

Vegetation strategy of *Vellozia crinita* (Velloziaceae)

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Abstract: Plant communities in which the herb layer is dominated by *Vellozia crinita* were surveyed in seven mountain ranges with a complex comprising open herbaceous or savanna-like montane vegetation overlying quartzite and sand, locally known as “campos rupestres” in the State of Minas Gerais, southeastern Brazil, by means of 92 vegetation relevés (totaling approx. 4629 m²). *Vellozia crinita* displayed a growth strategy which is rare among the Velloziaceae south of the Espinhaço mountain chain. While most species of *Vellozia* are phanerophytes with erect caudices and grow exclusively on or among rock outcrops, *V. crinita* is a caespitose chamaephyte with a profusely branched, repent caudex which grows under the ground or very slightly exposed. It forms cushions which stabilize convex mounds of colluvial sand, thus occupying a distinct niche in the “campos rupestres”. One association, two subassociations and two variants of the white-sand vegetation component are described as new.

Key words: campo rupestre; cerrado; phytocoenology; Velloziaceae; Minas Gerais; Brazil

Introduction

In the “campos rupestres” vegetation of southeastern and northeastern Brazil, white sand savannas alternate with quartzite outcrops, forming a mosaic in contact with several zonal vegetation types. Deeper soils in campo rupestre are usually colluvial deposits forming layers and pockets topped with white sand derived from erosion of the adjacent outcrops, and often include milky-quartz gravel. Benites et al. (2003) found that in campos rupestres: “Soils are shallow, sandy, oligotrophic and contain high amounts of exchangeable Aluminum. Humic to organic horizons are common in these soils indicating low degree of soil organic matter decomposition”. They conclude that, in comparison to soils on igneous lithologies, those overlying quartzite are “poorer in carbon and nutrients, exhibiting stronger signs of degradation that indicate a larger fragility of this biome.” These poorly developed soils rarely exceed 2m in depth, and their occurrence is dictated by local topography and vegetation.

Over half of the Neotropical species of Velloziaceae are endemic to the campos rupestres of the Espinhaço chain (Giulietti & Pirani 1988; Giulietti et al. 1997). Many, if not all species of *Vellozia* are longevous and have very slow growth (Alves 1994). In deep and mechanically unstable sandy soils, in which the water table is deeper than 40–50cm, it can be unavailable to the herb layer for prolonged periods. In campo rupestre the herb layer of such areas is often dominated by low and caespitose *Vellozia* species, while the erect and shrubby ones usually grow on and among rock outcrops. Distinct

species of *Vellozia* have apparently developed specific strategies in these contrasting environments (Table 1).

Vellozia crinita is endemic to a few campo rupestre localities in the State of Minas Gerais. In the white sand component of the seven studied campo rupestre localities, *Vellozia crinita* always displayed a peculiar, mound-forming growth strategy, which locally blocks erosion, and ultimately dictates vegetation physiognomy. The campos rupestres are naturally subjected to periodic savanna fire and occasional strong winds, to both of which they are well adapted (Kolbek & Alves 2008). However, these singular habitats are under increasing threat of disappearing, especially due to degradation by cattle (mainly grazing, trampling and manure deposition). In that respect it is alarming that, under such pressure, *V. crinita* is only considered vulnerable, by IUCN criteria, according to the most recent list of endangered species of Minas Gerais (BIODIVERSITAS 2007).

The purpose of the present survey was to investigate the peculiar vegetation strategy of *Vellozia crinita*, which sets it apart from the erect, rock-dwelling species, to describe the vegetation units dominated by it in the white sand component of the southeastern campos rupestres, and to verify the implications of this relatively unique growth-form for habitat conservation.

Material and methods

White-sand savannas with *Vellozia crinita* were studied in seven small mountain ranges with campo rupestre in the State of Minas Gerais (Fig. 1): Serra Bico de Pedra

Table 1. Distinct vegetation strategies of caespitose and erect *Vellozia* species.

Strategy	Erect, shrubby species	Caespitose species
Fire	Growing among outcrops where the discontinuous herb layer limits spread of fire.	Prostrate caudex at least partly buried in sand, thus insulated from fire.
	Leaf rosettes of adult plants above flames from burning herb layer.	Mounds with densely packed rosettes keep out grasses, reducing spread of fire.
Drought	Velamehn radicum and poikilohydry.	Velamen radicum and poikilohydry.
	Shallow substrate: roots reach water table more easily.	Roots reach the deep water table in both arid and wet season (Fig. 2).
Wind	Rooting in mechanically stable substrate: outcrops and fissures.	Low stature: prostrate mounds with caudices at least partly underground.
Competition	Adaptation to extreme oscillations of temperature and humidity.	Densely packed rosettes in mounds hinder establishment of other herbs.



Fig. 1. Relative positions of the study sites in this paper (round dots) and the Cipó range (square) studied by Garcia & Diniz (2003) and Garcia et al. (2007).

(20.474° S, 43.595° W, 1071–1236m alt.), Serra da Chapada (20.471° S, 43.588° W, 1276–1286m alt.), Serra do Ouro Branco (20.490° S, 43.695° W, 1420–1529m alt.), the latter representing the southern limit of the Espinhaço chain, and including southern outliers: Serra de São José, site a (21.086° S, 44.169° W, 1175m alt.), Serra de São José, site b (21.114° S, 44.168° W, 897–899m alt.), Serra do Lenheiro (21.131° S, 44.306° W, 990–1194m alt.), Serra do Ouro Grosso (21.307° S, 44.638° W, 950–992m alt.), and Serra de Carrancas (21.440° S, 44.707° W, 1260–1302m alt.). The analyzed vegetation spans 256km from northeast to southwest, with 23,317km² mostly within the Cerrado biome.

The habitat delimitations used herein are somewhat simpler than those of Conceição & Pirani (2005). The combinations of substrate and local topography permit the rough distinction of three main types of terrestrial habitats in campo rupestre, each of which can harbor several distinct

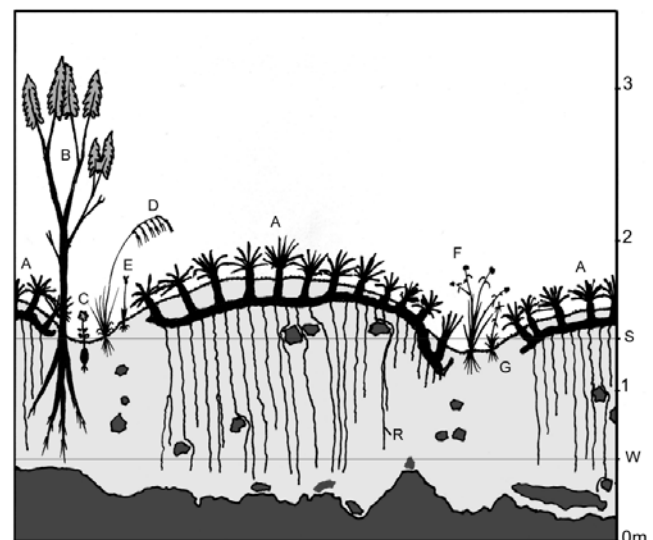


Fig. 2. Schematic bisect of the ass. *Vellozia crinitae*-*Loudetiopsis chrysothrici* showing soil depths, underground caudices and root systems; A – *Vellozia crinitae*; B – the shrub *Hyptidendron asperrium*; C – the geophyte *Dipladenia polymorpha*; D – the grass *Loudetiopsis chrysothrix* outside the *Vellozia* mound; E – *Xyris rupicola*; F – the sedge *Rhynchospora globosa*; G – the sedge *Rhynchospora tenuis*; R – adventive roots of *Vellozia crinitae*; S – summer level of water table; W – winter level of water table. Drawn according to photographs from the Serra de São José and soil profiles.

types of vegetation: (1) rock outcrops and boulders, (2) rock crevices and fissures, and (3) deposits of sandy soil. All of these tend to form intricate mosaics, but relatively sharp borders usually separate the patches of vegetation.

During over thirty field trips implemented from 1989 to 2006, relevés using the scale of Braun-Blanquet (1932) were systematically used to sample vegetation on white sand colluvial deposits in the studied sites. The sample plots were selected subjectively in what seemed to be homogenous vegetation stands, and had no defined geometric shape. Soil samples were excavated for the study of underground plant structures.

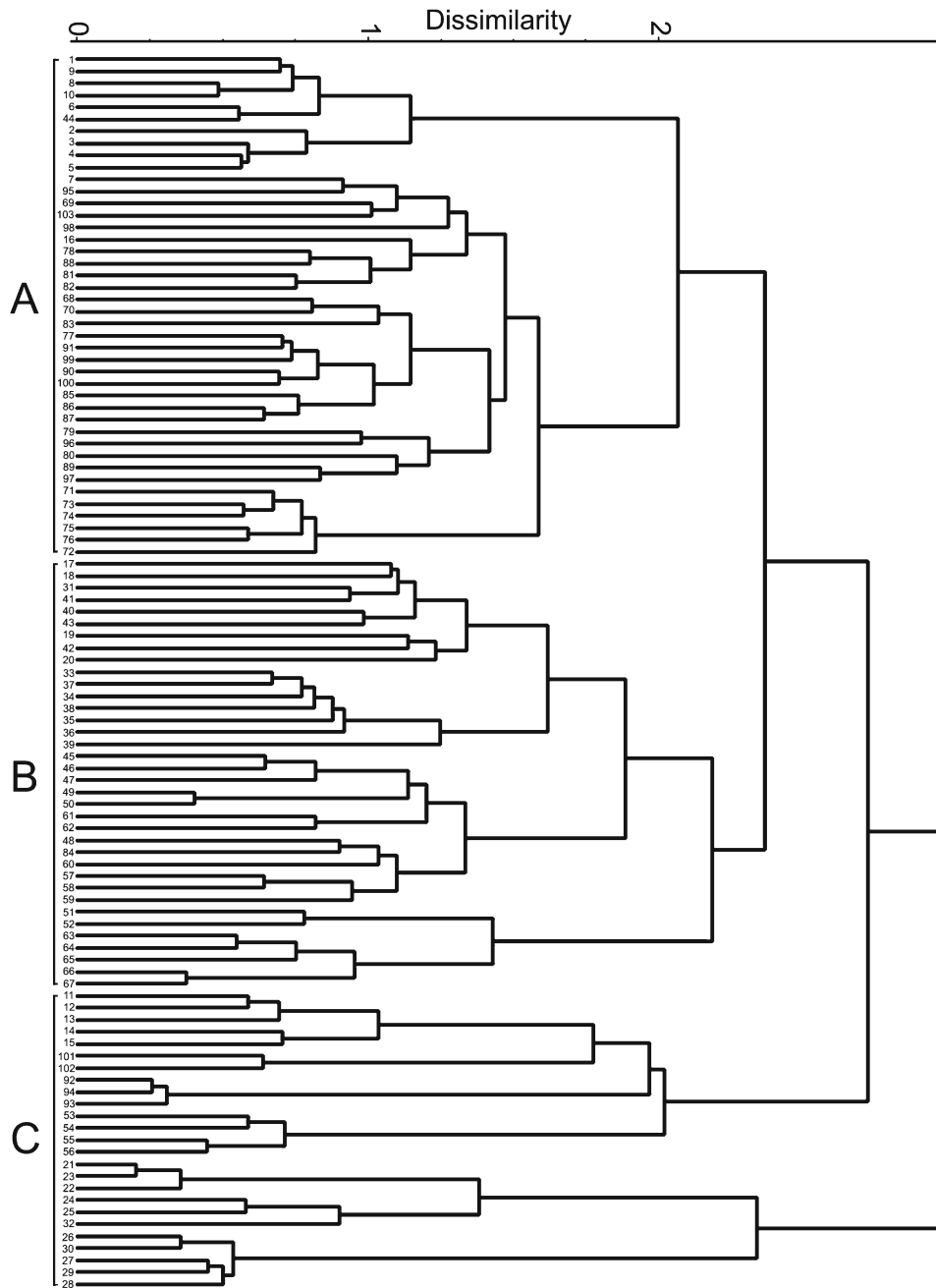


Fig. 3. Hierarchical clustering of all obtained relevés. A and B –Ass. *Vellozia crinitae*-*Loudetiopsietum chrysothrici*; A – Subass. *Vellozia crinitae*-*Loudetiopsietum chrysothrici rhynchosporetosum tenuis*; B – Subass. *Vellozia crinitae*-*Loudetiopsietum chrysothrici rhynchosporetosum tenuis*; C – *Vellozia crinitae*-*Loudetiopsietum chrysothrici rhynchosporetosum consanguineae*. The high dissimilarity levels among the three mail clusters were expected, and are due mainly to the heterogeneity of sample plots imposed by local topography. Dendrogram generated by SYN-TAX 2000 software.

Relevés were pre-ordinated using JUICE 6.5.7 (Tichý 2002) and statistically analyzed in SYN-TAX 2000 software (Podani 2001), using a hierarchical classification algorithm (complete linkage, Euclidian distance) based on quantitative data, by β -flexible clustering method ($\beta = -0.25$), Chord's coefficient was used.

Nomenclature of all species found in the field follows determinations by specialists, for vascular plants subsequently cross checked and updated via the Missouri Botanical Garden's Vast nomenclatural database W³TROPICOS (2007). Authors of plant names follow Brummitt & Powell (1992). Distribution data was obtained from literature and complemented by access to the JBRJ (2007) database,

W³TROPICOS (2007), GBIF (2007), USDA (2007), and Clayton et al. (2007).

In tables and appendix, numbers 100, 101, 102, 103 are replaced as 00, 01, 02, 03.

Voucher specimens were deposited in the herbaria of the Rio Botanic Garden (RB) to 1996, and later in the National Museum, Rio de Janeiro (R).

Results

In stands with *Vellozia crinita*, the tree layer is usually less than 3.5 m tall, and very open (hence it was consid-

Table 2. (continued)

In two relevés only:

A: *Byrsonima bumeliaefolia* +:79, 80, *Hyptis reticulata* +:79, 2:81, *Marcetia taxifolia* 1:69, +:71.

B: *Campomanesia pubescens* +:68, r:79, *Chamaecrista rotundata* +:16, r:81, *Chamaecrista rotundifolia* +:85, 86, *Diplusodon buxifolius* +:16, 1:03, *Gomphrena virgata* 1:68, +:72, *Hyptis complicata* 1:68, +:96, *Hyptis fruticosa* r:73, +:74, *Peixotoa tomentosa* +:16, 85.

C: *Baccharis calvescens* +:79, 90, *Calopogonium velutinum* 1:80, +:81, *Dyckia argentea* +:79, 80, *Erythroxyllum tortuosum* 1:68, r:96, *Hyptis althaeifolia* +:4, 1:5, *Lindsaea stricta* 1:81, r:82, *Peixotoa catarinensis* +:79, 96, *Rhynchospora consanguinea* +:79, r:96, *Stachytarpheta sellowiana* r:80, +:83, *Syngonanthus gracilis* 1:87, +:98, *Vellozia crassicaulis* 2:96, +:97, *Vernonia linearifolia* +:78, 81, *Xyris bahiana* 1:78, 88, *X. sp.* r:7, +:03, *X. tenella* 1:88, +:97.

D: *Clusia arrudea* r:75, 76.

E: *Cladonia miniata* +:79, 1:80.

In one relevé only:

A: *Byrsonima bumeliaefolia* +:68, *Chamaecrista cathartica* +:76, *Erythroxyllum betulaceum* 1:98, *Hyptidendron asperrimum* 1:16, *Ilex amara* r:80, *Lippia lupulina* +:79, *Microlicia isophylla* +:03, *Strypmodendron adstringens* +:79, *Tillandsia streptocarpa* +:72, *T. tenuifolia* +:72, *Mimosa polycephala* var. *taxifolia* +:99, *Trembleya laniflora* +:98, *Vitex polygama* +:96.

B: *Chamaecrista hedyaroides* +:75, *Chionolaena arbuscula* r:98, *Chresta scapigera* +:03, *Declieuxia aspalathoides* r:81, *Gaylussacia montana* +:16, *Gomphrena scapigera* r:98, *Jacaranda paucifoliolata* r:80, *Lippia florida* +:98, *Macrosiphonia velame* r:98, *Microlicia euphorbioides* +:71, *Peixotoa catarinensis* r:80, *Polygala pseudoerica* +:82, *Spigelia heliotropoides* +:80, *Tocoyena formosa* r:95.

C: *Anemia villosa* r:16, *Buchnera lavandulacea* r:79, *Chaptalia runcinata* r:71, *Commelina erecta* +:88, *Danthonia montana* +:72, *Diplusodon buxifolius* +:16, *Dyckia minarum* r:71, *Hippeastrum glaucescens* +:98, *H. morelianum* r:83, *Hypogynium virgatum* +:1, *Leiothrix prolifera* 2:69, *Lessingianthus simplex* +:8, *Paepalanthus elongatus* 2:97, *Pfaffia jubata* +:96, *Phyllanthus niruri* r:82, *Polypodium hirsutissimum* +:72, *Psidium incanescens* +:80, *Rhynchospora albiceps* r:6, *Skeptrostachys congestiflora* r:82, *Spermacoce capitata* +:85, *Trachypogon vestitus* 1:72, *Trimezia juncifolia* r:80, *Vitex polygama* 2:97.

D: *Dasyphyllum brasiliense* +:69, *Gaylussacia riedelii* +:79.

ered part of the tall shrub layer in the tables). *Eremanthus erythropappus* is the most constant tree species, in this study with a mean height of 126 cm (8–307 cm), while in forests and among outcrops this species can reach 12 m (Souza et al. 2007). *Eremanthus erythropappus* has been considered a “pioneer” species, due to its capacity of colonizing forest clearings (Pedralli et al. 1997, 2000). In the studied localities, seedlings of *E. erythropappus* have been found almost in every investigated campo rupestre vegetation subtype. Other tree species with high constancies are *Tibouchina heteromalla* (9–180 cm, mean = 48 cm) and *Hyptidendron asperrimum* (18–296 cm).

In the studied communities, *Vellozia crinita* dominates the herb layer, in which it has no co-dominant species. The herb layer with *V. crinita* consists of a series of regularly spaced mounds separated by sparse herbs and small subshrubs (Fig. 2). Unlike most erect species in its genus, the caespitose *V. crinita* does not depend directly on the presence of a rock outcrop. Individual plants have repent, horizontally growing, half-buried, profusely branched caudices and adventitious roots projected downwards at relatively regular intervals. They live very long and form rounded mounds in mildly sloping white sand deposits. Each mound may bear over 100 leaf rosettes/m². Given time the cushions accumulate sand more than the surrounding vegetation, and thus become slightly convex, but usually not taller than 10 cm. Small trees and shrubs grow sparsely among the mounds, as do tussock grasses or sedges and geophytes, with a few therophytes. Populations observed in the all ranges are identical in physiognomy. The moss layer is sparse and usually poorly developed. The influence of overgrazing by cattle is indicated by frequent occurrence of the invasive *Melinis minutiflora*, *Spermacoce brachystemonoides* and *Ageratum fastigiatum* (Kolbek & Alves 2008).

The synthesis of vegetation with *Vellozia crinita*

revealed three clusters (Fig. 3). Despite the considerable species richness, not many species are common to all three clusters and, if they are, their constancies tend to differ. Species in the shrub layer common to all of these are only *Eremanthus erythropappus*, *E. crotonoides*, and *Myrsine monticola* (all very frequent throughout the southern campos rupestres). In the subshrub layer, this is also true for *Cuphea ericoides* and *Tibouchina heteromalla* and in the herb layer for *Lagenocarpus rigidus* subsp. *rigidus*, *Loudetiopsis chrysothrix*, and the invasive ruderal *Ageratum fastigiatum*, *Melinis minutiflora* and *Spermacoce brachystemonoides*.

The three clusters (Table 2–4) include the characteristic *Vellozia crinita*, along with *V. crassicaulis*, *Cuphea thymoides*, *Peixotoa tomentosa*, *Arthrocerus melanurus*, *Bulbostylis paradoxa*, *Dipladenia polymorpha*, *Schizachyrium tenerum*, and *Xyris rupicola*.

Vellozia crinitae-*Loudetiopsietum chrysothrici* ass. nova hoc loco

Nomenclatural type: Table 2, rel. 81

Characteristic species: *Vellozia crinita*, *Loudetiopsis chrysothrix*, *Peixotoa tomentosa*, *Arthrocerus melanurus* subsp. *melanurus*, *Bulbostylis paradoxa*, *Dipladenia polymorpha*, *Schizachyrium tenerum*, *Xyris rupicola*.

A predominantly herbaceous terrestrial community on white quartzitic sand in which herbs cover a mean of 65% while the shrub layer is kept open by fires which occur once every 2–3 years, reaching a mean cover of 8%. The moss layer has a mean cover of 11%. The longevous, cushion-forming *V. crinita* dominates the herb layer in most of the sampled stands. *Bulbostylis paradoxa* is a pyrophyte widespread throughout Neotropical savannas on latossol, it is only occasionally found in campo rupestre on quartzitic sand, but in this community it is considered a diagnostic species. *Loudetiopsis chrysothrix* and *Eremanthus erythropappus* also pene-

Table 3. (continued)

C: *Ageratum conyzoides* r:17, +:62, *Alstroemeria* cf. *cunha* 2:51, r:52, *Aspilia foliacea* +:17, 1:34, *Bulbostylis paradoxa* +:45, 60, *Clusia arrudea* r:36, +:43, *Coccoypselum lanceolatum* +:39, 43, *Cyperus lanceolatus* r:39, +:47, *Emilia sonchifolia* +:61, 62, *Gomphrena agrestis* r:17, +:43, *Hypoxis decumbens* +:61, 62, *Inulopsis scaposa* +:42, 62, *Klotzschia brasiliensis* r:38, 84, *Lycopodiella camporum* 2:19, +:42, *Microlicia isophylla* 2:34, +:60, *Smilax seringoides* +:40, r:41, *Xyris* sp. 2:57, 58.

D: *Eupatorium barbicense* 2:36, 1:59; *Miconia ligustroides* r:36, +:39; *Myrsine monticola* +:40, 43.

E: Lichenes indet 3:49, 50.

In one relevé only:

A: *Byrsonima basiloba* 1:20, *Byrsonima variabilis* 1:36, *Cecropia lyratiloba* +:40, *Kielmeyera coriacea* +:40, *Pseudobombax longiflorum* 1:40, *Gomidesia eryocalyx* +:43, *Jacaranda paucifoliolata* 1:40, *Miconia ligustroides* +:19, *M. peppericarpa* 1:39, *M. theaezans* +:19, *Microlicia fasciculata* +:18, *Plenckia populnea* +:40, *Vellozia kolbekii* 2:17.

B: *Lychnophora passerina* +:60, *Microlicia fulva* r:20, *Sauvagesia glandulosa* +:17.

C: *Aechmea nudicaulis* +:43, *Alstroemeria* sp. +:43, *Andropogon selleanus* +:59, *Anemia villosa* r:42, *Arthrocereus melanurus* +:43, *Aylthonia tomentosa* +:43, *Ayapana amygdalina* +:17, *Baccharis trimera* 1:20, *Bulbophyllum ipanenensis* +:43, *Cuphea thymoides* 1:31, *Declieuxia cordigera* r:40, *Dipladenia polymorpha* +:33, *Erythroxyllum tortuosum* +:40, *Guapira opposita* r:40, *Hippeastrum morelianum* +:43, *Hydrocotyle quinqueloba* 1:42, *Koellensteinia tricolor* +:42, *Lagenocarpus polyphyllus* +:37, *Lavoisiera bergii* +:42, *Lessingianthus simplex* +:35, *Lindsaea stricta* 1:17, *Lycopodiella alopecuroides* +:42, *Microlicia fasciculata* 1:19, *M. fulva* +:42, *Phlebodium pseudoaureum* r:43, *Phyllanthus niruri* +:43, *Plantago australis* ssp. *hirtella* 2:20, Poaceae indet. 1:35, *Psychotria* sp. 1:59, *Pteridium aquilinum* r:41, *Rhynchospora riedeliana* 2:19, *Sarcoglottis cogniauxiana* +:58, *Scleria bracteata* +:61, *Spermacoce verticillata* r:41, *Stachytarpheta sellowiana* +:65, *Trachypogon vestitus* +:37, *Vellozia crassicaulis* +:57.

D: *Baccharis platypoda* +:42, *Cassia splendida* 1:41, *Macairea radula* 1:42, *Miconia theaezans* r:43, *Tibouchina frigidula* +:20.

E: *Campylopus pilifer* 1:84.

trate into another association of this alliance (in prep.). *Arthrocereus melanurus* subsp. *melanurus* occurs as a characteristic species, but is usually restricted to spots with an outcrop or shallower soil. This community was detected in the Serra São José, Lenheiro, Ouro Grosso (Itutinga), Ouro Branco and Carrancas Ranges in altitudes 950–1536 m alt. on slopes with inclinations of 0–60° and various expositions.

Within the association, two subassociations were distinguished (see Fig. 3 A–B, Tabs 2, 3):

***Vellozia crinitae*-*Loudetiopsietum chrysothrici rhynchosporetosum tenuis* subass. nova hoc loco**

Nomenclatural type: identical with the type of the association name.

Differential species: *Comolia sertularia*, *Rhynchospora globosa*, *R. recurvata*, *R. tenuis*, *Syngonanthus niveus*. The subassociation represents the terrestrial, seasonally wet stands with higher dominance of three species of the genus *Rhynchospora* and of *Syngonanthus niveus*. Average cover of shrub layer per relevé is 9%, herb layer 65% and moss layer 13%. The number of species varies from 4 to 43, averagely 16, mainly depending on the sample plot size. Stands of this terrestrial community are situated on white quartzitic sand with frequent milky quartz gravel in Serra do Ouro Grosso (Itutinga), Serra do Ouro Branco, Serra de São José, and Serra do Lenheiro. The environmental characteristics are comparable to those of the described association but with seasonally humid, shallower (ca. 30 cm deep) soils.

Within the subassociation two variants were distinguished:

a) var. *typicum* (Tab. 2, Fig. 3A), with high dominance and constancy of *Vellozia crinita* and the highest encountered constancy of *Arthrocereus melanurus* subsp. *melanurus* (absent from Serra do Ouro

Branco) when compared to other investigated stands of the association.

Stands are situated in Serra de São José, Serra do Lenheiro, Serra do Ouro Grosso (Itutinga), Serra do Ouro Branco, in altitudes of 1040–1420m alt. on slopes with inclinations of 0–30°, with apparent preference for eastward exposition. Average cover of shrub layer per relevé is 8% (0–35%), herb layer 62% (20–95%) and moss layer 11% (0–70%). Number of species varies from 5 to 33, averagely 16.

b) var. *Xyris bahiana* and *Syngonanthus gracilis*, with *Croton gnidiaceus*, *Leiothrix prolifera*, *Paepalanthus planifolius*, and *Senecio pohlii* (Tab. 3, Fig. 3B).

Stands were investigated in the Serra de São José and Serra do Lenheiro in altitudes of 950–1320m alt. on slopes with inclinations of 0–60°, with predominantly westward and southward expositions. Average cover of shrub layer per relevé is 11% (0–65%), herb layer 69% (40–95%) and moss layer 16% (0–50%). Number of species varies from 4 to 43, averagely 16.

***Vellozia crinitae*-*Loudetiopsietum chrysothrici rhynchosporetosum consanguineae* subass. nova hoc loco**

Nomenclatural type: Tab. 4, rel. 92

Differential species: *Jacaranda paucifoliolata*, *Clitoria guianensis*, *Dyckia minarum*, *Hyptis althaefolia*, *Rhynchospora consanguinea*, *Schizachyrium tenerum*.

The subassociation (Fig. 3C) represents the stands with higher dominance of *Rhynchospora consanguinea*. This terrestrial community on white quartzitic sand has an average cover of shrub layer per relevé is 5% (0–10%), herb layer 60% (9–95%) and moss layer 2% (0–7%). Number of species varies from 9 to 16, averagely 11. Stands are situated in Serra do Lenheiro, Carrancas, Serra de São José in altitudes of 1175–1394m alt. on slopes with milder inclinations (0–20°) and deeper soils (>60 cm) than the previous syntaxa. Plots are mainly

Table 4. *Vellozio crinitae-Loudetiopsietum chrysothrici rhynchosporetosum consanguineae*.

Relevé number	11	12	13	14	15	01	02	92	94	93	53	54	55	56	%
High shrub layer (A)															
<i>Eremanthus erythropappus</i>	.	.	.	2	1	.	.	1	+	+	r	.	.	.	43
<i>Myrsine monticola</i>	.	.	.	.	.	.	.	.	.	.	r	r	+	r	29
<i>Byrsonima basiloba</i>	.	.	.	.	.	.	.	.	.	.	r	.	+	r	21
<i>Vernonia crotonoides</i>	.	.	.	.	.	.	.	.	.	.	+	1	.	.	14
<i>Jacaranda paucifoliolata</i>	.	.	.	.	.	r	.	.	.	.	+	r	r	r	36
<i>Evolvulus helichrysoides</i>	.	.	.	.	.	+	+	.	.	.	.	.	.	.	14
<i>Lippia lupulina</i>	.	.	.	.	.	+	+	.	.	.	.	.	.	.	14
<i>Vochysia thyrsoidea</i>	.	.	.	.	.	.	.	.	.	.	2	.	.	+	14
Low shrub layer (B)															
<i>Cuphea thymoides</i>	.	.	.	.	.	.	.	.	.	.	1	1	1	+	29
<i>Clitoria guianensis</i>	.	.	.	.	.	.	.	.	.	.	+	+	r	+	29
<i>Peixotoa tomentosa</i>	.	.	.	.	.	.	.	.	.	.	r	+	r	r	29
<i>Tibouchina heteromalla</i>	.	.	.	.	.	.	.	2	1	1	.	.	.	.	21
<i>Gomphrena virgata</i>	.	r	r	.	.	.	.	.	.	.	.	.	.	.	14
<i>Cuphea ericoides</i>	.	.	+	.	+	.	.	.	.	.	.	.	.	.	14
<i>Diplusodon buxifolius</i>	.	.	.	1	1	.	.	.	.	.	.	.	.	.	14
<i>Croton antisiphiliticus</i>	.	.	.	.	.	+	1	.	.	.	.	.	antisiphiliticus	.	14
<i>Anacardium humile</i>	.	.	.	.	.	+	r	.	.	.	.	.	.	.	14
<i>Chamaechrista desvauxii</i>	.	.	.	.	.	r	+	.	.	.	.	.	.	.	14
<i>Jacaranda decurrens</i>	.	.	.	.	.	.	.	+	1	.	.	.	.	.	14
<i>Aristolochia gracilis</i>	.	.	.	.	.	.	.	.	.	.	+	+	.	.	14
Herb layer (C)															
<i>Loudetiopsis chrysothrix</i>	4	4	1	2	2	1	+	2	1	2	4	4	4	5	100
<i>Vellozia crinita</i>	1	1	1	.	1	1	+	2	2	2	.	.	.	.	64
<i>Melinis minutiflora</i>	1	1	r	.	.	.	.	+	1	1	+	+	+	.	64
<i>Rhynchospora consanguinea</i>	.	.	.	.	.	.	.	+	+	+	1	1	1	1	50
<i>Hyptis althaeifolia</i>	1	2	2	1	1	.	.	.	.	.	.	.	.	.	36
<i>Schizachyrium tenerum</i>	1	1	1	1	1	.	.	.	.	.	.	.	.	.	36
<i>Dyckia minarum</i>	r	+	1	r	.	.	.	.	.	.	.	.	.	.	29
<i>Spermacoce brachystemonoides</i>	.	.	+	.	.	.	.	+	+	+	.	.	.	.	29
<i>Vellozia crassicaulis</i>	.	1	1	r	.	.	.	.	.	.	.	.	.	.	21
<i>Chaetostoma cupressinum</i>	.	.	.	.	.	.	.	3	2	2	.	.	.	.	21
<i>Lagenocarpus *rigidus</i>	.	.	.	.	.	.	.	2	2	2	.	.	.	.	21
<i>Senna cf. organensis</i>	.	.	.	.	.	.	.	+	1	+	.	.	.	.	21
<i>Dipladenia polymorpha</i>	.	.	.	.	.	.	.	+	+	+	.	.	.	.	21
<i>Xyris rupicola</i>	.	.	.	.	.	.	.	+	+	+	.	.	.	.	21
<i>Arthroceres melanurus</i>	+	.	1	.	.	.	.	.	.	.	.	.	.	.	14
<i>Myrsine monticola</i>	1	.	.	.	.	.	.	.	.	.	+	.	.	.	14
<i>Bulbostylis paradoxa</i>	.	r	+	.	.	.	.	.	.	.	.	.	.	.	14
<i>Triumfetta rhomboidea</i>	.	.	1	.	1	.	.	.	.	.	.	.	.	.	14
<i>Vernonia linearifolia</i>	.	.	.	.	.	+	+	.	.	.	.	.	.	.	14
<i>Ageratum fastigiatum</i>	.	.	.	.	.	.	.	.	.	.	+	r	.	.	14
Moss layer (D)															
<i>Campylopus savannarum</i>	+	+	+	+	+	.	.	.	.	.	.	.	.	.	36

In one relevé only:

A: *Annona crassiflora* r:01.

B: *Campomanesia pubescens* r:02, *Chresta scapigera* +:92, *Galactia martii* r:01, *Jacaranda paucifoliolata* 1:53, *Stachytarpheta sellowiana* +:01.

C: *Leptocoryphium lanatum* r:14, *Oxalis hirsutissima* +:01, *Phyllanthus niruri* +:15.

oriented toward the East. The species assemblages in table 4 suggest that subdivisions into further vegetation units can be made once sufficient additional relevés are obtained.

Discussion

Homogenous stands in the studied environment may occupy areas ranging from just a few to several hundred square meters. When the floristic composition and structure of sample plots of similar sizes are compared, the ass. *Vellozio-Loudetiopsietum* turns out to be relatively homogenous. In the intricate mosaic of campo rupestre plant communities, when smaller stands are registered, the variability described above is the inevitable

consequence of species poverty. Despite this fact, the stands are easily distinguishable and separated from surrounding communities (on shallow soil or on outcrops) by sharp borders.

The Velloziaceae are among the plants best adapted to campo rupestre through drought-resistance structures, mechanisms which allow for quick uptake of water and mist, and by synchronizing flower production with rainfall (Owoseye & Sanford 1972; Gaff 1987; Alves & Kolbek 1994; Porembski & Barthlott 1995). Several *Vellozia* species are also notorious for their longevity and resistance to fire (Alves 1994; Kubitzki 1998).

Other psammophilous, caespitose and probably mound-forming species of the genus *Vellozia* are known to occur, especially in localities along the Espinhaço

chain situated to the north of the study area (Mello-Silva 1995). Within sandy grasslands of campo rupestre, these species may well have an analogical function to that of *V. crinita*, but no studies of their vegetation strategy have been published to date.

The laboratory study of germination properties of two erect, outcrop-dwelling and three caespitose, probably psammophilous *Vellozia* species (Garcia & Diniz 2003; Garcia et al. 2007) revealed that all have very small seeds which germinate best when exposed to light, but require higher temperatures (35–40 °C) to germinate in darkness. At 15 °C, all species exhibited deficient germination or none at all.

Though the influence of fire was not considered by Garcia & Diniz (2003) and Garcia et al. (2007), the described germination properties are consistent with species in which seed-dormancy is broken by sudden increases in temperature by passing fires. A fire would be required to produce the optimum germination temperature for seeds which are insulated by a layer of sandy soil, which is known to be an efficient thermal insulator. Furthermore, germination is only one of the processes necessary for the successful establishment of the plants. Small seeds have very few reserves, which mean that soon after they germinate, the subsequent development of the plants becomes highly dependent on photosynthesis. Effective germination in both species of *Vellozia* investigated by Garcia et al. (2007) proved to depend on light. It is thus not probable that adult plants of *Vellozia* spp. could develop from seeds germinated under the soil surface, unless they become exposed by erosion.

Two other species of *Vellozia* (present in relevés), with distinct vegetation strategies, occur sympatrically in the Serra de São José, which is the type locality of *V. crinita*. *Vellozia kolbekii* is an erect, to 2 m tall, sparingly branched shrubby species which grows exclusively among exposed outcrops and narrow fissures. An intermediate strategy is exhibited by *V. crassicaulis*: when young, this species forms prostrate mounds on shallower sandy and stony soils (<10 cm deep) or in outcrop fissures, but older individuals, in localities not affected by fire, can have erect branches up to 50 cm tall. *Vellozia crinita* and *V. kolbekii* have distinct habitat preferences: they do not grow together in the same community. Of the 168 sampled vascular species, 109 grow exclusively in stands with *V. crinita*, 11 grow together with *V. kolbekii* but not the former, and only 26 grow with both. The species of intermediate strategy, *V. crassicaulis*, is present in only six relevés, in five of which (Tab. 2: 96, 97; Tab. 3: 57 and Tab. 4: 12, 13) it co-occurs with *V. crinita*, indicating the presence of spots with shallow soil. In the sixth relevé with *V. crassicaulis*, the other two species are absent.

We can conclude that for the stability of the studied vegetation, *Vellozia crinita* is the most important species. The caespitose habit and the repent, profusely branched caudices are convenient adaptations to strong wind, while the usually subterranean position of the caudices is an effective defense against fire. Though individuals are longevous and slow-growing, forming

mounds with densely packed rosettes allows *V. crinita* to cover larger areas, thus occupying a distinct niche not disputed by erect shrubby species of *Vellozia*. However, *V. crinita* is unable to compete successfully against shading by invasive herbaceous species, which grow profusely in areas affected by cattle.

Juvenile individuals have very rarely been observed in all sites surveyed herein (see also Alves 1994). If campo rupestre dominated by *Vellozia* spp. should be preserved, further investigation of the environmental conditions necessary for the germination and subsequent growth of juvenile *Vellozia* populations is urgently needed. The classification of *V. crinita* and other species as vulnerable (viz. BIODIVERSITAS 2007) may be an understatement of the dangers truly faced by *Vellozia* species due to the use of campos rupestres as grazing areas for livestock. Hence not only the species, but also the studied plant communities and associated biota are in peril.

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Appendix. Relevé data follow this order: relevé number in bold, date (day, month, year), locality (CCS = Serra de Carrancas, SBP = Serra Bico de Pedra, SCH = Serra da Chapada, SLN = Serra do Lenheiro, SOB = Serra do Ouro Branco, SOG = Serra do Ouro Grosso, SSJ = Serra de São José), altitude (m a.s.l.), exposition, inclination (in °), area (m²), cover of woody layers (%), cover of herb layer (%), cover of moss layer (%), cover of stones (%).

Vellozia crinitae-*Loudetiopsietum chrysothrici rhynchosporetosum tenuis* var. *typicum*

1	28	10	2004	SSJ	1178	E	5	4	5	25	4	0
9	29	10	2004	SLN	1178	E	5	4	0	30	0	0
8	29	10	2004	SLN	1178	E	5	4	3	50	1	0
10	29	10	2004	SLN	1178	E	5	4	1	30	1	0
6	29	10	2004	SSJ	1178	E	5	4	5	30	0	0
44	12	9	1989	SSJ	1150	W	5	6	0	40	40	0
2	28	10	2004	SSJ	1178	E	5	4	1	20	1	0
3	28	10	2004	SSJ	1178	E	5	4	0	50	2	0
4	28	10	2004	SSJ	1178	E	5	4	0	30	1	0
5	28	10	2004	SSJ	1178	E	5	4	0	40	1	0
7	29	10	2004	SLN	1178	E	5	4	0	30	0	0
95	1	11	1989	SSJ	1230	S	10	18	<5	25	0	10
69	12	9	1989	SSJ	1150	SW	5	9	5	60	45	10
03	27	10	2005	SOG	1175	W	10	32	4	80	4	0
98	31	10	2004	SOB	1536	ENE	10	60	4	90	0	0
16	2	10	1997	SSJ	1400	–	0	10	4	60	4	0
78	3	10	1989	SSJ	1300	SE	20	50	<5	60	<5	5
88	22	10	1989	SSJ	1270	SSW	15	25	15	75	30	0
81	6	10	1989	SSJ	1410	SSE	20	60	15	60	40	5
82	6	10	1989	SSJ	1410	SSW	15	50	<5	60	50	10
68	12	9	1989	SSJ	1140	ESE	10	150	10	65	30	20
70	12	9	1989	SSJ	1150	W	5	160	<5	70	70	10
83	7	10	1989	SSJ	1230	E	10	25	<5	70	<5	10
77	20	9	1989	SSJ	1040	W	5	16	0	90	0	10
91	18	10	1989	SSJ	1300	WSW	10	15	0	90	0	0
99	26	10	2005	SSJ	1175	N	20	10	10	75	4	4
90	18	10	1989	SSJ	1300	WNW	10	15	10	85	0	0
00	26	10	2005	SSJ	1175	E	5	64	5	80	1	20
85	18	10	1989	SSJ	1200	W	10	50	<5	95	0	0

86	18	10	1989	SSJ	1200	–	0	50	<5	95	0	0
87	18	10	1989	SSJ	1200	NW	10	50	<5	80	0	0
79	3	10	1989	SSJ	1375	NNW	20	80	20	80	10	5
96	21	9	1989	SSJ	1040	NE	15	100	<5	75	0	10
80	5	10	1989	SSJ	1420	N	20	30	<5	30	15	5
89	18	10	1989	SSJ	1300	WNW	15	15	0	75	10	0
97	5	10	1989	SSJ	1375	N	30	30	0	50	40	10
71	15	9	1989	SSJ	1200	E	8	200	35	70	10	10
73	18	9	1989	SSJ	1200	E	10	100	20	70	0	10
74	18	9	1989	SSJ	1200	E	10	100	15	80	<5	10
75	18	9	1989	SSJ	1200	E	10	100	35	75	10	10
76	18	9	1989	SSJ	1200	E	10	100	20	80	<5	10
72	15	9	1989	SSJ	1220	E	10	400	25	70	5	10

Vellozia crinitae-*Loudetiopsietum chrysothrici rhynchosporetosum tenuis* var. *Xyris bahiana*, *Syngonanthus gracilis*

17	2	10	1989	SSJ	1320	W	15	40	10	50	4	80
18	20	10	1989	SSJ	1370	SE	35	12	25	70	10	80
31	1	11	1989	SLN	1270	S	45	18	20	95	0	70
41	13	9	1989	SSJ	1000	S	35	25	10	85	10	0
40	23	9	1989	SSJ	1000	WNW	35	150	10	70	4	0
43	22	9	1989	SSJ	1020	WNW	30	100	5	60	0	0
19	23	10	1989	SSJ	1120	N	10	20	4	95	10	90
42	14	9	1989	SSJ	1000	SE	20	10	0	85	40	0
20	23	10	1989	SSJ	1100	–	0	30	50	70	0	0
33	1	10	1989	SSJ	1320	NE	15	36	10	55	4	0
37	23	9	1989	SSJ	1220	WNW	10	105	20	60	4	0
34	1	10	1989	SSJ	1310	NE	20	48	5	60	4	0
38	23	9	1989	SSJ	1030	SSW	10	120	35	75	40	0
35	2	10	1989	SSJ	1330	NW	25	60	10	40	20	50
36	22	9	1989	SSJ	1030	SW	30	60	30	80	50	0
39	19	10	1989	SSJ	1300	NW	60	1.5	4	50	0	50
45	23	9	1989	SSJ	1220	W	10	40	4	75	4	0
46	23	9	1989	SSJ	1220	W	5	24	0	80	10	0
47	23	9	1989	SSJ	1230	SW	25	30	4	70	50	0
49	23	9	1989	SSJ	1230	W	10	100	4	70	30	0
50	23	9	1989	SSJ	1230	W	5	48	0	85	40	0
61	23	9	1989	SSJ	1240	SW	15	100	4	90	20	0
62	24	9	1989	SSJ	1240	SW	15	36	0	95	10	0
48	23	9	1989	SSJ	1230	SW	20	35	0	45	0	0
84	3	7	1989	SSJ	1230	–	0	500	<5	90	5	0
60	23	9	1989	SSJ	1240	S	20	32	4	60	0	0
57	20	9	1989	SSJ	1030	W	15	32	0	70	4	0
58	20	9	1989	SSJ	1040	W	15	105	4	55	10	0
59	20	9	1989	SSJ	1040	SW	10	160	4	75	0	0
51	7	11	1989	SSJ	950	–	0	12	0	80	0	0
52	7	11	1989	SSJ	950	–	0	12	5	75	0	0
63	20	10	1989	SSJ	1200	N	10	6	65	50	50	0
64	20	10	1989	SSJ	1200	NW	10	12	10	50	50	0
65	20	10	1989	SSJ	1200	NW	10	6	30	60	30	0
66	20	10	1989	SSJ	1230	–	0	4	0	65	30	0
67	20	10	1989	SSJ	1230	–	0	4	0	60	30	0

Vellozia crinitae-*Loudetiopsietum chrysothrici rhynchosporetosum consanguineae*

11	29	10	2004	SLN	1394	E	20	4	0	70	5	0
12	29	10	2004	SLN	1394	E	20	4	0	60	5	0
13	29	10	2004	SLN	1394	E	20	4	0	30	7	0
14	29	10	2004	SLN	1394	E	20	4	10	30	2	0
15	29	10	2004	SLN	1394	E	20	4	5	40	3	0
01	27	10	2005	CCS	1175	NE	10	32	4	9	0	0
02	27	10	2005	CCS	1175	W	10	15	4	9	0	0
92	30	10	1989	SSJ	1110	–	0	36	10	95	0	0
94	30	10	1989	SSJ	1110	–	0	36	5	80	0	10
93	30	10	1989	SSJ	1110	–	0	36	5	80	0	10
53	01	11	1989	SLN	1190	ESE	10	25	10	80	0	1
54	01	11	1989	SLN	1190	E	10	25	5	85	0	1
55	01	11	1989	SLN	1190	E	20	25	4	80	0	1
56	01	11	1989	SLN	1190	ESE	20	25	5	90	0	1