 0.16 mm long) ferrugineous erect or ascending trichomes, and also pubescent with pale ferrugineous irregularly oriented straight to slightly undulate nonglandular trichomes to 0.3 mm long; bracteoles ovate-deltoid, 1-1.5 mm long, muriculate, rarely also sparsely puberulent along midvein, midvein planar to prominent, margin ciliolate with a mix of ferrugineous glandular trichomes and pale ferrugineous nonglandular trichomes. Calyx green strongly flushed deep pink, 2.2-2.7 × 3.4-3.7 mm, sparsely muriculate or glabrous; limb ca. 2 mm long; lobes broadly deltoid-ovate, 1.1-1.2 × 1.8-2 mm, margins with a mixture of ferrugineous glandular and pale ferrugineous nonglandular trichomes, the latter more prevalent distally, apex acute. Corolla 5-lobed, white slightly flushed with dull pink distally, broadly urceolate, widest at middle, ca. 4.5×2.9 mm, glabrous both outside and within; lobes recurved, ovate, ca. 1×1 mm, margins eciliolate, apices obtuse. Stamens 10, included within corolla, ca. 4.5 mm long; filaments ± S-curved, ca. 3 mm long, glabrous; anthers 1.7–1.9 mm long, thecae 1.4–1.5 mm long, echinulate, tubes parallel, 0.3–0.4 mm long, smooth, pores strongly



Figure 1. *Diplycosia platyphylla* P.W.Fritsch. **A** Habitat **B** Habit **C** Branchlet with inflorescences **D** Inflorescence **E** Immature fruit. (D.S. Penneys 2302). Scale bars: **C** = 10 cm, **D**, **E** = 1 cm. Photos P.W.F.

oblique. Nectary 10-lobed; lobes emarginate. Ovary cylindric-hemispherical, ca. 1.5×1.5 mm. Style 2.5–3 mm long, glabrous. Immature fruit green flushed red, 5–6 × 5–6 mm, style persistent; mature fruiting calyx lavender, accrescent, fleshy.

Etymology. The species is named for its notably wide leaves relative to those of most other species in the genus.

Phenology. Flowering and fruiting in April.

Distribution and habitat. *Diplycosia platyphylla* is known only from a single location on Mt. Apo, Mindanao Island, North Cotabato Province, Philippines. Several



Figure 2. *Diplycosia platyphylla* P.W.Fritsch. A Fertile branchlet B Pedicel and flower C Calyx lobe apex
D Flower with calyx and corolla partly cut away to show androecium and gynoecium E Stamen, ventral view F Stamen, lateral view G Immature fruit H Fruiting pedicel. Drawing by L. Heagy from D.S. Penneys 2302 (CAS) and photographic images of the living plant.

individuals were found growing in gravel on an ultramafic open sunny rockslide area in the Tropical Lower Montane Rain Forest biome at 1718 m a.s.l. with *Nepenthes* L., *Huperzia* Bernh., and *Vaccinium* L. on a general NW-facing 30–60% slope but in a flat microhabitat along a roadside.

Conservation status. *Diplycosia platyphylla* is known from a single population and single collection, with only several plants seen. Although the species is afforded pro-

tection by its occurrence in Mount Apo National Park, it is at risk through apparent extreme rarity. We categorize this species as Critically Endangered (CR): D.

Discussion. The new species is similar to Diplycosia urceolata Stapf from Mount Kinabalu in Borneo, Sabah, Malaysia by its stout glabrous branchlets, coriaceous glabrous leaf blades with rounded apices, and 4-7 mm-long pedicels with a mixture of muriculate trichomes and pale ferrugineous nonglandular trichomes. It differs from this species most readily by its green or slightly flushed pink petioles 4-7 mm long (vs vivid red and 10–13 mm), wider leaf blades [7–7.5 cm vs (2.5–)3.5–5(–7.5) cm], acute calyx lobe apices (vs obtuse), and lavender mature fruiting calyx (vs black). It is also similar to D. sanguinolenta Sleumer from Mount Kinabalu in its large coriaceous leaf blades $[9-14(-17) \times 5-8(-9.5) \text{ cm for } D. \text{ sanguinolenta; Sleumer 1967}]$ and generally acute calyx lobes, but is easily distinguished by a petiole 4-7 mm long (vs 12-15 mm) and a white corolla ca. 4.5 mm long (vs bright red and 13–15 mm long), among other characters. The new species would key to couplet 3 of the key to the Philippine *Diplycosia* in Argent (2013). The two leads at that point in the key identify the varieties of D. luzonica (A.Gray) Merrill, i.e., D. l. var. calelanensis (Elmer) Sleumer and D. l. var. merrittii (Merrill) Sleumer, distinguished by "Leaves broadly pointed to rounded with the terminal gland forming a short mucronate point the largest leaves up to 5 cm long" vs "Leaves acuminate, with a narrowly acute apex, the largest leaves more than 6 cm long," respectively. Because the new species possesses leaves that are rounded (or strongly emarginate) at the apex but are 8.3–9.7 cm long (the larger ones), the new species does not match either of these leads. Thus, it can be distinguished from all other Philippine Diplycosia by the combination of glabrous branchlets and (larger) leaf blades 8.3-9.7 mm long with an apex that is rounded or strongly emarginate, and with a prominent terminal gland.

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RESEARCH ARTICLE



Onosma anatolica, a new species of Boraginaceae from Turkey

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Abstract

Onosma anatolica Binzet, is described and illustrated as a new species from Niğde province in southern Anatolia, Turkey. It belongs to sect. *Onosma L. subsect. Asterotricha* (Boiss.) Gürke. The new species is closely related to *Onosma subulifolia* Riedl from which it is distinguished. *O. anatolica* is readily distinguished from *O. subulifolia* by its sterile shoots, the green-grey stem indumentum, longer bracts, yellow and puberulous petals. The IUCN threat category of *O. anatolica* is determined as "CR (Critically Endangered)". A distribution map and anidentification key for *O. anatolica* and *O. subulifolia* supplement the study.

Keywords

Boraginaceae, Onosma, Endemic, Niğde, Turkey

Introduction

The family Boraginaceae s.s. comprise some 1600 species (Chacon et al. 2016, Luebert et al. 2016 Mehrabian et al. 2012, Kolarčik 2010; Cecchi and Selvi 2009). Members of the family are widespread in western and central Asia and in the Mediterranean area (Jávorka 1906, Meusel et al. 1978). The family comprises about 44 genera and 375 species in Turkey (Güner 2012).

The genus *Onosma* L. (Boraginaceae-Lithospermeae) is one of the largest in the Boraginaceae and includes about 230 species, mainly distributed in the Mediterranean

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region, southwest Asia, and temperate Europe (Boissier 1879, Riedl 1967, Peruzzi and Passalacqua 2008, Binzet et al. 2010, Mehrabian et al. 2011, 2014, Ranjbar and Almasi 2014). In Turkey, the genus is represented by about 103 species as the rate of species endemism amount to 50% (Riedl 1978, Davis et al. 1988, Yıldırımlı 2000, Riedl et al. 2005, Binzet and Orcan 2007, Kandemir and Türkmen 2010, Aytac and Türkmen 2011, Koyuncu et al. 2013, Guner 2012, Binzet 2016). This genus is perennial, usually suffrutescent or consists of biennial herbs (Stevanovic et al. 2003, Akçin and Binzet 2011). Onosma is systematically difficult, and most of the diagnostic characters are based mainly on the whole indumentums, leaf and flower morphology (Ball 1972, Riedl 1978, Peruzzi and Passalacqua 2008, Pavlova 2009). To identify the sectional categories of the Onosma members, the indumentum of the stem and the leaves are of significance (Özcan 2009). The genus has been divided into three groups, originally described as sections, but here recognized only as informal groups: Asterotricha, with basal leaves covered by stellate trichomes or asterosetae (i.e. along tubercled seta with several shorter rays at its base), Haplotricha, with basal leaves covered by simple setae, and *Heterotricha*, with both simple setae and asterosetae on the basal leaves (Boissier 1879, Peruzzi et al. 2004, Peruzzi and Passalacqua 2008, Koyuncu et al. 2013).

During a field trip in June 2011, some interesting *Onosma* specimens were collected from the Niğde province in Southern Anatolia. The few plants gathered in 2011 were complemented by collection conducted in June 2015 from the same site. Detailed morphological studies indicated that the population of *Onosma* from the Niğde province represent a hitherto unknown species related to *O. subulifolia.* This species is described here as new to science bringing the total number of the species known from Turkey to 104.

Material and methods

Specimens of *Onosma anatolica* were collected by the author during three field excursions in Niğde province in June 2011 and June 2015. Totally 8 herbarium specimens were collected from one locality and deposited in ANK, GAZI and the Herbarium of Mersin University. I have compared the new *Onosma anatolica* specimens with *O. subulifolia* based on relevant taxonomic literature (Riedl 1978). The holotype photo of *O. subulifola* was taken from E. Preliminary conservation assessments were made using the IUCN (2012) guidelines. For the palynological definision in total 50 pollen grains and 20 mature nutlets were measured using a light microscope (LM) and stereo-binocular microscope. In addition, observations were made using a scanning electron microscope (SEM).

For pollen studies using LM, grains were taken from fresh and herbarium materials prepared according to the Wodehouse methods (Wodehouse 1935). The polar axis (P), equatorial axis (E), and other characteristics (plg, plt, clg, clt, exine, intine and t; see Table 1 for abbreviations) of the pollen grains were measured using an Olympus BX40 with a 100× objective until a Gaussian curve was acquired (Table 1). For SEM observations, pollen grains obtained from each specimen were transferred onto stubs and coated with platinum. The SEM micrographs were taken with a ZEISS supra 55. In this study, nomenclature for pollen morphology was used in accordance with Wodehouse (1935), Faegri and Iversen (1989) and Punt et al. (1994).

Morphological characters of *Onosma subulifera* used in this paper for comparation were obtained from relevant taxonomic literature (Riedl 1978).

Results

Onosma anatolica Binzet, sp. nov. (Sect. Onosma subsect. Asterotricha) urn:lsid:ipni.org:names:60472943-2

Figures 1, 2

Type. Turkey, C5 Niğde: Çamardı, 2 km South of Demirkazık village, subalpine community with dwarf shrub and thorn-cushion, 1760 m, limestone, 22 June 2015, 37°50'47"N, 35°05'32"E, *Binzet 201501* (holotype: ANK; isotype: GAZI).

Diagnosis. Onosma anatolica is related to O. subulifolia especially by its habit, calyx and corolla length. However, the new species differs mainly in its sterile shoots; a green-grey stem with adpressed setose trichomes, the setae arising from short stellate hairy and shortly hairy (not bluish-black, otherwise glabrous as in O. subulifolia); sterile rosette leaves and basal leaves $-50 \times 1-1,5(-1.8)$ mm, revolute-subulate; cauline leaves $-20 \times 1-1.5(-1.8)$ mm, (as opposed to $15-32 \times 1.5(-1.8)$ mm in O. subulifolia); an inflorescence of 1-2 cymes, sometimes elongated after flowering (not short subcapitate); flower bracts $8-15 \times 1-2$ mm, the apex acute (as opposed to 7-8 mm, apex lingulate in O. subulifolia); pedicel 1-2 mm (not 1-1.5 mm); calyx 6-8 mm in flower, 8-12 mm in fruit, suboblate in shape, patent strigose on ±tubercles and shortly hairy on the outside and rarely hairy on the inside (as opposed to 10-11 mm, subobtuse, and hispid in O. subulifolia); corolla yellow, clavate, puberulous, lobes 1 mm long, 1.7 mm wide at base, widely triangular (as opposed to white, clavate-campanulate, glabrous, lobes short, acute in O. subulifolia); and nutlets $3-3.5 \times 2-2.3$ mm, short beaked, grey.

Description. Perennial rhizomatous herb, rhizome divided into several, ca. 8 mm diameter, subterranean, creeping branches. Aerial stems up to 12 cm tall(including inflorescence), ca. 1(-1.5) mm in diameter, green to grey, covered by adpressed setose, setae arising from short stellate trichomes, shortly hairy, sterile rosette to 5 cm. Leaves crowded at base, leaves of the sterile rosette and basal leaves $-50\times1-1.5$ (-1.8) mm, acute, revolute-subulate, adpressed setose, setae arising from stellate trichomes (asterotrichous state). Cauline leaves $-20\times1-1.5(-1.8)$ mm, acute, indistinct revolute-subulate, upper surface covered by densely adpressed setae arising from stellate hairy and sparsely adpressed setose, setae arising from stellate hairy on lower surfaces. Upper cauline leaves resembling lower ones, but smaller in size. Inflorescence of 1-2 cymes, forming a short subcapitate cluster, sometimes elongating after flowering. Flower bracts $8-15 \times 1-2$ mm, linear-subulate, abruptly narrowed and tapering towards an



Figure 1. In situ photographs of *O. anatolica* (**a** habit **b** flowers).

acute apex, \pm patent setose with stellate trichomes and tubercles. Pedicels 1–2 mm. Calyx 6–8 mm in flower, 8–12 mm in fruit, free to base, lobes narrowly linear, suboblate densely covered with patent strigose on \pm tubercles and shortly hairy on the



Figure 2. The holotype of *Onosma anatolica* from the herbarium ANK: *Binzet 201501*, 22 June 2015. (Photo Rıza Binzet).

outside and rarely hairy on the inside. Corolla yellow, 15–18 mm, clavate, puberulous, reflexed lobes 5, 1 mm long, 1.7 mm wide at base, widely triangular, acute, annulus glabrous. Anthers included, linear, ca. 6 mm, sagittate, connate at base, included or

sterile tips exerted. Filaments ca. 5 mm. Style 3–5 mm protruding outside the corolla limb, stigma small, distinctly bilobed. Nutlets 3–3.5×2–2.3 mm, shortly beaked, grey. Pollen grains heteropolar, shape prolate P/E(Polar axis/Equatorial axis) ratio 1.35.

Etymology. The species epithet *anatolica* refers to Anatolia, the Asian part of Turkey.

Distribution and ecology. Onosma anatolica is distributed in southern Anatolia (Niğde) and grows in subalpine dwarf shrub and thorn-cushion communities. The geological substrat is limestone and the new species occurs only between 1700 and 1800 m. The species belongs to the Irano-Turanian floristic region. Species growing in close proximity to the vew species are: Astragalus angustifolius Lam. subsp. angustifolius, Euphorbia kotcchyana Fenzl. Bromus cappadocicus Boiss. et Bal. Marrubium heterodon (Benth.) Boiss. & Balansa, Poa bulbosa L., Bromus tectorum L., Centaurea pseudoreflexa Hayek, Centaurea chrysantha Wagenitz, Astragalus sp. Sideritis libanotica Labill. subsp. Linearis (Bentham). Bornm., Anthemis sp., Galium incanum SM., Convolvulus compactus Boiss., and Alyssum aureum (Fenzl.) Boiss. Phytosociologically the community where the new species occurs can be grouped into Astragalo-Brometea Quézel 1973 class and Astragalo-Brometalia Quézel 1973 order (Quézel 1973, Eren et al. 2004, Parolly 2004).

Conservation status. *Onosma anatolica* is hitherto known only from the type locality, and its estimated area of occupancy is less than 50 km². Moreover, the area is subjected to heavy grazing pressure. Because of its localized distribution, small population size and grazing pressure, it should be considered as 'Critically Endangered (CR)" according to the IUCN criteria A3 and B2 (IUCN 2012).

Additional specimens (paratype). Type locality, 10 June 2011, Binzet 201122 (Mersin University).

Additional specimens examined. *Onosma subulifolia*: Turkey A5 Sinop: after Kargi, 250 m, *Tobey 2625*, 11 May 1969 (holotype, E 00022534, photo).

Phenology. Flowering from May to June, setting fruit until late July.

Palynology. Pollen grains are heteropolar, trisyncolporate and subprolate. Exine surface of the grains is insular. The insulae have free scabrae and the scabrae are widely spaced. The average means of the number of scabrae in each insulae range from 6 to 15. The main palynological characters and SEM micrographs of *O. anatolica* are presented in Table 1 and Figure 5.

Nutlet morphology. Nutlet size shows some variations, Nutlets $3-3.5\times2-2.3$ mm, shortly beaked, and grey. Nutlet surface ornamentation is rugose and characterized by the epidermal cells of the nutlet surface having small or fine wrinkles (Fig. 6).

Taxa	Pollen shape	Р	E	plg	plt	clg	clt	Ex	i	t
	P/E	[µm]	[µm]	[µm]	[µm]	[µm]	[µm]	[µm]	[µm]	[µm]
O. anatolica	prolate 1.35	17.31	12.76	2.90	3.02	12.76	2.95	0.70	0.50	5.93

Table 1. Pollen morphological parameters of O. anatolica (W: Wodehouse Method).

P: length of the polar axis; E: width of the equatorial axis; plg: length of the pores (pori); plt: width of the pores (pori) clg: length of the colpus (colpi); clt: width of the colpus (colpi); Ex: exine thickness; i:intine thickness; t: length of the polar triangular edge.



Figure 3. The holotype of *Onosma subulifolia*: Tobey 2615, 11 May 1969 (E 00022534); image available at website: Source: http://elmer.rbge.org.uk/bgbase/vherb/bgbasevherb.php



Figure 4. Distribution map of *O. anatolica* Binzet (filled triangle) and *O. subulifolia* (filled circle).



Figure 5. SEM microphotograph of pollen of O. anatolica.



Figure 6. SEM microphotograph of nutlet of *O. anatolica*.

An updated key to the several flowering stems and sterile rosettes, leaves I-I.5(-I.8) mm broad species of Onosma (Asterotrichous group) in Turkey is proposed below.

1	Bracts 7-8 mm, calyx 10-11 mm, corolla white, clavate-campanulate, gla-
	brous
_	Bracts 8–15 mm, calyx 6–12 mm, corolla yellow, clavate, puberulous
	O. anatolica

Discussion

Onosma anatolica belongs to Onosma sect. Asterotricha subsect. and it is distributed in Southern Anatolia (Niğde) and grows on the steppe and rocky pastures. It is an element belong to the Irano-Turanian floristic region. It shows some affinity to O. subulifolia which is placed in the same subsection and can be easily distinguished from that species by its sterile shoots; green-grey stem with adpressed setose trichomes, the setae arising from stellate hairy and shortly hairy, sterile rosette leaves and basal leaves $-50 \times 1-1.5(-1.8)$ mm; revolute-subulate, cauline leaves $-20 \times 1-1.5(-1.8)$ mm; bracts $8-15 \times 1-2$ mm; calyx 6-8 mm in flower, 8-12 mm in fruit, suboblate, patent strigose on ±tubercles and shortly hairy on the outside, rarely hairy on the inside; yellow corolla, clavate, puberulous, nutlets $3-3.5 \times 2-2.3$ mm in size, short beaked, grey. Details of the differences between O. anatolica and O. subulifolia are presented in Table 2.

	O. subulifolia	O. anatolica		
Stem	Bluish-black, adpressed	Green-grey, woody at base, adpressed setose with stellate hairy and		
	setose, otherwise glabrous.	shortly hairy.		
Leaves	15–32 × 1–1.5(-1.8) mm, Sterile rosette and basal leaves -50 × 1–1.5(-1.8) mm, revulate-sub			
	involute-subulate, densely	late, adpressed setose with stellate hairy. Cauline leaves -20 x 1–1.5(-		
	adpressed setose.	1.8) mm, indistinct revulate-subulate, densely covered, adpressed se-		
		tose with stellate hairs on upper surfaces and sparsely adpressed setose		
		with stellate hairs on lower surfaces.		
Inflorescence	Short subcapitate	Cymes 1–2, short subcapitate, sometimes elongated after flowering.		
Bracts	7–8 mm, flat, apex lin-	$8-15 \times 1-2$ mm, linear-subulate, abruptly narrowed and tapering		
	gulate.	towards an acute apex, ±patent setose, stellate and tuberculate.		
Pedicel	-1–1.5 mm	1–2 mm		
Calyx	10–11 mm, lobes narrowly	6–8 mm in flower, 8–12 mm in fruit, lobes narrowly linear suboblate,		
	linear, subobtuse, hispid.	patent strigose on ± tubercles and shortly hairy on outside and rarely		
		hairy on inside.		
Corolla	White, clavate-campanu-	Yellow, clavate, puberolous, lobes 1 mm long, 1.7 mm wide at base,		
	late, glabrous, lobes short,	widely triangular.		
	acute.			
Nutlets	Unknown	3–3.5 × 2–2.3 mm, shortly beaked, grey.		

Table 2. The morphological differences between Onosma anatolica and O. subulifolia.

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RESEARCH ARTICLE



Melicope oppenheimeri, section Pelea (Rutaceae), a new species from West Maui, Hawaiian Islands: with notes on its ecology, conservation, and phylogenetic placement

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Abstract

Melicope oppenheimeri K.R. Wood, Appelhans & W.L. Wagner (section *Pelea* (A. Gray) Hook. f., Rutaceae), a rare endemic tree from West Maui, Hawaiian Islands, is described and illustrated with notes on its ecology, conservation, and phylogenetic placement. The new species differs from Hawaiian congeners by its carpels basally connate 1/5, narrowed into a strongly reflexed beak 10–15 mm long. It also differs in a combination of leaves with 7–10 pair of secondary veins; cymes to 3 cm long; peduncles 5–6.5 mm long; flowers perfect; capsules 4–9 × 40–52 mm; and a densely appressed short-sericeous ovary. *Melicope oppenheimeri* is known only from an isolated cliff-base plateau in upper Waihe'e Valley, West Maui. Its discovery brings the number of recognized *Melicope* J.R. Forst. & G. Forst. species in the Hawaiian Islands to 49. A table is included indicating the conservation status of Hawaiian *Melicope* and *Platydesma* H. Mann., which is nested within *Melicope* sect. *Pelea*.

Melicope oppenheimeri falls into the IUCN Critically Endangered (CR) Red List category.

Keywords

Rutaceae, Melicope, M. section Pelea, new species, Hawaiian Islands, West Maui, Critically Endangered

Introduction

Melicope J.R. Forst. & G. Forst. is the largest genus of the Citrus family (Rutaceae) and consists of ca. 235 species of shrubs and trees (Hartley 2001, Appelhans et al. 2014a). The distribution of Melicope ranges from the Malagasy and Indo-Himalayan regions in the east to the Hawaiian and Marguesan Islands in the west and from Nepal, southern China, Taiwan and the Japanese Ogasawara Islands in the north to New Zealand and Australia in the south (Hartley 2001). Ongoing phylogenetic studies of Melicope and closely related genera indicate the need for revisionary work in this group with several of the related small genera belonging in Melicope in order for it to be monophyletic (Harbaugh et al. 2009, Appelhans et al. 2014b). In the most recent systematic revision by Hartley (2001) Melicope was subdivided into four sections: Lepta (Lour.) T.G. Hartley; Melicope; Pelea (A. Gray) Hook. f.; and Vitiflorae T.G. Hartley. Only section Lepta proved to be a monophyletic group in a recent molecular study (Appelhans et al. 2014b). The currently known 48 endemic Hawaiian species are all members of sect. Pelea, which consists of 85 species almost exclusively restricted to the Australasian-Outer Melanesian-Pacific region. Within sect. Pelea, only the Hawaiian group proved to be monophyletic (Appelhans et al. 2014c). The Hawaiian endemic species all have unifoliolate leaves; plants presumably hermaphroditic or dioecious; carpels that range from being basally connate to fully connate, and with variations in exocarp and endocarp that contrast from glabrous to pubescent. Hartley (2001) inferred that Melicope was present in eastern Gondwanaland before about 96 Ma and states that the Hawaiian species represent a radiation that most likely traces back to a single colonization of the archipelago by a species from sect. Pelea. While Hartley's age estimate of *Melicope* is doubtful since the oldest fossils of the whole family date to the Late Cretaceous (Knobloch and Mai 1986, Gregor 1989) and molecular dating studies estimated its origin in the Oligocene or Miocene (Muellner et al. 2007, Appelhans et al. 2012), his suggestion for a single colonization of the Hawaiian archipelago was supported by molecular phylogenetic analyses (Harbaugh et al. 2009, Appelhans et al. 2014b, c). The most recent molecular phylogenetic studies also indicate that the Hawaiian genus Platydesma H. Mann is nested within Melicope sect. Pelea and that the seven known Marquesan *Melicope* endemics are a closely related group resultant from two independent colonization events from Hawaiian Melicope (Harbaugh et al. 2009, Appelhans et al. 2014c).

Methods

All measurements and descriptions were taken from dried herbarium specimens or from notes made in the field and are presented in the descriptions as follows: length × width, followed by units of measurement (mm or cm).

Taxonomic treatment

Melicope oppenheimeri K.R. Wood, Appelhans & W.L. Wagner, sp. nov. urn:lsid:ipni.org:names:60472944-2 Figs 1, 4, 5

Diagnosis. Differs from Hawaiian congeners by its combination of leaves having 7–10 pair of secondary veins; cymes to 3 cm long; peduncles 5–6.5 mm long; flowers perfect; carpels basally connate 1/5, narrowed into a strongly reflexed beak 10–15 mm long, capsules $4-9 \times 40-52$ mm; and ovary appressed densely short-sericeous.

Type. United States of America. Hawaiian Islands, West Maui: Wailuku District, Waihe'e Valley, *Metrosideros polymorpha* var. *glaberrima-Cheirodendron trigynum* wet forest, 20°54.15'N; 156°33.95'W, 770 m elev., 12 Sep 2006, *Hank Oppenheimer & Jill Miller H90609* (holotype: PTBG-070667; isotypes: BISH, US)

Description. Trees 3-4 m tall, bark medium brown, young branchlets light brown, glabrate, 3-6 mm wide in third internode, terminal branchlets yellowish brown tomentose with a waxy scurf. Leaves opposite, unifoliolate, coriaceous, the blade obovate to broadly elliptic, occasionally orbicular, $5-17.5 \times 3.5-8.5$ cm, the margin entire, the base rounded to obtuse, the apex rounded, obtuse to acute, or emarginate, secondary veins usually 7-10 pairs, connected by a moderately arched vein 2-11 mm from margin with higher order venation reticulate, both surfaces glabrous, occasionally glabrate along midrib of abaxial surface, young leaves glabrate to sparsely puberulent on lower surface; petiole shallowly canaliculate, $10-30 \times 1-3$ mm at middle, glabrate. *Flowers*: perfect, 3–5 in axillary cymes up to 3 cm long, peduncles 5–6.5 mm long, sparsely short-puberulent, pedicles 5-8 mm, short-puberulent, bracteoles 1.5-3 mm long, sepals broadly ovate, tip short acuminate, externally sparsely shortpuberulent, glabrous within, $3 \times 2.5 - 2.8$ mm, connate basally 1/4 to 1/3 of length; petals tinged purple, narrowly ovate, lanceolate, $6-8 \times 2.5-3$ mm, glabrous internally and externally, tips recurved, nectary disk with sparsely scattered hairs; ovary densely appressed short-sericeous; style ca. 1.7 mm long, with finely appressed hairs; stigma capitate, four lobed, glabrous; stamens 8, filaments glabrous, the antesepalous ones 5-7 mm long, antepetalous ones 4-5 mm long, all with pollen. Capsules purple tinged when fresh, $4-9 \times 40-52$ mm, carpels connate basally for ca. 1/5 their length, narrowed into a strongly reflexed beak 10-15 mm long, exocarp glabrate with few hairs widely spaced over surface, endocarp sparsely to evenly puberulent. Seeds 2 per carpel, ovoid, 5–9 mm long.

Phenology. To date, *Melicope oppenheimeri* has been observed with flower buds in January and August, with flowers at anthesis during September, and with fruit during January, February, May, August, September, and November.

Etymology. We are pleased to name this new species in honor of Hank Oppenheimer, botanist with the Maui Nui Plant Extinction Prevention Program, who collected the type specimen and has made many valuable contributions to the understanding and conservation of the Hawaiian flora.



Figure 1. Melicope oppenheimeri K.R. Wood, Appelhans & W.L. Wagner. **A** Flowering branch, Oppenheimer & Hansen H20505 (PTBG) **B** Inflorescence **C** Undehisced fruit, showing beaked carpels **D** Fruit, partly open **E** Fruit, fully opened **F** Fruit endocarp showing venation and hairs **B–F** from Oppenheimer & Miller H90609 (PTBG) (Illustration by Alice Tangerini).

Specimens examined. United States. Hawaiian Islands, West Maui: Wailuku District, Waihe'e Valley, south side, below and north of Kahoolewa Ridge, 20°54.15'N; 156°33.95'W, 770 m elev., 8 Aug 1998, *Wood & Perlman 7408* (BISH, PTBG, US); loc. cit., 9 Aug 1998, *Perlman & Wood 16,338* (CANB, PTBG); loc. cit., 10 AUG 1998, *Wood & Perlman 7419* (BISH, PTBG, US); loc. cit., 15 Feb 2005, *Oppenheimer & Hansen H20,505* (BISH, PTBG, US); loc. cit., 19 May 2009, *Perlman* & Oppenheimer 21,642 (PTBG).

The following couplets can be inserted into the existing key to Hawaiian *Melicope* (treated as *Pelea*) by Stone, Wagner, and Herbst (in Wagner et al. 1999, pp. 1179–1182) to accommodate *M. oppenheimeri*.

19(18)	Exocarp sparsely to densely puberulent or tomentose, at least toward base or
	along suture
19	Exocarp glabrous or glabrate, sometimes with a few hairs widely spaced over
	surface
49(19)	Endocarp densely and uniformly short-villous; K
49	Endocarp glabrous or sparsely puberulent, especially along suture
50(49)	Leaves ternate; O
50	Leaves opposite
51(50)	Most petioles 0–10 mm long
51	Most petioles over 10 mm long
58(51)	Ovary sparsely to densely puberulent or tomentulose, but exocarp glabrate or
	nearly so in fruit
58	Ovary and exocarp glabrous
59(58)	Flowers perfect, carpels narrowed into a reflexed beak 10-15mm long; WM
59	Flowers unisexual, carpels straight or somewhat reflexed, apex not beaked
59a(59)	Capsules (16–)25–40(–50) mm wide, carpels connate 1/4–1/3 their length;
	pedicels 5-20 mm long; L, EM, H M. volcanica
59a	Capsules 11–20 mm wide, carpels connate (1/3–)1/2 their length or more;
	pedicels 2-5 mm long; K, O

Distribution and ecology. Although seven trees of *Melicope oppenheimeri* have been documented since its discovery in 1998, only three trees are still surviving in the upper headwaters of Waihe'e Valley, West Maui (Figures 2, 3). No trees have yet been located outside of the type locality and access to the site has only been by helicopter.

The plant communities of upper Waihe'e Valley are varied and merge together in and around the 0.25 km² cliff-base plateau region where trees of *Melicope oppenheimeri* occur. The plateau itself represents a relictual low statured *Metrosideros* Banks ex Gaertn. (Myrtaceae)-*Cheirodendron* Nutt. ex Seem. (Araliaceae) lowland wet forest community. Other relic native components of the plateau include ferns such as *Asplenium lobulatum* Mett. (Aspleniaceae), *Cibotium glaucum* (Sm.) Hook. & Arn. (Cibotiaceae), *Ctenitis*



Figure 2. Map of Maui, Hawai'i showing location of *Melicope oppenheimeri* in upper Waihe'e Valley.

latifrons (Brack.) Copel. (Dryopteridaceae), *Diplazium sandwichianum* (C. Presl) Diels (Athyriaceae), two endemic genera of ferns, namely *Adenophorus* Gaudich. (Polypodiaceae) and *Sadleria* Kaulf. (Blechnaceae), along with herbs, shrubs, and small trees including *Antidesma platyphylla* H. Mann (Phyllanthaceae), *Broussaisia arguta* Gaudich. (Hydrangeaceae), *Coprosma pubens* A. Gray (Rubiaceae), *Dubautia plantaginea* Gaudich. (Asteraceae), *Peperomia hirtipetiola* C. DC. (Piperaceae), and various species of *Clermontia* Gaudich., *Cyanea* Gaudich. (both Campanulaceae), and *Cyrtandra* J.R. Forst. & G. Forst. (Gesneriaceae). Steeper ridges and slopes that edge the plateau are dominated by matting ferns of *Dicranopteris* Bernh.(Gleicheniaceae) (Wood 1997).

Unfortunately, past habitat degradation by introduced pigs (*Sus scrofa* L.) has altered the plant composition of the plateau, which is now being dominated by a succession of invasive weeds, which threaten *Melicope oppenheimeri*, especially *Ageratina adenophora* (Spreng.) R.M. King & H. Rob. (Asteraceae), *Buddleja asiatica* Lour. (Scrophulariaceae), *Clidemia hirta* (L.) D. Don (Melastomataceae), *Erigeron karvinskianus* DC. (Asteraceae), and *Tibouchina herbacea* (DC.) Cogn. (Melastomataceae) (Wood 1997).

Towering over the plateau and most outstanding, are vertical caldera-like basalt cliffs dominated by a native sedge and grass association called *Machaerina* Vahl (Cyperaceae)-*Deschampsia* P. Beauv. (Poaceae) wet cliff community. The cliffs are seeping with springs and waterfalls and strata of past volcanic flows are clearly evident. Additional components of this Waihe'e cliff community include *Sadleria pallida*



Figure 3. Map of upper Waihe'e Valley, West Maui, with red dot indicating the location of *Melicope oppenheimeri* on the cliff-base plateau region.

Hook. & Arn., *Pipturus albidus* (Hook. & Arn.) A. Gray (Urticaceae), *Eragrostis grandis* Hillebr., *Isachne distichophylla* Munro ex Hillebr. (both Poaceae), and *Dubautia scabra* (DC.) D.D. Keck.

Superb examples of *Metrosideros-Cheirodendron* montane wet forest dominate above these cliffs in association with windswept wet shrublands and occasional bog communities in and around the locality known as Kaho'olewa Ridge (Wood 1997). At the base of the cliffs, which enclose the southern perimeter of the plateau lie heaps of basalt talus with accumulated substrates which are moderately deep in sections and appear to be fine textured brown silty clay.

The forests spreading below the plateau are composed of *Metrosideros* mixed lowland riparian vegetation, which are closed to open in canopy and dissected by deeply



Figure 4. Habit of *Melicope oppenheimeri (Oppenheimer & Miller H90609*). Photo by H. Oppenheimer, 12 Sep 2006.

carved streams with steep banks 10–30 m in height. The native flora of this lower riparian community has similarities to the cliff-base plateau but with a greater diversity, including *Ilex anomala* Hook. & Arn. (Aquifoliaceae), *Perrottetia sandwicensis* A. Gray (Dipentodontaceae), *Polyscias oahuensis* (A. Gray) Lowry & G.M. Plunkett (Araliaceae), and *Pritchardia forbesiana* Rock (Arecaceae), along with species of *Kadua* Cham. & Schltdl. (Rubiaceae), *Myrsine* L. (Primulaceae), and *Psychotria* L. (Rubiaceae) (Wood 1997). Notable observations of native birds in the upper Waihe'e region include nesting seabird colonies of dark-rumped petrels (*Pterodroma sandwichensis* Ridgeway) along with native forest birds such as 'apapane (*Himatione sanguinea* Gmelin), and 'amakihi (*Chlorodrepanis virens wilsoni* Rothschild).

Phylogenetic placement. *Melicope oppenheimeri,* like all Hawaiian *Melicope*, falls into section *Pelea*, which has a distribution ranging from Taiwan, the Philippines, and Borneo eastward to the Hawaiian and Marquesas Islands, and south to New Caledonia. Only *Melicope triphylla* (Lam.) Merr. is distributed in the Southeast Asian areas mentioned above, and the remainder of sect. *Pelea* is restricted to New Guinea and Pa-

cific archipelagos (Hartley 2001). Section *Pelea* proved to be polyphyletic in molecular phylogenetic analyses, and monophyly can be reached if the New Caledonian species are excluded and the Hawaiian endemic genus *Platydesma* is included in the section (Appelhans et al. 2014b). Hartley (2001, pp. 31, 139-140) stated that the Hawaiian species mostly resemble the New Caledonian species - especially M. vieillardii - based on several "primitive" characters including bisexual flowers, persistent sepals and petals, apically acute staminal filaments, basally connate carpels, glabrous endocarp, and Type A seed attachment, however, a close phylogenetic relationship of the Hawaiian and the New Caledonian species could not be verified (Appelhans et al. 2014b). The Hawaiian species of Melicope have been treated under the genus Pelea by Wagner et al. (1990) and the authors divided the taxon into the four sections Apocarpa B. Stone; Cubicarpa B. Stone; Megacarpa B. Stone; and Pelea. If the Hawaiian groups are to continue to be recognized, they would need to be treated as subsections. Only the latter of these sections, which consists of three species, proved to be monophyletic (Appelhans et al. 2014b, c). Two specimens of Melicope oppenheimeri (the paratypes Wood & Perlman 7408 and Wood & Perlman 7419) have been included in phylogenetic research (Appelhans et al. 2014b, c) and they are listed under the original determination Melicope reflexa (H. St. John) T.G. Hartley & B.C. Stone in these studies. The two specimens are part of a largely unresolved clade consisting of representatives of Cubicarpa and Megacarpa. The closest relatives of M. oppenheimeri could not be determined due to the low genetic variation in the sampled nuclear and plastid markers. We are currently working on resolving phylogenetic relationships of Hawaiian Melicope using Next-generation sequencing.

Morphology and related taxa. Although beaked fruit have evolved in a few species of *Melicope* belonging to sections *Melicope* and *Vitiflorae* (Hartley 2001, p. 19), this character is unique to *M. oppenheimeri* within sect. *Pelea* (Figure 1C, 5B). Beaked fruit have also evolved in Hawaiian *Platydesma* sect. *Cornutia* B.C. Stone, which is nested within *Melicope* sect. *Pelea*, but which is not an immediate relative of *M. oppenheimeri*.

Morphologically, *Melicope oppenheimeri* resembles the Moloka'i endemic species *M. reflexa*, with both having reflexed carpels that are coherent at base. Significant differences between *M. oppenheimeri* and *M. reflexa* include capsules connate 1/5, 4–9 \times 40–52 mm (vs. capsules connate 1/4, 10–17 \times 20–33 mm); endocarp sparsely to evenly puberulent (vs. endocarp glabrous); ovary appressed densely short-sericeous (vs. ovary glabrous); pedicles 5–8 mm (vs. pedicles15–20 mm); and flowers perfect, 3–5, on robust peduncles (vs. flowers unisexual, 1–3, on delicate peduncles).

Two other morphologically similar Hawaiian *Melicope*, also with carpels coherent at base include *M. molokaiense* (Hillebr.) T.G. Hartley & B.C. Stone and *M. volcanica* (A. Gray) T.G. Hartley & B.C. Stone. *Melicope molokaiense*, which is known from Molokai and Maui, differs from *M. oppenheimeri* in having capsules connate 1/4, $10-17 \times 21-39$ mm; endocarp glabrous; ovary glabrous; and flowers unisexual. *Melicope volcanica*, which is known from Lana'i, Moloka'i, East Maui, and the big island of Hawai'i, similarly differs with capsules connate 1/3-1/4, and flowers unisexual, yet



Figure 5. Melicope oppenheimeri **A** Flowers **B** Fruit, showing beaked carpels (*Oppenheimer & Miller* H90609). Photos by H. Oppenheimer, 12 Sep 2006.

also differs with leaves having 10–20 pair of secondary veins; cymes ca. 6 cm long; and peduncles 7–38 mm long. *Melicope oppenheimeri* has leaves with 7–10 pair of secondary veins; cymes ca. 3 cm long; and peduncles 5–6.5 mm long.

Melicope species are generally either exclusively hermaphroditic or dioecious, yet there are a few recorded exceptions (Hartley 2001, p. 10). Although *M. oppenheimeri* is apparently hermaphroditic, we cannot make a definitive statement on the breeding system of this rare narrow endemic, having only six collections for study, and limited flowering material.

Conservation status. Plant and animal endemics from isolated oceanic islands are often endangered or critically endangered (Kreft et al. 2008, Sakai et al. 2002). The ongoing decline of native pollinators (Kearns et al. 1998) and seed dispersers (Milberg and Tyrberg 1993), in combination with other primary extrinsic factors such as invasive non-native plants, predation by introduced vertebrates, loss and fragmentation of natural habitats, and devastation by severe storms, are leading to an increase in extinctions throughout the islands of Oceania (Sakai et al. 2002, Wood 2007, 2012, Kingsford et al. 2009). Other prominent factors such as strict habitat requirements, very low historic population densities and narrow geographic range increase the risk of extinction. (Sakai et al. 2002, Wood 2007, 2015). It is currently unclear how many of the estimated 10,000 native Hawaiian insect species have gone extinct, but at this point in time the Hawaiian Islands have lost 79 of its native bird species and are left with only 32 (James and Olson 1991, Olson and James 1991, Burney et al. 2001, Boyer 2008). The authors maintain a checklist of endemic Hawaiian vascular plant taxa that have no known wild individuals remaining. Of the estimated 1191 native vascular plant species in Hawai'i, 130 taxa are now presumed extinct. Evidently 41 of these possible extinctions have occurred in the Hawaiian lobeliads (Campanulaceae), a family renowned for their co-evolution with Hawai'i's unique forest birds, the honeycreepers, in the endemic subfamily Drepanidinae of the Fringillidae or finch family (Wood 2014, 2015). The Lamiaceae or mint family falls second in this severe category, with 22 species that are presumed extinct. With two-thirds of the surviving forest bird species in Hawai'i being critically **Table 1.** Checklist of endemic Hawaiian *Melicope* and *Platydesma* with conservation status and island distribution. (Status Symbols: C=candidate for federal listing; E=federally listed as endangered; EX=possibly extinct; PEPP=Plant Extinction Prevention Program (50 or less individuals known in wild); SOC=species of concern. Island Distribution: K=Kaua'i; O=O'ahu; Mo=Moloka'i; L=Lana'i; M=Maui; H=Big Island of Hawai'i; Note: *Platydesma* had been shown to be nested in *Melicope* [Harbaugh et al. 2009, Appelhans et al. 2014c]).

Taxon	Status	Distribution
Melicope adscendens (H.St.John & E.P.Hume) T.G.Hartley & B.C.Stone	E, PEPP	М
Melicope anisata (H.Mann) T.G.Hartley & B.C.Stone		К
Melicope balloui (Rock) T.G.Hartley & B.C.Stone	E, EX	М
Melicope barbigera A.Gray		К
Melicope christophersenii (H.St.John) T.G.Hartley & B.C.Stone	Е	0
Melicope cinerea A.Gray	SOC	0
Melicope clusiifolia (A.Gray) T.G.Hartley & B.C.Stone		K, O, Mo, L, M, H
Melicope cruciata (A.Heller) T.G.Hartley & B.C.Stone	SOC	К
Melicope degeneri (B.C.Stone) T.G.Hartley & B.C.Stone	E, PEPP	К
Melicope elliptica (A.Gray) T.G.Hartley & B.C.Stone		O, Mo, M
Melicope feddei (H.Lév.) T.G.Hartley & B.C.Stone		К
Melicope haleakalae (B.C.Stone) T.G.Hartley & B.C.Stone	SOC	М
Melicope haupuensis (H.St.John) T.G.Hartley & B.C.Stone	E, PEPP	K
Melicope hawaiensis (Wawra) T.G.Hartley & B.C.Stone	SOC	Mo, L, M, H
Melicope hiiakae (B.C.Stone) T.G.Hartley & B.C.Stone	Е	0
Melicope hosakae (H.St. John) W.L. Wagner & R.K. Shannon		0
Melicope kaalaensis (H.St.John) T.G.Hartley & B.C.Stone		0
Melicope kavaiensis (H.Mann) T.G.Hartley & B.C.Stone		K
Melicope knudsenii (Hillebr.) T.G.Hartley & B.C.Stone	E, PEPP	К, М
Melicope lydgatei (Hillebr.) T.G.Hartley & B.C.Stone	E, PEPP	0
Melicope macropus (Hillebr.) T.G.Hartley & B.C.Stone	EX, SOC	K
Melicope makahae (B.C.Stone) T.G.Hartley & B.C.Stone	Е	0
Melicope molokaiensis (Hillebr.) T.G.Hartley & B.C.Stone		Mo, M
Melicope mucronulata (H.St.John) T.G.Hartley & B.C.Stone	E, PEPP	Mo, M
Melicope munroi (H.St.John) T.G.Hartley & B.C.Stone	Е	Mo, L
Melicope nealae (B.C.Stone) T.G.Hartley & B.C.Stone	EX, SOC	K
Melicope oahuensis (H.Lév.) T.G.Hartley & B.C.Stone		0
Melicope obovata (H.St.John) T.G.Hartley & B.C.Stone	EX, SOC	М
Melicope oppenheimeri K.R.Wood, Appelhans & W.L.Wagner	PEPP	М
Melicope orbicularis (Hillebr.) T.G.Hartley & B.C.Stone		М
Melicope ovalis (H.St.John) T.G.Hartley & B.C.Stone	Е	М
Melicope ovata (H.St.John & E.P.Hume) T.G.Hartley & B.C.Stone		К, О
Melicope pallida (Hillebr.) T.G.Hartley & B.C.Stone	Е	К, О
Melicope paniculata (H.St.John) T.G.Hartley & B.C.Stone	Е	K
Melicope peduncularis (H.Lév.) T.G.Hartley & B.C.Stone		K, O, Mo, M
Melicope pseudoanisata (Rock) T.G.Hartley & B.C.Stone		М, Н
Melicope puberula (H.St.John) T.G.Hartley & B.C.Stone	E	К
<i>Melicope quadrangularis</i> (H.St.John & E.P.Hume) T.G.Hartley & B.C.Stone	E, PEPP	K
Melicope radiata (H.St.John) T.G.Hartley & B.C.Stone		Н

Taxon	Status	Distribution
Melicope reflexa (H.St.John) T.G.Hartley & B.C.Stone	E, PEPP	Mo
Melicope rotundifolia (A.Gray) T.G.Hartley & B.C.Stone		О
Melicope saint-johnii (E.P.Hume) T.G.Hartley & B.C.Stone	Е	О
Melicope sandwicensis (Hook. & Arn.) T.G.Hartley & B.C.Stone	SOC	О
Melicope sessilis (H.Lév.) T.G.Hartley & B.C.Stone		Mo, M
Melicope volcanica (A.Gray) T.G.Hartley & B.C.Stone		Mo, L, M, H
Melicope waialealae (Wawra) T.G.Hartley & B.C.Stone		Κ
Melicope wailauensis (H.St.John) T.G.Hartley & B.C.Stone	EX, SOC	Mo
Melicope wawraeana (Rock) T.G.Hartley & B.C.Stone		К, О
Melicope zahlbruckneri (Rock) T.G.Hartley & B.C.Stone	E, PEPP	Н
Platydesma cornuta Hillebr. var. cornuta	Е	О
Platydesma cornuta Hillebr. var. decurrens B.C.Stone	Е	О
Platydesma remyi (Sherff) O.Deg., I.Deg, Sherff & B.C.Stone	C, PEPP	Н
<i>Platydesma rostrata</i> Hillebr.	E	K
Platydesma spathulata (A.Gray) B.C.Stone		К, О, М, Н

endangered and a continued decline in native arthropods, there is grave concern for the endangered Hawaiian flora and for their unique insular relationships with biodiversity as a whole. Even today, little is known about the life cycles, breeding system variations, and habitat preferences found in the Hawaiian flora (Sakai et al. 2002, Wood 2015), but it is known that *Melicope* rely on insects for pollination and birds for dispersal (Hartley 2001). Within Hawaiian *Melicope* five species are currently presumed extinct, 19 are federally listed as endangered, and with the inclusion of *M. oppenheimeri*, ten species fall into the Plant Extinction Prevention Program (PEPP) category, meaning there are 50 or fewer individuals remaining (see Table 1). Members of Hawaiian Rutaceae are currently in the process of being evaluated according to IUCN categories and criteria.

IUCN Red List Category. When evaluated using the World Conservation Union (IUCN) criteria for endangerment (IUCN 2001), *Melicope oppenheimeri* falls into the Critically Endangered (CR) category, which designates this species as facing a very high risk of extinction in the wild. Our formal evaluation can be summarized by the following IUCN hierarchical alphanumeric numbering system of criteria and subcriteria: CR B1 ab(i,ii,iii,v)+2ab(i,ii,iii,v); C2a(ii); D; which reflects a severely limited Extent of Occurrence (EOO) and Area of Occupancy (AOO) of less than 1 km² and a wild population of only three individuals. It should be noted that seed collections of *M. oppenheimeri* have been made by Maui PEPP staff during routine monitoring and there is currently a single cultivated individual being grown at the Olinda Rare Plant Facility on East Maui.

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RESEARCH ARTICLE



Tulipa cinnabarina subsp. toprakii (Liliaceae), a new subspecies from southwestern Anatolia

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Abstract

A new subpecies, *Tulipa cinnabarina* subsp. *toprakii* **subsp. nov.** (Liliaceae) from Turkey is described. Diagnostic characters, descriptions, detailed illustrations, geographical distribution, conservation status and ecological observations on the new taxon are provided. It is also compared with the closely related *Tulipa cinnabarina* subsp. *cinnabarina*.

Keywords

New taxon, taxonomy, Tulipa, Turkey

Introduction

In Turkey, Eker et al. (2014) revised the genus *Tulipa*. According to detailed morphologic, geographic and cytotaxonomic studies of the taxa, the genus *Tulipa* was divided into two subgenera and they represented 17 species, two subspecies and two varieties (in total 19 taxa).

Ayhan Toprak, who is a biologist and "expert of plant conservation areas", collected an interesting specimen of *Tulipa* from near Milas district in Muğla province. He sent some interesting pictures of this specimen to us for identification in 2015. In April 2016, we gathered flowering material from the natural population of this plant. As a

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result of our detailed morphological studies, it was concluded that the collected *Tulipa* specimens differ from all of the other *Tulipa* species by their morphological characters except of *T. cinnabarina*. Although it is close to *T. cinnabarina*, it is morphologically separated as subspecific rank from *T. cinnabarina*.

Materials and methods

The specimens of the new taxon were collected from their natural habitats in Turkey, and dried according to standard herbarium protocols. Voucher specimens are deposited in the herbaria; EGE and AIBU. Then, we tried to identify the specimens using the keys in the taxonomic revision of Eker et al. (2014) and the floras of neighbouring regions such as Iran (Rechinger 1990), Iraq (Wendelbo 1985), Syria, Palestine (Post and Dinsmore 1933), central Asia, Caucasus (Vvedensky 1935), and Europe (Grey-Wilson and Matthews 1980). In addition, the specimens were compared with similar specimens at international and national herbaria: AIBU, AEF, ANK, BM, ISTE, ISTF, GAZI, E, EGE, FUH, HUB, K, KNYA, NGBB and VANF. All quantitative as well as most of the qualitative characters excluding the colour features were examined in dried specimens. Measurements were made using a precise ruler under a stereo-microscope.

Taxonomic treatment

Tulipa cinnabarina K.Perss. subsp. *toprakii* Yıldırım & Eker, subsp. nov. urn:lsid:ipni.org:names:60472945-2 Figs 1–2

Diagnosis. *Tulipa cinnabarina* subsp. *toprakii* differs from similar *T. cinnabarina* subsp. *cinnabarina* by its smaller anthers, narrower outer perianth segments, outer segments with mostly blackish base or buff colored on all of outer surfaces, and smaller capsul sizes, weakly stoloniferous structure, and 2–4 leaves.

Type. Turkey. Muğla: Milas, on the road of Milas to Akgedik Dam, near Yusufça Village, open slopes and in olive orchard, 457 m, 37°20'7"N; 27°52'6"E, 02 April 2016, *H.Yıldırım 3750 & Y. Altıoğlu* (holotype EGE!, isotypes AIBU!, NGBB!).

Description. Plant 18.0–39.0 cm. Stem glabrous, stem width 1–2.5 mm, subterranean stem length 7.0–14.0 cm, aerial stem length 7.0–20.0 cm. Weakly stoloniferous or not. Bulb ovoid, $1.5-2.2 \times 1.8-2.4$ cm. Bulb neck 2.5–7.0 cm. Tunics coriaceous, dark brown, innermost tunics with a ring of short hairs around basal plate and, adpressed, pilose, bristly with longer hairs at neck, middle part glabrous. Leaves 2–4, falcate to erect-patent, lanceolate, canaliculate, glaucous, alternate or ± crowded, leaf margin membranous, glabrous or ciliate, and entire; lowest leaf $13.0-21.0 \times 0.7-1.3$ cm, subacute; second lowest leaf $10.0-17.0 \times 0.4-0.9$ cm, acute to subacute. Flower solitary, infundibular, bright dark red to orange red inside and paler red to orange red



Figure 1. Habitat of *T. cinnabarina* subsp. *toprakii* in the wild (A–B).

outside with mostly blackish base or buff colored on all of outer surfaces, mostly no blotch inside, rarely with a very short yellow blotch; outer tepals elliptic, narrowed at base, suacute to acute, glabrous and pubescent only at tip, $27-41 \times 6-8$ mm; inner



Figure 2. Habit of *T. cinnabarina* subsp. *toprakii* (**A**) and *T. cinnabarina* subsp. *cinnabarina* (**B**), *T. cinnabarina* subsp. *toprakii* (**C** from *Yıldırım 3750 & Altıoğlu*), *T. cinnabarina* subsp. *cinnabarina* (**D** from *Eker 2030 & 2186*), The flower from the exterior (**I**), The flower from the interior (**2**), The matured fruit (**3**).

tepals elliptic-obovate, narrowed at base, obtuse or obtuse-apiculate, pubescent at tip and distinctly pubescent at base, $29-44 \times 10-16$ mm. If it is present, outer and inner blotchs 6–10 mm in length; blotch 1/5-1/6 length of segments. Filaments blurred shades of red, orange, yellow or brown, lanceolate and pubescent at base; outer filaments 7.0–11.5 mm, inner ones 8.0–12.5 mm. Anthers 2.5–6.0 × 1.0–1.5 mm when



Figure 3. Distribution map of subspecies of *T. cinnabarina*: triangle symbol is natural range of *T. cinnabarina* subsp. *cinnabarina* while star symbol is natural range of *T. cinnabarina* subsp. *coprakii* in Turkey.

dry, oblong, bluish-black when fresh, apiculate or not. Pollen yellow or orange. Ovary oblong, fusiform or subfusiform, pale green, yellowish-green or reddish-green when fresh, glabrous, $9.0-11.0 \times 3.0-5.0$ mm. Style short or obscure, $0.5-1.5 \times 1.0-2$ mm. Stigma pubescent, whitish-yellow or yellow when fresh, $0.5-0.6 \times 1.0-1.5$ mm. Capsule $1.5-2.0 \times 1.0-1.3$ cm, elliptic-obovoid to obovoid, glabrous; neck 0.5-1.0 mm, rib 14.0-16.0 mm, beak 2.0-4.0, apicula 0.5-1.0 mm; tepal scar 0.5-1.0 mm. Seeds numerous, flattened with rugose surface, triangular with two rounded angles to orbicular, light brown, $4.0-5.0 \times 3.0-4.0$ mm, winged.

Etymology. This new subspecies is named in honour of Ayhan Toprak, who first collected the new species. The Turkish name of this species is given as "Milas Lâlesi", according to the guidelines of Menemen et al. (2013).

Suggested conservational status. The occupancy area (AOO) of *Tulipa cinnabarina* subsp. *toprakii* was calculated as 0.012 km² in which about 600–750 individuals were estimated to occur. The individual of new subspecies found in *Olea europaea* L. orchard. On the other hand, overgrazing by sheep and goat herds and development of new road for mines were observed to be producing negative effects on the surroundings of the known populations, which are seriously threatened habitats of it. These strong anthropic pressures on this new subspecies are responsible for rapid habitat destruction, and they could cause a dramatic decrease of the number of reproductive individuals in the near future. Therefore, in accordance with the criteria of the IUCN (2012), *Tulipa cinnabarina* subsp. *toprakii* is here assessed as "Critically Endangered" (CR) B2ab(i,ii,iii), on account of its restricted distribution in Turkey with an inferred severe decline of the extent of occurrence, the occupancy area and quality of the habitat.

Distribution and ecology. *Tulipa cinnabarina* subsp. *toprakii* is endemic to west Anatolia (Fig. 3). It is an element belonging to the Mediterranean floristic region. It grows on calcareous soils at opening slopes and clearings in *Olea europaea* orchard. The associated species include: *Allium neopolitanum* Cyr., *Anthemis cretica* L. subsp. *leucanthemodies* (Boiss) Griersan., *Anthemis macrotis* (Rech.f) Oberpr & Voght, *Cistus creticus* L., *Fritillaria minuta* Boiss., *Melilotus indica* (L.) All., *Olea europaea*, *Ophrys iricolor* Desf., *Pinus brutia* Ten. *Ranunculus muricatus* L., *Ranunculus repens* L.

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RESEARCH ARTICLE



A nonet of novel species of Monanthotaxis (Annonaceae) from around Africa

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Abstract

As part of an ongoing revision of the genus *Monanthotaxis* Baill. (Annonaceae), nine new species are described and one variety is reinstated to species rank. Two new species from West Africa (*Monanthotaxis aquila* P.H.Hoekstra, **sp. nov.** and *Monanthotaxis atewensis* P.H.Hoekstra, **sp. nov.**), four new species from Central Africa (*Monanthotaxis couvreurii* P.H.Hoekstra, **sp. nov.**, *Monanthotaxis latistamina* P.H.Hoekstra, **sp. nov.**, *Monanthotaxis tripetala* P.H.Hoekstra, **sp. nov.**, *Monanthotaxis zenkeri* P.H.Hoekstra, **sp. nov.**), one new species from Tanzania (*Monanthotaxis flipes* P.H.Hoekstra, **sp. nov.**), one new species from the area around Maputo (*Monanthotaxis maputensis* P.H.Hoekstra, **sp. nov.**), one new species from the Comoro Islands (*Monanthotaxis komorensis* P.H.Hoekstra, **sp. nov.**) and *Monanthotaxis klainei* (Engl.) Verdc. var. *angustifolia* (Boutique) Verdc. is raised to species level leading to the replacement name *Monanthotaxis atopostema* P.H.Hoekstra, **nom. nov.** (not *Monanthotaxis angustifolia* (Exell) Verdc.). Complete descriptions, comparisons with related species, ecological information and IUCN conservation assessments are given for the new species. Five species were classified as critical endangered, two species as endangered, one as vulnerable and one as least concern, warranting the need of further collecting and studying those species.

Keywords

Monanthotaxis, Annonaceae, Africa, *Gilbertiella*, new species, Mayotte, Comoros, Gabon, Cameroon, Tanzania, Mozambique, Ivory Coast, Ghana, South Africa, Republic of Congo, Atewa Range, Ottotomo, Rondo

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Introduction

The genus Monanthotaxis Baill. belongs to the tribe Uvariae in the family Annonaceae (Chatrou et al. 2012). Species of *Monanthotaxis* are scandent shrubs or lianas, and are confined to tropical Africa and Madagascar. The generic circumscription of the genus has seen considerable changes in the past. The genus was described by Baillon (1890) based on the presence of a single whorl of six petals, and a single whorl of stamens. Most species of Annonaceae typically have two whorls of three petals, and many whorls of stamens. Baillon (1890) named the genus Monanthotaxis after these characteristics (in Greek mono = one, anthir = stamen, taxis = order). In the following 60 years three additional species were described in the genus *Monanthotaxis* that displayed these generic characteristics. Then, Verdcourt (1971) synonymized the genus Enneastemon Exell and the African species of the genus Popowia Endl. into Monanthotaxis based on their similarity. Species of Popowia only differed from Monanthotaxis by having the petals in two whorls, however species of Enneastemon have the petals intermediate between Popowia and Monanthotaxis, which is a single whorl at the base of the flower, and in two whorls apically. With the rise of molecular phylogenetic analyses it has appeared that the genus *Friesodielsia* is polyphyletic, with most of the African species being sister to the genus Monanthotaxis (Chatrou et al. 2012; Richardson et al. 2004; Wang et al. 2012). Further data sampling has also revealed that the monotypic genus Exellia is nested in Monanthotaxis.

Alongside a molecular phylogenetic analysis of Monanthotaxis and related genera, a taxonomic revision of the genus is being undertaken. This revision has revealed nine new species of the genus *Monanthotaxis* which are described in this article. Two are from West Africa, four from western Central Africa, one from Tanzania, one from Southern Mozambique and one from the Comoros. This follows a general pattern in recent revisions of both Annonaceae and other tropical African forest taxa that most new species are found in western central Africa and Tanzania (e.g. Bissiengou et al. 2013; Breteler and Wieringa 2008; Breteler 2010; Couvreur et al. 2006; van der Burgt et al. 2015; Wieringa and Mackinder 2012). Also Madagascar is an area with many undescribed species, this is also true for Monanthotaxis, at least seven species will be described in another paper. It is striking that all species here described (except *M. filipes*) had already been collected at least 40 year ago, some even more than 100 years ago. Although of many of them only recently good flowering material became available, this does prove the importance of herbaria, and the need for exploring their collections (Bebber et al. 2010). Each of these species belongs clearly to the genus Monantho*taxis*, as they share the following morphological characteristics with all other species: a climbing habit, glaucous leaves, loosely coherent floral chambers, and moniliform monocarps. DNA sequences have confirmed their phylogenetic position within Mo*nanthotaxis*, and these analyses will be published soon in a separate paper with the new generic delimitation of Monanthotaxis (Guo et al. in press). With the species described here, the current number of species of Monanthotaxis will raise to 67.
Material and methods

Over 2000 collections of *Monanthotaxis, Exellia, Gilbertiella* and African *Friesodielsia* were examined from the following herbaria: A, AMD, B, BM, BNRH, BR, BRLU, C, E, EA, FHO, G, GC, K, L, LBV, LISC, LISU, M, MA, MO, NU, NY, P, SRGH, U, US, WAG and YA. All measurements were taken from dried specimens, colours were described based on the collector's information. For the species description the same terminology is being applied as in Hoekstra et al. (2014) with the exception that sterile stamens are called staminodes and the peduncle a sympodial rachis, to be in concordance with other Annonaceae literature (e.g. Endress and Armstrong 2011; Maas et al. 2003). The extent of occurrence and area of occupancy were calculated using GeoCAT (Bachman et al. 2011) and preliminary conservation status are proposed following the IUCN Red List Category Criteria (IUCN Standards and Petitions Subcommittee 2016).

Taxonomic treatment

Monanthotaxis atopostema P.H.Hoekstra, nom. nov.

urn:lsid:ipni.org:names:77157214-1

- Replacement name for: *Atopostema angustifolia* Boutique, Bull. Jard. Bot. Brux. 21:121 (1951) (non *Monanthotaxis angustifolia* (Exell) Verdc., Kew Bull. 25: 21, 1971).
- *Popowia klainei* Engl. var. *angustifolia* (Boutique) Le Thomas, Adansonia, sér. 2, 3: 291 (1963).
- *Monanthotaxis klainei* (Engl.) Verdc. var. *angustifolia* (Boutique) Verdc., Kew Bull. 25: 21 (1971).

Note. This species was described by Boutique (1951) based on the different leaf shape compared to *Monanthotaxis klainei* (Engl.) Verdc. The lack of other distinguishing features with *M. klainei* was the reason of Le Thomas (1963) and Verdcourt (1971) to treat it as a variety of *M. klainei*. However, they had only the availability of one flowering specimen. Now with an increased number of specimens available including fruiting material, we warrant it necessary to appraise this taxon again at species level. This species differs from *Monanthotaxis klainei* as mentioned by Boutique in the leaf shape, i.e. oblong to elliptic vs obovate in *M. klainei*, the rounded leaf base vs subcordate, the generally lower number of secondary veins (6–8 vs 7–12 in *M. klainei*) and it differs in the number of ovules per carpel (up to 6 vs 1 or 2 in *M. klainei*) and therefore also in the number of seeds per fruit. This species occurs sympatrically with *M. klainei* var. *klainei*, but differs from that species in having shorter pedicels (up to 12 mm in fruiting material vs 15–24 mm in fruiting material of *M. klainei* var. *klainei*). Actually, this species is much more similar in general aspects with *Monanthotaxis aquila* P.H.Hoekstra and *Monanthotaxis couvreurii* P.H.Hoekstra which are newly described

in this article. It can be distinguished from those two species by the characteristics mentioned in Table 1. The epithet "atopostema" refers to the genus *Atopostema* Boutique in which it first was described. It is used as a noun.

Monanthotaxis aquila P.H.Hoekstra, sp. nov.

urn:lsid:ipni.org:names:60472946-2 Figs 1, 2, Table 1

Type. IVORY COAST. Sassandra, Dakpadou-Sago, 29 March 1968, *C. Geerling 2327* (holotype: WAG [2 sheets, barcodes: WAG0005568!, WAG0005569!]; isotype: BR [BR0000015315335!]).

Diagnosis. Vegetatively similar to *M. atopostema* P.H.Hoekstra from Congo and *Monanthotaxis couvreurii* P.H.Hoekstra from Cameroon. Differs from the latter species in having staminodes alternating with the stamens, and free stamens. Differs from *M. atopostema* in having only 2 to 3 ovules per carpel, while the latter taxon has up to 6 seeds per monocarp.

Description. Liana; young branches reddish brown with very short reddish brown hairs 0.1 mm, old branches dark brown, cylindrical with a few lenticels, glabrescent. Leaves: petioles 4–6 × 0.7–1.1 mm, not grooved, pubescence as branches; lamina 3.5–11.5 \times 1.9–4.8 cm, length: width ratio 1.8–2.7, oblong, elliptic to slightly obovate, base cuneate to rounded, apex acute to acuminate, acumen to 1 cm, chartaceous, adaxially glossy dark green, abaxially dark silvery green, adaxially glabrous or midrib with a few short hairs, abaxially glabrescent, midrib of young leaves with short appressed yellowish hairs, venation eucamptodromous, secondary veins 6-8, from base curving upwards, tertiary venation scalariform. Inflorescences ramiflorous, axillary or supra-axillary, composed of a solitary flower or a 2 to 3 flowered rhipidium; sympodial rachis 0.5–2 mm with dense appressed short hairs; *flowering pedicels* $10-18 \times 0.3-0.4$ mm, with scattered appressed hairs; *lower bracts* lanceolate to ovate, $0.6-0.9 \times 0.3-0.5$ mm, indumentum as sympodial rachis; upper bracts at lower half of pedicel, ovate to lanceolate, $0.4-0.7 \times 0.3-0.4$ mm; flower *buds* ovate to triangular. Flowers bisexual; *sepals* 3, connate at base, $0.6 \times 1.2-1.3$ mm, broadly ovate, apex obtuse, with appressed yellowish hairs; receptacle flat, 1.6–2.0 mm in diameter; petals yellow, in two whorls of 3, but base of inner petals visible in bud; outer petals, $3.4-4.5 \times 2.1-2.8$ mm, ovate, outside with scattered yellowish appressed hairs, inside with very short appressed hairs at apex; *inner petals* $2.3-3.5 \times 1.3-1.5$ elliptic to slightly rhombic, outside with very short yellowish hairs at the apex and in the centre, inside only with hairs at the apex; stamens 9 in one whorl, free, clavate 0.7-0.8 mm, filaments 0.3-0.4 mm, anther cells lateral, connective slightly papillose, truncate, square from above, staminodes 6 alternating between the stamens, but wantingwhere in front of inner petals 0.3 mm, glabrous; carpels 12-13, $0.9-1.0 \times 0.4-0.5$ mm, ellipsoid, densely hairy, with 2-3ovules, lateral, stigma subsessile, globose 0.1 mm, glabrous. Fruits: Unknown.

Distribution. Ivory Coast, province Sassandra. Figure 2.

Ecology. Secondary forest, on sandy soil.



Figure 1. *Monanthotaxis aquila* P.H.Hoekstra. **A–H** drawn from the type (Geerling & Bokdam 2327). **A** Leaf **B** Leaf detail **C** Inflorescence **D** Flower. Illustration by M. Spitteler, reproduced from Hawthorne & Jongkind (2006).

Table 1. Differences between Monanthotaxis aquila, M. couvreurii and M. atopostema.

	M. aquila	M. couvreurii	M. atopostema
Nr of ovules per carpel	1-2	4	up to 6
Nr of staminodes	6	0	6?
Nr of stamens	9	13–15	9
Stamens free or basally connate	free	connate	free
Nr of carpels	12–13	9–12	ca 20
Nr of secondary veins	6–8	7–11	6–8
Distribution	Ivory Coast	Cameroon	Congo (Kinshasa)

Phenology. Flowering the end of March.

Conservation status. Proposed IUCN Red List Category: **Critically Endangered** (CR): B2ab(iii), only known from the type collection and the forests of that area are under serious threat (Chatelain et al. 1996).

Etymology. Aquila is the Latin word for eagle. This species is named after my son Arend, the Dutch word for eagle. Aquila is used here as a noun.

Discussion. This species belongs to a group of species with bisexual flowers, ovate flower buds and predominantly cauliflorous or ramiflorous inflorescences. Most species of this group have obovate to oblanceolate leaves, whereas this species has oblong to elliptic-oblong leaves, a characteristic shared with *Monanthotaxis couvreurii* and *Mo*-



Figure 2. Distribution map of Monanthotaxis aquila (blue triangle) and Monanthotaxis atewensis (red square).

nanthotaxis atopostema. For the differences between those species see Table 1. *Monan-thotaxis vogelii* (Hook. f.) Verdc. is similar to *M. aquila*, but differs in having obovate to oblanceolate leaves with the secondary veins being straight and only slightly curving upwards near the leaf margin and the petals are shorter. Vegetatively *Monanthotaxis mannii* (Baill.) Verdc. looks similar to *M. aquila*, but differs in having the inflorescences on the leafy twigs (vs rami- or cauliflorous), and rounded flower buds (vs ovate).

Monanthotaxis atewensis **P.H.Hoekstra, sp. nov.** urn:lsid:ipni.org:names:60472947-2 Figs 2, 3

Type. GHANA. Eastern Region, Atewa Range Forest Reserve, 2 June 1973, *J.B. Hall GC43672* (holotype: WAG [2 sheets, barcode WAG0019665!, WAG0019666!]; isotypes: GC!, K [K000040198!], MO [2189255]!)



Figure 3. *Monanthotaxis atewensis* P.H.Hoekstra. **A, B, D** drawn from the type (Hall & Lock GC43672) **C** drawn from Hall & Enti GC36426. **A** Leaf **B** Leaf detail **C** Old flower **D** Fruit. Illustration by M. Spitteler, from Hawthorne and Jongkind (2006).

Monanthotaxis atewae Hawthorne & Jongkind (2006: 72); invalid: description in English, no type designated (this termination, although admissible, does not follow recommandation 60D of the ICBN).

Diagnosis. Easily distinguishable from all other *Monanthotaxis* species by the lanceolate sepals 1 cm long. Resembles *M. stenosepala* (Engl. & Diels) Verdc., but differs in the longer sepals, erect hairs on the leaves and branches, and a larger number of seeds per monocarp.

Description. Scandent shrub or liana, to 9 m tall; young branches dark brown, with scattered erect reddish brown hairs 0.3-0.5 mm, old branches light brown, glabrescent with a few lenticels. Leaves: *petioles* $3-5 \times 1.0-1.2$ mm, grooved adaxially, indumentum as branches; *lamina* $5.7-15.9 \times 2.4-5.4$ cm, length:width ratio 2.0-3.1, oblong to slightly oblanceolate or obovate, base rounded, truncate or subcordate, apex acute to acuminate, acumen to 1.5 cm, chartaceous, abaxially greyish, adaxially glabrous,

the midrib impressed with a few short hairs near the base, abaxially sparsely to densely covered with short erect reddish brown hairs, venation eucamptodromous, secondary veins 8-14, first straight halfway curving upwards, tertiary venation scalariform. Inflorescences leaf-opposed, composed of a solitary flower to a 3-flowered rhipidium; sympodial rachis 2–4 mm; *flowering pedicels* 21×0.7 mm, with short vellowish ascending to erect hairs; *lower bract* strongly reduced or wanting; *upper bract* around the middle of the pedicel, ovate, 1.7×1.4 mm, densely covered with short appressed hairs; sepals 3, free, $10-12 \times 2.6-2.7$ mm, lanceolate, apex acute, with dense short appressed hairs; receptacle 3.0 mm in diameter, flat; petals unknown; stamens unknown, scars in a single whorl; carpels 1.2 × 0.5 mm, ellipsoid, dense hairy, stigma elongate 0.5 mm, grooved, glabrous. Fruits: pedicels $20-37 \times 0.6-1.1$ mm; sepals persistent or caducous; stipes 4–6 mm long, slightly grooved; monocarps 1–9, ellipsoid with 1 to 5 seeds, 13–35 \times 5–6 mm, slightly to strongly constricted between the seeds, slightly vertucose, apex apiculate, apex to 2.0 mm, with scattered short erect hairs, unripe fruits green. Seeds 9×6 mm, ellipsoid, base and apex rounded, tawny brown, raphe visible from base to apex, ruminations lamelliform.

Distribution. Ghana, Eastern Region, Atewa Range Forest Reserve. Figure 2. **Ecology.** Forest, in thicket, at 750 m altitude.

Phenology. Fruiting in May and June.

Conservation status. Proposed IUCN Red List Category: **Critically Endangered** (CR): B2ab(iii), only known from the Atewa Range Forest Reserve and although it is a protected area, the forest is under threat of bauxite mining and logging (Kusimi 2015; Ntiamoa-Baidu et al. 2000). Furthermore, the species has not been collected in more than 40 years.

Etymology. Named after the Atewa Range Forest Reserve in Ghana, to which this species seems to be endemic.

Additional specimens examined (paratypes). GHANA. Eastern Region: Atewa Range Forest Reserve, 12 May 1967, *J.B. Hall GC36426* (K [K000040199], WAG [WAG0019664]).

Discussion. This species can easily be distinguished from all other species of *Monanthotaxis* by the large lanceolate sepals. The species is similar to *Monanthotaxis stenosepala* (Engl. & Diels) Verdc., which also has lanceolate sepals and light brown older branches. However, the sepals of *M. stenosepala* are 4 to 6 mm vs 10 to 12 mm in *M. atewensis* and the pubescence and number of seeds is different as described in the diagnosis. Two fruiting specimens from Liberia (*Stoop 331* and *Adam 26189*) closely resemble *M. atewensis*, but no sepals are present to verify the identification. Furthermore, the monocarps are more densely vertuces and the peduccle is shorter and the pedicel larger than the two specimens of *M. atewensis* from Ghana. More material or more recent material for DNA extraction is needed to assess the status of those specimens from Liberia.

For now we consider this species an endemic to the Atewa Range. This is the first plant species that is endemic to this mountain range. However, for several Upper Guinean endemics (e.g. *Dorstenia embergeri* Mangenot) this range is their most eastern outpost. Some other plants are only known from these mountains and one or two other localities in Ghana. The Atewa Range is home of 3 endemic butterfly species (McCullough et al. 2007). This new endemic urges for a strict protection of this unique mountain chain.

Monanthotaxis couvreurii P.H.Hoekstra, sp. nov.

urn:lsid:ipni.org:names:60472948-2 Figs 4, 5, Table 1

Type. CAMEROON, Central Province, Ottotomo Forest Reserve, 45 km SW of Yaoundé, ca 5 km on main path into reserve. 3°35.21'N; 11°17.63'E, 24 April 2015, *T.L.P. Couvreur* 762 (holotype: WAG [3 sheets, barcodes: WAG.1576998!, WAG.1576999!, WAG.1577000!]).

Diagnosis. Differs from all *Monanthotaxis* species by the stamens that are basally connate. The leaves are similar to *Monanthotaxis atopostema* P.H.Hoekstra from Congo and *Monanthotaxis aquila* P.H.Hoekstra from Ivory Coast, but the flowers of *M. couvreurii* differ in having no staminodes and the leaves have more secondary veins with smaller spaces in between.

Description. Liana; young branches reddish brown with dense ascending reddish brown hairs 0.1–0.2 mm, old branches greyish brown, slightly grooved,. Leaves: *petioles* $3-5 \times 0.8-0.9$ mm, slightly grooved, indumentum as branches; *lamina* $4.5-12.0 \times 1.8-$ 4.3 cm, length:width ratio 2.1-2.9, oblong to obovate, base cuneate to rounded, apex acute to acuminate, acumen to 1 cm, chartaceous, discolorous, adaxially glossy green, abaxially light greyish green, adaxially sparsely covered with whitish appressed hairs 0.1 mm, soon glabrescent, abaxially with scattered appressed whitish yellowish hairs 0.1-0.2 mm, venation eucamptodromous, secondary veins 7-11, from base curving upwards, tertiary venation scalariform sometimes obscure. Inflorescences cauliflorous, ramiflorous or axillary, composed from a two-flowered rhipidium in the axils of the leaves to many-flowered clusters on the trunk; sympodial rachis 1-15 mm; *flowering* pedicels $4-20 \times 0.2-0.6$ mm, with scattered ascending to erect hairs 0.1 mm; lower bracts strongly reduced or wanting; upper bracts wanting; flower buds ovate. Flowers bisexual; sepals 3, $0.8-0.9 \times 0.9-1.0$ mm, triangular, apex acute, with dense yellowish hairs; receptacle flat, 1.2–2.0 mm in diameter; petals light yellow to white, in two whorls of 3, but base of inner petals visible in bud; outer petals, 3.5–5.0 × 2.0–3.5 mm, ellipticovate, outside with dense short yellowish hairs, inside with a few hairs near the margins; inner petals 3.0-4.5 × 1.2-1.5 mm, elliptic to narrowly ovate, outside with yellowish hairs at the apex and at the centre, inside glabrous or with a few hairs at the margins; stamens 13-15 in one whorl, connate at base, linear-obconic 0.8-0.9 mm, filaments 0.4 mm, anther cells lateral to extrorse, connective papillose, truncate, rounded from above, staminodes 0; carpels 9-12, 1.2-1.3 × 0.3-0.4 mm, subcylindric to ellipsoid, dense hairy, with 4 lateral ovules, stigma subsessile 0.2 mm, globose, glabrous. Fruits: Not seen, but according to collection Farron 7359 with 4 articles.



Figure 4. *Monanthotaxis couvreurii* P.H.Hoekstra. **A–F** photographs in the field of the type collection (TLP Couvreur 762). Photos: Thomas Couvreur.

Distribution. Cameroon, Central Province, Ottotomo Forest Reserve. Figure 5. **Ecology.** Old secondary forest, on slope, at 700 m altitude. **Phenology.** Flowers collected in April and May.

Conservation status. Proposed IUCN Red List Category: **Critically Endangered** (CR): B2ab(iii), only known from the Ottotomo Forest Reserve in Cameroon. The



Figure 5. Distribution map of *Monanthotaxis couvreurii* (red diamonds), *Monanthotaxis latistamina* (blue squares), *Monanthotaxis tripetala* (green triangles) and *Monanthotaxis zenkeri* (black asterisk).

increase of human population around the reserve intensifies the pressure on the forest, while the surrounding forests are increasingly degrading (Sassen and Jum 2007), warranting the critically endangered status of this species.

Etymology. Named after Thomas L.P. Couvreur, a passionate Annonaceae systematist and collector of the type of this species and of *Monanthotaxis latistamina* P.H.Hoekstra also described in this article.

Additional specimens examined (all paratypes). CAMEROON. Central Province: Ottotomo reserve, 5 May 1970, *C. Farron 7266* (P [P01954685]); Ottotomo reserve, 26 May 1970, *C. Farron 7359* (P [P01954686], YA [YA0044284]). **Discussion.** This species belongs to a group of species with predominantly ramiflorous inflorescences, bisexual flowers and ovate flower buds and looks vegetatively very similar to *M. aquila* and *M. atopostema*. For the differences between these species see Table 1. *M. couvreurii* can be distinguished from all *Monanthotaxis* species in having the stamens basally connate (see figure 4F). *Monanthotaxis klainei* (Engl.) Verdc. also has the stamens connate in one whorl, but in that species the stamens are alternating with staminodes.

Monanthotaxis filipes P.H.Hoekstra, sp. nov.

urn:lsid:ipni.org:names:60472949-2 Figs 6, 7, Table 2

Type. TANZANIA, Lindi district, Rondo plateau, Rondo forest Reserve, 10°07'S; 39°13'E, 7 February 1991, *G.S. Bidgood 1402* (holotype: K [2sheets!]; isotypes: BR [BR0000013186036!], C!, EA!, MO [4027188!], P [P01967237!], UPS!, WAG [WAG0071696!]).

Diagnosis. This species is similar to *Monanthotaxis trichantha* (Diels) Verdc. because of the dense yellow short indumentum on the young stems. It differs in the pendulous flowers on filiform pedicels, and in the outer petals covering the inner petals in bud.

Description. Shrub, 1 m tall; young branches yellow-brown, with dense appressed to ascending yellowish hairs 0.3–0.7 mm, old branches dark brown to greyish brown, cylindrical, glabrescent with many lenticels. Leaves: petioles $3-5 \times 0.7-1.0$ mm, indumentum as branches; lamina $3.7-10.7 \times 1.5-4.4$ cm, length: width ratio 1.6-3.3, oblong to elliptic to slightly obovate, base rounded, truncate or slightly subcordate, with thickened margin at base, apex acute, chartaceous, discolorous, abaxially pale bluish green adaxialy soon glabrescent, with whitish appressed hairs when young, abaxially densely covered with ascending yellowish white hairs, venation eucamptodromous, midrib impressed adaxially, secondary veins 7-10, first straight halfway curving upwards, tertiary venation scalariform. Inflorescences supra-axillary, 2-6 mm above leaf axil, 1-2-flowered rhipidium; sympodial rachis 0-1 mm; flowering pedicels filiform $18-55 \times 0.2$ mm, with a few scattered ascending to erect hairs; *lower bract* strongly reduced or wanting; *upper bract* halfway the pedicel, very small, 0.3×0.1 mm or just a dense tuft of hairs or wanting; *flower buds* rounded. Flowers bisexual, pendulous; sepals 3, connate at the base, broadly ovate to almost cupuliform, $0.5 \times 1.1-1.2$ mm, obtuse to rounded, with dense yellow appressed hairs; receptacle 1.5-2 mm in diameter, flat; petals creamy white, 6 in two whorls; outer petals, 2.5-2.7 × 2.8-3.6 mm, broadly ovate, densely covered with short yellowish hairs on the outside and apex of the inside, glabrous at base of inside; *inner petals* $1.9-2.0 \times 1.2-1.4$ mm, ovate to rhombic, indumentum as in outer petals; stamens (13?-)15 in one to two whorls, free, flattened obovate, 1.1-1.3 mm long, filaments 0.3-0.4 mm long, anthers extrorse,



Figure 6. Monanthotaxis filipes P.H.Hoekstra. A–H drawn from the type (Bidgood 1402). A Habitus
B Leaf with flower C Flower with petals removed D Outer petal inside E Stamen inside F Stamen lateral
G Stamen outside H Carpel. Illustration by H. de Vries.



Figure 7. Distribution map of *Monanthotaxis filipes* (red square) in Tanzania and *Monanthotaxis komorensis* (green circles) on the Comoros archipelago.

connective truncate, not hiding anther cells, glabrous, staminodes 0; *carpels* 9, $1.2 \times 0.2-0.3$ mm, subcylindric, densely hairy, but glabrous near apex, with 2 lateral ovules, stigma elongate 0.4 mm, grooved, glabrous. **Fruits** unknown.

Distribution. Tanzania, Lindi Region. Figure 7.

Ecology. Steep escarpment with dense thicket, stony-gravelly soil at 700 m altitude. **Phenology.** Flowers collected the 7th of February.

Conservation status. Proposed IUCN Red List Category: **Critically Endangered** (CR): B2ab(ii, iii), only known from one collection in the Rondo Forest Reserve in South-east Tanzania. Although it occurs in a forest reserve, satellite images provided by Google Earth (assessed May 2016) show that a major part of the forest in the reserve systematically has been removed, and forest cover is declining over the years.

Etymology. From the latin *fili*, thread-like, and *pes*, foot/stalk; referring to the filiform pedicels.

	M. filipes	M. trichantha
Flowering pedicel length	18–55 mm	2–8 mm
Inflorescence position	supra-axillary	extra-axillary/leaf opposed
Number of petals visible in bud	3	6
Outer petals form	broadly ovate	ovate to elliptic
Inner petals form	ovate	elliptic

Table 2. Differences between Monanthotaxis filipes and M. trichantha.

Discussion. This species is vegetatively very similar to *M. trichantha* which also occurs in South-East Tanzania. The flowers and inflorescences are very different with *M. filipes* having pending flowers on long pedicels and the inflorescences supra-axillary, while *M. trichantha* has short pedicels which are extra-axillary or leaf-opposed (table 2). Apart from *M. filipes*, long filiform pedicels only occur in some species of *Monanthotaxis* from Madagascar (e.g. *Monanthotaxis caesia* (Diels) Verdc. and *Monanthotaxis heterantha* (Baill.) Verdc. These species lack the dense indumentum on the young twigs. Also *Monanthotaxis oligandra* Exell has pending supra-axillary inflorescences, but in this species the sympodial rachis (peduncle) is filiform instead of the pedicels, which are very short. Furthermore, *M. oligandra* lacks the dense yellow pubescence and has very different flowers with all petals in a single whorl.

Monanthotaxis komorensis P.H.Hoekstra, sp. nov.

urn:lsid:ipni.org:names:60472950-2 Figs 7, 8

Type. MAYOTTE, Grande Terre, Mont Combani, départ du GR menant au sommet, 10 January 2002, *F. Barthelat 671* (holotype: P [P00273165!]; isotypes: G [G00404210!], K, MAYOT, MO [5735265!]).

Diagnosis. Differs from all other *Monanthotaxis* species in the combination of having solitary flowers on a short pedicel with 6 staminodes alternating with 6 stamens.

Description. *Liana* or shrub to 2m; young branches dark reddish brown with ascending to slightly erect yellowish hairs 0.2 mm, old branches greyish brown to blackish brown, glabrescent with lenticels. **Leaves:** *petioles* $2-3(-4) \times 1.4-1.6$ mm, grooved adaxially, slightly more dense indumentum as branches; *lamina* $4.0-17.0 \times 1.8-5.7$ cm, length:width ratio 2.2-3.4, oblong to elliptic lanceolate, base subcordate, apex acute, chartaceous, discolorous, adaxially glossy green, abaxially glaucous, adaxially glabrous or with a few yellowish hairs at the base of the midrib, abaxially with scattered short ascending whitish yellowish hairs 0.1-0.3 mm, soon glabrescent, venation festooned brochidodromous, secondary veins (8-)13-18, from base curving upwards, tertiary venation reticulate, adaxially slightly raised. **Inflorescences** axillary, leaf-opposed or terminal, composed of a solitary flower; sympodial rachis reduced or



Figure 8. *Monanthotaxis komorensis* P.H.Hoekstra. **A** Photographs in the field of collection Barthelat 833 **B–C** idem, Barthelat 1045, **D** idem, Barthelat 1319. Photos: Fabien Barthelat.

wanting; flowering pedicels $3-6 \times 0.4-0.5$ mm with ascending to erect hairs 0.1-0.2mm; lower bracts wanting; upper bracts halfway the pedicel, ovate to lanceolate, 0.3–0.8 × 0.4–0.5 mm; *flower buds* rounded to slightly ovate. **Flowers** bisexual; *sepals* 3, 0.6–0.8 \times 1.4–1.6 mm, broadly ovate, with short yellowish hairs, apex obtuse; *receptacle* flat, 1.8–2.5 mm in diameter; petals 6 in two whorls, creamy yellow with pinkish to reddish brown base of the inner petals; *outer petals* $5.5-7.0 \times 5.3-5.4$ mm, ovate, outside with short yellowish appressed hairs, inside with very short hairs, but glabrous at base; inner petals $4.2-4.4 \times 3.0-3.3$ mm, rhombic, outside with short yellowish hairs, inside with very short hairs, but glabrous at base; stamens 6-7 in one whorl, free, obconic 1.2 mm, filaments 0.4 mm, anthers lateral to introrse, connective glabrous, truncate, prolonged inward, staminodes 6 alternating between the stamens, 0.7 mm, glabrous; carpels 8, $1.4-1.5 \times 0.2$ mm, subcylindric, densely hairy, with 2 lateral ovules, stigma elongate 0.6 mm, with a few hairs at base. Fruits: pedicels 9 × 0.9 mm; sepals persistent, slightly acrescent; stipes 2.0-2.5 mm; monocarps up to 7, ellipsoid with 1 or 2 seeds, 10-17 \times 5–6 mm, slightly constricted between the seeds, apex rounded, glabrous or with a few short hairs, vertucose, ripe fruits red. Seeds 6×5 mm, ellipsoid, apex slightly apiculate, flattened were touching with other seed, ochre-brown, raphe slightly visible as a longitudinal furrow from base to apex, ruminations lamelliform.

Distribution. Mayotte, Grande Terre and Mbouzi; Comoros, Anjouan. Figure 7. **Ecology.** Not rare in humid and lowland hill forests, including secondary vegetation. It is also found in shady places in dry forest, especially along riversides.

Phenology. Flowering from November to January, fruits collected in January and April.

Vernacular names. Shibushi language: Fotsy ambadiki (*F. Barthelat 590*), Fotsy Ambadiky bé (*F. Barthelat 1045*), Fotsy ambadiky lahy (*F. Barthelat 1045*), Foutsi Ambadiki (*O. Pascal 280*), Sari langilangy (*H. Ralimanana 277*), Tchavadiki (*O. Pascal 338*).

Conservation status. Proposed IUCN Red List Category: **Vulnerable**(VU): B2ab(I, ii, iii, iv), EOO (including Anjouan) 1231 km², AOO 32 km², 9 locations. This species has probably disappeared from the island Anjouan as the only collections were made more than 100 year ago, however there are 9 recent collections from Mayotte from different localities on the island Grande Terre of which some in nature reserves and one on Mbouzi, a protected island. The vegetation of the island Mayotte remains under threat, likely reducing the population of *M. komorensis* in the future.

Etymology. Named after the Comoro Archipelago. Komorensis is written with a K as in the Latin script of the Comorian language and Shimaore.

Additional specimens examined (all paratypes). COMOROS. Anjouan: Lavanchie 24 (P [P00213916]) and Lavanchie 25 (P [P00213917]). MAYOTTE. Grande Terre: Mamoudzou, reserve forestière de Majimbini, 24 Jan 2001, F. Barthelat 269 (G [G00404208], K, MAYOT, MO, P [P00229255]); Mont Combani, 15 Nov 2001, F. Barthelat 590 (G [G00404209], K, MAYOT, MO [5730093], P [P00273086]); Tsararano, Tchaourembo, 17 Oct 2002, F. Barthelat 1045 (MAYOT, P [P00290506]); Mlima Combani, 28 Dec 1995, O. Pascal 280 (P [P00127022]); Dapani, 17 Jan 1996, O. Pascal 338 (P [P00127021]); Mlima Combani, 15 April 1996, O. Pascal 487 (G [G00404211], K, MO, P [P00127020]); Mont Combani, 12°57.44'S, 45°07.75'E, 16 Nov 2002, H. Ralimanana 277 (G [G00404207], K, MAYOT, P [P00538263], TAN); vallon à station pompage Ouroveni, 8 Nov 1989, H. Tinguy 1028 (P [P01987602]). Ilot MBouzi: 12°48.33'S, 45°14.00'E, 26 April 1999, M.M. Pignal 1285 (P [P00176736]).

Discussion. This is the only known species of *Monanthotaxis* on the Comoros and Mayotte. It is easily distinguished from almost all other *Monanthotaxis* species by having 6 staminodes alternating with 6 stamens, all in a single whorl. The only other species sharing that feature, viz. *Monanthotaxis congoensis* Baillon and *M. paniculata* P.H.Hoekstra are very different. These have a single whorl of petals (vs two whorls in *M. komorensis*), inflorescences of raceme-like or panicle-like rhipidia, their young branches are densely covered with yellowish brown short hairs and they occur in Central Africa. The flowers of *Monanthotaxis glaucocarpa* (Baill.) Verdc., a species from Madagascar, are not known. This species differs from *M. komorensis* in having longer pedicels (>30 mm vs 9 mm), longer stipes (7–9 mm vs 2.0–2.5 mm) and longer and bigger seeds (12–15 mm vs 6 mm). Further, the leaves are less elongate and the young branches are glabrous.

Monanthotaxis latistamina P.H.Hoekstra, sp. nov.

urn:lsid:ipni.org:names:60472951-2 Figs 5, 9, 10, Table 3

Type. GABON. Ogooué-Ivindo, Ivindo National Park, along main trail departing from behind the herbarium at the Research station of Ipassa, 0°30.23'N, 12°47.59'E, 11 November 2013, *T.L.P. Couvreur 565* (holotype: WAG [3 sheets, barcodes: WAG.1577028!, WAG.1577029!, WAG.1577030!]; isotype: LBV, YA).

Diagnosis. Closely related to *Gilbertiella congolana* Boutique by the papillose petals and stamens. Differs from *G. congolana* by having 6 oblong stamen (vs 12 linear stamen) which are wider than deep (vs rounded in cross-section).

Description. Scandent shrub or liana to 4 m high; young branches sparsely pubescent with appressed yellowish hairs 0.1-0.2 mm, old branches dark, blackish, soon glabrescent sometimes with a few lenticels. Leaves: *Petioles* $5-12 \times 1.3-1.7$ mm, grooved adaxially, indumentum as branches; *lamina* $6-13 \times 3.5-7.2$ cm, length:width ratio 1.6-2.7, oblong or elliptic to slightly obovate, base cuneate, rounded to subcordate with thickened black margin at base, apex acute to acuminate, acumen to 1.3 cm long, chartaceous to subcoriaceous, adaxially green, abaxially light greyish green, young leaves with a few short appressed hairs, soon glabrescent, venation eucamptodromous, secondary veins 7-8(-10) oblique, from base curving upwards, tertiary venation reticulate, raised adaxially, leaves are punctate, although difficult to see in older leaves. Inflorescences axillary or terminal, solitary, in fascicle-like rhipidia or in a to 4 cm long short lax panicle-like rhipidium with up to 6 flowers; sympodial rachis appressed pubescent to glabrescent; *flowering pedicels* $8-17 \times 0.3-0.4$ mm, indumentum as sympodial rachis; lower bracts strongly reduced or wanting; upper bracts lanceolate to ovate $0.6-0.7 \times 0.4-0.6$ mm, same pubescence as sympodial rachis, placed halfway the pedicel; *flower buds* globose to slightly ellipsoid. **Flowers** bisexual; *receptacle* 1.2– 1.5 mm in diameter; sepals 3, united at base, 0.8–1.0 ×1.2–1.5 mm, ovate to broadly ovate, adaxially with short appressed yellowish hairs, apex obtuse to slightly acute; petals 6 in one whorl, but 3 petals overlapping others at apex in bud, in young flowers green, $1.6-2.5 \times 0.7-1.2$ mm elliptic to slightly ovate, with inwardly reflexed appendage at apex, outside papillose to slightly short appressed pubescent, inside papillose, most dense at apex; stamens 6, in one whorl, alternate with petals, light green, oblong, densely papillose wider than thick $1.0-1.2 \times 0.6-0.7$ mm, radial width 0.2-0.3 mm, filaments 0.1 mm, anthers 2, extrorse, connective appendage small, just visible between the anthers, densely papillose, truncate; staminodes 0; carpels 6-9, 1.0-1.4 × 0.4-0.6 mm, ellipsoid densely reddish brown pubescent with 6 lateral ovules, stigma globose to slightly elongated, grooved to almost bifurcate, 0.1-0.2 mm, glabrous. Fruits reported as yellowish, not seen.

Distribution. Gabon, province Ogooué-Ivindo. Republic of Congo, province Niari. Figure 5.

Ecology. Evergreen forest and forest on shallow soil at summit of hill, elev. 519–1017 m.



Figure 9. *Monanthotaxis latistamina* P.H.Hoekstra. A-H drawn from the type (Couvreur 565). **A** Habitus **B** Flower bud **C** Open flower with 2 petals and one stamen removed **D** Outer petal outside **E** Outer petal inside **F** Stamen inside **G** Stamen lateral **H** Carpel. Illustration by E. Winkel.

Table 3. Differences between Monanthotaxis latistamina and Gilbertiella congolana.

	M. latistamina	G. congolana
Nr of stamens	6	12–15
Stamen form	oblong, wider than thick	obconical to clavate, circular in cross-section
Petiole width	1.3–1.7 mm	0.7–0.8 mm

Phenology. Flowers collected in May, October and November.

Conservation status. Proposed IUCN Red List Category: **Endangered** (ED): B2ab(iii), EOO 17682 km², AOO 16 km². Although the species has quite a wide distribution, it is only known from four collections, one of which is from a protected area.



Figure 10. *Monanthotaxis latistamina* P.H.Hoekstra. **A–D** Photographs in the field from the type collection (TLP Couvreur 565). Photos: Thomas Couvreur.

The other collections are from areas under threat of logging and habitat destruction, which is why we suggest the status of endangered.

Etymology. Named latistamina for the wide, but flattened stamens, which differentiates it from the similar *Gilbertiella congolana* Boutique.

Additional specimens examined. REPUBLIC OF CONGO. Niari: Edge of the Missanda plain, 28 October 1975, *P. Sita 3966* (P [P01982495],P [P01982496], WAG [WAG.1575264]; excluded as paratype). GABON. Ogooué-Ivindo: Ca 4 km NNW of Ikei-Bokaboka, 0°57.18'N, 13°41.45'E, 18 May 2003, *L. Ngok Banak 1811* (paratypes: BRLU, LBV [LBV0001649], MO [6357151], P, WAG [WAG0148822]; Belinga mountain, 1°04.87'N; 13°12.18'E, 11 November 2015, *J.J. Wieringa 8320* (paratypes: WAG [3 sheets, WAG.1575172, WAG.1575173, WAG.1575174]).).

Discussion. This species is similar to *Gilbertiella congolana* Boutique from Congo (Kinshasa), but it differs in stamen number and form, furthermore *Monanthotaxis latis-tamina* has thicker petioles, while the petioles of *G. congolana* are more slender (Table 3).

Although *M. latistamina* is similar to *G. congolana* we do describe it in *Monanthotaxis* as *Gilbertiella* Boutique will be synonymized with *Monanthotaxis*. Boutique (1951) described *Gilbertiella* based on linear stamens, outer petals that cover the inner petals in bud only at the apex, and an apical appendage on the inside of the petals. These characters on their own occur in other species of *Monanthotaxis* as well. The outer petals overlapping the inner petals only at the apex occurs in a quarter of all *Monanthotaxis* species, the linear stamens occur in some species such as *Monanthotaxis filamentosa* (Diels) Verdc. and *Monanthotaxis maputensis* P.H.Hoekstra (figure 11) and a more or less developed appendage on the petals occurs in species such as *Monanthotaxis le-testui* Pellegrin and male flowers of *Monanthotaxis cauliflora* (Chipp) Verdc. and often in young flower buds. All other characteristics of *Gilbertiella congolana* are typical or at least normal for *Monanthotaxis*, such as having only a few stamens in one whorl and uniseriate stipitate monocarps. Also Walker (1971) reported a strong affinity between *Monanthotaxis* and *Gilbertiella* based on the microbaculate pollen exine. Based on all these similarities we place *Monanthotaxis latistamina* in the genus *Monanthotaxis latistamina* within the genus *Monanthotaxis* (Guo et al. in press).

The specimen of *Monanthotaxis latistamina* from the Republic of Congo has some differences with the three specimens from Gabon. The flower buds and stems of the specimen dried very blackish and the leaves are coriaceous and greyish vs chartaceous and green in the Gabonese specimens. However the distinguishing characteristics with *G. congolana* are the same as with the Gabonese specimens. More collections are needed to verify if this is just an aberrant collection or a different (sub)species. For now this collection is retained as belonging to *M. latistamina* based on the similarities in flowers and stamen, but it is excluded as a paratype.

Monanthotaxis maputensis P.H.Hoekstra, sp. nov.

urn:lsid:ipni.org:names:60472952-2 Figs 11, 12, Table 4

Type. MOZAMBIQUE. Maputo, Moamba, Chinhanguanine, margem esquerda do rio Incomáti, 14 December 1979, *J. de Koning* 7766 (holotype: WAG [WAG0349310!]; isotypes: MO [3880761!], LMA).

Diagnosis. Closely related to *Monanthotaxis caffra* (Sond.) Verdc., but differs in having long filaments which occupy more than half of the total stamen length, while *M. caffra* has short filaments and the anther cells occupy more than half of the total stamen length. Further *M. maputensis* has shorter and less hairy leaves, the fruiting pedicels are more slender and the stipes are shorter than with *M. caffra*.

Description. *Shrub*, scandent shrub or liana, to 10 m tall, diameter to 3 cm; young branches reddish brown, with scattered appressed or erect light-brown hairs 0.4 mm long, quickly glabrescent, old branches dark brown with (whitish) lenticels. **Leaves:** *petioles* $2-4 \times 0.7-1$ mm, grooved adaxially, indumentum as branches; *leaf lamina* $2.8-6.7(-8.1) \times 1.5-3.3$ cm, length:width ratio 1.6-2.7(-3.3), elliptic to ovate or slightly obovate, base cuneate to rounded, with slightly thickened margins, apex obtuse to acute, chartaceous/coriaceous, discolorous, upper side shiny dark-green, lower side glaucous to light green, upper side soon glabrescent, lower surface with appressed yellowish/light



Figure 11. *Monanthotaxis maputensis* P.H.Hoekstra. **A** drawn from Mendonça 4480 **B–J** drawn from Exell 565 **A** Habitus with fruit **B** Habitus with flowers **C** Flower bud **D** Open flower with 2 petals removed **E** Outer petal **F** Inner petal **G** Stamen inside **H** Stamen lateral **I** Carpel inside **J** Carpel lateral. Illustration by E. Winkel.

brown hairs 0.2 mm long, glabrescent, venation eucamptodromous, midrib yellowish or reddish, secondary veins 5–8, from base curving upwards, tertiary venation reticulate, raised adaxially and slightly abaxially, or not visible abaxially, often pellucid-punctate. **Inflorescences** leaf-opposed, composed of a solitary flower or a 2–3 flowered rhipidium; sympodial rachis 0–3 mm; *flowering pedicels* 6–14 × 0.3–0.4 mm, glabrescent; *lower bracts* broadly ovate, 1.5 × 1.4 mm; *upper bracts* broadly triangular to ovate, placed near middle of pedicel, 0.5 × 0.5 mm; *flower buds* ovate, dried greyish yellowish with yellow margins. **Flowers** bisexual; *receptacle* 2–3 mm in diameter, flat, with short brown hairs between the carpels and stamens; *sepals* 3, 0.5–0.7 × 1.5–2 mm, broadly ovate, with short



Figure 12. Distribution map of *Monanthotaxis maputensis* (red squares) and *Monanthotaxis caffra* (green circles). Large squares/circles denote flowering material of which the stamens were checked, small squares/circles are fruiting or sterile material or only seen from scans. White squares are aberrant fruiting collections of *M. maputensis*, question marks are fruiting specimens which have intermediate characters between the two species.

reddish brown pubescence near the margins, apex obtuse; *petals* pale yellowish to yellow, inside drying reddish brown to purple. 6 in two whorls; *outer petals*, $2.5-4 \times 3.2-4$ mm, broad ovate, shortly pubescent with yellowish hairs on the outside, more densely

	M. maputensis	M. caffra
Length of filament divided by total stamen length	0.5-0.7	0.2–0.3
Outer petal length	2.5–4.0 mm	5–7 mm
Leaf length	2.8–6.7 (–8.1) cm	5.5–10.8 cm
Leaf length:width ratio	1.6-2.7(-3.3)	2.6-3.4
Secondary veins	5–8	9–10
Fruiting pedicel width	0.4–0.9 mm	1.0–1.5 mm
Seed form	globose to ellipsoid	ellipsoid

Table 4. Differences between Monanthotaxis maputensis and Monanthotaxis caffra.

pubescent near margins, inside densely pubescent at the apex; *inner petals*, $3.0-3.4 \times 1.7-2.2$ ovate to elliptic, outside and inside pubescent at apex; *stamens* 12–15 in one or two whorls, free, obconic to clavate, 0.8-1.2 mm long, filaments 0.4-0.8 mm long, anthers latrorse, theca 0.3-0.5 mm, connective glabrous, truncate, staminodes 0; *carpels* 10-13, $1.2-1.6 \times 0.4-0.5$ mm, subcylindric to ellipsoid, glabrous except for some hairs at the base, 1 (–2) ovules, stigma elongate, 0.3-0.4 mm long, grooved, glabrous. **Fruits**: *pedicels* $8-14 \times 0.4-0.9$ mm; *sepals* persistent; *stipes* 2.5-4.0 mm long, slightly to strongly longitudinally grooved, sparsely covered with appressed hairs when young; *monocarps* 1-10, globose to elliptic with 1(-2) seed, $7.5-15 \times 5$ mm, 2-seeded ones to 19 mm long, slightly constricted between the seeds, apex apiculate, apex 0.5 mm, rugulose to smooth, glabrous in ripe fruits, ripe fruits bright red. **Seeds** $5.5-8.0 \times 4.5-6.6$ mm, globose to ellipsoid, ochre-brown, raphe not visible, ruminations lamelliform.

Distribution. From just South of the border of South Africa and Mozambique north to 23 degrees in the province Inhambane in Mozambique. Figure 12.

Ecology. Occurring in different types of thickets and forests on sandy soils, at 0–150 m altitude.

Phenology. Flowers collected in November, December and February to April, fruits collected from March to September.

Conservation status. Proposed IUCN Red List Category: **Least Concern** (LC): EOO 43433 km², AOO 128 km². Within the distribution range it has been collected from more than 10 different localities and at least 3 nature reserves. Furthermore it is quite common in the coastal dunes of Mozambique, therefore we suggest the status of Least Concern for this species.

Etymology. Named after the town and province Maputo, the center of the distribution and where most collections originate from.

Additional specimens examined (all paratypes, except when noted as excluded). MOZAMBIQUE. Gaza: Macia-Messano, 28 Aug 1980, *A. Nuvunga 292* (WAG [WAG0065948]); 3 km from Gumbe, 26 May 1965, *Â. Pereira 456* (MO [2177512], SRGH; excluded as paratype); between João Belo and Lumane, 6 Mar 1941, *A.R. da Torre 2635* (LISC [LISC035251]). Inhambane: Massinga, Pomene, 10 km from Hotel to Rio Das Pedras, 16 Jul 1981, *J. de Koning 9063* (LMA, MO [3880770]; excluded as paratype). Maputo: Marracuene, 12 km from Vila Luísa to Manhiça, *M.F. Correia 578* (LISC, MO, SRGH); Ilha de Inhaca, 8 Jun 1970, *M.F. Correia 1690* (LISC); Lourençco Marques, Ilha da Inhaca, 20 Jun 1973, *M.F. Correia 2892* (M, MO); Maputo Reserve, 21 March 1976, *M.A. Diniz 102* (MO [2830862], WAG [WAG0053942]); Goba, 23 Feb 1955, A.W. Exell 565 (LISC); Ilha da Inhaca, 19 May 1984, *E.M.C. Groenendi-ik 1377* (MO [3877333], WAG [WAG0053945]); Ilha da Inhaca, 25 June 1984.

Feb 1955, A.W. Exell 565 (LISC); Ilha da Inhaca, 19 May 1984, E.M.C. Groenendijk 1377 (MO [3877333], WAG [WAG0053945]); Ilha da Inhaca, 25 June 1984, E.M.C. Groenendijk 1426 (MO [3877334], WAG [WAG0053936]); Ilha da Inhaca, 28 Sep 1984, E.M.C. Groenendijk 1493 (MO [3877332], WAG [WAG0053944]); Ilha da Inhaca, 29 Jul 1985, E.M.C. Groenendijk 1760 (LMU, WAG [WAG0067887], WAG [WAG0067888]); Maputo, 13 Feb 1947, R.M. Hornby 2613 (L [L.1762399], P [P01954698], SRGH); Inhaca Island, 11 Aug 1980, P.C.M. Jansen 7375 (WAG [WAG0053938]); 5 km from Matola-Gare, 13 Feb 1982, P.C.M. Jansen 7808 (BR, G, LMA, WAG [WAG0243995], WAG [WAG0243996]); Rikatla, Nov 1917, H.A. Junod 105 (G [G00308289]); Delagoa Bay, 1890, H.A. Junod 255 (G [G00308287]); Delagoa Bay, 1893, H.A. Junod 522 (G [G00308290]); nearby Bobole, 24 Nov 1978, J. de Koning 7316 (LISC, LMA, MO [3878659]); between Boane and Catuane, 12 Jun 1979, J. de Koning 7379 (K, LMU, MO [3880192], WAG [WAG0375988], WAG [WAG0375989]); 4 km from Catembe, 6 May 1981, J. de Koning 8680 (BR [BR0000013186029], K, LISC, MO [3306014], SRGH); Manhica, 3.5 km from Palmeira, 15 Apr 1975, A. Marques 2725 (WAG [WAG0053940]); Salamanga, 3 Jun 1948, F.A. Mendonça 4480 (MO); Salamanga, 3 Jul 1948, F.A. Mendonça 4493 (EA, WAG [WAG0053946]); Ilha da Inhaca, 3 Jul 1975, A.R. Moura 56 (MA [MA376952], WAG [WAG0053941]); Lourenco Marques, 6 Jun 1946, A. de A. Pimenta 8204 (LISC [2 sheets]); Ilha da Inhaca, 13 Feb 1965, J.E. Rodrigues 329 (WAG [WAG0053934]); Delagoa Bay, 6 Jan 1898, F.R.R. Schlechter 12006 (E [E00624364], G [G00308301], HBG, L [L 0188015], L [L 0188016], L [L 0188017], MO [3726269], P [P01954701], PH [PH00021144], US [553351]); Ilha da Inhaca, 6 Aug 1984, D. Zunguze 781 (WAG [WAG0071706]). SOUTH AFRICA. Kwazulu-Natal: Ndumu Game Reserve, 16 Feb 1969, E.S. Pooley 387 (E [E00624367], PRE); Usuthu Forest, 27 March 1969, 27 Mar 1969, E.S. Pooley 450 (E [E00624366], NU, PRE); Ndumu to Maputa km 23, 7 Mar 1973, F. White 10469 (FHO [00004050]); Tembe Elephant Park, 18 Nov 2000, P.C. Zietsman 4264 (MO [5837895], NY [00642339]).

Discussion. Most specimens of *M. maputensis* can be readily distinguished from the similar *Monanthotaxis caffra*, based on the vegetative and fruiting characters (table 4). These characters overlap in areas where the species occur in close vicinity. The differences in stamen morphology, however, remains clear, even in these areas. In South Africa, close to the border with Mozambique, *M. maputensis* is confined to sandy soils at low elevations (<200m), while *M. caffra* occurs there at higher elevations (>600m). Note however that *M. caffra* occurs at sea-level too, in South Africa (Figure 12). *M. caffra* and *M. maputensis* are also similar to *Monanthotaxis parvifolia* (Oliv.) Verdc., which can be distinguished by the rounded to cuneate leaf base (vs subcordate in *M. parvifolia*), the scattered soon glabrescent young branches (vs dense ferruginous pubescence in *M. parvifolia*). Other characteristics to distinguish *M. maputensis* from *M. parvifolia* are the shorter pedicels and shorter petioles in the former species, and fewer carpels in the latter (10–12 vs 12–17).

Two fruiting specimens in the northern range of the distribution (*A. Pereira* 456 and *J. de Koning* 9063) were slightly aberrant. *A. Pereira* 456 has slightly bigger leaves and thick stipes, while the specimen *J. de Koning* 9063 is more hairy than other specimens and has erect hairs on the young branches. The specimens *K. Balkwill* 2999 and *A.A. Balsinhas* 3187 from Kwazulu-Natal had intermediate characters between *M. maputensis* and *M. caffra* and did not contain any stamens to verify the identification.

Monanthotaxis tripetala P.H.Hoekstra, sp. nov.

urn:lsid:ipni.org:names:60472953-2 Figs 5, 13

Type. CAMEROON. East Province, 15 km E of Dimako, village halfway Bertoua-Doumé, 11 June 1965, *A.J.M. Leeuwenberg 5828* (holotype: WAG (2 sheets, barcodes: WAG0110801!, WAG0110802!); isotypes: B [B100190273!], BR [BR0000014126253], C, EA!, K!, LISC, MO, P [P01967268!], PRE, YA).

Diagnosis. Differs from other *Monanthotaxis* species in having bisexual flowers with three thick outer petals, and wanting or strongly reduced inner petals. The other species of *Monanthotaxis* with three petals or reduced inner petals have unisexual flowers, such as *Monanthotaxis diclina* (Sprague) Verdc. and *Monanthotaxis cauliflora* (Chipp) Verdc.

Description. Liana, 3 m high, diameter 11 mm; young branches reddish brown, with very short appressed reddish brown hairs, old branches dark brown, cylindrical, glabrescent with few lenticels. Leaves: petioles $2-4 \times 0.6-1.0$ mm, indumentum as branches; lamina $4.2-12.3 \times 1.8-4.9$ cm, length: width ratio 1.8-2.8, oblong to elliptic, base rounded, with thick globose glands at base, apex acute to acuminate, subcoriaceous, discolorous, adaxially glossy dark green, abaxially dull greenish white, adaxially glabrescent, young with scattered appressed white hairs, midrib impressed, glabrescent with appressed yellowish hairs, abaxially glabrescent with scattered appressed white hairs, more dense and yellowish on midrib, venation eucamptodromous, secondary veins 7-9, from base curving upwards, tertiary venation scalariform, not visible adaxially. Inflorescences axillary, composed of a solitary flower or a 2-flowered rhipidium; sympodial rachis 0-6 mm with yellow appressed hairs; flowering pedicels $12-20 \times 0.2-0.4$ mm, with appressed yellowish hairs; *lower bract* wanting; *upper bract* in the upper half of the pedicel or wanting, lanceolate, 0.5×0.2 mm with dense hairs; *flower buds* rounded. **Flowers** bisexual; *sepals* 3, free, $0.5 \times 0.8-1.0$ mm, broadly ovate, apex obtuse, with dense yellow appressed hairs; receptacle 1.5 mm in diameter, flat; *petals* 3(-4) in one(-two) whorls; *outer petals*, $2.0-2.2 \times 2.2$ mm, ovate, with appressed yellowish hairs on the outside, and papillose near the apex on the inside; *inner petals* usually wanting, rarely a single strongly reduced petal present, $1.5 \times 0.5-0.6$ mm, elliptic, with scattered yellowish papillae on the outside and base of the inside; stamens 9-12 in 1 whorl, free, linear-clavate, 1.2 mm long, filaments 0.6 mm long, anther cells extrorse to lateral not hiding connective, glabrous, staminodes 0; carpels 9, 1.1-1.2 ×



Figure 13. *Monanthotaxis tripetala* P.H.Hoekstra. **A–J** drawn from the type (Leeuwenberg 5828). **A** Habitus **B** Leaf base abaxially **C** Leaf base adaxially with inflorescence **D** Flower with one petal removed **E** Petal inside **F** Flower petals removed **G** Stamen outside **H** Stamen inside **I** Stamen lateral **J** Carpel. Illustration by H. de Vries.

0.3–0.4 mm, subcylindric to ellipsoid, densely hairy, ovules 3–4 lateral, stigma subsessile 0.1–0.2 mm, glabrous. **Fruits**: unknown.

Distribution. Cameroon, East province and Gabon, Ogooué-Ivindo. Figure 5. **Ecology.** Evergreen Forest and Old secondary Forest, at 515–650 m altitude. **Phenology.** Flowers collected in June.

Conservation status. Proposed IUCN Red List Category: **Endangered** (ED): B2ab(iii), EOO 6370 km², AOO 16 km². This species is only known from 4 collections from 3 locations of which only one in a protected area. The other location (Belinga) is under threat of mining companies and the location in Cameroon is in an area with increasing human population growth, therefore we suggest the status of endangered.

Etymology. Named for the three petals, one of the diagnostic characteristics of this species.

Additional specimens examined (all paratypes). GABON. Ogooué-Ivindo: Station d'Ipassa, 22 Jun 1978, *J. Florence 1409* (P [P01985718]); Belinga, A. Moungazi 252 (P [P01982463]); Ipassa reserve, 0°30.39'N; 12°47.65'E, 7 Nov 2015, *J.J. Wierin-ga 8229* (WAG [WAG.1575731, WAG.1575732, WAG.1575733, WAG.1575734] & spirit collection [WAG0116914]).

Discussion. This species can easily be distinguished from all other *Monanthotaxis* species by the small bisexual flowers with 3 outer petals and wanting to strongly reduced inner petals. Some other species exist, such as *Monanthotaxis cauliflora* (Chipp) Verdc., *Monanthotaxis diclina* (Sprague) Verdc. and *Monanthotaxis mortehanii* (De Wild.) Verdc., which have reduced inner petals, but those have unisexual flowers. Another probably new species from Cameroon which is currently still under study, also has completely wanting inner petals, but also that species has unisexual flowers.

The type specimen from Cameroon has reflexed and thickened edges at the leaf base (e.g. figure 13B), which is wanting in the specimens from Gabon, where only a slight depression can be seen next to the petiole insertion. This character is variable in other species as well, such as *Monanthotaxis schweinfurthii* (Engl. & Diels) Verdc. The very distinctive, small flowers with only 3(–4) petals in the Gabon specimens make these specimens belong to *M. tripetala*.

The specimen of Moungazi 252 has a gall on one of the branches, which has not been observed in any of the currently collected material of the *Monanthotaxis* species, while the collection of Wieringa 8229 has many brown velvety galls on one of the leaves (WAG spirit collection). The latter type of gall has been observed in other *Monanthotaxis* species in Central Africa.

Monanthotaxis zenkeri P.H.Hoekstra, sp. nov.

urn:lsid:ipni.org:names:60472954-2 Figs 5, 14, Table 5

Type. CAMEROON. South Province, Bipinde, probably October 1907, *G.A. Ze-nker 3495a* (holotype: G [G00308331!]; isotypes: BR [BR0000013211349!], E [E00624356!], HBG!, K!, L [L.1759466!], MO [3726267!]).

	M. zenkeri	M. filamentosa	M. bicornis
Outer petal length	2.0–3.1 mm	20–22 mm	5–8 mm
Nr of stamen whorls	3-4	3-4	2
Nr of stamens	35	34-46	15–18
Nr of carpels	16	9–14	6–9
Nr of ovules per carpel	4–5	7–10	3
Flower bud	globose	ovoid to lanceolate	rounded
Pedicel length	4–6 mm	0–8 mm	8–16 mm (Cameroon) 23–55 mm (Congo)
Indumentum on	densely covered with	densely covered with	densely covered with
young branches	erect hairs 0.3–0.4 mm	erect hairs 1.2–2.0 mm	appressed hairs 0.1-0.2 mm

Table 5. Differences between species of *Monanthotaxis* with anther cells converging on apex of stamen.

Diagnosis. The only other two species of *Monanthotaxis* with the anther cells convergent apically hiding the connective are *Monanthotaxis bicornis* (Boutique) Verdc. and *M. filamentosa* (Diels) Verdc., it differs from both in having small flowers and further can be distinguished from the first by the almost glabrous leaves with cuneate base and having only 15 stamens, while *M. filamentosa* has long erect hairs on the stems and pedicels and has ovate to ovate-lanceolate flower buds with much longer petals.

Description. Probably a liana. Young branches brown, densely covered with reddish brown, erect hairs 0.3–0.4 mm, old branches dark brown, cylindrical, glabrescent with few lenticels. Leaves: petioles $3-6 \times 0.7-2.3$ mm, indumentum as branches; lamina 4.7-20.1 × 2.3-9.5 cm, length:width ratio 2.0-2.3, obovate to elliptic-obovate, base rounded, with thickened margin at base, apex obtuse to acute, subcoriaceous to chartaceous, adaxially glabrescent, young with a few short erect yellow-brown hairs, midrib impressed with short erect yellow-brown hairs, lower surface with dense erect short yellow-brown hairs, venation eucamptodromous, secondary veins (8-)10-12, first straight halfway curving upwards, tertiary venation scalariform. Inflorescences axillary, a 1-3-flowered rhipidium; sympodial rachis 0-2 mm with dense short ascending to erect reddish brown hairs; flowering pedicels 4-6 × 0.4-0.5 mm, with dense short ascending to spreading hairs; lower bract strongly reduced or wanting; upper *bract* in the lower half of the pedicel, ovate, $0.6-0.8 \times 0.5-0.8$ mm with dense hairs; flower buds rounded; sepals 3, slightly connate at base, 1.1 × 1.5 mm, broadly ovate to broadly triangular, apex obtuse, with dense yellow appressed hairs; receptacle 1.5 mm in diameter, flat; petals 6 in two whorls; outer petals, 2.0-3.1 × 2.1-2.5 mm, ovate, short appressed yellowish hairs on the outside and inside along the margins, glabrous at base and center of the inside; *inner petals* $1.8-2.4 \times 1.3-1.6$ mm, rhombic, with dense short yellow hairs on the outside and apex of the inside; stamens 35 in 3 to 4 whorls, free, linear-obconic, 0.7–0.8 mm long, filaments 0.4 mm long, anther cells extrorse converging apically and hiding the connective, with hairs at edges of the anther cells, staminodes 0; carpels ca 16, 1.1-1.4 × 0.3 mm, subcylindric to ellipsoid, with dense hairs, ovules 4-5, lateral, stigma curved, elongate to subglobose, 0.2 mm long, glabrous, but long hairs at base of stigma. Fruits: unknown.

Distribution. Cameroon, South province. Figure 5.



Figure 14. *Monanthotaxis zenkeri* P.H.Hoekstra. **A–J** drawn from the type (Zenker 3495a). **A** Habitus **B** Leaf underside **C** Flower bud **D** Flower with petals removed **E** Old flower **F** Stamen lateral **G–H** Stamen outside **J** Stamen inside **J** Carpel. Illustration by H. de Vries.

Ecology. Forest.

Phenology. Flowering in October.

Conservation status. Proposed IUCN Red List Category: **Critically Endangered** (CR): B2ab(iii), only known from the type collection, which was collected more than a hundred years ago in an unprotected area. Actually, the species may well be extinct already.

Etymology. Named after G.A. Zenker, who collected many specimens of *Monan-thotaxis* in Cameroon from the end of the 19th and the beginning of the 20th century. The types of seven species of *Monanthotaxis* were collected by him.

Discussion. Sprague and Hutchinson (1916) noted that they had seen the specimen Zenker 3495a, but felt reluctant to describe it because of the immature flowers on the specimens in the Kew herbarium. However, the flowers are fully developed on the specimens of G and HBG where the flowers are open, some of which have lost the petals already.

M. zenkeri is one of three species of *Monanthotaxis* with anther cells converging at the apex of the stamen. It can be distinguished easily from the other two species by the small flowers and dense short erect hairs on the young branches and leaves (Table 5). Vegeta-tively, this species is quite similar to *Monanthotaxis diclina* (Sprague) Verdc. which also is densely covered with short reddish brown hairs. However, the flowers are very different, *M. diclina* has unisexual flowers, the female inflorescences are cauliflorous and the male inflorescences axillary. Furthermore, the stamens are very different as *M. diclina* has 6 stamen in one whorl with the anther cells latrorse and an external whorl of 12 staminodes.

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DATA PAPER



Flora-On: Occurrence data of the vascular flora of mainland Portugal

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Abstract

The Flora-On dataset currently includes 253,310 occurrence records for the class Embryopsidae (vascular plants), comprising data collated via the platform http://flora-on.pt/ relating to observation records of vascular plants across mainland Portugal. Observations are uploaded directly to the database primarily by experienced botanists and naturalists, typically on a weekly basis, and consist of geo-referenced data points for species (or infraspecific taxa) along with their date of observation and phenological state.

The Flora-On project aims to compile and make publicly accessible chorological, ecological, morphological and photographic information for the entire vascular flora of Portugal. The project's website offers powerful query and visualization capabilities, of which we highlight the probabilistic bioclimatic and phenological queries which operate based on the empirical density distributions of species in those variables.

Flora-On was created and continues to be maintained by volunteers who are Associate members of Sociedade Portuguesa de Botânica (Botanical Society of Portugal). Given its focus on research-grade and current data, the Flora-On project represents a significant contribution to the knowledge of the present distribution and status of the Portuguese flora.

Keywords

Portugal, vascular plants, occurrence, observation

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Project details

Project title

Flora-On, Interactive Flora of Portugal

Personnel

Miguel Porto (Programmer)

Funding

The project does not have direct funding from any source, the platform being entirely built and maintained by volunteers. Maintenance costs of the web server are covered by the Associate membership fees of Sociedade Portuguesa de Botânica (Botanical Society of Portugal). However, externally funded projects have contributed through the provision of data.

Study area description

Portugal is located at the south westernmost extent of Europe (Figure 1) and is bound by the Atlantic Ocean to the west and south and by Spain to the north and east. Being approximately rectangular in shape, Portugal extends circa 220 km from east to west and 550 km from north to south. It lies within the Mediterranean biogeographic region, with the vast majority of its land falling within the Mediterranean macrobioclimate but extends in the north into the temperate macrobioclimate. The area of mainland Portugal is approximately 89,015 km² and, together with mainland Spain (492,127 km²), forms a geographically well-defined territory known as the Iberian Peninsula.

The orography of Portugal is heterogeneous, particularly from north to south, with the Mountains and Plains of the Iberian northwest and of the Iberian Central System dominating the northern parts of its territory (Pereira et al. 2014). This region is characterised by rugged landscapes dominated by granitic and metasedimentary geological formations which extend almost as far south as river Tejo (the largest river in Portugal which divides the country in half). Serra da Estrela mountain, its highest peak, rises 1,991 m above sea level. The Plains of the southwest Iberian Peninsula occupy almost all the central and southern interior territory (Pereira et al. 2014), this region being characterised by a very smooth landscape with some scattered high relief formations, such as Serra de São Mamede (1027 m), Serra de Monchique (902 m), and Serra do Caldeirão (589 m). The western and southern coastal regions are otherwise occupied by the Mesozoic and Cenozoic Basins (Pereira et al. 2014) and are characterised by the dominance of maritime and alluvial sedimentary formations and calcareous reliefs, some of which are

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Figure 1. Location of mainland Portugal (black) which, together with Spain (dark grey), forms the Iberian Peninsula. Dashed line represents the boundary of the Mediterranean macrobioclimate, which contacts with the temperate macrobioclimate to the north.

very prominent, including Serra de Montejunto (666 m), Maciço Calcário Estremenho (610 m), Serra da Arrábida (499 m), and Barrocal Algarvio (479 m).

Across mainland Portugal the vegetation is mainly Mediterranean in terms of both its structure and floristic composition. Semi-deciduous and perennial oak woodlands, "montado", shrublands, grasslands and silvo-agricultural systems occupy most of this area. Mainland Portugal supports approximately 2,900 native vascular plant taxa (Sequeira et al. 2010), 137 of which are considered endemic.

Design description

The Flora-On project aims to compile and make publicly accessible chorological, ecological, morphological and photographic information of the entire vascular flora of Portugal. Occurrence data is regularly uploaded to the website by active collaborators, typically on a weekly basis, and consists of geo-referenced data points of species (or infraspecific taxa) along with their date of observation and phenological state. Additionally, other research projects contributed data to the project from their exhaustive sampling campaigns. An open-source version of the platform is currently under development and can be found at https://github.com/miguel-porto/flora-on-server/

The strength of the Flora-On platform lies in its ability to execute a diversity of query types (Table 1). In addition to the usual deterministic queries in relation to taxonomic, morphological and geographical information, Flora-On enables users to

Table I. Example of query types which can be entered by users into the Flora-On search box. Any comma-separated combination of queries can be entered into the search box. Currently, Flora-On only accepts queries in Portuguese. The table provides the English translation in parentheses.

Type of query	Example queries (meaning)	Returns
Morphological	arbusto espinhoso, flores amarelas (spiny shrub, yellow flowers)	All taxa that present the specified attribute combination
	continentalidade>14	
	(continentality index greater than 14)	All taxa whose cumulative density
Bioclimatic	tempminima: 1.4-3.7, precipitação: 1300–1900	distribution in each variable, within the
range	(minimum temperature between 1.4 and 3.7°C and annual precipitation between 1,300 and 1,900 mm)	specified ranges, is greater than a given threshold
D. I.	tempmaxima~Cistus albidus	All taxa whose density distribution of the
Bioclimatic similarity	(maximum temperature profile similar to that of <i>Cistus albidus</i>)	observations in the specified variable is similar to that of the specified species, given a threshold of similarity
	altitude<100, costa>100000	All taxa whose cumulative density
Geographical	(altitude lower than 100 m and distance to coast	distribution in each variable, within the
variable ranges	greater than 100 km)	threshold
	Algarve (existing within Algarve region)	All taxa with at least one observation within
Geographical themes	NC06 (existing in NC06 UTM square)	the boundaries of the specified region, natural park, county, UTM square, or other geographical theme
Geographical	perto: 38 4278 -9 1949	Taxa having at least one observation within a
proximity	(close to 38.4278° N -9.1949° W)	given radius from the specified coordinate
1		Taxa with a distribution similar to that
Geographical	distribuição~Staehelina dubia	of Staehelina dubia, computed as the
similarity	(distribution similar to that of <i>Staehelina dubia</i>)	intersection of their density distributions,
		given a threshold of similarity
		All taxa whose cumulative density
Phenological range	20 julho o 0 agosto	distribution of flowering dates within
	(20 July to 9 August)	the specified range is greater than a given
		threshold, i.e., taxa whose flowering period is
		concentrated within the specified range
Phenological	floração-Scilla autumnalis	All taxa whose density distribution of
similarity	(flowering profile similar to that of	flowering dates is similar to that of <i>Scilla</i>
	Scilla autumnalis)	<i>autumnalis</i> , given a threshold of similarity
Phenological precise date	7 fevereiro	All taxa which may be found in flower at
	(7 February)	the given date (regardless of the flowering
- 	·	distribution throughout the year)
	(less than 3 LTM squares)	10×10 km UTM squares

conduct quantitative probabilistic species queries in relation to bioclimatic distribution, altitudinal distribution and flowering dates. With such queries species can be filtered and ranked by the degree of matching criteria defined by the user for one or more quantitative variables (including flowering date). This innovative feature is based upon empirical density distributions of species that are computed internally for each variable (Figure 2), and for the precise observed flowering dates, using a kernel smoother. The


Figure 2. Internal structure, data flow and front-end interfaces of Flora-On. Pink boxes represent the front-end interfaces that interact with the user (input and/or output). Green boxes represent the data, either permanent or temporary (dashed box). Blue boxes represent the internal server-side algorithms that parse the user queries, process and summarise the raw data, and deliver the results to the front-end interfaces.

density distributions are stored in the database as binary objects to allow fast querying with MySQL native extensions.

Flora-On is designed in such a way that the results of any type of query, irrespective of its complexity, can be visualized across different facets, evidencing aggregated bioclimatic, geographical, phenological or morphological features of the species that match the query. All queries can be expressed through plain text, but to simplify the querying process for general users, four front-end graphical query interfaces are provided to aid query building (Figure 2, top row). The query algorithm, after passing and processing the input query (Figure 2, middle row), then delivers the results to the output modules of the application, which summarise and display the query results according to the different facets (Figure 2, bottom row):

- I) The standard search displays the species photographs ordered by different criteria;
- II) The bioclimatic explorer displays jointly the occurrences of the species that match the query in a bioclimatic/environmental space, with the possibility of overlaying multiple queries in the same plots, evidencing the ecological differences between species or groups of species (http://flora-on.pt/#b);
- III) The WebGIS displays (with the ability to download the output) the map of the number of species that match the query per Universal Transverse Mercator (UTM) square, e.g. richness of spiny species, richness of summer-flowering species, richness of species occurring in less than five UTM squares, etc. (http://flora-on.pt/#w);
- IV) The multi-way interactive identification key allows users to identify species by iteratively narrowing down possible species, freely choosing its way through a set of characters. Displayed characters are adjusted for each iteration according to the list of possible species, and are highlighted according to their discriminant power, to enhance the efficiency of the identification process (http://flora-on.pt/#z);
- V) The joint flowering profile displays the aggregated flowering profile of all species matching the query, e.g. flowering profile of the species occurring in areas with an annual precipitation above 1,500 mm (currently accessible through the standard search results).

Data published through

IPT: http://flora-on.pt:8080/ipt/resource.do?r=flora-on GBIF: http://www.gbif.org/dataset/7fe3eb5c-42bd-49d7-a30b-82c353ef6575 Website: http://flora-on.pt/

Taxonomic coverage

The Flora-On dataset includes 253,310 occurrence records of the class Embryopsidae. The top orders, comprising 75% of the records, include: Asterales (13.8%); Lamiales

ASTERACEÁE					FABACEAE			POACEAE					
Senecio	Pulicaria	Chamaemelum	Crepis	Centaurea	Trifolium		Ulex		Briza	Brachypo	odium Ag	Agrostis	
Leontodon	Dittrichia Tolpis Ca		arlina Galad	titesHelichrysum			Cytisus		Dactylis	Bromus	Vulpia	Avena	
	Calendula a	oleostephus Log	fia Cynara	Bellis Reichardia	Vicia	Lathyru	S Ornithopu	s Acacia	11-1	Stipa Arun	do Festuci	2 Ambenasherum	
Sonchus	Phagnalon	actuca consumeror	Conyza Atractylis C	iondrille <mark>Arternisia</mark> Cichorium		Medicago	Ononiseum	ospartum Lupinus	Hoicus	Aira Connectour He	ordeum Pasamenum A	longynum Paspatum	
Andryala	Carduus	rospermum Scolymus Bidens	Cheirolophus Stashelina Hisp Scorzonera Cart	idetta Propositiva contanton Carthur hannut Arnosente Erigeron Inula	Genista	Coronilla	StauracanthusHymi	enocarpos Adenocarpu	Lolium G	audinia	pogor Elymus Ga	strictium#iypamieni	
Hypochaeris	Cirsium A Picris	chillea ^{Aetheorhiza} Cantolina Klasea	Lapsana Silybum Aster Otenthus	Salara Salatago Coulta Even yela Salaran Salara Salara Salara Salara Salaran Salara Salara Salara Salara	Lotus	Bituminaria Erophaca	Anthyllis Reta	malus Ceratonia Mellos ma ma	^{Cynosurus} M Poa P	Melica _{Cynoden} Lay	Dlinia AegilopsSets gurus ^{Enternation} ^{tana} Danthonia Mer		
		-	Citorita Lec	203 67202	CARV			Soft Street States			Panicum Neel		
Lavandula	AMIACEA a Thymu amium ^{Cimpodi}	IS Menth		Cistus	Sil		Stellaria _E	APD Tryngium Thapsia	ACEAE DenantheFoeni DaucusTo	PLAN Plan Plan	ntago	Linaria	
Teucrium Ro.	smarinus ^{Origanur}	Lycopus Ajuga sa	- Halimiu	m Tuberaria	Arenaria Dianthu	Polycarpon Sp	ergula Paronychi A ia Saonara Hermiani Bu	pium ^{Conopodi} Ferui	um Carum Margolia . a Crithmum Scandberrow Wa ^m onontarum basana france		lis Veron	ica ^{Antimhinun}	
Stachys Prunella Salvia					Spergularia	A Mecebrum Cherrorychi		nyrnium _{Heracleu}	Conium Amm Cooky	Anarrhin	Sibthor		
Asparagus	Urginea	Rubus	Crataegus Sanguisorba	Geranium	Erodium	phrys C	Drchis	Rumex	EL	ıphorbia	Carex	Cyperus	
Scilla	HyacinthoideaOmithopatur	Rosa Pr	unus Geum Annana		Sera	apias Daciyloritica rilia Aceraso		olygonur	n Merc	curialis Ricinus	Scirpoides	ochanis ^(solepi)	
Ruscus Dipcad		Potentilla Py CRASSU		RANUNCULA			CAPRIFOLI	aceae A A	RACEAE risarum	RHAMNAC	AE IRID	ACEAE Gladiolus	
FAGACEAE		Sodur	Umbilicus	A		PICACEAE	Sambue			RIACEAE DENNSTAL	Dynanskiris A		
Quercus		Sedun	Craceula	Anemone AMARYLLIDA Narcissus		pericum	Convolvulus	Urtica	Parietaria	Pterie	diumArm	eria	
							UPRESSACEAE MYRTACEAE		F SMILACACEAE LYTHRACEAE				
Castanea		Galium	Sherardia	Allium Campanula	SALI Second CEAE	caceae Salix	luniperus	Myrtus Eucalyptu	Smilax	Lythrum	Alnus	Anogramma	
ERICA	CEAE		Crucianella	Jas	sione		AMARANTHACEAE	DIOSCOREACEAE		ACACEAE SAXFRAGAC	Arehadala	SANTALACEAE	
Erica	Calluna	Rubia	Valantia Aspenula	wateroorg		stacia	tenopodium Amaranthur alimione <mark>Suundu Beta</mark>	Tamus	Sesamoides	Saxifra	simethis	Osyris	
		OLEACEAE		PRIMULAC	EAE	s	alsola	Malvaceae	Aristolochia	pobrotus Hede	ra Athyrium	Osmunda	
Arbutus	Corema	Phillyre	a Fraxinus	Anagallis		aphne	Centranthus	Lavatera		ACEAE Selaginella	Phytolacci Polyg	ala Epilobium	
BRASSICACEAE Raphanus		Olea	Jasminum	ASPLENIAC		ANCHACEAE	Fedia Valeriani SOLANACEAE	Linum			Verbena Ulmus d	EAE TYPHATEAE	
Iberis	6 Rorippa Arabis	BORAGI	Comphalodes Myosotis	, topiernum		Darisia di	Solanum	GENTIANACEAE Centaurium		RACEAE Equisetur ^{Pa}	eonia hadescanta de	Droseva name	
Cardamine Bacuret	cincya montesta Ayaan moore	Echium	Applying Para	JUNCACE	Crobance CAE	VERACEAE	DXALIDACEAE	Blackstonia	Bryonia uu	ACEAE FICUS	Davatha Massie	unne Seara	
Malcolmia _{Cakilo}	nymbriam Sillights arrands Operan Aphilian		Cynoplossum Persystem Cerren	Juncus	Papa	Vel Fumaria	Oxalis	VIOLACEAE			nsha Vitic		
Teesdalia errora	Draba Review	Lithodora	Heliotopiam Autoenne Nores		Chelida	onium		viola	Polypodium _{Alise}	Batteria Ilex cy	tinu: Fuegge		

Figure 3. Tree map of the Flora-On dataset based on a two-level taxonomic classification. Families are delineated with thick lines and genera with thin lines. The size of the rectangles is proportional to the number of records held. The plot was built with the R package 'treemap' (Tennekes 2016).

(11.3%); Poales (10.3%); Fabales (8.6%); Caryophyllales (6.5%); Asparagales (5.8%); Malvales (4.6%); Apiales (3.7%); Rosales (3.4%); Malpighiales (3.1%); Ericales (3%); and Fagales (2.7%).

In total, this dataset includes occurrence records for 150 plant families and 2073 taxa (Figure 3). Families with the greatest numbers of species in Portuguese mainland are also those families with the greatest number of occurrence records within this dataset, including: Asteraceae (32,638); Fabaceae (21,529); and Poaceae (20,656); although some genera are still under-represented. This is probably due to the nature of the dataset, given that the greatest part of the contributions results from non-exhaustive field observations which likely result in the under-representation of the more inconspicuous taxa, or taxa difficult to identify in the field.

Taxonomic ranks

Kingdom: Plantae (Chlorobionta)

Phylum: Streptophyta

Class: Embryopsidae

- Order: Alismatales, Apiales, Aquifoliales, Arecales, Asparagales, Asterales, Boraginales, Brassicales, Buxales, Caryophyllales, Celastrales, Ceratophyllales, Commelinales, Cornales, Cucurbitales, Cupressales, Cyatheales, Dioscoreales, Dipsacales, Ephedrales, Equisetales, Ericales, Fabales, Fagales, Gentianales, Geraniales, Hymenophyllales, Isoetales, Lamiales, Laurales, Liliales, Lycopodiales, Malpighiales, Malvales, Myrtales, Nymphaeales, Ophioglossales, Osmundales, Oxalidales, Pinales, Piperales, Poales, Polypodiales, Proteales, Ranunculales, Rosales, Salviniales, Santalales, Sapindales, Saxifragales, Selaginellales, Solanales, Vitales, Zygophyllales
- Family: Acanthaceae, Aizoaceae, Alismataceae, Amaranthaceae, Amaryllidaceae, Anacardiaceae, Apiaceae, Apocynaceae, Aquifoliaceae, Araceae, Araliaceae, Arecaceae, Aristolochiaceae, Asparagaceae, Aspleniaceae, Asteraceae, Basellaceae, Betulaceae, Blechnaceae, Boraginaceae, Brassicaceae, Butomaceae, Buxaceae, Cactaceae, Campanulaceae, Cannabaceae, Caprifoliaceae, Caryophyllaceae, Celastraceae, Ceratophyllaceae, Cistaceae, Cleomaceae, Colchicaceae, Commelinaceae, Convolvulaceae, Cornaceae, Crassulaceae, Cucurbitaceae, Culcitaceae, Cupressaceae, Cynomoriaceae, Cyperaceae, Cytinaceae, Davalliaceae, Dennstaedtiaceae, Dioscoreaceae, Dipsacaceae, Droseraceae, Drosophyllaceae, Dryopteridaceae, Elaeagnaceae, Elatinaceae, Ephedraceae, Equisetaceae, Ericaceae, Euphorbiaceae, Fabaceae, Fagaceae, Frankeniaceae, Gentianaceae, Geraniaceae, Haloragaceae, Hydrangeaceae, Hydrocharitaceae, Hymenophyllaceae, Hypericaceae, Iridaceae, Isoetaceae, Juglandaceae, Juncaceae, Juncaginaceae, Lamiaceae, Lauraceae, Lentibulariaceae, Liliaceae, Linaceae, Linderniaceae, Lycopodiaceae, Lythraceae, Malvaceae, Marsileaceae, Melanthiaceae, Menyanthaceae, Molluginaceae, Moraceae, Myricaceae, Myrtaceae, Nartheciaceae, Nyctaginaceae, Nymphaeaceae, Oleaceae, Onagraceae, Ophioglossaceae, Orchidaceae, Orobanchaceae, Osmundaceae, Oxalidaceae, Paeoniaceae,

Papaveraceae, Passifloraceae, Phyllanthaceae, Phytolaccaceae, Pinaceae, Pittosporaceae, Plantaginaceae, Platanaceae, Plumbaginaceae, Poaceae, Polygalaceae, Polygonaceae, Polypodiaceae, Pontederiaceae, Portulacaceae, Potamogetonaceae, Primulaceae, Proteaceae, Pteridaceae, Ranunculaceae, Resedaceae, Rhamnaceae, Rosaceae, Rubiaceae, Ruppiaceae, Rutaceae, Salicaceae, Salviniaceae, Santalaceae, Sapindaceae, Saxifragaceae, Scrophulariaceae, Selaginellaceae, Simaroubaceae, Smilacaceae, Solanaceae, Tamaricaceae, Taxaceae, Thelypteridaceae, Thymelaeaceae, Tropaeolaceae, Typhaceae, Ulmaceae, Urticaceae, Valerianaceae, Verbenaceae, Violaceae, Vitaceae, Woodsiaceae, Xanthorrhoeaceae, Zosteraceae, Zygophyllaceae Common names: Vascular plants

Spatial coverage

General spatial coverage

The Flora-On dataset covers almost the entire territory of mainland Portugal, although there remains a significant lack of information for some areas, particularly in the central and southern interior regions (Figure 4a). As expected for a dataset that is not complete, the number of species per UTM square (Figure 4b) correlates to the number of records, illustrating the gap in information for some regions. Indeed, whilst the



Figure 4. Number of occurrences (**a**) and species (**b**) recorded in Portugal mainland per 10×10 km square. The dataset used in this analysis includes a total of 253,310 records. Numbers were classified with geometrical intervals. The dots are placed at the centre of WGS84 UTM squares.



Figure 5. Number of Portuguese (**a**) and Iberian (**b**) endemic plants per 10×10 km UTM square. The dataset used in the analysis corresponds to a total of 253,310 records. Note that low values do not necessarily mean absence of endemic species, as many areas are under-sampled (Figure 4a). Class breaks are manual. The dots are placed at the centre of WGS84 UTM squares. N.B. Iberian endemics (**b**) do not include Portuguese endemics.

project presently includes occurrence data spread across the whole country, the more intensively surveyed areas include the more coastal regions and some key areas towards the interior. Nonetheless, it is worth noting the high numbers of species of some 10x10 km UTM squares, up to 700 observed species in some cases, revealing high taxonomic diversity of some parts of the Portuguese mainland territory (Figure 4b).

The number of Portuguese endemic species recorded per UTM square (Figure 5a) illustrates a well defined pattern, with the highest endemic species richness occurring across the central and southern coastal regions, including Lisbon and Setúbal, coast of Alentejo, and Algarve (from Sagres to Faro). These areas exhibit particularly isolated climatic and/or geological features, such as the wet coastal mountains of Sintra and Monchique, the inland sand plains of Setúbal, the Atlantic coastal cliffs, and the vast dry limestone regions of Setúbal and Algarve. Additionally, the data illustrates the importance of the mountain ranges in the interior north and the regions nearby the frontier in the northeast quadrant as areas of high Iberian endemic species richness (excluding Portuguese endemics) per UTM square (Figure 5b). Figure 5 further illustrates some coincidence between areas with high Portuguese endemic richness and high Iberian endemic richness.



Figure 6. Barplot depicting the number of occurrence records observed per year. Occurrences observed before 1990 (127) were omitted for clarity. 7,681 records are not dated.

Coordinates

36°43'12"N and 42°10'12"N Latitude; 9°37'12"W and 6°9'36"W Longitude

Temporal coverage

Although the bulk of the dataset corresponds to observations made between 1 January 1995 and 2 February 2016 (Figure 6), historic records prior to this period also exist.

Collection name

Flora-On: Interactive Flora of Portugal

Collection identifier

c9d06ad2-6369-47dd-9372-ade1a5055096

Methods

Method step description

For each occurrence, GPS coordinates are recorded by the collaborators wherever possible; otherwise approximate coordinates and their level of precision are recorded. Plants are identified at least to species level. Thereafter, collaborators upload the data to the Flora-On database via a webmapping interface or by uploading a record table. Coordinates are then generalised to the UTM 10×10 km grid and are made publicly available for download as tables and as a geographical layer through a WFS service: http://flora-on.pt/wfs. High resolution data can be provided upon request, subject to approval by Sociedade Portuguesa de Botânica and involved collaborators.

Study extent description: This dataset includes observations falling within mainland Portugal, most of which were made after the Flora-On platform was made available online (25 February 2012).

Sampling Description: A large proportion of the records corresponds to nonexhaustive observations of collaborators, although a significant amount of data results from fieldwork completed as part of other externally funded projects. When possible, plants are identified in the field at least to species level. Otherwise, plant material is collected and identification is confirmed in the lab by the collaborators. Phenological state is recorded if plants are flowering at the time of observation.

Quality Control Description

Taxon nomenclature is fully controlled via use of a reference checklist, allowing neither spelling errors nor outdated synonyms. The reference checklist includes only currently accepted nomenclature which corresponds to an updated version of the "Checklist da Flora de Portugal (Continental, Açores e Madeira)" (http://ipt.gbif.pt/ipt/resource. do?r=alfa_checklist_florapt).

The responsibility of species identification rests with the collaborators, most of which have expertise in plant identification. Additionally, the Editorial Board of Flora-On is committed to ensure a high reliability of uploaded data, hence checking regularly for unlikely or doubtful occurrence records, and asking collaborators to provide pictures, descriptions or specimens whenever needed. The Editorial Board estimates at least 95% of the records to be correctly identified under the most up-to-date nomenclature.

Datasets

The current Flora-On dataset published through GBIF includes occurrence and phenological data. Phenological data, for now, is limited to a 'Yes'/'NA' field in respect of flowering, and is linked to the date of the observation. In addition, Flora-On also utilises a morphological dataset not currently published elsewhere, as well as a number of other quantitative data fields that numerically describe the flowering period, bioclimatic and altitudinal distribution profiles of each taxon (Figure 2).

Morphological data is a compilation of information from different bibliographic sources (Castroviejo 1986–2015, Franco 1971–1984, Franco and Rocha-Afonso 1994–2003) and from direct observation in the field, which includes ca. 15 categorical reproductive and vegetative plant traits, such as colour and number of petals, type of fruit and type of growth. The primary purpose of this trait data was to aid the general public on the identification of taxa, but it is part of the roadmap to enrich the dataset with more traits and make it freely available.

Species altitude profiles and bioclimatic profiles are estimated by applying a kernel density on elevation and bioclimatic data, i.e. the set of elevation and bioclimatic variable values at which each taxon was observed. Elevation data is extracted by crossing taxa occurrence data with the ASTER Global Digital Elevation Model (METI, NASA). Bioclimatic data are extracted from the climatic variables and bioclimatic indices compiled and developed by Monteiro-Henriques et al. (2015).

The Flora-On dataset represents a major contribution to the knowledge of the present distribution of Portuguese and Iberian flora. Despite the lack of information in several parts of the territory, Flora-On dataset constitutes the most complete and up to date source of research-grade occurrence data on the Portuguese flora, since a great concern is put on ensuring the correctness of the data. Other existing nation-wide platforms covering occurrence data of the Portuguese flora have either a partial coverage or do not specifically target validated data. Furthermore, previous data on the Portuguese flora was limited to herbarium and bibliographic sources, which are largely not digitally accessible or accessible only in a very coarse format.

Finally, the Flora-On project has been stimulating the collection of new data on the distribution of species, which has resulted in great improvements in the knowledge of many species. Indeed, the voluntary field work conducted by the collaborators has significantly improved the knowledge about the current status of many rare, protected by national and international legislation, or hardly known species, and several new species not known to occur in Portugal have been recently found.

Dataset description

Object name: Darwin Core Archive Flora-On: occurrence data of the flora of mainland Portugal Character encoding: UTF-8

Format name: Darwin Core Archive format

Format version: 1.0

Distribution: http://flora-on.pt:8080/ipt/archive.do?r=flora-on

Publication date of data: 2016-02-19

Language: Portuguese

Licences of use: This work is licensed under a Creative Commons Attribution Non Commercial (CC-BY-NC) 4.0 License.

Metadata language: English

Date of metadata creation: 2014-12-04

Hierarchy level: Dataset

Used Darwin Core Terms: id, modified, language, rights, institutionID, collectionID, institutionCode, collectionCode, datasetName, ownerInstitutionCode, basisOf-Record, dataGeneralizations, occurrenceID, catalogNumber, occurrenceRemarks, recordedBy, reproductiveCondition, occurrenceStatus, eventDate, year, month, day, country, countryCode, county, municipality, decimalLatitude, decimalLongitude, geodeticDatum, footprintWKT, footprintSRS, identifiedBy, dateIdentified, scientificName, higherClassification, kingdom, phylum, class, order, family, genus, specificEpithet, infraspecificEpithet, taxonRank, scientificNameAuthorship, nomenclaturalCode.

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RESEARCH ARTICLE



Typification of species names in Adenocaulon and Eriachaenium (Compositae/Asteraceae, Subfamily Mutisioideae, Tribe Mutisieae, Subtribe Adenocaulinae)

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Abstract

During the course of a recent research project on *Adenocaulon* and *Eriachaenium* it became apparent that some of the species names had not been typified. In this study we located and designated as much type material as possible for these two genera. We indicate holotypes or lectotypes where appropriate, including one for the type of the genus *Adenocaulon*.

Keywords

Asteraceae, Composiate, North, Central and South America, Asia, Asia-America disjunct distribution

Introduction

In the process of preparing a manuscript on the phylogenetic placement of *Eriachae-nium* Sch. Bip. and *Adenocaulon* Hook. (Funk et al. 2016) it became obvious that many names remained untypified. These two genera have interesting morphologies and distributions but until recently their affinities had never been fully understood (Funk et al. 2016) and the location of the types was not fully resolved. Tracking down the type material required assistance from herbaria in Argentina, Chile, Europe, the UK, and USA (see acknowledgements). We found as much type material as possible and when necessary we provide lectotypifications. No doubt there are isotypes and isolectotypes

that we have not located but these should be easier to find with the information we have provided (see Appendix).

The species of *Eriachaenium* and *Adenocaulon* are listed below along with their Type citations [! indicates that the specimen was seen by one of the authors and * indicates that it was seen on-line at either JSTOR-GP (continuously updated), the P website (Paris-MNHN, continuously updated), the Virtual Herbaria (continuously updated) or in some cases curators of herbaria sent photos of newly discovered type material. This newly discovered material should be available on JSTOR-GP soon. Dates for collecting trips and potential herbaria that might contain type material were taken from TL-2 (*Taxonomic Literature*, Second edition) and IH II (*Index Herbariorum*, part II) and are cited in the text appropriately. Bittmann (1990a, 1990b) studied the genus *Adenocaulon* and published a detailed study of the morphology and ecology along with a preliminary evaluation of the nomenclature including a description of a new species (Bittmann 1990a).

Taxonomy

Adenocaulon W.J. Hooker

Adenocaulon bicolor W.J. Hooker

Adenocaulon bicolor W.J. Hooker, Botanical Miscellany 1(1): 19–20. Apr 1829. Plate XV.

Syntype material. [Although the cover page of *Botanical Miscellany* volume 1 lists the publication date as 1830, according to Stafleu and Cowan (1979, page 290) it was published in three parts and part 1 (pages 1–96) was published in 1829]

Syntype 1. USA [Washington State], Dense forest of Straits of Juan de Fuca, and near Fort Vancouver and Columbia River, West coast of North America, [1824–1825], *John Scouler s.n.* [1017] [Lectotype: K! here designated; isolectotypes: E00230668*, NY00158065!; OXF* 00005489 (not yet available on JSTOR-GP)]

Scouler's trip to Northwest USA was in 1824–1825 (Vegter 1986) and the area between the Straits and Fort Vancouver and the Columbia River is in Washington State. The E specimen has "Scouler (1017)" written on it. Vegter (1986) also lists CGE as a possible location for an additional Scouler's collection but none were found (pers. comm. C. Bartram).

Syntype 2. North America, in the Rocky Mountains, [1825–1827], *Thomas Drummond s.n.* [K! (not yet available on JSTOR-GP)]

Lanjouw & Stafleu (1954) reported that Drummond's collections could also be in A, AWH, B, BM, CGE, DELS, DS, E, FI, G, G-DC, GH, GL, GOET, LD, OXF, P, PH, S, TCD, UC, UMO, UPS, US (not found), W (not found), WU]. They also said that Drummond was in North America 1825–1827 and that he made a second trip 1831–1835 but the latter trip was after the species was described. Stafleu and Cowan

(1976) report that the location of Drummond's original herbarium is unknown but indicate that BM & K have the best sets of his plants.

- Adenocaulon integrifolium T. Nuttall, Transactions of the American Philosophical Society, New Series 7[1]: 289. 1841. Type material: United States, Oregon, Shady woods of the Wahlamet, near its confluence with the Oregon, [1834], T. Nuttall, s.n. [Holotype: GH00000615*; isotypes: K! (not yet available on JSTOR-GP); PH00224269*]
- Vegter (1983) listed the date of the expedition as 1834 and said that additional material might have been sent to LIV (not found) and NY (not found). Bittmann (1990a) listed PHIL as the location of an isotype but it appears that this refers to the isotype at PH which was annotated by Bittmann (E. Benamy, pers. com.). According to Stafleu and Cowan (1981, page 786) the prologue was contained in part 1 of volume 7 and published on 12 May 1841.

Adenocaulon chilense E.F. Poeppig ex C.F. Lessing

Adenocaulon chilense E.F. Poeppig ex C.F. Lessing, Linnaea 6: 107–108. 1831.

Type material. Chile. Antuco, [Dec 1828], *E.F. Poeppig 225, diar. 755.* [Holotype most likely at B and destroyed; Lectotype here designated as W* (W1889-0050720); isolectotypes: G00495616*, HAL0110867*, M0029893*, P02505554*, W0064359*, & W0064360*]. Vegter (1983) listed the date of the field trip as 1827–1829 and she listed additional possible locations of herbarium material as: B, BR, CGE, F, FI-W, GOET, K, KIEL, L, LE, LZ, MO, NY, OXF, PR, PRC, US, WRSL.

Lessing's descriptions seem to be based on specimens that he examined at B. They were most likely collected by B staff/associates or sent to B as a gift/exchange. The Compositae herbarium at B was destroyed during WWII (Hiepko 1987) so when duplicates can be found they are designated as lectotypes. Lessing participated in two series of papers about Compositae in the journal *Linnaea*. The title of Lessing's first series of papers in Linnaea was Synanthereis Herbarii Regii Berolinensis (Lessing 1929, 1830a, 1830b, 1930c). The second series included two papers by Lessing (1831a, 1831b), the latter of which included the type description of *A chilense*. These two articles were part of a larger series entitled De plantis in expeditione speculatoria Romanzoffiana observatis disserere pergunt AD. de Chamisso et D. de Schlechtendal, and although Chamisso's original collections were no doubt at LE and Schlechtendal's at HAL they both probably sent duplicates to B and it is likely that Lessing worked from the duplicate material. Interestingly the "Romanzoffiana" treatment is part of a larger series of papers that began in volume 1 of Linnaea (Chamisso 1826). In his preface Chamisso (1826) says that the exploratory expeditions were supported by Count de Romanzoff the Imperial Chancellor in 1815, hence the name of the article. The preface mentions other collectors but does not mention Poeppig. Poeppig's original set is supposed to be at W

(Vegter 1983) and it is likely that a duplicate was sent to B. There are two collections at W (E. Vitek, pers. comm.) and one has been selected as the lectotype.

There is some confusion as to the collecting number: on many specimens there are two numbers, the number of the printed labels differing somewhat from the "diario" numbers that are often handwritten. As a result, some records for this particular collection have the number 755 but others list 255 (likewise JSTOR-GP entries list one or the other). Some specimens clearly have both 755 & 225 printed on the labels and others do not. It is possible that the collecting number is 755 as it appears handwritten on the lectotype (and on the printed lables as "diar. 755") and other type material has 255 printed on the labels and this may be a species number. Vitek (pers. comm.) provided an example of how the collecting number might be cited and we have followed that.

- Adenocaulon lechleri C.H. Schultz Bipontinus, Flora 38: 113. 1855. Type material. Chile. Ad portum Port Famine, s.d. [1850–1853], W. Lechler 1245 [Holotype: P02505548* ex Herb. Sch. Bip.; isotypes, BR0000005630134*, G00222157*, G00222158*, G00222159*, GH00000617*, M0029894*, M0029895*, NY00158067*, P02505546*, P02505547*, P03313093*]. On JSTOR-GP there is specimen from K from *Herbarium Hookerianum* collected by Lechler (s.n.) but with a date of 20 January 1854 and a different location. This is not believed to be type material. Chaudhri et al. (1972) gave the dates of this trip as 1850–1853.
- *Boerhavia nudicaulis* R.A. Philippi, Linnaea 29: 37. 1857. Type material. Chile. Chillán, 1 Dec 1855, *P. Germain s.n* [Holotype: SGO000001680*; isotypes: G00414903*; K000500419!. K000500419 is not listed as a type in JSTOR-GP and the date printed on the label is '1856 et 1857", but it has the correct location and was originally identified as *B. nudicaulis* so it is probably an isotype.]

According to Lanjouw and Stafleu (1957), Germain was in Chile 1854–1890 and they indicated that there may be additional specimens at BM, F, FI, P, W and Philippi types may be at BAF (no reply).

Adenocaulon himalaicum M.P. Edgeworth

Adenocaulon himalaicum M.P. Edgeworth, Transactions of the Linnean Society of London 20: 64. 1851.

Type material. Himalaya in sylvis, 7000–9000 ft, between Nagkanda and Kotgurh [India, Himachal Pradesh], 1844, *M.P. Edgeworth 15* [Holotype: K000250901!; Probable isotypes: K! K000250901, OXF* (OXF00005487, not yet available in JSTOR-GP)].

The printed label on the Holotype has a date of 1844, the OXF sheet has the handwritten date of Oct 1840, and the K isotype has no date. TL2 (Stafleu & Cowan 1976 and Lanjouw & Stafleu 1957) indicated that an additional specimen maybe at G-DC (not found, pers. comm. Loze). Only the K specimen has a printed label with a date and a "collecting number" so these may have been added by Kew. Since dates on these older specimens are often mixed up it seems likely that the second K specimen and the OXF specimen are isotypes.

Adenocaulon adhaerescens C.J. Maximowicz

Adenocaulon adhaerescens C.J. Maximowicz, Primitiae florae Amurensis: 152–154. 1859.

Type material. Russia, Amur, [7 July 1855], C.J. Maximowicz s.n.

Amur is an area in Siberia (Russia) near the border with China. Vegter (1976) indicated that Maximowicz went to Amur in 1854–1856 and again in 1859–1860 but the latter years are too late for this species description. The lectotype selected below has the date of 7 July 1855 on the label.

According to the protologue there are five syntypes all collected by Maximowicz from Amur, the Khabarovsk Region of Russia. Maximowicz worked at LE and so the material he used to describe this species should be there.

Syntype 1. Borbi (an Nadelholzrändern, 27 June fl. pr.) [Borbi, Russia: 51.24, 139.36; 14 Km SSE of Tsimmermanovka and the Amur River (Anonymous 1864)]

Syntype 2. Ussuri-Mündung [mouth of the Ussuri River], Wäldern, and especially frequent in Waldstegen, Poddale, 20 May (sterile)

Syntype 3. Chungar [Khungari River], 11 July (fl. pr.) Lectotype here designated: LE01013892* (not yet available in JSTOR-GP); Isolectotypes: H1023222*, K000768768!, S0940878*)

Syntype 4. Dshare [mouth of "Dondon" (now Anyuy) River], 18 July (flor. et frf.) **Syntype 5.** Ssargu [now Sharga Lake], 14 July 1855 (fl. et defl.)

Syntype 3 was selected as the lectotype because the location, day and month are the same as those listed in the protologue. All other specimens either had no information on the actual sheet or conflicting information. Vegter (1976) listed other herbaria that might hold type material: L, NY, PU, W.

Adenocaulon lyratum S.F. Blake

Adenocaulon lyratum S.F. Blake, Journal of the Washington Academy of Sciences 24: 435–436. 1934.

Type material. Guatemala. In open woods, Chichavac, Dept. Chimaltenango, alt. 2530 m, 20 Sept 1933, *A.F. Skutch 622*, [Holotype: US00128315!; Isotypes: CAS0000062!; GH00000616*; K000500423*; LL00374377*; MICH1108850*]

Adenocaulon nepalense M. Bittmann

Adenocaulon nepalense M. Bittmann, Candollea 45: 403-405. 1990.

Type material. Nepal, Jaljale, 3400 m, 22 Aug 1984, *M. Farille & G. Lachard* 847509 [Holotype: GOET000995*; isotype: G (as cited by Bittman 1990a; not found in the G herbarium, pers.comm. L. Gautier)]

Eriachaenium C.H. Schultz Bipontinus

Eriachaenium magellanicum C.H. Schultz Bipontinus

Eriachaenium magellanicum C.H. Schultz Bipontinus, Flora 38: 120–121. 1855.

Type material. Chile. Prov. Magallanes: Oazy Harbour, s.d. [1850–1853], *W. Lechler 1256* [Holotype: P04388712* ex Herb. Sch. Bip.; isotypes: K000500417!, K000500418!, P04388711*, S10-34491*]

Chaudhri et al. (1972) list the dates of this trip as 1850–1853.

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Appendix

TYPE collections [collector(s) and number, date collected, basionym, current species name]

Drummond T., s.n., [1925–1927], Adenocaulon bicolor WJ Hooker
Edgeworth M.P., 15, 1844, Adenocaulon himalaicum Edgeworth
Farille M. & Lachard G. 847509, 22 Aug 1984, Adenocaulon nepalense M Bittmann
Germain P., s.n., 1 Dec 1855, Boerhavia nudicaulis Phil. = Adenocaulon chilense Lessing
Lechler W., 1245, [1850–1853], Adenocaulon lechleri Sch. Bip. = Adenocaulon chilense
Lessing
Lechler W., 1256, [1850–1853], Eriachaenium magellanicum Sch. Bip.
Maximowicz C.J., s.n., s.d. [1854–1856], Adenocaulon adhaerescens Maximowicz = Adenocaulon himalaicum Edgeworth
Nuttall T., s.n., s.d. [1834], Adenocaulon integrifolium T Nuttall = Adenocaulon bicolor
WJ Hooker
Poeppig E.F., 225 and/or 755, s.d. [1827–1829], Adenocaulon chilense Lessing
Scouler J., s.n, s.d. [1824–1825], Adenocaulon bicolor JD Hooker

Skutch A.F., 622, 20 Sep 1933, Adenocaulon lyratum SF Blake

CORRESPONDENCE



Dichodon parvipetalum, a new combination for the Chinese Caryophyllaceae

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Abstract

The generic name *Dichodon* (Bartl. ex Rchb.) Rchb. was previously reinstated based on results from recent molecular phylogenetic studies. Accordingly, *Dichodon parvipetalum* (Hosok.) G. Yao, a new combination for the species *Cerastium parvipetalum* Hosok. is proposed.

Keywords

Caryophyllaceae, Cerastium, Dichodon, Dichodon parvipetalum, China

Introduction

The genus *Cerastium* L. in the broad sense consists of nearly 100 species mainly distributed in temperate and cold regions, with 23 species occurring in China (Lu and Morton 2001). Traditionally, the genus was subdivided into two subgenera: *Cerastium* (characterized by five carpels, five styles and ten capsule teeth) and *Dichodon* (Bartl. ex Rchb.) Boiss. (characterized by three carpels, three styles and six capsule teeth) (Schischkin 1970). In a recent molecular phylogenetic study (Greenberg and Donoghue 2011), the subgenus *Cerastium* was supported as the sister-group of *Moenchia* Ehrhart., a clade with four styles and eight capsule teeth, while the other subgenus *Dichodon* was sister to *Holosteum* L., which has three styles and six capsule teeth. Based on these results, Hernández-Ledesma et al. (2015) accepted the subgenus *Dichodon* at

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the generic level and reinstated it as *Dichodon* (Bartl. ex Rchb.) Rchb. in their comprehensive taxonomic study of Caryophyllales. In the *Flora of China*, two species (viz. *Cerastium cerastoides* (L.) Britton and *C. parvipetalum* Hosok.) belonging to the subgenus *Dichodon* were accepted (Lu and Morton 2001). The former species has already been transferred to *Dichodon* (*Dichodon cerastoides* (L.) Rchb.) by Reichenbach (1841), while the other species, endemic in Taiwan, has not been formally transferred to *Dichodon*. Accordingly, the new combination *Dichodon parvipetalum* is proposed below.

New combination

Dichodon parvipetalum (Hosok.) G. Yao, comb. nov.

urn:lsid:ipni.org:names:60473146-2

Basionym. *Cerastium parvipetalum* Hosok., Trans. Nat. Hist. Soc. Taiwan 22: 227. 1932. TYPE: CHINA. Taiwan, Kaohsiung, 3 Jan. 1931, *T. Hosokawa 93* (Holotype: TAI!, no.116065)

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