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Pollen morphology of Brazilian species of *Verbesina* L. (Heliantheae - Asteraceae)[1]

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ABSTRACT

There are nine species of the plant genus *Verbesina* in Brazil, which are distributed in the Northeast, Center-West, Southeast and South regions of the country. The objective of the present study was to describe the pollinic morphology of eight of these species to better characterize them and evaluate potential species-level taxonomic characters. Acetolysed pollen material was measured within seven days under light microscopy, while non-acetolyzsed pollen grains were used for scanning electronic microscopy. The pollen grains were found to be oblate-spheroidal, medium-sized, isopolar, monads that are 3-colporate with a subtriangular amb, a small polar area, a long colpus, a lalongate endoaperture, a caveate exine and an echinate sexine. Although the shape of the pollen grains of these Brazilian species of *Verbesina* is homogeneous, some attributes were observed to be useful for characterizing the species, such as exine thickness, distance between spines and side of the apocolpus.

Keywords: Brazil, Compositae, Heliantheae, morphology, pollen, *Verbesina*

Introduction

The family Asteraceae, order Asterales (APG IV 2016) has a holistic distribution but is common in the dry and open tropical montane climate zone (Anderberg *et al.* 2007). The family includes 13 subfamilies, 44 tribes, about 1,700 genera and proximately 27,000 species, and represents about 10 % of all Angiosperms (Funk *et al.* 2009; Panero *et al.* 2014; Panero & Crozier 2016). There are about 2,097 species of Asteraceae grouped among 289 genera in Brazil (Flora do Brasil 2020).

The genera *Verbesina* belongs to the tribe Heliantheae (subtribe Verbesininae) and possesses around 300 species distributed throughout the Americas, with the most occurring in Mexico and the Andes (Panero 2007). Nine species have been recorded in Brazil, which are distributed in the Northeast, Southeast, Center-West and South regions of the country, especially in forest environments.

Pollen morphology has contributed to characterizing and differentiating taxa of Asteraceae at the subfamily, tribe and subtribe levels (Skvarla & Turner 1966; Bolick 1991; Cancelli *et al.* 2007; Coutinho & Dinis 2007; Wortley *et al.* 2007; Stanski *et al.* 2016; among others), however, few studies have focused on pollen morphology for distinguishing species of Asteraceae because pollen grains have been found to be morphologically homogeneous within the same genus (Gonçalves 1976). Nonetheless, pollen morphology has been used to distinguish species of some genera of the tribe Heliantheae, such as *Ambrosia*, *Clibadium*, *Eclipta*, *Parthenium*, *Viguiera*, *Xanthium* and *Wedelia* (Gonçalves-Esteves & Esteves 1986; 1989a; b).

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Most studies involving pollen morphology of *Verbesina* have been descriptive, such as Gonçalves (1976), who analyzed 17 species, including three Brazilian species (*Verbesina diversifolia* [=*V. macrophylla*], *V. glabrata* and *V. sordescens*); Roubik & Moreno (1991) who studied *V. gigantea* of Panama; Sanchez & Lupo (2009) who investigated *V. lilloi* from Argentina; and Jesus & Lima (2013) who reported on *V. macrophylla* from Bahia, Brazil. Other references to *Verbesina* are pollen catalogs such as Cancelli *et al.* (2010) for Rio Grande do Sul, Brazil, with *V. glabrata* and *V. sordescens*; and Radaeski *et al.* (2014; 2016) with *V. sordescens*.

Some studies that have addressed the pollen morphology of *Verbesina* have indicated the existence of characters with potential use for characterizing and differentiating species of the genus. Harker & Jiménez-Reyes (2002) found that some pollen grain characters, such as shape, size, number of spicules, transverse size colpus and polar area index, were useful for separating *Verbesina barrancae* and *V. crocata*, two morphologically close Mexican species.

The objective of the present study was to describe the pollen morphology of eight Brazilian species of *Verbesina* to better characterize the species of the genus and to evaluate potential species-level taxonomic characters.

Materials and methods

Pollen material was obtained from floral buds of specimens of eight species of *Verbesina* (*V. baccharifolia* Mattf., *V. bipinnatifida* Baker, *V. floribunda* Gardner, *V. glabrata* Hook. & Arn., *V. luetzelburgii* Mattf., *V. macrophylla* (Cass.) S.F. Blake, *V. nicotianifolia* Baker, *V. sordescens* DC.) deposited in the following herbaria: BHCB, CEN, HUCS, HUEFS, MBML, RB, UB (Thiers 2017) (Tab. 1).

Pollen material was prepared for light microscopy using acetolysis following the method of Erdtman (1952), with the modifications proposed by Melhem *et al.* (2003). Acetolysed pollen grains were measured within seven days of their preparation, in accordance with Salgado-Labouriau (1973). Twenty-five measurements of polar diameter (PD) and equatorial diameter (ED) in equatorial view, and 10 measurements of the equatorial diameter in polar view (EDPV) and apocolpium side (AS), were made on standard material distributed among at least three slides. For other dimensions, such as those of apertures, exine layers and diameters of comparison material, 10 pollen grains were measured on at least in three slides and the arithmetic mean calculated. Description of polar area and aperture size followed the classification established by Faegri & Iversen (1966) for the polar area index. Pollen grain size classes follow Erdtman (1952).

Permanent slides of pollen material generated for this study are deposited in the Laboratory of Palynology of the National Museum of the Federal University of Rio de Janeiro.

For scanning electron photomicrography, two to three anthers were removed from flowers or flower buds extracted from herbarium specimens. The anthers were macerated using properly flamed forceps and stylus to release non-acetolysed pollen grains over a metallic stub previously covered with double-sided carbon tape. The material was spatter-coated with gold for approximately three minutes and then analyzed and photomicrographed using a JSM-5310 scanning electron microscope at the Optical and Scanning Microscopy Laboratory, Federal University of Rio de Janeiro.

To assess whether pollen characteristics discriminated the studied species of *Verbesina*, a principal component analysis (PCA) was performed using eleven metric variables. The results were biplotted on a graph with axes 1 and 2 of the PCA.

Results

The pollen grains of the studied species of *Verbesina* were found medium-sized (25–50 µm) oblate-spheroidal, isopolar, monads with a subtriangular amb, (PD/ED 0.95–0.99) (Tab. 2).

The confidence interval 95 % for polar diameter (PD) in equatorial view ranged 25.3-42.3 µm, with the lowest values being for *Verbesina macrophylla* (25.3-26.3 µm) and the greatest for *V. baccharifolia* (39.5-42.3 µm) (Tab. 2).

All species had a low polar area index (0.35-0.48 µm) (Tab. 2), were 3-colporate, and had: long colpus (9.3–14.5 x 2.9–5.0 µm), acute apices, lalongate endoaperture (2.2–4.6 x 8.8–14.2 µm) with constriction, caveate exine (2.2–3.4 µm) echinate sexine, spines (4.0–5.9 x 3.0–4.1 µm) with perforations at the base, and distance between spines of 6.1–8.6 µm. The colpus with medium constrictions is more perceptible in *V. floribunda*. The longest colpus was found in *Verbesina luetzelburgii* (14.5 µm) and the shortest in *V. nicotianifolia* (9.3 µm); *V. luetzelburgii* (4.6 µm) had the longest endoaperture while *V. bipinnatifida* (2.2 µm) had the shortest; and *V. floribunda* (14.2 µm) had the largest endoaperture while *V. bipinnatifida* and *V. macrophylla* (8.8 µm) had the smallest (Tab. 3).

In all species the exine was found to be caveate and echinate (Figs. 1, 2). The sexine and nexine were almost always of the same thickness, but when they did differ the sexine was thicker than the nexine. Mean width exine ranged 2.2-3.4 µm (Tab. 3). The sexine and nexine are very close to the cavea, making it difficult to see.

Four to six pairs of spines were observed around the aperture in equatorial view (Figs. 1D, H, L, P, 2D, H, L, P), which were longer than wide and with perforations at the base. The shortest spines were found in *Verbesina macrophylla* (4.0 µm) while the longest were for *V. baccharifolia* (5.9 µm). The distance between spines varied (6.1-8.6 µm), with it being the greatest in *V. floribunda* (8.6 µm) and least in *V. sordescens* (6.1 µm) (Tab. 3).

Table 1. Species used in the morphological analysis of pollen grains in *Verbesina* L. (Asteraceae-Heliantheae).

Species	Voucher	Herbarium
Verbesina baccharifolia Mattf.	Ganev 363, Ganev 1824, Ganev 1928	HUEFS, HUEFS, HUEFS
Verbesina bipinnatifida Baker	Moreira *et al.* 116, Vervloet & Bausen 164, Lombardi & Salino 1671	CEN, MBML, BHCB
Verbesina floribunda Gardner	Moreira *et al.* 102, Moreira *et al.* 101, Forzza *et al.* 3066	CEN, CEN, RB
Verbesina glabrata Hook. & Arn.	Moreira *et al.* 115, Fontana & Toniato 619, Moreira *et al.* 103	CEN, BML, CEN
Verbesina luetzelburgii Mattf.	Moreira *et al.* 117, Moreira *et al.* 118, Moreira *et al.* 119	CEN, CEN, CEN
Verbesina nicotianifolia Baker	Proença 865	UB
Verbesina macrophylla (Cass.) S.F. Blake	Moreira *et al.* 112, Moreira *et al.* 110, Moreira *et al.* 111	CEN, CEN, CEN
Verbesina sordescens DC.	Wasum s.n., Wasum 3706, Scur 1136	HUCS 12414, HUCS, HUCS

Table 2. Measurements of pollen grains in Brazilian *Verbesina* L. (Heliantheae-Asteraceae) species in equatorial view: (n=25) and polar view: (n=10); PAI = polar area index.

Species	Equatorial View			Polar View		
	Polar diameter (µm)	Equatorial diameter (µm)	PD/ED	Equatorial Diameter (µm)	Apocolpous Side (µm)	PAI
V. baccharifolia Mattf.	35.0(40.9)50.0	37.5(41.9)50.0	0.98	37.5(41.5)45.0	15.0(17.8)22.5	0.43
V. bipinnatifida Baker	27.5(31.0)40.0	27.5(31.9)40.0	0.97	25.0(31.2)35.0	10.0(13.5)15.0	0.43
V. floribunda Gardner	30.0(34.2)45.0	30.0(35.6)42.5	0.96	32.5(36.0)40.0	10.0(12.5)15.0	0.35
V. glabrata Hook. & Arn.	30.0(33.3)37.5	32.5(34.2)37.5	0.97	30.0(32.7)35.0	12.5(14.7)15.0	0.45
V. luetzelburgii Mattf.	32.5(37.0)40.0	35.0(37.3)40.0	0.99	37.5(39.2)42.5	15.0(16.7)17.5	0.43
V. macrophylla (Cass.) S.F. Blake	25.0(25.8)27.5	25.0(27.2)30.0	0.95	25.0(26.7)27.5	10.0(12.7)15.0	0.48
V. nicotianifolia Baker	27.5(30.9)35.0	27.5(31.4)37.5	0.98	30.0(32.7)35.0	12.5(14.2)15.0	0.43
V. sordescens DC.	30.0(33.1)37.5	32.5(34.8)37.5	0.95	32.5(35.0)37.5	15.0(16.2)17.5	0.46

Table 3. Measurements of the aperture and layers of exine pollen grains in Brazilian *Verbesina* L. species (Heliantheae-Asteraceae); n=10; DBS = distance between spines; * measured without the spines.

Specie	Colpus		Endoaperture		Exine layers*			Spine		
	length (µm)	width (µm)	length (mm)	width (µm)	exine	sexine	nexine	length (µm)	width (µm)	DBS
V. baccharifolia Mattf.	14.4	5.0	4.4	12.6	3.3	1.7	1.6	5.9	4.1	7.9
V. bipinnatifida Baker	11.5	3.2	2.2	8.8	3.4	1.7	1.7	4.5	3.5	7.0
V. floribunda Gardner	10.6	2.9	4.3	14.2	3.4	1.9	1.5	5.3	3.3	8.6
V. glabrata Hook. & Arn.	14.1	4.5	4.2	12.3	2.8	1.4	1.4	5.0	3.1	7.5
V. luetzelburgii Mattf.	14.5	4.6	4.6	12.7	3.3	1.7	1.6	5.8	3.7	6.9
V. macrophylla (Cass.) S.F. Blake	9.7	3.3	3.7	8.8	2.6	1.6	1.0	4.0	3.0	6.7
V. nicotianifolia Baker	9.3	3.9	3.0	9.5	2.2	1.2	1.0	4.8	3.0	6.5
V. sordescens DC.	10.4	4.9	3.9	10.4	2.9	1.9	1.0	5.2	3.4	6.1

Verbesina glabrata was the only species to exhibit variation in pollen grain shape, ranging from oblate-spheroidal to prolate-spheroidal (Tabs. 2, 4). The mean PD and ED of the comparison material of *V. macrophylla* were 31.9 µm and 32.6 µm, respectively, which differed from that of the standard material (25.8 µm and 27.2 µm, respectively), however, pollen grain shape did not differ. The comparison material for the other species had means that fell within the range found for the standard material.

Principal component analysis (PCA)

The first two axes of the PCA explained 83.6 % of the variability of the analyzed data. The first axes explained 64.8 % of the data, with *Verbesina bipinnatifida*, *V. macrophylla* and *V. nicotianifolia* having, in general, the lowest values for PD, ED, EDPV, colpus length, endoaperture length and spine length, while *Verbesina baccharifolia* and *V. luetzelburgii* had

Table 4. Measurements of pollen grains of comparison materials in Brazilian *Verbesina* L. (Heliantheae - Asteraceae) species in equatorial view: n=10; $\bar{X}$ = arithmetic mean.

Species	Polar diameter (PD)	Equatorial diameter (ED)	PD/ED
	$\bar{X}$	$\bar{X}$	
V. baccharifolia Mattf.	38.0	39.5	0.96
	37.5	38.3	0.98
V. bipinnatifida Baker	30.3	30.5	0.99
	30.5	31.5	0.97
V. floribunda Gardner	32.0	33.2	0.96
	34.2	35.2	0.97
V. glabrata Hook. & Arn.	35.0	36.5	0.96
	38.5	37.7	1.02
V. luetzelburgii Mattf.	36.7	38.5	0.95
	37.0	37.5	0.99
V. macrophylla (Cass.) S.F. Blake	32.3	32.5	0.99
	31.5	32.7	0.96
V. sordescens DC.	36.8	37.5	0.98
	37.5	38.3	0.98

the highest values for these attributes. These attributes were closely correlated, as shown in Figure 3.

The second axis explained 18.8 % of the data, with *Verbesina floribunda* having the highest values for distance between spines (DBS), exine thickness and endoaperture width, and the lowest values for the apocolpus side (AS) index and colpus width.

Discussion

Pollen grains of *Verbesina* can be classified as the "Aspilia" type described by Salgado-Labouriau (1973), because they are medium to large in size, 3-colporate, and lalongate, with an endoaperture with a medium constriction, an echinate exine and conical spines with perforations at the base.

Previous studies of *Verbesina* have shown that pollen grain shape can vary from suboblate to prolate-spheroidal (PD / ED 0.75-1.14), with oblate-spheroidal to prolate-spheroidal being most common, as was reported by Gonçalves (1976) who analyzed 17 species of *Verbesina*, including three Brazilian species (*V. diversifolia* DC = *V. macrophylla*, *V. glabrata* and *V. sordescens*). These differences in pollen grain shape (Gonçalves 1976; Jesus & Lima 2013; Radaeski *et al.* 2016) (Tab. 5) are

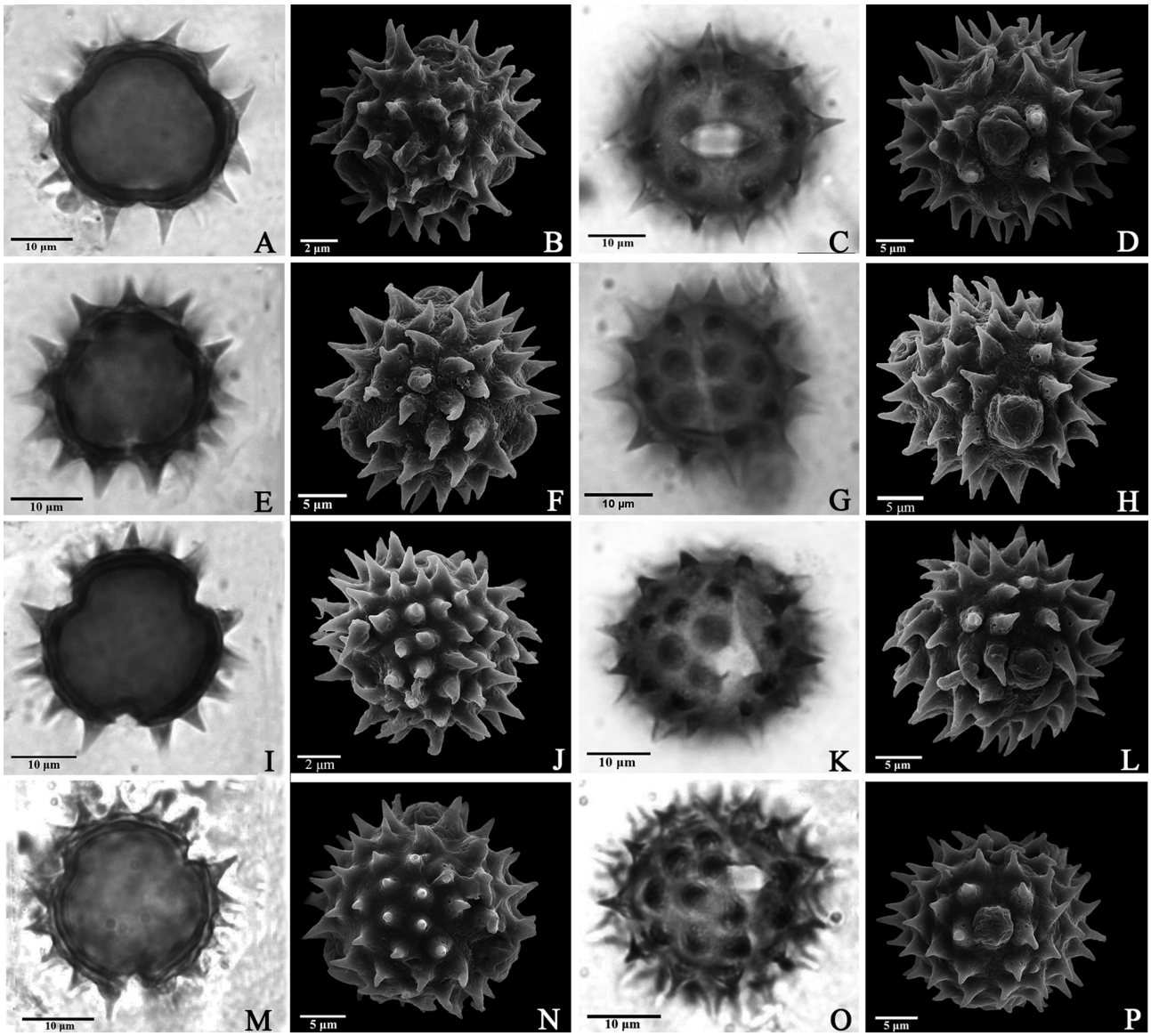

Figure 1. Photomicrographs and electromicrographis of pollen grains of Brazilian *Verbesina* L. (Heliantheae-Asteraceae) species. 1st and 3rd columns - Photomicrographs under light microscopy; 2nd and 4th columns - electromicrophis in SEM. *Verbesina baccharifolia* – polar view: **A.** optical section, **B.** general aspect; equatorial view: **C.** optical section, **D.** aperture. *Verbesina bipinnatifida* - polar view: **E.** optical section, **F.** general aspect, equatorial view: **G.** optical section, **H.** aperture. *Verbesina floribunda* - polar view: **I.** optical section, **J.** general aspect, equatorial view: **K.** general aspect, **L.** aperture. *Verbesina glabrata* - polar view: **M.** optical section, **N.** general aspect, equatorial view: **O.** general aspect, **P.** aperture.

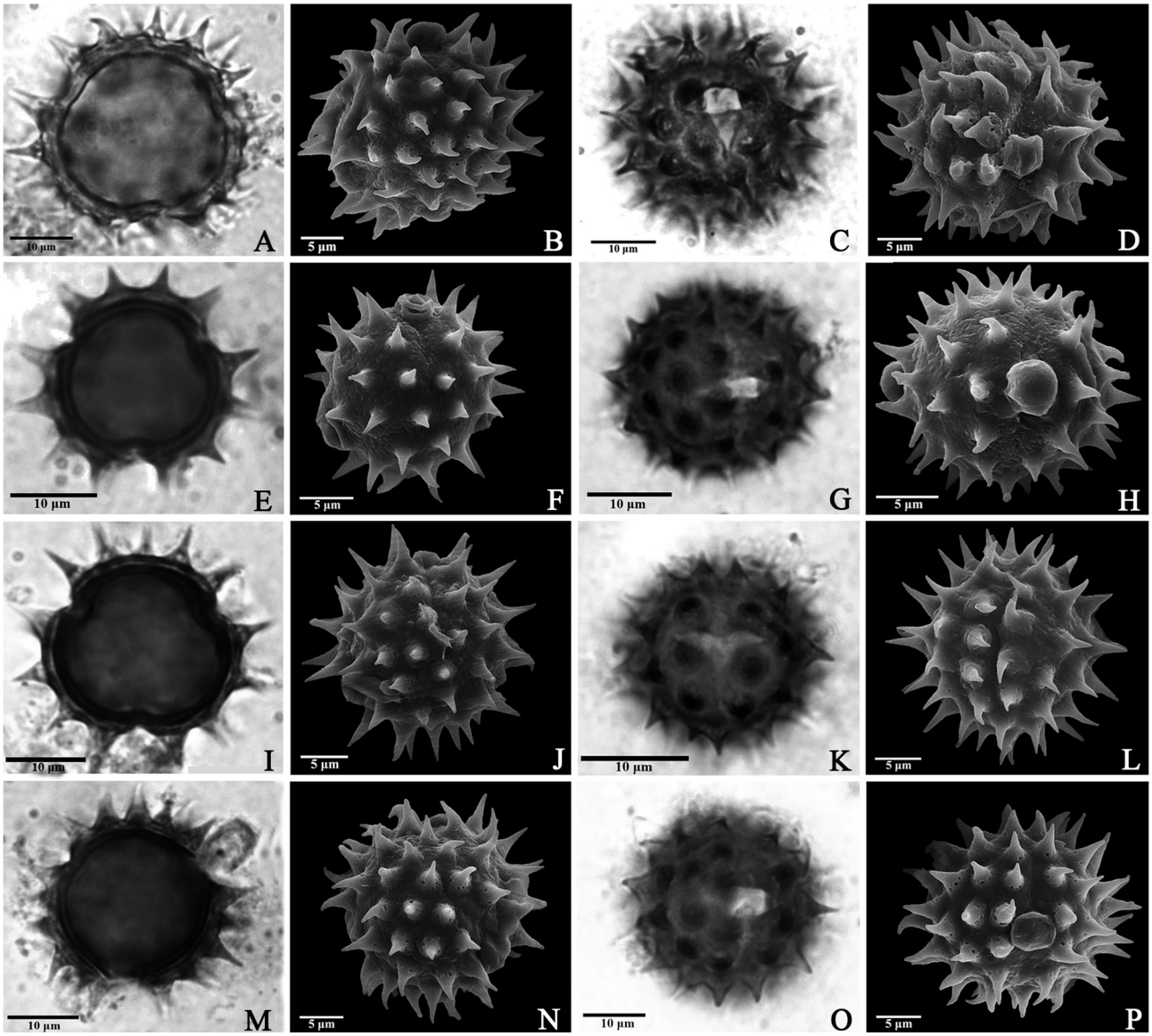

Figure 2. Photomicrographs and electromicrographis of pollen grains of Brazilian *Verbesina* L. (Heliantheae-Asteraceae) species. 1st and 3rd columns - Photomicrographs under light microscopy; 2nd and 4th columns - electromicrophis in SEM. *Verbesina luetzelburgii* - polar view: **A.** optical section, **B.** general aspect; equatorial view: **C.** optical section, **D.** aperture. *Verbesina macrophylla* - polar view: **E.** optical section, **F.** general aspect, equatorial view: **G.** optical section, **H.** aperture. *Verbesina nicotianifolia* - polar view: **I.** optical section, **J.** general aspect, equatorial view: **K.** general aspect, **L.** aperture. *Verbesina sordescens* - polar view: **M.** optical section, **N.** general aspect, equatorial view: **O.** general aspect, **P.** aperture.

Table 5. Shape of pollen grains and presence of cavea reported in previous studies that dealt with Brazilian taxa of the genus *Verbesina* (Heliantheae-Asteraceae).

Specie	Shape	Exine / thickness	Reference	Present study
Verbesina glabrata Hook. & Arn.	prolate-spheroidal	-	Gonçalves 1976	oblate-spheroidal to prolate-spheroidal
	spheroidal	not caveate	Cancelli *et al.* 2010	
Verbesina macrophylla (Cass.) S.F. Blake	prolate-spheroidal	-	Gonçalves 1976	oblate-spheroidal
	prolate-spheroidal	caveate	Jesus & Lima 2013	
Verbesina sordescens DC.	prolate-spheroidal	–	Gonçalves 1976	oblate-spheroidal
	oblate-spheroidal	caveate	Cancelli *et al.* 2010	
	oblate-spheroidal	caveate	Radaeski *et al.* 2014	
	prolate-spheroidal	cavea / 1µm	Radaeski *et al.* 2016	

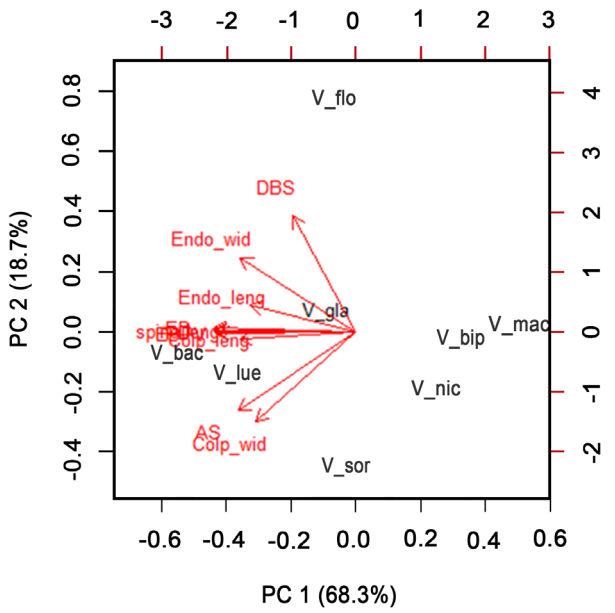

Figure 3. Analysis of principal components composed of metric variables of pollen from *Verbesina* L. (Heliantheae-Asteraceae). Variables in red mean: PD - polar diameter in equatorial view, ED - equatorial diameter, EDPV - equatorial diameter in polar view, AS - apocolpus side, colp-leng: colpus length, colp-wid: colpus width, endo-leng: length of endoaperture, endo-wid: width of endoaperture, spine-leng: length of spine, DBS - distance between spines. The species names are abbreviated.

consistent with the high coefficient of variation found, which in the present study ranged 4.6-10.4 % for PD and 4.7-11.6 % for ED, showing tha the shape of the pollen grain is variable.

The presence of a cavea has been reported to be very common in the tribe Heliantheae (Cancelli *et al*. 2007; Stanski *et al*. 2013; Radaeski *et al*. 2016). In some genera the cavea is evident and its thickness easily measured, as observed by Magenta *et al*. (2010) with *Viguiera*, for which it ranged 0.8-1.5µm.

Due to the proximity of the sexine and nexine, the cavea in *Verbesina* is difficult to visualize, which can lead to the false impression of its non-existence, as pointed out by Cancelli *et al*. (2010) for *Verbesina glabrata*. Some studies of species of *Verbesina* did not indicate the presence of a cavea, while others indicated that only the exine is of the cavea; only Radaeski *et al*. (2016) reported measurements of the cavea, which was 1µm for *V. sordescens* (Tab. 5).

Although the pollen grains of the studied Brazilian species of *Verbesina* exhibited homogeneity of shape, aperture type, and ornamentation of the sexine, some attributes show potential usefulness for characterizing species, such as the distance between spines, and dimensions of the apocolpus side and aperture. Thus, these characters of pollen grains have potential taxonomic value for distinguishing species.

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