

Morphometric Analysis of *Schizachyrium* (Poaceae–Andropogoneae) Reveals Two New Species from South America

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Abstract—*Schizachyrium* (Poaceae–Andropogoneae) includes ca. 60 species distributed in tropical and subtropical regions of the world. Although the genus has been revised recently for South America, a group of specimens with intermediate traits from Cerrado vegetation of Brazil and Paraguay was found. The aim of this paper is to assess the morphological variation of these specimens to clarify their taxonomic identity. Thirty-seven traits (15 qualitative and 22 quantitative characters) were analyzed using multivariate methods (cluster and principal coordinate analysis). The analysis included specimens from Central Brazil and Paraguay, as well as the type material of several morphologically similar species. The results obtained showed that the samples investigated form two clearly distinct groups from the species hitherto recognized. Based on this morphometric analysis, two new species of *Schizachyrium* from South America are proposed, one of them occurring in Brazil and Paraguay (*Schizachyrium angustispiculatum*), and the other restricted to Brazil (*S. vallsii*). Moreover, *Andropogon luxurians* proved as a distinct taxon from *Schizachyrium sanguineum*, being proposed the new combination of the name for the genus *Schizachyrium* (*S. luxurians*). Descriptions and illustrations of the two new species and the new combination are presented, as well as a key to separate them from other morphologically related species.

Keywords—Brazil, Cerrado vegetation, grasses, Paraguay, systematics.

Schizachyrium Nees (Poaceae–Andropogoneae) includes ca. 60 species distributed in tropical and subtropical regions of the world, especially in America and Africa (Clayton and Renvoize 1986; Nicora and Rúgolo de Agrasar 1987). The genus is represented in America by ca. 30 species (Filgueiras 2003), 19 of which occur in South America, from Colombia to Chile, Argentina, and Uruguay (Peichoto 2010). In South America, the genus is most diverse and species rich in the region comprising northeastern Argentina, southern Paraguay and Brazil, and Uruguay (Peichoto 2007). Furthermore, two well-defined groups of South American *Schizachyrium* species can be distinguished based on inflorescence traits (Peichoto et al. 2008). The first group includes taxa with thick rachis internodes, straight, and sparsely branched and hairy inflorescences. The other group is characterized by slender rachis internodes, zigzagging, and highly branched and hairy inflorescences (Peichoto et al. 2008).

However, during a recent revision of the genus in South America (Peichoto 2010), some individuals with intermediate traits between the two groups of species (i.e. with inflorescences that are highly branched, and sometimes very hairy, but with straight rachis internodes) were found in the Cerrado vegetation of Brazil and Paraguay. Such specimens could not be assigned to any of the known *Schizachyrium* species recorded for the region, because the intermediate traits they displayed hampered the identification. Nevertheless, most of these specimens were labeled by other botanists as *S. condensatum* (Kunth) Nees, *S. sanguineum* (Retz.) Alston, or *S. microstachyum* (Desv. ex Ham.) Roseng., B. R. Arrill. and Izag.

Schizachyrium condensatum and *S. microstachyum* are characterized by their slender and recurved rachis internodes; their highly branched inflorescences have a corymb-like shape in *S. condensatum* and generally panicle-like shape in *S. microstachyum* (Peichoto and Vegetti 2007). However, *S. sanguineum* is distinguished by its sparsely branched inflorescences, but

with straight rachis internodes and appressed spikelets. Therefore, the intermediate specimens in the Cerrado vegetation of Brazil and Paraguay would represent new taxonomical entities and/or some kind of hybrid.

Although the general appearance of the specimens with intermediate traits resembles that of these three species, certain inflorescence traits, such as the dilated and straight rachis internodes and the slightly hairy inflorescence, are rather characteristic of *S. beckii* Killeen, a native species of Bolivia (Killeen 1990). In addition, some *Schizachyrium* specimens from the Cerrado are morphologically highly similar to *Andropogon luxurians* Ekman, which is currently considered a synonym of *S. sanguineum* (Türpe 1984; Filgueiras 2003; Peichoto 2010). Therefore, in this paper, we disentangle the taxonomic identities of these *Schizachyrium* individuals, assessing their morphological variation with multivariate analysis.

MATERIALS AND METHODS

We examined a total of 64 herbarium *Schizachyrium* specimens from BAA, BM, C, CTES, F, FCQ, GH, K, LIL, MBM, MO, MVFA, NY, P, S, SI, UB, US, and W (herbarium acronyms follow Thiers 2014). Of these, we selected 27 specimens that were morphologically complete and suitable for measurements (see Table 1) and multivariate analysis. We also considered reference material of morphologically similar species (type specimens were included): *S. beckii*, *S. condensatum*, *S. microstachyum*, *S. sanguineum*, and *Andropogon luxurians* (Appendix 1). Thirty-seven exomorphological traits (15 qualitative and 22 quantitative; see Table 1) were measured based on Peichoto et al. (2008), and translated into a data matrix of 27 OTUs (operational taxonomic units) × 37 variables. This matrix was analyzed statistically with the software Infostat version 2013 (Di Rienzo et al. 2013). The unweighted pair-group method (UPGMA) was used for cluster analysis. The distortion of the phenogram was measured by estimating the cophenetic correlation coefficient (r) between the cophenetic value matrix and the mean distance matrix. Morphological features were also analyzed with a Principal Coordinates Analysis (PCoA). Because both qualitative and quantitative characters were analyzed, the Gower similarity measure was used.

TABLE 1. Morphological characters (and states) used for numerical analysis.

1. Plant height (Continuously variable, measured in cm). 2. Ligule length (mm). 3. Ligule consistency (1 papyraceous; 2 membranaceous). 4. Blade length (cm). 5. Blade width (mm). 6. Blade apex (1 subacute; 2 acute; 3 mucronate). 7. Inflorescence shape (1 panicle-like form; 2 corymb-like form). 8. Inflorescence: ramification degree / number of racemes per inflorescence (1 highly branched / more than 50 racemes; 2 branched / 25–50 racemes; 3 sparsely branched / less than 25 racemes). 9. Spatheole length (mm). 10. Spatheole shape (1 convolute; 2 subconvolute; 3 open). 11. Peduncle length (mm). 12. Peduncle position at maturity (1 included in the spatheole; 2 apical portion visible (1/5 of length) in the apex of the spatheole; 3 1/3 or more of their length visible in the apex of the spatheole). 13. Raceme length (mm). 14. Number of pairs of spikelets per raceme. 15. Rachis internode shape (1 straight; 2 recurved). 16. Rachis internode length (mm). 17. Apex width of the rachis internode (mm). 18. Hairs' length of the rachis internode (mm). 19. Rachis internode coloration (1 reddish; 2 straw-coloured). 20. Rachis internode surface (1 without asperities; 2 with some asperities; 3 with many asperities). 21. Spikelets disposition at maturity (1 appressed or subappressed; 2 divergent). 22. Sessile spikelet (SS): lower glume length (mm). 23. SS: lower glume width (mm). 24. SS: lower glume consistency (1 coriaceous; 2 papyraceous; 3 carthaceous). 25. SS: back of lower glume (1 flat; 2 flat or slightly convex; 3 conspicuous convex). 26. SS: dorsal surface of lower glume (1 with asperities; 2 without asperities). 27. SS: visibility of nerves of the lower glume (1 nerves not visible; 2 nerves slightly visible; 3 2–4 nerves visible). 28. SS: apex of lower glume (1 subacute; 2 acute; 3 bifid; 4 bimucronate). 29. SS: upper glume length (mm). 30. SS: sterile lemma length (mm). 31. SS: fertile lemma length (mm). 32. SS: awn length of fertile lemma (mm). 33. Caryopsis length (mm). 34. Pedicellate spikelet (PS): glumes length (mm). 35. PS: pedicel length (mm). 36. PS: hairs' length of the pedicel (mm). 37. PS: awn length (mm).

The mean average, standard deviation, and range of variation of quantitative variables were calculated for each group of individuals resulted from multivariate analysis. Significance of differences among groups for each trait was assessed with a one-way ANOVA (significance level of 5%) after Bartlett's test of homogeneity. Also, the Tukey's test was used to assess significance of differences between each pair of means (significance level of 5%). Finally, the geographical distribution of analyzed specimens was plotted on a map using the software Diva-Gis (Hijmans et al. 2004).

RESULTS

The UPGMA phenogram based on morphological similarities (F1) is shown in Fig. 1. The cophenetic correlation $r = 0.89$ indicates a good fit between the cophenetic value matrix and the mean taxonomic distance matrix. Specimens are grouped into two main clusters. Cluster I includes the specimens of *Schizachyrium sanguineum*; while cluster II includes two groups. The first group (III) includes *S. microstachyum* (V) and *S. condensatum* (VI) specimens. The second group (IV) includes the type specimen of *S. beckii* (VII) and a subgroup (VIII) formed by *Andropogon luxurians* specimens (IX) and two subgroups (X, XI) with the remainder specimens. Subgroup X comprises both specimens from Brazil (Bahia, Goiás, and Minas Gerais) and the specimen from Paraguay (Amambay), whereas subgroup XI exclusively includes specimens from Brazil (Bahia, Distrito Federal, Goiás, Maranhão, Mato Grosso, and Minas Gerais).

(F2) The PCoA results also inferred two discrete groups (Fig. 2), which coincide with clusters X and XI. The first two PCoA coordinates accounted for 39.3% of the variation (23.2% and 16.1%, respectively). Coordinate 1 separated the specimens of subgroups X and XI as well as the specimens of *Andropogon*

luxurians and *Schizachyrium beckii* from the specimens of *S. condensatum*, *S. microstachyum*, and *S. sanguineum* (see Fig. 2). Coordinate 2 separated the specimens of *S. sanguineum*, *S. microstachyum*, and *S. condensatum*.

DISCUSSION

Our morphometric analysis revealed two new South American *Schizachyrium* species (clusters X and XI) and suggests that *Andropogon luxurians* is sufficiently different from *S. sanguineum* to be considered a separate taxon, therefore prompting a new name combination.

Although specimens in the two *Schizachyrium* clusters display some similarities with the type material of related species, the results of our multivariate analysis revealed that they possess traits that clearly differentiate them (Table 2). (T2) In group X, specimens are morphologically related to *S. beckii*, but differ in their longer spatheoles, slightly longer rachis internodes with narrower apex, noticeably narrower spikelets (both, sessile and pedicellate), and a slightly shorter awn in sessile spikelets. In group XI, specimens are reminiscent of *A. luxurians*, but differ in their shorter racemes, slightly narrower rachis internodes, and shorter lower glume and awn of the sessile spikelet. These differences between groups X and XI allow us to propose two new species of *Schizachyrium*: *S. angustispiculatum* sp. nov. and *S. vallsii* sp. nov., respectively (see the taxonomic treatment below).

The principal taxonomic traits that distinguish the new species from related taxa are listed in Table 2, and are also presented in form of a key to South American *Schizachyrium* species.

The taxon *Andropogon luxurians* is currently recognized as a synonym of *S. sanguineum* (Türpe 1984; Filgueiras 2003; Peichoto 2010). But our revision of the type material of *Andropogon luxurians* and the inclusion of specimens in our multivariate analysis showed that this taxon has several traits that allow us to distinguish it from *S. sanguineum*: the spatheoles are 20–35 mm long (vs. 30–70 mm in *S. sanguineum*), the rachis internodes are 4.5–6 mm long (vs. 5–7 mm), the lower glume of sessile spikelets is chartaceous and dorsally flat (vs. notoriously coriaceous and dorsally convex), and the lower glume of pedicellate spikelets is 1.5–3 mm long (vs. 3–5 mm). Based on these differences we propose the new name combination *Schizachyrium luxurians* (Ekman) Peichoto and Welker.

Our results also indicate that the new species here described, *S. angustispiculatum* and *S. vallsii*, exhibit intermediate traits (highly branched inflorescences and straight rachis internodes) between the morphological groups previously distinguished among South American taxa based on inflorescence traits (Peichoto et al. 2008). Such intermediate traits – together with the fact that in the area where these species occur also grow other species belonging to both morphological groups – suggest a putative hybrid origin of *S. angustispiculatum* and *S. vallsii* between *S. condensatum* or *S. microstachyum* and *S. luxurians* or *S. sanguineum*.

Hybridization is thought to have played a major role in plant evolution (Stebbins 1959; Grant 1981; Arnold 1992; Rieseberg and Wendel 1993). In the tribe Andropogoneae, interspecific and intergeneric hybridization is especially known in genera like *Andropogon* L., *Eriochrysis* P. Beauv., *Miscanthus* Andersson, and *Saccharum* L. (Killeen 1990; Sobral et al. 1994; Nair et al. 2005; Aitken et al. 2007; Norrmann 2009; Nagahama et al. 2012, 2013). In *Schizachyrium*, although some specimens with intermediate traits have been observed in the field (Peichoto and

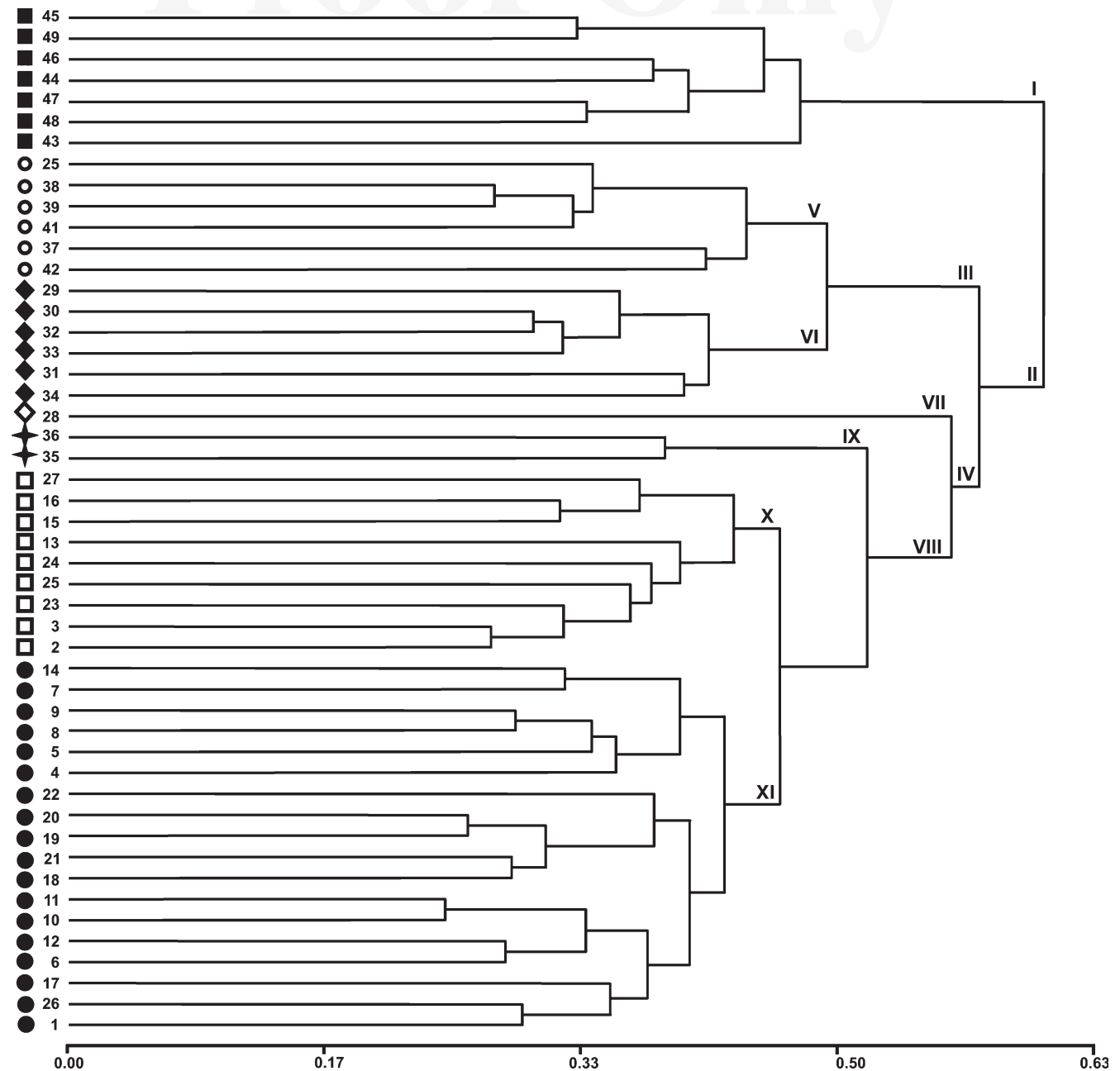


FIG. 1. UPGMA phenogram based on morphological data of *Schizachyrium* specimens. Symbols indicate groups of specimens resulted from the analysis and morphologically similar species included in the study: black square, *Schizachyrium sanguineum*; open circle, *S. microstachyum*; black diamond, *S. condensatum*; open diamond, *S. beckii*; black cross, *Andropogon luxurians*; open square, cluster X; and black circles, cluster XI.

Welker pers. obs.), there is no data of ongoing natural hybridization. In many groups of species, cytogenetic studies have contributed to identify patterns of hybridization among some taxa (Galdeano and Norrmann 2000; Norrmann and Keeler 2003; Norrmann 2009; Scrivanti et al. 2010; Nagahama and Norrmann 2012). In this sense, most of the *Schizachyrium* South American species have been cytologically explored (Peichoto et al. 2011). This study has shown that most of the species with highly branched, hairy inflorescences, slender rachis internodes, and divergent spikelets are diploids, whereas polyploidy has played a fundamental role in the evolution of the species with little branched and less hairy inflorescences, thick rachis internodes, and appressed spikelets. Cytogenetic analy-

sis of the new *Schizachyrium* species here described would contribute to test the hypothesis of their hybrid origin.

With the identification of the new species, *S. angustispiculatum* and *S. vallsii*, the number of species occurring in Brazil and Paraguay is updated. Before this study, 16 species were cited for Brazil (Peichoto 2010; Welker and Longhi-Wagner 2012a, 2012b) and 13 species for Paraguay (Peichoto 2010). From our results the number of *Schizachyrium* species recorded for Brazil and Paraguay up to 19 and 14 species, respectively. Moreover, our results also show that the Brazilian State of Minas Gerais (with 14 species of *Schizachyrium*) is a new center of diversity of the genus, in addition to (or replacing) the region comprising northeastern Argentina,

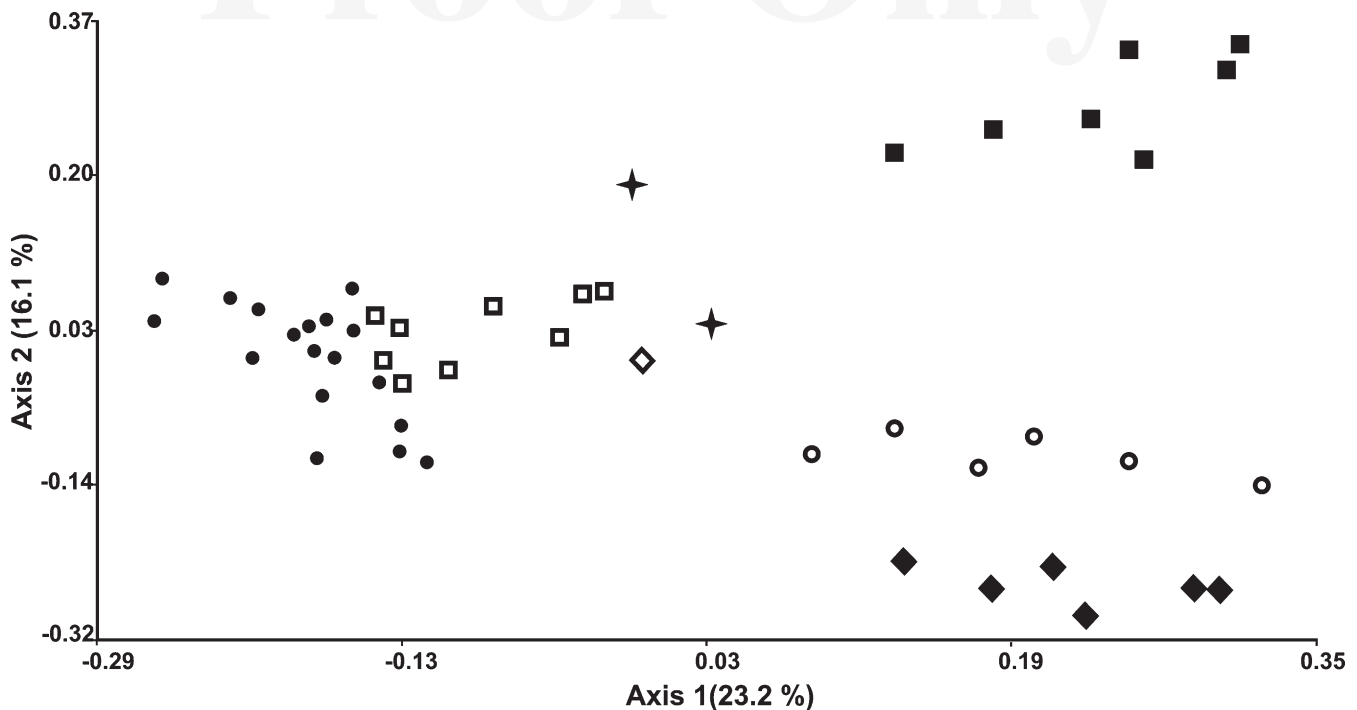


FIG. 2. PCoA ordination plots of the sample points in the plane of the first two principal axes based on morphological data of *Schizachyrium* specimens. Symbols indicate groups of specimens resulted from cluster analysis (UPGMA) and morphologically similar species included in the study: black square, *Schizachyrium sanguineum*; open circle, *S. microstachyum*; black diamond, *S. condensatum*; open diamond, *S. beckii*; black cross, *Andropogon luxurians*; open square, cluster X from UPGMA; and black circles, cluster XI from UPGMA.

southeastern Paraguay, southern Brazil and Uruguay (with 12 species), which has been considered the main center of species diversity in South America (Peichoto 2007). Minas Gerais includes most of the Espinhaço Range, a chain of mountains extending up to the Chapada Diamantina, in the state of Bahia. The Espinhaço Range presents great plant diversity with a large number of endemic species, with the campos rupestres (rocky fields) being the dominant vegetation type. These mountains also represent the center of species diversity for various plant groups (Giulietti and Pirani 1988; Drummond et al. 2005; Viana and Filgueiras 2008; Longhi-Wagner and Welker 2012; Longhi-Wagner et al. 2012).

TAXONOMIC TREATMENT

Schizachyrium angustispiculatum Peichoto and Welker, sp. nov.—TYPE: BRAZIL. Goiás: 18 km E of São Domingos, highway GO-110, 15 May 2000, G. Hatschbach et al. 71106 (holotype: CTES!; isotypes: C!, K!, MBM!, MO!).

Schizachyrium angustispiculatum is similar to *S. beckii*, but is distinguished by its longer spatheoles ((22–) 25–30 mm), longer and narrower rachis internodes (4–4.5 × 0.5–0.7 mm), distinctly narrower sessile (0.5–0.6 (–0.7) mm) and pedicellate spikelets (0.4–0.5 mm), and slightly shorter awn of the sessile spikelet (11–13 (–14) mm).

Perennial, caespitose, 90–150 cm high; culms solid, erect, nodes glabrous, slightly dark, sometimes the basal portion of the culms with white-waxy coating. Leaf sheaths glabrous, striated, keeled; ligule 1.5 mm long, papyraceous; blades 8–15 cm × 4–8 mm, flat or conduplicate, apex acute, navicular. Inflorescence panicle-like shaped, highly branched with 35–150 racemes, sometimes sparsely branched with 12–25 racemes; spatheole (22–) 25–30 mm long, generally subconvolute;

peduncle of each raceme 10–12 mm long, included in the spatheole at maturity. Racemes 22–25 mm long, sparsely pilose, with 4–6 pairs of spikelets. Rachis internodes straight, straw-coloured, 4–4.5 mm long, with rough surface and often with 2 marginal lines of trichomes 1–2 mm long, apical portion concave, 2-toothed, 0.5–0.7 mm wide. Spikelets subappressed to rachis; sessile spikelet 5–5.5 (–6) mm long including the calus; lower glume 4.5–5.5 × 0.5–0.6 (–0.7) mm, carthaceous, the back flat or slightly convex, glabrous, without visible nerves, apex bimucronate; upper glume 4.7–5 mm long, keeled; lower lemma sterile, 4–4.5 mm long, hyaline, margins pilose; upper lemma fertile, 3.5–3.8 mm long, hyaline, apical portion sparsely pilose, with lobes 3–3.2 mm long and awn 11–13 (–14) mm long between the lobes. Caryopsis 3 mm long, embryonic macule 1/3 of its length. Pedicellate spikelet: lower glume 2–2.5 × 0.4–0.5 mm, awn 2.5–3.5 (–4) mm long; pedicel 3.5–4 mm long, dorsiventrally compressed, with 2 marginal lines of trichomes 1–2 mm long. Figure 3. F3

Etymology—The specific epithet makes reference to the narrow spikelets.

Distribution and Habitat—This species occurs in Brazil (Bahia, Goiás, and Minas Gerais) and Paraguay (Amambay). It probably occurs also in Mato Grosso do Sul (Fig. 4). It is unique to the Cerrado Biome, growing in campos rupestres and savannas with small shrubs, on sandy or rocky soils. It is recorded at elevations of 800–1,200 m. F4

Observation—This species also looks like *S. glaziovii* which shows shorter spatheole (20–25 mm long.), rachis internodes recurved at maturity, divergent spikelets, lower glume of the sessile spikelet with obtuse or acute apex, with a fissile hyaline middle part giving a bifid appearance, awn of the pedicellate spikelet 1.5–2.5 mm long. These characters allow the differentiation of both species.

TABLE 2. Comparison of the morphological characters of *Schizachyrium angustispiculatum*, *S. vallsii*, *S. luxurians*, and other species involved in this study.

Character	<i>S. angustispiculatum</i>	<i>S. luxurians</i>	<i>S. vallsii</i>	<i>S. beckii</i>	<i>S. condensatum</i>	<i>S. microstachyum</i>	<i>S. sanguineum</i>
Plant height (cm)	90–150	90–100	80–120(–150)	80–130	35–120	40–150	40–120
Ligule length (mm)	1.5	1.5	1.5	2	1.5–2	1–2.5	1–2
Inflorescence: number of racemes and shape	Highly branched, with 35–150 racemes; sometimes sparsely branched, with 12–25 racemes; panicle-like form	Branched, with 35–40 racemes; panicle-like form	Highly branched, with 70–100 racemes; less commonly sparsely branched, with 12–20 racemes; corymb-like form or panicle-like form	Branched, with 40–60 racemes; panicle-like form	Highly branched, with 70–120 racemes; corymb-like form	Highly branched, with 60–150 racemes; panicle-like form, sometimes subcorymb-like form	Sparsely branched, with 5–25 racemes; panicle-like form
Spatheole: length (mm) and shape	(22–)25–30, subconvolute	20–35, convolute	18–25(–30), subconvolute, sometimes convolute	15–25, convolute	12–20 mm, open or subconvolute	20–25, convolute	30–70, convolute
Peduncle: length (mm) and position at maturity	10–12, included in the spatheole	25–38, apical portion exerted	5–22(–33), included in the spatheole, sometimes with apical portion exerted	10–20(–30), included in the spatheole or apical portion exerted	3–5.5, included in the spatheole	15–25(–30), apical portion exerted	20–80, apical portion exerted
Raceme: length (mm), pilosity and number of pairs of spikelets	22–25, sparsely pilose, with 4–6 pairs of spikelets	40–50, conspicuously pilose, with 8–11 pairs of spikelets	25–35(–55), conspicuously pilose, with 5–11 pairs of spikelets	15–30, sparsely pilose, with 4–6 pairs of spikelets	12–18, pilose, with 4–5 pairs of spikelets	25–36, pilose, with 5–8 pairs of spikelets	30–100, pilose to conspicuously glabrous, sometimes with 5–15 pairs of spikelets
Rachis internodes: length (mm), shape, coloration, and width of apical portion	4–4.5, straight, straw-coloured, concave apical portion, 2-toothed, 0.5–0.7 mm	4.5–6, straight, reddish, slightly concave apical portion, 3–4-toothed, ca. 1 mm	3–4.5, straight, concave apical portion, 2-toothed, 0.5–0.8 mm	3–4, straight, straw-coloured, slightly concave apical portion, 2-toothed, ca. 1 mm	2.5–4, recurved at maturity, straw-coloured, slightly concave apical portion, 0.5 mm	4–5, recurved at maturity, straw-coloured, apical portion 2-toothed, 0.5 mm	5–7, straight, reddish, oblique apical portion, sometimes with 2 tooth slightly hinted, ca. 1 mm
Spikelets: disposition	Subappressed	Subappressed	Subappressed	Subappressed	Divergent	Divergent	Appressed, sometimes subappressed
Sessile spikelet (SS): lower glume length and width (mm), consistency, shape and pilosity on the back	4.5–5.5 × 0.5–0.6(–0.7), carthaceous, flat or slightly convex back, glabrous	5–6 × 0.7, carthaceous, flat back, glabrous	4–5(–5.5) × 0.4–0.7, papyraceous or carthaceous, slightly convex back, glabrous	5–5.5 × 0.7, carthaceous, flat or slightly convex back, glabrous	3–4.5 × 0.5–0.7, carthaceous, flat back, glabrous	3.5–5 × 0.4–0.5, carthaceous, flat or slightly convex back, glabrous	6–7.5 × 0.4–0.7, carthaceous, conspicuously convex back, variable pilosity at glabrous
SS: sterile lemma length (mm)	4–4.5	4	3–4(–4.5)	3.5–4	3.5–4.3	3–4.5	5.5–6
SS: fertile lemma length (mm)	3.5–3.8	3.5	2.5–3.5(–4)	3–3.5	3–4	3–4	4–5
SS: awn length (mm)	11–13(–14)	16–17	8–12(–13)	13–15	7–10	11–16	15–20
Caryopsis length (mm)	3	not seen	2.5–3	3	2.4–3	2–2.6	3–3.5
Pedicellate spikelet (PS): length and width (mm)	2–2.5 × 0.4–0.5	1.5–3 × 0.4–0.5	1.5–2.5 × 0.25–0.3	2–2.5 × 0.5–0.7	1–2 × 0.25	1–2 × 0.25	3–5 × 0.7–0.8
PS: awn length (mm)	2.5–3.5(–4)	3	2–3.5(–4)	2.5–3	0.5–1.5	1–2	2–2.5
PS: pedicel length (mm)	3.5–4	3.5	3–3.5(–4)	2.5–3	2.5–4	3–5.5	6–7



FIG. 3. *Schizachyrium angustispiculatum*. A. Flowering culm, basal and apical portion. B and C. Pair of spikelets and rachis internode. D. Rachis internode, dorsal view. E. Lower glume of sessile spikelet, ventral view. F. Upper glume of sessile spikelet, lateral view. G. Sterile lemma and lodicules, ventral view. H. Fertile lemma, lateral view and the awn sectioned between lobes. I. Lodicules. J. Caryopsis. K. Pedicellate spikelet, ventral view (Hatschbach et al. 71106, CTES).

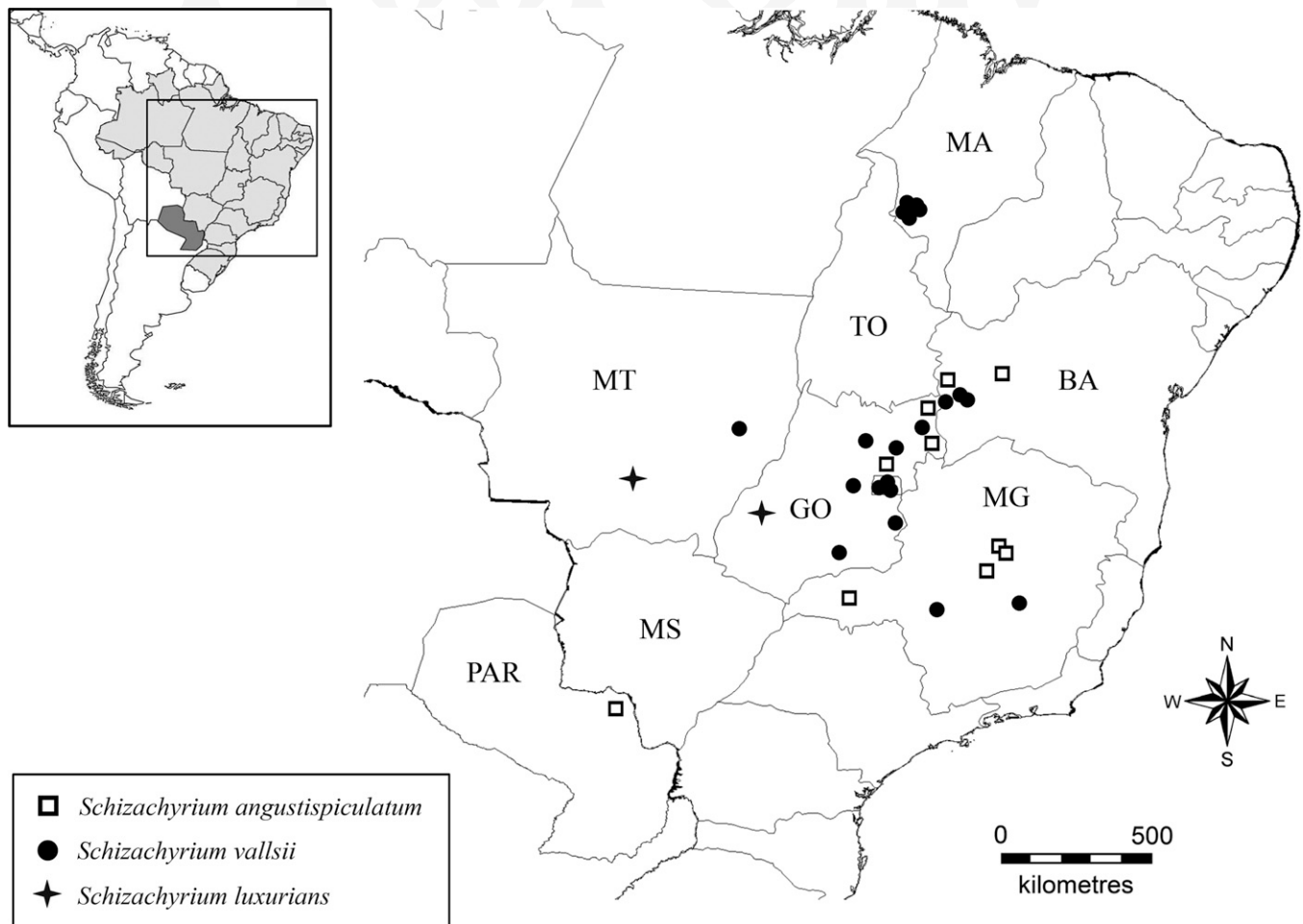


FIG. 4. Distribution map of *Schizachyrium angustispiculatum*, *S. luxurians*, and *S. vallsii*. Paraguay (PAR); Brazilian States: Bahia (BA), Goiás (GO), Maranhão (MA), Minas Gerais (MG), Mato Grosso do Sul (MS), Mato Grosso (MT), Tocantins (TO).

Additional Specimens Examined—BRAZIL. s. loc., 1907, *A. Glaziou* 20072 (NY). Bahia: São Desidério, at the intersection of the Galheirão River and highway BR-020, 8 Apr 1976, *G. Davidse et al.* 12150A (K, MO); 45 km W of Wanderley along highway BR-242, 7 Apr 1976, *G. Davidse et al.* 12054 (MO). Goiás: Água Fria de Goiás, highway GO-118, 8 May 2000, *G. Hatschbach et al.* 70653 (CTES, K); Posse, 16 km SW of the Goiás-Bahia border along highway BR-020, 8 Apr 1976, *G. Davidse et al.* 12190 (MO). Minas Gerais: Corinto, highway BR-496, near km 113, 13 Apr 1996, *G. Hatschbach et al.* 64643 (SI); Joaquim Felício, Serra do Cabral, 15 Apr 1996, *G. Hatschbach et al.* 64765 (CTES, K, LIL, SI), *G. Hatschbach et al.* 64838 (CTES, SI); Prata, along road to Fazenda Nhô Pádua, 21 Mar 1963, *T. Sendulsky* 43 (K).

PARAGUAY. Amambay: Parque Nacional Cerro Corá, Jan 1993, *N. Soria* 5871 (FCQ).

Schizachyrium vallsii Peichoto and Welker, sp. nov.—
TYPE: BRAZIL. Bahia: São Desidério, Campinas, ca. 10 km S of Piau River, ca. 150 km SW of Barreiras, 850 m, 13 Apr 1966, *H. S. Irwin et al.* 14711 (holotype: MO!; isotypes: NY!, UB!, US!).

Schizachyrium vallsii is similar to *S. luxurians* but it differs by the slightly narrower rachis internodes 3–4.5 × 0.5–0.8 mm wide at the apex; sessile spikelet with lower glume 4–5 (–5.5) mm long and awn 8–12 (–13) mm long.

Perennial, caespitose, 80–120 (–150) cm high; culms solid, erect, nodes glabrous, slightly dark. Leaf sheaths glabrous, striated, keeled; ligule 1.5 mm long, papyraceous; blades (7–) 8–15 (–20) cm × 4–7 (–10) mm, flat or conduplicate, apex acute, navicular. Inflorescence corymb-like to panicle-

like shaped, highly branched with 70–100 racemes, less commonly sparsely branched with 12–20 racemes; spatheole 18–25 (–30) mm long, subconvolute, sometimes convolute; peduncle of each raceme 5–22 (–33) mm long, included in the spatheole, sometimes with the apical portion exerted at maturity. Racemes 25–35 (–55) mm long, distinctly white-pilose, with 5–11 pairs of spikelets. Rachis internodes straight, reddish, 3–4.5 mm long, with rough surface and often with 2 marginal lines of trichomes 1.5–2 (–2.5) mm long, apical portion concave, 2-toothed, 0.5–0.8 mm wide. Spikelets subappressed to rachis; sessile spikelet 5–5.5 mm long including the callus; lower glume 4–5 (–5.5) × 0.4–0.7 mm, papyraceous or chartaceous, the back slightly convex, glabrous, with 2–4 nerves, apex acute or subacute, with central portion hyaline, very tenuous, that breaks easily giving the appearance of a bifid apex, sometime clearly bifid or bimucronate; upper glume 4–4.5 mm long, navicular; lower lemma sterile, 3–4 (–4.5) mm long, hyaline, margins slightly pilose; upper lemma fertile, 2.5–3.5 (–4) mm long, hyaline, glabrous, with lobes 2–3 mm long and with awn 8–12 (–13) mm long between the lobes. Caryopsis 2.5–3 mm long, embryonic macule 1/3 of its length. Pedicellate spikelet: lower glume 1.5–2.5 × 0.25–0.3 mm, with awn 2–3.5 (–4) mm long; pedicel 3–3.5 (–4) mm long, dorsiventrally compressed, with 2 marginal lines of trichomes 1–2.5 mm long. Figures 5 and 6.

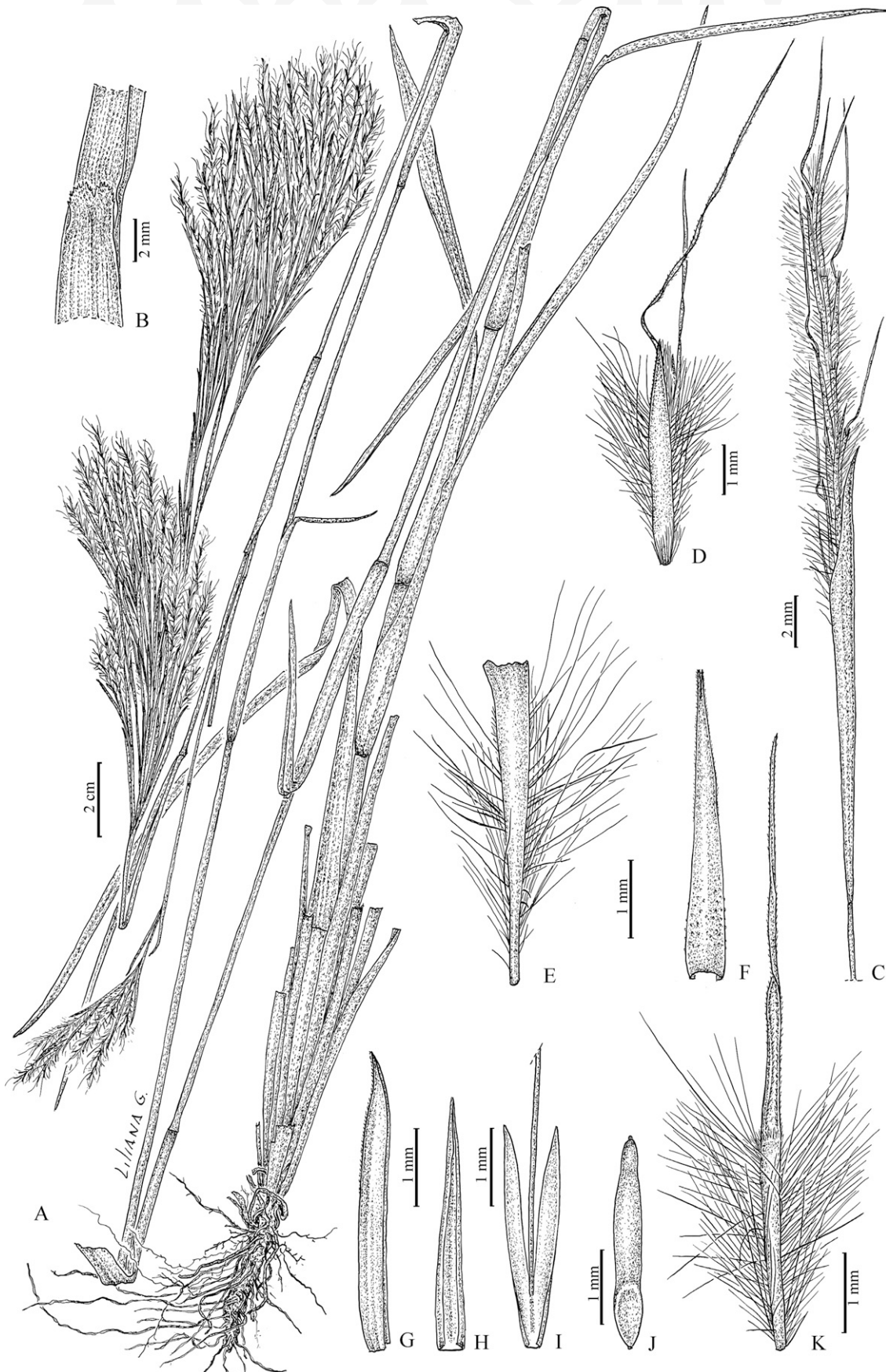


FIG. 5. *Schizachyrium vallsii*. A. Flowering culm. B. Ligule, ventral view. C. Raceme and spatheole. D. Pair of spikelets. E. Rachis internode, dorsal view. F. Lower glume of sessile spikelet, dorsal view. G. Upper glume of sessile spikelet, lateral view. H. Sterile lemma, ventral view. I. Fertile lemma and the awn sectioned between lobes. J. Caryopsis. K. Pedicellate spikelet, ventral view (Irwin *et al.* 14711, MO).



FIG. 6. Variation of ramification degree in inflorescences of *Schizachyrium vallsii*. A. Anderson 10277 (CTES). B. Swallen 4036 (NY).



FIG. 7. *Schizachyrium luxurians*. A. Flowering culm. B. Ligule, lateral view. C. Raceme, spatheole and apical portion of peduncle. D and E. Pair of spikelets and rachis internode. F. Rachis internode, dorsal view. G. Lower glume of sessile spikelet, dorsal view. H. Lower glume, ventral view. I. Sterile lemma, lateral view. J. Sterile lemma, ventral view. K. Fertile lemma, lateral view with the awn between lobes. L. Pedicellate spikelet, ventral view (*Malme s. n., S*).

Etymology—This species is dedicated to Dr. José Francisco Montenegro Valls, who is an enthusiastic collector and a great expert on Brazilian grasses.

Distribution and Habitat—This new species occurs exclusively in Brazil, in the States of Bahia, Distrito Federal, Goiás, Maranhão, Mato Grosso, and Minas Gerais (Fig. 4). It probably occurs also in the state of Tocantins. It is unique to the Cerrado Biome, growing in savanna or grasslands with small shrubs, in sandy or quartzite soils. It is recorded at an altitude of 500–1,300 m.

Observation 1—The inflorescences of this species show great morphological variability in the degree of branching. Some specimens present highly branched inflorescences, from corymb-like (Fig. 5, A) to panicle-like shape (Fig. 6, A), and other specimens present less branched inflorescences (Fig. 6, B) (see next note). A similar variation in the morphology of the inflorescences may be found also in *Schizachyrium microstachyum* (Peichoto 2010).

Observation 2—The inflorescences of the specimens Swallen 4022, 4036, 4134 and 4135, collected in Maranhão, are looser due to the less branched stems (Fig. 6, B). This morphological feature may explain the distribution of these specimens (numbers 18, 19, 20, and 21 in the analysis) within the subgroup identified as XI on UPGMA and their close location in the resulting graphs (Figs. 1 and 2).

Additional Specimens Examined—BRAZIL. s. loc., 1844, *M. Weddell* 1865 (P). Bahia: São Desidério, Campinas, ca. 150 km SW of Barreiras, 13 Apr 1966, *H. S. Irwin et al.* 14717 (F, NY); São Desidério, 22 km S of the Galheirão River along highway BR-020, 8 Apr 1976, *G. Davidse et al.* 12221 (MO). Distrito Federal: 31 km from Brasília on Anápolis road, 23 February 1965, *W. D. Clayton* 4810 (K); Brasília, 3 Mar 1965, *W. D. Clayton* 4918 (K, SI); ca. 18 km SSW of Brasília, Fazenda Água Limpa, 10 May 1976, *J. A. Ratter and S. G. Fonseca* 3005 (K, MO). Goiás: Cocalzinho de Goiás, Serra do Pirineus, ca. 15 km N of Corumbá de Goiás, 14 May 1973, *W. R. Anderson et al.* 10277 (CTES, NY); 44 km by road SE of Cristalina, Cristal River, 6 Apr 1973, *W. R. Anderson et al.* 8277 (C, F, MO, NY, W); Morrinhos, 63 km N of Itumbiara along highway BR-153, 10 Apr 1976, *G. Davidse et al.* 12239 (MO); Niquelândia, Morro do Cristo, 16 Apr 1996, *F. C. A. Oliveira et al.* 572 (SI); Posse, Prata River, 9 Apr 1966, *H. S. Irwin et al.* 14580 (F, NY, US); 4 km by road E of São João d'Aliança, Serra Geral do Paraná, 24 Mar 1973, *W. R. Anderson et al.* 7856 (F, K, MO). Maranhão: Carolina to Balsas, 20–25 Mar 1934, *J. R. Swallen* 4022 (NY), 4036 (MO), 4129 (GH), 4134 (MO), 4135 (MO). Mato Grosso: Água Boa, ca. 75 km N of Nova Xavantina, Serra do Roncador, 5 Jun 1966, *H. S. Irwin et al.* 16629 (BM, F, GH, MO, NY). Minas Gerais: ca. 4 km W of Campos Altos along highway BR-262 to Uberaba, 29 Feb 1976, *G. Davidse and T. P. Ramamoorthy* 10849 (MO); Lagoa Santa, 42 km N of Belo Horizonte, 23–24 Mar 1925, *A. Chase* 9010 (US).

Schizachyrium luxurians (Ekman) Peichoto and Welker, comb. nov. *Andropogon luxurians* Ekman, Ark. Bot. 10 (17): 6, t. 1, f. 1, t. 6, f. 2. 1911—TYPE: BRAZIL. Mato Grosso,

[Chapada dos Guimarães] Cascata Grande prope Burity (Serra da Chapada) in campis glareosis, nebulis catarrhactae saepe humectatis, 8 Jun 1903, *G. O. Malme s. n.* (holotype: SI; fragmentos: BAA-00001443 (fragm. ex US)!, MVFA-0000155 (fragm. ex US) JSTOR image!, US-75694 (fragm. ex US) JSTOR image!).

Perennial, caespitose, 90–100 cm high; culms solid, erect, nodes glabrous, slightly dark. Leaf sheaths glabrous, striated, keeled; ligule 1.5 mm long, papyraceous; basal blades 10–15 cm × 10–11 mm, stem blades 5–7 cm × 7–8 mm, flat or conduplicate, apex slightly obtuse, conspicuously mucronate. Inflorescence panicle-like shaped, branched with 35–40 racemes; spatheole 20–35 mm long, convolute; peduncle of each raceme 25–38 mm long, apical portion exerted at maturity. Racemes 40–50 mm long, distinctly white-pilose, with 8–11 pairs of spikelets. Rachis internodes straight, reddish, 4.5–6 mm long, with rough surface and often with 1 marginal line of trichomes 1–2 mm long, apical portion concave, 3–4-toothed, 1 mm wide. Spikelets subappressed to rachis; sessile spikelet 5–6 mm long including the callus; lower glume 5–6 × 0.7 mm, chartaceous, the back flat, glabrous, with 4 conspicuous nerves, apex acuminate-bimucronate; upper glume keeled 5 mm long; lower lemma sterile, 4 mm long, hyaline, margins pilose; upper lemma fertile, 3.5 mm long, hyaline, glabrous, with lobes 3–3.2 mm long and awn 16–17 mm long between the lobes. Caryopsis not seen. Pedicellate spikelet: lower glume 1.5–3 × 0.4–0.5 mm, with awn 3 mm long; pedicel 3.5 mm long, dorsiventrally compressed, with 2 marginal lines of trichomes 1–1.5 mm long. Figure 7. [E7]

Distribution and Habitat—This species is known so far only from the Brazilian States of Mato Grosso and Goiás (Fig. 4). It is unique to the Cerrado Biome, growing in cerrado grasslands and on rocky hillsides. It is recorded at elevations from 950–1,200 m.

Observation—Ekman (1911) described *Andropogon luxurians* in the subgenus *Schizachyrium* and based on of the specimen *Malme s. n.* collected in Mato Grosso (Brazil). Türpe (1984) considered this name as a synonym of *S. sanguineum*, followed by some authors (Filgueiras 2003; Peichoto 2010). However, a comprehensive analysis of the morphological characters of the type material allowed us to determine that certain features of the inflorescence (distinctly pilose; shorter rachis internodes and spikelets, lower glume of sessile spikelet with markedly flat back) differentiate it from *S. sanguineum*. The morphometric analysis here conducted confirmed the identity of both taxa.

Additional Specimens Examined—BRAZIL. Goiás: 30 km S of Caiapônia, 29 Apr 1973, *W. R. Anderson et al.* 9415 (NY).

KEY TO THE SCHIZACHYRIUM SPECIES INVOLVED IN THIS STUDY

1. Rachis internodes straight, sometimes slightly thick. Spikelet appressed or subappressed to the rachis 2
2. Lower glume of the sessile spikelet 6–7.5 mm long, the back conspicuously convex, pilose to glabrous. Pedicellate spikelet 3–5 mm long. Rachis internodes 5–7 mm long, apical portion oblique, with 2 inconspicuous teeth *S. sanguineum*
2. Lower glume of the sessile spikelet 4–5.5(–6) mm long, the back flat or slightly convex, glabrous. Pedicellate spikelet 1.5–2.5(–3) mm long. Rachis internodes 3–5(–6) mm long, apical portion concave, 2–4 toothed 3
3. Racemes sparsely pilose. Rachis internodes straw-coloured. Lower glume of the sessile spikelet without visible nerves on the back 4
4. Spatheole 15–25 mm long. Apex of the rachis internodes 1 mm wide. Lower glume of the sessile spikelet 0.7 mm wide. Pedicellate spikelet 0.5–0.7 mm wide *S. beckii*
4. Spatheole (22–)25–30 mm long. Apex of the rachis internodes 0.5–0.7 mm wide. Lower glume of sessile spikelet 0.5–0.6(–0.7) mm wide. Pedicellate spikelet 0.4–0.5 mm wide *S. angustispiculatum*
3. Racemes conspicuously white-pilose. Rachis internodes reddish. Lower glume of the sessile spikelet with 2–4 nerves on the back 5
5. Rachis internodes 4.5–6 × 1 mm. Lower glume of the sessile spikelet 5–6 mm long, awn of the upper lemma 16–17 mm long *S. luxurians*

5. Rachis internodes 3–4.5 × 0.5–0.8 mm. Lower glume of the sessile spikelet 4–5(–5.5) mm long, awn of the upper lemma 8–12(–13) mm long *S. vallsii*
1. Rachis internodes recurved at maturity, generally thin. Spikelets divergent from its base 6
6. Inflorescence generally panicle-like shaped, wide. Spatheole strongly convolute. Peduncle 15–25(–30) mm long, apical portion exerted at maturity. Raceme 25–36 mm long. Sessile spikelet with awn 11–16 mm long *S. microstachyum*
6. Inflorescence corymb-like form, capitate. Spatheole open or subconvolute. Peduncle 3–5.5 mm long, included at maturity. Raceme 12–18 mm long. Sessile spikelet with awn 7–10 mm long *S. condensatum*

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APPENDIX 1—*Schizachyrium* specimens selected for the morphometric analysis. The initial number of each sample corresponds to UPGMA analysis. The Brazilian specimens are cited at first term in alphabetical order of Brazilian states and after according to the surname of the first collector.

Specimens analyzed—BRAZIL. 1. s. loc., Weddell 1865 (P). 2. Bahia: 45 km W of Wanderley along highway BR-242, Davidse et al. 12054 (MO). 3. Bahia: São Desidério, at the intersection of the Galheirão River and highway BR-020, Davidse et al. 12150A (MO). 4. Bahia: São Desidério, 22 km S of the Galheirão River along highway BR-020, Davidse et al. 12221 (MO). 5. Bahia: São Desidério, Campinas, ca. 10 km S of Piau River, ca. 150 km SW of Barreiras, Irwin et al. 14711 (MO). 6. Bahia: São

- Desidério, Campinas, ca. 150 km SW of Barreiras, *Irwin et al.* 14717 (F). 7. Distrito Federal: 31 km from Brasília on Anápolis road, *Clayton* 4810 (K). 8. Distrito Federal: Brasília, *Clayton* 4918 (K). 9. Distrito Federal: ca. 18 km SSW of Brasília, Fazenda Água Limpa, *Ratter and Fonseca* 3005 (MO). 10. Goiás: 4 km by road E of São João d'Aliança, Serra Geral do Paraná, *Anderson et al.* 7856 (F). 11. Goiás: 44 km by road SE of Cristalina, Cristal River, *Anderson et al.* 8277 (F). 12. Goiás: Cocalzinho de Goiás, Serra do Pirineus, ca. 15 km N of Corumbá de Goiás, *Anderson et al.* 10277 (CTES). 13. Goiás: Posse, 16 km SW of the Goiás-Bahia border along highway BR-020, *Davidse et al.* 12190 (MO). 14. Goiás: Morrinhos, 63 km N of Itumbiara along highway BR-153, *Davidse et al.* 12239 (MO). 15. Goiás: Água Fria de Goiás, highway GO-118, *Hatschbach et al.* 70653 (CTES). 16. Goiás: 18 km E of São Domingos, highway GO-110, *Hatschbach et al.* 71106 (CTES). 17. Goiás: Posse, Prata River, *Irwin et al.* 14580 (F). 18. Maranhão: Carolina to Balsas, *Swallen* 4022 (NY). 19. Maranhão: Carolina to Balsas, *Swallen* 4134 (MO). 20. Maranhão: Carolina to Balsas, *Swallen* 4135 (MO). 21. Maranhão: Carolina to Balsas, *Swallen* 4036 (MO). 22. Minas Gerais: Ca. 4 km W of Campos Altos along highway BR-262 to Uberaba, *Davidse and Ramamoorthy* 10849 (MO). 23. Minas Gerais: Joaquim Felício, Serra do Cabral, *Hatschbach et al.* 64765 (CTES). 24. Minas Gerais: Joaquim Felício, Serra do Cabral, *Hatschbach et al.* 64838 (CTES). 25. Minas Gerais: Prata, along road to Fazenda Nhô Pádua, *Sendulsky* 43 (K). 26. Mato Grosso: Água Boa, ca. 75 km N of Nova Xavantina, Serra do Roncador, *Irwin et al.* 16629 (F). 27. PARAGUAY. Amambay: Parque Nacional Cerro Corá, *Soria* 5871 (FCQ). *Schizachyrium beckii* Killeen: 28. BOLIVIA. Santa Cruz: Ñuflo de Chavez, Serranía de San Lorenzo, 10 km W of San Javier, *Killeen* 1987 (F, type of *S. beckii*). *Schizachyrium condensatum* (Kunth) Nees: BRAZIL. 29. Paraná: Curitiba, Capão da Imbuia, *Dombrowski* 5991 (CTES). 30. Paraná: Palmeira to Ponta Grossa, 9 km from Palmeira, *Rúgolo de Agrasar et al.* 1676 (MO). 31. Paraná: Bella Vista, territory of Ponta Porá, *Swallen* 9472 (MO). 32. Rio Grande do Sul: Vacaria, *Guimarães and Grippa* 1378 (CTES). 33. Santa Catarina: Lages to São Joaquim, SC-438, *Keller and Paredes* 7041 (CTES). 34. COLOMBIA. Prope Ibaguê, *Humboldt and Bonpland s.n.* (P, type of *S. condensatum*). *Schizachyrium luxurians* (Malme) Peichoto and Welker: BRAZIL 35. Goiás: 30 km S of Caiapônia, *Anderson* 9415 (NY). 36. Mato Grosso: Chapada dos Guimarães, Cascata Grande prope Buriti (Serra da Chapada), *Malme s.n.* (S, type of *Andropogon luxurians*). *Schizachyrium microstachyum* (Desv. ex Ham.) Roseng., B. R. Arrill. and Izag.: BRAZIL. 37. Amazonas: Manaus, Igarapé do Franco, *Chagas s.n.* (NY). 38. Mato Grosso do Sul: Corumbá, Fazenda Nhumirim-Pantanal, *Allem* 119 (MO). 39. Minas Gerais: Vicosia, State Agricultural School, *Irwin* 2280 (F). 40. Rio Grande do Sul: Dom Pedrito, road Bagé-Dom Pedrito, *Longhi-Wagner et al.* 2522 (CTES). 41. Rio Grande do Sul: Porto Alegre, Jardim Botânico, *Martins* 85 (CTES). 42. WEST INDIES. *Desvaux* 8 (P, type of *S. microstachyum*). *Schizachyrium sanguineum* (Retz.) Alston: BRAZIL. 43. s. loc., *Sellow s.n.* (LE, type of *Schizachyrium hirtiflorum* Nees (synonym of *S. sanguineum*)). 44. Bahia: Rio de Contas, Barra do Brumado, *Hatschbach et al.* 56813 (CTES). 45. Goiás: 30 km S of Caiapônia, *Anderson* 9423 (CTES). 46. Goiás: Cristalina, Morro do Urubu, *Hatschbach* 43756 (CTES). 47. Mato Grosso: Barra do Garças, *Anderson* 9696 (CTES). 48. Minas Gerais: Espinhaço Range, 3.5 km by road of rio Jequití and Mendaha, *Anderson* 8905 (CTES). 49. Minas Gerais: Serra do Cipó, 10-20 km NE of Cardeal Mota, road to Conceicao do Mato Dentro, *Arbo et al.* 4205 (CTES).