

Floristics of the Dunbar Valley serpentinite site, Songimvelo Game Reserve, South Africa

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The Dunbar Valley serpentinite outcrop has a flora comprising 254 taxa (species and below) in 172 genera and 63 families. Dunbar Valley has more species than other studied serpentinite sites in the Barberton Greenstone Belt (BGB). The genus *Senecio* is the most speciose genus in the BGB. The level of species endemism at Dunbar Valley is 2.0%. Most of the serpentinite endemics in the BGB show phytogeographical affinities with the Sudano-Zambezian Region. Six modified-Whittaker plots, three on serpentinite and three on non-serpentinite soils, were sampled. Sørensen's index was 0.312, indicating low similarity in species between serpentinite and non-serpentinite sites (β -diversity) at Dunbar Valley, as at other sites in the BGB. α -diversity (using the Shannon–Wiener index) for the serpentinite was 2.631 ± 0.901 and for the non-serpentinite, 2.886 ± 0.130 . However, a Student's *t*-test showed no significant difference in α -diversity between the two habitats. There was also no significant difference in species richness between serpentinite and non-serpentinite sites. Total species showed negative correlations with total nickel, altitude and serpentinite outcrop size (area) for six sites in the BGB. Number of endemic taxa showed no correlation with environmental variables. © 2003 The Linnean Society of London, *Botanical Journal of the Linnean Society*, 2003, 143, 271–285.

ADDITIONAL KEYWORDS: checklist of flora – endemism – phytogeography – species diversity.

INTRODUCTION

The term serpentinite, in its narrowest sense, is applied to the minerals antigorite and chrysolite that have the general formula $Mg_3Si_2O_5(OH)_4$ and are derived from ultramafic rocks (Brooks, 1987). Ultramafic rocks occupy less than 1% of the land surface of the earth and are found on all the continents, bearing important minerals such as nickel, chromium and cobalt amongst others. Rocks that are rich in serpentine minerals derived from the alteration of previously existing olivines and pyroxenes are known as serpentinites (Brooks, 1987).

Soils derived from serpentinite rocks vary from one site to another as the type of soil produced during the weathering process depends on factors such as the nature of the parent material, climate, relief, time, and biological activity (Brooks, 1987). Generally, ser-

pentinite soils have a high concentration of nickel, chromium, cobalt, and iron; a high magnesium-to-calcium ratio; and a low concentration of soil nutrients such as nitrogen, phosphorus, and potassium (Brooks, 1987; Balkwill *et al.*, 1997). These conditions have considerable effect on the vegetation growing in these soils, resulting in serpentinite sites supporting a very unusual and specialized flora consisting of species that have evolved some degree of resistance to heavy metals (Williamson, Robinson & Balkwill, 1997). Therefore, serpentinite sites are expected to have low diversity (Kruckeberg, 1954).

There is usually some contrast between the serpentinite flora and the nearby non-serpentinite sites (Brooks, 1987). In addition, a number of taxa that are endemic to the serpentinite soils usually occur. However, the existence of endemics with restricted distributions depends largely on the availability of suitable habitats as the individual populations of the serpentinite endemics are usually small and vulnerable to local disturbances (Brooks, 1987). Although serpen-

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tinite sites are considered important as reservoirs of rare and endemic species and have untapped potential for contributing to the understanding of evolutionary science, the sites are neglected areas of research and many have not been described biologically; additionally, many are under threat because of not being formally conserved (Proctor & Nagy, 1992; Balkwill *et al.*, 1997).

In South Africa, major outcrops of serpentinite are found in two regions, namely the Greenstone Belt of the Barberton Mountainland in Mpumalanga and a band from Potgietersrus to Duiwelskloof in the Northern Province. In addition, smaller outcrops of serpentinite also occur on the Witwatersrand (Gauteng) and in KwaZulu-Natal. There are 36 serpentinite sites in Mpumalanga, 30 of which have been mapped by geologists and six small sites are considered to be serpentinitiferous as a result of the presence of the nickel hyperaccumulators *Berkheya coddii* Roessler and/or *B. rehmannii* Thell. var. *rogersiana* Thell. Balkwill *et al.* (1997) give a list of serpentinite sites in southern Mpumalanga with their approximate sizes (area), range of altitudes and the veld types in which they occur.

So far serpentinite studies in South Africa have concentrated mainly on the sites in the Barberton Greenstone Belt (BGB). These sites have shown considerable diversity in physical features and soil chemical properties (Morrey, Balkwill & Balkwill, 1989; Balkwill *et al.*, 1997). More than 1000 taxa at species level and below, including 31 endemics, have been recorded on serpentinite sites in the BGB and are considered serpentinite-tolerant. However, the conservation status of most of the endemics has not been assessed and most would be classified as either rare or endangered based on the new International Union for the Conservation of Nature categories (Hilton-Taylor, 1997).

The main objectives of this study were: (a) to identify previously unidentified material from the Dunbar Valley serpentinite site that had been collected and housed in the C. E. Moss Herbarium, University of the Witwatersrand and to update and analyse a checklist of flora of the site; (b) to determine species richness and diversity of the Dunbar Valley and compare these with other studied sites in South Africa; (c) to determine the phytogeographical affinities of the serpentinite endemics of the BGB through their close relatives; and (d) to determine whether environmental factors such as size, altitude, and soil properties (i.e. pH, total nickel, total chromium, magnesium-to-calcium ratio) influence species numbers and endemism on serpentinite sites.

STUDY AREA

Dunbar Valley occurs within the Songimvelo Game Reserve (SGR), which is situated in the Barberton

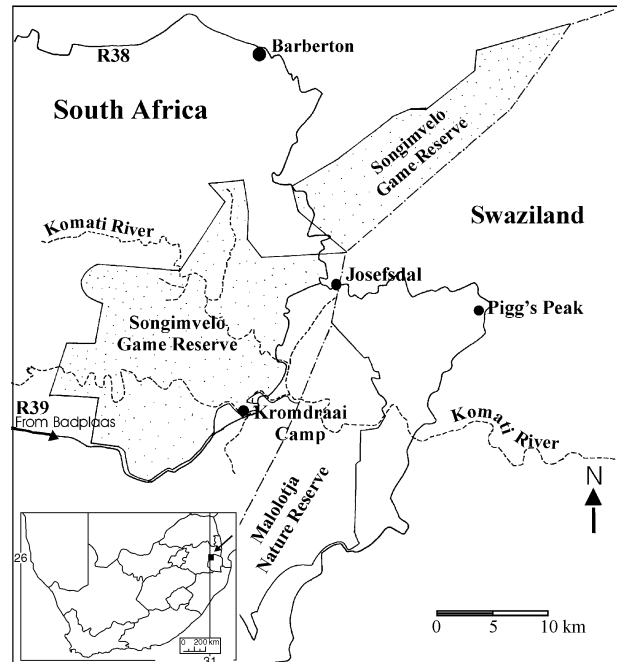


Figure 1. The locality of the Songimvelo Game Reserve in Mpumalanga, South Africa.

Mountainland of Mpumalanga, South Africa. The Dunbar Valley serpentinite site is at the lower end of the altitudinal range (800–880 m) of the SGR with an approximate area of 1.9 km² (Fig. 1). The vegetation of the SGR is highly diverse with representation of three biomes, namely Savanna, Grassland, and Forest (Stalmans, Robinson & Balkwill, 1999). The Dunbar Valley serpentinite outcrop falls within the Grassland Biome.

The SGR is drained by numerous perennial rivers and streams, of which the Komati is the most important. Rains fall mainly from November to March and vary from less than 800 mm per annum in the lowland areas to over 1600 mm in the high-altitude areas. The mean minimum and maximum monthly temperatures range between 5.4 and 7.9°C in July and 22 and 34°C in January for the highland and lowland areas, respectively, and frost is common in winter months (Anonymous, 1986; Gamble, 1988). The local people living within this area are the bakaNgwane people from Swaziland. They are peasant farmers cultivating crops (mainly maize) and keeping livestock in the form of cattle.

The SGR supports large game including African elephant [*Loxondonta africana* (Blumenbach)], white rhinoceros [*Ceratotherium simum* (Burchell)], eland [*Taurotragus oryx* (Pallas)], Burchell's zebra [*Equus burchelli* (Gray)] and blue wildebeest [*Connochaetes taurinus* (Burchell)]. Others are kudu [*Tragelaphus strepsiceros* (Pallas)], mountain reedbuck [*Redunca fulvorufula* (Afzelius)], warthog [*Phacochoerus aethi-*

opicus (Pallas)] and hippopotamus (*Hippopotamus amphibius* L.).

MATERIAL AND METHODS

COMPILATION OF CHECKLIST OF FLORA

A preliminary systematic checklist of the Dunbar Valley serpentinite site was obtained from the computerized database of the C. E. Moss Herbarium Management System and is arranged following the Engler system (Arnold & De Wet, 1993) and the electronic update of the same (Plants in southern Africa database). The checklist was a compilation of plant specimens collected and currently deposited in the C. E. Moss Herbarium by K. Balkwill, M.-J. Balkwill, F. Hologne, A. Lee, E. Masilo, M. Stalmans and S. D. Williamson. Unidentified material collected and deposited in the C. E. Moss Herbarium and that collected from modified-Whittaker plots during this study were identified using the Quick Guides and relevant literature. The identification of the specimens on the checklist that represented taxa not already on the checklist were verified before names were added to the computerized Herbarium Management System, which was used to update the checklist. The currently accepted conservation status of each taxon on the checklist was ascertained using the *Red Data List of Southern African Plants* and its updates (Hilton-Taylor, 1996a,b, 1997).

ENDEMICS AND THEIR PHYTOGEOGRAPHICAL AFFINITIES

Because endemic taxa are restricted to the serpentinite patches in the BGB, their phytogeographical affinities cannot be inferred from their distributions, and thus the distributions of closest relatives were used for this purpose. Keys, cladograms, statements of relationships, and natural groupings in recent monographs, revisions, and relevant literature were used to determine the close relatives of the serpentinite endemics. The distributions of the close relatives were determined from maps in monographs and revisions or drawn from data obtained from PRECIS, the computerized information system of the National Botanical Institute in Pretoria, South Africa. The distribution of the close relatives was compared with the phytogeographical regions proposed by Werger (1978) and a phytogeographical affinity was assigned on this basis. A chi-square test of goodness of fit (χ^2) was used to determine whether the endemics were evenly distributed among the families.

SPECIES RICHNESS AND DIVERSITY

To determine α - and β -diversity of serpentinite and non-serpentinite sites, vegetation sampling was con-

ducted between 12 and 22 May 2000. Modified-Whittaker plots (Stohlgren, Falkner & Schnell, 1995) were used. Six 20 m \times 50 m plots with their subplots were sampled, three on serpentinite and three on the adjacent non-serpentinite. These plots were placed parallel to the contours of the hill (i.e. at right angles to a habitat gradient) on both serpentinite and non-serpentinite sites. The first plot was placed at the base of the slope. The second plot was placed in the middle of the slope and the third on the crest of the hill.

Ten 1 m² (0.5 m \times 2 m) and two 10 m² (2 m \times 5 m) subplots were placed systematically inside the perimeter of the 1000 m² (20 m \times 50 m) plot and one 100 m² (5 m \times 20 m) subplot was centred in the plot. The three subplots were independent and non-overlapping. From the ten outer perimeter 0.5 m \times 2 m non-contiguous plots, the numbers of species were recorded on the field data sheet. The same procedure was applied for the two 2 m \times 5 m outer perimeter and non-overlapping subplots and within the one 5 m \times 20 m centred subplot. Additional species occurring in the 20 m \times 50 m plot were recorded. The modified-Domain Scale (Kent & Coker, 1994) was used to determine the relative percentage cover of individual plant species in the 20 m \times 50 m plot. The same procedure was repeated on the non-serpentinite site.

Species were classified as trees if they appeared in *Trees of Southern Africa* (Coates Palgrave, 1983). χ^2 was used to test whether frequency occurrences of monocotyledons and dicotyledons on serpentinite and non-serpentinite deviated significantly (Watt, 1997) from the expected ratio of 1 : 3 (ratio based on the total number of monocotyledons and total number of dicotyledons recorded in South Africa (Arnold & De Wet, 1993)).

β -diversity between serpentinite and non-serpentinite sites was calculated using Sørensen's index (Q_s):

$$Q_s = [2c/(a + b)]100$$

where a and b are the number of species occurring on serpentinite and non-serpentinite sites, respectively, and c is the number of species shared by a and b (Kent & Coker, 1994). This was compared with other studied sites in the BGB (S. D. Williamson *et al.*, unpubl. data). The α -diversity was calculated using the Shannon–Wiener index (H') as (Kent & Coker, 1994):

$$H' = -\sum_{i=1}^s p_i \ln p_i$$

where s is the number of species, p_i is the proportion of the individuals or the abundance of the i th species expressed as a proportion of the total cover and \ln is the logarithm to the base e . The Shannon–Wiener index (H') is widely used as it combines species richness and evenness and it is not affected by sample size (Kent & Coker, 1994).

Student's *t*-tests (Watt, 1997) were used to test for significant differences between average species richness of the serpentinite and non-serpentinite sites and also to test whether total numbers of species and endemics were correlated with environmental variables such as size or area, altitude, and soil chemical properties (i.e. levels of nickel, chromium, pH, magnesium-to-calcium ratio) for six sites in the BGB (i.e. Agnes Mine, Diepgezet, Kaapsehoop, Mundt's Concession, Groenvaly, and Dunbar Valley). Correlation coefficients were used to determine whether altitude influenced phytogeographical affinities (i.e. Sudano-Zambeian, Afromontane and Tongaland-Pondoland Regions) of the endemics present at a site.

RESULTS

CHECKLIST OF FLORA

The Dunbar Valley serpentinite site has a total of 254 species and infraspecific taxa in 172 genera and 63 families (Appendix, Table 1). Pteridophytes are represented by only one family, two genera and four taxa. Monocotyledons are relatively few, contributing 15.9% at family level, 24.2% at generic level, and 25.2% at

species and infraspecific taxon level. The family Gramineae makes up 65.0% of the monocotyledon species and 17.2% of the total flora. There is no dominant genus in this family. Cyperaceae is the second largest monocotyledon family, contributing about 2.8% to the total number of species at Dunbar Valley.

The dicotyledons are in the majority, comprising 186 species of the Dunbar Valley flora. Four families dominate: Compositae (30 species, 11.8% of the total species); Leguminosae (23 species, 9.1%); Asclepiadaceae (13 species, 5.1%); and Euphorbiaceae (11 species, 4.3%). These families represent 30.3% of the total Dunbar Valley flora. Dicotyledons are dominant at family (68.2%), generic (74.4%), and species and infraspecific taxon (73.2%) levels (Table 1).

Gramineae has the highest number of taxa of the total Dunbar Valley flora but a relatively low species-to-genus ratio of 1.7, indicating that there is a spread of taxa over a number of genera (Table 2). By contrast, Thymelaeaceae has a high species-to-genus ratio of 3.0, indicating that its taxa are spread within a few genera. In the flora as a whole, Rubiaceae has the lowest species-to-genus ratio of 1.0, represented by seven taxa in seven genera. The genus *Senecio* has the highest total number of taxa at all the studied sites except

Table 1. Numbers of families, genera, species, and infraspecific taxa of the Dunbar Valley serpentinite site

Taxonomic level	Pteridophytes		Angiosperms Monocotyledons		Dicotyledons		All Total
	Total	%	Total	%	Total	%	
Family	1	1.6	10	15.9	52	68.2	63
Genus	2	1.2	42	24.2	128	74.4	172
Species and infraspecific taxa	4	1.6	64	25.2	186	73.2	254

Table 2. Number of genera, species and infraspecific taxa in families represented by five or more species and the species:genus ratio for those families at Dunbar Valley

Family	Genera		Species		Species-to-genus ratio
	Total	% total	Total	% total	
Gramineae	26	15.1	44	17.2	1.7
Compositae	13	7.6	30	11.8	2.3
Leguminosae (Papilionoideae)	13	7.6	23	9.1	1.8
Asclepiadaceae	8	4.6	13	5.1	1.6
Euphorbiaceae	8	4.6	11	4.3	1.4
Rubiaceae	7	4.1	7	2.8	1
Cyperaceae	6	3.5	7	2.8	1.2
Labiatae	5	2.9	7	2.8	1.4
Scrophulariaceae	5	2.9	7	2.8	1.4
Acanthaceae	5	2.9	8	3.1	1.6
Thymelaeaceae	2	1.2	6	2.4	3

Table 3. Number of taxa at different hierarchical levels and numbers of endemics at Agnes Mine (AM), Mundt's Concession (MC), Diepgezet (DG), Kaapsehoop (KH), Groenvaly (GV) and Dunbar Valley (DV) in South Africa. Values in bold type are the highest in each row

Level	Serpentine sites					
	AM	MC	DG	KH	GV	DV
Families	50	35	62	49	54	63
Genera	147	83	191	127	132	172
Species and infraspecific taxa	201	104	209	170	198	254
Endemics	14	6	5	9	6	5
% Endemism	6.9	5.8	2.4	5.3	3	2
Size of site (km ²)	6.75	8.5	0.74	11.63	14.5	1.9

Dunbar Valley. The Dunbar Valley flora has a 2.0% level of endemism with five serpentine endemics, namely *Berkheya coddii*, *B. rehmannii* var. *rogersiana*, *Helichrysum* sp. nov., *Ocimum* sp. nov. 1 and *Sartidia* sp. nov. (Table 3).

ENDEMICS AND THEIR PHYTOGEOGRAPHICAL AFFINITIES

Thirty-one serpentine endemics are significantly unevenly distributed among families ($\chi^2 = 37.95$, $P < 0.05$, d.f. = 1) and they show affinities with three phytogeographical regions (Table 4). Approximately 53% of the endemics show affinities with the Sudano-Zambezian Region, 42% with the Afromontane Region and 5% with the Tongaland-Pondoland Regional Mosaic. There was no correlation (r -values < 0.5100) between altitude and numbers of endemics with any particular phytogeographical region.

SPECIES RICHNESS AND DIVERSITY

In modified-Whittaker plots, the total number of taxa recorded on serpentine and non-serpentine sites were 57 and 65, respectively, of which 19 taxa were recorded on both sites. Thirty-five dicotyledons and 30 monocotyledons were recorded on serpentine plots. Thirty-four dicotyledons and 30 monocotyledons were recorded on non-serpentine plots. A chi-square test showed no significant deviation ($\chi^2 = 3.45$, $P > 0.05$, d.f. = 1) from the expected ratio of 1 : 3 for monocotyledons and dicotyledons on serpentine whereas on non-serpentine it showed a significant departure from the expected ratio ($\chi^2 = 16.08$, $P < 0.05$, d.f. = 1). Of the 57 species recorded on serpentine, 78.9% were herbs and 21.1% were trees/shrubs. On the non-serpentine site, herbs accounted for 83.1% and trees/shrubs accounted for 16.9%.

The quotient of similarity (Sørensen's index) between the two sites was 31.2% (Table 5a). The

Sørensen's indices within serpentine plots ranged from 35.7 to 57.6% whereas for non-serpentine they ranged from 28.1 to 44.4% (Table 5b). A t -test showed no significant difference between Sørensen's indices within serpentine and non-serpentine plots. The Shannon–Wiener index (H') per 0.1 ha was 2.631 ± 0.901 on the serpentine site and 2.886 ± 0.310 on the non-serpentine site. Statistically, there was no significant difference ($P > 0.05$) in α -diversity between the two sites (Table 6). Species richness per 0.1 ha for serpentine and non-serpentine sites was 29.0 ± 4.3 and 31.7 ± 2.9 , respectively (not significantly different, $P > 0.05$, Table 7).

Total species for six sites showed significant negative correlation with nickel ($P < 0.05$), altitude, and size ($P < 0.05$), whereas pH, chromium, and magnesium-to-calcium ratio showed no correlations. Endemism showed no correlation with soil chemical properties, altitude, or size.

DISCUSSION

THE FLORA OF THE DUNBAR VALLEY SERPENTINITE SITE

The flora of Dunbar Valley with 254 species in 172 genera and 63 families can be described as relatively species rich in comparison with other studied serpentine sites in South Africa (Tables 1, 3). Low levels in families, genera, and species occur at Mundt's Concession. The higher number of taxa recorded at Dunbar Valley may be due to the duration, density, and intensity of collection compared with other sites. The flora has few pteridophytes, a situation similar to other studied serpentine sites in the BGB (Kidger, 1993; Williamson, 1994; Balkwill & Balkwill, 1999).

Monocotyledons usually make up between 40% and 60% of total species on serpentine sites (Werger, Wild & Drummond, 1978). From modified-Whittaker plots sampled at Dunbar Valley, monocotyledons accounted

Table 4. Endemics of studied sites, their close relatives and the phylogeographical affinities of the close relatives. SZ = Sudano-Zambezian Region, AM = Afromontane Region and TP = Tongaland-Pondoland Region. (**Serpentine endemics at Dunbar Valley; + vulnerable taxa.)

Taxon	Close relative(s)	Source	SZ	AM	TP
+ <i>Aloe thorncroftii</i> Pole-Evans	<i>Aloe suprafoliata</i> Pole-Evans	Van Wyk & Smith (1996)	+		
<i>Asystasia subbiflora</i> C.B. Clarke	<i>Asystasia retrocarpa</i> T.J. Edwards	Edwards (1991)	+		
<i>Athrixia</i> sp. nov.	<i>Athrixia subsimplex</i> Brenan	Smith & Balkwill (in press)		+	
** <i>Berkheya coddii</i> Roessler	<i>Berkheya angotensis</i> O. Hoffm.	Williamson (1994) and Röessler (1959)	+		
** <i>Berkheya nivea</i> N.E. Br.	<i>Berkheya rehmannii</i> Thell. var. <i>rehmannii</i>	Williamson (1994) and Röessler (1959)	+		
** <i>Berkheya</i> Thell. <i>rehmannii</i> var. <i>rogersiana</i> Thell.	<i>Berkheya rehmannii</i> Thell. var. <i>rehmannii</i>	Williamson (1994) and Röessler (1959)	+		
<i>Berkheya</i> sp. nov.	<i>Berkheya seminivea</i> Harv. & Sond.	Williamson (1994) and Röessler (1959)	+		
<i>Brachystelma dyeri</i> K. Balkwill & M. Balkwill	<i>Brachystelma gracile</i> E.A. Bruce	Dyer (1983)	+		
<i>Brachystelma</i> sp. nov.	<i>Brachystelma frankiae</i> N.E. Br.	Dyer (1983)	+		
<i>Cheilanthes</i> sp. nov.	<i>Cheilanthes hirta</i> Sw. var. <i>hirta</i>	Burrows (1990)	+		
<i>Cyphia bolusii</i> E. Phillips	<i>Cyphia alba</i> N.E. Br.	Wimmer (1968)		+	
<i>Cyphia elata</i> Harv. var. <i>gerrardii</i> (Harv.) E. Wimm. forma <i>decurrrens</i> E. Wimm.	<i>Cyphia elata</i> Harv. var. <i>elata</i>	Wimmer (1968)		+	
<i>Dicoma</i> sp. nov.	<i>Dicoma zeyheri</i> Sond.	Pope (1991)	+		
<i>Dicoma</i> sp. nov.	<i>Dicoma anomala</i> Sond.	Pope (1991)	+		
<i>Gladiolus serpeniticola</i> Goldblatt & J.C. Manning	<i>Gladiolus crassifolius</i> Baker	Goldblatt & Manning (1998)		+	
	<i>Gladiolus hollandii</i> L. Bolus	Goldblatt & Manning (1998)	+		
	<i>Gladiolus densiflorus</i> Baker	Goldblatt & Manning (1998)			+
<i>Gymnosporia</i> sp. nov.	<i>Gymnosporia heterophylla</i> Loes.	Jordaan (unpubl. data)			+
** <i>Helichrysum</i> sp. nov.	<i>Helichrysum confertifolium</i> Klatt	Lee (1996)		+	
<i>Indigofera crebra</i> N.E. Br.	<i>Indigofera ingrata</i> N.E. Br.	Brown (1925)	+		
	<i>Indigofera tristoides</i> N.E. Br.	Brown (1925)		+	
<i>Inezia</i> sp. nov.	<i>Inezia spectiosa</i> F. Bruce	Smith & Balkwill (in press)		+	
** <i>Ocimum</i> sp. nov. 1	<i>Ocimum obovatum</i> E. Mey. ex Benth. ssp. <i>obovatum</i> var. <i>obovatum</i>	Balkwill (unpubl. data)	+		
<i>Ocimum</i> sp. nov. 2	<i>Ocimum obovatum</i> E. Mey. var. <i>hians</i>	Balkwill (unpubl. data)	+		
<i>Ozoroa barbertonensis</i> Retief	<i>Ozoroa albicans</i> R. Fern. & A. Fern.	Retief (1990)	+		
	<i>Ozoroa schinzii</i> R. Fern. & A. Fern.	Retief (1990)	+		
<i>Ozoroa</i> sp. nov.	<i>Ozoroa barbertonensis</i> Retief	Balkwill (unpubl. data)	+		
+ <i>Protea curvata</i> N.E. Br.	<i>Protea laetans</i> L.E. Davidson	Rourke (1980)		+	
	<i>Protea comptonii</i> Beard	Rourke (1980)		+	
<i>Rhus pygmaea</i> Moffett	<i>Rhus pondoensis</i> Schönll.	Moffett (1999)		+	
<i>Salpinctum hirsutum</i> T.J. Edwards	<i>Salpinctum natalense</i> T.J. Edwards	Edwards & Getliffe Norris (1989)	+		
** <i>Sartidia</i> sp. nov.	<i>Sartidia jucunda</i> (Schweick.) De Winter	Gibbs Russel <i>et al.</i> (1990)	+		
<i>Senecio</i> sp. nov.	<i>Senecio anomalochrous</i> Hilliard	Balkwill & Balkwill (1999)		+	
<i>Senecio</i> sp. nov.	<i>Senecio coronatus</i> Harv.	Balkwill & Balkwill (1999)		+	
<i>Sclerochiton triacanthus</i> A. Meeuse	<i>Sclerochiton ilicifolius</i> A. Meeuse	Vollesen (1991)	+		
<i>Thunbergia galpinii</i> Lindau	<i>Thunbergia atriplicifolia</i> E. Mey.	Balkwill & Campbell (1999)		+	
Total = 31			19	15	2

Table 5a. Sørensen's indices of similarities between serpentinite and non-serpentinite sites at Rosentuin (RT), Sawmill (SM), Kalkloof (KL), Groenvaly (GV), Mundt's Concession (MC), Magnesite (MM), Dunbar Valley (DV), and Core Zone (CZ). (Dunbar Valley site based on present study; information for other sites based on unpublished data of S. D. Williamson and co-workers.)

	RT	SM	KL	GV	MC	MM	DV	CZ
S' Index	0.461	0.440	0.434	0.399	0.393	0.359	0.312	0.311

Table 5b. Sørensen's indices within serpentinite plots and non-serpentinite plots at Dunbar Valley ($t = 10.144, P > 0.05$)

Plots	Serpentinite	Plots	Non-serpentinite
1 & 2	0.576	4 & 5	0.444
1 & 3	0.357	4 & 6	0.295
2 & 3	0.441	5 & 6	0.281
Mean	0.458 ± 0.274	Mean	0.339 ± 0.224

Table 6. Species diversity (H') for serpentinite and non-serpentinite sites in the Dunbar Valley

Site	Shannon-Wiener index (H')	T -value	P at 0.05
Serpentinite	2.631 ± 0.901	25.213	n.s.
Non-serpentinite	2.886 ± 0.130		

Table 7. Average species richness (i.e. number of species recorded per 1000 m²) on serpentinite and non-serpentinite sites. (Dunbar Valley site based on present study; information for other sites based on unpublished data of S. D. Williamson and co-workers.)

Site	Serpentinite	Non-serpentinite	Probability level	
Rosentuin	72.25 ± 11.65	69.00 ± 5.15	$P > 0.05$	n.s.
Sawmill	75.00 ± 5.79	78.50 ± 9.66	$P > 0.05$	n.s.
Kalkloof	83.50 ± 6.58	81.50 ± 8.73	$P > 0.05$	n.s.
Groenvaly	80.25 ± 6.80	73.50 ± 10.74	$P < 0.05$	*
Mundt's Concession	65.00 ± 3.08	67.50 ± 4.72	$P > 0.05$	n.s.
Magnesite	73.00 ± 6.63	54.25 ± 9.36	$P < 0.05$	*
Dunbar Valley	29.00 ± 4.30	31.66 ± 2.88	$P > 0.05$	n.s.
Core Zone	75.50 ± 4.82	84.00 ± 5.15	$P < 0.05$	*

for 36.4% of angiosperms on serpentinite and 46.9% on non-serpentinite. Statistically, there was no significant difference in the number of monocotyledons between serpentinite and non-serpentinite ($t = 9.00, P > 0.05, d.f. = 1$). However, these findings are area-specific and cannot be generalized because different environmental factors and anthropogenic activities as well as evolutionary history prevail at different serpentinite areas.

The floristic poverty of the serpentinite soils on the Great Dyke in Zimbabwe is attributed to tree species being almost absent from the serpentinite soils (Wild, 1965). At Dunbar Valley, 78.9% of the species recorded

on modified-Whittaker plots were herbs (i.e. grasses, forbs, or sedges) with few trees. This could be attributed to trees having tap root systems and nickel affecting the root meristem (Robertson, 1992).

The most speciose genus occurring on serpentinite sites in the BGB is *Senecio*. However, genera such as *Helichrysum*, *Vernonia*, *Pearsonia*, *Acalypha*, *Eragrostis*, *Berkheya*, and *Gnidia* are also well represented. The largest families are Gramineae, Compositae, Leguminosae (Papilionoideae), Asclepiadaceae, Euphorbiaceae, Rubiaceae, Cyperaceae, Labiatae, Scrophulariaceae, Acanthaceae, and Thymelaeaceae (Table 2). These families are also among the largest in

other studied serpentinite sites in the BGB (Kidger, 1993; Williamson, 1994; Balkwill & Balkwill, 1999).

The 2.0% level of endemism (Table 3) at Dunbar Valley is less than the 2.7% for all the studied serpentinite sites in the BGB. These endemics occur in all vascular plant groups; pteridophytes, monocotyledons, and dicotyledons, with the largest number of endemics occurring in Compositae (14) followed by Acanthaceae (four). Families contributing least to the serpentinite endemics are Adiantaceae, Celastraceae, Iridaceae, Leguminosae, Liliaceae, Gramineae and Proteaceae.

Of the 254 taxa recorded, nine are listed as red data taxa (Hilton-Taylor, 1996a,b, 1997). Four taxa are classed as not threatened [*Dianthus mooiensis* F.N. Williams ssp. *kirkii* (Burtty Davy) Hooper, *Protea gagedi* J.F. Gmel., *Heteropyxis canescens* Oliv. and *Xerophyta villosa* (Baker) L.B. Sm. & Ayensu]; two are classed as insufficiently unknown (*Rhus pondoensis* Schönk. and *Berkheya coddii*); two as rare [*Asclepias eminens* (Harv.) Schltr. and *Acalypha angustata* Sond. var. *glabra* Sond.]; and one as indeterminate (*Pegoletia lanceolata* Harv.). Two endemics (*Aloe thorncroftii* Pole-Evans and *Protea curvata* N.E. Br.) of the serpentinite sites of the BGB are classified as vulnerable (Table 4). The presence of red data species makes it imperative to conserve serpentinite sites.

Serpentinite sites are considered living laboratories where processes of evolution can be studied *in situ* (Kruckeberg, 1984). Some serpentine hyperaccumulating species may be used for bio-recovery of minerals and other metal-tolerant species may be very useful for successfully rehabilitating mine tailings and workings (Brooks, 1987; Liston & Balkwill, 1997). Therefore, Dunbar Valley, with five endemic species and two hyperaccumulators (*Berkheya coddii* and *B. rehmannii* var. *rogersiana*), can be regarded as a reservoir of rare and specialized species with high potential for contributing considerably to the understanding of evolutionary science and to the restoration of vegetation after mining of metals (Bradshaw, 1997).

PHYTOGEOGRAPHICAL AFFINITIES OF THE SERPENTINITE ENDEMICS OF THE BGB

Restriction of endemic species to serpentinite sites varies from highly localized (a single outcrop) to regional and widespread occurrences (Kruckeberg, 1984). *Helichrysum* sp. nov. near *H. confertifolium* Klatt, recorded only at Dunbar Valley (Lee, 1996), shows a striking example of a very highly localized endemic.

The site-by-site comparison of the occurrences of endemics based on lowest and highest altitudes showed no correlation ($P > 0.05$) with phytogeographical regions (i.e. Sudano-Zambeian, Afromontane or

Tongaland-Pondoland), indicating that altitude in the BGB does not appear to influence the phytogeographical affinities of serpentinite endemics. The endemics have by far the strongest phytogeographical affinities with the Sudano-Zambeian Region.

SPECIES RICHNESS AND DIVERSITY OF DUNBAR VALLEY IN COMPARISON WITH OTHER SITES

Like other studied sites in the BGB (Table 5a), Dunbar Valley has a low level of similarity in species composition (β -diversity) between serpentinite and non-serpentinite sites. Quotients of similarity within serpentinite and non-serpentinite showed low levels of species overlap within each of the habitats (Table 5b). This could be due to differences in vegetation ecoclines (Lee, 1996) affecting both serpentinite and non-serpentinite soils. The low levels in species richness per 0.1 ha at Dunbar Valley in comparison with other sites could be attributed to differences in timing of sampling.

Kruckeberg (1954) suggested that serpentinite soils should have low species richness because of extreme deficiency in soil nutrients and high concentrations of heavy metals. Del Moral (1972) found that because no continuous canopy developed on serpentinite, the resultant heterogeneity caused higher diversity than on surrounding non-serpentinite where mature forest developed. Whittaker (1960) found that species richness in the Siskiyou Mountains in the USA was higher on serpentinite soils than on non-serpentinite soils. Conversely, Werger *et al.* (1978) found a lower species number on serpentinite than on non-serpentinite soils. At Dunbar Valley, there was no significant difference ($P > 0.05$) in species diversity (H') between serpentinite and non-serpentinite sites (Table 6). This might have been due to the non-serpentinite plots having been purposely placed on grassland of the non-serpentinite area.

Within the BGB, species richness was significantly higher on serpentinite than on adjacent non-serpentinite soils at two of seven sites (Table 7). One site had species richness significantly higher on non-serpentinite soil than on serpentinite soil whereas four sites showed no significant differences in species richness. This study showed no significant difference ($P > 0.05$) in species richness between serpentinite and non-serpentinite soils at Dunbar Valley, a situation similar to some studied sites in the BGB (Table 7). These findings suggest that the effect of serpentinite soils on species richness is area-specific, resulting from a complex interplay of many factors such as soil chemical composition, altitude, and size of the serpentinite outcrop. Sometimes other factors such as soil moisture, the nature of dispersal, and competitive abilities of colonizing plants and major disturbance events such as

fire, grazing, and other human activities can outweigh the importance of serpentinite soils in determining species richness (Proctor & Craig, 1978; Tokeshi, 1999).

Wilson, Lee & Mark (1990) found that there was a decrease in total species with increased altitude in New Zealand on serpentinite soils. A similar situation occurs in the BGB. A significant negative correlation ($P < 0.05$) exists between total species and altitude. Negative correlation between total species and altitude can be considered to result from: (a) lower temperatures – some plant species do not withstand extremely low temperatures; and (b) increased isolation of some habitats at higher altitudes (Tokeshi, 1999).

The significant negative correlation ($P < 0.05$) between total species and total nickel concentration shows that fewer plant species can survive at higher concentrations of nickel in the soil. The phytotoxicity of nickel has been suggested to be one of the factors causing serpentinite soils to be infertile (Brooks, 1987). Therefore, it can be suggested that nickel plays a role in the determination of species diversity on the serpentinite sites in the BGB.

The weak negative correlation ($r = -0.4538$) between total species and area for six sites in the BGB shows a departure from the generalized phenomenon of positive linear correlation on contemporary patterns in plant community ecology and the prediction that there is an increase in habitat diversity with an increase in area (Shmida, 1984; Stohlgren *et al.*, 1995). However, exceptions to this generalization in comparing species richness of the tropical areas with that of the temperate zones have been reported (Tokeshi, 1999). Endemism showed no correlation ($r = 0.57$) with size of serpentinite outcrops, indicating that endemism is independent of size of area, at least in the BGB.

CONCLUSION

The serpentinite outcrop at Dunbar Valley has a rich and diverse flora with five serpentinite endemics and one (*Helichrysum* sp. nov. near *H. confertifolium*) has only been recorded at this site, thus making it an important area for conservation of plant diversity. Like other serpentinite sites, Dunbar Valley has potential to contribute to the understanding of the evolutionary history of serpentinite species. Although the Dunbar Valley serpentinite outcrop is located within the Songimvelo Game Reserve (hence protected and relatively undisturbed), the conservation of the serpentinite site depends largely on the land-use practices that will be allowed by the Mpumalanga Parks Board, which is responsible for the management of the reserve. Cultivation of crops by the local people, cou-

pled with grazing and burning practices on the serpentinite site, could lead to loss of the serpentinite habitat.

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REFERENCES

- Anonymous.** 1986. Master plan and management guidelines for the Songimvelo Natural Resources Area. Unpublished Plan, Chris Mulder Association.
- Arnold TH, De Wet BC, eds.** 1993. Plants of southern Africa: names and distribution. *Memoirs of the Botanical Survey of South Africa* **62**: 1–825.
- Balkwill K, Campbell G.** 1999. Taxonomic studies in Acanthaceae: testa microsculpturing in southern African species of *Thunbergia*. *Botanical Journal of the Linnean Society* **131**: 301–325.
- Balkwill K, Williamson SD, Kidger CL, Robinson ER, Stalmans M, Balkwill MJ.** 1997. Diversity and conservation of serpentine sites in southern Mpumalanga (Eastern Transvaal), South Africa. In: Jaffré T, Reeves RD, Becquer T, eds. *The ecology of ultramafic and metalliferous areas*. Nouméa: Orstom, 133–138.
- Balkwill MJ, Balkwill K.** 1999. *Characteristics, diversity, endemism and conservation of selected serpentine sites in the Barberton Greenstone Belt*. Unpublished Post Congress Tour Booklet, University of the Witwatersrand.
- Bradshaw AD.** 1997. Restoration after mining of metals – an ecological view. In: Jaffré T, Reeves RD, Becquer T, eds. *The ecology of ultramafic and metalliferous areas*. Nouméa: Orstom, 239–248.
- Brooks RR.** 1987. *Serpentine and its vegetation: a multi-disciplinary approach*. London: Croome Helm Limited.
- Brown NE.** 1925. New species of *Indigofera* from Transvaal and Swaziland. Bulletin of miscellaneous information. *Kew Bulletin* **1925**: 142–159.
- Burrows JE.** 1990. *Southern African ferns and fern allies*. Sandton: Frandsen.
- Coates Palgrave K.** 1983. *Trees of Southern Africa*. Cape Town: C. Struik.
- Del Moral R.** 1972. Diversity patterns in forest vegetation of the Wenatchee Mountains, Washington. *Bulletin of the Torrey Botanical Club* **99**: 57–64.

- Dyer RA. 1983.** *Ceropegia, Brachystelma and Riocreuxia in southern Africa*. Rotterdam: A.A. Balkema.
- Edwards TJ. 1991.** A new species of *Asystasia* from southern Africa, with notes on its alliances. *South African Journal of Botany* **57**: 305–309.
- Edwards TJ, Getliffe Norris F. 1989.** *Salpinctum*, a new genus of Acanthaceae in southern Africa. *South African Journal of Botany* **55**: 6–10.
- Gamble F. 1988.** Climate of the Transvaal Escarpment. In: Ferrar AA, Isaacs G, Stacey JR, eds. *Environmental conservation features of the Transvaal Escarpment*. Pretoria: Council for Scientific Institute and Research.
- Gibbs Russell GE, Watson L, Koekemoer M, Smook L, Barker NP, Anderson HM, Dallwitz MJ. 1990.** Grasses of southern Africa. *Memoirs of the Botanical Survey of South Africa* **58**: 1–438.
- Goldblatt P, Manning J. 1998.** *Gladiolus in Southern Africa*. South Africa: Fernwood Press.
- Hilton-Taylor C. 1996a.** Red Data List of southern African plants. *Strelitzia* **4**: 1–117.
- Hilton-Taylor C. 1996b.** Red Data List of southern African plants. 1. Corrections and additions. *Bothalia* **27**: 177–182.
- Hilton-Taylor C. 1997.** Red Data List of southern African plants. 2. Corrections and additions. *Bothalia* **27**: 195–209.
- Kent M, Coker P. 1994.** *Vegetation description and analysis: a practical approach*. Chichester: John Wiley and Sons Ltd.
- Kidger CL. 1993.** *Floristics of Josefsdal serpentine outcrop in Songimvelo Game Reserve*. Unpublished Honours Project. University of the Witwatersrand.
- Kruckeberg AR. 1954.** The ecology of serpentine soils. 2. Plant species in relation to serpentine soils. *Ecology* **35**: 267–274.
- Kruckeberg AR. 1984.** California serpentine: flora, vegetation, geology, soils and management problems. *University of California Publications in Botany* **78**: 1–180.
- Lee A. 1996.** *The floristics of the serpentine soils of Dunbar Valley, Songimvelo Game Reserve*. Unpublished Honours Project. University of the Witwatersrand.
- Liston RJ, Balkwill K. 1997.** Suitability of serpentine plants for the revegetation of chrysotile asbestos tailings. In: Jaffré T, Reeves RD, Becquer T, eds. *The ecology of ultramafic and metalliferous areas*. Nouméa: Orstom, 275–283.
- Moffett RO. 1999.** A new species of *Rhus* (Anacardiaceae), endemic to serpentine near Barberton, Mpumalanga (Eastern Transvaal). *Botanical Journal of the Linnean Society* **130**: 37–42.
- Morrey DR, Balkwill K, Balkwill MJ. 1989.** Studies on serpentine flora: preliminary analyses of soils and vegetation associated with serpentine rock formations in the south-eastern Transvaal. *South African Journal of Botany* **55**: 171–177.
- Pope GV. 1991.** Notes on *Dicoma* Cass. (Compositae). *Kew Bulletin* **46**: 699–709.
- Proctor J, Craig CG. 1978.** The occurrence of woodland and riverine forests on the serpentine of the Great Dyke, Southern Rhodesia. *Kirkia* **11**: 129–132.
- Proctor J, Nagy L. 1992.** Ultramafic rocks and their vegetation: an overview. In: Baker AJM, Proctor JE, Reeves RD, eds. *Vegetation of ultramafic (serpentine) soils*. Andover: Intercept, 469–494.
- Retief E. 1990.** A new species of *Ozoroa* from the Transvaal. *Bothalia* **20**: 219–221.
- Robertson AI. 1992.** The relation of nickel toxicity to certain physiological aspects of serpentine ecology: some facts and a new hypothesis. In: Baker AJM, Proctor JE, Reeves RD, eds. *Vegetation of ultramafic (serpentine) soils*. Andover: Intercept, 331–336.
- Rössler H. 1959.** Revision der Arctotidae-Gorteriinae (Compositae). *Mitteilungen der Botanischen Staatssammlung München* **3**: 71–500.
- Rourke JP. 1980.** *The proteas of southern Africa*. London: Purnell.
- Shmida A. 1984.** Whittaker's plant diversity sampling methods. *Israel Journal of Botany* **33**: 41–46.
- Smith S, Balkwill K. in press.** New Compositae from the serpentine soils of the Barberton Greenstone Belt, South Africa. *Kew Bulletin* in press.
- Stalmans M, Robinson ER, Balkwill K. 1999.** Ordination and classification of vegetation of Songimvelo Game Reserve in the Barberton Mountainland, South Africa for the assessment of wildlife habitat, distribution and quality. *Bothalia* **29**: 305–325.
- Stohlgren TJ, Falkner MB, Schnell LD. 1995.** A modified-Whittaker nested vegetation sampling method. *Vegetatio* **117**: 1113–1121.
- Tokeshi M. 1999.** *Species coexistence: ecological and evolutionary perspectives*. Oxford: Blackwell Science Limited.
- Van Wyk B-E, Smith GF. 1996.** *Guide to the aloes of South Africa*. Pretoria: Briza Publications.
- Vollesen K. 1991.** A revision of the African genus *Sclerochiton* (Acanthaceae: Acantheae). *Kew Bulletin* **46**: 1–50.
- Watt TA. 1997.** *Introductory statistics for biology students*. London: Chapman & Hall.
- Wenger MJA. 1978.** *Biogeography and ecology of Southern Africa*. The Hague: Dr W. Junk.
- Wenger MJA, Wild H, Drummond BR. 1978.** Vegetation structure and substrate of the northern part of the Great Dyke, Rhodesia: gradient analysis and the dominance-diversity relationships. *Vegetatio* **37**: 151–161.
- Whittaker RH. 1960.** Vegetation of the Siskiyou Mountains, Oregon and California. *Ecological Monographs* **30**: 279–332.
- Wild H. 1965.** The flora of the Great Dyke of Southern Rhodesia with special reference to the serpentine soils. *Kirkia* **5**: 49–86.
- Williamson S. 1994.** Biosystematic studies of serpentine flora in the south-eastern Transvaal. Unpublished MSc thesis, University of the Witwatersrand.
- Williamson SD, Robinson ER, Balkwill K. 1997.** Evolution of two endemic serpentine taxa in Mpumalanga. *South African Journal of Botany* **63**: 507–513.
- Wilson JB, Lee GL, Mark AF. 1990.** Species diversity in relation to an ultramafic substrate and altitude in southwest New Zealand. *Vegetatio* **86**: 15–20.
- Wimmer FE. 1968.** *Engler das Pflanzenreich Campanulaceae—Cyphioideae 4*. Berlin: Academia-Verlag.

APPENDIX

CHECKLIST OF THE FLORA OF THE DUNBAR VALLEY
SERPENTINITE SITE

Taxa collected at the Dunbar Valley serpentinite site, Songimvelo Game Reserve, are listed below. Families are arranged in order of the Cronquist system and genera are arranged within families following the Engler system. Each name is followed by voucher specimens, all of which are deposited in the C. E. Moss Herbarium (J). Some collectors are abbreviated as follows: AL = A. Lee, FH = F. Hologne, GVC = G. V. Cron, KB = K. Balkwill, KC = K. Changwe, KE = K. Ellery, MS = M. Stalmans, SDW = S. D. Williamson, WNE = W. N. Ellery.

ACANTHACEAE

- Chaetacanthus costatus* Nees KB *et al.* 7635; AL 255
Ruellia malacophylla C.B. Clarke AL 82
Ruellia stenophylla C.B. Clarke AL 200
Lepidagathis scabra C.B. Clarke AL 186
Barleria gueinzii Sond. AL 79
Barleria ovata E. Mey. ex Nees FH 344
Barleria wilmsiana Lindau AL 223
Justicia anagaloides (Nees) T. Anderson KB *et al.* 7699

ADIANTACEAE

- Cheilanthes hirta* Sw. var. *hirta* KB 9163; WNE & KE 92/92
Cheilanthes involuta (Sw.) Schelpe & N.C. Anthony var. *involuta* WNE & KE 92/93
Cheilanthes involuta (Sw.) Schelpe & N.C. Anthony var. *obscura* (N.C. Anthony) N.C. Anthony FH 475
Pellaea calomelanos (Sw.) Link var. *calomelanos* KB *et al.* 7702

AIZOACEAE

- Limeum viscosum* (Gay) Fenzl ssp. *viscosum* var. *kraussii* Friedr. KB 9160

AMARANTHACEAE

- Kyphocarpa angustifolia* (Moq.) Lopr. KB 9155; KB *et al.* 7701

ANACARDIACEAE

- Ozoroa* sp. nov. AL 166
Rhus pondoensis Schönl. KB 9182; KB *et al.* 7687; AL 165; E. Masilo E 44; SDW 164
Rhus pyroides Burch. var. *gracilis* (Engl.) Burt Davy KB 9154

ANNONACEAE

- Annona senegalensis* Pers. ssp. *senegalensis* KC 20/01

ASCLEPIADACEAE

- Aspidoglossum glabrescens* (Schltr.) Kupicha M. Stalmans 3017
Aspidoglossum interruptum (E. Mey.) Bullock FH 385; AL 224
Pachycarpus asperifolius Meisn. AL 272; SDW 155
Pachycarpus concolor E. Mey. E. Masilo E 65
Pachycarpus scaber (Harv.) N.E. Br. KB *et al.* 7717
Stenostelma corniculatum (E. Mey.) Bullock KB *et al.* 7695; R. Kunitz & G. Otto 54
Asclepias adscendens (Schltr.) Schltr. WNE & KE 92/97; R. Kunitz & G. Otto 57
Asclepias aurea (Schltr.) Schltr. KB *et al.* 7714
Asclepias eminens (Harv.) Schltr. KB *et al.* 7689; AL 288
Sisyranchus randii S. Moore SDW 165
Brachystelma macropetalum (Schltr.) N.E. Br. KB 9153
Ceropegia rendalii N.E. Br. FH 501
Tenaris rubella E. Mey. KB *et al.* 7683

ASPARAGACEAE

- Asparagus setaceus* Kunth FH 773; AL 093

ASPHODELACEAE

- Trachyandra reflexipilosa* (Kuntze) Oberm. FH 10
Chlorophytum aridum Oberm. AL 193
Chlorophytum fasciculatum (Baker) S. Kativu WNE & KE 92/71
Aloe sp. prob. *A. minima* Baker FH 1391
Chortolirion angolense (Baker) A. Berger FH 1360

BORAGINACEAE

- Cynoglossum lanceolatum* Forssk. KC 20/04
Lithospermum sp. near *L. cinereum* DC. E. Masilo E 51
Lithospermum officinale L. KB *et al.* 7725

CAMPANULACEAE

- Wahlenbergia undulata* (L. f.) A. DC. var. *undulata* KB 9168; FH 428
Wahlenbergia virgata Engl. KB *et al.* 7636

CARYOPHYLLACEAE

- Dianthus mooiensis* F.N. Williams ssp. *kirkii* (Burt Davy) Hooper KB *et al.* 7637

CELASTRACEAE

- Maytenus heterophylla* (Eckl. & Zeyh.) N. Robson sens. lat. = *M. angularis* Sim KB 9177; KB *et al.* 7705; E. Masilo E 46; SDW 161

COMMELINACEAE

- Commelina africana* L. var. *africana* AL 292

COMPOSITAE/ASTERACEAE

- Vernonia hirsuta* (DC.) Sch. Bip. var. *hirsuta* E. Masilo E 70
Vernonia natalensis Sch. Bip. ex Walp. GVC 133; WNE & KE 92/111
Vernonia steetziana Oliv. & Hiern AL 104
Aster peglerae Bolus E. Masilo E 72
Nidorella auriculata DC. KB *et al.* 7696; WNE & KE 92/100; AL 180; AL 181
Helichrysum sp. nov. cf. *H. confertifolium* Klatt FH 551
Helichrysum coriaceum Harv. WNE & KE 92/108
Helichrysum nudifolium (L.) Less. KB *et al.* 7711
Helichrysum oreophilum Klatt FH 211
Helichrysum rosum (Bergius) Less. AL *s.n.*
Athrixia phyllicoides DC. KC 20/10
Pegolettia lanceolata Harv. KB *et al.* 7691; GVC 134
Geigeria burkei Harv. ssp. *burkei* var. *burkei* FH 1453; FH 253; FH 878
Geigeria burkei Harv. ssp. *burkei* var. *elata* Merxm. KB *et al.* 7693; GVC 131; AL 099; E. Masilo E 68
Callilepis laureola DC. KB *et al.* 7686
Acanthospermum glabratum (DC.) Wild FH 955
Xanthium strumarium L. KC 20/11
Zinnia peruviana (L.) L. KC 20/12
Schistostephium rotundifolium (DC.) Fenzl ex Harv. KC 20/13
Artemisia afra Jacq. ex Willd. AL 102
Senecio coronatus (Thunb.) Harv. WNE & KE 92/107
Senecio erubescens Aiton var. *crepidifolius* DC. KB *et al.* 7716
Senecio gregatus Hilliard FH 948
Senecio latifolius DC. E. Masilo E 68
Senecio microglossus DC. KB *et al.* 7647
Senecio serratuloides DC. var. *serratuloides* AL 192
Senecio venosus Harv. KB *et al.* 7646
Haplocarpha scaposa Harv. E. Masilo E 74
Berkheya coddii Roessler KB 9207; KB *et al.* 7710; GVC 126
Berkheya insignis (Harv.) Thell. KB *et al.* 7639; E. Masilo E 59
Berkheya setifera DC. I.H. Hartley 1303
Berkheya rehmannii Thell. var. *rogersiana* Thell. FH 650
Dicoma anomala Sond. FH 617
Dicoma swazilandica S. Ortiz, Rodr. Oubiña & Pulgar AL 107
Dicoma zeyheri Sond. ssp. *zeyheri* FH 572; FH 787; AL 110

CONVOLVULACEAE

- Convolvulus sagittatus* Thunb. FH 1408
Xenostegia tridentata (L.) D.F. Austin & Staples ssp. *angustifolia* (Jacq.) A. Meeuse WNE & KE 92/98

CRASSULACEAE

- Kalanchoe paniculata* Harv. KB 9171
Crassula acinaciformis Schinz KC 20/17

CUCURBITACEAE

- Corallocarpus bainesii* (Hook. f.) A. Meeuse AL 226
Cucumis zeyheri Sond. AL 227

CYPERACEAE

- Cyperus obtusiflorus* Vahl var. *obtusiflorus* AL 301
Cyperus obtusiflorus Vahl var. *sphaerocephalus* (Vahl) Kükenthal WNE & KE 92/109
Mariscus dregeanus Kunth AL 216
Fuirena pubescens (Poir.) Kunth WNE & KE 92/80
Bulbostylis oritrephes (Ridl.) C.B. Clarke ssp. *australis* B.L. Burt AL 217
Abildgaardia ovata (Burm. f.) Kral WNE & KE 92/82
Scleria bulbifera Hochst. ex A. Rich. WNE & KE 92/101

DIPSACACEAE

- Cephalaria petiolata* Compton KB 9185; FH 276
Scabiosa columbaria L. KB *et al.* 7712; WNE & KE 92/113; AL 291

EBENACEAE

- Euclea crispa* (Thunb.) Gürke ssp. *crispa* KC 20/15
Diospyros lycioides Desf. ssp. *nitens* (Harv. ex Hiern) De Winter KB *et al.* 7723
Diospyros whyteana (Hiern) F.B. White E. Masilo E 64

ERICACEAE

- Erica drakensbergensis* Guthrie & Bolus AL 308

EUPHORBIACEAE

- Securinega virosa* (Roxb. ex Willd.) Pax & K. Hoffm. KB *et al.* 7688
Phyllanthus maderaspatensis L. KB 9178; KB *et al.* 7718; WNE & KE 92/102; AL 018; SDW 162
Acalypha angustata Sond. var. *glabra* Sond. E. Masilo E 42
Acalypha peduncularis E. Mey. ex Meisn. KB *et al.* 7707; SDW 156
Acalypha villicaulis Hochst. WNE & KE 92/112
Acalypha wilmsii Pax ex Prain & Hutch. E. Masilo E 71
Tragia rogersii Prain WNE & KE 92/96
Jatropha latifolia Pax var. *angustata* Prain E. Masilo E 63
Clutia pulchella L. var. *pulchella* E. Masilo E 74a
Euphorbia pseudotuberosa Pax FH 1438
Chamaesyce inaequilatera (Sond.) Soják AL 023

GENTIANACEAE

- Chironia purpurascens* (E. Mey.) Benth. & Hook. f. ssp. *purpurascens* R. Kunitz & G. Otto 55

GERANIACEAE

- Monsonia transvaalensis* Knuth AL 21
Pelargonium luridum (Andr.) Sweet E. Masilo E 43

GRAMINEAE/POACEAE

- Imperata cylindrica* (L) Raeusch. WNE & KE 92/78; J. McDonald & R. Smit 46
Eulalia villosa (Thunb.) Nees AL 130
Bothriochloa insculpta (A. Rich.) A. Camus WNE & KE 92/81; AL 135
Schizachyrium sanguineum (Retz.) Alston FH 578; AL 318
Andropogon eucomus Nees L. Smook 8122
Andropogon schirensis A. Rich. FH 207; FH 468; FH 876
Cymbopogon excavatus (Hochst.) Stapf ex Burt Davy WNE & KE 92/79; AL 115; AL 310
Cymbopogon validus (Stapf) Stapf ex Burt Davy AL 116
Cymbopogon sp. cf. *C. marginatus* (Steud.) Stapf ex Burt Davy KC 20/14
Hyparrhenia filipendula (Hochst.) Stapf var. *pilosa* (Hochst.) Stapf AL 316
Hyparrhenia newtonii (Hack.) Stapf var. *newtonii* FH 340
Hyparrhenia rudis Stapf FH 341
Hyperthelia dissoluta (Nees ex Steud.) Clayton WNE & KE 92/88 (infl.); L. Smook 8105
Monocymbium ceresiiforme (Nees) Stapf FH 395; AL 274
Trachypogon spicatus (L. f.) Kuntze FH 449; AL 138
Heteropogon contortus (L) Roem. & Schult. KB 9174; WNE & KE 92/75; L. Smook 8108
Diheteropogon amplexens (Nees) Clayton FH 1606; AL 140
Themeda triandra Forssk. WNE & KE 92/76; AL 141
Digitaria diagonalis (Nees) Stapf var. *diagonalis* AL 142; AL 319
Brachiaria brizantha (A. Rich.) Stapf WNE & KE 92/90; AL 126
Brachiaria serrata (Thunb.) Stapf WNE & KE 92/103; WNE & KE 92/87
Panicum natalense Hochst. FH 796
Setaria lindenbergiana (Nees) Stapf WNE & KE 92/89
Setaria sphacelata (Schumach.) Moss var. *sphacelata* AL 139
Tricholaena sp. aff. *T. monachne* (Trin.) Stapf & C.E. Hubb. KB 9172; AL 317
Melinis nerviglumis (Franch.) Zizka WNE & KE 92/73; AL 123
Melinis repens (Willd.) Zizka ssp. *repens* FH 226; FH 412
Tristachya leucothrix Nees WNE & KE 92/86
Loudetia flavida (Stapf) C.E. Hubb FH 1596

- Loudetia simplex* (Nees) C.E. Hubb KB 9173; WNE & KE 92/85
Loudetia sp. near *L. simplex* (Nees) C.E. Hubb. AL 110
Aristida canescens Henr. ssp. *canescens* WNE & KE 92/72; AL 128; L. Smook 8118
Aristida congesta Roem. & Schult. ssp. *barbicollis* (Trin. & Rupr.) De Winter AL 132; AL 292
Aristida diffusa Trin. ssp. *burkei* (Stapf) Melderis FH 1420
Aristida transvaalensis Henr. L. Smook 8119
Sartidia sp. nov. KB 9167; AL 126
Sporobolus congoensis Franch. I.H. Hartley 1312
Sporobolus sanguineus Rendle L. Smook 8106
Sporobolus stapfianus Gand. WNE & KE 92/77
Eragrostis capensis (Thunb.) Trin. WNE & KE 92/84
Eragrostis chloromelas Steud. AL 129
Eragrostis racemosa (Thunb.) Steud. WNE & KE 92/83
Bewsia biflora (Hack.) Gooss. AL 315

GUTTIFERAE/CLUSIACEAE

- Hypericum aethiopicum* Thunb. ssp. *sonderi* (Bredell) N. Robson KB *et al.* 7645

HYACINTHACEAE

- Dipcadi viride* (L.) Moench KB 9158

HYPOXIDACEAE

- Hypoxis* sp. near *H. acuminata* Baker & *H. rigidula* Baker KB 9210; AL 145
Hypoxis iridifolia Baker WNE & KE 92/95
Hypoxis rigidula Baker var. *pilosissima* Baker E. Masilo E 58

IRIDACEAE

- Gladiolus ecklonii* Lehm. FH 5; AL 1; AL 144

LABIATAE/LAMIACEAE

- Tinnea galpinii* Briq. KB *et al.* 7682
Leonotis leonurus (L.) R. Br. AL 201
Stachys natalensis Hochst. var. *galpinii* (Briq.) Codd AL 081
Stachys natalensis Hochst. var. *natalensis* KB 9176; KB *et al.* 7640; KB *et al.* 7709; GVC 127; AL 254; E. Masilo E 49
Hemizygia transvaalensis (Schltr.) Ashby KB 9157; FH 1449
Ocimum sp. near *O. obovatum* E. Mey. ex Benth. KB 9162
Ocimum obovatum E. Mey. ex Benth. ssp. *obovatum* var. *galpinii* (Gürke) A.J. Paton KB *et al.* 7703
Ocimum sp. nov. KB *et al.* 7706; SDW 160

LEGUMINOSAE/FABACEAE (MIMOSOIDEAE)

- Acacia karoo* Hayne KC 20/20
Dichrostachys cinerea (L.) Wight & Arn. ssp. *nyassana* (Taub.) Brenan KC 20/21

- Elephantorrhiza elephantina* (Burch.) Skeels KB 9209; KB *et al.* 7685
- LEGUMINOSAE/FABACEAE (CAESALPINIOIDEAE)
Chamaecrista comosa E. Mey. var. *capricornia* (Steyaert) Lock AL 242
Peltophorum africanum Sond. GVC 137
- LEGUMINOSAE/FABACEAE (PAPILIONOIDEAE)
Lotononis calycina (E. Mey.) Benth. KB 9165; WNE & KE 92/94
Lotononis carinata (E. Mey.) Benth. KB 9164; KB *et al.* 7638; E. Masilo E 55; SDW 163
Pearsonia aristata (Schinz) Dummer E. Masilo E 76
Pearsonia sessilifolia (Harv.) Dummer ssp. *marginata* (Schinz) Polhill KB *et al.* 7641; AL 230
Pearsonia sessilifolia (Harv.) Dummer ssp. *sessilifolia* KB 9179
Crotalaria globifera E. Mey. AL 244
Argyrolobium robustum T.J. Edwards KB 9159; KB *et al.* 7648; AL 177
Indigofera dregeana E. Mey. KB *et al.* 7684
Indigofera swaziensis Bolus var. *swaziensis* AL 240
Tephrosia capensis (Jacq.) Pers. var. *capensis* FH 612
Tephrosia elongata E. Mey. var. *elongata* KB 9180
Stylosanthes fruticosa (Retz.) Alston KB *et al.* 7697
Zornia capensis Pers. KB *et al.* 7719
Dalbergia armata E. Mey. E. Masilo E 56
Rhynchosia minima (L.) DC. var. *prostrata* (Harv.) Meikle KB 9206
Rhynchosia monophylla Schltr. GVC 142
Rhynchosia sp. cf. *sordida* (E. Mey.) Schinz KB 9161; KB *et al.* 7681
Rhynchosia totta (Thunb.) DC. var. *totta* AL 94
Rhynchosia totta (Thunb.) DC. var. *graciliflora* Baker f. FH 465
Eriosema distinctum N.E. Br. FH 473; FH 892; AL 53
Eriosema sp. KB *et al.* 7722
Vigna unguiculata (L.) Walp. ssp. *protracta* KB 9166
- LOBELIACEAE
Cyphia elata Harv. var. *elata* FH 416; AL 171
- LYTHRACEAE
Nesaea schinzii Koehne FH 1448
- MALPIGHIACEAE
Sphedamnocarpus pruriens (Juss.) Szysz. ssp. *pruriens* AL 277
- MALVACEAE
Hibiscus aethiopicus L. var. *ovatus* Harv. E. Masilo E 48
Hibiscus calyphyllus Cav. E. Masilo E 62
Hibiscus trionum L. AL 304
- MELASTOMATACEAE
Dissotis canescens (E. Mey. ex R.A. Graham) Hook. f. glandular form WNE & KE 92/105
- MYRTACEAE
Heteropyxis canescens Oliv. KB *et al.* 7721
- OCHNACEAE
Ochna natalitia (Meisn.) Walp. KB *et al.* 7642; AL 299
- OLEACEAE
Jasminum quinatum Schinz WNE & KE 92/110
- ORCHIDACEAE
Eulophia clavicornis Lindl. var. *nutans* (Sond.) Hall WNE & KE 92/70
- PASSIFLORACEAE
Basananthe sandersonii (Harv.) W.J. de Wilde KB *et al.* 7643
- PEDALIACEAE
Ceratotheca triloba (Bernh.) Hook. f. FH 616; AL 038
- PERIPLOCACEAE
Raphionacme galpinii Schltr. KB 9175
Raphionacme procumbens Schltr. KB *et al.* 7694; R. Kunitz & G. Otto 56; E. Masilo E 66
- POLYGALACEAE
Polygala hottentotta C. Presl KB 9186; GVC 129; AL 91
Polygala serpentaria Eckl. & Zeyh. GVC 143
- PROTEACEAE
Faurea speciosa (Welw.) Welw. WNE & KE 92/91
Protea gagedi J.F. Gmel. KB 9208
- RANUNCULACEAE
Clematis brachiata Thunb. AL 172
- ROSACEAE
Rubus rigidus Sm. GVC 132; E. Masilo E 45
- RUBIACEAE
Cephalanthus natalensis Oliv. KC 20/06
Pentanisia angustifolia (Hochst.) Hochst. KB *et al.* 7704; KB *et al.* 7720; AL 077; E. Masilo E 75
Vangueria infausta Burch. ssp. *infausta* KC 20/07
Pachystigma latifolium Sond. KB 9181; KB *et al.* 7715; WNE & KE 92/106; AL 39; E. Masilo E 60
Pavetta edentula Sond. KC 20/08
Anthospermum rigidum Eckl. & Zeyh. ssp. *pumilum* (Sond.) Puff AL 13
Spermacoce natalensis Hochst. KC 20/09

SANTALACEAE

Thesium exile N.E. Br. KB *et al.* 7644

SCROPHULARIACEAE

Peliostomum leucorrhizum E. Mey. ex Benth. AL 306

Bowkeria cymosa MacOwan KC 20/05

Jamesbrittenia grandiflora (Galpin) Hilliard AL 221

Jamesbrittenia micrantha (Klotzsch) Hilliard WNE & KE 92/99

Alectra orobanchioides Benth. AL 27

Striga asiatica (L.) Kuntze KB 9184; AL 280

Striga bilabiata (Thunb.) Kuntze KB *et al.* 7698; GVC 128; AL 62; AL 222

SOLANACEAE

Solanum tomentosum L. E. Masilo E 41

STERCULIACEAE

Waltheria indica L. E. Masilo E 47

THUNBERGIACEAE

Thunbergia atriplicifolia E. Mey. ex Nees KB *et al.* 7700; AL 253

THYMELAEACEAE

Gnidia caffra (Meisn.) Gilg I.H. Hartley 1295

Gnidia capitata L. f. KB *et al.* 7690; FH 665; AL 281

Gnidia gymnostachya (C.A. Mey.) Gilg KB 9183; KB *et al.* 7708; FH 274; FH 896; SDW 159

Gnidia rubescens Peterson KB 9169; GVC 130; WNE & KE 92/104; AL 169; E. Masilo E 54; M. Stalmans 2797

Dais cotinifolia L. E. Masilo E 61

TILIACEAE

Corchorus asplenifolius Burch. KC 20/02

Corchorus confusus Wild KB 9170; KB *et al.* 7692; AL 300; E. Masilo E 53; SDW 157

Plectranthus verticillatus (L. f.) Druce KC 20/03

UMBELLIFERAE/APIACEAE

Alepidea setifera N.E. Br. KB 9211; AL 196

Heteromorpha involucrata Conrath AL 197; E. Masilo E 73

Pimpinella transvaalensis H. Wolff FH 1410; AL 199

VELLOZIACEAE

Xerophyta villosa (Baker) L.B. Sm. & Ayensu KB 9156

VERBENACEAE

Lippia javanica (Burm. f.) Spreng. AL 91

VITACEAE

Cyphostemma humile (N.E. Br.) Desc. ex Wild & Drumm. ssp. *dolichopus* (C.A. Sm.) Wild KB *et al.* 7649