REVISTA CONTRIBUCIONES A LAS CIENCIAS SOCIALES

Pollen inventory in urban remnants of Cerrado in midwest Brazil

Inventário polínico de remanescentes urbanos de Cerrado no centro-oeste do Brasil

Inventario de polen en remanentes urbanos del Cerrado en el centro oeste de Brasil

DOI: 10.55905/revconv.17n.12-071

Originals received: 09/30/2024
Acceptance for publication: 10/21/2024

Wilma Gomes Ortigosa
Bachelor of Biological Sciences
Institution: Universidade Federal de Mato Grosso do Sul
Address: Campo Grande - Mato Grosso do Sul, Brazil
E-mail: wilmaortigosa@gmail.com
Orcid: https://orcid.org/0000-0003-0544-5554

Karine Munck Vieira
Doctor in Ecology and Conservation
Institution: Universidade Federal de Mato Grosso do Sul
Address: Campo Grande - Mato Grosso do Sul, Brazil
E-mail: munck.karine@gmail.com
Orcid: https://orcid.org/0000-0003-2291-8835

Eduardo Custódio Gasparino
Doctor in Plant Biodiversity and Environment
Institution: Institutos de Pesquisas Ambientais do Estado de São Paulo
Address: São Paulo - São Paulo, Brazil
E-mail: eduardo.gasparino@unesp.br
Orcid: https://orcid.org/0000-0001-6078-7341

Andréa Cardoso Araujo
Doctor in Ecology
Institution: Universidade Estadual de Campinas
Address: Campinas - São Paulo, Brazil
E-mail: andrea.araujo@ufms.br
Orcid: https://orcid.org/0000-0003-0394-2012

ABSTRACT
Studies focusing on plant-pollinator interactions in urban environments aim to understand how the anthropized landscape affects interactions and, consequently, the reproductive success of plants. In these studies, the identification of plant species visited can be performed through focal observations and the analysis of pollen loads carried by vectors. Therefore, pollen inventories are

essential for assisting in studies focused on the analysis of pollen grains carried by pollinators and palynological studies, favoring the scientific interpretation of the biodiversity in each area. Data was collected over 12 months in 14 remnants of different physiognomies of the Cerrado domain within the urban perimeter of Campo Grande, Mato Grosso do Sul. In these places, the 118 plant species distributed in 39 families that received visits from pollinating insects had their pollen grains photographed and characterized. The families with the highest number of species were Asteraceae, with 19 species (22.42%); Fabaceae, with 15 species (17.7%), and Malvaceae, with nine species (10.62%). The high representation of Asteraceae can be explained as its being the largest botanical family among Angiosperms, being adapted to various types of environments, and being very common in anthropized areas. This pollen guide can support future studies focused on plant-pollinator interactions, mostly in urban remnants of the Cerrado.

Keywords: Cerrado, pollination, pollen, flowers, urbanization.

RESUMO

Estudos focados nas interações planta-polinizador em ambientes urbanos, visam compreender como a paisagem antropizada afeta as interações e, consequentemente, o sucesso reprodutivo das plantas. Nesses estudos, a identificação das espécies vegetais visitadas pode ser realizada por meio de observações focais e da análise das cargas polínicas transportadas pelos vetores. Portanto, os inventários polínicos são essenciais para auxiliar em estudos voltados para a análise de grãos de pólen transportados por polinizadores, bem como em estudos palinológicos, favorecendo a interpretação científica da biodiversidade de uma determinada área. Foram realizadas coletas ao longo de 12 meses em 14 remanescentes de diferentes fitofisionomias do Cerrado, no perímetro urbano de Campo Grande, Mato Grosso do Sul. Nesses locais, as 118 espécies de plantas distribuídas em 39 famílias que receberam visitas de insetos polinizadores tiveram seus grãos de pólen caracterizados e fotografados. As famílias que apresentaram maior número de espécies foram: Asteraceae com 19 espécies (22,42%), Fabaceae com 15 espécies (17,7%) e Malvaceae com nove espécies (10,62%). A maior representatividade de Asteraceae pode ser explicada por ser a maior família botânica dentre as Angiospermas e por ser uma família adaptável a vários tipos de ambientes, sendo muito comum em áreas antropizadas. Esse guia polínico pode apoiar estudos fututos focados nas interações entre plantas-polinizadores, principalmente em áreas urbanas de Cerrado.

Palavras-chave: Cerrado, polinização, pólen, flores, guia polínico, urbanização.

RESUMEN

Los estudios centrados en las interacciones planta-polinizador en ambientes urbanos tienen como objetivo comprender cómo el paisaje antropizado afecta las interacciones y, en consecuencia, el éxito reproductivo de las plantas. En estos estudios, la identificación de las especies de plantas visitadas puede realizarse a través de observaciones focales y el análisis de las cargas de polen transportadas por los vectores. Por lo tanto, los inventarios de polen son esenciales para auxiliar en estudios centrados en el análisis de los granos de polen transportados por los polinizadores, así como en estudios palinológicos, favoreciendo la interpretación científica de la biodiversidad en un área determinada. La recolección de datos se realizó durante 12 meses en 14 remanentes de diferentes fisonomías del dominio Cerrado dentro del perímetro urbano de Campo Grande, Mato Grosso do Sul. En estos lugares, las 118 especies de plantas distribuidas en 39 familias que recibieron visitas de insectos polinizadores, tuvieron sus granos de polen fotografiados y caracterizados. Las familias con mayor número de especies fueron Asteraceae con 19 especies (22,42%), Fabaceae con 15 especies (17,7%) y Malvaceae con nueve especies (10,62%). La alta representación de Asteraceae se puede explicar por ser la familia botánica más grande entre las angiospermas, estando adaptada a varios tipos de ambientes y muy común en áreas antropizadas. Esta guía de polen puede apoyar futuros estudios centrados en las interacciones planta-polinizador, principalmente en remanentes urbanos del Cerrado.

Palabras clave: Cerrado, polinización, polen, flores, urbanización

1 INTRODUCTION

Urbanization results in the transformation of land use and is taking place all over the planet, and the changes related to this process can radically impact ecological patterns and processes (Faeth *et al.*, 2005). However, fragments of native vegetation persisting in urban environments can support considerable species richness (Bosch *et al.*, 2009). Recent studies have evaluated how urbanization affects plant-pollinator interactions, particularly in landscapes characterized by heterogeneous mosaics of structure and function, which often exhibit higher biodiversity than better-preserved adjacent areas (Ferreira *et al.*, 2013; Carlos, 2017; Silva, 2019).

In pollination, pollen from one plant is transferred to the stigma of another (Courtney *et al.*, 1981), primarily by animals seeking resources like pollen and nectar in exchange for their services. Because pollen grains can remain in the bodies of pollinators for extended periods, analyzing pollen loads can provide a record of visitation history, even revealing interactions that may not be captured through direct observation of visitors at the flowers (Vizentin-Bugoni *et al.*, 2018). However, the success of this analysis depends on the accurate identification of pollen grains, which can be challenging, considering that few pollen guides are available.

In addition to supporting studies on pollination, palynological data has applications in several areas, such as assessing species distribution across landscapes by examining pollen deposited in sediments and airborne pollen. Furthermore, by dating sedimentary deposits, it is possible to evaluate changes in past vegetation and its evolution over time (Moore & Webb, 1978). Therefore, pollen morphology analyses are essential for paleovegetation reconstructions based on paleoenvironmental and paleoclimatic interpretations (Gasparino & Cruz-Barros, 2006). In this way, pollen guides not only assist the identification of pollen grains with application to studies in pollination ecology, reducing the analysis time by specifying which pollen grain is associated with a particular plant, but they are also helpful for comparative palynological studies, thus favoring the scientific interpretation of the biodiversity of a given area.

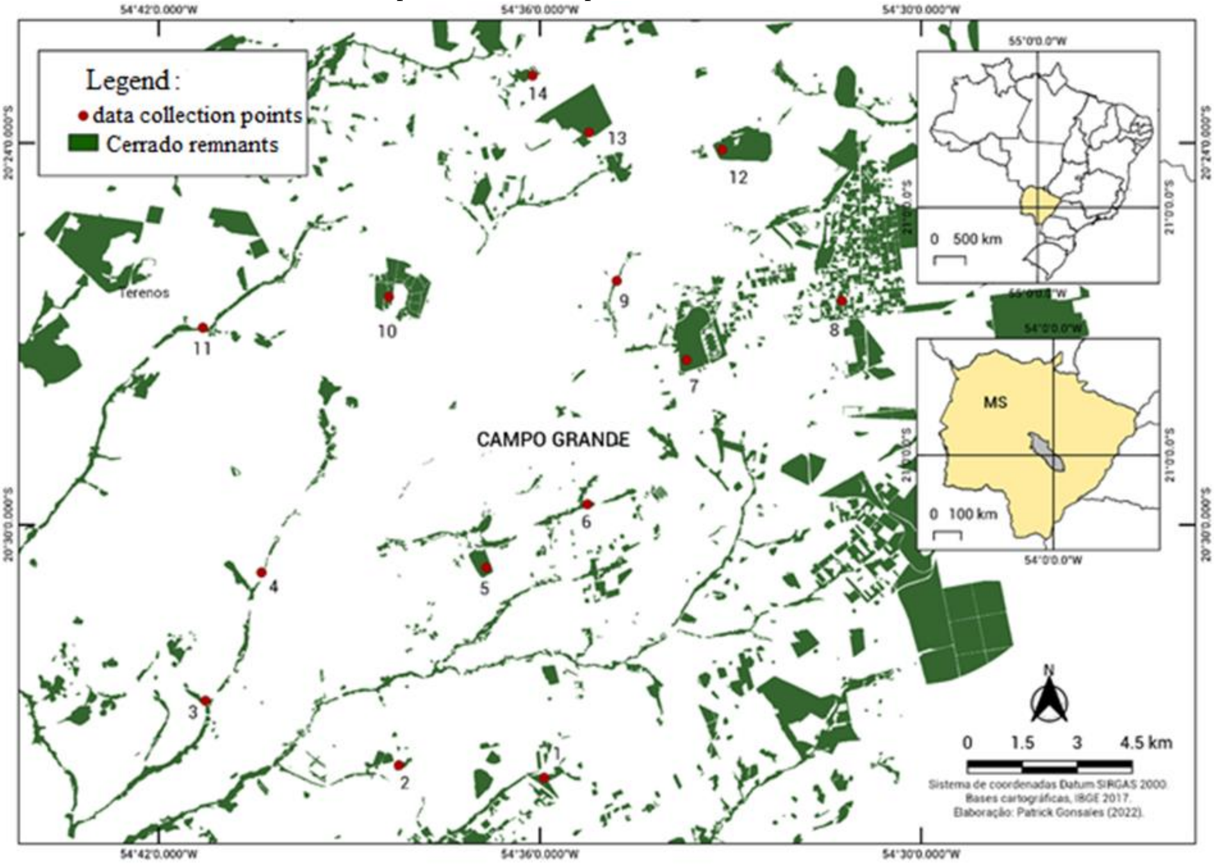
Due to the importance as mentioned above and the scarcity of pollen inventories for the Cerrado (e.g., Cassino *et al.*, 2016; Takeda *et al.*, 2000, Mendonça *et al.*, 2008), this study aimed to prepare a pollen guide describing the morphology of pollen grains from plants visited by insects in urban remnants of Cerrado, in the municipality of Campo Grande, Mato Grosso do Sul state.

2 MATERIAL AND METHODS

2.1 AREA AND PERIOD OF STUDY

The municipality of Campo Grande, located in the Sedimentary Basin of Paraná River, is the largest city in the State of Mato Grosso do Sul. The relief is gently undulated, forming an extensive urban core (Weingartner, 2008). According to the Municipal Institute of Urban Planning (PLANURB, 2021), approximately 20.7% of Campo Grande's area corresponds to Cerrado remnants. According to the Municipal Secretariat for the Environment and Urban Management (SEMADUR), the introduced pastures predominated in the landscape and occupied large surfaces of land in the city. However, this physiognomy has been changing gradually due to the introduction of soy and corn cultivation in the western and eucalyptus in the eastern portions of the municipality.

Figure 1: Location of the 14 Cerrado remnants from which flowers were collected for pollen characterization in the urban perimeter of Campo Grande, Mato Grosso do Sul.



Source: Bases Cartográficas IBGE 2017. Preparation: Patrick Gonsales.

2.2 DATA COLLECTION AND POLLEN PREPARATION

All individual plant species measuring up to four meters in height and bearing flowers visited by insects (in the orders Hymenoptera, Lepidoptera, Diptera, and Coleoptera) were recorded throughout 12 months (September/2018 to August/2019) in a plot measuring 1040 m² established in each of the 14 remnants (Figure 1). The flowers were photographed, collected, and fixed in vials with 70% alcohol. They were then taken to the laboratory, their anthers were removed and macerated on a microscope slide, and a solution of 50% glycerin, stained with 0.5% basic fuchsin in 50% ethanol, was added (Dafni, 1992; Bosch *et al.*, 2009). This technique is easy to prepare and allows the identification of the main characteristics of pollen grains. The pollen grains were then photographed at 40x magnification, using a Nikon optical microscope, model Coolpix 950. Voucher specimens of plants were herborized for identification by specialists, and had their nomenclature verified in The Plant List database (http://www.theplantlist.org).

2.3 DESCRIPTION OF POLLEN GRAINS

For the description of pollen grains, photographs of the slides obtained from all species recorded were examined, and information on their morphology and size was registered, following the methodology usually employed (Hesse *et al.*, 2009; Silva *et al.*, 2010; Bauermann *et al.*, 2013). We used the Online Pollen Catalog Network (RCPol) for identification, and definitions of the used terms are available in Punt *et al.* (2007). Pollen grains were measured using photographs taken under a microscope at 40x magnification. The Microsoft PowerPoint program was used to include scales in the images based on the measurements performed on the original images. For this purpose, a line passing through the central axis of the pollen grain was measured in centimeters and then converted into micrometers (µm), knowing that each trace of the ruler coupled to the microscope, with a 40x objective lens, is equivalent to 2.5 µm. The pollen grains were classified according to the morphological criteria presented below (considering a polar and/or an equatorial view) based on the proposed by Erdtman (1952) and Punt *et al.* (2007), and the standardization of the description followed by Bellonzi *et al.* (2020), briefly:

1) pollen unit: monad, tetrad, and polyad
2) size: small (10-25µm), medium (25.1-50µm), large (50.1-100µm), very large (100.1-200µm), giant (> than 200µm)
3) polarity: apolar, heteropolar, isopolar,
4) amb: circular, subcircular, subtriangular, tetragonal, tetrahedral, triangular
5) shape: oblate, oblate-spheroidal, prolate**,** prolate-spheroidal, quadrangular, spheroidal,
6) aperture type: colpate, colporate, inaperturate, porate, pantocolpate,
7) exine ornamentation: baculate, Croton pattern, echinate, microechinate, microreticulate, psilate, reticulate, rugulate

In some cases, when a given characteristic could not be clearly observed by the employed technique it was indicated as “not visualized”.

3 RESULTS

We characterized in detail pollen grains from 118 species distributed in 39 families - 86.67% of the species recorded in the sampling plots (Table 1; Figures 2, 3, and 4). The families with the highest number of species were Asteraceae, with 19 species (16%), Fabaceae with 15 species (12.9%), and Malvaceae with nine species (7.7%), but most of the families recorded were represented by only one species (Table 1).

All Asteraceae species showed a monad pollen unit, pollen grains mostly large (50-100µm) or very large (100.1-200µm), isopolar polarity, subcircular, subtriangular and circular amb. The most frequent Asteraceae pollen grains were oblate-spheroidal, which was different in only two cases. Colporate aperture was the most common, with only two cases of the porate aperture. As for the exine ornamentation, the echinate type (spiny) stood out, with only three species having reticulated ornamentation. On the other hand, the Fabaceae species showed great variation in pollen characteristics, with grains of all size classes. As for polarity they were mainly isopolar. The dispersal unit was mostly monad, except for two species (*Mimosa setosa* and *Mimosa verrucosa*) which presented tetrad dispersal unit. The pollen amb was subcircular, subtriangular, circular, triangular, and tetragonal. The shape was oblate, spheroidal, and oblate-spheroidal. Most of the species in this family showed pollen grains with a colporate aperture, only one species showed a pantoporate aperture (*Canavalia mattogrossensis*). The exine ornamentation present in the species were baculate, echinate, reticulate, microreticulate. The third family with the highest number of species, Malvaceae, had pollen grains with a monad-type dispersion unit, with large (50.1-100 µm), very large (100.1-200 µm) and giant (> 200 µm) sizes, isopolar polarity, being apolar in three species. Pollen amb was circular, subcircular and triangular. The main aperture type was colporate, and in three species they were porate, whereas the shape of the pollen grains varied between spheroidal and oblate-spheroidal. The exine ornamentation was echinate for all species in which it was possible to identify this characteristic (Table 1; Figures 2, 3 and 4).

4 DISCUSSION

The plant families represented by the highest number of species in this study (Asteraceae, Fabaceae and Malvaceae), are among the most frequent in the Cerrado, with high species richness (Souza *et al.*, 2018). All species of Asteraceae have pollen grains that are commonly tricolporate, medium to large, generally echinate (spiny), lophate or psilate (Roque & Bautista, 2008). These ornamental characteristics provide greater adherence to the body of the pollinating agents and are usually associated with insect pollination (Salgado-Labouriuau, 2007). In fact, in a study evaluating the pollination of 279 species of Cerrado, bees were the main pollinators of Asteraceae, along with Lepidoptera, Diptera, and wasps (Silberbauer-Gottsberger & Gottsberger, 1988). Thus, the predominance of Asteraceae species in the sampled areas coincides with the reported by other surveys of entomophyllous plants carried out in this domain (Imperatriz-Fonseca *et al.*, 2011, Almeida-Anacleto *et al.*, 2012). Fabaceae, another very representative family in the study, is considered an important pollen source for bees in several regions. Species in this family present a great variation in floral morphology, including the specialized papillary flowers, which require bees to be strong enough to trigger the release of pollen from the stigma and pollinate the flowers, a mechanism known as "buzz pollination" (Silberbauer-Gottsberger & Gottsberger 1988).

Species of Fabaceae, along with Malvaceae, present pollen grains with great morphological variation, mainly in terms of exine ornamentation pattern and pollen aperture, which characterize these families as eurypalynous (Saad, 1960; Martinez, 1982; Jiménez-Reyes, 2002; Bocage *et al.*, 2008). The aperture of the pollen grains plays a role in adjusting their volume to different levels of environmental humidity, regulates the rate of water entry during its hydration, and is where the pollen tube exits during pollen germination (Prieu *et al.*, 2016). The aperture shape of pollen grains can be elongated, constituting a colpus (when the aperture extends from pole to pole) or sulcus (when the aperture is located at the poles); or it can be rounded, constituting a porus (Carmello-Guerreiro & Appezzato-da-Glória, 2012). A compound aperture is called colporus (a normally elongated ectoaperture similar to a colpus, and an endoaperture, normally circular) which was the most frequent in the present study (Blackmore & Crane 1998; Furness, 2007).

Although this study was conducted in Cerrado remnants within an urban environment, we recorded an expressive richness of plant species native to Cerrado. The recorded species have pollen with a wide variety of morphologies and characteristics related to their pollination by insects. Furthermore, the guide will be helpful for studies evaluating pollen loads carried by insects, mainly in Cerrado habitats, as well as future palynological studies.

ACKNOWLEDGMENTS

To Prof. Dr. Geraldo Damasceno Jr. for identifying the plants. To CNPq (National Council for Scientific and Technological Development) for a Scientific Initiation Scholarship to WGO, and a research fellowship to ACA (#307991/2021-0), and to the Coordination for the Improvement of Higher Education Personnel (CAPES) for the doctoral scholarship to KMV.

REFERENCES

ALMEIDA-ANACLETO, D.; MARCHINO, L.C.; CAMARGO, A.C.; MORETI, C.; SOUZA, V.C. Plants used by bees as pollen sources in the Brazilian "Cerrado". **Sociobiology**, v. 59, p. 1483–1493, 2012.

BAUERMANN, S. G.; RADAESKI, J.; EVALDT, A.C.P.; QUEIROZ, E.P.; MOURELLE, D.; PRIETO, A.R.; SILVA, C.I. **Pólen nas angiospermas: diversidade e evolução**. Canoas: Ed. ULBRA, 2013. 214 p.

BELLONZI, T. K.; DUTRA, F.V.; SOUZA, C.N.; REZENDE, A.A.; GASPARINO, E.C. Pollen types of Sapindaceae from Brazilian forest fragments: apertural variation. **Acta Botânica Brasilica**, v. 34, p. 327–341, 2020.

BLACKMORE S.; CRANE P.R. The evolution of apertures in the spores and pollen grains of embryophytes. In: Owens S.J., Rudall P.J. eds. **Reproductive biology**. Kew: Royal Botanic Gardens, 159–182, 1998.

BOCAGE, A. D.; SOUZA, M.A.; MIOTTO, S.T.S.; GONÇALVES-ESTEVES, V. Palinotaxonomia de espécies de Acacia (Leguminosae-Mimosoideae) no semiárido brasileiro. **Rodriguésia**, v. 59, p. 587-596, 2008.

BOSCH, J.; GONZÀLEZ, A.M.M.; RODRIGO, A.; NAVARRO, D. Plant-pollinator networks: adding the pollinator’s perspective. **Ecology Letters**, v. 12, p. 409-419, 2009.

CARLOS, P. P. **Características florais e visitantes de *Turnera subulata* Sm. (Passifloraceae) em gradiente de urbanização**. 2017. Dissertação (Mestrado) - Instituto Nacional de Pesquisas da Amazônia, Manaus.

CARMELLO-GUERREIRO, S.; APEZZATO-DA-GLÓRIA, B. **Anatomia Vegetal**. 3. ed. Minas Gerais: Editora UFV, 2012. 135 p.

CASSINO, R. F.; MARTINHO, C. T.; CAMINHA, S. Diversidade de grãos de pólen das principais fitofisionomias do cerrado e implicações paleoambientais. **Gaea: Journal of Geoscience**, v. 9, p. 4–29, 2016.

COURTNEY, S.P.; HILL, C.J.; WESTERMAN, A. Pollen carried for long periods by butterflies. **Oikos**, v. 38, p. 260-263, 1981.

DAFNI, A. **Pollination ecology: a practical approach**. New York: University Press, 1992.

ERDTMAN, G. **Pollen morphology and plant taxonomy: angiosperms**. Stockholm: Alquimist and Wiksell, 1952.

FAETH, S.H.; WARREN, P.S.; SHOCHAT, E.; MARUSSICH, W.A. Trophic dynamics in urban communities. **BioScience**, v. 55, n. 5, p. 399-407, 2005.

FERREIRA, P. A.; BOSCOLO, D.; VIANA, B. F. What do we know about the effects of landscape changes on plant–pollinator interaction networks? **Ecological Indicators**, v. 31, p. 35–40, 2013.

FURNESS, C. Why does some pollen lack apertures? A review of inaperturate pollen in eudicots. **Botanical Journal of the Linnean Society**, v. 155, p. 29–48, 2007.

GASPARINO, E. C.; CRUZ-BARROS, M. A. V. **Palinologia**. São Paulo: Instituto de Botânica, 2006. (Apostila).

HESSE, M.; HALBRITTER, H.; ZETTER, R.; WEBER, M.; BUCHNER, R.; FROSCH-RADIVO, A.; ULRICH, S. **Pollen terminology: an illustrated handbook.** Springer-Verlag, 2009.

IMPERATRIZ-FONSECA, V. L., ALVES-DOS-SANTOS, I.; SANTOS-FILHO, P.S.; ENGELS, W.; RAMALHO, M.; WILMS, W.; AGUILAR, J.B.V.; PINHEIRO-MACHADO, C.A.; ALVES-D.A.; KLEINERT, A. M.P. Checklist das abelhas e plantas melitófilas no estado de São Paulo, Brasil. **Biota Neotropica**, v. 11, p. 631-655, 2011.

INSTITUTO MUNICIPAL DE PLANEJAMENTO URBANO– PLANURB. Perfil socioeconômico de Campo Grande, Estado do Mato Grosso do Sul. Campo Grande, 2021. 528 p.

JIMÉNEZ-REYES, N. **Morfología de los granos de polen de la familia Malvaceae de Jalisco, México**. 2002. Tese (Doutorado) - Universidade de Guadalajara, México. Disponível em: http://repositorio.cucba.udg.mx:8080/xmlui/bitstream/handle/123456789/5474/Jimenez_Reyes_Ma_Noemi.pdf?sequence=1. Acesso em: 15 ago. 2021.

MARTINEZ, F. S. **Morfologia polínica de algumas Malvaceas mexicanas**. México: Instituto Nacional de Antropologia e História, Centro Regional del Sureste, 1982. 68 p.

MENDONÇA, K., MARCHINI, L.C.; SOUZA, B.A.; ALMEIDA-ANACLETO, D.; MORETI, A.C.C.C. Plantas apícolas de importância para *Apis mellifera* L. (Hymenoptera: Apidae) em fragmento de cerrado em Itirapina, SP. **Neotropical Entomology**, v. 37, n. 5, p. 513-521, 2008.

MOORE, P. D.; WEBB, J. A. **An illustrated guide to pollen analysis**. New York: Halsted Press, 1978. 133 p.

PRIEU, C.; MATAMORO-VIDAL, A.; RAQUIN, C.; DOBRITSA, A.; MERCIER, R.; GOUYON, P.H.; ALBERT, B. Aperture number influences pollen survival in *Arabidopsis mutants*. **American Journal of Botany**, v. 103, n. 3, p. 452-459, 2016.

PUNT, W.; HOEN, P.P.; BLACKMORE, S.; NILSSON, S.; LE THOMAS, A. Glossary of pollen and spore terminology. **Review of Palaeobotany and Palynology**, v. 143, n. 1-2, p. 1-81, 2007.

REDE DE CATÁLOGOS POLÍNICOS ONLINE (RCPol). Disponível em: http://chaves.rcpol.org.br/taxon. Acesso em: 10 jan. 2020.

ROQUE, N.; BAUTISTA, H. **Asteraceae: caracterização e morfologia floral**. Salvador: EDUFBA, 2008. 42 p.

SAAD, S. I. The sporoderm stratification in the Malvaceae. **Pollen et Spores**, v. 2, p. 13-41, 1960.

SALGADO – LABOURIAU, M. L. **Critérios e Técnicas para o Quaternário**. São Paulo: Editora Edgard Blücher, 2007. 385p.

SECRETARIA MUNICIPAL DE MEIO AMBIENTE E GESTÃO URBANA. Disponível em: http://www.campogrande.ms.gov.br/semadur/. Acesso em: 28 jul. 2020.

SILBERBAUER-GOTTSBERGER, I.; GOTTSBERGER, G. A. Polinização de plantas do cerrado. **Revista Brasileira de Biologia**, v. 48, p. 651-663, 1988.

SILVA, C. A. S. A. **A influência da paisagem na provisão do serviço de polinização por insetos no girassol.** 2019. Tese (Doutorado) - Universidade de São Paulo, Escola Superior de Agricultura "Luiz de Queiroz".

SILVA, C. I.; MELLO, M.A.R.; OLIVEIRA, P.O.A. palinologia como uma ferramenta importante nos estudos das interações entre *Xylocopa* spp. e plantas no cerrado. ***In:*** **Anais do IX Encontro Sobre Abelhas, FUNPEC**, Ribeirão Preto, Brazil, p. 72-79, 2010.

SOUZA, V. C.; FLORES, T.B.; COLLETTA, G.D.; COELHO, R.L.G. **Guia das plantas do Cerrado**. 1. ed. Piracicaba, São Paulo: Taxon Brasil Editora e Livraria, 2018. 584 p.

TAKEDA, I. J. M.; FARAGO, P.V.; SOUZA, M.K.F.; GELINSKI, V.V. Catálogo polínico do Parque Estadual de Vila Velha, Paraná - 1ª parte. **Arq Ciênc Saúde Unipar**, v. 6, n. 1, p. 61-73, 2000.

VIZENTIN-BUGONI, J.; MARUYAMA, P.K.; SOUZA, C.S.; OLLERTON, J.; RECH, A.R.; SAZIMA, M. Plant-pollinator networks in the tropics: a review. In: Dáttilo, W.; Rico-Gray, V. (Eds.). **Ecological networks in the tropics**. Dordrecht: Springer, 2018. p. 73–91.

WEINGARTNER, G. A. **A construção de um sistema: os espaços livres públicos de recreação e de conservação em Campo Grande, MS**. 2008. Tese (Doutorado) - Faculdade de Arquitetura e Urbanismo, Universidade de São Paulo.

REVISTA CONTRIBUCIONES A LAS CIENCIAS SOCIALES

ANNEXES

Table 1. Plant species recorded and their respective pollen characteristics in 14 urban fragments in Campo Grande, Mato Grosso do Sul, Brazil.

Species	Dispersion unit	Size	Polarity	Amb	Shape	Aperture Type	Exine ornamentation
Acanthaceae							
Justicia carnea Lindl.	Monad	VL	Isopolar	Circular	Prolate	Colporate	NV
Ruellia brevifolia (Pohl) C. Ezcurra	Monad	VL	Isopolar	Circular	Oblate-spheroidal	Porate	Reticulate
Thunbergia grandiflora (Roxb. ex Rottl.) Roxb.	Monad	VL	Isopolar	Circular	Oblate-spheroidal	Colpate	NV
Annonaceae							
Xylopia aromatica (Lam.) Mart.	Tetrad	VL	Apolar	Tetragonal	Spheroidal	Inaperturate	NV
Asteraceae							
Austroeupatorium inulaefolium (Kunth) R.M.King & H.Rob.	Monad	L	Isopolar	Circular	Oblate-spheroidal	Colporate	Echinate
Baccharis trinervis (Lam.) Pers.	Monad	L	Isopolar	Subtriangular	Prolate-spheroidal	Colporate	Echinate
Chromolaena cylindrocephala (Sch.Bip. ex Baker) R.M.King & H.Rob.	Monad	L	Isopolar	Subtriangular	Oblate-spheroidal	Colporate	Echinate
Chromolaena laevigata (Lam.) R.M.King & H.Rob.	Monad	L	Isopolar	Subcircular	Oblate-spheroidal	Colporate	Echinate
Chromolaena squalida (DC.) R.M.King & H.Rob.	Monad	L	Isopolar	Subtriangular	Oblate-spheroidal	Colporate	Echinate
Chromolaena maximilianii (Schrad. ex DC.) R.M.King & H.Rob.	Monad	L	Isopolar	Subcircular	NV	Colporate	NV
Chrysolaena sceptrum (Chodat) Dematt.	Monad	L	Isopolar	NV	Oblate-spheroidal	Colporate	NV
Eclipta prostrata (L.) L.	Monad	L	Isopolar	Subtriangular	NV	Colporate	Echinate
Elephantopus mollis Kunth.	Monad	VL	Isopolar	Circular	Oblate-spheroidal	Porate	Reticulate
Lepidaploa muricata (DC.) H.Rob.	Monad	VL	Isopolar	Subtriangular	NV	Colporate	Reticulate
Mikania micrantha Kunth	Monad	L	Isopolar	Subcircular	NV	Colporate	Echinate
Orthopappus angustifolius (Sw.) Gleason	Monad	L	Isopolar	Subcircular	NV	Porate	Reticulate
Praxelis clematidea (Griseb.) R.M.King & H.Rob.	Monad	L	Isopolar	Subcircular	NV	Colporate	Echinate
Senecio pohlii Sch.Bip. ex Baker	Monad	L	Isopolar	Circular	NV	Colporate	Echinate
Tithonia diversifolia (Hemsl.) A.Gray	Monad	VL	Isopolar	Subcircular	Oblate-spheroidal	Colporate	Echinate
Trixis antimenorrhoea (Schrank) Mart. ex Baker	Monad	L	Isopolar	Subcircular	Prolate	Colporate	NV
Unxia kubitzkii H.Rob.	Monad	L	Isopolar	Circular	NV	Colporate	Echinate
Vernonanthura brasiliana (L.) H.Rob.	Monad	VL	Isopolar	Subcircular	Oblate-spheroidal	Colporate	Echinate

Vernonanthura membranacea (Gardner) H.Rob.	Monad	VL	Isopolar	Circular	NV	Colporate	Echinate
Bignoniaceae							
Adenocalymma pedunculatum (Vell.) L.G.Lohmann	Monad	VL	Apolar	NV	Spheroidal	Inaperturate	Reticulate
Fridericia florida (DC.) L.G.Lohmann	Monad	M	Isopolar	Subtriangular	NV	Colporate	Microreticulate
Fridericia platyphylla (Cham.) L.G.Lohmann	Monad	VL	Isopolar	Subtriangular	NV	Colporate	Microreticulate
Tecoma stans (L.) Juss. ex Kunth	Monad	VL	Isopolar	Subcircular	NV	Colporate	NV
Boraginaceae							
Cordia polycephala (Lam.) I.M.Johnst.	Monad	VL	Isopolar	Subcircular	NV	Porate	Reticulate
Bromeliaceae							
Pseudananas sagenarius (Arruda) Camargo	Monad	VL	Isopolar	NV	Spheroidal	Colpate	NV
Cactaceae							
Pereskia aculeata Mill.	Monad	G	Apolar	NV	Spheroidal	Pantocolpate	Microechinate
Cannabaceae							
Celtis iguanaea (Jacq.) Sarg.	Monad	L	Isopolar	Circular	NV	Porate	NV
Caryocaraceae							
Caryocar brasiliense A.St.-Hil.	Monad	M	Isopolar	Triangular	NV	Colporate	Microreticulate
Chrysobalanaceae							
Couepia grandiflora (Mart. & Zucc.) Benth. ex Hook.f.	Tetrad	VL	Isopolar	Tetrahedral	NV	NV	Rugulate
Hirtella gracilipes (Hook.f.) Prance	Monad	VL	Isopolar	NV	Prolate	Colporate	NV
Licania humilis Cham. & Schltdl.	Monad	VL	Isopolar	Subtriangular	NV	Colporate	Rugulate
Convolvulaceae							
Ipomoea triloba L.	Monad	G	Apolar	NV	Spheroidal	Pantoporate	Echinate
Cucurbitaceae							
Momordica charantia L.	Monad	G	Isopolar	Subcircular	NV	Colporate	Reticulate
Dilleniaceae							
Curatella americana L.	Monad	L	Isopolar	Subtriangular	NV	Colporate	Psilate
Davilla elliptica A.St.-Hil.	Monad	L	Isopolar	Subcircular	NV	Colporate	Microreticulate
Erythroxylaceae							
Erythroxylum suberosum A.St.-Hil.	Monad	VL	Isopolar	Circular	NV	Colporate	NV
Euphorbiaceae							
Chamaesyce hyssopifolia (L.) S	Monad	L	Isopolar	NV	Prolate-spheroidal	colporate	NV

Croton grandivelus Baill	Monad	VL	Apolar	NV	Spheroidal	Inaperturate	Croton pattern
Croton urucurana Baill.	Monad	VL	Apolar	NV	Spheroidal	Inaperturate	Croton pattern
Julocroton montevidensis Klotzsch ex Baill.	Monad	G	Apolar	NV	Spheroidal	Inaperturate	Croton pattern
Maprounea guianensis Aubl.	Monad	VL	Isopolar	Subcircular	NV	Colporate	NV
Fabaceae							
Bauhinia rufa (Bong.) Steud.	Monad	S	Isopolar	NV	Oblate-spheroidal	Colporate	NV
Bauhinia ungulata L.	Monad	G	Isopolar	Subtriangular	NV	Colporate	Baculate
Camptosema ellipticum (Desv.) Burkart	Monad	VL	Isopolar	Subcircular	NV	Colporate	NV
Canavalia mattogrossensis (Barb.Rodr.) Malme	Monad	G	Apolar	NV	Spheroidal	pantoporate	Echinate
Centrosema macrocarpum Benth.	Monad	VL	Isopolar	Subcircular	NV	Colporate	Reticulate
Centrosema sagittatum (Willd.) L.Riley	Monad	G	Isopolar	NV	Oblate	Colporate	NV
Leucaena leucocephala (Lam.) de Wit	Monad	L	Isopolar	Subcircular	NV	Colporate	NV
Leucochloron incuriale (Vell.) Barneby & J.W.Grimes	Monad	VL	Isopolar	Circular	NV	Colporate	NV
Machaerium hirtum (Vell.) Stellfeld	Monad	L	Isopolar	Subtriangular	NV	Colporate	Microreticulate
Mimosa setosa Benth.	Tetrad	M	NV	Tetragonal	NV	NV	NV
Mimosa verrucosa Benth.	Tetrad	L	NV	Tetragonal	NV	NV	NV
Senna alata (L.) Roxb.	Monad	VL	Isopolar	Subtriangular	NV	Colporate	Reticulate
Senna pendula (Willd.) H.S.Irwin & Barneby	Monad	VL	Isopolar	Subcircular	NV	Colporate	Reticulate
Senna pilifera (Vogel) H.S.Irwin & Barneby	Monad	VL	Isopolar	NV	Oblate-spheroidal	Colporate	NV
Sesbania exasperata Kunth.	Monad	VL	Isopolar	Triangular	NV	Colporate	NV
Lamiaceae							
Hyptidendron sp.	Monad	L	Isopolar	NV	Prolate-spheroidal	Colpate	NV
Hyptidendron canum (Pohl ex Benth.) Harley	Monad	L	Isopolar	Subtriangular	NV	Colporate	NV
Lauraceae							
Nectandra cuspidata Nees & Mart.	Monad	VL	Apolar	NV	Spheroidal	Inaperturate	NV
Ocotea minarum (Nees & Mart.) Mez	Monad	VL	Apolar	Circular	Spheroidal	Inaperturate	Reticulate
Malpighiaceae							
Byrsonima intermedia A.Juss.	Monad	L	Isopolar	Subcircular	NV	Colporate	NV
Byrsonima verbascifolia (L.) DC.	Monad	L	Isopolar	NV	Oblate-spheroidal	Colporate	NV
Christianella multiglandulosa (Nied.) W.R.Anderson	Monad	VL	Isopolar	Circular	NV	Colporate	NV
Heteropterys aphrodisiaca Machado	Monad	VL	Apolar	Circular	Spheroidal	Porate	Rugulate

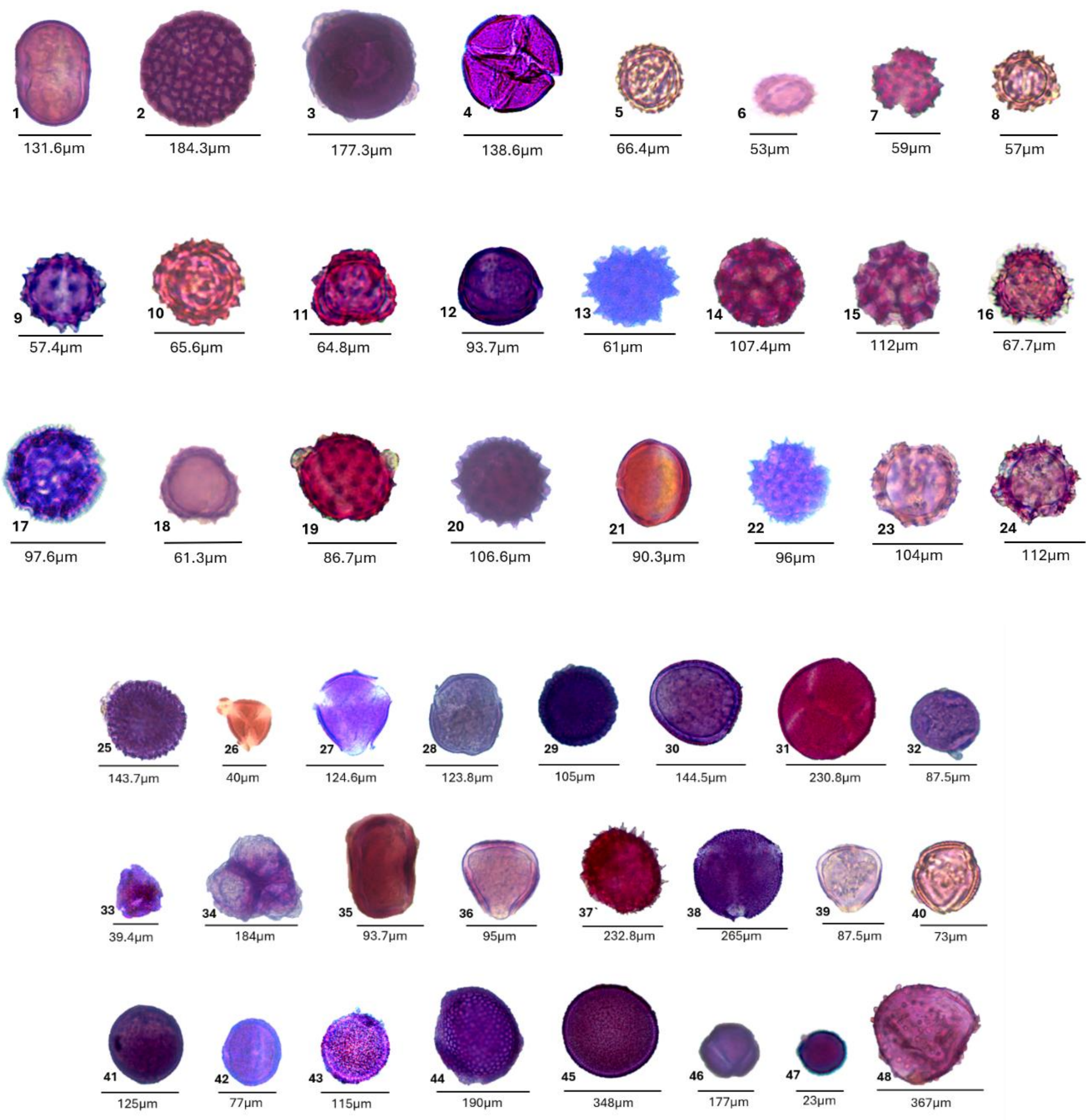
Mascagnia cordifolia (A. Juss.) Griseb.	Monad	VL	Apolar	Quadrangular	Spheroidal	Porate	Rugulate
Stigmaphyllon sp.	Monad	VL	Apolar	Circular	Spheroidal	Porate	NV
Malvaceae							
Helicteres denticulenta Cristóbal	Monad	L	Isopolar	Triangular	NV	Colporate	NV
Luehea divaricata Mart.	Monad	VL	Isopolar	Subcircular	Oblate-spheroidal	Colporate	NV
Pavonia communis A. St.-Hil.	Monad	L	Isopolar	Circular	Oblate-spheroidal	Colporate	NV
Sida sp.	Monad	VL	Apolar	Circular	Spheroidal	Porate	NV
Sida rhombifolia L.	Monad	G	Apolar	Circular	Spheroidal	Porate	Echinate
Sidastrum paniculatum (L.) Fryxell	Monad	VL	Apolar	Circular	Spheroidal	Porate	Echinate
Urena lobata L.	Monad	G	Isopolar	Circular	NV	Colporate	Echinate
Waltheria indica L.	Monad	VL	Isopolar	Circular	NV	Colporate	NV
Waltheria communis A.St.-Hil.	Monad	VL	Isopolar	Circular	NV	Colporate	NV
Melastomataceae							
Miconia nervosa (Sm.) Triana	Monad	VL	Isopolar	NV	Prolate-spheroidal	Colporate	NV
Meliaceae							
Guarea guidonia (L.) Sleumer	Monad	L	Isopolar	Subcircular	Oblate	Colporate	NV
Trichilia pallida Sw.	Monad	L	Isopolar	Circular	NV	Colporate	NV
Muntingiaceae							
Muntingia calabura L.	Monad	VL	Isopolar	Subcircular	NV	Colporate	NV
Myrtaceae							
Campomanesia adamantium (Cambess.) O.Berg	Monad	L	Isopolar	Triangular	NV	Colporate	Psilate
Eugenia sp.	Monad	L	Isopolar	Triangular	NV	Colporate	Psilate
Eugenia punicifolia (Kunth) DC.	Monad	L	Isopolar	Subtriangular	NV	Colporate	Psilate
Myrcia laruotteana Cambess.	Monad	L	Isopolar	Triangular	NV	Colporate	Psilate
Ochnaceae							
Ouratea hexasperma (A. St.-Hil.) Baill.	Monad	L	Isopolar	Subtriangular	NV	Colporate	NV
Onagraceae							
Ludwigia laruotteana (Cambess.) H. Hara	Monad	VL	Isopolar	NV	Oblate-spheroidal	Porate	NV
Passifloraceae							
Passiflora edulis Sims	Monad	L	Isopolar	Circular	NV	Colpate	Reticulate
Piperaceae							

Piper aduncum L.	Monad	M	Isopolar	Circular	Prolate	Colpate	Psilate
Primulaceae							
Myrsine guianensis (Aubl.) Kuntze	Monad	L	Isopolar	NV	Oblate-spheroidal	Colporate	NV
Ranunculaceae							
Clematis dioica L.	Monad	L	Isopolar	NV	Prolate-spheroidal	Colporate	NV
Rubiaceae							
Alibertia edulis (Rich.) A.Rich. ex DC.	Monad	L	Isopolar	Subtriangular	NV	Colporate	Microreticulate
Conyza bonariensis (L.) Cronquist	Monad	L	Isopolar	Subtriangular	NV	Colporate	NV
Cordiera sessilis (Vell.) Kuntze	Monad	L	Isopolar	NV	Prolate-spheroidal	Colporate	NV
Palicourea crocea (Sw.) Schult.	Monad	VL	Apolar	Circular	Spheroidal	Inaperturate	Reticulate
Palicourea rigida Kunth	Monad	VL	Apolar	Circular	Spheroidal	Inaperturate	NV
Psychotria carthagenensis Jacq.	Monad	L	Isopolar	Subtriangular	NV	Colporate	NV
Sapindaceae							
Matayba guianensis Aubl.	Monad	L	Heteropolar	Triangular	NV	Colporate	NV
Serjania acoma Radlk.	Monad	VL	Heteropolar	Triangular	NV	Colporate	NV
Serjania caracasana (Jacq.) Willd.	Monad	L	Heteropolar	Triangular	NV	Colporate	Psilate
Serjania erecta Radlk.	Monad	VL	Isopolar	Triangular	NV	Colporate	NV
Serjania meridionalis Cambess.	Monad	L	Isopolar	Triangular	NV	Colporate	Psilate
Sapindus saponaria L.	Monad	L	Heteropolar	Subtriangular	NV	Colporate	NV
Sapotaceae							
Chrysophyllum marginatum (Hook. & Arn.) Radlk.	Monad	L	Isopolar	NV	Prolate	Colporate	NV
Solanaceae							
Solanum americanum Mill.	Monad	M	Isopolar	Subtriangular	NV	Colporate	NV
Solanum lycocarpum A. St.-Hil.	Monad	L	Isopolar	Subtriangular	NV	Colporate	NV
Solanum paniculatum L.	Monad	L	Isopolar	Subcircular	NV	Colporate	NV
Solanum riparium Pers.	Monad	L	Isopolar	Circular	NV	Colporate	NV
Solanum sisymbriifolium Lam.	Monad	L	Isopolar	Subcircular	NV	Colporate	NV
Solanum viarum Dunal	Monad	L	Isopolar	NV	Prolate-spheroidal	Colporate	NV
Styracaceae							
Styrax camporum Pohl	Monad	VL	Isopolar	Triangular	NV	Colporate	Reticulate
Turneraceae							

Turnera subulata Sm.	Monad	L	Isopolar	NV	Oblate	Colporate	NV
Verbenaceae							
Lantana trifolia L.	Monad	L	Isopolar	NV	Prolate-spheroidal	Colporate	NV
Stachytarpheta cayennensis (Rich.) Vahl	Monad	G	Isopolar	Subtriangular	NV	Colpate	Baculate
Violaceae							
Pombalia communis (A.St.-Hil.) Paula-Souza	Monad	L	Isopolar	Subtriangular	NV	Colporate	Reticulate
Vitaceae							
Cissus verticillata (L.) Nicolson & C.E.Jarvis	Monad	M	Isopolar	Circular	NV	Colporate	NV

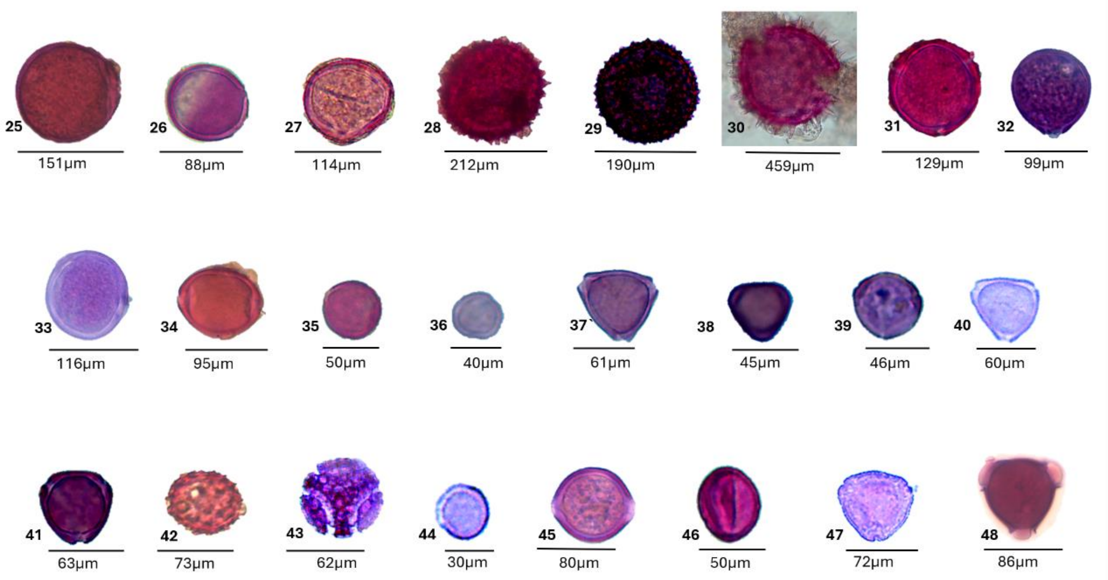
Dispersion unit, Size (S = small; M = medium, L = large, VL = very large and G = giant), Amb, Shape, Aperture type and Exine ornamentation. NV indicates a characteristic that was not visualized.

Figure 2 – Pollen grains of species recorded in the 14 fragments in the urban area of Campo Grande, Mato Grosso do Sul, Brazil.



1. *Justicia carnea* ƒ, 2. *Ruellia brevifolia* ƒ, 3. *Thunbergia grandiflora* ƒ (Acanthaceae); 4. *Xylopia aromatica* Δ (Annonaceae); 5. *Austroeupatorium inulaefolium* ƒ, 6. *Baccharis trinervis*†, 7. *Baccharis trinervis* ƒ, 8. *Chromolaena cylindrocephala* ƒ*;* 9. *Chromolaena laevigata* ƒ*;* 10. *Chromolaena squalida* ƒ, 11. *Chromolaena maximilianii*†, 12. *Chrysolaena sceptrum* ƒ, 13. *Eclipta prostrata*†, 14. *Elephantopus mollis*†, 15. *Lepidaploa muricata*†, 16. *Mikania micrantha*†, 17. *Orthopappus angustifolius*†, 18. *Praxelis clematidea*†, 19. *Senecio pohlii*†, 20. *Tithonia diversifolia* ƒ, 21. *Trixis antimenorrhoea* ƒ, 22. *Unxia kubtzkii*†, 23. *Vernonanthura brasiliana* ƒ, 24. *Vernonanthura membranacea*† (Asteraceae), 25. *Adenocalymma pedunculatum*Δ, 26. *Fridericia florida*†, 27. *Fridericia platyphylla*†, 28. *Tecoma stans*† (Bignoniaceae), 29. *Cordia polycephala*† (Boraginaceae), 30. *Pseudoananas sagenarius* ƒ (Bromeliaceae), 31. *Pereskia aculeata*Δ (Cactaceae), 32. *Celtis iguanaea*† (Cannabaceae), 33. *Caryocar brasiliense*Δ (Caryocaraceae), 34. *Couepia grandiflora*Δ , 35. *Hirtella gracilipes* ƒ, 36. *Licania humilis*† (Chrysobalanaceae), 37. *Ipomoea trilobata*† (Convolvulaceae), 38. *Momordica charantia*† (Cucurbitaceae), 39. *Curatella americana*† (Dilleniaceae), 40. *Davilla elliptica*†, 41. *Erythroxylum suberosum*† (Erythroxylaceae), 42. *Chamaesyce hyssopifolia* ƒ, 43. *Croton grandivelus*Δ, 44. *Croton urucurana*Δ, 45. *Julocroton montevidensis*Δ, 46. *Maprounea guianensis*† (Euphorbiaceae), 47. *Bauhinia rufa* ƒ, 48. *Bauhinia ungulata*† (Fabaceae). † polar view, ƒ equatorial view. Δ apolar pollen. Source: Elaborated by the authors.

Figure 3 – Pollen grains of species recorded in the 14 fragments in the urban area of Campo Grande, Mato Grosso do Sul, Brazil.

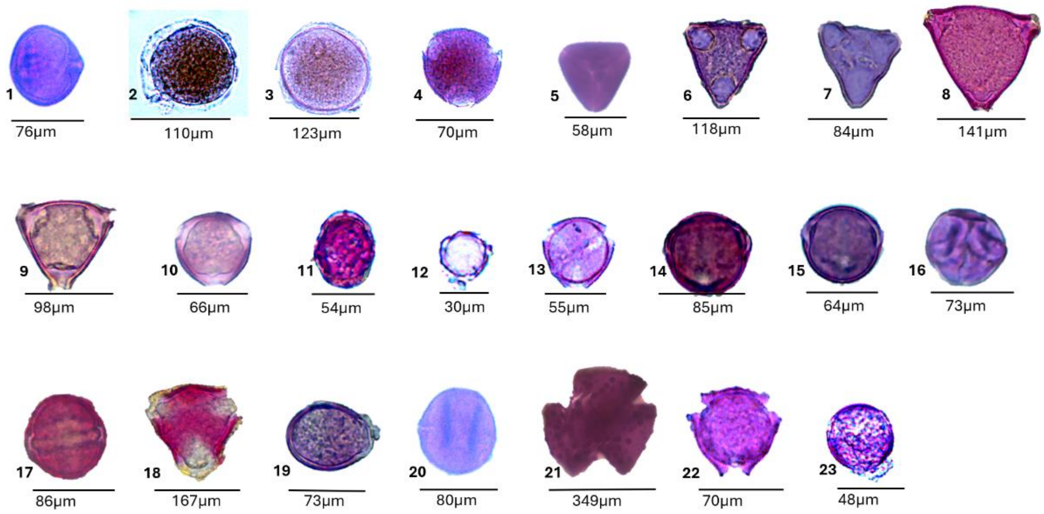


1. *Camptosema ellipticum*†, 2. *Canavalia mattogrosensis*Δ, 3. *Centrosema macrocarpum*†, 4. *Centrosema sagittatum* ƒ, 5. *Leucaena leucocephala*†, 6. *Leucochloron incuriale*†, 7. *Machaerium hirtum*† , 8. *Mimosa setosa*Δ, 9. *Mimosa verrucosa*Δ, 10. *Senna alata*†, 11. *Senna pendula*†, 12. *Senna pilifera* ƒ, 13. *Sesbania exasperata*† (Fabaceae), 14. *Hyptidendron* sp ƒ., 15. *Hyptidendron canum*† (Lamiaceae), 16. *Nectandra cuspidata*Δ , 17. *Ocotea minarum*Δ (Lauraceae), 18. *Byrsonima intermedia*†, 19. *Byrsonima verbascifolia* ƒ, 20. *Christianella multiglandulosa*† , 21. *Heteropterys aphrodisiaca*Δ, 22. *Mascagnia cordifolia*Δ , 23. *Stigmaphyllon* sp Δ (Malpighiaceae), 24. *Helicteres denticulenta*† (Malvaceae), 25. *Luehea divaricata* ƒ, 26. *Pavonia communis* ƒ, 27. *Sida sp.* Δ, 28. *Sida rhombifolia*Δ, 29. *Sidastrum paniculatum*Δ, 30. *Urena lobata*†, 31. *Waltheria indica*†, 32. *Waltheria communis*† (Malvaceae), 33. *Miconia nervosa* ƒ (Melastomataceae), 34. *Guarea guidonia*†, 35. *Trichilia pallida*† (Meliaceae), 36. *Muntingia calabura*† (Muntigiaceae), 37. *Campomanesia adamantium*†, 38. *Eugenia* sp†., 39. *Eugenia puniciflora*†, 40. *Myrcia laruotteana*† (Myrtaceae), 41. *Ouratea hexasperma*† (Ochnaceae), 42. *Ludwigia laruotteana* ƒ (Onagraceae), 43. *Passiflora edulis*† (Passifloraceae), 44. *Piper aduncum* ƒ (Piperaceae), 45. *Myrsine guianensis* ƒ (Primulaceae), 46. *Clematis dioica* ƒ (Ranunculaceae), 47. *Alibertia edulis*†, 48. *Conyza bonariensis*† (Rubiaceae). † polar view, ƒ equatorial view. Δ apolar pollen.

Source: Elaborated by the authors.

REVISTA
CONTRIBUCIONES
A LAS CIENCIAS
SOCIALES

Figure 4 – Images of pollen grains of species recorded in the 14 fragments in the urban area of Campo Grande, Mato Grosso do Sul, Brazil.



1. *Cordiera sessilis* [ƒ], 2. *Palicourea crocea*[Δ], 3. *Palicourea rigida*[Δ], 4. *Psychotria carthagenensis*[†] (Rubiaceae), 5. *Matayba guianensis*[†], 6. *Serjania acoma*[†] , 7. *Serjania caracasana*[†], 8. *Serjania erecta*[†], 9. *Serjania meridionalis*[†], 10. *Sapindus saponaria*[†] (Sapindaceae), 11. *Chrysophyllum marginatum* [ƒ](Sapotaceae), 12. *Solanum americanum*[†], 13. *Solanum lycocarpum*[†], 14. *Solanum paniculatum*[†], 15. *Solanum riparium*[†], 16. *Solanum sisymbriifolium*[†], 17. *Solanum viarum*[†] (Solanaceae), 18. *Styrax camporum*[†] (Styracaceae), 19. *Turnera subulata* [ƒ] (Turneraceae), 20. *Lantana trifolia* [ƒ], 21. *Stachytarpheta cayennensis*[†] (Verbenaceae), 22. *Pombalia communis*[†] (Violaceae), 23. *Cissus verticillata*[†] (Vitaceae). [†] polar view, [ƒ] equatorial view. [Δ] apolar pollen.
Source: Elaborated by the authors.