South African Journal of Botany 2005, 71(2): 221–227
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SOUTH AFRICAN JOURNAL OF BOTANY
ISSN 1727–9321

Differences between *Pelargonium moniliforme* (Geraniaceae) and the closely related *P. vinaceum*

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Received 4 May 2004, accepted in revised form 28 September 2004

A multidisciplinary study of living plants and herbarium specimens of what was hitherto known as *Pelargonium moniliforme* Drège ex Harv. (section *Hoarea* (Sweet) DC.) reveals two different taxa: *P. moniliforme*, which can reach a height of 400mm when in flower and *P. vinaceum* EM Marais, which only reaches a height of 180mm in exceptional cases. *P. moniliforme* also has larger flowers and longer hypanthia than *P. vinaceum*. The leaves of *P. vinaceum* are covered with short glandular hairs with appressed bristles along the margins, whereas those of *P. moniliforme* have long glandular hairs interspersed with soft patent hairs and with appressed or patent stiff hairs along the margins. *P. moniliforme* always has five fertile stamens, in contrast to the two to four in *P. vinaceum*. In addition, the taxa have different distributions and flowering times. *P. moniliforme* has a more southern distribution, in an area with an annual precipitation of 150–350mm, and flowers in September when leaves are still present. *P. vinaceum* occurs more to the north in an area with an annual rainfall of less than 150mm, and flowers in October and November after the leaves have died. Similarities in the flower and leaf morphology, leaf anatomy and karyology reveal a close relationship between the two species. Illustrations of the two species are provided as well as a combined map of the rainfall figures and the distributions of the two species.

Introduction

Pelargonium moniliforme Drège ex Harv. and *P. vinaceum* EM Marais (section *Hoarea* (Sweet) DC.) are a pair of closely-related species sharing macromorphological characters, like the simple, to trifoliolate, prostrate leaves, wine-red unbranched scapes, long hypanthia and cream to yellow-coloured spathulate petals with prominent dark red blotches on the posterior petals, revealing a close relationship between the two species. *P. moniliforme* was first collected by F Masson during the 18th century (Masson s.n., BM), but the name was only validly published by WH Harvey in 1860, based on a collection made by JF Drège in October 1830 at Zilverfontein in Namaqualand. Drège's collection comprised a large number of replicates, which was named by EHF Meyer as *P. moniliforme* and distributed to several European herbaria (Gunn and Codd 1981). The name *P. moniliforme*, without a description, was also documented in Drège's 'Zwei pflanzengeografische Documente' in 1843. Since the beginning of the *Pelargonium* L'Hérit. project at the University of Stellenbosch in 1975, specimens were collected in the Richtersveld and southern Namibia, which differ subtly from the material of *P. moniliforme* from further south. Eventually a syndrome of discontinuities between the two forms emerged, enabling the recognition of the northern populations as a separate species, *P. vinaceum*. Since my PhD thesis, where I described *P. vinaceum*, was reprinted and distributed by the Geraniaceae Group (England), the name *Pelargonium vinaceum* EM Marais is considered effectively published from March 2000. This paper aims at a full documentation of *P. vinaceum.* At the same time the similarities and differences between this species and the closely related *P. moniliforme* are discussed with regard to the morphology, anatomy, pollen morphology, karyology and ecology.

Materials and Methods

Morphology, anatomy and palynology

Morphological observations were made on herbarium specimens as well as on plants collected in the field and cultivated in the Botanical Garden of the University of Stellenbosch, RSA. Leaf anatomical studies were performed on fresh material from plants growing in the garden for more than one season (Table 1). The laminae were wax-embedded, cut with a rotary microtome and stained with Alcian Green (Joel 1983). For the acetolysis of pollen grains material was sampled from plants growing in the garden (Table 1). Acetolyzed pollen grains were measured under a light microscope (25 pollen grains per specimen) and the structure of the pollen walls was studied with a scanning electron microscope.

Table 1: Specimens of *P. moniliforme* and *P. vinaceum* studied for pollen morphology and leaf anatomy

Species Specimen	STEU number	Pollen measurements Min.	Max.	*x* (µm)	Leaf anatomy
P. moniliforme					
Boucher 77	996	50	62	59	+
Lavranos 17478	2324				+
Marais 68	3303	58	62	59	
Marais 73	3318				+
Marais 75	3321	53	60	57	
Marais 217	3652				+
Marais 355	3996	58	65	61	+
P. vinaceum					
Lavranos 20785	3220	55	72	62	+
Marais 77	3339	55	65	59	+
Williamson 3527	3626				+
Van Jaarsveld 9695	3858	53	72	65	
Visser s.n.	3859				+
Williamson 4010	3915	53	70	61	+

Annual rainfall figures

Mean annual rainfall figures were extracted from the database of the Computing Centre for Water Research, University of Natal, Pietermaritzburg. A minute-by-minute grid of mean annual precipitation for the study area (in decimal degrees) was extracted in an export format for the Geographical Information System (GIS), and the final map was prepared in a GIS package called ArcView (version 2.1).

Results and Discussion

The similarities between the two species include macromorphological characters like the simple, to trifoliolate, prostrate leaves, wine-red unbranched scapes, long hypanthia, and cream-coloured to yellow spathulate petals with prominent dark red blotches on the posterior petals. These markings are identical in the two species and in both cases the posterior petals are borne in such a way that the blotches appear as a single nectar guide. The similarities also include the anatomy of the laminae, pollen morphology and chromosome number. Concerning leaf anatomy, both species have dorsiventral laminae with (adaxially) two layers of long but broad palisade cells and (abaxially) a loosely-arranged spongy tissue. Pollen morphology reveals similarities with regard to the equatorial diameter of the pollen grains (*P. moniliforme*: 57–61µm; *P. vinaceum*: 59–65µm; Table 1) and the structure of the tectum. In both species the tectum can be described as striate (Bortenschlager 1967, Marais 1994a, Figure 1) because the main parallel muri are thicker and more prominent than the lower connecting ones. Both species are diploid with x = 11 (Gibby *et al.* 1996).

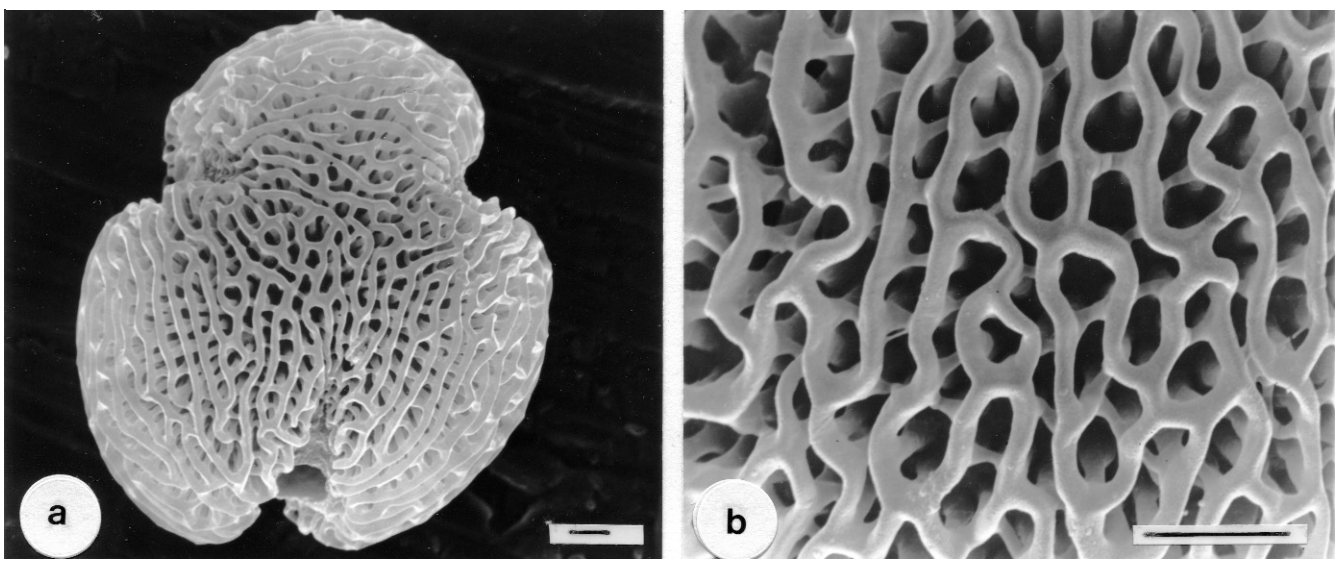

Figure 1: Scanning electron micrographs of: (a) polar view of the pollen grain of *P. vinaceum* (Marais 77, STEU); (b) mesocolpium of the pollen grain of *P. moniliforme* (Marais 355, STEU). Scale bar: 5µm

Table 2: Morphological differences between *P. moniliforme* and *P. vinaceum*

	P. moniliforme	*P. vinaceum*
Height of plants	140–400mm	75–100 (–180)mm
Indumentum on leaves	Leaves covered with long glandular hairs interspersed with soft patent hairs and appressed or patent stiff hairs along the margins	Leaves covered with short glandular hairs and appressed bristles along the margins
Number of flowers per pseudo-umbel	12–40 (–50)	10–27 flowers
Dimensions of posterior petals	13–22 x 3–8mm	10–15.5 x 3.5–6mm
Dimensions of anterior petals	10.5–17.5 x 3–6.5mm	7.5–12 x 3–4.5mm
Hypanthium length	20–77mm	11–26mm
Anterior stamen length	11–16mm	5–11.5mm
Number of fertile stamens	5	2–4
Mericarp: base length	5mm	4mm
Mericarp: tail length	24–28mm	18mm

The differences between the two species include the size of the plants, the indumentum of the leaves and the number of fertile stamens (Table 2), as well as differences in the distribution areas and flowering times. The plants of *P. moniliforme* (Figure 4) can reach a height of 400mm when in flower, whereas *P. vinaceum* (Figure 3), only in exceptional cases, grows up to 180mm. *P. moniliforme* usually has a larger number of flowers per pseudo-umbel, larger flowers and longer hypanthia than *P. vinaceum*, and the number of fertile stamens of *P. vinaceum* varies from two to four, whereas *P moniliforme* always has five. Differences also occur with regard to the indumentum on the leaves. In *P. moniliforme* the leaves are covered with long glandular hairs interspersed with soft patent hairs and with appressed or patent stiff hairs along the margins, whereas the leaves of *P. vinaceum* are covered with short glandular hairs with appressed bristles along the margins.

The distribution area of *P. vinaceum* is north of that of *P. moniliforme* (Figure 2), and although there is no clear borderline between the species, when their distribution areas are compared to the annual rainfall figures, there is an indication that *P. vinaceum* prefers areas with an annual precipitation of less than 150mm, and except for one collection in the Holgat River Valley near the coast, *P. moniliforme* grows in areas with an annual rainfall of 150–350mm. *P. moniliforme* is one of the early flowering species of section *Hoarea* and flowers in September, while leaves are still present but fading, whereas *P. vinaceum* flowers in October and November, after the leaves have died.

The differences between the two taxa enable the recognition of two separate species and the similarities in floral morphology and leaf structure reveal a close relationship between them. This close relationship is supported by a phylogenetic tree, constructed from the DNA sequences of the rDNA ITS; however, the clade in which these two species appear as sister species to *P. pinnatum* (L.) L'Hérit. has a very poor jack-knife support (Touloumenidou *et al.* 2004).

In *Pelargonium* pollination can be regarded as a prerequisite for fruit formation (Marais 1999), and poor fruitset under cultivated conditions – in the Botanical Garden of the University of Stellenbosch – of the majority of species of section *Hoaroa* can be ascribed to the absence of suitable

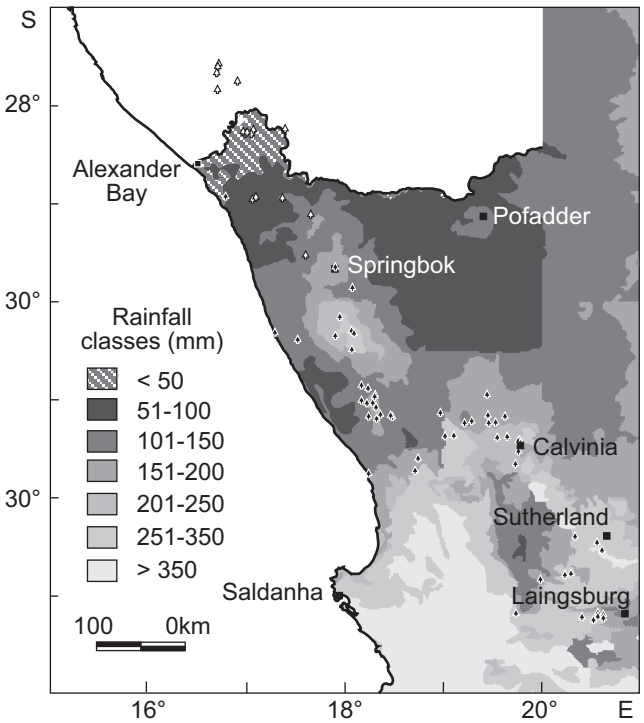

Figure 2: Geographical distributions of *P. moniliforme* (blue) and *P. vinaceum* (red)

pollinators for the different species. Since fruitset in the garden for both *P. moniliforme* and *P. vinaceum* is rare, self-compatibility, although not uncommon in *Pelargonium* (*P. candicans* Spreng., Marais 1981, *P. dolomiticum* Knuth, Zietsman 1993, *P. appendiculatum* (L. f.) Willd., Meve 1995, *P. oblongatum* Harv., Marais 1999), can be excluded for these two species. Manning and Goldblatt (1997) described *P. moniliforme* with the very long hypanthium (20–77mm) as probably belonging to the *Moegistorhynchus longirostris* pollination guild. This is a group of plant species, representing different genera from different families, and characterised by their long (50–90mm) and narrow floral tubes, white, cream or salmon petals with reddish nectar guides, and reddish, well-exerted anthers. All the members

Figure 3: *Pelargonium vinaceum*: (a) flowering plant x 1; (b) plant with leaves x 1; (c) petals x 2; (d) androecium x 3; (e) gynoecium x 5

Figure 4: *Pelargonium moniliforme*: (a) flowering plant x 1; (b) androecium x 2; (c) gynoecium x 2; (d) petals x 1; (e) tuber x 1

of the guild are pollinated by long-proboscid flies, some exclusively by *Moegistorhynchus longirostris* (Wiedemann), but taxa with larger distribution ranges like – *P. moniliforme* – could also be pollinated by the long-tongued flies *Philoliche gulosa* (Wiedemann) and *Philoliche rostrata* (L.). Comparing the distribution range of *P. moniliforme* (Figure 2) to that of the three long-tongued flies (Figure 8 in Manning and Goldblatt 1997), the range of the former falls within that of the three fly species. Comparing this distribution map of the flies (Manning and Goldblatt 1997) to that of *P. vinaceum* it seems that the flies do not share the same distribution range with *P. vinaceum.* Thus the presence or absence of these long-tongued flies appears to be one of the selective forces in the evolution of *P. moniliforme* and *P. vinaceum.*

Affinities within section Hoarea

On morphological characters alone, it is difficult to determine the position of *P. moniliforme* and *P. vinaceum* within section *Hoarea*. Although the wine-red scapes and hypanthia of both species are very similar to those of *P. caroli-henrici* B. Nord., the two species do not share other morphological characters with the latter species. The long, straight protruding stamens of *P. moniliforme* and *P. vinaceum* are very similar to those of *P. incrassatum* (Andr.) Sims, *P. grenvilleae* (Andr.) Harv., *P. radicatum* Venten., *P. campestre* (Eckl. & Zeyh.) Steud., *P. nephrophyllum* EM Marais, *P. carneum* Jacq. and *P. radiatum* (Andr.) Pers., but all of these species have different leaf shapes. They also reveal a large variation in the shape, size and orientation of the petals during anthesis, as well as the length of the hypanthia (Marais 1994a). However, the structure of the tectum of the pollen grains of all these species is very similar (Marais 1994a) and all of them have the same chromosome number (2n = 22, Gibby *et al.* 1996).

The above-mentioned species do not only differ with regard to leaf shape, but also with regard to the anatomy of the laminae. The lamina anatomy of *P. moniliforme* and *P. vinaceum* resembles that of other *Hoarea* species, with simple to trifoliolate prostrate leaves like *P. nephrophyllum* (Marais 1992), *P. curviandrum* EM Marais, *P. triandrum* EM Marais (Marais 1994b) and *P. aestivale* EM Marais (Marais 1995). Further studies should be undertaken to see what the possible correlation is between the anatomy of the laminae and the leaf shape (simple, trifoliolate or pinnately divided), leaf orientation (prostrate or erect) and environmental conditions.

[1] Since my thesis (Marais 1994a) was reprinted and distributed by the Geraniaceae Group (England) in 2000, the name *Pelargonium vinaceum* EM Marais is considered effectively published from March 2000 (Article 29 of the International Code of Botanical Nomenclature, Greuter *et al.* 1994)

Taxonomy

Pelargonium vinaceum EM Marais, Taxonomic studies in *Pelargonium*, section *Hoarea* (Geraniaceae): 190–193 (2000).[1]

TYPE. Namibia, 2716 (Witputz): 40km north of Rosh Pinah, on road to Aus, (-DB), 07-1984, Marais 77 (NBG, holotypus; BOL, K, MO, PRE, S).

Diagnostic features

P. vinaceum is a geophyte with entire, seldom trifoliolate, prostrate leaves, the older ones larger with long petioles (c. 40mm) and the younger ones gradually reducing in size. The leaves are covered with short glandular hairs and appressed bristles along the margins. When in flower *P. vinaceum* is smaller than *P. moniliforme*, and reaches a height of only 75–100mm, or in exceptional cases 180mm. The wine-red, usually unbranched scape bears a pseudo-umbel with 10–27 flowers. The wine-red hypanthia (11–26mm long) are 2.5–3.5 times the length of the sepals. The specific epithet *vinaceum* refers to the wine-red scape and hypanthia of this species. The cream-coloured to pale yellow flowers with wine-red blotches on the posterior two petals are smaller (posterior petals 10–15.5mm long; length/width ratio 2–4) than those of *P. moniliforme*. The number of fertile stamens varies from two to four. The stamens are long (5–11.5mm) and protrude from the flower with the anterior ones 1–2 times the length of the sepals. During anthesis a noteworthy lengthening of the style and stigma branches takes place. The bases of the mericarps are about 4mm long, are lacking glandular hairs and the tails are up to 18mm long (Figure 3).

Distribution and ecology

P. vinaceum occurs from Rosh Pinah in southern Namibia, in the Richtersveld and as far south as the Nigramoep plateau south of Steinkopf (Figure 2), an area receiving an annual rainfall of less than 150mm, mainly during winter. It grows in karroid vegetation in rock crevices in granites, shale or sandy soil and flowers from October to November after the leaves have died.

Material studied

–2716 (Witputz): Witputz Süd (-DA), Lavranos 20785 (STEU); 40km N of Rosh Pinah, on road to Aus (-DB), Marais 77 (BOL, K, MO, NBG, PRE, S); Spitskop 9km N of Rosh Pinah (-DC), Van der Walt and Vorster 1275 (STEU); Zebrafontein (-DD), Beukes 10108 (BLFN); 35km N of Rosh Pinah (-DD), Leuenberger 3227 (WIND); Venter 8630 (STEU).

–2816 (Oranjemund): Die Koei, Helskloof (-BD), Drijfhout 2942 (STEU); Numees (-BD), Visser s.n. (STEU); Von Willert s.n. (STEU); W slope of Numees Mountain (-BD), Williamson 4010 (STEU).

–2817 (Vioolsdrif): Verberg, Gamkap (-AB), Van Jaarsveld 9695 (STEU); 15km E of Helskloof, road to Grasdrif (-AC), Graham 3527 (STEU); Beukes 10102 (BLFN); three miles SW of Brakfontein (-CC), Nordenstam 1799 (S); Tierpoortberge, Kliphoogte (-CD), Drijfhout 1431 (STEU).

–2917 (Springbok): Nigramoep Plateau, 35km S of Steinkopf (-DA), Williamson 4341 (STEU).

Pelargonium moniliforme Drège ex Harv. in Flora Capensis 1: 264 (1860); Knuth: 333 (1912); Dyer: t. 9342 (1934). TYPE. Northern Cape Province, 2918 (Gamoep): Zilverfontein, Namaqualand. (-CC), 600–900m, 27-10-1830, *Drège s.n.* (as. *P. moniliforme*) (TCD! lecto, here designated;[2] CGE!, E!, Gx4!, K!, L!, MEL!, MO!, OXF!, Px2!, PRE!, S!, SAM!, Wx2!); Zeyher 2067 (S!).

Geraniospermum moniliforme (Harv.) Kuntze: 95 (1891).

Diagnostic features

P. moniliforme is a geophyte with entire to trifoliolate prostrate leaves, the older ones larger with long petioles (c. 60mm) and the younger ones gradually reducing in size. Although vegetative plants reach a height of more or less 40mm above ground level, the scapes can grow up to 400mm high. This is especially true for plants growing under bushes with scapes being supported by the bushes. The leaves are covered with long glandular hairs interspersed with soft patent hairs and the margins with appressed or patent stiff hairs. The thick, usually unbranched, scape is wine-red with very long (3–4mm), prominent non-glandular hairs. The wine-red hypanthia are three to eight times the length of the sepals and also covered with long, prominent non-glandular hairs. The flowers are cream-coloured to yellow with dark red blotches. The blotches are sometimes restricted to the posterior petals. Measurements of almost all organs of *P. moniliforme* exceed those of *P. vinaceum*. Each scape bears a pseudo-umbel with 12–40 (-50) flowers with very long hypanthia (20–77mm long). The petals of *P. moniliforme* are larger (posterior two 13–22mm long; length/width ratio: 2–4.5) and the stamens longer (anterior two 11–16mm long) than those of *P. vinaceum*. The five fertile stamens protrude from the flower with the anterior ones 1.5–2 times the length of the sepals. During anthesis a noteworthy lengthening of the style and stigma branches takes place. The bases of the mericarps are about 5mm long, are lacking glandular hairs and the tails are 24–28mm long (Figure 4).

The specific epithet refers to the series of small tubers formed by the main or lateral roots. This, however, occurs in several other species in section *Hoarea* and is not unique to *P. moniliforme*.

Geographical distribution and ecology

P. moniliforme occurs from Holgat River Valley in the south-west of the Richtersveld to Karoo Poort in the south and Matjiesfontein in the east (Figure 2). This area receives an annual rainfall of 150–350mm, mainly in winter. P. moniliforme grows in sand or in clay, on quartzite outcrops and stony areas, on foothills or on flats, in direct sunlight, or in partial shade in rock shelters or under bushes. Sometimes it occurs in large populations, but it is more usual

[2] The choice for the TCD specimen as lectotype is based on the fact that Harvey worked at TCD when compiling the Geraniaceae for Volume 1 of Flora Capensis (Gunn and Codd 1981).

for the plants to occur singly. It occurs in short karroid vegetation, in marginal Namaqualand broken veld (Veldtype 33, Acocks 1988), and also in tall dense shrub vegetation as in the Kamiesberge. *P. moniliforme* is grazed by animals. This may be the reason why plants more often occur under bushes than in direct sunlight; they are the only ones to survive heavy grazing. Plants growing under bushes usually have very long scapes. Flowering time is during September, at a stage when the leaves are fading.

Material studied

–2816 (Oranjemund): Holgat River Valley (-DD), Hardy 604 (K, PRE).

–2917 (Springbok): Near Springbok (-DB), Lewis 1174 (SAM).

–2918 (Gamoep): Zilverfontein (-CC), Drège s.n. (CGE, E, Gx4, K, L, MEL, MO OXF, Px2, PRE, S, SAM, TCD, Wx2); Drège 3236 (P); Zeyher 2067 (S).

–3017 (Hondeklipbaai): Hondeklipbaai (-AD), Bruyns 1516 (STEU); Bowesdorp (-BB), Thorne s.n. (SAM); Wallekraal (-BC), Boucher 77 (STEU); between Garies and Kamieskroon (-BD), Hutchinson 827 (BOL, K).

–3018 (Kamiesberg): 8km from Garies to Leliefontein (-AC), Marais 73 (STEU); 3km from Leliefontein to Kamieskroon (-AC) Marais 75, 76 (STEU); Kamiesberg (-AC), Marais 133 (STEU); between Garies and Nuwerus (-CC) Marloth 12489 (BOL, PRE, STEx3); Eenkoker, Kamiesberg (-CC), Pearson 6751 (K); 10km N of Bitterfontein (-CD), Hugo 2900 (PRE, STE); 5km on Kliprand road, N of Bitterfontein (-CD), Marais 282 (STEU).

–3019 (Loeriesfontein): Loeriesfontein, village ground (-CD), Marais 123 (STEU).

–3118 (Vanrhynsdorp): Mierhofkasteel (-AA), Barker NBG856/50 (NBG); 6km W of Bitterfontein (-AA) Marais 70, 71 (STEU); 19km NW of Bitterfontein (-AA), Nordenstam and Lundgren 1788 (S); Komkans (-AA), Nordenstam and Lundgren 1719 (STE); near Nuwerus (-AB), Acocks 16435 (K); 13m SW of Nuwerus (-AB), Acocks 19592 (K, PRE); Nuwerus (-AB), Barker 3730 (NBG); Leighton 1124 (BOL); Martin 842 (NBG); Nordenstam 1355 (S, STE); Spitsberg, SE of Nuwerus (-AB), Oliver 5939 (STE); between Bitterfontein and Nuwerus (-AB), Salter 1593 (BM, K); Bitterfontein (-AB), Alice and Godman 745 (BM); Schlechter 11030 (Z); Karee Mountains, S of Nuwerus (-AB), Van Zyl s.n. (STEU); Bokkeveldsberg (-BB), Marloth 7798 (PRE); Strandfontein (-CC), Acocks 15024 (PRE); Vanrhynsdorp (-DA), Kolbe 14293 (BOL); Vleikraal, E of Klawer (-DA), Walters 5 (STEU); Walters 184 (PRE).

–3119 (Calvinia): Brandkop, N of Nieuwoudtville (-AA), Stokoe s.n. (SAM); near Brandkop (-AA), Leipoldt 4394 (BOL); Hantamrivierdrif (-AB), Barker 9494 (NBG); Hantamrivier, 30m NW of Calvinia (-AB), Lewis 4068 (SAM); 30m from Calvinia to Loeriesfontein (-AB), Maguire 2001 (NBG); Perdeberg, between Loeriesfontein and Calvinia (-AB), Marais 125 (STEU); Vanrhyns Pass, Loeriesfontein junction (-AC), Hardy 80 (K, PRE); Nieuwoudtville (-AC), Leipoldt s.n. (BOL); Witkleigat (-BA), Marais 275 (STEU); Grootrivier (-BB), Marais 272 (STEU); Toren Road (-BC), Bayer 1905 (NBG); 20km from Calvinia to Loeriesfontein (-BC), Marais 273 (STEU); Akkerendam (-BD), Acocks 17749 (PRE); Taylor 2654, 2816 (NBG); Ambraalshoek, Calvinia (-BD), Marais 119 (STEU); Hills N of Calvinia (-BD), Marloth 12782 (PRE); Calvinia (-BD), Schmidt 279 (PRE); Blauwkranz Pass (-DA), Hall 3866 (NBG); Marais 68 (STEU); Rebunie Mountains (-DB), Marloth 10303 (PRE).

–3219 (Wuppertal): 6km from Bizansgat to Sutherland (-DD), Marais 217 (STEU).

–3220 (Sutherland): Ouberg Pass (-AD), Marais 252 (STEU); Tankwa, Klein Roggeveld (-BC), Marloth 10388 (PRE); between Hottentotskloof and Sutherland (-BC), Leipoldt s.n. (BOL); Thyshoogte (-CC), Marais 218, 224 (STEU); between Windheuwel and Bloemfontein (-CD), Marais 335 (STEU); Verlatenkloof, Sutherland (-DA), Leighton 3186 (BOL, K); Marais 225 (STEU).

–3319 (Worcester): 4km N of Karoo Poort (-BA), Lavranos and Pehlemann 17478 (STEU).

–3320 (Montagu): Jagerskraal (-AB), Bayer 3608 (NBG); Matjiesfontein (-BA), Compton 3306 (BOL, K); Marloth 9580 (PRE); Van der Walt s.n. (STEU); Whitehill, Karoo Garden (-BA), Compton 11809, 15228 (NBG); Whitehill ridge (-BA), Compton 13387 (NBG); Whitehill (-BA), Pillans 14143 (BOL); 4km from Matjiesfontein to Sutherland (-BA), Marais 210 (STEU); Gnaapkop, Matjiesfontein (-BA), Marais 355 (STEU); Bantams, Witteberge (-BC), Compton 12167 (NBG).

Acknowledgements — I would like to thank the Brenthurst Library for permission to reproduce the watercolour paintings done by the late Ellaphie Ward-Hilhorst and the Computing Centre for Water Research, University of Natal, Pietermaritzburg for the use of their database on the mean annual precipitation (MAP).

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Edited by JC Manning