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A new long-tubed subspecies of *Pelargonium dipetalum* (section *Hoarea*) (Geraniaceae) from the Albertinia-Swellendam area in Western Cape Province, South Africa

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Background: Field studies confirmed that unusually long-tubed populations of *Pelargonium dipetalum* from between Swellendam and Albertinia, Western Cape Province, South Africa, are a distinct ecotype adapted to pollination by the long-proboscid fly, *Prosoeca longipennis*. The geographical and morphological isolation of these populations suggests that they are reproductively isolated from short-tubed populations, which are pollinated by bees.

Objectives: To determine and describe the floral variation in *P. dipetalum*, with a view to recognising the long-tubed populations at some taxonomic level.

Method: All available collections were measured and compared.

Results: Populations of *P. dipetalum* were segregated into a short-tubed form with hypanthium 3 mm – 24 mm long and mostly pink petals that occurs from Betty's Bay to Knysna, and a long-tubed form with the hypanthium 34 mm – 54 mm long and consistently white petals that is restricted to a small area east of Swellendam between Suurbraak and Albertinia. We described the long-tubed form as the new subspecies *P. dipetalum* subsp. *stenosiphon*.

Conclusion: The new subspecies increases our understanding of the diversity in *P. dipetalum* and represents a new taxon of conservation concern.

Introduction

The genus *Pelargonium* L'Hér. ex Aiton (Geraniaceae) includes approximately 280 species distributed amongst 16 sections (Bakker *et al.* 2004). Section *Hoarea* (Sweet) DC., with ± 85 species occurring mainly in the winter rainfall region of South Africa (Marais 2014), is one of the largest sections in the genus. It comprises deciduous geophytes with carrot-shaped or turnip-shaped tubers covered with papery bark and a highly condensed stem with the leaves in a radical tuft and often dry at flowering (Marais 1994, 2014).

The section includes seven species with only the posterior two petals present, as opposed to the full complement of five petals commonly found in the genus (Manning & Goldblatt 2012; Marais 1994). *Pelargonium dipetalum* L'Hér. is the only member of this alliance occurring along the southern coast in Western Cape Province and extends from Betty's Bay to Knysna. The hypanthium in *P. dipetalum* typically varies between 7 mm and 18 mm in length, but the species also includes a few populations east of Swellendam with exceptionally long hypanthia, 35 mm – 50 mm long. These populations were not recognised as a separate taxonomic entity by Marais (1994), who made no correlation between their distribution and their distinctly longer hypanthium. This variant was, however, identified by Manning and Goldblatt (2005) as representing a distinct morph adapted to pollination by the long-proboscid fly *Prosoeca longipennis* Loew (Nemestrinidae).

A recent study of the *P. longipennis* pollination syndrome by Newman, Manning and Anderson (2014) defined the guild (Fenster *et al.* 2004) as including mainly autumn-flowering species with unscented, white to pink flowers with long floral tubes. A population of the long-tubed morph of *P. dipetalum* included in the study confirmed that it is adapted to pollination by *P. longipennis*, whereas the short-tubed morph of the species is visited by bees.

We document the distribution and variation in hypanthium length and petal colour in *P. dipetalum* and confirm that the long-tubed populations represent a variant that is morphologically and geographically discontinuous from the typical populations. We recognise these populations as the new subspecies *P. dipetalum* subsp. *stenosiphon*.

Research method and design

Fieldwork was conducted in the Langeberg area (Western Cape Province, South Africa) and herbarium specimens from the Bolus Herbarium (BOL), Compton Herbarium (NBG) (including the South African Museum [SAM]) and the Pretoria National Herbarium (PRE) were studied (abbreviations according to Holmgren, Holmgren & Barnett 1990).

Hypanthium length and petal colour were recorded for all specimens (Appendix 1). The shortest and longest values for hypanthium length were recorded for each herbarium collection, as well as the mean hypanthium length for all short-tubed and long-tubed collections, respectively.

The distribution map was compiled using the quarter degree reference system (Leistner & Morris 1976).

Results

Populations of *P. dipetalum* are separable into two groups based on hypanthium length and petal colour. The common form corresponding with the type of the species has short-tubed flowers, with the hypanthium 3 mm – 23 mm long (9.7 mm ± 3.1 mm s.d.; *n* = 144) (Appendix 1; Figure 1), mostly pink petals (rarely white in populations near Knysna and Bredasdorp) (Figure 2) and a widespread distribution along the coast from Betty's Bay to Knysna (Figure 3). Three populations from slightly further inland between Suurbraak and Albertinia have consistently white petals and a significantly longer hypanthium 34 mm – 54 mm long (41.1 mm ± 9.0 mm s.d.; *n* = 8) (Figures 1–3; Appendix 1). There is no overlap in hypanthium length between the two variants.

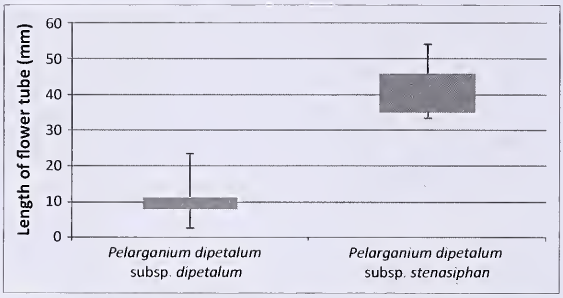
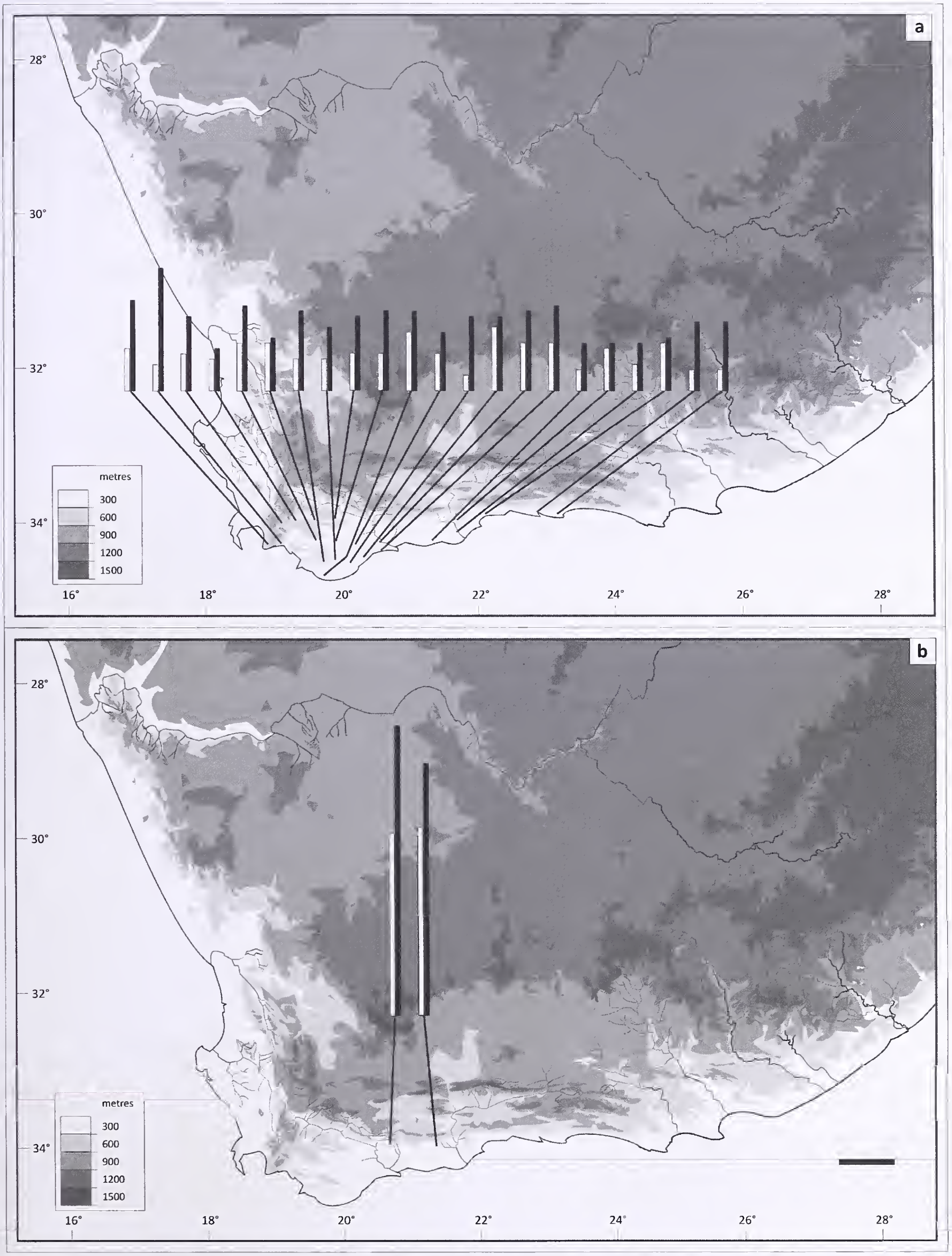


FIGURE 1: Hypanthium length in the two subspecies of *Pelargonium dipetalum*, showing the shortest and longest values plus the range in average shortest to average longest values per herbarium collection.

Source: (a) Photographed by A. Johns; (b) photographed by J. Manning

FIGURE 2: Photographs of *Pelargonium dipetalum* showing flowers of the two subspecies, (a) *Pelargonium dipetalum* subsp. *dipetalum* from Kogelberg with pink flowers and short hypanthium and (b) *Pelargonium dipetalum* subsp. *stenosiphon* from Albertinia with white flowers and long hypanthium.



Scale bar, 10 mm.

FIGURE 3: Geographical distribution of hypanthium length in *Pelargonium dipetalum*, showing the shortest (white bar) and longest (black bar) hypanthium length recorded for each quarter degree grid, with (a) depicting, *Pelargonium dipetalum* subsp. *dipetalum* and (b) depicting *Pelargonium dipetalum* subsp. *stenosiphon*.

The two variants are geographically separated and are morphologically distinct in hypanthium length and partially in petal colour, but we were unable to find any other differences between them. We accordingly treated the long-tubed populations as comprising a separate subspecies representing a distinct ecotype adapted to pollination by the long-proboscid fly *P. longipennis*.

Taxonomic treatment

Pelargonium dipetalum L'Hér., Geranologia, seu Erodii, Pelargonii, Monsoniae et Grieli historia iconibes illustrata: t. 43 (1792). *Geranium dipetalum* (L'Hér.) Poir.: 744 (1812). *Geraniospermum dipetalum* (L'Hér.) Kuntze: 95 (1891). *Seymouria l'héritieri* Sweet: 77 (1824–1826), nom. illegit. superfl. pro *P. dipetalum* L'Hér. *Pelargonium l'héritieri* (Sweet) Don: 731 (1831). Type: Illustration in L'Héritier: t. 43 (1792) (icono.!).

Hoarea erythrophylla Eckl. & Zeyh.: 60 (1835). *Pelargonium erythrophyllum* (Eckl. & Zeyh.) Steud.: 285 (1841). Type: South Africa, [Western Cape], 'Rivier Zonder Einde apud villam Knoblauch (Zwellendam)', *Ecklon & Zeyher 457* [S, lecto., designated by Marais: 245 (1994)—JSTOR image!; S, isolecto.—JSTOR image!] (JSTOR 2011a, 2011b).

Pelargonium nivenii Harv.: 271 (1860). *Geraniospermum nivenii* (Harv.) Kuntze: 95 (1891). Type: South Africa, [Western Cape], 'elevated places in Sweetmilk Valley [Soetmelksvallei]', *Niven s.n.* [S, holo.—JSTOR image!] (JSTOR 2012).

Description

Geophytic herb up to 350 mm; tuber round to elongate, sometimes with a moniliform root. *Stipules*: subulate and adnate to petioles for two thirds of their length, 12 mm – 37 mm × 1 mm – 2 mm, ciliate. *Leaves*: erect; petioles 30 mm – 200 mm long, rigid, hirsute with appressed or patent hairs; blades green or occasionally purple beneath, simple to irregularly pinnatisect to bipinnatisect, elliptic in outline, 20 mm – 120 mm × 13 mm – 30 mm, acuminate, bases cuneate, lamina hirsute above and appressed-hirsute beneath. *Inflorescence*: 30 mm – 200 mm long, scape with 2–3(5) pseudo-umbels, each with (3)4–8(12) flowers; peduncles 25 mm – 150 mm long, with glandular hairs interspersed with bristle-like hairs; bracts subulate, 3 mm – 7 mm × 1 mm – 2 mm, hirsute beneath with distally appressed hairs; pedicels *c.* 0.5 mm long. *Hypanthium*: 3 mm – 54 mm long, reddish-brown, densely covered with glandular hairs interspersed with bristle-like hairs. *Sepals*: 5, lanceolate, acute, 5.0 mm – 11.5 mm × 1.2 mm – 4.0 mm, reflexed, green to reddish-brown, indumentum as for peduncle. *Petals*: 2 in posterior position, pink to white, usually with darker-coloured nectar guides, obovate to spathulate, 12 mm – 19 mm × 3 mm – 7(–10) mm, emarginate, bases cuneate, recurved during anthesis. *Stamens*: white to pale pink, papillate; fertile stamens 5, posterior filament shortest, 6.5 mm – 11.0 mm long, lateral and anterior filaments 7.5 mm – 12.0 mm long, free filaments wine-red; staminodes 2.0 mm – 5.5 mm long; anthers dark red, 1.5 mm – 2.5 mm long, pollen orange. *Gynoecium*: pink; ovary 3 mm – 6 mm long; style 1.5 mm – 6.0 mm long, lengthening during anthesis; stigma branches 1 mm – 3 mm long, wine-red. *Fruit*: bases of mericarps 5 mm – 8 mm long, eglandular, tails 20 mm – 31 mm long. Description based on Marais (1994, 2000).

Pelargonium dipetalum subsp. *dipetalum*

Diagnosis

Petals pale to dark pink, rarely white; hypanthium 3 mm – 17(–23) mm long (Figure 2a).

Distribution

Subsp. *dipetalum* occurs from Betty's Bay eastwards to Belvedere near Knysna (Figure 3a).

Additional specimens seen

WESTERN CAPE.—**3418** (Simonstown): Kogelberg Forest Reserve above road to Oudebosch farm, (-BD), 30 Mar. 1971, *Boucher 1487* (NBG); Kogelberg State Forest, halfway between first turn and first bridge, left of road to Oudebos, (-BD), 02 Mar. 1992, *Kruger 407* (NBG, PRE); Fairy Glen, firebreak, (-BD), 12 Mar. 1970, *Boucher 1186* (NBG); Hangklip, Betty's Bay, north-east corner of plot 3009 near boundary with school plot 2759, (-BD), 04 Mar. 1999, *Forrester 1310* (PRE); Betty's Bay, (-BD), 05 Feb. 1963, *Levyns 11417* (BOL); Betty's Bay, lower mountain slopes above Anna's Hof, (-BD), 21 Feb. 1989, *Rourke 1924* (NBG). **3419** (Caledon): Central koppie, Haasvlakte, Houhoek, (-AA), 29 Jan. 1988, *Boucher & Stindt 5373* (NBG); Houhoek, Houtech terrain, (-AA), 13 Apr. 1988, *Boucher & Stindt 5395* (NBG); Houhoek, Houtech terrain, (-AA), 16 Apr. 1988, *Boucher & Stindt 5396* (NBG); Elgin, Caledon, (-AA), 24 Apr. 1943, *Compton 14523* (NBG); Houhoek, at hotel, (-AA), 04 Apr. 1892, *Guthrie 2225* (NBG); near Palmiet River, Oudeburg, (-AA), 26 Apr. 1943, *Leighton 503* (PRE); Houhoek, (-AA), 12 Apr. 1896, *Schlechter 667* (PRE); Houhoek, (-AA), 12 Apr. 1896, *Schlechter 7561* (BOL); Elgin, at the Bridge, Caledon, (-AA), 06 Mar. 1926, *Smith 2539* (PRE); Caledon, hill north of Baths, (-AB), 31 Mar. 1922, *Marloth 11085* (NBG, PRE); Kleinmond, kloof north-west of Heuningklip, (-AC), 28 Apr. 1948, *De Vos 941* (NBG); Driebosch, Kleinmond, Caledon, (-AC), 01 Mar. 1943, *Marais s.n.* (NBG); Suikerboskop east of Bot River Lagoon, (-AC), 25 Apr. 1975, *Oliver 5798* (NBG, PRE); Kleinmond, (-AC), 22 Apr. 1922, *Stokoe 1327* (BOL); Groot Hagelkraal near Pearly Beach, (-AC), 16 Mar. 1983, *Van Wyk 1154* (NBG); Happy Valley, Riviersonderend Mountains, (-BA), 12 Apr. 1941, *Compton 10665* (NBG); flats at foot of

BOX 1: Key to subspecies of *Pelargonium dipetalum*.

1A. Hypanthium 3 mm – 17(–23) mm long; petals pink, rarely white.......*P. dipetalum* subsp. *dipetalum*

1B. Hypanthium 35 mm – 54 mm long; petals white.......*P. dipetalum* subsp. *stenosiphon*

Riviersonderend Mountains near Neethlings Farm, (-BA), 29 Apr. 1950, *Wilman 978* (PRE); Riviersonderend Mountains, (-BB), Apr. to May 1950 [without day], *Lewis SAM63209* (PRE); Zonderend near Olifantsbos, (-BB), 01 Apr. 1922, *Marloth 11090* (PRE); Riviersonderend, (-BB), 30 Apr. 1950, *Middlemost 1509* (NBG); foothills of Riviersonderend Mountains, (-BB), Apr. to May 1950 [without day], *Stokoe 63208* (PRE); Sandies Glen near Sandfontein, north-east sandstone slope of Koueberg, (-BC), 18 Mar. 1977, *Hugo 908* (NBG, PRE); 4 km north-west of Napier, near Quarry Kop, (-BD), 31 May 1995, *Dreyer 525* (PRE); Skoenmakers River, ± 10 km west of Napier, (-BD), 18 Mar. 1977, *Thompson 3487* (NBG); Koks River, near entrance to farm, (-DA), 11 Mar. 1979, *Hugo 1606* (NBG); Groot Hagelkraal, Hagelkraal River area, north-east of farmstead, (-DA), 18 Apr. 1975, *Oliver 5895* (NBG); beacon 147, hills just north-west of Elim, (-DA), 29 Mar. 1971, *Oliver 3344* (NBG); Hagelkraal, poort near Hagelkraal River, (-DA), 10 Mar. 1979, *Thompson 3917* (NBG); on road from Elim to 'Die Dam', (-DA), 22 Mar. 1982, *Van Wyk 801* (NBG); flats north-west of Soetanysberg, Rietfontein Private Nature Reserve, (-DB), 25 Feb. 1994, *Beyers 224* (NBG); Bredasdorp, Rietfontein, (-DB), 13 Apr. 1978, *Esterhuysen 34910* (BOL); near Mierkraal, south-west of Bredasdorp, (-DB), 14 Mar. 1977, *Hugo 823* (NBG); 4 miles [6.44 km] west of Elim, Bredasdorp, (-DB), 18 Feb. 1951, *Maguire 845* (NBG); Vogel Valley, (-DB), 23 Apr. 1897, *Schlechter 1867* (PRE); Koks River, north-west of Buffeljagts Mountain, (-DC), 17 Mar. 1978, *Hugo 1197* (NBG). **3420** (Bredasdorp): De Hoop Nature Reserve, flats north of station, (-AD), 17 Mar. 1977, *Hugo 881* (NBG); De Hoop Farm, (-AD), 1971 [without day or month], *Van der Merwe 2015* (NBG); De Hoop, Potberg Nature Reserve, (-BC), 16 Feb. 1979, *Burgers 1810* (NBG); De Hoop, Hamerkop, (-BC), 29 Jan. 1985, *Fellingham 869* (NBG); Zoetendal's vlei, east of Soetanysberg, (-CA), 25 Mar. 1982, *Fellingham 398* (NBG), Uyshoek, 7 km due north of Arniston, (-CA), 15 Mar. 1977, *Hugo 840* (NBG, PRE); Eiland's Valley between Bredasdorp and Skipskop, (-CA), 16 Mar. 1978, *Hugo 1174* (NBG); hill near Bredasdorp, (-CA), [without date], *Leighton NBG 671/33* (BOL); De Hoop, Moerasfontein at second gate from main road, (-CA), 31 Jan. 1985, *Van Wyk 2171* (NBG); De Hoop, Buffelsfontein, along road to Ryspunt, (-CB), 18 Mar. 1985, *Van Wyk 2208* (PRE); Uitvlugt, south slopes of Bredasdorp, (-DA), 16 Mar. 1978, *Boucher 3775* (NBG). **3421** (Riversdale): Still Bay ridge north of rifle range, (-AD), 15 Feb. 1979, *Bohnen 5071* (NBG, PRE); Schoemanshoek in Albertinia, the Fisheries Road, (-BA), 14 Mar. 1978, *Boucher 3720* (NBG); Cauca se Laagte, south of Albertinia, (-BC), 20 Mar. 1975, *Oliver 5717* (NBG, PRE); Albertinia, Gouriqua/Ystervarkpunt, (-BC), 20 Jan. 1987, *Willemse 65* (NBG). **3422** (Mossel Bay): Mossel Bay, near new town extension at Golden Rendezvous Hotel, (-AA), 29 Mar. 1987, *Vlok 1855* (NBG); Knysna, Belvidere, (-BB), Feb. 1921 [without day], *Duthrie 500* (BOL, PRE, SAM). **3423** (Knysna): Knysna, (-AA), 20 Feb. 1955, *Adamson D331* (PRE); Knysna, (-AA), Mar. 1921 [without day], *Breyer 25210* (PRE); Knysna, (-AA), Feb. 1921 [without day], *Breyer 23973* (PRE); Knysna Heads, (-AA), Feb. 1922 [without day], *Fourcade 2018* (BOL).

Without precise locality: Caledon division, *Purcell 45919* (SAM).

***Pelargonium dipetalum* subsp. *stenosiphon* J.C.Manning & M.M.le Roux, subsp. nov.**

Type: SOUTH AFRICA. **Western Cape**: (3421) Riversdale: 2 km west of Dekriet siding on main road, (-AB), 10 Apr. 1979, *Bohnen 5551* (NBG, holo.).

Diagnosis

Petals white; hypanthium 35 mm – 54 mm long (Figure 2b).

Distribution

Subsp. *stenosiphon* is localised along the southern foothills of the Langeberg west of Swellendam, between Suurbraak and Albertinia (Figure 3b).

Conservation

Unlike subsp. *dipetalum*, which is relatively widespread and partially protected in nature reserves, subsp. *stenosiphon* has a much more limited range. The taxon is recorded from an area 90 km × 20 km in extent, much of which is under pressure from agricultural activity. No known populations are formally protected and the conservation status of the subspecies needs to be assessed.

Additional specimens seen

WESTERN CAPE.—**3420** (Bredasdorp): Swellendam, Zuurbraak [Suurbraak], (-BA), 01 Mar. 1930, *Thode A2301* (NBG, PRE). **4321** (Riversdale): flats west of Dekriet siding west of Albertinia, (-AB), 19 Mar. 1975, *Oliver 5692* (NBG).

Discussion

The two subspecies of *P. dipetalum* are distinguished by hypanthium length and mostly also by petal colour (Figure 1 and Figure 2). The flowers in subsp. *dipetalum* are usually pale to dark pink, but two populations, one near Bredasdorp and the other at Belvedere near Knysna, have white flowers, and the hypanthium ranges from 3 mm to 23 mm long. The petals in subsp. *dipeatlum* are always marked with dark nectar guides. In contrast, the petals in subsp. *stenosiphon* are consistently white with only faint nectar guides and the hypanthium is 35 mm – 54 mm long.

The floral differences between the two subspecies of *P. dipetalum* are associated with a shift in pollination system from bee-pollination in the typical ecotype to pollination by the long-proboscid fly *P. longipennis* in subsp. *stenosiphon*.

In an analogous situation, Becker and Albers (2010) recently described *P. alternans* subsp. *longicalcar* M.Becker & F.Albers (2010) for populations from the Outeniqua Mountains in the Little Karoo differing from the other two subspecies in having a longer hypanthium [(12–)18 mm – 36 mm long in *P. alternans* subsp. *longicalcar* versus 3 mm – 9 mm in subsp. *alternans* and subsp. *parviinflorescens* M.Becker & F.Albers (2010)]. The long-tubed subspecies in this species is also thought to be pollinated by a long-proboscid fly and has undergone evolutionary changes similar to those documented for *P. dipetalum* subsp. *stenosiphon*.

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

M.M.l.R. (South African National Biodiversity Institute) and J.C.M. (South African National Biodiversity Institute) collectively performed the research. J.C.M. conducted the fieldwork and provided input during the compilation of the manuscript; M.M.l.R. compiled the manuscript.

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Appendix 1

APPENDIX 1: Hypanthium length in *Pelargonium dipetalum* subspp. *dipetalum* and *stenosiphon*. Measurements are for the shortest and longest hypanthium represented on each herbarium collection studied.

Subspecies	Collector(s) and number	Herbarium	Hypanthium length (mm)	
			Shortest	Longest
Pelargonium dipetalum subsp. *dipetalum*	Boucher 1487	NBG	12	17
	Boucher 1186	NBG	11	11
	Forrester 1310	PRE	8	8
	Kruger 407	NBG	10	15
	Kruger 407	PRE	9	15
	Levyns 11417	BOL	13	14
	Rourke 1924	NBG	10	13
	Boucher and Stindt 5373	NBG	11	12
	Boucher and Stindt 5396	NBG	9	11
	Boucher and Stindt 5395	NBG	12	13
	Compton 14523	NBG	10	12
	Guthrie 2225	NBG	8	12
	Leighton 503	PRE	9	13
	Schlechter 667	PRE	10	14
	Schlechter 7561	BOL	7	9
	Smith 2539	PRE	8	9
	Marloth 11085	NBG	7	8
	Marloth 11085	PRE	6	7
	De Vos 941	NBG	10	23
	Marais s.n.	NBG	9	11
	Oliver 5798	NBG	6	8
	Oliver 5798	PRE	5	8
	Stokoe 1327	BOL	10	13
	Van Wyk 1154	NBG	8	13
	Compton 10665	NBG	9	10
	Wilman 978	PRE	9	10
	Lewis SAM 63209	PRE	7	10
	Marloth 11090	PRE	7	14
	Middlemost 1509	NBG	8	13
	Stokoe 63208	PRE	7	13
	Hugo 908	NBG	11	13
	Hugo 908	PRE	9	16
	Dreyer 525	PRE	7	9
	Thompson 3487	NBG	10	15
	Hugo 1606	NBG	10	15
	Oliver 5895	NBG	6	11
	Oliver 3344	NBG	8	11
	Thompson 3917	NBG	7	10
	Van Wyk 801	NBG	8	9
	Beyers 224	NBG	8	10
	Esterhuysen 34910	BOL	9	12
	Hugo 823	NBG	8	10
	Maguire 845	NBG	7	12
	Schlechter 1867	PRE	6	9
	Hugo 1197	NBG	11	15
	Hugo 881	NBG	7	9
	Van der Merwe 2015	NBG	9	11
	Burgers 1810	NBG	14	15
	Fellingham 869	NBG	9	10
	Fellingham 398	NBG	3	7
	Hugo 840	NBG	10	14
	Hugo 1174	NBG	4	5
	Hugo 840	PRE	7	9
	Leighton NBG 671/33	BOL	7	11
	Van Wyk 2171	NBG	8	9
	Van Wyk 2208	PRE	12	14
	Boucher 3775	NBG	9	16
	Bohnen 5071	PRE	4	5

Source: Herbaria names abbreviated according to Holmgren, P.K., Holmgren, N.H. & Barnett, L. (eds.), 1990, *Index herbariorum. Part 1: The herbaria of the world*, 8th edn., New York Botanical Garden, New York

NBG, Compton Herbarium; PRE, the Pretoria National Herbarium; BOL, the Bolus Herbarium; SAM, the South African Museum.

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APPENDIX 1 (Continues...): Hypanthium length in *Pelargonium dipetalum* subspp. *dipetalum* and *stenosiphon*. Measurements are for the shortest and longest hypanthium represented on each herbarium collection studied.

Subspecies	Collector(s) and number	Herbarium	Hypanthium length (mm)	
			Shortest	Longest
	Bohnen 5071	NBG	8	9
	Boucher 3720	NBG	8	9
	Oliver 5717	NBG	8	9
	Oliver 5717	PRE	8	9
	Willemse 65	NBG	5	8
	Vlok 1855	NBG	9	10
	Duthrie 500	5AM	6	9
	Duthrie 500	PRE	4	13
	Duthrie 500	BOL	7	9
	Adamson D331	PRE	8	9
	Breyer 25210	PRE	10	13
	Breyer 23973	PRE	6	9
	Fourcade 2018	BOL	4	8
	Purcell 45919	5AM	4	8
Pelargonium dipetalum subsp. *stenosiphon*	Thode A2301	NBG	34	54
	Thode A2301	PRE	34	54
	Bohnen 5551	NBG	35	36
	Oliver 5692	NBG	35	47

Source: Herbaria names abbreviated according to Holmgren, P.K., Holmgren, N.H. & Barnett, L. (eds.), 1990, *Index herbariorum. Part 1: The herbaria of the world*, 8th edn., New York Botanical Garden, New York

NBG, Compton Herbarium; PRE, the Pretoria National Herbarium; BOL, the Bolus Herbarium; SAM, the South African Museum.

Factors influencing the adaptation and distribution of *Colophospermum mopane* in southern Africa's mopane savannas – A review

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Note:
This article was republished with the correct R^2 values reflecting in Figure 3.

Colophospermum mopane is the dominant tree or shrub within mopane woodland in the subtropical areas of southern Africa's savanna ecosystems. This article provided a review on the adaptation capabilities of mopane against fire, browsing activity and environmental stresses. It further reviewed and tested the extent to which rainfall, temperature, altitude and soil types had an effect on the distribution of mopane in southern Africa. Mopane is adapted to survive moisture stresses, low nutrient environments and even disturbances caused by fire and browsing by large herbivores through its physical, physiological and chemical responses. Adaptation of mopane to various stresses enables it to dominate the low-lying areas of southern Africa's savannas. The distribution of mopane is best associated with low to moderate rainfall (R^2 = 0.38), high temperature (R^2 = 0.42), low altitudes (R^2 = 0.44) and a variety of soil types. An increase in the annual rainfall (> 800 mm) and altitude (> 800 m.a.s.l.), coupled with a reduction in the minimum temperature and acidic soil, limits the distribution of mopane. Mopane in South Africa occurs under similar environmental conditions to those in Zimbabwe and Zambia, but quite different from those in Angola, Namibia, Mozambique, Malawi and Botswana where mopane occurs.

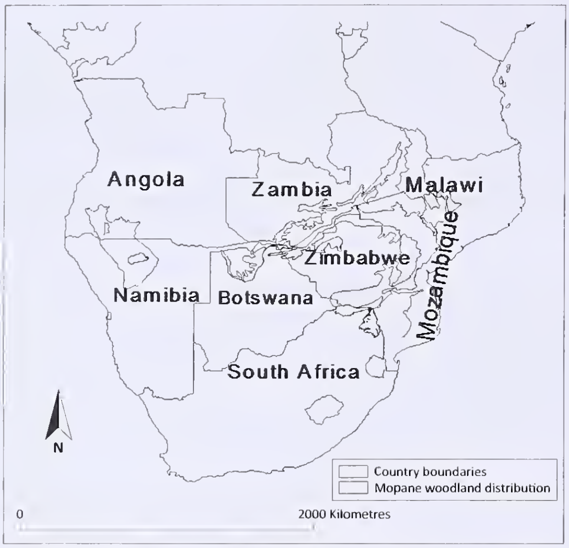
Introduction

Colophospermum mopane (Kirk ex Benth.) Kirk ex J.Léonard, commonly known as mopane, is the dominant tree or shrub within mopane woodland in the subtropical areas of southern Africa's savanna ecosystems, between latitudes 9° S and 25° S (Henning 1976; Mapaure 1994; Sebego 1999; Werger & Coetzee 1978; White 1983). Estimates show that mopane woodland accounts for about 30% – 35% of the 1.5 million km^2 of savannas in southern Africa (Mapaure 1994; White 1983), which represents more than a quarter of land area in the region. Mopane is distributed in the hot, dry, valley bottoms and adjacent plains of southern Angola and northern Namibia, across Botswana and Zimbabwe to central and southern Mozambique, and from the Luangwa valley in Zambia and central Malawi to northern South Africa (Mapaure 1994; Porter 1968; Siebert 2012; Timberlake, Chidumayo & Sawadogo 2010; Werger & Coetzee 1978; White 1983) (Figure 1). The total area covered by mopane woodland in the whole of southern Africa is 555 000 km^2 (Mapaure 1994) (Table 1).

Previous studies have demonstrated that rainfall, altitude and soil types influence the distribution of mopane in southern Africa (e.g. Burke 2006; Cole 1986; Mapaure 1994; Voorthuizen 1976; Werger & Coetzee 1978). Mopane occurs in areas receiving low to moderate annual rainfall ranging from 400 mm to 800 mm (Madams 1990; Thompson 1960; Werger & Coetzee 1978). These are normally areas at altitudes ranging from 200 m.a.s.l. to 600 m.a.s.l. (White 1983), with variable soils, but usually fine-grained, having textures ranging from sandy through loamy to clayey. The species is also known to occupy both shallow and deep soils, containing significant amounts of exchangeable sodium (Madams 1990; Thompson 1960; Werger & Coetzee 1978).

Other factors influencing the distribution of mopane include minimum temperature and dry season day length (Stevens *et al.* 2014). Mopane is commonly distributed in high temperature areas (Table 2) and minimum temperature of < 5 °C limits its distribution (Burke 2006; Cole 1986; Henning 1976; Stevens *et al.* 2014; Timberlake, Nobanda & Mapaure 1993; Werger & Coetzee 1978; White 1983; Whitecross, Archibald & Witkowski 2012), especially in its southern range (Stevens *et al.* 2014). However, although mopane is predominantly in frost free areas, the species is capable of withstanding light frost (Thompson 1960) and tall mopane trees of > 4 m in height can survive minimal frost damage (Whitecross *et al.* 2012).

Mopane is considered an important plant species to people, and wild and domestic animals in its distribution in southern Africa. Rural dwellers use it for firewood (Liengme 1983), construction of traditional structures (Makhado *et al.* 2009) and, to a lesser extent, for medicinal purposes (Madzibane & Potgieter 1999; Mashabane, Wessels & Potgieter 2001). In some parts of the region, there has been increasing use of mopane in urban areas for firewood as the cost of electricity keeps increasing. Mopane also hosts mopane worms, larvae of the moth *Imbrasia belina*, which are consumed for their nutritional value (Dreyer & Wehmeyer 1982; Voorthuizen 1976) and traded to generate income (Styles 1996). Dry mopane leaves, twigs and pods provide a valuable source of browse for wild animals such as elephants (Ben-Shahar & MacDonald 2002) and greater kudu (Hooimeijer *et al.* 2005), especially during the dry season and drought periods (Bonsma 1942; Macala, Sebolai & Majinda 1992; Mosimanyana & Kiflewahid 1988; Timberlake 1995), when the tannins have leached out. In addition, the secretion of *Arytaina mopane* nymphs, commonly known as lerp, increases the palatability of mopane leaves (Ross 1977; Van Wyk 1972), because the lerps have high sucrose content (Styles 1993). The lerps are highly sought after by baboons, monkeys, birds (Herremans-Tonnoeyr & Herremans 1995) and even humans, especially in the northern part of South Africa (Pettey 1925) and Botswana (Sekhwela 1989), because of their sweetness; they contain about 53% water-soluble sugars (Sekhwela 1989).



Source: This map is an extract from Mucina and Rutherford's (2006) data on the vegetation of South Africa, Lesotho and Swaziland (VegMap) and White's (1983) data on vegetation of Africa. For more information, please consult the reference list of the article: Makhado, R.A., Mapaure, I., Potgieter, M.J., Luus-Powell, W.J. & Saidi, A.T., 2014, 'Factors influencing the adaptation and distribution of *Colophospermum mopane* in southern Africa's mopane savannas – A review', *Botholio* 44(1), Art. #152, 9 pages. http://dx.doi.org/10.4102/abc.v44i1.152

FIGURE 1: The distribution of mopane-dominated woodlands in southern Africa.

Considering the extensive distribution of mopane in the low-lying areas of southern Africa and its importance to human livelihoods, domestic and wild animals throughout its distribution range, it becomes a research challenge when factors influencing its distribution are not easily detectable (Siebert 2012) or not even well understood (Stevens *et al.* 2014). Various sources have contributed to the understanding of mopane distribution (e.g. Cole 1986; Du Plessis 2001; Henning 1976; Madams 1990; Mapaure 1994; Thompson 1960; Timberlake 1995; Timberlake *et al.* 1993; Werger & Coetzee 1978; White 1983), but there is still a gap in identifying the underlying factors influencing mopane distribution in southern Africa (Siebert 2012; Stevens *et al.* 2014). This is creating a subsequent gap in our ability to

TABLE 1: Area covered by mopane-dominated woodland in southern Africa.

Country	Area (km²)	Proportion of country area (%)	Proportion of total mopane area (%)
Angola	112 500	9	20
Zimbabwe	101 500	26	18
Mozambique	98 000	13	18
Botswana	85 000	15	15
Namibia	77 000	9	14
Zambia	43 500	6	8
South Africa	23 000	2	4
Malawi	10 000	9	2
Total	**550 500**	**89**	**100**

Source: These data are taken from Mapaure, I., 1994, 'The distribution of *Colophospermum mopane* (Leguminosae-Caesalpinioideae) in Africa', *Kirkia* 15, 1–5

TABLE 2: Environmental factors associated with the distribution of mopane in southern Africa.

Country	Mean annual rainfall (mm)	Mean daily temperature (°C)	Altitudinal range (m.a.s.l.)	Soil types	References
Angola	100–600	16–25	100–1200	g, s, a	1, 2, 7, 9
Zimbabwe	450–700	16–30	300–950	c, so, l, g, ss, fe	1, 6, 7, 9
Mozambique	400–700	20–29	100–500	c, ls, s, bs, a	1, 2, 6, 9
Botswana	400–600	13–30	800–900	s, si, cl, c, b, h	1, 2, 6, 9
Namibia	50–600	12–31	150–1000	l, f	2, 6, 7, 8, 9, 11
Zambia	600–1000	14–30	400–1000	a, fv, sl, g, l, ss, fe, h	1, 2, 5, 6, 7, 9
South Africa	250–650	15–31	200–800	a, g, b, c, s, l	1, 3, 4, 6, 9, 10
Malawi	700–800	19–28	450–500	sc, m	1, 2, 9
Minimum	50–550	12–25	100–500	-	-
Maximum	700–1000	20–31	800–1200	-	-
Average	369–700	16–29	313–856	-	-

Sources: 1, Mapaure (1994); 2, Werger and Coetzee (1978); 3, Acocks (1953); 4, Mucina and Rutherford (2006); 5, Porter (1968); 6, Henning (1976); 7, Madams (1990); 8, Erkkilä and Siiskonen (1992); 9, Du Plessis (2001); 10, Rutherford *et al.* (2006); 11, Okitsu (2005).

For more information, please consult the reference list of the article: Makhado, R.A., Mapaure, I., Potgieter, M.J., Luus-Powell, W.J. & Saidi, A.T., 2014, 'Factors influencing the adaptation and distribution of *Colophospermum mopane* in southern Africa's mopane savannas – A review', *Botholio* 44(1), Art. #152, 9 pages. http://dx.doi.org/10.4102/abc.v44i1.152

Soil types symbols: a, alluvial; b, basaltic; bs, brown soils; c, clayey; cl, clay loamy; f, ferruginous; fe, ferrallitic; fv, fluvisol-vertisol; g, granitic; h, halomorphic; l, lithosols; ls, loamy sand; m, mopanosols; s, sandy; sc, sandy clays; sl, sandy-loamy; si, silt; so, sodic; ss, sandstone.

effectively manage mopane and the wild animals it supports. Current climatic changes provide further complexities for predicting the distribution of mopane. As a result, there is a need to adequately review existing information in an integrated manner. This will allow a better understanding of the factors influencing the distribution of mopane in southern African. This review is also critically important because it gives insight into the potential future distribution scenarios of mopane. An extensive review of a mixture of literature (i.e. journal articles, books, conference proceedings and reports), specifically dealing with adaptation of mopane and factors influencing its distribution in southern Africa was carried out. The aim of this article is therefore to provide a review of the mechanisms that enable mopane to survive disturbances caused by fire, browsing activity by large herbivores and environmental stresses in the savanna ecosystem. The article further tested the effect of environmental factors on the distribution of mopane in the southern Africa's savanna ecosystem.

Adaptation of mopane to fire and browsing activity

Mopane is widely distributed in the southern Africa's savanna (Mapaure 1994), an ecosystem which supports frequent fires (Andreae *et al.* 1994; Kennedy 2000; Scholes 1995) and large herbivores (Sankaran & Anderson 2009). Fire negatively affects the morphology of mopane (Gandiwa & Kativu 2009; Mlambo & Mapaure 2006), destroys the aerial components of mopane shrubs (Henning 1976) and causes a reduction in mopane height and stem circumference (Kennedy & Potgieter 2003).

In addition, mopane is highly browsed by large herbivores such as elephants (Ben-Shahar 1993; Ben-Shahar & MacDonald 2002; Smallie & O'Connor 2000), mainly owing to its high nutritional value (Ben-Shahar & MacDonald 2002; Bonsma 1942; Macala *et al.* 1992; Mosimanyana & Kiflewahid 1988). Elephants' preference for mopane makes it susceptible to elephant-induced damage (Lewis 1991). Elephants' feeding behaviour can transform mopane woodlands to coppiced shrubby stands. Furthermore, elephants also inhibit height recruitment of mopane by repeatedly breaking the branches, ring-barking, heavy browsing and toppling the tree (Lewis 1991; Smallie & O'Connor 2000). As a result, fire and browsing activity has a notable effect on mopane structure, which also has implications on the growth and distribution of mopane in southern Africa's savannas.

Despite the disturbances caused by fires and browsing activity by large herbivores, mopane is capable of surviving through its coppicing ability and production of chemicals for defence. Various authors have shown that mopane coppices rapidly (Luoga, Witkowski & Balkwill 2004; Mlambo & Mapaure 2006; Mushove 1992; Mushove & Makoni 1993; Tietema 1989) after it has been disturbed by fire and browsing animals. In addition, mopane wood contains crystals of calcium oxalate, which contribute to high wood density (Prior & Cutler 1992) and also enhance resistance of the wood to fire (Centro Informatico Cientifico de Andalucia [CICA] 1996). These crystals effect the burning properties of the wood through producing considerable amounts of carbon dioxide, which retards the fire flame (CICA 1996). During the growing season, mopane also produces a high concentration of secondary metabolites, such as tannins and phenols, in order to deter herbivores from browsing it (Kohi *et al.* 2010; Wessels, Van der Waal & De Boer 2007), regardless of its high nutritional value. Therefore, the ability of mopane to coppice after disturbances and produce chemical defence enables it to survive disturbances caused by fire and browsing animals.

Adaptation of mopane to environmental stresses

It is well documented that mopane has the ability to survive low to moderate rainfall (Henning 1976; Timberlake 1995), water stresses (Choinski & Tuohy 1991; Mantlana 2002) and high temperatures (Dye & Walker 1980; Henning 1976), but *how* the species is able to survive such 'harsh' environmental conditions in southern Africa has not been adequately reviewed. It is the physical characteristics (e.g. Henning 1976; Madams 1990) and physiological mechanisms (e.g. Choinski & Tuohy 1991; Dye & Walker 1980; Henning 1976; Johnson *et al.* 1996; Mantlana 2002), which enable mopane to tolerate water stress and high temperature conditions. It is the response of mopane roots and leaves to changes in the surrounding environment that enables it to survive these 'harsh' environmental conditions and dominate most low-lying parts of southern Africa's savanna. The physical and physiological abilities of mopane are therefore discussed in this article in order to better explain the mechanisms that enable the species to survive in hot, dry, low-lying areas of southern Africa.

Root-related adaptations

Mopane is essentially a shallow-rooted species (Henning 1976; Smit & Rethman 1998) and has high root biomass (Smit & Rethman 1998). It is considered a shallow-rooted species because its roots are mainly found at a depth of 20 cm – 120 cm (Mantlana 2002; Smit & Rethman 1998; Thompson 1960), but can also reach 2 m in deep soils (Mantlana 2002; Sebego 1999; Timberlake & Calvert 1993). Mantlana (2002) indicated that the total root density for short and tall mopane was highest in the first 20 cm of the soil profile and then declined with increase in soil depth. The combination of a shallow rooting system and high root biomass places mopane in a competitive advantage in areas where conditions lead to the development of a zone of maximum water retention and nitrogen near the surface (Dye & Walker 1980; Henning 1976; Mlambo, Nyathi & Mapaure 2005; Smit & Rethman 1998). The high, fine root densities of mopane, especially at a depth of 20 cm – 120 cm (Mantlana 2002; Smit & Rethman 1998; Thompson 1960), are important as they facilitate quick water and nutrient acquisition and transport (Madams 1990; Mantlana 2002).

Another advantage is that the B horizon under mopane sodic soils is relatively impermeable (Dye & Walker 1980), which provides more moisture retention to the A and O Horizons where most of mopane roots are found. The relatively impermeable B horizon further restricts moisture from filtrating down to the C horizon. As indicated by Dye and Walker (1980), these characteristics enable shallow-rooted species such as mopane to have a competitive advantage for moisture uptake over deep-rooted species. It is believed that the shallow rooting system of mopane, complemented by its high root biomass, enables it to quickly absorb and store the available moisture and nutrients near the soil surface, enabling it to survive the 'harsh' environmental conditions of southern Africa's savanna.

The roots play a further critical role in the survival of mopane. Mopane coppices easily (Mushove 1992; Mushove & Makoni 1993; Tietema 1989; Tietema, Kgathi & Merkesdal 1988), mainly because its roots have the ability to produce root suckers, which enables the shoots to grow faster than newly established seedlings (Luoga *et al.* 2004). As indicated by Mantlana (2002), the ability of mopane roots to coppice confers a degree of resilience to natural and anthropogenic disturbance, which is critical in ensuring its survival.

Cell sap-related adaptations

Stressed mopane shows a marked increase in relative nitrogen content, which suggests that the resistance of mopane to severe soil moisture stress is partly caused by the build-up of soluble nitrogenous compounds within the cell sap. In addition, the uptake of magnesium also plays a direct role in the maintenance of water use efficiency of mopane by catalysing the metabolic production of organic solutes, thereby increasing the osmotic pressure of the cell sap and thus enhancing the ability of mopane to withstand moisture stresses (Henning 1976).

Leaf-related adaptations

Mopane is physiologically adapted to dry (moisture-stressed) environmental conditions (e.g. Choinski & Tuohy 1991; Dye & Walker 1980; Prior 1991). It is adapted through restricting transpiration, a mechanism that enables the species to maintain high water potential (Henning 1976). This is largely through folding the leaves, stomatal responses and osmotic adjustment, which are considered critical mechanisms in enabling mopane to survive water-stressed and high temperature conditions of southern Africa.

Leaf responses

The mopane leaf has two triangular leaflets shaped like wings of a butterfly. The leaves are leathery and resinous (Henning 1976). The leathery membrane on the leaf acts as a buffer layer to avoid direct heat from the sun and also reduces the rate of water loss through evapotranspiration. Mopane also has a tendency to fold its leaflets together, especially during the heat of the day (Madams 1990; Timberlake 1995). When the leaflets are folded together, especially when the leaf temperature exceeds 30 °C, it reduces direct heat from the sun. This means that the few exposed stomata will close, which also assists in reducing the loss of water through evapotranspiration. When the stomata are closed, the rate of photosynthesis is reduced, confirming the findings by Prior (1991), who indicated that photosynthesis by mopane leaves is lower during the heat of the day than during the night or cool days when the temperature is relatively low. In addition, mopane is a deciduous species and sheds its leaves during the dry season, mainly from August to October. The ability of mopane to lose its leaves enables it to conserve water that could have been lost during evapotranspiration.

Stomatal responses

Stomata are randomly distributed on the adaxial (top) and abaxial (bottom) surface on mopane leaves, occupying mainly the minor veins (Potgieter & Wessels 1998). However, mopane has fewer stomata on the exposed adaxial leaf surface compared with most other species (Prior 1991), which implies that the stomata are mainly distributed on the abaxial surface. The few exposed stomata on the adaxial surface of mopane leaves therefore limit the number of openings on the leaf; hence less moisture is lost through the leaves. It has also been shown that mopane stomatal conductance declines almost linearly at light saturation from March to August, at 585 mmol $m^{-2}s^{-1}$ – 172 mmol $m^{-2}s^{-1}$, respectively (Mantlana 2002). The decline in mopane stomatal conductance occurs when the soil moisture is low, especially during dry seasons and drought conditions. This mechanism enables mopane to conserve water during hot, dry conditions. Mantlana (2002) suggested that the reduction in stomatal conductance observed when soil water deficit increased may be explained by the reduction in predawn leaf water potential. However, this article states that leaf temperature needs to be taken into account because it also has an influence on mopane stomatal conductance. Nevertheless, the ability of mopane to close the stomata during high temperature and water-stress periods enables it to reduce the loss of moisture and nutrients, which is critical in ensuring its future survival under the hot, dry conditions of southern Africa.

Osmotic adjustment

The ability of mopane to grow and tolerate water-stressed conditions is also through its osmotic adjustment (Henning 1976; Timberlake 1995). Osmotic adjustment processes lower cell osmotic potential, thereby enabling intercellular water to flow towards the inside of cells. This process is an important mechanism in maintaining cell turgor pressure under reduced soil water potential and thus enables the plant to tolerate drought or water-limiting conditions (Chen & Jianga 2010; Hsiao *et al.* 1976).

As a result of the osmotic adjustment, mopane has the ability to germinate and establish root growth at lower water potentials than otherwise would be possible. The seeds of mopane can germinate and withstand water stress from -0.2 MPa to -0.51 MPa without wilting (Choinski & Tuohy 1991; Henning 1976; Johnson *et al.* 1996). Although the predawn xylem pressure potential analysis for mopane suggests a high water stress in the dry season (February *et al.* 2007), the species is able to survive water-stress conditions because of its ability to use water efficiently (Mantlana 2002), which is probably the result of its osmotic adjustment. By using a combination of physical and physiological adaptations, mainly involving roots and leaves, mopane is able to tolerate hot, dry conditions mainly found in low-lying areas of southern Africa.

All these adaptation mechanisms enable mopane to use the available limited moisture and nutrients efficiently in order to survive semi-arid to arid conditions of southern Africa. This article has further reviewed and tested the effect of environmental factors on the distribution of mopane in southern Africa. The variables used include rainfall, temperature, altitude, and soil types.

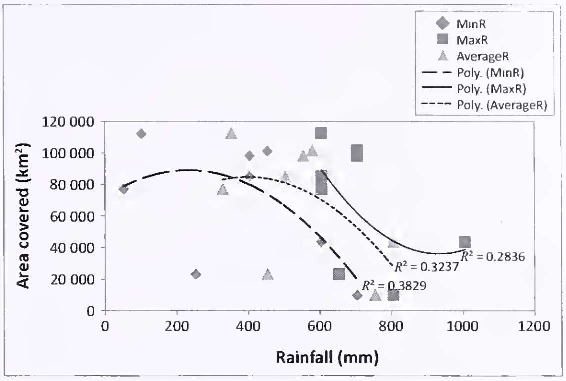
Environmental drivers and factors influencing mopane distribution

Various authors have shown that the distribution of mopane in southern Africa is associated with climatic and edaphic factors (e.g. Madams 1990; Mapaure 1994; O'Connor 1992; Werger & Coetzee 1978). Its distribution is principally influenced by moisture availability expressed through rainfall, temperature, altitude and soil texture (Bennett 1985; Henning 1976; Mapaure 1994; Stevens *et al.* 2014; Timberlake 1995; Werger & Coetzee 1978). It should be noted that rainfall and temperature co-vary with altitude; however, Stevens *et al.* (2014) indicated that there is little evidence of which factors, or combinations thereof, determine the distribution limit of this species. This article therefore reviews and discusses the extent to which rainfall, temperature, altitude and soil types influence the distribution of mopane in southern Africa.

The data used were derived from various sources (Table 1 and Table 2). The areas covered by mopane in southern Africa (Table 1) were plotted against minimum, average and maximum rainfall, temperature and altitude using a polynomial regression analysis (Figures 2–4). The rationale for using polynomial regression was that all functions (linear and non-linear) were showing weak relationships and this was worse when fitting a linear function. However, a polynomial function gave a better fit compared to linear function, which is the reason it was used here.

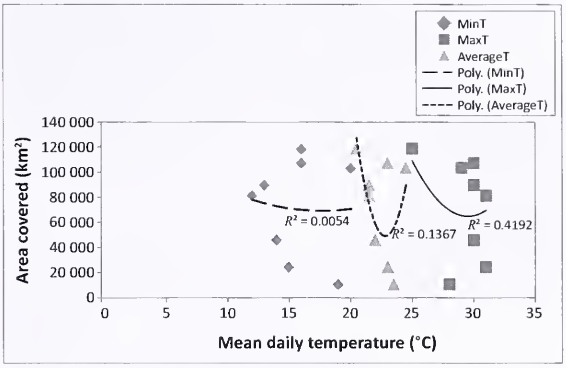
Rainfall

Mopane is distributed along a variable rainfall gradient, ranging from an annual average of 50 mm in Namibia to 1000 mm in Zambia (Table 2). However, areas receiving low to moderate rainfall, especially between 400 mm and 800 mm per annum, better correlate with the distribution of mopane in southern Africa (Madams 1990; Mapaure 1994; Werger & Coetzee 1978). The above finding is closer to the average of 369 mm – 700 mm per annum as estimated in this article (Table 2). It includes all countries within its distribution, with the exclusion of Zambia where rainfall can reach 1000 mm per annum. However, it should be noted that areas receiving 250 mm – 450 mm of rainfall per annum are considered as the most favourable environmental niche for the growth and distribution of mopane (Siebert 2012; Thompson 1960).



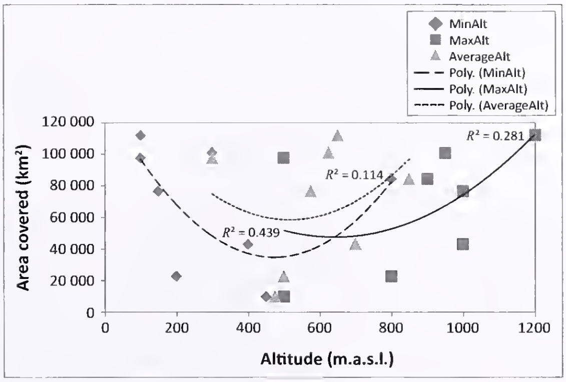
Source: Authors' own creation
Note: The dotted and solid lines represent the fitted polynomial regression curve at 95% confidence interval.
R, rainfall; min; minimum; max, maximum; poly, polynomial regression.

FIGURE 2: Effect of rainfall on the distribution of mopane in southern Africa.



Source: Authors' own creation
Note: The dotted and solid lines represent the fitted polynomial regression curve at 95% confidence interval.
T, temperature; min; minimum; max, maximum; poly, polynomial regression.

FIGURE 3: Effect of temperature on the distribution of mopane in southern Africa.



Source: Authors' own creation
Note: The dotted and solid lines represent the fitted polynomial regression curve at 95% confidence interval.
Alt, altitude; min; minimum; max, maximum; poly, polynomial regression.

FIGURE 4: Effect of altitude on the distribution of mopane in southern Africa.

The review showed that low rainfall positively correlates with the distribution of mopane in southern Africa, but the relationship becomes weak when the annual rainfall exceeds 600 mm per annum (Figure 2). This corroborates well with the findings by Porter (1968) and Henning (1976), who both indicated that an increase in rainfall to > 800 mm per annum becomes the limiting factor to mopane distribution. As also indicated by Thompson (1960), the limitation of mopane from higher rainfall zones is probably the result of competition with other species, which are more suited to those wetter conditions, low temperature, acidic soil conditions and high frequency of disturbances such as fires.

However, our analysis indicated that the relationship between rainfall and mopane distribution was higher at minimum or low annual rainfall ($R^2 = 0.38$), slightly declined at average rainfall ($R^2 = 0.32$) and then significantly declined at maximum or higher rainfall ($R^2 = 0.28$). Although this relationship is positive, it clearly gives a less than 40% confidence (Figure 2), which concurs with Stevens *et al.* (2014) that rainfall alone cannot be considered as the major factor determining the distribution of mopane. It is further indicated that the probability of mopane presence drops to < 50% when precipitation exceeds 380 mm in the wettest quarter (Stevens *et al.* 2014), which confirms that the species favours low rainfall areas (Figure 2). The possibilities of rainfall decline as a result of climate change means that it will further favour the distribution of mopane in areas such as Zambia, which is currently considered a high rainfall area.

Temperature

Mopane is distributed in hot and dry environments, where temperatures can exceed 35 °C (Dye & Walker 1980; Mucina & Rutherford 2006; Porter 1968). Low winter temperature and frost are important limiting factors for mopane distribution, especially along its southernmost boundary (Cole 1986; Henning 1976; Siebert 2012; Stevens *et al.* 2014; Werger & Coetzee 1978; White 1983). The mean daily temperature regime within its distribution in southern Africa ranges from 12 °C to 31°C (Table 2), averaging between 16 °C and 29 °C, as also found by Du Plessis (2001). However, its distribution is limited in areas where the average minimum winter temperature is below 5 °C (Cole 1986; Henning 1976; Rutherford *et al.* 2006; Stevens *et al.* 2014; Voorthuizen 1976; Werger & Coetzee 1978; White 1983), which confirms that the species is adapted to high temperature areas.

The review revealed that the distribution of mopane is best associated with an average daily maximum temperature of 30 °C ($R^2 = 0.42$) (Figure 3), but that relationship declines when the mean daily maximum temperature drops (Figure 3). Although the relationship between mean daily temperature and mopane distribution is positive, it clearly gives a less than 43.0% confidence (Figure 3). Stevens *et al.* (2014) also found that minimum temperature in the coldest month was the strongest determinant for mopane distribution, accounting for 42.2% of the modelled distribution. However, these results do not give a degree of confidence of at least > 50.0% to better explain an important factor associated with the distribution of mopane. This therefore means that temperature alone cannot be considered as the most important factor determining the distribution of mopane in southern Africa. However, it is important to take into account that the probability of mopane presence drops below 50.0% at minimum temperatures less than 5 °C in the coldest month of July. Therefore, minimum temperature is predicted to limit the distribution of mopane from entering the cold interior of the southernmost boundary of southern Africa (Stevens *et al.* 2014). The limitation of mopane at low temperature zones is because of occasional events of frost (Stevens *et al.* 2014; Whitecross *et al.* 2012), which mainly destroys trees and shrubs less than 4 m in height (Whitecross *et al.* 2012). However, an increase in temperature will further facilitate the distribution of mopane in areas currently considered as cold, especially in areas west and slightly south of its current distribution range (Stevens *et al.* 2014).

Altitude

Sebego (1999) indicated that topographic location could be one of the important factors determining the distribution of mopane. Siebert (2012) found that the occurrence of mopane is associated with low-lying, flat and undulating areas. The distribution of mopane is normally along the flood plains and valley bottoms of large rivers such as the Cunene, Chobe, Limpopo, Luangwa, Okavango, Shire and Zambezi (Cole 1986; Mapaure 1994; Werger & Coetzee 1978). However, this article confirms that mopane can be found at variable altitudes ranging from 100 m.a.s.l. to 1200 m.a.s.l. (Table 2), but attaining optimal distribution and growth at altitudes ranging from 313 m.a.s.l. to 856 m.a.s.l. on average (Table 2), which is closer to the 200 m.a.s.l. – 600 m.a.s.l. and 400 m.a.s.l. – 700 m.a.s.l. average as indicated by White (1983) and Mapaure (1994), respectively. Porter (1968) further indicated that mopane rarely occurs at altitudes > 900 m.a.s.l., but this article has shown that it can be occasionally found at > 900 m.a.s.l. in countries such as Angola, Namibia and Zambia (Table 2). These are normally areas where unfavourable soil conditions prevent the growth of other species (Henning 1976), thus favouring the distribution of mopane.

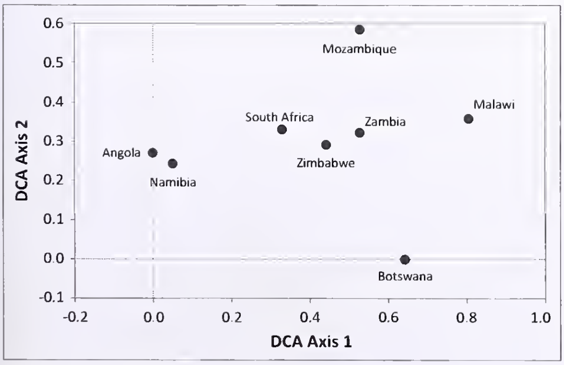
The relationship between altitude and mopane distribution is positive; although, that relationship gives a < 45% confidence (Figure 4). This also means that altitude alone cannot be considered as the important factor determining the distribution of mopane in southern Africa. However, the distribution of mopane correlates well at low altitude ($R^2 = 0.44$), but that relationship declines at higher altitudes ($R^2 = 0.28$) (Figure 4). This finding corroborates the findings from various authors who also indicated that the distribution of mopane is associated with low-lying, flat and undulating areas (e.g. Werger & Coetzee 1978; Cole 1986; Mapaure 1994; Siebert 2012). This implies, as also indicated by Henning (1976), that limited distribution of mopane at higher altitudes might be the result of combined influences of increased precipitation, lower temperatures, acidic soils and disturbances such as fires.

Soil type

According to Madams (1990), soil type also correlates well with the distribution of mopane. Mopane is capable of surviving on a variety of soil types (Henning 1976; Madams 1990). It grows in arid areas on relatively fertile, fine-grained soil, sandy-loamy soil to clayey soil (Henning 1976; Madams 1990; Timberlake 1995; Werger & Coetzee 1978) (Table 2). Mopane is most frequently associated with shallow soils (Henning 1976) and normally found in alluvium and colluvium soils (Timberlake 1995). It is sometimes found in deep soil (Mapaure 1994; Werger & Coetzee 1978), but the calcrete layer near the surface hinders mopane root penetration into the deep soil.

The soils in areas where mopane occurs tend to have high exchangeable sodium content (Dye & Walker 1980; Werger & Coetzee 1978), which inevitably results in reduced permeability and increased susceptibility to soil erosion (Scholes 1997). Mopane mainly survives on alkaline soils (Werger & Coetzee 1978) and is less common on acidic soils (Henning 1976). White (1983) further indicated that mopane does not occur on true saline soils in which water-soluble salts exceed 0.2% – 0.3%. As a result, mopane is thus considered as an indicator species of alkaline soil (Werger & Coetzee 1978).

Soil having low nitrogen (< 0.2% at 0 cm – 10 cm), phosphorus (< 1.5 ppm), low moisture (15.0%) and exchangeable magnesium favours the growth and performance of mopane, but an increase in soil sodium and potassium levels results in a decline in the growth yield, which is probably because of increased soil osmotic suction, whilst increasing magnesium seems to improve soil moisture uptake (Henning 1976). Therefore, mopane exhibits a shrub structure on shallow sodium-rich soils or clay soils derived from basalt (Mapaure 1994; Mlambo 2006). These are areas with limited soil depth and are normally occupied by 'bonsai' shrubby mopane which grow up to 1.5 m in height. The 'cathedral' mopane grow quite tall on deep nutrient-rich alluvial soils (Mapaure 1994; Timberlake 1995): up to 6 m in height on heavy impervious soils and up to 25 m in areas having sandy-loamy and alkaline soils (Werger & Coetzee 1978). It is also important to note that the distribution of mopane is limited in the acrisolic soils, possibly because acrisols derived from acid igneous and metamorphic rocks, limit the growth of mopane, but support the growth of other species such as *Acacia*, *Boscia*, *Grewia*, *Combretum* and *Terminalia* (Madams 1990).



Source: Authors' own creation
DCA, detrended correspondence analysis.

FIGURE 5: Ordination of the drivers of mopane distribution in different countries in southern Africa.

Ordination of mopane distribution

An ordination diagram illustrates the environmental factors included in Table 2 that are suggested to influence the distribution of mopane in different countries in southern Africa (Figure 5). The ordination graph shows that mopane is distributed in variable environmental conditions in different countries, but there are some similarities. For instance, mopane in Namibia occurs under similar environmental conditions to those in Angola, but quite different from those in Mozambique, Malawi and Botswana (Figure 5). In addition, mopane in South Africa occurs under similar environmental conditions to those in Zimbabwe and Zambia, but quite different from those in Angola, Namibia, Mozambique, Malawi and Botswana (Figure 5). However, mopane demonstrates a relatively wide tolerance range for the various environmental factors under which it occurs within its distribution range.

Conclusion

Colophospermum mopane is distributed along variable local climatic, topographical and edaphic factors in the low-lying areas of southern Africa. It mainly occupies areas receiving low to moderate rainfall, at low lying altitudes, with high temperature and variable soil types. An increase of annual rainfall (> 800 mm), altitude (> 800 m.a.s.l.), acidic soil and a decline in minimum winter temperature (< 5 °C) limits the distribution of mopane. Limited distribution of mopane in areas receiving high rainfall, low temperatures and at higher altitudes is probably a result of the combined effects of freeze events, competitive interactions with other species and disturbances such as fires. An increase in temperature has the potential to drive mopane from its current distribution in high temperature areas to colder zones at its southernmost boundaries, whilst a reduction in annual rainfall could drive mopane from its current distribution in low to moderate rainfall areas to high rainfall zones. However, this article demonstrated that the distribution of mopane in southern Africa is not fundamentally determined by climatic factors, but possibly by edaphic factors (soil type and nutrients), competitive interaction with other species and disturbances such as fires and browsing activity by large herbivores.

It is further concluded that the physical, chemical and physiological responses of mopane enable it to survive various disturbances and 'harsh' environmental conditions in southern Africa's savanna ecosystem. This means that a better understanding of the adaptation mechanisms and distribution of mopane is critical and can be used to explain the distribution and survival of the species in these 'harsh' conditions in southern Africa. This understanding can also be used to further identify the ecology of the many mammalian and invertebrate herbivores that are found within the mopane ecosystem. Such information is essential for holistic management of mopane woodland and shrublands in southern Africa.

However, because of the complexity associated with identifying factors which associate best with the distribution of mopane in southern Africa, we recommend that such complexity be addressed through the development of an integrated model. Such a model needs to include climatic factors (e.g. rainfall and temperature), topographical factors (e.g. altitude and slope), edaphic factors (e.g. soil types and soil nutrients) and disturbances (e.g. fires, herbivory and competition). Once developed, such a model can significantly improve the precision of predicting the distribution of not just mopane, but also other vegetation formations and associated wild animals in the savannas.

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

R.A.M. (University of Limpopo) was responsible for reviewing the literature and writing of the article. I.M. (University of Namibia), M.J.P. (University of Limpopo), W.J.L-P. (University of Limpopo) and A.T.S. (National Research Foundation) were responsible for providing technical input in the article and supervision.

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Moraea orthrosantha (Iridaceae: Irideae), a new species from Namaqualand, South Africa

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Background: Recent fieldwork in Namaqualand, Northern Cape Province, South Africa, indicated the existence of an undescribed member of *Moraea* subgenus (subg.) *Umbellatae* Goldblatt & J.C.Manning, a small, early branching clade of the genus.

Objectives: To describe the new species of *Moraea* subg. *Umbellatae.*

Method: Recent collections were compared with existing material and published literature.

Results: *Moraea orthrosantha* is described as a new species, differing from *Moraea margaretae* in the well-developed nodes between the cauline leaves. Two earlier collections of the species were misidentified as *M. margaretae.*

Conclusion: The new species increases our understanding of the diversity of *Moraea* in southern Africa and assists in conservation assessments of both *M. margaretae* and *M. orthrosantha.*

Introduction

Fieldwork in Namaqualand, Northern Cape Province, South Africa, in late spring of 2012 and 2013 yielded the discovery of a population of a yellow-flowered *Moraea*, representing an undescribed member of subgenus (subg.) *Umbellatae* Goldblatt & J.C.Manning, an early branching clade of the genus currently comprising nine species (Goldblatt & Manning 2013; Goldblatt, Manning & Schnitzler 2013). The new species, described here as *Moraea orthrosantha*, has a well-developed and multi-branched aerial stem with a solitary leaf at each node, conventional *Moraea*-type flowers with larger outer tepals and well-developed, petaloid style branches with prominent crests. These features are plesiomorphic in the genus (Goldblatt *et al.* 2013), suggesting that *M. orthorosantha* is unspecialised in subg. *Umbellatae*. The largely sub-Saharan genus *Moraea* now comprises some 226 species (Goldblatt & Manning 2013), most of them restricted to the southern African winter rainfall region. Subgenus *Umbellatae* now includes 10 species, all endemic to western South Africa and extending from the Richtersveld of Northern Cape Province to the Cape Peninsula and Caledon District in Western Cape Province. We include a key to the species of subg. *Umbellatae*.

Research method and design

We examined all relevant collections at Bolus Herbarium, University of Cape Town (BOL); Compton Herbarium, South African National Biodiversity Institute, Cape Town (NBG), National Herbarium, South African National Biodiversity Institute, Pretoria (PRE) and South African Museum Herbarium, South African National Biodivoersity Institute, Cape Town (SAM), the primary southern African herbaria (acronyms after Holmgren, Holmgren & Barnett 1990). Plants were examined in the field for 3 h and 12 specimens were pressed as type material for distribution to herbaria (as cited below). Type material was collected under permit number 010/2012 from the Northern Cape Department of Environment and Nature Conservation. Additional specimens are cited following the Degree Reference System (Leistner & Morris 1976).

Taxonomic treatment

Moraea orthrosantha Goldblatt & J.C.Manning, sp. nov.

Type: SOUTH AFRICA. **Northern Cape**: 3017 (Hondeklipbaai):15.5 km N of Garies, sandy slopes at ± 645 m, 30°27′ S 17°37′ E (–BD), 10 Oct. 2013, *Goldblatt & Porter 13990* (NBG, holo.; K, MO, PRE, iso.).

Description

Plants up to 350 mm high. *Corm*: 8 mm – 11 mm diameter; tunics brown, ± woody, inner layers entire, outer splitting from base. *Stem*: with three or four (five) internodes, with one or

Source: Artist – John Manning
Scale bar: (a) 10 mm; (b) 2 mm.

FIGURE 1: Diagrammatic representation of *Moraea orthrosantha* holotype depicting, (a) the flowering plant and (b) stamens and style.

two branches at each node; branches slightly flexed above sheath of subtending leaf. *Leaves*: three to five, lowermost longest, inserted 10 mm – 20 mm above ground, linear, channeled, ± straight or loosely twisted, up to 450 mm long, upper leaves progressively shorter, none entirely sheathing. *Rhipidial spathes*: inner 35 mm – 40 mm long, ± truncate, apex brown, somewhat lacerated; outer half to two-thirds as long, with acute, brown apex. *Flowers*: buff-yellow, lightly brown-veined, outer tepal limbs with deep yellow nectar guides at bases edged brown, darkly veined abaxially, spreading slightly below horizontal, inner tepals with reddish-brown spot at bases of limbs, similarly spreading; outer tepals oblanceolate, 30 mm – 32 mm long, limbs 20 mm – 22 mm × 10 mm – 12 mm, claws ± 10 mm long; inner tepals oblanceolate, ± 22 mm × 5 mm – 6 mm. *Stamens*: with filaments 8 mm – 9 mm long, united in lower 5 mm – 6 mm, diverging distally; anthers dark purple, 3.5 mm – 5.0 mm long; pollen red. *Ovary*: exserted, oblong-elliptic, 5 mm – 6 mm long; style branches ± 10 mm long, crests 10 mm – 14 mm long, erect, narrowly wedge-shaped. *Capsules*: narrowly obovoid, 9 mm – 11 mm long. *Seeds*: softly angular, ± 1 mm long, with rugulo-reticulate surface, light yellow-brown. *Flowering time*: late September to late October; flowers opening ± 07:00 and collapsing ± 12:00 (Figure 1).

Distribution and ecology

Moraea orthrosantha is known only from a small area north of Garies in Northern Cape Province, South Africa, in the higher country south of Garagams (Figure 2). Plants appear to be restricted to locally wetter sites; in trampled or drier situations they are much smaller in size. The soil in which they grow is the typical granitic gravel of Namaqualand and plants sometimes occur in rocky ground. We did not make an accurate count of the number of plants at the site but we located over 40 individuals, including some immature and not of flowering age.

Etymology

As the specific epithet suggests, flowers open soon after sunrise and collapse at about noon. The epithet derives from the Greek *orthros* [morning] and *anthos* [flower]. There are few other examples of this flowering phenology in the genus and none known in subg. *Umbellatae*.

Conservation status

The habitat is relatively undisturbed, although it is located less than 20 m from the main road from Cape Town to Springbok. Future road expansion will severely impact the

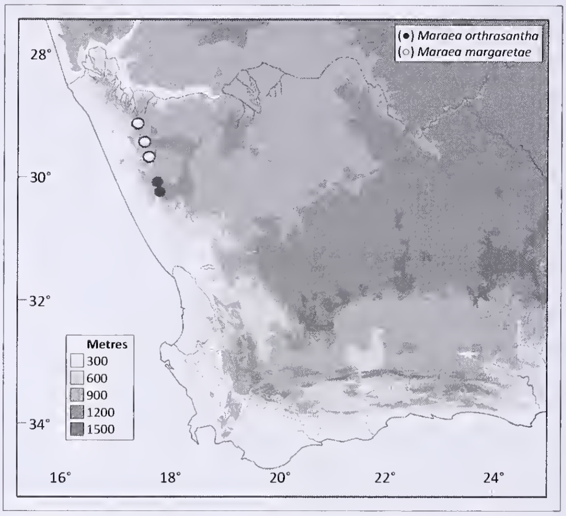

FIGURE 2: Distribution of *Moraea orthrosantha* and the closely related *Moraea margaretae*.

BOX 1: Key to the species of *Moraea* subgenus *Umbellatae*.

1A. Plants with stem subterranean; leaves and rhipidia clustered at ground level:
    2A. Tepals unequal, outer larger and with nectar guides at limb bases; style branches well developed with prominent crests .... *M. longiflora*
    2B. Tepals subequal, outer ± as long as inner and both with nectar guides at limb bases; style branches divided almost to base into paired filiform arms without crests .... *M. singularis*
1B. Plants with stem aerial; either lowermost leaf inserted at ground level or all leaves and branches clustered at ground level but then rhipidia stalked:
    3A. Foliage leaves all clustered at ground level; branches (when present) produced at ground level .... *M. margaretae*
    3B. Plants wither with lowermost leaf inserted at or close to ground level or all leaves inserted at stem apex well above ground; branches (when present) arising well above ground:
        4A. Lowermost leaf (of two or more) inserted at or close to ground level:
            5A. Branches crowded at stem apex; tepals free .... *M. linderi*
            5B. Branches borne along stem, not crowded above:
                6A. Tepals free to base; inner tepals present .... *M. orthrosantha*
                6B. Tepals united in short tube; inner tepals lacking .... *M. cooperi*
        4B. All leaves clustered at stem apex well above ground:
            7A. Style branches filiform and extended between stamens, without .... *M. nana*
            7B. Style branches flattened, appressed to opposed anthers, with or without prominent crests:
                8A. Style branches bearing prominent crests 10 mm – 12 mm long; filaments united in column 8 mm – 10 mm long .... *M. intermedia*
                8B. Style branches without crests; filaments in column 5 mm – 7 mm long, united or free distally:
                    9A. Plants 150 mm – 450 mm high; outer tepals 19 mm – 27 mm × 9 mm – 12 mm; inner rhipidial spathes 30 mm – 40 mm long .... *M. umbellata*
                    9B. Plants 90 mm – 150 mm high; outer tepals 15 mm – 24 mm × 6 mm – 10 mm; inner rhipidial spathes 20 mm – 35 mm long .... *M. maximiliani*

known habitat. Summer grazing by stock should not affect the population as the plants will be dormant. The possible occurrence of additional populations in the area requires further investigation.

Diagnosis

In its vegetative and floral morphologically, *M. orthrosantha* is perhaps the least specialised member of subg. *Umbellatae*. The species is distinguished by its vegetative habit: mature plants have stems up to 350 mm high with several leaves, one at each of up to four or five aerial nodes and one or two branches per node. The flowers are typical of the genus, having free tepals, well-developed petaloid style branches with erect crests and prominent nectar guides at the bases of the outer tepal limbs. Somewhat unusually, the bases of the inner tepal limbs are marked with a small, dark reddish-brown spot. The buff or dull yellow colour of the perianth is typical of the subgenus. In contrast, most other species of the subgenus have branches crowded at the first aerial node, this either approximately at ground level (*Moraea margaretae* Goldblatt) or well above ground level (*Moraea linderi* Goldblatt and *Moraea intermedia* Goldblatt & J.C.Manning). All three of these species have well-developed style branches and crests but other species have the style branches reduced to narrow lobes without crests [*Moraea maximiliani* (Schltr.) Goldblatt & J.C.Manning and *Moraea umbellata* Thunb.] or divided into paired filiform arms [*Moraea nana* (L.Bolus) Goldblatt and *Moraea singularis* Goldblatt & J.C.Manning]. The remaining two species (*Moraea cooperi* Baker and *Moraea longiflora* Ker Gawl.) have the tepals united in a perianth tube.

The morning blooming phenology is unusual in *Moraea*: the flowers of most species of subg. *Umbellatae* for which phenology is known open in the late morning and collapse in the late afternoon (exact times are unrecorded for any of these species). Records for *M. margaretae*, with which *M. orthrosantha* is most easily confused, indicate that the flowers open mid-morning and collapse toward sunset (Goldblatt 1986). Perhaps significantly, the three Namaqualand species of *Moraea* sect. *Flexuosae* Goldblatt, including *Moraea schlechteri* (L.Bolus) Goldblatt, also have fugaceous flowers opening early in the morning and collapsing after 12:30.

History

Moraea orthrosantha was first recorded by Rudolf Schlechter in 1897 at Brakdam between Garies and Garagams (south of Kamieskroon) in Namaqualand. His collection and a subsequent one made by Frances Leighton in 1945 constitute the only early records of the species. Both were referred to as *M. margaretae* (Goldblatt 1976), an action clearly mistaken in light of the new collections and examination of living plants. These early collections bracket the type locality, 15.5 km north of Garies.

Additional specimens examined

SOUTH AFRICA. **Northern Cape:** 3017 (Hondeklipbaai): hills at 'Brackdam', (–BD), 08 Sept. 1897, *Schlechter 11120* (BM); 6 miles [± 9 km] north of Garies (–DB), 03 Sept. 1945, *Leighton 1129* (BOL).

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

Both authors collaborated on all aspects of the research.

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A new species of *Berkheya* (Asteraceae, Arctotideae) from the Northern Cape, South Africa

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Background: *Berkheya* is a large, mainly southern African genus of approximately 75 species, several of which are poorly known and under-collected. Since revision in 1959, only a few new species have been described. Publication of new taxa facilitates conservation objectives and contributes to a better understanding of the southern African flora.

Objectives: The objectives of this study were to describe a new species of *Berkheya*, consider its taxonomic position within the genus and assess its conservation status.

Methods: Macromorphology and micromorphology of the new species were compared with known species.

Results: *Berkheya dumicola* N.G.Bergh & Helme was described from two subpopulations from the northern Bokkeveld escarpment, Northern Cape Province, South Africa. The species is a tall shrub with radiate flowerheads, toothed receptacle alveole margins, a uniseriate pappus of small, rounded scales and very short twin-hairs on the cypsela.

Conclusion: *Berkheya dumicola* is a new species with a unique combination of features. Based on morphological characteristics, its closest relative within the genus is likely to be the recently described *Berkheya chrysanthemoides* J.C.Manning & Goldblatt. The limited geographic extent and small population size of *B. dumicola* warrant an International Union for Conservation of Nature (IUCN) status of 'Endangered'.

Introduction

Berkheya Ehrh. (Asteraceae) is the largest genus in Arctotideae subtribe Gorteriinae, the 'spiny daisies' of southern Africa. The genus has been shown to be paraphyletic using both molecular (Funk & Chan 2008; Funk, Chan & Keeley 2004) and morphological data (Karis 2006) and changes in generic circumscriptions in the subtribe are anticipated (Karis *et al.* 2009). Based on current evidence, *Berkheya* consists of approximately 75 species distributed predominantly in South Africa. The genus was last revised by Roessler (1959) and has thus not been treated as a whole for over 50 years, despite several useful regional treatments, including Goldblatt and Manning (2000), Hilliard (1977), Manning and Goldblatt (2012a) and Snijman (2013), and the description of a handful of new species (Hilliard 1977; Hilliard & Burtt 1975; Manning *et al.* 2010; Manning & Goldblatt 2012b). The prevalent covering of sharp spines makes *Berkheya* species difficult and painful to collect and the genus is poorly known and under-collected, despite forming a prominent component of many plant communities.

Berkheya species occur in several bioregions but are concentrated in the Greater Cape Floristic Region, where they are most strongly associated with the winter-rainfall desert (succulent Karoo) vegetation (Verboom *et al.* in press). Most species are perennial herbs, less commonly shrubs, distinguished from allied genera by the possession of, (1) involucral bracts that are always spiny and basally connate but never hardened into a woody structure, (2) a honeycombed receptacle with the cypselas embedded in alveoli that are all of equal size and (3) a pappus (Roessler 1959).

Roessler (1959) divided *Berkheya* into eight series based on characters of the receptacle alveolar margins, cypsela hair type, pappus arrangement and structure, degree of connation of the involucral bracts, leaf morphology (including degree of division, margin serration and indumentum), leaf arrangement (opposite versus alternate), presence or absence of ray florets and growth form. Additional characters used to define species include hairiness of the stems and leaves, leaf shape and size, form of the leaf margins, size and structure of the leaf spines, arrangement and size of the capitula, ray floret colour and the size and morphology of the involucral bracts.

Berkheya material from a localised area in the northern Bokkeveld escarpment in the Calvinia region of the Northern Cape Province (Figure 1) was examined and this could be distinguished from other species in the genus by its tall, shrubby habit, relatively large and broad leaves, small radiate heads clustered in paniculate groups, very short uniseriate pappus scales and short hairs on the cypselas. This material represents a new species which is described in detail here.

Research method and design

Berkheya specimens from the South African National Biodiversity Institute's (SANBI) Compton Herbarium in Cape Town (NBG), SANBI's South African Museum Herbarium in Cape Town (SAM) and the Bolus Herbarium at the University of Cape Town (BOL) were compared with those of the new taxon. Holotype material was collected and dried using standard techniques in October 2013. Type material has been deposited in NBG, BOL and SANBI's National Herbarium in Pretoria (PRE), Kew Herbarium at the Kew Royal Botanic Gardens, United Kingdom (K) and the Swedish Museum of Natural History Herbarium in Stockholm (S).

Habitat and habit were documented in the field. Morphological structures were examined on dried and rehydrated specimens using a dissecting microscope. Images were captured from the microscopes using an Olympus SC30 digital camera attachment and the software Analysis getIT v. 5.1 (Olympus Soft Imaging Systems, Münster, Germany). Measurements were made on digital images using MeasureIT v. 5.1 from the same company.

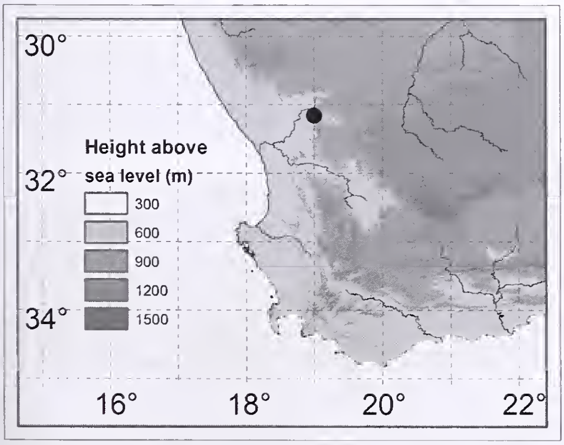
Plants were collected under collecting permit FLORA 02/02/2013 issued to Compton Herbarium staff by the Department of Nature Conservation, Northern Cape Province.

Taxonomic treatment

Berkheya dumicola N.G. Bergh & N.A. Helme, sp. nov.

Type

SOUTH AFRICA. **Northern Cape**: 3119 (Calvinia): Noord Bokkeveld, top of Die Hel pass, north-west of farm Kookfontein (–AA), 12 Oct. 2013, *Helme 7794* (NBG, holo.; BOL, PRE, K, S, iso.).



Source: Map drawn by M. Smith

The black dot represents the location of the two known populations of *Berkheya dumicola*.

FIGURE 1: Distribution of *Berkheya dumicola*.

Description

Well-branched shrub up to 2 m tall, with gnarled woody stem to 120 mm diameter at base, branches leafy towards apices (Figure 2a), thinly (glandular-) tomentose. *Leaves*: alternate, sessile, oblanceolate in outline, 30 mm – 80 mm × 20 mm – 50 mm, lamina narrowed to slender base ± 2 mm wide, pinnatifid, two-jugate with five primary lacinia, lacinia increasing in size distally, primary lateral lacinia each with smaller secondary lobe in distal axil, narrowed at base and often with additional slender patent lobes resembling spines, lacinia somewhat concave, triangular to narrowly triangular, shorter than to as long as the width of undivided portion, excurrent in apical yellowish spine but lacking spines along margins, margins revolute (Figure 2b), discolorous, adaxial surface thinly woolly when young, glabrescent, abaxial surface densely white-felted. *Capitula*: shortly pedunculate, 3–10 in loose corymbs at ends of short, slender flowering branches, several branches arranged together in paniculate synflorescences, radiate, 20 mm – 35 mm diameter across expanded ray florets, florets rich yellow. *Involucral bracts*: 4-seriate (Figure 2c), basally connate in involucre ± 4 mm deep, squarrose, concave, narrowly lanceolate, margins thickened, cartilaginous, yellowish, with apical spine 2 mm – 3 mm long and with 2 or 3 pairs of similar marginal spines, glabrous, outer bracts 5 mm – 8 mm × 2 mm – 3 mm, median 10 mm – 12 mm × 2 mm – 3 mm, inner narrowly lanceolate, 6 mm – 8 mm × 1.5 mm – 2.0 mm. *Receptacle*: deeply alveolate (Figure 2d), ovaries embedded in fleshy alveolar tissue, alveole margins extended into irregularly serrated cartilaginous teeth 1.0 mm – 2.5 mm long (Figure 3d). *Ray florets*: 8–10, sterile and lacking pappus, attached to small alveoles fused to inner surface of innermost involucral bracts (Figure 2d), tube ± 8 mm long, glandular-pubescent, limb narrowly oblanceolate, 12 mm – 15 mm × 3 mm – 5 mm, lamina apex unevenly 4-toothed with central division much shallower than two lateral divisions (Figure 3a). *Disc florets*: 16–18, hermaphrodite, corolla funnel-shaped, 8 mm – 9 mm long, tube ± 5 mm long, densely glandular-pubescent with long pale hairs, deeply lobed, lobes erect, narrowly lanceolate, ± 4 mm long, apically sparsely hairy with short clavate orange hairs on abaxial surfaces, lobe margins somewhat thickened (Figure 3b). *Anthers*: sagittate with lanceolate apical appendage, ± 5 mm long (Figure 3c). *Style*: papillose, with indistinct ring of antrorse hairs well below the branching point, style branches tapering towards apex, obtuse (Figure 3c). *Cypselas*: obovoid, 2.0 mm – 3.0 mm × 0.8 mm, angled, distally densely covered with, short, antrorse twin-hairs (Figure 3e). *Pappus*: of short scales, uniseriate, ± 20, entire, ± 0.3 mm × 0.2 mm, oblong-ovate, apex obtuse-truncate, glabrous (Figures 3e and 3f). *Pollen*: lophate. *Flowering time*: September to October.

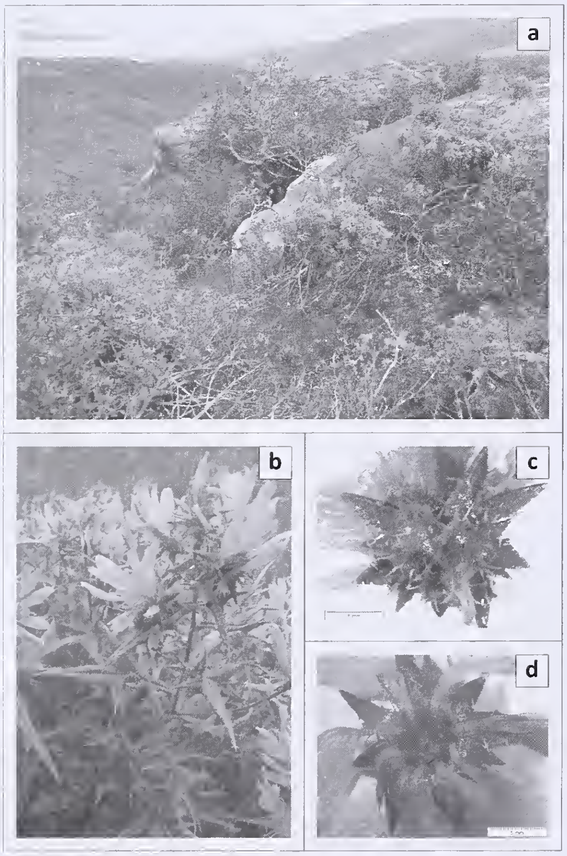
Distribution and habitat

This large, shrubby species has been collected from only one locality in the northern Bokkeveld, north-west of

Nieuwoudtville, on the very edge of the escarpment (Figure 1). Two subpopulations, each of approximately 30 plants, have been found growing about 800 m apart on steep, southwest-facing slopes amongst large sandstone boulders (Figure 2a). The plants occasionally sprawl over the rocky outcrops. The aspect appears to be important because *B. dumicola* was not seen in otherwise similar habitats along the escarpment edge which generally have a drier, more northerly aspect.

Ecology

The species grows in tall, fire-protected thicket vegetation. It is estimated that the habitat has not burnt for at least 80 years. The plants are rooted in deep loamy soils and, because of the steep slope and dense surrounding vegetation, are often partly shaded for part of the day. The thicket vegetation in which they occur includes species such as *Kiggelaria africana* L., *Gymnosporia buxifolia* (L.) Szyszyl., *Lobostemon glaucophyllus* (Jacq.) H.Buek., *Stachys* sp., *Podalyria myrtifolia* (Retz.) Willd. and *Diospyros austro-africana* De Winter. Average annual rainfall in the area is likely to be in the order of 400 mm – 500 mm per year, with pronounced and rapid declines to the east and west of the escarpment edge (Manning & Goldblatt 1997).



Source: Photographs (a) and (b) taken by N. Helme, (c) and (d) taken by N. Bergh, of rehydrated material from the type collection

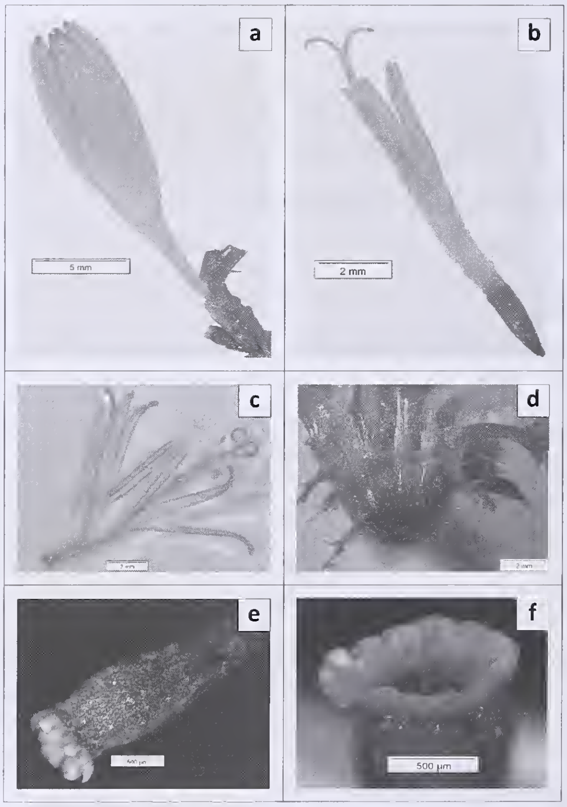
FIGURE 2: Macromorphological features and habitat of *Berkheya dumicola*, including, (a) habitat and habit, (b) inflorescence comprising clusters of three to ten heads; large leaves with spines present at the lacinia apices but not along the margins, (c) base of capitulum showing short peduncle and spiny, 4-seriate involucre and (d) deeply alveolate receptacle with irregularly fimbriate alveolar margins (disc florets corollas removed).

Etymology

The specific epithet 'dumicola' means 'thicket dweller' (Stearn 1967) and refers to the rocky, fire-protected vegetation in which this species occurs.

Diagnosis and relationships

Berkheya dumicola is an unusually large, shrubby species in a genus dominated by perennial herbs. The shrubby habit, radiate heads and relatively broad leaves (Figure 2b) are most consistent with *Berkheya* series *Fruticosae* Roessler, but members of this series are characterised by entire or shortly toothed (rarely fringed) receptacle alveolar margins, densely hairy cypselae with the silky hairs often long (up to 4 mm), and a biseriate pappus of lanceolate or subulate scales. The conspicuously fimbriate, serrate-toothed alveolar margins, shortly pubescent cypselae with twin-hairs and uniseriate pappus of short, obtuse scales (Figures 3d–3f) set *B. dumicola* apart from members of series *Fruticosae*. Only one other *Berkheya* species



Source: Photographs taken by N. Bergh

FIGURE 3: Micromorphological features of *Berkheya dumicola*, taken from rehydrated material of the type collection, depicting, (a) ray floret and associated receptacular tissue, (b) disc floret, (c) dissected disc floret showing style and anthers, (d) section through receptacle to show embedded cypselae and alveolar margins, (e) dry cypsela and (f) pappus.

shares this unusual combination of characters: the recently described *Berkheya chrysanthemoides* from the nearby central Bokkeveld. *Berkheya dumicola* differs from *B. chrysanthemoides* in having leaves that are broader (20 mm – 50 mm in *B. dumicola*; 15 mm – 30 mm in *B. chrysanthemoides*), lack marginal spines (both species have spines on the lacinia apices but *B. chrysanthemoides* also possesses smaller antrorse spines along the margins) and are conspicuously tomentose on their abaxial surfaces (contrasting with the abaxially glabrous leaves of *B. chrysanthemoides*). The capitula of *B. dumicola* are smaller (20 mm – 35 mm in *B. dumicola*; 40 mm – 50 mm in *B. chrysanthemoides*) and clustered together in larger groups (three to ten in *B. dumicola*; one to three in *B. chrysanthemoides*).

Manning *et al.* (2010) speculated that *B. chrysanthemoides* may have its closest taxonomic relatives in Roessler's (1959) series *Rigidae*, the species of which are characterised by similar alveole, pappus and cypsela characters, as well as sharing anther and pollen features. Species in series *Rigidae*, however, are generally herbaceous or suffruticose and lack ray florets. *Berkheya chrysanthemoides*, and now *B. dumicola*, therefore represent unusually large and radiate putative members of this series. It is remarkable that these likely sister-species, both only recently discovered, occur relatively nearby on the Bokkeveld escarpment. Both species are known from only a single locality each and further collections are required to determine their full geographical ranges and morphological variation.

Conservation status

The total global population of *B. dumicola* is currently thought to be less than 100 mature plants and the species thus fits the criteria for EN D1 (International Union for Conservation of Nature [IUCN] 2001). No threats to the species are currently known.

Other material examined

SOUTH AFRICA. **Northern Cape**: 3119 (Calvinia): Noord Bokkeveld, top of Die Hel pass, north-west of farm Kookfontein (–AA), 16 Sept. 2006, *Helme 4225* (NBG).

Discussion

Berkheya dumicola is morphologically most similar to *B. chrysanthemoides* and together they form an unusual and geographically proximate subgroup within *Berkheya* (*B. chrysanthemoides* is also from the Bokkeveld plateau, growing in the Oorlogskloof Nature Reserve approximately 50 km to the south of where *B. dumicola* occurs). Of consideration is the fact that both species are known from only very few specimens, so the documented range of within-species variation is small. However, many species do occur naturally in very geographically restricted ranges and with only a small number of individuals. Assessment of natural variation in these cases must, of necessity, be based on a small number of specimens. Careful comparison of morphological differences between *B. chrysanthemoides* and *B. dumicola* revealed a suite of characters, derived from both reproductive and vegetative structures, differing sufficiently and consistently to warrant separating the two taxa.

Conclusion

Berkheya dumicola is a new, possibly endangered species recently discovered in the northern part of the Bokkeveld plateau in the Northern Cape Province of South Africa.

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

N.A.H. (Nick Helme Botanical Surveys) discovered the plant and recognised it as a new species, as well as contributing to the manuscript and writing the sections on ecology and conservation status. N.G.B. (SANBI Kirstenbosch) performed the dissections and microscope work and wrote the initial taxonomy section and draft manuscript.

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Taxonomic status of *Pelargonium reniforme* Curt.

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Background: *Pelargonium reniforme* Curt. is a morphologically variable species that many authors have attempted to split or combine. Confusion relating to the differences between the two subspecies currently included under *P. reniforme* has impeded attempts to assess their conservation status. *Pelargonium reniforme* is closely related to *Pelargonium sidoides*; the two species are indistinguishable when not flowering and their distributions overlap in some areas.

Objectives: With this study, we aimed to clarify the taxonomic status of the two subspecies of *P. reniforme*, which has relevance in terms of their conservation status.

Method: Leaf shape, petiole length, internode length and flower colour were assessed by studying herbarium specimens of the two subspecies of *P. reniforme* and specimens of *P. sidoides*. Living specimens of the two subspecies were also examined in their natural habitat.

Results: The current investigation showed that the morphological characters used to distinguish the two subspecies of *P. reniforme* are too variable to separate them. Variation in some morphological characters may be related to environmental conditions.

Conclusion: The recognition of the two subspecies of *P. reniforme* as distinct taxa is no longer justified.

Introduction

There are over 200 species of *Pelargonium* L'Hér. ex Aiton in South Africa and comparatively few species elsewhere in the world (Vorster 2000). The genus *Pelargonium* is characterised by a zygomorphic flower with a nectariferous spur fused to the pedicel, five petals (rarely four or two), with the posterior petals larger than the anterior petals and 10 stamens, of which only two to seven are fertile (Van der Walt 1985).

There are 16 sections recognised in the genus (Bakker *et al.* 2004). *Pelargonium reniforme* Curt. is a member of section *Reniformia* (R.Knuth) Dreyer ex J.P.Roux (Roux 2013) and is distributed from Middelburg in Mpumalanga southwards to Riversdale in Western Cape and as far west as Mthatha in Eastern Cape. This species is a small shrublet with tuberous roots and pink to deep magenta flowers. Variation in *P. reniforme* in internode length, leaf shape and petiole length has led to several taxonomic opinions. Ecklon and Zeyher (1835) split *P. reniforme* into three distinct species of the genus *Cortusina* (DC.) Eckl. & Zeyh., namely *Cortusina velutina* Eckl. & Zeyh., *Cortusina rubro-purpurea* Eckl. & Zeyh. and *Cortusina reniformis* (Curt.) Eckl. & Zeyh., but these were reduced by Harvey (1860) to varieties as var. *velutinum* (Eckl. & Zeyh.) Harv., var. *sidaefolium* (Thunb.) Harv. and var. *reniforme*. Knuth (1912) later regarded var. *velutinum* as a synonym of *P. reniforme* and raised var. *sidaefolium* to species status as *P. sidaefolium* (Thunb.) Knuth, which is currently known as *P. sidoides* DC. In 1995, Dreyer, Marais and Van der Walt re-established the recognition of infraspecific taxa of *P. reniforme* by recognising *P. reniforme* subsp. *velutinum* (Eckl. & Zeyh.) Dreyer.

Pelargonium reniforme subsp. *reniforme* was applied by Dreyer, Marais and Van der Walt (1995) to plants with elongated internodes (5 mm – 12 mm), reniform leaves and petioles 5 mm – 50 mm long. This form, although sympatric with *P. reniforme* subsp. *velutinum*, is more abundant in the Port Elizabeth area, Eastern Cape, where it is restricted to drier coastal plains below 300 m.a.s.l. The form designated as *P. reniforme* subsp. *velutinum* has internodes of 1 mm – 7 mm in length and cordate or reniform leaves with petioles of 25 mm – 130 mm in length. Plants with characteristics corresponding to *P. reniforme* subsp. *velutinum* are, according to Dreyer *et al.* (1995), more abundant between Grahamstown and Queenstown, Eastern Cape. In all other respects the two subspecies are identical and their distinction is difficult.

The closely allied *Pelargonium sidoides* differs from *P. reniforme* in having black or very dark purple flowers. It is usually indistinguishable from *P. reniforme* when not flowering, in having an identical habit and leaves that are similar in shape and size, usually cordate and velvety. The distribution of *P. sidoides* overlaps with that of *P. reniforme* but is wider, the species occurring throughout Eastern Cape, Lesotho, Free State and southern Gauteng (Van der Walt & Vorster 1988).

Medicinal use and conservation status

Some *Pelargonium* species are valued by traditional healers for their medicinal uses. The roots or extracts of roots of both *P. sidoides* and *P. reniforme* are used to treat diarrhoea, bronchitis, stomach ailments and respiratory tract infections (Watt & Breyer-Brandwijk 1962). Both species play an important role in traditional medicine and are therefore subject to occasional harvesting for local use, but *P. sidoides* is harvested at a much larger scale for export to Europe for use in the manufacture of a number of medicinal products (Brendler & Van Wyk 2008).

The conservation statuses of the two subspecies of *P. reniforme* are listed as 'Not Evaluated' (South African National Biodiversity Institute [SANBI] 2013a, 2013b), as the difficulty in distinguishing between them hinders data collection for conservation assessments. There is concern about the conservation status of *P. reniforme* as it can be harvested along with *P. sidoides* where the two occur sympatrically because of their morphological similarity. The conservation status of *P. reniforme* is thus currently listed as 'Near Threatened' as a result of suspected widespread overharvesting (Raimondo *et al.* 2012). The conservation status of *P. sidoides* is 'Least Concern' because, although it is heavily harvested, it is a very widespread and common species (De Castro *et al.* 2012). The clarification of morphological differences between the two subspecies of *P. reniforme* is regarded as a high priority by the Threatened Species Programme (D. Raimondo pers. comm., 29 May 2012) so that the conservation status can be properly assessed. We therefore investigated the species in an attempt to resolve the taxonomic problem. Morphological comparisons were made between the two subspecies, as well as with the nearest relative, *P. sidoides*, to clarify taxonomic uncertainty and subsequently contribute to the conservation of this species. The possibility that variation in some morphological characters is related to environmental conditions was also investigated by observing specimens of both subspecies of *P. reniforme* in their natural habitat.

Research method and design

Specimens (101 in total) of both subspecies of *P. reniforme* from the National Herbarium in Pretoria (PRE), all wild-collected and covering the entire geographical range of the subspecies, were studied to assess morphological variation between the two subspecies. A total of 15 specimens were previously identified as *P. reniforme* subsp. *reniforme* and 86 as *P. reniforme* subsp. *velutinum*. In addition, 140 specimens of *P. sidoides* from PRE were investigated in order to determine whether similar variation occurred in this species. The diagnostic characters distinguishing the two subspecies – that is, the lengths of the petioles and the internodes, as well as the leaf-shapes – were recorded for each specimen. A digital image of the holotype of *P. reniforme subsp. velutinum* from the Herbarium at the Swedish Museum of Natural History, Stockholm (S) was also examined. Observations of both subspecies were made in the area between Humansdorp, East London and Queenstown.

Taxonomic treatment

Pelargonium reniforme Curt. in Curtis's Botanical Magazine 14: 493 (1800); Pers.: 229 (1806); Desf.: 457 (1809); Willd.: 703 (1809); Ait.: 171 (1812); Haw.: 307 (1812); Sweet: t. 48 (1820); DC.: 666 (1824); Hoffmg.: 95 (1824); Loudon: 574(1829); Don: 737 (1831); Steud.: 289 (1841); Harv.: 300 (1860); Knuth: 447 (1912); Pole-Evans: 672 (1937); Watt and Breyer-Brandwijk: 454 (1962); Batten and Bokelman: 89 (1966); Smith: 381 (1966); Clifford: 237 (1970); J.J.A. van der Walt: 40, Figure (1977); Webb: 69 (1894); Dreyer, Marais and Van der Walt: 325 (1995). *Cortusina reniforme* (Curt.) Eckl. & Zeyh.: 77 (1835). *Geranium reniforme* (Curt.) Andr.: 108 (18000; Poir.: 751 (1812); Steud.: 679 (1840). *Geraniospermum reniforme* (Curt.) Kuntze: 95 (1891). Iconotype: Curt.: t. 493 (1800).

Cortusina velutina Eckl. & Zeyh.: 77 (1935). *Pelargonium reniforme* var. *velutinum* (Eckl. & Zeyh.) Harv.: 300 (1860). *Pelargonium reniforme* subsp. *velutinum* (Eckl. & Zeyh.) Dreyer, in Dreyer, Marais and Van der Walt: 328 (1995). Type: SOUTH AFRICA. **Eastern Cape**: 'campestriis ad fluvium "Zwartkopsrivier" et collibus in "Adow" [Addo] (Uitenhage)', *Ecklon & Zeyher 598* (S, holo. – digital image!).

Description

Comparison of diagnostic characters of the two subspecies

Based on field observations as well as morphological comparison of herbarium specimens, *P. reniforme* subsp. *velutinum* was found to have internodes that were variable in length and a range of petiole lengths overlapping with those of subsp. *reniforme* (Table 1). This finding contradicts the descriptions given by Dreyer *et al.* (1995) to distinguish the two subspecies.

TABLE 1: Summary of diagnostic characteristics of *Pelargonium* species recorded from herbarium specimens.

Character	***Pelargonium reniforme* subsp. *reniforme***	***Pelargonium reniforme* subsp. *velutinum***	***Pelargonium sidoides***
Leaf shape	Reniform	Cordate or reniform	Cordate or reniform
Petiole length measurements from herbarium specimens (mm)	10–115	6–138	12–200
Petiole length according to Dreyer *et al.* (1995) (mm)	5–508	25–130	Not given
Internode length (mm)	1–15	1–10	1–3
Internode length according to Dreyer *et al.* (1995) (mm)	5–12	1–7	Not given

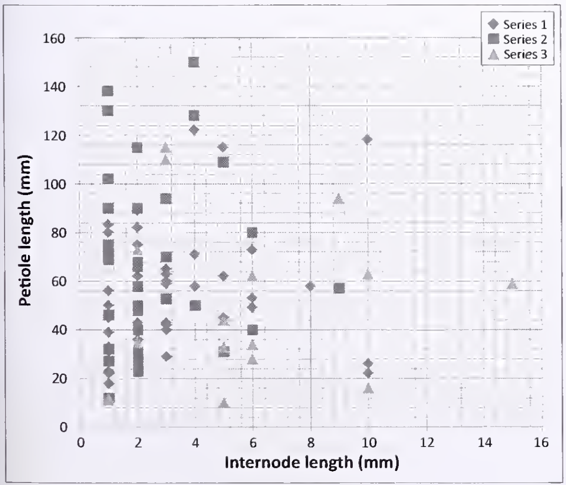
Source: Comparative data where stated from Dreyer, L.L., Marais, E.M. & Van der Walt, J.J.A., 1995, 'A subspecific division of *Pelargonium reniforme* Curt. (Geraniaceae)', *South African Journal of Botany* 61(6), 325–330

Character variation was plotted on a scatter plot chart (Figure 1), which shows that all variation overlaps in both subspecies. This implies that these characters cannot be used to distinguish the two subspecies. The petiole length of subspecies *velutinum* overlaps completely with that of subspecies *reniforme* and this characteristic is therefore also not useful to distinguish the two subspecies. Most of the specimens with characteristics that correspond with subspecies *velutinum* have cordate leaves; although, there are a few that are reniform. All specimens corresponding to subspecies *reniforme* have reniform leaves. Figure 1 shows that variation in the leaf shape is not correlated with petiole length or internode length and therefore this character is too variable to reliably be used to distinguish subspecies.

Pelargonium sidoides is vegetatively similar to the descriptions given in Dreyer *et al.* (1995) for subspecies of *P. reniforme*; however, one consistent characteristic of *P. sidoides* is the short internodes (usually 1 mm but never longer than 3 mm in length), whereas the internode length in *P. reniforme* varies between specimens. The other consistent difference between the two taxa is the flower colour, as described above.

Influence of habitat on morphology

Although specimens with the form *P. reniforme* subsp. *reniforme* are concentrated around Port Elizabeth, observations of plant characteristics in this area revealed that a possible cause for variation is the microhabitat in which the plant was growing. Plants growing in the shade of dense grass in the Port Elizabeth area tended to have both longer internodes (as in subsp. *reniforme*), as well as longer petioles (as in subsp. *velutinum*). It is possible that availability of nutrients, water and sunlight affects internode and petiole lengths, which could explain much of the variability of these characteristics in *P. reniforme*.



Source: Authors' own creation
Series 1, *Pelargonium reniforme* subsp. *velutinum* with cordate leaves; Series 2, *Pelargonium reniforme* subsp. *velutinum* with reniform leaves; Series 3, *Pelargonium reniforme* subsp. *reniforme* with reniform leaves.

FIGURE 1: Scatter-plot chart of character variation within *Pelargonium reniforme* subsp. *reniforme* and *Pelargonium reniforme* subsp. *velutinum*.

Conclusion

The findings of this study show that it is not possible to reliably distinguish between *P. reniforme* subsp. *reniforme* and *P. reniforme* subsp. *velutinum* and we recognise a single variable species for all populations.

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

M.A. (SANBI) examined herbarium specimens and took measurements under the training and guidance of J.E.V. (SANBI). M.A. contributed to writing of the manuscript and collated background information. J.E.V. undertook fieldwork, contributed to writing the manuscript and editing it and supervised the project.

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Ledebouria caesiomontana A.J.Hankey & N.Hahn (Hyacinthaceae: Hyacinthoideae): A new species from the Blouberg centre of endemism, Limpopo, South Africa

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Background: *Ledebouria* Roth (Hyacinthaceae: Hyacinthoideae) is a largely African genus with, more or less, 40 species occurring in South Africa. The species was first collected in December 1990 by R. Archer [*Archer, R.H. 503* (PRE)] and remained un-identified. Subsequently, N. Hahn also collected the species in 1992 [*N. Hahn 444* (ZPB)] and, upon failing to resolve the identity of the specimen, he approached A. Hankey who initiated further collaborative research.

Objective: To describe the new species of *Ledebouria* from Blouberg mountain massif in Limpopo Province, South Africa.

Method: Relevant existing specimens in herbaria were examined and morphological characters and states noted. The type specimen was collected during an expedition under the guidance of Prof. Dirk Bellstedt accompanied by Mr Adam Harrower.

Results: *Ledebouria caesiomontana* A.J.Hankey & N.Hahn sp. nov. was described and illustrated. The new species was distinguished from its closest relative, *Ledebouria papillata* S.Venter, by the ovary which lacks basal lobes, as well the absence of cataphylls and the irregular papillate ridges present only on the upper leaf surfaces.

Conclusion: *Ledebouria caesiomontana* is a new species restricted to the Blouberg mountain massif in Limpopo Province, South Africa. Initial estimates deem the species to be vulnerable (VU D2) as a result of especially anthropogenic-induced disturbances on the Blouberg.

Introduction

The genus *Ledebouria* Roth (Hyacinthaceae: Hyacinthoideae) was first erected by Roth (1821) when he described *Ledebouria hyacinthina* Roth from India. Baker (1870) subsequently placed the genus under *Scilla* L. where it typified section *Ledebouria*. Jessop (1970) resurrected the genus and recognised 15 South African species, characterised by the possession of bulbs with deciduous leaves and erect to mostly somewhat flaccid inflorescences with basal ovules paired in each locule, together with a stipitate ovary. The most recent revision of *Ledebouria* by Venter (1993) was followed by a synopsis of the genus by the same author (Venter 2008), wherein he recognises 39 South African species and makes reference to more than 60 species occurring in sub-Saharan Africa, with one or two each in India and Madagascar. Despite the large number of species currently recognised in *Ledebouria*, no formal infra-generic classification exists to date.

This study was initiated by N. Hahn, who collected the species from Blouberg mountain massif in Limpopo Province, South Africa, in 1992 [*N. Hahn 444* (ZPB)] and, upon failing to resolve the identity of the specimen, approached the first author for assistance. Subsequently, an examination of existing herbarium specimens revealed un-identified specimens that belonged to the same entity. Recollections by some of the authors, coupled with an analysis of characters and states based on herbarium specimens, fieldwork and living material, led to the conclusion that a new species was in hand. In this article, we describe the new species of *Ledebouria*.

Research method and design

Relevant specimens in the South African National Herbarium (PRE) and the Herbarium Soutpansbergensis (ZPB) formed the bulk of the material available for study. In addition, a collection of living plants housed at the Walter Sisulu National Botanical Garden, Roodepoort, Gauteng Province, provided material for illustrative and research purposes. The unknown entity was compared on a macromorphological and micromorphological basis with similar looking species. Measurement of plant parts was performed by hand using a combination of rulers and callipers.

Taxonomic treatment

Ledebouria caesiomontana A.J.Hankey & N.Hahn sp. nov.

Type: SOUTH AFRICA. **Limpopo:** 2329 (Blouberg): Beauley, 23.08467 °S, 29.00076 °E, 1658 m.a.s.l. cliff ledges in forest, (–AA), 24 Mar. 2007, *Hankey, A.J. 2129* (PRE, holo; NBG, iso).

Description

Plants mostly solitary to weakly gregarious by sobolifery (proliferating from the base of the bulb). *Bulbs*: hypogeal 20 mm – 25 mm × 10 mm – 15 mm, ovoid, dead bulb scales membranous, pale brown, live bulb scales tightly arranged, whitish, fleshy, truncate apically, with threads when torn. *Leaves*: (3–)4(–5), dull green, linear-oblanceolate, 70 mm – 100 mm × 10 mm – 15 mm, synanthous, apex acute, base canaliculate, with threads when torn, spreading, green, with irregular longitudinal papillate ridges, maculate with dark green to purple spots and blotches adaxially, glabrous, wholly purple-red, or green suffused with purple-red abaxially, margin entire, minutely papillate. *Inflorescence*: one per bulb, erect, 65 mm – 120 mm long, raceme 30 mm – 40 mm long, conical, with 12–20 loosely arranged flowers, scape terete, glabrous, 50 mm – 80 mm long, reddish-green. *Bracts*: present, 1.0 mm × 0.5 mm, deltoid, fleshy, reddish-green, prophylls absent. *Pedicels*: 5 mm – 7 mm long, pink. *Perianth*: campanulate; tepals oblong, cucullate apically, reflexed, 5.0 mm – 6.0 mm × 1.8 mm, pink with greenish-brown vitta. *Stamens*: epitepalous, erect, filaments 6 mm long, filiform, violet; anthers yellow, 0.5 mm long, dorsifixed. *Ovary*: six lobed, greenish, depressed ovoid, 1 mm × 2 mm, stipitate, stipe 0.5 mm × 0.5 mm, basal lobes absent, style 5 mm long, violet. *Flowering time*: October to December (Figure 1).

Distribution and ecology

Ledebouria caesiomontana occurs in Northern Mistbelt Forest vegetation (Mucina & Rutherford 2006) on the Blouberg massif. Specifically, it has been recorded from low deciduous forest and forest margins in shallow, moss-covered lithosols and rock crevices under the shade of woody vegetation. The species is cryptic and easily overlooked in its habitat because the bulbs are often tightly wedged in narrow rock crevices. This species is thus far only known from the Blouberg massif, where it has only been recorded from five collections (Figure 2).

The description of this new species brings the total of Blouberg endemic plant species to four (Hahn 2006), with the following endemic species previously known being: *Berkheya radyeri* Roessler, *Cineraria cyanomontana* Cron (Asteraceae) and *Streptocarpus longiflorus* (Hilliard & B.L.Burtt) T.J.Edwards (Gesneriaceae). The new species has thus far not been found in the Soutpansberg, an area known to share 13 near endemic taxa with the Blouberg (Hahn 2006).

Etymology

The specific epithet *caesiomontana* alludes to the Blouberg (meaning Blue Mountain) in the Limpopo Province of South Africa, from which the new species was collected.

Conservation status

Owing to *L. caesiomontana's* cryptic nature, it may easily be overlooked in the field and this may explain the low numbers of collections. *Ledebouria caesiomontana* is uncommon in its known distribution range but more extensive fieldwork may reveal additional populations.

The forests on the Blouberg are systematically being eradicated as a result of slash and burn practices. To date, no official study has been undertaken on the Blouberg to ascertain the extent these activities could potentially have on the conservation of *L. caesiomontana* or the Blouberg as a whole. An urgent study needs to be conducted on the Blouberg to assess the impact and inform the conservation measures required to halt the rapid loss of forests in the area. In the light of the preceding factors, we expect that the species would be best ascribed as VU D2 in terms of the International Union for Conservation of Nature's (IUCN) Red List status (IUCN 2012).

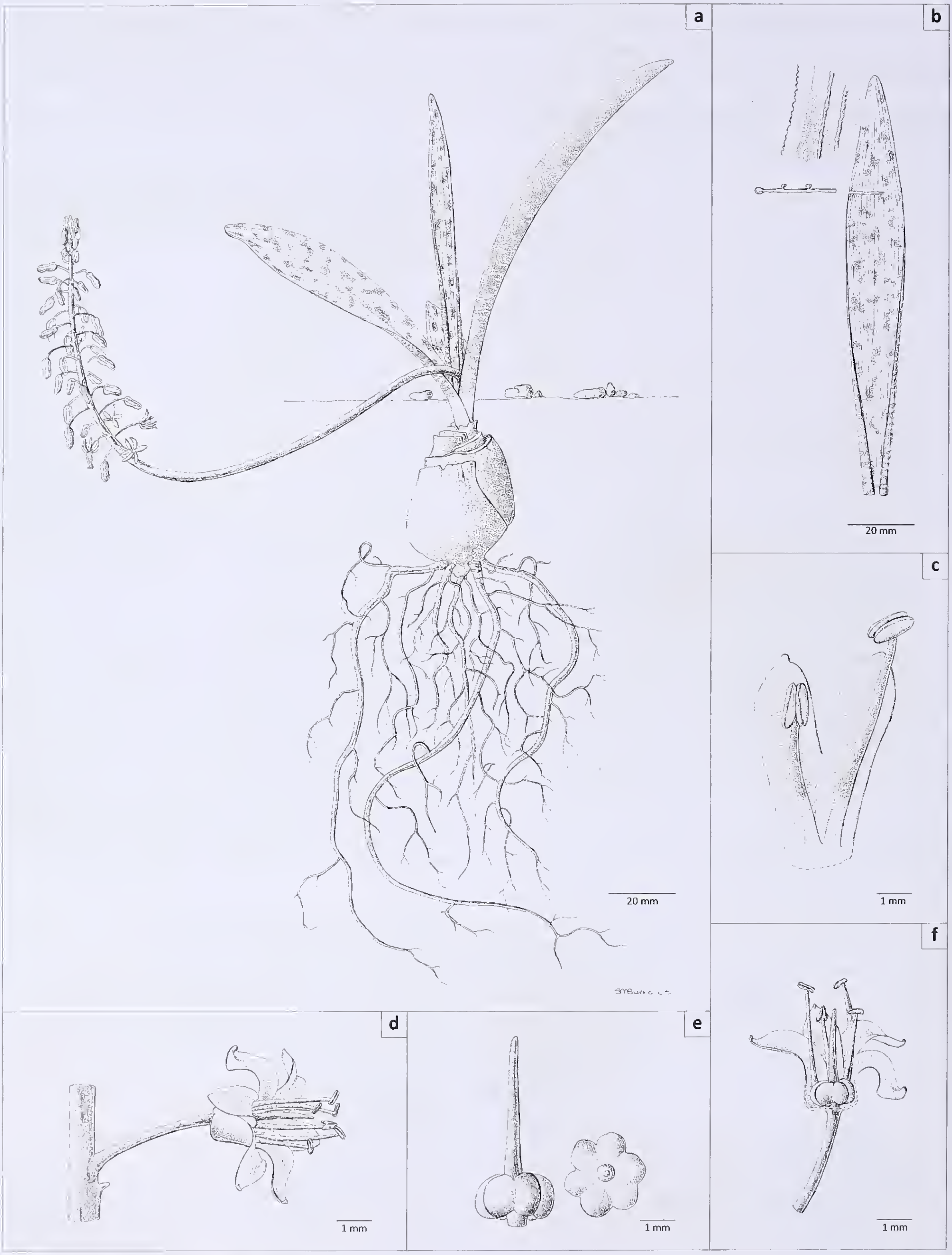
Diagnosis

Ledebouria caesiomontana is most similar to *Ledebouria papillata*, from which it is distinguished by several characters (Table 1). The new species lacks the characteristic basal ovary lobes of *L. papillata* – not illustrated by Venter (1993, 2008) but clearly noted in the descriptions. Furthermore, *L. caesiomontana* differs in the absence of regular longitudinal rows of papillae on the scape and leaves, instead having irregular papillate ridges only on the adaxial surface of the leaf and not on the scape or the abaxial leaf surface. This species also lacks the two basal cataphylls noted by Venter (2008) as diagnostic for *L. papillata*.

Ledebouria asperifolia (Van der Merwe) S.Venter (Venter2008) also possesses longitudinal rows of papillae on the lower leaf surface (and occasionally on the upper leaf surfaces) and may be superficially similar to *L. caesiomontana*. However, *L. asperifolia* is larger in all respects, and has purplish-brown dead bulb scales persistent on the bulb. The distribution of these two species is furthermore, distinct (Figure 2).

Additional specimens examined

SOUTH AFRICA. **Limpopo:** 2329 (Blouberg): Blouberg, Blouberg Nature Reserve, 13 Dec. 1990, *Venter, S. 13507* (PRE); Blouberg NR, Farm Dantsig 3, 05 Dec. 1990, *Archer, R.H. 503* (PRE); Blouberg, Beauley, 23.0776 °S, 28.99324 °E, 1692 m.a.s.l., cliff ledges in forest, 24 Mar. 2007, *Hankey, A.J. 2130* (PRE) (–AA). 2328 (Tolwe): Blouberg, Beauley, 23°4′40.14″ S , 28°59′38.50″ E, 1710 m.a.s.l., in flower, 09 Dec. 1992, *N. Hahn 444*, (ZPB) (–BB).



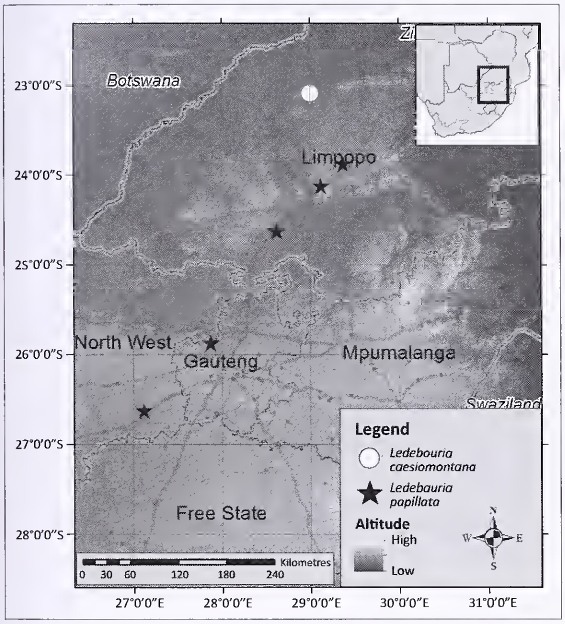
Source: Illustrations by S. Burrows; specimen voucher: *Hankey, A.J. 2129*

FIGURE 1: Illustrations of *Ledebouria caesiomontana* depicting, (a) flowering plant, (b) adaxial leaf surface showing ridges and ornamentation detail, (c) inner and outer tepal section showing stamens, (d) flower, pedicel and floral bract, (e) ovary lateral and dorsal view and (f) flower, section showing ovary and stamens.

TABLE 1: Differences between *Ledebouria papillata* and *Ledebouria caesiomontana*.

Category	***Ledebouria papillata*** **(Venter 2008)**	***Ledebouria caesiomontana***
Distribution	Pietersburg plateau, Gauteng and Eastern Cape Provinces	Endemic to the Blouberg, Limpopo Province
Bulb	With prominent neck and 2 basal cataphylls reaching ground level – not shown in illustration by Venter (2008)	Without prominent neck, cataphylls absent
Leaves	2–4, glossy dark green, with venation prominent	3–5, dull mid-green, with venation obscure
Leaf base	Sub-petiolate with vertical purple stripes	Clasping, canaliculate without vertical stripes
Epidermal ornamentation	Longitudinal rows of papillae on adaxial and abaxial leaf surfaces and scape	Irregular longitudinal ridges on the adaxial leaf surface only; Abaxial leaf surface and scape glabrous
Inflorescence	Erect	Spreading, becoming flaccid
Perianth	2.0 mm – 3.5 mm long	5.0 mm – 6.0 mm long
Ovary	Basal lobes present – not shown in illustration by Venter (2008)	Basal lobes absent

Source: *Ledebouria papillata* data taken from Venter, S., 2008, 'Synopsis of the genus *Ledebouria* Roth (Hyacinthaceae) in South Africa', *Herbertia* 62, 85–155



Source: Map drawn by M. Lötter

FIGURE 2: Known distribution of *Ledebouria caesiomontana* and *Ledebouria papillata*.

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

A.J.H. (Walter Sisulu National Botanical Garden) was responsible for the morphological study and wrote the description, whilst N.H. (Herbarium Soutpansbergensis) provided the conservation, ecological and phytogeographic notes. M.H.B. (New Zealand Forest Research Institute) undertook a supervisory and advisory role, providing taxonomic guidance and editing.

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Gladiolus filiformis, a poorly known species from North West Province, South Africa

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Background: *Gladiolus filiformis* was described in 1998 from only the type specimen, which was collected in 1977.

Objectives: The aim of this article was to expand our knowledge of the morphology, distribution, ecology, and conservation status of this poorly known species.

Method: Data presented were based on field observations, with dissections and diagnostic descriptions conducted in the field.

Results: A comprehensive account of the morphology, distribution, ecology and conservation status for *G. filiformis* was presented for the first time.

Conclusion: *Gladiolus filiformis* is more common than previously thought. The species is not an edaphic specialist and it occurs mainly on sediments of the Transvaal supergroup. Its heteromorphically winged fruit were described here, showing an intermediate form between *Gladiolus pretoriensis* and *Gladiolus oatesii*.

Introduction

The North West Department of Economic Development, Environment, Conservation and Tourism is presently conducting a biodiversity inventory of the rare, endangered and endemic plants in the province, including *Gladiolus filiformis*, which is considered to be rare and endangered.

In December 2010, *G. filiformis* Goldblatt & J.C. Manning was rediscovered by the authors. This species was previously known only from its type locality and was described from a single herbarium specimen (Goldblatt & Manning 1998).

The aim of this article is to expand our knowledge of the morphology, distribution, ecology and conservation status of this poorly known species.

Research method and design

All presently known populations of *G. filiformis* were surveyed over a period of three flowering seasons, from December 2010 to February 2013. Approximately 300 live plants were examined.

Live plants were measured and dissected in the field. Distribution and ecological data were captured with the aid of a Trimble Juno ST, Personal Digital Assistant. Co-ordinates were recorded using datum WGS 84. All data gathered from the biological surveys are stored in a Global Information System database to be incorporated into the planned Biodiversity Information Management System for North West Province.

Landowners' permission was obtained for this study and no permits were required. Specimens were deposited in the Compton Herbarium (NBG) and Herbarium Soutpansbergensis (ZPB).

Taxonomic treatment

Gladiolus filiformis Goldblatt & J.C. Manning in Gladiolus South Africa: 182 (1998).

Type: SOUTH AFRICA: 'North Eastern Cape' **[North West Province]**: [2525: Mafikeng], Gopane Mountains, rocky koppie, rocky red soil, altitude 1100 m.a.s.l. [*sic*], [(–BD)], 29 Dec. -1977, *C.P. Peeters, N.P. Gericke & G.G. Burelli 509* (PRE, holo.!).

Description

Plants: 350 mm – 500(–720) mm tall. *Corm*: obconic, up to 30 mm in diameter, ivory coloured; tunics of reticulate fibres. *Cataphylls*: brown, membranous, protruding about 20 mm above ground. *Leaves*:

usually three, occasionally four, basal leaves reaching to base of inflorescence, second leaf sheathing lower third of stem, blades terete and four-grooved with margins and veins thickened, 1.0 mm – 2.5 mm in diameter. *Stems*: erect, usually simple, up to 2 mm in diameter. *Inflorescence*: a (5–)6 mm – 10(–12) mm flowered spike. *Bracts*: green tinged, reddish at apex, drying after anthesis, outer bracts 9.3 mm – 24.4 mm × 3.8 mm – 7.0 mm long, inner bracts 0.833–1.000 times shorter than outer bracts. *Flowers*: usually light mauve, rarely tinged pink, dorsal tepal usually dark lilac with burgundy markings at base; upper lateral tepals midrib burgundy on the inside; lower lateral tepals with various white and darker markings, apex with two burgundy lines on outside; lower median tepal with or without various white and darker markings, base with single or double burgundy line on the inside; unscented by day. Length of flower measured from base of tube to tip of dorsal tepal (49.2–)51.2 mm – 64.0(–70.0) mm long; perianth tube filiform, curved, (25.4–)27.1 mm – 36.5(–40.8) mm long; dorsal tepal elliptic to broadly elliptic (19.8–)20.3 mm – 24.1(–24.8) mm × (14.7–)14.9 mm – 19.3(–22.0) mm, apex acute, base tapering; upper lateral tepals elliptic (15.1–)15.9 mm – 21.6(–25.0) mm × (9.1–)9.7 mm – 11.9(–13.6) mm, apex acuminate, base tapering; lower lateral tepals elliptic to narrowly elliptic (14.6–)15.4 mm – 18.3(–20.3) mm × (5.8–)5.9 mm – 8.8(–10.6) mm, apex acuminate, base attenuate; lower median tepal elliptic (14.6–)15.4 mm – 18.3(–20.3) mm × (6.5–)7.3 mm – 10.3(–11.7) mm, apex acuminate, base tapering. *Stamens*: outer filaments from ovary (31.7–)32.8 mm – 42.1(–45.5) mm long, unattached section (9.2–)10.3 mm – 13.0 (–14.2) mm long; median filament from ovary (32.5–)33.5 mm – 43.5(–47.3) mm long, unattached section (8.6–)10.6 mm – 13.9 mm long; anthers (5.3–)5.9 mm – 8.1(–9.0) mm long, yellow. *Ovary*: ovoid (2.5–)2.9 mm – 4.2(–4.4) mm long; style (31.8–)37.7 mm – 49.8(–54.2) mm long, branching at apex, branches (2.8–) 3.0 mm – 4.6(–6.0) mm long. *Capsule*: ellipsoid, 7.7 mm – 11.8 mm long. *Seeds*: irregularly shaped, 1.8 mm – 3.1 mm long, brown, surface granulate, wings heteromorphous (wings of different shapes), apical wing 0.9 mm – 2.4 mm long; basal wing 0.2 mm – 0.7 mm long, lateral wing 0.2 mm – 0.5 mm long with the opposing wing usually absent or underdeveloped. *Flowering period*: Mainly December, but can extend from October to February (Figure 1).

The north-western plants, including the type, are smaller than those found to the south-east. The inflorescences of the type specimen have only two flowers but the plant was described as having five flowers. Five flower inflorescences are the lower limit for this species, with the number usually lying between six and ten, with an upper limit of twelve observed. The flowering structure of the type specimen is also smaller than those observed. The perianth tube of the type specimen was stated as approximately 20 mm, whereas the length in the plants studied was found to be between 27.1 mm and 36.5 mm, with the lower and upper limit between 25.4 mm and 40.8 mm. The shape, length and colouration of the dorsal tepals, upper tepals, lower lateral tepals and lower median tepals are described for the first time as they were omitted in the original description of *G. filiformis*. The rare pink form of *G. filiformis* has not been recorded before. The unattached outer and median filament sections were found to be of different sizes with the latter usually shorter; this suggests a possible diagnostic feature. No fruiting characteristics were recorded for the species prior to this study. The newly described heteromorphically winged seeds of *G. filiformis*, with the lateral wings absent or underdeveloped and the apical wing up to 2.4 mm long, are intermediate between the wingless seeds of *Gladiolus pretoriensis* and the broad, evenly winged seeds of *Gladiolus oatesii*, which are up to 5 mm long (Lewis, Obermeyer & Barnard 1972).

Related taxa

Gladiolus filiformis has an elongated, recurved, filiform perianth tube, which is diagnostic of the species (Goldblatt & Manning 1998). *Gladiolus pretoriensis* Kuntze is similar and is also a Southern Bankenveld endemic, but it is usually a smaller plant with smaller pink flowers. *Gladiolus pretoriensis* fruits are said to be wingless, whilst those of *G. filiformis* are heteromorphically winged. *Gladiolus filiformis* could also be confused with *G. oatesii* Rolfe, but this species has a funnel-shaped perianth tube and linear, as opposed to lanceolate, leaves.

Distribution and ecology

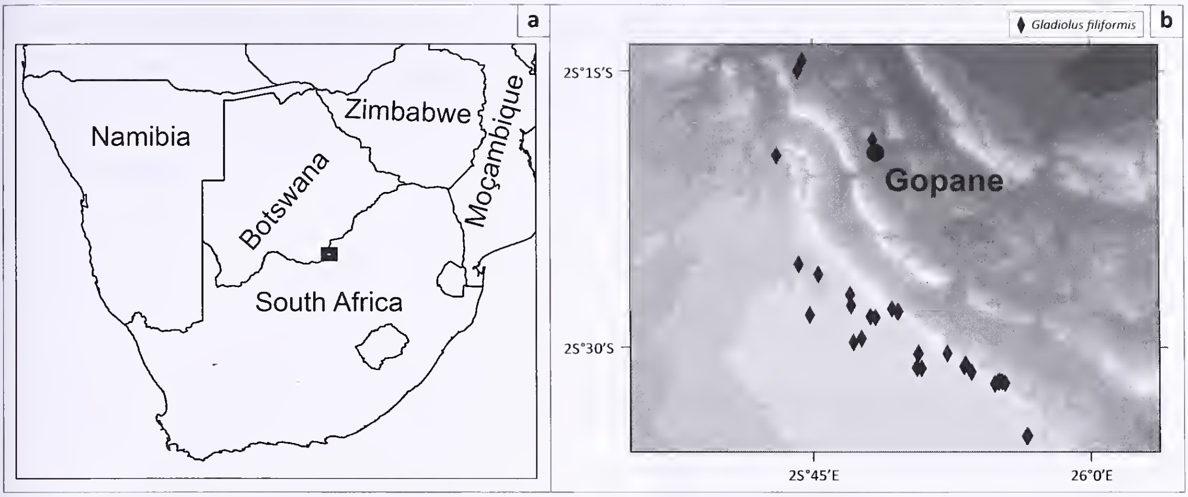
The type locality is stated as Gopane Mountains on a rocky koppie, growing in rocky red soil at an altitude of 1100 m.a.s.l. The Gopane Mountains are not indicated on any map, but two towns with the name are. The first reference applies to the remains of an old military base east of Skilpadhek Border Post (2525BC). The whole area around the base is above 1220 m.a.s.l. and we could find no rocky koppie with red soil in the vicinity. The second Gopane is the town in which the Livingston Mission Station (2525BD) is situated. Most of the area is above 1180 m.a.s.l. and there is a rocky koppie to the north-west, with red soil. This koppie is known as Sedukwane (1303 m.a.s.l.). It was on this koppie that we located *G. filiformis* at an altitude of 1290 m.a.s.l., hence this is most likely the type locality (Figure 2). Peeters, Gericke and Burelli, who collected the type, are therefore most probably in error as it is impossible for *G. filiformis* to have been collected at an altitude of 1100 m.a.s.l.

Gladiolus filiformis is presently only known from the extreme western sections of the Southern Bankenveld (Partridge *et al.* 2010), where it grows on hills, hill slopes and plateaus. The plant is not an edaphic specialist, having been observed growing in soils derived from sediments of the Transvaal supergroup, comprising banded ironstone, conglomerate and chert or dolomite areas. The type locality is situated on a dolerite koppie, the remains of a post–Transvaal supergroup volcanic plug. Most populations of *G. filiformis* occur in grassland, except for those towards its western extremities, including the type locality, which are found in open scrubland. Its presently known distribution, from the north-west (Maphephane) to its south-eastern extremity (Tweefontein), stretches across an expanse of 40 km.

Gladiolus filiformis was found growing sympatrically with *Gladiolus permeabilis* Delaroche subsp. *edulis* (Burchell ex

Source: Illustrations by Hermien Roux
Scale bar: (a) 4.0 mm; (b) 3.6 mm and (c) 0.5 mm.

FIGURE 1: *Gladiolus filiformis* vegetative and reproductive morphology depicting, (a) inflorescence, (b) capsules – open and unopened and (c) seed.



Source: Figure provided by Norbert Hahn

FIGURE 2: Distribution of *Gladiolus filiformis*, (a) regionally within South Africa and (b) locally within North West Province.

Ker Gawler) Obermeyer, but not with its near relatives *G. pretoriensis* or *G. oatesii*.

Conservation status

A word of caution is necessary in attempting a conservation assessment of this species. Flowering of the species was prolific in the seasons of December 2010 and December 2012 – January 2013 as a result of good rains in the beginning of December in both seasons, with plants flowering in their thousands. The period of October 2011 – February 2012 was a poor rainfall season, with only a few plants flowering. In the good seasons the plants bloomed mainly from December to January, whilst in the poor times they flowered sporadically from October to February.

At the type locality, grazing by goats could pose a threat, a road runs through two of the southern populations, a radio station is built at the third population and a pipeline transects the eastern populations. Notwithstanding the above there are no indications of the populations declining.

The present known extent of occurrence of this species is 287 km^2, thus it does not qualify as 'Critically Rare' (Goldblatt & Victor 2009). The estimated number of mature individuals far exceeds 100 000 and the populations seem stable, thus excluding criteria VU C or VU D1 (International Union for Conservation of Nature 2001). A status of 'Least Concern' is proposed, but this will need to be revised if future mining activities are embarked upon in the area.

Additional collections

BOTSWANA: Troverston, 25°14'30.024" S, 25°44'07.104" E, 11 Jan. 2013, *N. Hahn 3038* (NBG, ZPB). SOUTH AFRICA: **North West Province:** Sedukwana, 25°17'59.520" S, 25°47'55.038" E; 25°28'44.538" S, 25°50'12.276" E, 15 Dec. 2010, *N. Hahn 2767, 2772* (NBG, ZPB); Moilwas, 25°26'37.992" S, 25°49'11.016" E, 16 Feb. 2013, *N. Hahn, 3053* (ZPB); Tweefontein, 25°32'53.052" S, 25°55'42.618" E, 01 Jan. 2013, *N. Hahn 3033* (NBG, ZPB).

Acknowledgements

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

H.R. (North West Provincial Government) assisted with fieldwork and data capture, helped write the manuscript and drew the accompanying plate. N.H. (North West Provincial Government) did most of the fieldwork, the dissections for the diagnostic description and wrote most of the article.

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Lectotypification of *Kniphofia pauciflora* Baker (Asphodelaceae: Asphodeloideae)

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Background: Problems amongst the syntypes and duplicates were noted for the critically endangered *Kniphofia pauciflora* Baker.

Objective: To resolve the typification of *K. pauciflora*.

Method: Literature and specimens (including type material) were examined from relevant herbaria.

Results: Lectotypification was necessary in this case. The lectotype designated was *Wood 1096* (K) from 'Natal, Claremont flat' [KwaZulu-Natal, Clairmont flat]. This was undertaken to specify a single type specimen and to clarify the status of the duplicates. Also included is an account of the last remaining population of *K. pauciflora* at the Clairwood Racecourse, Durban, South Africa.

Conclusion: The lectotype was designated as *Wood 1096* (K).

Introduction

The earliest herbarium collection of *Kniphofia pauciflora* Baker that we have been able to locate is that made by Johann Wahlberg in 1841 in KwaZulu-Natal Province (previously Natal), South Africa and recorded as occurring between 'Port Natal and Pieter. Mauritzburg' (*Wahlberg s.n.*). The species was next collected by John Sanderson on 10 September 1858 in 'Port Natal, Clairmont flat' (*Sanderson 49*) and again in 1860 without a precise locality in 'Natal' (*Sanderson 416*). In October 1883, John Medley Wood made a collection in Clairmont (*Wood 1096*). Based on the specimens collected in 1860 (*Sanderson 416*) and 1883 (*Wood 1096*), Baker (1885) named and described the species. Wood made a further collection in 1892, again in Clairmont (*Wood 4662*). In August of the following year, Friedrich Schlechter collected the species near Clairmont, spelt as 'Claremont' on his label (*Schlechter 3160*). Using Schlechter's specimen, Baker (1904) described the new species *Kniphofia pedicellata* Baker. Berger (1908), subsequently reduced *K. pedicellata* to a synonym of *K. pauciflora*.

The two collections (*Sanderson 416* and *Wood 1096*) cited by Baker (1885, 1896) were treated by Codd (1968, 2005) as syntypes. The *Wahlberg s.n.* and *Sanderson 49* specimens were overlooked by Baker (1885, 1896) and Berger (1908). The *Wahlberg s.n.* specimen was determined by Codd in August 1961 and included in the citation of specimens in his treatment of *Kniphofia* Moench (Codd 1968).

As part of our current taxonomic research on *Kniphofia* species in southern Africa that are under threat and requiring conservation, we traced earlier known localities for species from herbarium records. For *K. pauciflora*, minor problems amongst the syntypes and duplicates were noted and it was found to be the only member of the genus not previously typified. We found it necessary to lectotypify the species to specify a single specimen and to clarify the status of the duplicates. In this note, we also provide an account of the last remaining population of *K. pauciflora* at the Clairwood Racecourse, Durban, South Africa.

Research method and design

A thorough review of the literature pertaining to this species was conducted (see 'Introduction' as well as 'Results and discussion'). Herbarium material, either actual specimens or images, were examined for the type and include collections housed in the Natural History Museum, London (BM), Bolus Herbarium, University of Cape Town, Cape Town (BOL), Royal Botanic Garden Edinburgh, Edinburgh (E), Royal Botanic Gardens, Kew (K), KwaZulu-Natal Herbarium, South African National Biodiversity Institute, Durban (NH), National Herbarium, South African National Biodiversity Institute, Pretoria (PRE), Swedish Museum of Natural History, Stockholm (S), South African Museum Herbarium, South African National Biodiversity Institute, Cape Town (SAM), Trinity College, Dublin (TCD) and Universität Zürich, Zürich (Z) (herbarium acronyms follow Holmgren, Holmgren and Barnett [1990]).

Results and discussion

Lectotypification of *Kniphofia pauciflora*

The specimen *Sanderson 416*, at K, has two intact open flowers and an undehisced capsule, whilst the duplicate at TCD has two intact old flowers. This distorts the characteristic inflorescence in *K. pauciflora* and does not match the description. Furthermore, the *Sanderson* specimen lacks a precise locality; information that is useful for determining *Kniphofia* species in KwaZulu-Natal. *Wood 1096* (K) is the most appropriate specimen for a type of the species as it best matches the description. There are two specimens on the sheet with full inflorescences clearly representative of the species. Specimens with the same collector number are also held at NH and BOL but show discrepancies in the collecting dates on their labels. The Kew Herbarium received the specimen from John Medley Wood in April 1881 and this is written on the specimen sheet as well as in the record of plant determinations sent from the Director of K to NH. In the Herbarium Catalogue (Numbers 1–1944) at NH (Figure 1a), *Wood 1096* is recorded as collected in October with no year and is amongst entries collected during 1880, starting with *Wood* number 790 and ending with 1187 for that year. The label on the NH specimen in Wood's handwriting indicates the collection date as October 1883 (Figure 1b). The collection date on the BOL specimen label is November 1886, again in Wood's handwriting (Figure 1c). It is inferred that *Wood 1096* was collected in 1880 and received by K in 1881. Presumably the specimens collected in October 1883 (NH) and November 1886 (BOL) were collected during return visits to the same population and therefore allocated the collector number of the year 1880.

The available evidence suggests that of the three specimens numbered *Wood 1096*, only the K specimen collected in 1880 constitutes original material and is therefore available for lectotypification. The NH and BOL collections must be regarded as topotypes, without nomenclatural standing.

Kniphofia pauciflora *Baker* in Journal of Botany, London 23: 280 (1885); Baker: 65, t.10 (1892a); Baker: t.7269 (1892b); Baker: 279 (1896); Mallett: 101, t.43 (1906); Berger: 41 (1908); Codd: 438 (1968); Codd: t.1995 (1989); Codd: 31 (2005). Type: South Africa, KwaZulu-Natal: 'Natal, Claremont flat', Wood 1096 (K—image!, lecto. designated here) (Figure 2, barcode/id K000256208).

K. pedicellata Baker: 998 (1904). Type: South Africa, KwaZulu-Natal: 'Clairmont', Schlechter 3160 (Z—image!, holo.).

Distribution and habitat

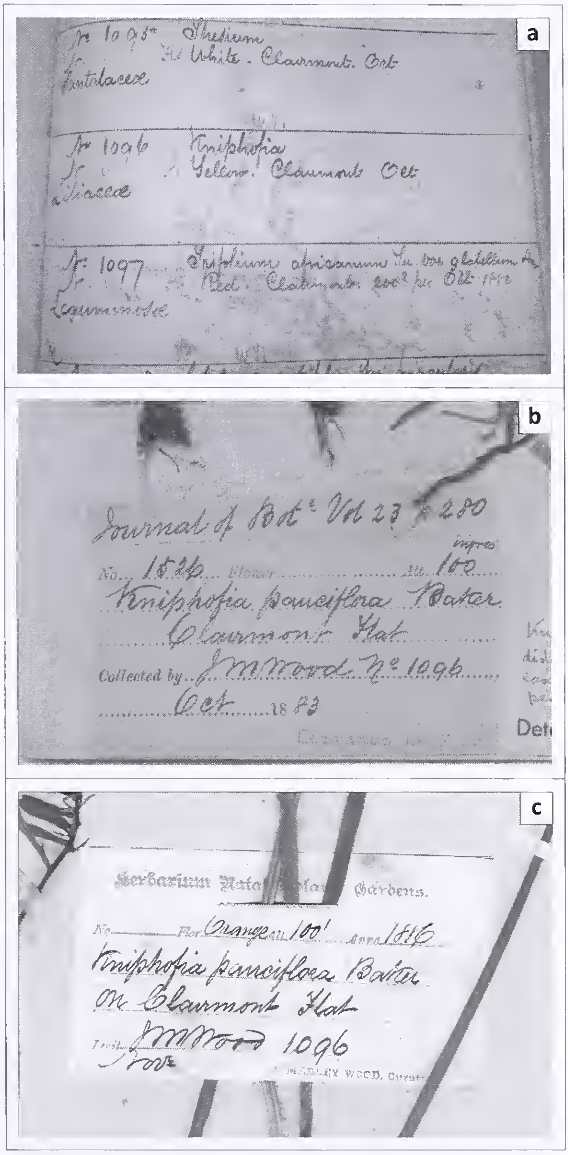
Kniphofia pauciflora is a South African endemic, restricted to KwaZulu-Natal Province. It is currently known from a single locality in Durban, namely the inner field of the track in the Clairwood Racecourse. Prior to 1956, *K. pauciflora* was known to have a wider distribution within the Durban area but populations were reduced through urban development. Codd (1968) makes reference to J.W. Reyburn's observation of the Pinetown (Mariannhill) area as being drained and the population could no longer be found.

Ecology

The species grows at 24 m.a.s.l. in seasonally waterlogged grassland, in full sun (Figure 3a). The soil is dark-coloured and sandy.

Conservation status

The status of *K. pauciflora* is 'Critically Endangered' according to Raimondo *et al.* (2009). The species was



No 1095 Thesium
White . Claremont. Oct
Santalaceae

No 1096 Kniphofia
Yellow. Claremont Oct
Liliaceae

No 1097 Trifolium africanum
Red . Claremont.

Journal of Botᶜ Vol 23 p 280
No. 1526 ... 100
Kniphofia pauciflora Baker
Claremont Flat
Collected by J M Wood No 1096
Oct 1883

Herbarium Natal Botanic Gardens.
No. Flor Orange alt 100' Anno 1886
Kniphofia pauciflora Baker
On Claremont Flat
J M Wood 1096
Nov
MEDLEY WOOD, Curator

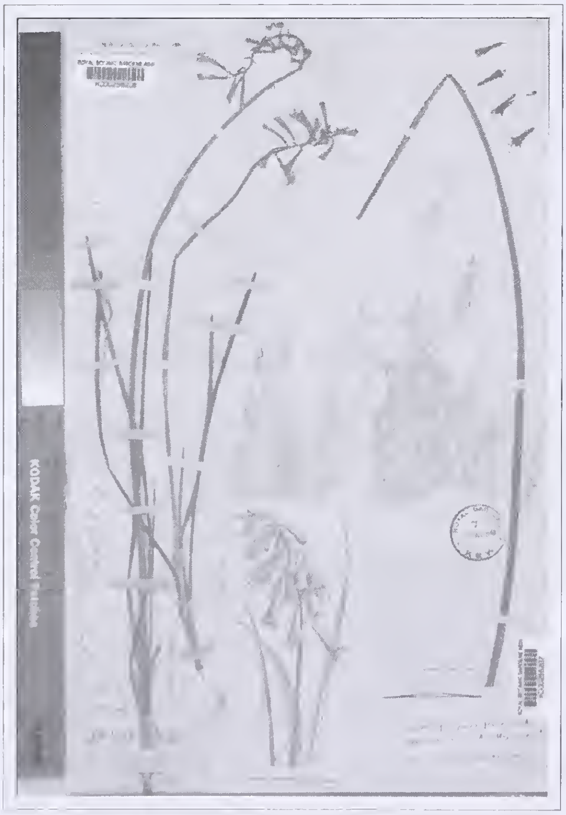
Source: Reproduced with permission from Bolus Herbarium (BOL) and South African National Biodiversity Institute, KwaZulu-Natal Herbarium (NH)

FIGURE 1: *Kniphofio* data depicting, (a) photograph of KwaZulu-Natal Herbarium Catalogue showing entry for 1096 in Wood's handwriting, (b) label data on KwaZulu-Natal Herbarium specimen and (c) label data on Bolus Herbarium specimen.

previously thought to be extinct (Hilton-Taylor 1996; Scott-Shaw 1999). In September 2012, 21 clumps of plants were recorded at Clairwood Racecourse, with an average of six inflorescences per clump (Figure 3b). The population was successful in its habitat as a result of the interest shown by Gold Circle, the former owners of the racecourse, and conservation efforts by the lead author since 1968. The present owners of the racecourse are Capital Property Fund. The habitat (and species) is now threatened by a proposed logistics and distribution park to support the development of a dug-out port at the former Durban International Airport (South Durban Basin). This confirms its status as 'Critically Endangered'.

Other material examined

SOUTH AFRICA, **KwaZulu-Natal:** Port Natal [Durban], Claremont flat, 10 Sept. 1858, Sanderson 49 (TCD); Clairmont, Oct. 1880, Wood 1096 (K); Clairmont flat, Oct. 1883, Wood 1096 (NH); on Clairmont flat, Nov. 1886, Wood 1096 (BOL); Clairmont, near Durban, 22 Sept. 1892, Wood 4662 (BOL, E, NH, SAM, Z); near Claremont, Aug. 1893, Schlechter 3160 (Z, two sheets); Clairmont, 12 Sept. 1898, Wood 7293 (PRE); Clairmont, 30 Sept. 1899, Wood 7639 (BM); Clairmont, 25 Sept. 1907, Wood 10495 (NH, Z); Clairwood Racecourse, 07 Sept. 1968, Baijnath 593 (UDW); Clairwood Racecourse, ex. cult., May 1985, Baijnath s.n. PRE58798 (PRE); near Durban, Jan. 1914, Indian Collector s.n. NH15971/2 (NH, two sheets); Port Natal and Pieter. Mauritzburg [Durban and Pietermaritzburg], 1841, Wahlberg s.n. (S); Pinetown District, Mariannhill, Oct. 1951, Reyburn s.n. NH40464 (NH); Pinetown District, Mariannhill, Nov. 1954, Reyburn s.n. NH42151, PRE 37002 (NH, PRE); Pinetown, ex cult., 12 Nov. 1956, Reyburn s.n. PRE 37003 (PRE); without precise locality, 1860, Sanderson 416 (K, TCD).

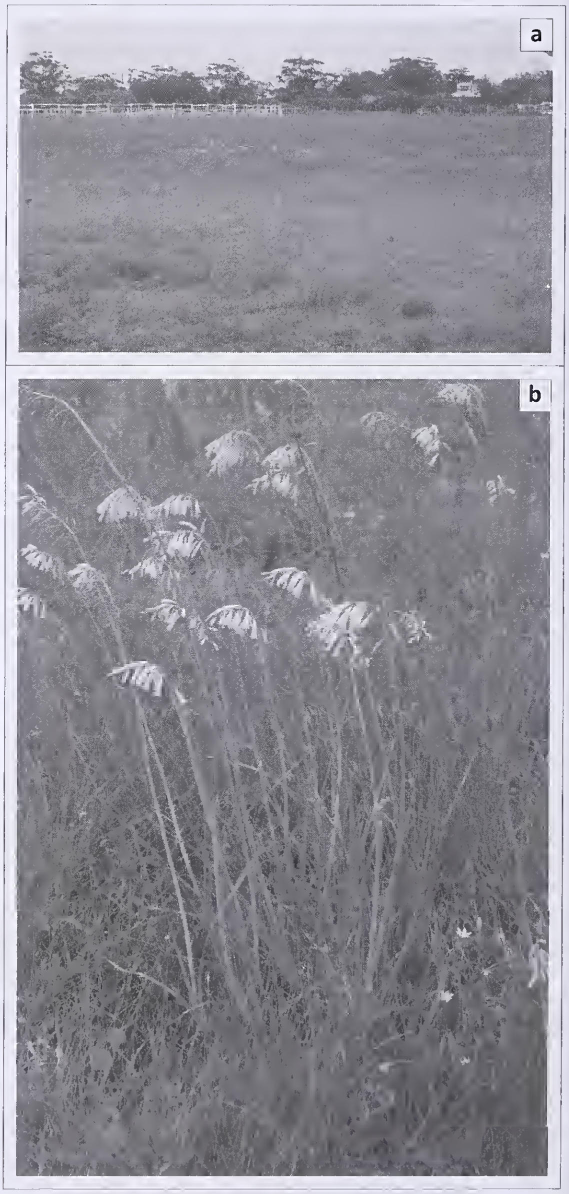


Source: Reproduced with the consent of the Board of Trustees, Royal Botanic Gardens, Kew

FIGURE 2: Image of lectotype of *Kniphofia pauciflora* (*Wood 1096*).

Acknowledgements

The Curators of BM, BOL, E, K, NH, PRE, S, SAM, TCD and Z are thanked for providing images of *K. pauciflora* specimens.



Source: Photographs by H. Baijnath

FIGURE 3: *Kniphofia pauciflora* as seen growing within the inner field of the track in the Clairwood Racecourse, Durban, South Africa, (a) habitat and (b) clumps.

Dr Yashica Singh kindly allowed access to J.M. Wood's collecting records and communications with K held at NH. South African National Biodiversity Institute's Biodiversity Information Management Directorate, Cape Town provided PRECIS data and its Mary Gunn Library, Pretoria made available earlier literature. University of KwaZulu-Natal is thanked for research support. We are grateful to Gold Circle staff for access to the Clairwood Racecourse site.

Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

H.B. (University of KwaZulu-Natal) was responsible for data collection. Both H.B. and S.R. (University of KwaZulu-Natal) contributed to the manuscript preparation.

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Nomenclatural adjustments in African plants 1

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Background: Ongoing systematic studies of the African flora necessitate periodic nomenclatural adjustments and corrections.

Objectives: To effect requisite nomenclatural changes.

Method: Relevant literature was surveyed and type material located and studied.

Results: Nomenclatural corrections were published in *Justicia* L. (Acanthaceae), *Babiana* Ker Gawl. and *Geissorhiza* Ker Gawl. (Iridaceae) and *Zaluzianskya* F.W.Schmidt (Scrophulariaceae).

Conclusions: Firstly, a complete enumeration of all southern African species of *Justicia* was provided within the infrageneric classification for the genus accepted by Graham (1988) and later modified and expanded by Ensermu (1990) and Hedrén (1990). In this circumscription, *Justicia* includes such well-established segregates in an African context as *Adhatoda* Miller, *Aulojusticia* Lindau, *Duvernoia* E.Mey. ex Nees, *Monechma* Hochst. and *Siphonoglossa* Oersted. Both southern African species of *Adhatoda* were transferred to *Justicia*, as well as all of the southern African species of *Monechma*, with eight new combinations or replacement names provided. All species were placed to section within *Justicia*. Secondly, the type of *Gladiolus nervosus* Lam. (1788) was considered to be conspecific with *Gladiolus strictus* Aiton (1789) and is therefore the earliest available name for the species currently known as *Babiana stricta* (Aiton) Ker Gawl. The new combination *Babiana nervosa* (Lam.) Goldblatt & J.C.Manning was provided. Thirdly, *Geissorhiza ornithogaloides* has been regarded as a new species described by F.W. Klatt (1866) but the name should be treated as the combination *G. ornithogaloides* (Lichst. ex Roem. & Schult.) Klatt, based on *Ixia ornithogaloides* Lichst. ex Roem. & Schult. (1817a). Examination of the type showed that it is conspecific with *Geissorhiza marlothii* R.C.Foster (1941) and it is therefore the valid name for the taxon treated as *G. ornithogaloides* subsp. *marlothii* (R.C.Foster) Goldblatt. An epitype for the taxon was designated and the new combination *G. ornithogaloides* subsp. *flava* (Klatt) Goldblatt & J.C.Manning was provided for the taxon currently treated as *G. ornithogaloides* subsp. *ornithogaloides*. Lastly, *Reyemia* Hilliard was reduced to a synonym of *Zaluziaskya* as sect. *Reyemia* (Hilliard) J.C.Manning & Goldblatt and the new combination *Zaluziaskya chasmanthiflora* (Hilliard) J.C.Manning & Goldblatt was provided. A neotype was selected for *Zaluziaskya nemesioides* Diels.

1. Synopsis of the genus *Justicia* L. (Acanthaceae) in southern Africa, with eight new combinations for species of *Adhatoda* Miller and *Monechma* Hochst.

Authors: John C. Manning and Peter Goldblatt

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Introduction

Justicia L. (Acanthaceae: Ruellieae: Justiciinae) (Scotland & Vollesen 2000) is the largest genus of Acanthaceae, containing at a conservative estimate some 600 spp. (Graham 1988). As noted by Graham (1988) in her landmark review of the delimitation of *Justicia*, the circumscription of the genus has historically followed one of two divergent trends – either the adoption of a broad view of the genus, or towards the recognition of greater or lesser numbers of small segregate genera. The worldwide distribution of *Justicia* and the high degree of morphological variation amongst the species has hampered the general acceptance of one or the other of these two options, with workers generally focused on regional floristic accounts and thus missing the taxonomic wood for the trees. The result has been a confusing situation, whereby some regional floras recognise one or more of the segregate genera whilst others do not. The need for a stable, or at least comprehensive, classification of the genus stimulated Graham (1988) to undertake the first worldwide morphological survey of *Justicia* since Lindau's (1895) revision for *Die natuürlichen Pflanzenfamilien*. The result of her extensive study of vegetative and floral morphology and pollen ultrastruture was the conviction that the genus is most appropriately and satisfactorily circumscribed in the broad sense favoured by Lindau (1895), thus including such well-established segregates in an African context as *Adhatoda* Miller, *Aulojusticia* Lindau, *Duvernoia* E.Mey. ex Nees and *Siphonoglossa* Oersted.

The resulting infrageneric classification for *Justicia* proposed by Graham (1988) recognised sixteen sections, seven of them in southern Africa, and enumerated 295 species, representing an estimated half of the species in the genus. Amongst the species not listed were several from southern Africa. Although clearly not complete, Graham's classification forms the basis for future taxonomic studies in the genus and a framework in which to incorporate additional species.

Monechma Hochst. was retained by Graham (1988) as distinct from *Justicia*. The genus is traditionally diagnosed by its two-seeded capsules containing smooth, compressed seeds; whereas, *Justicia* is characterised by having mainly four-seeded (rarely two-seeded) capsules containing at most weakly compressed, mostly rugose (rarely smooth) seeds. The validity of this distinction in the light of the occurrence of intermediate forms was questioned by Hedrén (1990), who concluded that the two taxa could not be upheld at generic level. Accordingly, he reduced *Monechma* to a section within *Justicia*, as had been done earlier by Lindau (1895), thus increasing the number of sections in southern Africa to eight. In the same year, *J.* subsect. *Ansellia* (C.B.Clarke) V.A.W.Graham was raised by Ensermu (1990) back to sectional level as sect. *Ansellia* C.B.Clarke.

Graham's (1988) classification of *Justicia* was not implemented for the floristic treatment of the tribe for southern Africa (Baden *et al.* 1995) but has been adopted in later regional treatments for sub-Saharan Africa (Scotland & Vollesen 2000). As a result, the generic circumscriptions currently accepted for the southern African subregion are now out of line with those for the *Flora of tropical East Africa* (Darbyshire, Vollesen & Kelbessa 2010) and the *Flora of Somalia* (Hedrén & Thulin 2006) to name just two, both of which adopt the broad circumscription of *Justicia* accepted by Graham (1988) and Hedrén (1990), as will the planned volume for the Flora Zambesiaca region.

A start at integrating the treatment of the southern African flora with recent accounts for the rest of the continent was made by the formal transfer to *Justicia* of the remaining species of *Aulojusticia* (= *Siphonolossa* spp.) by Manning and Goldblatt (2012) and *Duvernoia* by Cubey (2006). What remains to be effected is the transfer to *Justicia* of the two southern African species of *Adhatoda* and all of the southern African species of *Monechma*, several of which require new combinations or replacement names, as well as the placement within the appropriate sections in Graham's (1988) classification of the southern African species that were left unplaced by her. We do this here and provide a complete enumeration of the southern African species within the infrageneric classification developed by Graham (1988) and modified and expanded by Ensermu (1990) and Hedrén (1990). This will facilitate the uniform curation of the southern African material in a system compatible with that adopted elsewhere in sub-Saharan Africa.

Results

The primary characters used by Graham (1988) to circumscribe her sections are the structure of the inflorescence and the pollen, notably the number of apertures and the condition of the margocolpi. Placing the currently unplaced species in an appropriate section in the system was mostly straightforward through direct association with allied species already in the system. Notable exceptions to this are the two southern African species of *Adhatoda*, *A. andromeda* (Lindau) C.B.Clarke and *A. densiflora* (Hochst.) J.C.Manning. Their association with the genus *Adhatoda* dates from the treatment of the family for *Flora capensis* by Clarke (1901), who included them in *Adahatoda* rather than in *Justicia* on account of their pollen having entire rather than areolate margocolpi, the latter then considered to be diagnostic for *Justicia*. Their placement in *Adhatoda* was later questioned by Manning and Getliffe-Norris (1995), who considered that they merited segregation from the tropical African and Indian members of the genus. These species, including the type of *Adhatoda*, were assigned by Graham (1988) to sect. *Vasica*, diagnosed by a shrubby habit and 2-aperturate pollen.

The South African *Adhatoda* species, both perennial herbs with 3-aperturate pollen, would certainly be misplaced in sect. *Vasica* and conform best to the small sect. *Rhaphidospora* (Nees) T.Anderson, based on the combination of their contracted, cymose infloresences and 3-aperturate pollen with entire margocolpi. This pollen type is otherwise found only in sect. *Betonica* and in the New World sect. *Drejerella*, both of which have strictly simple, spike-like inflorescences. The pollen type in *Adhatoda andromeda* and *Adhatoda densiflora* is evidently ancestral in *Justicia* (Graham 1988) and thus not phylogenetically informative, whilst the highly condensed inflorescences are difficult to interpret. It is possible that the two species are better segregated in a separate section but a trend towards a similar contraction of the inflorescence is evident in *Justicia bolusii* C.B.Clarke, which seems correctly placed in this section, and we include them here pending evidence to the contrary.

We place *Justicia minima* A.Meeuse, unusual amongst African species in its 4-fid calyx, in sect. *Tyloglossa*, largely on its similarity in inflorescence and pollen morphology to *Justicia linearispica*, placed here by Graham (1988).

Our placement in sect. *Harniaria* of the species previously treated as the genus *Aulojustcia*, as recommended by Hedrén (1990), is entirely consistent with the derived, sessile inflorescences and 2-aperturate pollen with areolate margocolpi that define this section. Similarly, placement of

Justicia cuneata Vahl. in the same section accords with its sessile, 1-flowered axillary cymes and areolate margocolpi.

The southern African species of *Monechma* as treated by Immelman (1995) were placed *en bloc* in sect. *Monechma*, following Hedrén (1990). Inflorescence morphology in the section is very variable (Hedrén 1990), raising the possibility that the section is not monophyletic, although all species examined share derived 2-aperturate pollen with areolate margocolpi.

Taxonomic treatment

Justicia L., Species plantarum: 15 (1753).

Type: *J. hyssopifolia* L., lecto., designated by Hitchcock & Green (1929), fide Graham (1988).

Description

Herbaceous or shrubby perennials or annuals. *Leaves*: opposite, simple, entire. *Inflorescence*: a simple false-spike or compound with dichasial or spike-like subunits. *Flowers*: each subtended by a bract and two bracteoles (or bracts absent in simple dichasia), white, yellow, pink to purple or red. *Calyx*: mostly 5-partite to near base, rarely ± halfway, segments equal or with 1 segment reduced or absent and then 4-partite. *Corolla*: funnel-shaped or trumpet-shaped, bilabiate, upper lip usually bifid (rarely entire), lower lip trilobed, throat usually pubescent within. *Stamens*: 2, dithecous [rarely monothecous fide Graham (1988) but not in the southern African taxa], thecae equal or unequal, usually superposed, often oblique, lower usually with sterile tail-like appendage. *Pollen*: 2 or 3(4) porate, subprolate to perprolate, surface finely reticulate, trema ornamented with 4 or more margcocolpi, these either entire and band-like or discontinuous and forming areoli or peninsulae. *Ovary*: with 2 ovules per locule, pubescent or glabrous; style lying within channel (rugula) along upper lip; stigma minutely 2-lobed. *Capsules*: ± clavate with sterile stipe, 4-seeded, or 2-seeded or 3-seeded by abortion, valves remaining entire during dehiscence or rarely septum and adjacent capsule walls rising (placenta elastic). *Seeds*: supported by retinacula, spheroidal to discoid, testa smooth or variously ornamented. ± 600 spp., worldwide in tropics and subtropics.

I. Sect. ***Vasica*** Lindau. Type: *J. adhatoda* L., lecto., designated by Graham: 584 (1988).

> *Adhatoda* Miller. Type: *Adhatoda 'zeylesianum'* Miller = *J. adhatoda* L.
> *Duvernoia* E.Mey. ex Nees. Type: *D. adhatodoides* E.Mey. ex Nees = *J. adhatodoides* (E.Mey. ex Nees) V.A.W.Graham.

Shrubby perennials. *Inflorescence*: a simple false-spike with 1 or 3 flowers per axil. *Calyx*: 5-partite with segments equal. *Corolla*: 12 mm – 38 mm long, white or cream. *Anther*: thecae equal or unequal, superposed and oblique, appendages mostly small. *Pollen*: 2-aperturate, margocalpi areolate or entire. *Ovary*: glabrous or pubescent. *Capsules*: sterile for 0.4–0.6 length. *Seeds*: scarcely or distinctly compressed, rugulose-tuberculate-alveolate.

J. aconitiflora (A.Meeuse) Cubey [*Duvernoia aconitiflora* A.Meeuse]
J. adhatodoides (E.Mey. ex Nees) V.A.W.Graham [*Duvernoia adhatodoides* E.Mey. ex Nees, *Adhatoda duvernoia* C.B.Clarke, nom illegit. superfl.]

II. Sect. ***Betonica*** (Nees) T.Anderson [*Adhatoda* sect. *Betonica* Nees]. Type: *J. betonica* L., lecto., designated by Graham: 586 (1988).

Herbaceous or shrubby perennials. *Inflorescence*: spiciform, 1-sided with one flower per node, bracts conspicuous and usually exceeding calyx, often ± scarious. *Calyx*: 5-partite with segments equal or 4-partite plus one reduced segment. *Corolla*: 2.4 mm – 13.0 mm long, white, pale pink or blue. *Anther*: thecae equal or slightly unequal, superposed and oblique, appendages large or rarely lacking. *Pollen*: 3-aperturate, margocolpi entire. *Ovary*: glabrous or pubescent. *Capsules*: sterile for ± 0.4 length. *Seeds*: scarcely or distinctly compressed, rugulose-tuberculate or appressed-pubescent.

J. betonica L.
> *J. betonicoides* Burkill & C.B.Clarke
> *J. cheiranthifolia* Nees

J. montis-salinarum A.Meeuse

BOX 1: Key to *Justicia* L. (Acanthaceae) sections in southern Africa.

1A. Inflorescences sessile or very shortly pedunculate (peduncle < 10 mm long), 1-flowered to 6-flowered:
  2A. Mature capsules with one smooth, shiny seed per locule, always dehiscent; pollen 2-aperturate, margocolpi areolate .... VII. sect. *Monechmo*
  2B. Mature capsules with two seeds per locule, rarely only one and then seeds either rough or capsules indehiscent; pollen various:
    3A. Inflorescences sessile; pollen 2-aperturate, margocolpi areolate .... VI. sect. *Hornierio*
    3B. Inflorescences shortly pedunculate; pollen 2-aperturate, margocolpi entire........ V. sect. *Justicia*
1B. Inflorescences distinctly pedunculate or more than 7-flowered:
  4A. Inflorescence a simple false-spike (sometimes terminal and in adjacent axils giving a compound appearance); ovary pubescent; pollen margocolpi entire:
    5A. Flowers two or more per node, the inflorescence thus cylindrical; bracts oblanceolate to elliptic, foliar; calyx lobes shorter than tube; pollen 2-aperturate, margocolpi entire .... I. sect. *Vosico*
    5B. Flowers mostly solitary at the nodes, the inflorescence thus one-sided; bracts ovate and ± scarious with green veins; calyx lobes longer than tube; pollen 3-aperturate, margocolpi entire........ II. sect. *Betonico*
  4B. Inflorescence either compound and evidently cymose, or spike-like but then ovary glabrous; pollen margocolpi entire or areolate:
    6A. Inflorescence evidently dichasial, the axis glandular; ovary mostly pubescent; pollen 3-aperturate, margocolpi entire or ± areolate........ III. sect. *Rhophidosporo*
    6B. Inflorescence spike-like; ovary glabrous:
      7A. False-spike with 1–3(–15) flowers per node; pollen 3-aperturate, margocolpi areolate .... IV. sect. *Tyloglosso*
      7B. False-spike with 1 flower per node; pollen 2-aperturate, margocolpi areolate .... VIII. sect. *Ansellia*

III. Sect. **Rhaphidospora** (Nees) T.Anderson [*Rhaphidospora* Nees]. Type: *J. glabra* Koenig ex Roxb. = *J. scandens* Vahl

Shrubby or herbaceous perennials. *Inflorescence*: dichasial, axis glandular. *Calyx*: 5-partite with segments equal. *Corolla*: 9 mm – 27 mm long, white or cream to pale pink. *Anther*: thecae equal or slightly unequal, superposed and oblique, appendages large. *Pollen*: 3-aperturate, margocalpi entire or ± areolate. *Ovary*: mostly pubescent. *Capsules*: sterile for ± 0.5 length. *Seeds*: scarcely or distinctly compressed, rugulose-tuberculate or rarely echinate.

Group A: Shrubs; inflorescence a ± open or contracted cyme.

J. bolusii C.B.Clarke
J. campylostemon (Nees) T.Anderson [*Leptostachya campylostemon* Nees]
J. scandens Vahl
    J. glabra Koenig ex Roxb.

Group B: Herbaceous perennials; inflorescence a highly contracted, strobilate cyme. (Note: these two species are placed here based on the combination of their highly contracted dichasial inflorescences and 3-aperturate pollen with entire margocolpi. This pollen type is otherwise found only in sect. *Betonica* and in the New World sect. *Drejerella*, both of which have strictly simple, spike-like inflorescences.)

J. andromeda (Lindau) J.C.Manning & Goldblatt, *comb. nov. Duvernoia andromeda* Lindau in Engler & Prantl, Die natürlichen Pflanzenfamilien 4 (3B): 339 (1895). *Adhatoda andromeda* (Lindau) C.B.Clarke: 76 (1901).
J. densiflora (Hochst) J.C.Manning & Goldblatt, *comb. nov. Gendarussa densiflora* Hochst. in Flora 28: 71 (1845). *Adhatoda densiflora* (Hochst.) J.C.Manning in Manning & Getliffe-Norris: 490 (1985).

IV. Sect. **Tyloglossa** (Hochst.) Lindau [*Tyloglossa* Hochst.]. Type: *J. palustris* (Hochst.) T.Anderson, lecto designated by Graham: 590 (1988).

Herbaceous perennials. *Inflorescence*: compound but spike-like with 1–3(–15) flower per node. *Calyx*: 5-partite with segments equal (rarely 4-partite). *Corolla*: 5 mm – 12 mm long, white, yellow or purple. *Anther*: thecae equal, superposed and parallel or oblique, appendages large. *Pollen*: 3-aperturate, margocolpi areolate. *Ovary*: glabrous. *Capsules* sterile for ± 0.35 length. *Seeds*: scarcely compressed, ammonite-like or rugose.

J. flava (Vahl) Vahl [*Dianthera flava* Vahl]
    J. fasciata Nees
J. kirkiana T.Anderson
J. minima A.Meeuse (Note: placed here on account of its spike-like inflorescence and 3-aperturate pollen with areolate margocolpi. Although the white flowers and 4-partite calyx are anomalous in the section, *L. linearispica* C.B.Clarke from tropical Africa, placed here by Graham (1988) as a 'Peripheral species', has a very similar inflorescence and 4-partite calyx with the fifth segment reduced.)
J. petiolaris (Nees) T.Anderson
    subsp. ***petiolaris***
    subsp. ***bowiei*** (C.B.Clarke) Immelman [*J. bowiei* C.B.Clarke]
    subsp. ***incerta*** (C.B.Clarke) Immelman [*J. incerta* C.B.Clarke]

V. Sect. ***Justicia***

Shrubs or perennials. *Inflorescence*: a simple dichasium, bracts absent. *Calyx*: 5-partite with segments equal. *Corolla*: 17 mm – 21 mm long, white or cream. *Anther*: thecae equal or slightly unequal, level or slightly superposed and oblique, appendages large. *Pollen*: 2-aperturate, margocolpi entire. *Ovary*: glabrous. *Capsules*: sterile for ± 0.5 length. *Seeds*: not compressed, verrucose.

J. cordata (Nees) T.Anderson [*Leptostachya cordata* Nees]
J. guerkeana Schinz
J. orchioides L.f.
    subsp. ***orchioides***
    subsp. ***glabrata*** *Immelman*
J. platysepala (S.Moore) P.G.Mey. [*Monechma platysepala* S.Moore]
J. thymifolia (Nees) C.B.Clarke [*Adhatoda thymifolia* Nees]

VI. Sect. **Harnieria** (Solms-Laub.) Benth. [*Harnieria* Solms-Laub.]. Type: *H. dimorphocarpa* Solms-Laub = *J. heterocarpa* T.Anderson
    Aulojusticia Lindau. Type: *A. linifolia* Lindau = *J. linifolia* (Lindau) V.A.W.Graham
    [*Siphonoglossa* pp. excl. type.]

Shrubs, herbaceous perennials or annuals. *Inflorescence*: a sessile axillary cluster of ± sessile flowers, bracts usually absent. *Calyx*: 5-partite with segments equal. *Corolla*: funnel-shaped or trumpet-shaped with short or elongate tube, 5 mm – 58 mm long, white or yellow to lilac or purple. *Anther*: thecae equal, superposed and parallel or oblique, appendages large. *Pollen*: 2-aperturate, margocolpi areolate. *Ovary*: glabrous. *Capsules*: sterile for ± 0.3 length. *Seeds*: scarcely compressed, rugulose-tuberculate.

Group A: Corolla tube shorter than lips.

J. capensis Thunb.
J. cuneata Vahl (Note: placed here on account of its 1-flowered, sessile axillary cymes and 2-aperturate pollen with areolate margocolpi.)
    subsp. ***cuneata***
    subsp. ***hoerleiniana*** (P.G.Mey.) Immelman [*J. hoerleiniana* P.G.Mey.]
    subsp. ***latifolia*** (Nees) Immelman [*Gendarussa orchoides* subsp. *latifolia* Nees]
J. heterocarpa T.Anderson
    subsp. ***heterocarpa***
    subsp. ***dinteri*** (S.Moore) Hedrén [*J. dinteri* S.Moore]

J. odora (Forssk.) Vahl [*Dianthera odora* Forssk.]
J. protracta (Nees) T.Anderson [*Gendarussa protracta* Nees]
J. kraussii C.B.Clarke
    subsp. ***protracta***
    subsp. ***rhodesiana*** (S.Moore) Immelman [*J. rhodesiana* S.Moore]
J. puberula Immelman

Group B: Corolla tube longer than lips.

J. linifolia (Lindau) V.A.W.Graham [*Aulojusticia linifolia* Lindau, *Siphonoglossa linifolia* (Lindau) C.B.Clarke]
J. nkandlaensis (Immelman) J.C.Manning & Goldblatt [*Siphonoglossa nkandlaensis* Immelman]
J. tubulosa (Nees) T.Anderson [*Adhatoda tubulosa* Nees]
    Gendarussa leptantha Nees, *Siphonoglossa leptantha* (Nees) Immelman
    subsp. ***tubulosa***
    subsp. ***late-ovata*** (C.B.Clarke) J.C.Manning & Goldblatt [*J. pulegioides* var. *late-ovata* C.B.Clarke]

VII. Sect. ***Monechma*** (Hochst.) T.Anderson [*Monechma* Hochst.]. Type: *J. bracteata* (Hochst.) Zarb.

Shrubs or annual or perennial herbs. *Inflorescence*: a terminal spike, axillary clusters, or scattered. *Calyx*: 5-partite with segments equal. *Corolla*: 5 mm – 19 mm long, white, red or yellow. *Anther*: thecae equal or the lower slightly larger, superposed, appendages large. *Pollen*: 2-aperturate, margocolpi areolate. *Ovary*: glabrous or almost so. *Capsule*: sterile for 0.3–0.5 length. *Seeds*: compressed, smooth, sometimes fringed.

J. callothamnum (Munday) J.C.Manning & Goldblatt, *comb. nov. Monechma callothamnum* Munday in South African Journal of Botany 53: 140 (1987).
J. cleomoides S.Moore [*Monechma cleomoides* (S.Moore) C.B.Clarke]
J. crassiuscula (P.G.Mey.) J.C.Manning & Goldblatt, *comb. nov. Monechma crassiusculum* P.G.Mey. in Mitteilungen der Botanischen Staatssammlung München 3: 604 (1960).
J. debilis (Forssk.) Vahl. [*Monechma debile* (Forssk.) Nees]
J. desertorum Engl. [*Monechma desertorum* (Engl.) C.B.Clarke]
J. distichotrichum Lindau [*Monechma distichotrichum* (Lindau) P.G.Mey.]
J. divaricata Licht. ex Roem. & Schult. [*Monechma divaricatum* (Licht. ex Roem. & Schult.) C.B.Clarke [as '(Nees) C.B.Clarke'] [Note: the formal publication of Lichtenstein's manuscript name '*Justicia divaricata*' by Roemer and Schultes (1817a) has been overlooked until now, and the later *Adhatoda divaricata* Nees (1847) has been erroneously accepted as the basionym for the taxon.]
J. dregei J.C.Manning & Goldblatt, *nom. nov.* pro *Monechma mollissimum* (Nees) P.G.Mey. in Mitteilungen der Botanischen Staatssammlung München 2: 304 (1957), non *Justicia mollissima* (Nees) Y.F.Deng & T.F.Daniel (2011). *Adhatoda mollisima* Nees: 391 (1847). (Note: the replacement epithet honours J.F. Drège who collected the type.)
J. fleckii J.C.Manning & Goldblatt, *nom. nov.* pro *Monechma grandiflorum* Schinz in Vierteljahrsschrift der Naturforschenden Gesellschaft in Zürich 61: 441 (1916), non *J. grandiflora* Dum. Cours. (1811). (Note: the replacement epithet honours E. Fleck who collected the type.)
J. genistifolia Engl. [*Monechma genistifolium* (Engl.) C.B.Clarke]
    subsp. ***genistifolia***
    subsp. ***australe*** (P.G.Mey.) J.C.Manning & Goldblatt, ***comb. nov.*** *Monechma australe* P.G.Mey. in Mitteilungen der Botanischen Staatssammlung München 3: 602 (1960). [*Monechma genistifolium* subsp. *australe* (P.G.Mey.) Munday]
J. incana (Nees) T.Anderson [*Gendarussa incana* Nees]
J. karroica J.C.Manning & Goldblatt, *nom. nov.* pro *Monechma robustum* Bond in Journal of South African Botany 6: 67 (1940), non *Justicia robusta* T.Anderson ex C.B.Clarke (1900).
J. leucoderme Schinz [*Monechma leucoderme* (Schinz.) C.B.Clarke]
J. namibensis J.C.Manning & Goldblatt, *nom. nov.* pro *Monechma calcaratum* Schinz in Vierteljahrsschrift der Naturforschenden Gesellschaft in Zürich 61: 441 (1916), non *J. calcarata* Wall. (1830), nec Hochst. (1843).
J. salsola S.Moore [*Monechma salsola* (S.Moore) C.B.Clarke]
J. saxatilis (Munday) J.C.Manning & Goldblatt, *comb. nov. Monechma saxatile* Munday in South African Journal of Botany 3: 363 (1984).
J. serotina (P.G.Mey.) J.C.Manning & Goldblatt, *comb. nov. Monechma serotinum* P.G.Mey. in Mitteilungen der Botanischen Staatssammlung München 11: 112 (1973).
J. spartioides T.Anderson [*Monechma spartioides* (T.Anderson) C.B.Clarke]
J. tonsum (P.G.Mey.) J.C.Manning & Goldblatt, *comb. nov. Monechma tonsum* P.G.Mey. in Mitteilungen der Botanischen Staatssammlung München 2: 304 (1957).

VIII. Sect. ***Anselliana*** C.B.Clarke. [*Justicia sect. Rostellaria* subsect. *Anselliana* (C.B.Clarke) V.A.W.Graham]. Type: *J. anselliana* (Nees) T.Anderson, lecto., designated by Graham: 598 (1988).

Herbaceous perennials or rarely shrubs. *Inflorescence*: a simple false-spike with 1 flower per node. *Calyx*: 5-partite with segments equal. *Corolla*: 5 mm – 7 mm long, white or lilac. *Anther*: thecae equal, superposed and parallel or oblique, appendages large. *Pollen*: 2-aperturate, margocolpi areolate. *Ovary*: glabrous. *Capsule*: sterile for ± 0.3 length. *Seeds*: scarcely compressed, rugulose or reticulate-alveolate.

J. anagalloides (Nees) T.Anderson [*Adhatoda anagalloides* Nees]
J. anselliana (Nees) T.Anderson [*Adhatoda anselliana* Nees]
J. exigua S.Moore
J. matammensis (Schweinf.) Oliv. [*Adhatoda matammensis* Schweinf.]

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Authors' contributions

Both authors collaborated on all aspects of the research.

2. Nomenclatural corrections in *Babiana* and *Geissorhiza* (Iridaceae: Crocoideae)

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Introduction

Babiana Ker Gawl. (93 spp.) (Goldblatt & Manning 2007, 2012) is relatively widespread in southern Africa and centred in the winter rainfall zone in the west of the subcontinent. One of the better known species in Western Cape Province, *Babiana stricta* (Aiton) Ker Gawl. (1803), is a combination based on *Gladiolus strictus* Aiton (1789). The location of a type, if it exists, is unknown and Goldblatt and Manning (2004) designated the illustration in *Curtis's Botanical Magazine* accompanying the combination as a neotype. Lewis (1959), in her monograph of *Babiana*, cited *Gladiolus nervosus* Lam. (1788) as a synonym of *B. stricta* and used the later epithet *stricta* for the species. Her apparently inexplicable action is perhaps due to the presence of the name *Babiana nervosa* Ker Gawl. in Index Kewensis, which we assume she would have seen. Checking the reference therein, we find neither *G. nervosus* nor *B. nervosa* mentioned. In our accounts of *Babiana* we overlooked Lewis's error and maintained *B. stricta*, although in somewhat revised circumscription (Goldblatt & Manning 2004, 2007). The type of *G. nervosus*, cultivated at the Jardin Botanique in Paris, was grown from material collected by Pierre Sonnerat at the Cape, which he visited briefly en route to and from Mauritius in 1773 and 1781 (Gunn & Codd 1981). The specimen is well preserved and is without doubt the species known as *B. stricta*, as evinced by the stiff, acute, upright leaves of that species, flowers with a narrow, straight perianth tube ± as long as the tepals, inner floral bracts divided to the base, a pubescent ovary and most significant, arrow-shaped anthers wider at the base.

We note that Lewis's circumscription of *B. stricta* included four varieties: of these var. *erectifolia* (G.J.Lewis) G.J.Lewis is included in *B. nervosa*, var. *grandiflora* G.J.Lewis is now *Babiana tubaeformis* Goldblatt & J.C.Manning, var. *regia* G.J.Lewis is *Babiana regia* (G.J.Lewis) Goldblatt & J.C.Manning and var. *sulphurea* (Jacq.) Baker has been excluded as the type cannot be associated with any known species (Goldblatt & Manning 2007; Goldblatt, Manning & Gereau 2008). Lamarck's epithet *nervosus* is valid in *Gladiolus* and is available in *Babiana* [indexes of plant names show the name *B. nervosa* Ker Gawl. (1804) but it does not appear in the purported place of publication nor in Ker Gawler's earlier article dealing with *B. stricta*]. We provide the new combination here and reduce *B. stricta* to synonymy. For completeness we include the full synonymy of the species.

Taxonomic treatment

Babiana nervosa (Lam.) Goldblatt & J.C.Manning, *comb. nov.* *Gladiolus nervosus* Lam., Encyclopédie méthodique 2: 724 (1788). Type: South Africa, without precise locality, ex hort. Paris, *Sonnerat s.n.* (P: Herb. Lamarck, holo.—digital image!).

Gladiolus strictus [Sol. in] Aiton: 63 (1789) *syn. nov.* *Babiana stricta* (Aiton) Ker Gawl.: t. 621 (1803). Type: South Africa, without precise locality or collector, illustration in Ker Gawl.: t. 621 (1803) [neotype designated by Goldblatt & Manning: 94 (2004)].

Babiana erectifolia G.J.Lewis: 3 (1938). *Babiana stricta* var. *erectifolia* G.J.Lewis: 43 (1959). Type: South Africa, [Western Cape], Brand Vlei, near Worcester, Sept. 1932, *G.J. Lewis s.n.* as Nat. Bot. Gard 2686/32 (BOL, holo.!).

Gladiolus ringens Thunb.: 186 (1800), hom. illegit. non Andrews (1798). Type: South Africa, without precise locality, *Thunberg s.n.* (UPS: Herb. Thunberg, syn.).

?*Babiana caesia* Eckl.: 32 (1827). Type: South Africa, without precise locality, ?*Ecklon s.n.* (location unknown, not at S).

Babiana flavocaesia Eckl.: 32 (1827). Type: South Africa, vicinity of Stellenbosch, ?*Ecklon s.n.* (S, holo.!).

In *Geissorhiza* Ker Gawl. (100 spp.) (Goldblatt & Manning 2009, 2013), the nomenclature of *G. ornithogaloides* and its two subspecies need adjustment. The name *Geissorhiza ornithogaloides* is currently treated as a new species described by F.W. Klatt in 1866 (Goldblatt 1985). We note, however, that Klatt cited as a syntype, *Lichtenstein s.n.* from the 'Koue Bokkeveld'. This specimen is the type of *Ixia ornithogaloides* Lichst. ex Roem. & Schult. (1817a). Although Klatt did not cite a basionym for his species, it should be treated as a combination according to the *International Code of Botanical Nomenclature* Art. 41.4 (especially examples 7, 8 and 10) as it is based in part on the same type (Greuter *et al.* 2000).

The identity and type locality of the Lichtenstein collection matches what is currently *G. ornithogaloides* subsp. *marlothii*, based on *Geissorhiza marlothii* R.C.Foster (1941). As a result, the name subsp. *marlothii* must be replaced by subsp. *ornithogaloides* and this taxon, in turn, requires a new name in place of its current circumscription as subsp. *ornithogaloides*. We accordingly replace it with the name subsp. *flava* based on *Geissorhiza flava* Klatt (1882). The choice of *Ecklon & Zeyher Irid.* 225 (51.8) from Caledon as lectotype of *G. ornithogaloides* Klatt by Goldblatt (1985) falls away. We also cite an epitype for *G. ornithogaloides* because the type specimens lack corms, important in distinguishing the two subspecies. The revised nomenclature is as follows.

Geissorhiza ornithogaloides (Licht. ex Roem. & Schult.) Klatt in Linnaea 34: 656 (1866). *Ixia ornithogaloides* Licht. ex Roem. & Schult.: 376 (1817b). *Trichonema ornithogaloides* (Licht. ex Roem. & Schult.) A.Dietr.: 583 (1833). Type: South Africa, [Western Cape], Koue Bokkeveld [Cold Bokkeveld], possibly Nov. 1803, *Lichtenstein s.n.* (B, holo.!).

subsp. ***ornithogaloides***

Geissorhiza marlothii R.C.Foster: 66 (1941), *syn. nov. G. ornithogaloides* subsp. *marlothii* (R.C.Foster) Goldblatt: 325 (1985). Type: South Africa, [Western Cape], Cold Bokkeveld, Houdenbeck, 850 m, *Marloth 10612* (B, holo.!; NBG!, PRE!, iso.); [Western Cape], Schoongesig, Ceres, *Hanekom 1222* (NBG, epi., designated here).

subsp. ***flava*** (Klatt) Goldblatt & J.C.Manning, *comb. & stat. nov. Geissorhiza flava* Klatt: 392 (1882). *G. ornithogaloides* var. *flava* (Klatt) R.C.Foster: 68 (1941). Type: South Africa, [Western Cape], without precise locality, *Breutel s.n.* (B, holo.!).

[*Waitzia flava* Reichb. in Klatt: 392 (1882), cited in synonymy]

[*Geissorhiza romuleoides* Eckl: 27 (1827), nom. nud.]

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

Both authors collaborated on all aspects of the research.

3. *Reyemia* included in *Zaluzianskya* (Scrophulariaceae: Limoselleae) with the new combination *Zaluzianskya chasmanthiflora* (Hilliard) J.C.Manning & Goldblatt

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Introduction

The genus *Reyemia* Hilliard (1992) (Scrophulariaceae: Limoselleae) was established for two species of annual herbs from the Hantam and Roggeveld Plateau in Northern Cape Province, South Africa, neither of them well known. *Reyemia nemesioides* (Diels) Hilliard (previously *Zalusianskya nemesioides* Diels) has been collected several times along the length of the Hantam-Roggeveld escarpment between Calvinia and Sutherland, but *Reyemia chasmanthiflora* Hilliard is still known only from the type locality near Williston. The relationships of *Reyemia* were presumed by Hilliard (1994) to lie with *Zalusianskya* F.W.Schmidt, with which it shares a derived, shortly toothed and plicate calyx and similar, centrally depressed, cushion-shaped seeds. It was distinguished from *Zaluzianskya* by what was described as a 'loosely paniculate' inflorescence, a resupinate corolla with a patch of clavate hairs inside the throat on the posticous side, and with two stamens and two staminodes. Examination of the specimens confirms that the inflorescence comprises essentially spicate units, sometimes with the lower flowers shortly pedicellate. Species of *Zalusiaskya* have simple or sparsely branched, spicate or racemose inflorescences, non-resupinate flowers, sometimes with a ring of clavate hairs in the mouth, and either four or two stamens, usually without staminodes (Hilliard 1992). The differences between the two genera are thus centred on the strongly branched inflorescence and more zygomorphic flowers in *Reyemia*.

An examination of phylogenetic relationships in Manuleae and Selagineae by Kornhall, Heidari and Bremer (2001), based on the plastid gene regions *ndh*F and *trn*L, confirmed the close relationship between *Reyemia* and *Zaluzianskya*. This analysis, although including just four species of *Zaluzianskya* plus *R. chasmanthiflora*, provided the first indication that the latter was, in fact, nested in *Zaluzianskya*. A subsequent, more intensively sampled study of relationships within *Zaluzianskya* by Archibald, Mort and Wolff (2005) used a combination of nuclear ITS and plastid *rps*16 and *trn*L-F gene regions from a sampling of 23 species of *Zaluzianskya*, plus the second species of *Reyemia*, *R. nemesioides*, to produce the first broad phylogenetic analysis of the genus. This study confirmed that *Reyemia* is deeply nested within *Zaluzianskya*, as sister to the clade comprising those members of section *Holomeria* (Benth.) Hilliard & Burtt with four fertile stamens. The placement is entirely consistent with the morphological similarities between the two genera noted by Hilliard (1994) and supplemented by additional states identified by Archibald *et al.* (2005), viz. filaments decurrent to the base of the corolla tube and a ligulate stigma.

These findings led Archibald *et al.* (2005) to conclude that the differences in floral morphology between the two genera are no greater than exists amongst other species of *Zaluzianskya* and that *Reyemia* should be merged with *Zaluzianskya*.

The entire corolla lobes in the former species of *Reyemia* and in members of *Zaluzianskya* sect. *Holomeria* supports the close relationship between the two groups suggested by the molecular analysis of Archibald *et al.* (2005). There are indications, however, that sect. *Holomeria* may not be monophyletic as currently defined because *Zaluzianskya benthamiana* was retrieved as a member of sect. *Zaluzianskya* subsect. *Zaluzianskya*. This species (plus *Zaluzianskya diandra* which was not included in the analysis) are unique in sect. *Holomeria* in having just two stamens, raising the possibility that the entire corolla lobes in *Z. benthamiana* and the other members of sect. *Holomeria* are convergent. This possibility, combined with the distinctive inflorescence and flowers of the former members of *Reyemia*, favours the retention of the two species as the separate section *Reyemia* within *Zaluzianskya*.

We implement this finding here in preparation for the forthcoming regional flora of the Karoo region. We also select an appropriate neotype from the same locality to replace the holotype of *Zaluzianskya nemesioides* in the Berlin Herbarium which has been lost.

Research method and design

We consulted the relevant literature and implemented the necessary nomenclatural conclusions. Type material is cited from the Berlin Herbarium (B) and Compton Herbarium, South African National Biodiversity Institute, Cape Town, South Africa (acronyms after Holmgren, Holmgren & Barnett 1990).

Taxonomic treatment

Zaluzianskya F.W.Schmidt, Neue und Seltene Pflanzen: 11 (1793), nom. cons., non *Zaluzianskia* Necker (= *Marsilea* L.). Type species: *Zaluzianskya villosa* F.W.Schmidt.

Sect. ***Reyemia*** (Hilliard) J.C.Manning & Goldblatt, syn. et stat. nov. *Reyemia* Hilliard in Edinburgh Journal of Botany 49: 297 (1992). Type species: *Reyemia chasmanthiflora* Hilliard = *Zaluzianskya chasmanthiflora* (Hilliard) J.C.Manning & Goldblatt.

Zaluzianskya chasmanthiflora (Hilliard) J.C.Manning & Goldblatt, comb. nov. *Reyemia chasmanthiflora* Hilliard in Edinburgh Journal of Botany 49: 297 (1992). Type: South Africa, [Northern Cape, Williston], Farm Annexe Kransfontein 721, 02 Sept. 1986, *Cloete & Haselau 172* (NBG [as STE], holo.).

Zaluzianskya nemesioides Diels in Botanische Jahrbücher fur Systematik, Pflanzengeschichte und Pflanzengeographie 23: 482 (1896). *Reyemia nemesioides* (Diels) Hilliard: 297 (1992). Type: South Africa, [Northern Cape], Hantam Mountains, *Meyer s.n.* (B†, holo.). Neotype, selected here: South Africa, Northern Cape, Calvinia, gravel flats below Hantamsberg, 15 Sept. 1996, *Goldblatt & Manning 10525* (NBG, neo.; MO, iso.).

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

Both authors collaborated on all aspects of the research.

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Schoenefeldia transiens (Poaceae): Rare new record from the Limpopo Province, South Africa

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Background: *Schoenefeldia* is a genus of C_4 grasses, consisting of two species in Africa, Madagascar and India. It is the only representative of the genus found in southern Africa, where it was previously only known from a few collections in the southern part of the Kruger National Park (Mpumalanga Province, South Africa), dating from the early 1980s.

Objectives: The objective of this study was to document a newly recorded population of *Schoenefeldia transiens* in an area that is exploited for coal mining.

Method: A specimen of *S. transiens* was collected between Musina and Pontdrift, about 30 km east of Mapungubwe National Park, in the Limpopo Province of South Africa. The specimen was identified at the National Herbarium (Pretoria).

Results: This is not only a new distribution record for the quarter degree grid (QDS: 2229BA), but is also the first record of this grass in the Limpopo Province. The population of *S. transiens* has already been fragmented and partially destroyed because of mining activities and is under serious threat of total destruction.

Conclusion: It is proposed that the population of *S. transiens* must be considered to be of conservation significance, and the population should be made a high priority in the overall environmental management programme of the mining company that owns the land.

Introduction

Schoenefeldia Kunth (1830:283) is a genus of C_4 grasses, consisting of two species in Africa, Madagascar and India (Watson & Dallwitz 1994). *Schoenefeldia transiens* (Pilger) Chiovenda (Chiovenda 1916:186; Pilger 1914: 418) is known from Ethiopia, Somalia, Sudan, Kenya, Tanzania, Uganda, Mozambique, Zimbabwe and South Africa (Clayton *et al*. 2014). It is the only representative of the genus found in southern Africa, where it was previously only known from a few collections in the southern part of the Kruger National Park (Mpumalanga Province, South Africa), dating from the early 1980s (see details under 'Additional specimens examined' below). No other specimens collected between 1982 and the current collection (2014) could be found.

A specimen of *S. transiens* was collected between Musina and Pontdrift, about 30 km east of Mapungubwe National Park, in the Limpopo Province of South Africa. This is not only a new distribution record for the quarter degree grid (QDS: 2229BA), but the first record of this grass in the Limpopo Province. As the collection reported on here was made in an area that is exploited by coal mines, the conservation of this species in the Limpopo Province is not secure.

Taxonomic treatment

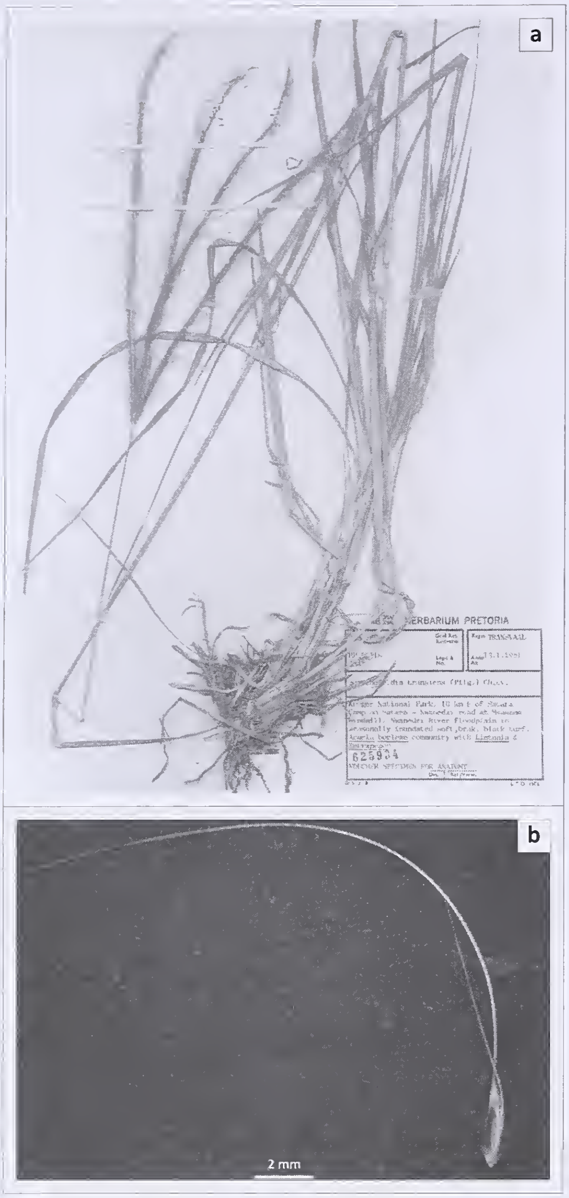
Schoenefeldia transiens (Pilg.) Chiov. in *Resultati scientifici della missione Stefanini-Paoli nella Somalia italiana. Le collezione botaniche* 1:186 (1916).

Basionym: *Chloris transiensis* Pilg., in *Botanische Jahrbücher für Systematik, Pflanzengeschichte und Pflanzengeographie* 51:418 (1914).

Type: TANZANIA. **Pare District:** KwaSengiwa-Majiyajuu, *Uhlig 882* (B100002186, holotype, e!).

Description

Densely tufted perennial grass, 700 mm – 1200 mm high. Leaf blade 350 mm × 5 mm. Inflorescence of 2–4 digitate racemes; racemes 130 mm – 200 mm long, with obviously secund spikelets, these solitary at point of attachment to rachis. Spikelet 3.5 mm – 5.0 mm long, small in comparison to awns; florets 1 or 2, fertile lemma awn 10 mm – 25 mm, sterile lemma awn 25 mm – 45 mm long,



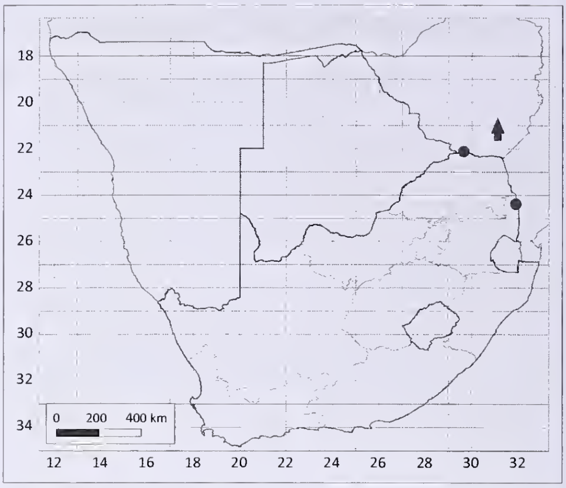
Source: Sample from Ellis 3548 (PRE), photographed by A.C. Mashau
Scale bar: (b), 2 mm.

FIGURE 1: *Schoenefeldia transiens*, depicted in, (a) habit (the growth form of the plant) and (b) lemma (the lower of two bracts enclosing the grass flower or floret).

awns flexuous, curving gracefully, becoming entangled with awns of other spikelets (Cope 1999; Gibbs Russell *et al.* 1990); anther 0.7 mm – 1.0 mm long (Figure 1). Flowering January to February. Reported to be cleistogamous.

Distribution and ecology

Schoenefeldia transiens occurs in southern Africa in the Mpumalanga and Limpopo Provinces of South Africa, and northwards through to East Africa, Ethiopia, Somalia and Sudan (Figure 2). The newly recorded *S. transiens* population in the Limpopo Province is situated in the Limpopo River Valley between Musina and Pontdrift, on the farm Over Vlakte 125 MS. It grows on a north-facing hill slope approximately 1 km south of the Limpopo River. Coordinates of specimens and sub-populations of the larger population of *S. transiens* on the farm Over Vlakte 125 MS in the Limpopo River Valley are 22°08′58.3″ S, 29°40′ 49.7′ E and 22°09′01.9″ S, 29° 40′39.6″ E.



Source: Created by H.M. Steyn

FIGURE 2: Known distribution range (●) of *Schoenefeldia transiens* in southern Africa, with the black arrow indicating that further populations can be found to the north.

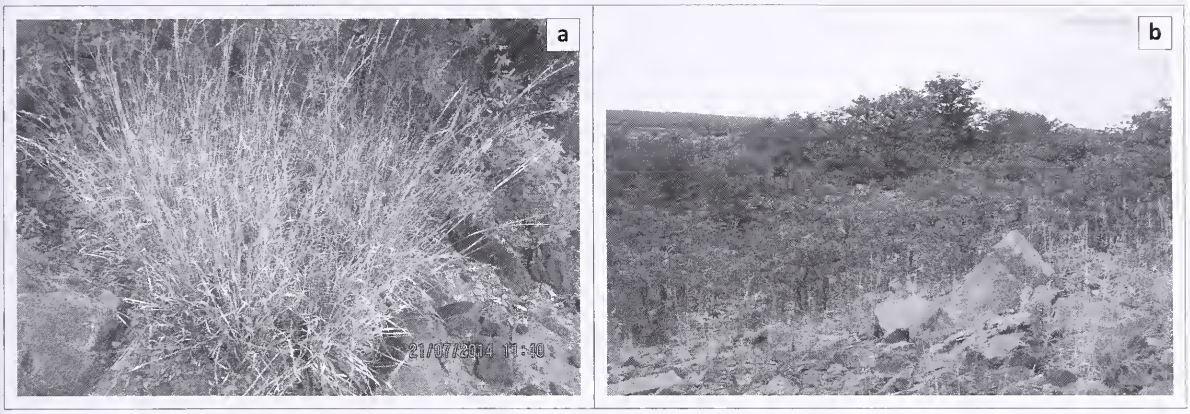
The new population of *S. transiens* occurs in *Colophospermum mopane* woodland on relatively seasonally flooded flats, in heavy soil, such as shallow loamy sandy soil that is associated with a high percentage of sandstone and quartzite surface rocks and outcrops (Figure 3). The habitat slope is between 5° and 10°, with a predominantly northern aspect. The woody component of the habitat is dominated by trees and shrubs that are mostly between 2.2 m and 0.8 m (average 1.5 m) high. The grass and herbaceous layer is only moderately to poorly developed due mainly to the shallow rocky nature of the substrate.

Other perennial grasses of significant abundance that occur together with *S. transiens* are *Fingerhuthia africana*, *Digitaria eriantha*, *Stipagrostis uniplumis* and *Sporobolus nitens*. Together with *C. mopane*, the woody vegetation is dominated by *Gardenia resiniflua* subsp. *resiniflua*, *Terminalia prunioides*, *Ximenia americana*, *Combretum apiculatum* and *Croton gratissimus* var. *subgratissimus*. Dominant herbs include *Barleria virgula*, *Seddera suffruticosa*, *Decorsea schlechteri*, *Hibiscus micranthus*, *Xerophyta humilis*, *Tephrosia polystachya* and *Indigofera nebrowniana*.

Conservation status and habitat sensitivity

The frequency of *S. transiens* in southern Africa is rare.

Although the habitat of the new population itself is not considered to be particularly sensitive, it is under imminent threat of destruction as a result of current open cast coal mining activities in the direct vicinity of the newly recorded



Source: Image (a) photographed by G. de Beer; (b) by A.R. Götze

FIGURE 3: *Schoenefeldia transiens* (a) tall grass in foreground, (b) occurring in the rocky *Colophospermum mopane* wooland.

population. A strong suspicion exists that the population has already been fragmented and partially destroyed because of mining activities. Depending on the future planning of mining activities, the whole population is under serious threat of total destruction. It is therefore proposed that this population of *S. transiens* be considered to be of conservation significance, and it should be made a high priority in the overall environmental management programme of the mining company that owns the land. It is the view of the authors that if this population is lost as a result of carelessness or ignorance by either the relevant conservation authorities or the current landowner (i.e. the mining company), it will be a loss not only to our natural heritage, but also a loss in terms of the gene pool of this species and to the biodiversity of the southern African region.

New collection record

SOUTH AFRICA. **Limpopo**: Limpopo River Valley, farm Over Vlakte 125 MS (QDS: 2229BA), 24 April 2014, *Götzel 355* (PRE!).

Additional specimens examined

SOUTH AFRICA. **Mpumalanga**: Kruger National Park, 10 km east of Satara Camp, Nwanedzi road at Msasame windmill (QDS: 2431BD), 13 Jan. 1981, *Ellis 3548* (PRE!); 12 km east of Satara along Nwanedzi river road, 28 Jan. 1982, *Ellis 3867* (PRE!); 6 km east of Satara along Nwanedzi river road, 31 Jan. 1981, *Ellis 3542; 3543* (PRE!).

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Competing interests

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Authors' contributions

A.C.M. (South African National Biodiversity Institute/University of Pretoria) prepared the draft and analysed the data, A.R.G. (*Environment Research Consulting*) collected plant material and made conceptual contributions.

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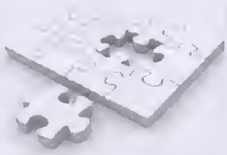

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Please do not hesitate to contact me if you require assistance in performing this task.

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