Trends in the scientific literature on *Stryphnodendron adstringens* (Leguminosae): an important Brazilian medicinal tree

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ABSTRACT. *Stryphnodendron adstringens*, commonly known as "barbatimão", is a native Brazilian savannah tree that has been long used in folk medicine due to its phytotherapy properties. The aim of the present study was to perform a scientometric analysis based on articles published in journals indexed in Web of Science database. Seventy publications on barbatimão were found and included in this scientometric research, most of which were published in English. The temporal trend analysis in the number of publications showed that the number of scientific articles about *S. adstringens* had increased significantly over the years. The papers found were published in 51 scientific journals, most of which are international. The main knowledge gaps relating to *S. adstringens* were in the fields of environmental sciences, evolutionary biology and genetics. The mains trends in barbatimão studies involves pharmacology pharmacy, forestry and medicinal chemistry. Tannin and medicinal plant were the most frequent keywords, showing its importance as a phytotherapeutic resource. Brazil was responsible for 92.96% of the knowledge about this species, obtained through scientific production. The analysis of the publications found made it possible to understand the current knowledge about the species *S. adstringens*.

Keywords: barbatimão, scientometrics analysis, scientific production, medicinal plant

INTRODUCTION

The *Stryphnodendron adstringens* (Mart.) Coville, also known as "barbatimão", is a plant from the Brazilian Cerrado Biome belonging to the Leguminosae family (Corrêa et al., 2012). This species occurs in cerrado lato sensu and campo rupestre vegetation, and there are registers of its occurrence in the states of Minas Gerais, Tocantins, Distrito Federal, Goiás, Mato Grosso, Mato Grosso do Sul, São Paulo, Paraná and Bahia (Souza & Gibau, 2018). It is a small, hermaphroditic, deciduous tree with a rough, light-colored, thick, tortuous trunk, with a height ranging from 2 to 8 m and diameter from 20 to 30 cm. The leaves alternate between composed and binary. Flowering occurs in September with fruiting from October to December. Its fruits are thick, fleshy pods, light brown and produce many brown seeds. Also, the species shows a preference for sandy and fast-draining soils (Felfili et al., 1999; Lorenzi, 2002, Lorenzi & Matos, 2002, Sanches et al., 2007).

This plant produces a broad spectrum of secondary metabolites, such as alkaloids, terpenes, flavonoids, steroids, saponins, with the tannins being the predominant constituent which attaches therapeutic value to the species (Santos Filho et al., 2011, Fiori et al., 2013, Nascimento et al., 2013). Tannins are found in various parts of the plant, frequently concentrated in the stem bark. The total tannin content in aqueous extracts of the stem bark ranges between 20 to 40% (Panizza et al., 1988, Lopes et al., 2009, Corrêa et al., 2012).

The therapeutic properties of barbatimão were recognized long ago by the French Auguste de Saint-Hilaire in the 18th century, and other European naturalists that traveled around Brazil in the early 19th century (Brandão et al., 2008; Brandão et al., 2012). More recently, several ethnobotanical studies have shown the therapeutic efficacy and use of the species by traditional communities (Costa et al., 2017, Ribeiro et al., 2017, Ricardo et al., 2018, Barreto & Spanholi, 2019, Migueis et al., 2019). Anti-inflammatory, antibacterial, antiseptic, astringent, and cicatrizing properties of the stem barks were the main attributes that characterized the folk choice of barbatimão (Souza-Moreira et al., 2018).

Due to its medicinal importance, this species was included in the "Plants for the Future Initiative -

Midwest region", an action of the Ministry of the Environment (MMA), in favor of the sustainable use of native species from Brazilian flora, with current or potential economic value used locally or regionally (Vieira et al., 2016). Many medicinal species from the Midwest region of Brazil have a broad and consolidated regional market (Vieira et al., 2016). For *S. adstringens*, it can mention the ointment FITOSCAR® manufactured by the Aspen Laboratory, developed from research carried out in a Brazilian university (Medical School of the University of Ribeirão Preto). This ointment was the first drug obtained from a dry extract of a Cerrado plant to have a record granted by the National Health Surveillance Agency (ANVISA). According to the package leaflet, the ointment is indicated as a healing agent on various types of lesions.

Recently, Souza-Moreira et al. (2019) published a review paper about the genus *Stryphnodendron* and Pellenz et al. (2019) about the *S. adstringens* species. Both studies highlight the importance of this species for traditional communities and reflect the relevance of the ethnopharmacological knowledge, besides the scientific evidence of its use as a medicinal plant. However, to date, no scientometric study was performed to evaluate the scientific production of this species.

The scientometrics research consists in the study of the quantitative and qualitative aspects of science and aims to investigate trends and biases in scientific literature.Scienciometry has been used to evaluate scientific knowledge in a country (Lancho-Barrantes & Cantú-Ortiz, 2019, Sooryamoorthy, 2019), and the impact of scientific research on the economy (Laverde-Rojas & Correa, 2019). To explore trends in a particular research field (Souza et al., 2018, Carvalho et al., 2019, Olmeda-Gómez et al., 2019), and in some specific cases to evaluate the scientific production for certain genera (Nabout et al., 2010, Chong-Carrillo et al., 2018) or species (Gomez-Verjan et al., 2015, Gupta et al., 2018, Pereira et al., 2018).

Thus, this study aimed to perform a scientometric analysis of the scientific literature about the species *S. adstringens* and identify the main trends of scientific production on the species over the years.

MATERIAL AND METHODS

A literature survey was performed in the Web of Science (Clarivate Analytics) database using the keywords: "*Stryphnodendron adstringens*" AND "Barbatimão" considering the period from 1945 to 2018. The Web of Science database was used because of its scope regarding the number of publications and the quality of indexed scientific journals. Only scientific articles that used the *S. adstringens* were considered as inclusion criteria for the analyses presented here.

For the selected papers, the following information was extracted: (i) year of publication; (ii) journal in which the article was published; (iii) nationality of the journal (Brazilian journal or international); (iv) authors; (v) number of authors per article; (vi) nationality of the first author (workplace); (vii) language used for publication; (viii) keywords; (ix) Web of Science categories field; (x) number of citations and the (xi) Impact Factor (IF) of the journals.

The data retrieved and selected in the Web of Science was exported in a BibTex file format. The Bibliometrix R package (Aria & Cuccurullo, 2017) was used to obtain the annual growth rate in the number of publications and information about the journals, authors, and institutions that published about the species. The VOSviewer program was used to construct a keyword co-occurrence network (Van Eck & Waltman, 2009). The keyword co-occurrence network is created when the keywords co-appear and form relationships within the engagement network. To evaluate the temporal trends on the number of articles, the number of citations and the number of authors per article obtained each year; a Pearson correlation test was performed. This was done with the R "*stats*" package (version 3.2.2), using the "*cor.test*" function (R Core Team, 2018).

RESULTS AND DISCUSSION

The initial search resulted in 150 publications between 1980 and 2018. After filtering the data, 70 scientific articles were retained and used for scientometric analysis. The first paper with the species was published in the year 1992 (Pasqual & Barros, 1992), in the "*Pesquisa Agropecuária Brasileira*" journal. The paper reports the effect of concentrations of BAP (6-benzylaminopurine) and ANA (naphthalene acetic acid) on the micropropagation of *S. adstringens*.

The temporal trend analysis in the number of publications showed that the number of scientific articles about *S. adstringens* had increased significantly over the years ($r = 0.807$; $p < 0.05$; Figure 1), with an average annual growth rate of 12.98%. Also, it should be noted that 77,46% of publications have occurred in the last ten years (Figure 1). Pereira et al. (2018) found a similar result in a scientometric study of the species *Jatropha curcas* L., where the authors observed a significant increase in the scientific production related to this species, mainly from the year 2007. The increase in the number of publications over the years shows that the scientific community has a greater interest in the Cerrado biome's resources, including knowing the species biology and pharmaceutical characteristics. This increase further shows the situation of scientific progress itself because of the number of publications is one metric capable of quantifying science progress and advancement (Verbeek et al., 2002).
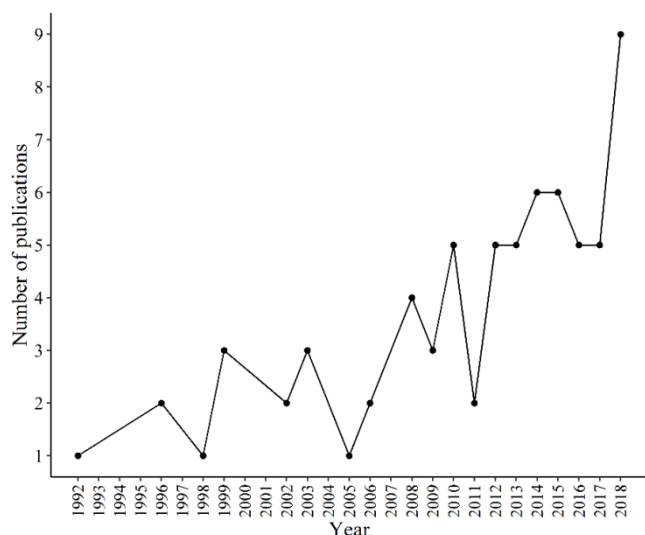
Figure 1. Temporal trend in the number of publications about *S. adstringens* between 1992 and 2018.

The 70 found papers were published in 51 scientific journals. However, 39 (76.47%) of these published only one article. The "*Journal of Brazilian Forest Science*" presented the largest number of publications (5 or 9.80% of the total of articles), followed by the "*Brazilian Journal of Pharmaceutical Sciences*", "*Ciência Florestal*", "*Phytochemistry*" and "*Phytotherapy Research*", each with three publications (Table 1).

Of the 51 scientific journals, 21 (40.38%) are national (Brazilian journal), while 30 (59.62%) are international. Regarding the impact factor of the journals obtained in the JCR for the year 2018, the "*Journal of Antimicrobial Chemotherapy*" and "*Journal of the European Academy of Dermatology and Venereology*" were both with an Impact Factor of 5,113 and only one publication in each (Table 1).

The paper of Ishida et al. (2006), published in the "*Journal of Antimicrobial Chemotherapy*", describes the antifungal potential of a crude extract, fractions, and subfractions of the stem bark of barbatimão against the yeast *Candida albicans*. The authors observed antifungal activity in the subfraction obtained by the suspension of 36 g of the crude extract in 360 ml of water (F2.4 subfraction), and low cytotoxicity to Vero cells, macrophages, and red blood cells. Despite, the subfraction (F2.4) of 'barbatimão' extracts showed satisfactory antifungal activity compared to fluconazole and nystatin, suggesting further studies to investigate the mechanisms of action and the possible development of a new antifungal agent (Ishida et al., 2006). In contrast, the paper of Vicente et al. (2009), published in the "*Journal of The European Academy of Dermatology and Venereology*", describes the effectiveness of a cream containing 6.0% extract of the steam bark of barbatimão for dermatological use in the treatment of hirsutism.

Table 1. List of scientific journals with the respective impact factor and the number of publications found about *S. adstringens*.

Journal	Impact Factor	N
Journal of Brazilian Forest Science	0,367	5
Brazilian Journal of Pharmaceutical Sciences	0,512	3
Ciência Florestal	0,529	3
Phytochemistry	2.905	3
Phytotherapy Research	3.766	3
Annals of Clinical Microbiology and Antimicrobials	2.924	2
Cerne	0,795	2
Evidence-Based Complementary and Alternative Medicine	1.984	2
Floresta e Ambiente	N/A	2
Iheringia Série Botânica	0,269	2
Industrial Crops and Products	4.191	2
Journal of Ethnopharmacology	3.414	2
Applied Biochemistry and Biotechnology	2.14	1
Brazilian Journal of Veterinary and Animal Sciences	0,242	1
Biochemical Systematics and Ecology	1,127	1
Biomed Research International	2.197	1
Bioresources	1.396	1
BMC Complementary and Alternative Medicine	2.479	1
Brazilian Journal of Botany	0,958	1
Science and Agrotechnology	1.098	1
Ciência Rural	0,553	1
Current Pharmaceutical Biotechnology	1.516	1
Eclética Química	N/A	1
Environmental and Molecular Mutagenesis	2.528	1
European Journal of Wood and Wood Products	1.901	1
Frontiers in Pharmacology	3.845	1
Genetic Resources and Crop Evolution	1.296	1
Interciência	0,264	1
International Journal of Molecular Sciences	4.183	1
Journal of Antimicrobial Chemotherapy	5.113	1
Journal of Apicultural Research	1.752	1
Journal of The European Academy of Dermatology and Venereology	5.113	1
Journal of Thermal Analysis and Calorimetry	2.471	1
Memorias do Instituto Oswaldo Cruz	2.368	1
Pesquisa Agropecuária Brasileira	0,668	1
Brazilian Journal of Veterinary Research	0,302	1
Pharmacognosy Magazine	1,26	1
Plant Biology	2.393	1
Plant Species Biology	2.077	1
Planta Medica	2.746	1
Plos One	2.776	1
Química Nova	0,622	1
Regulatory Toxicology and Pharmacology	2.996	1
Revista Agrogeoambiental	N/A	1
Brazilian Journal of Pharmaceutical Sciences	N/A	1
Brazilian Journal of Pharmacognosy	1,754	1
Scientia Forestalis	0,503	1
Semina: Ciências Agrárias	0,37	1
Symbiosis	2.009	1
Toxicology Letters	3.499	1
Tropical Animal Health and Production	1.089	1

The most important Brazilian journals were "*Memórias do Instituto Oswaldo Cruz*," "*Brazilian Journal of Pharmacognosy*" and "*Science and Agrotechnology*," with an impact factor of 2,368, 1,754 and 1,098, respectively. The Impact Factor, published annually in the Journal Citation Reports by Clarivate Analytics, is a metric commonly used to measure the quality of journals. This metric uses the citations received from the journal in a period to quantify its influence and to infer relative quality. In July 2019, nearly 12,500

journals indexed in the Web of Science have an impact factor, of which 130 are Brazilian journals.

Besides the impact factor, there are other measures to classify the quality of journals. In Brazil, since 1998 the QUALIS system of CAPES (Brazilian Federal Agency for the Improvement of Higher Education) has been used to classify the scientific production of the postgraduate programs, and it exists to compose the evaluation of these programs. The classification is allocated by evaluation areas under pre-defined criteria, periodically updated. The scientific journals are categorized into linear strata indicative of quality (indicators A, B, and C). For the classification in strata, the QUALIS examines aspects such as database indexing, H index, and the impact factor of journals (CAPES, 2017).

A total of 306 authors were identified, with an average of 4.31 authors per papers about the *S. adstringens.* The total number of authors who published per year increased significantly over the years ($r = 0.79$, p <0.01; Figure 3), which characterizes an increased interest of the general academic community on this plant and could be an effect of the popularization of the traditional Cerrado plant species. This popularization has been introduced, widely, by discussion around the classification of Cerrado biome as a biodiversity hotspot (Myers et al., 2000) warning to the need to preserve this biome. The authors with the highest number of papers were João Carlos Palazzo de Mello (17 or 23.94% of the publications; State University of Maringá), Celso Vataru Nakamura (9 or 12.68% of the publications; State University of Maringá) and Fábio Akira Mori (8 or 11.27% of the publications; Federal University of Lavras) (Figure 4).
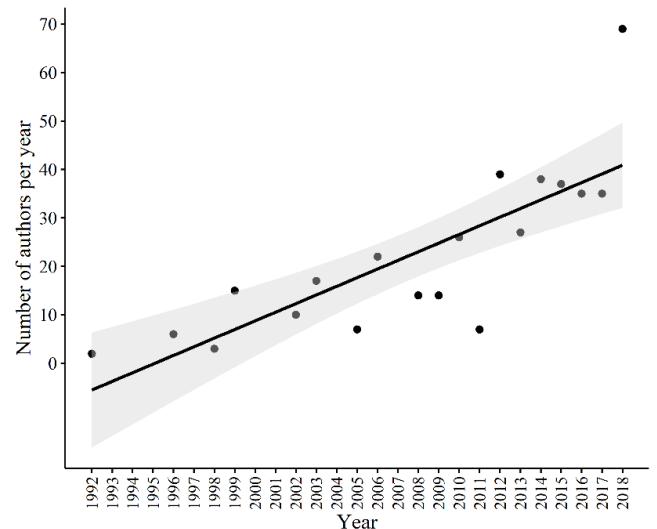

Figure 1. Total number of authors per year who published papers about *S. adstringens*.

Analyzing the number of citations per article, it was observed that the 70 papers on *S. adstringens* were cited together 673 times between 1992 and 2018. The number of citations ranged from zero to 69 citations. The most cited articles were Ishida et al. (2006) with 69 citations, Palazzo de Mello et al. (1996) with 59 citations and Audi et al. (1999) with 37 citations (Figure 4). The scientific productivity of authors in a given field of research and the impact factor of scientific journals are calculated based on the number of citations that publications received in a year. According to Bornmann & Daniel (2008), when a paper was cited, it had an impact and contributed to new knowledge in the cited publications. Therefore, citation analysis is a crucial tool for assessing the bibliometric impact of scientific production.
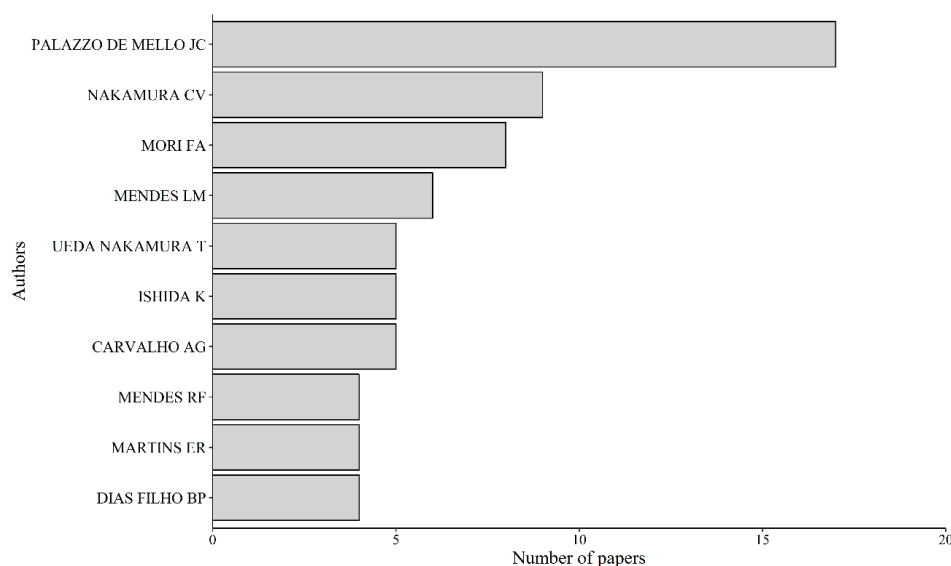

Figure 2. Authors with the highest number of publications about *S. adstringens*.

A negative and significant correlation was observed (r =-0.563 p < 0.01; Figure) between the number of citations and year of publication, it means, the average number of citations decreases over time since the publication. With rare exceptions, in the first two years after publication, the articles are rarely cited. However, if an article is cited in this period, it is likely to become influential in the corresponding scientific area (Vitanov, 2016). After five years, as the publication becomes known, it reaches the highest number of citations. However, if there are no citations, the work was of limited relevance to the academic community. After seven years of publication, the number of citations declines (Vitanov, 2016). Thus, researchers continually renew the structure of scientific information, always aggregating new data, using achievements from previous research.
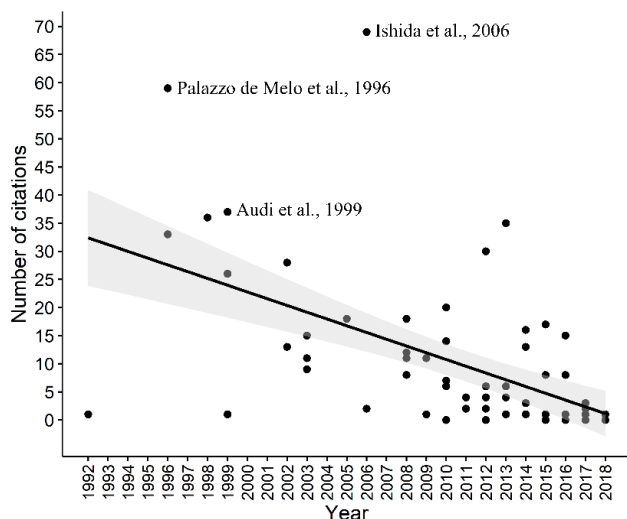

Figure 3. Number of citations received in articles about *S. adstringens.*

In relation to Web of Science categories field, it was noted that most of the papers are classified in "Pharmacology Pharmacy" (16 or 22.55% of the total articles), followed by "Plant Sciences" (15 or 21.13% of the total articles), "Forestry" (12 or 16.90% of the total articles) and "Medicinal Chemistry" (8 or 11.27% of the total articles). These categories together comprise 61.43% of the total number of papers. These results showed that there are still a lot of knowledge to be explored about the species, for example, in areas such as "Environmental Sciences," "Evolutionary Biology," "Genetics Heredity" and "Entomology," where only one publication was found.

The English language was the most used for writing the papers (69.01% or 49 articles), followed by Portuguese (28.17% or 20 articles) and Spanish (2.82% or two articles). The English language is considered the leading international language for communication and dissemination of scientific knowledge. According to Salager-Zeyer (2015) in developing countries, of the non-English national language, some journals publish the articles in the native language of the researchers, whether Portuguese, Chinese, Spanish, Russian, among others. However, in the search for greater visibility and more significant potential to be accessed worldwide, most journals started to publish papers only in the English language (Salager-Zeyer, 2015).

Liu (2017) analyzing 33,020,478 articles and revisions between the years 1990-2015, noted that 92.50% were published in English, while 7.50 were published in other languages, which implies a decrease in the participation of other languages in the scientific context. Packer (2016) described the growth of English language usage in Brazil and the distribution of the articles in Portuguese and English in the SciELO database by thematic area. According to Packer (2016), the total percentage of English publications increased from 80% in 2011 to 87% in 2015. In 2015 nearly 85% of the publications in the areas of Biological Sciences and Health Sciences and 60% in the areas of Engineering and Exact and Earth Sciences were published in English.

In relation to the research institution of the author of correspondence, a predominance of papers carried out at Brazilian institutions was observed (66 or 92.96% of the total of publications), which was expected because the species occurred in several regions of Brazil, mainly in areas of Cerrado and Caatinga (Souza & Gibau, 2019). A total of 23 institutions contributed to the 70 articles found. The institutions that presented the most significant number of articles, were the State University of Maringá (11 articles), Federal University of Lavras (8 articles), the Federal University of Minas Gerais (7 articles), the Federal University of Viçosa and São Paulo State University (both with 6 articles). Among the foreign institutions, the University of Munster was represented by three articles, while the Federal Institute of Technology of Zurich and the University of Seville by one article each.

The report research in Brazil published by Clarivate Analytics for CAPES presents Brazil as the 13th largest producer of scientific publications in the world, with a significant performance improvement from 2011 to 2016 (Cross et al., 2018). It was demonstrated that Brazilian scientific production is closely linked to postgraduate programs stricto sensu and the increase in the number of postgraduate programs and of new masters and doctors have been driving the progress of publications by Brazilian institutions. For example, the total number of Postgraduate Programs went from 1,259 in 1998 to 4,291 in 2018.

The most frequent keywords in the 70 papers were *Stryphnodendron adstringens*, barbatimão, tannin, cerrado, and medicinal plants. By analyzing the keywords, it was possible to observe the formation of three clusters. The first cluster with the words "barbatimão", "cerrado" and "tannin", the second

cluster with "medicinal plant", "savana" and "*Stryphnodendron adstringens*" and the third cluster with "apoptosis" and "proanthocyanidins".

The species *S. adstringens* is a medicinal plant well known and used by traditional communities that live in the region of the Brazilian Cerrado. The medicinal properties are mainly associated with condensed tannins, also known as proanthocyanidins (Fonseca & Librandi, 2008). The stem bark is considered one of the major natural sources of these compounds, registered in the Brazilian Pharmacopeia with at least 8% of this phenolic compound (ANVISA, 2010).

Several scientific studies were conducted to test the therapeutic value of the species, which justifies the main clusters of keywords found in this study. These studies have shown that the extract from the stem bark of barbatimão has several medicinal properties, such as anti-inflammatory (, Lima et al., 1998, Henriques et al., 2016), antioxidant (Souza et al., 2007, Baldivia et al., 2018, Sabino et al., 2018), antimicrobial (Holetz et al., 2005, Ishida et al., 2006, Santos et al., 2009, Trolezi et al., 2017) and gastric anti-ulcerogenic (Audi et al., 1999, Martins et al., 2002). Besides, the pharmacological activity of the species, proven by the commercialization of the Fitoscar® ointment (*Aspen Farmacêutica*), also stands out. The product is composed of a dry extract of *S. adstringens* 50% (60 mg) and excipients (macrogol, propylene glycol, methylparaben, and propylparaben) and is indicated as a healing agent in epithelial tissue lesions (Minatel et al., 2010).

CONCLUSION

The *Stryphnodendron adstringens* species have been traditionally used in Brazil as a folk remedy for various diseases because of their multiple biological activities. The findings from this study demonstrate a continuous increase in scientific production about this species.The main trends in *S. adstringens* studies were related in the field of pharmacology pharmacy, forestry and medicinal chemistry, mainly because of its biological and clinical actions, including anti-inflammatory, antioxidant, antiulcer, antimicrobial, and antiparasitic effects. On the other hand, there is great geographical bias, with most of the data acquired, and researchers involved, being concentrated in Brazil, which was expected because the species is a Brazilian native tree, mainly found in areas of Caatinga and Cerrado.

CONFLICT OF INTEREST
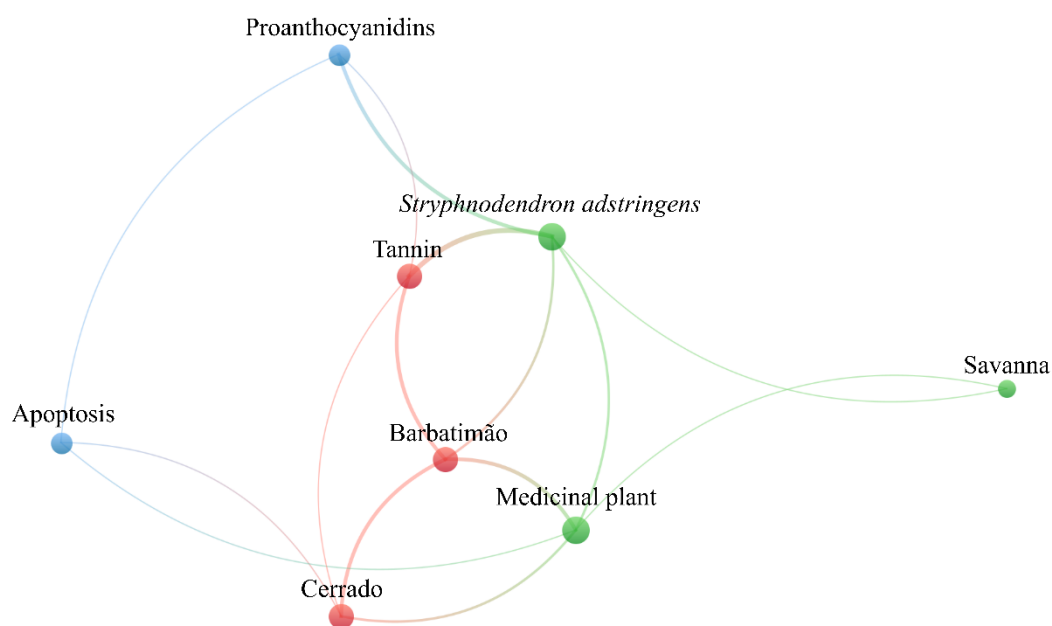
The authors declare no conflict of interest.

Figure 4. Co-occurrence of keywords obtained from articles about *S. adstringens*.

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