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Bibliometric Analysis of Fava-d'anta (*Dimorphandra* spp.): An Comprehensive Review on Scientific Production

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HIGHLIGHTS

- First bibliometric and comprehensive review on *Fava d'Anta* (*Dimorphandra* spp.).
- Brazil leads in publications and citations in research on *Dimorphandra* spp.
- Interest in fava-d'anta's antioxidant and therapeutic properties persists.
- Rutin and quercetin are the main phytoconstituents reported in the species.

Abstract: Fava-d'anta (*Dimorphandra* spp.) is a significant medicinal plant known for its rich array of bioactive compounds and traditional applications in healthcare, particularly in underprivileged communities with limited access to formal medical services. This study aims to explore the scientific output related to Fava-d'anta through a bibliometric analysis, highlighting trends and key contributions in the field. Using the Bibliometrix package in R, data were collected from Scopus and Web of Science, covering publications from 1969 to 2023.The analysis revealed a growing interest in this area of research, with a substantial number of citations and a wide range of covered topics, including phytochemistry, biology, and pharmacology. Most of the documents are original research articles, reflecting a strong focus on generating new empirical data. Moreover, the study emphasizes the collaborative nature of research in this field, with notable contributions from Brazilian institutions. This review underscores the importance of integrating traditional knowledge with scientific research to enhance the understanding and application of *Dimorphandra* species in public health.

Keywords: Dimorphandra; Phytochemistry; Quercetin; Rutin; Astilbin; Polyphenols; Phytotherapy.

INTRODUCTION

Medicinal plants play a key role in the care of underprivileged communities, serving as an affordable source of treatment for various health conditions. They are essential for meeting primary health needs, especially in areas where access to formal medical services is limited [1]. Moreover, the use of these plants reflects valuable traditional knowledge, which contributes to the autonomy and cultural preservation of communities [2–4]. Programs such as Living Pharmacies (‘*Farmácias Vivas*’), the brainchild of late Professor Francisco José de Abreu Matos in Brazil, attempt to incorporate this knowledge with science, offering access to herbal medicines prepared from locally grown plants, thus enhancing not only traditional medicine, but also strengthening phytotherapy in public health [5].

The inclusion of herbal medicine in Brazilian public health is facing several difficulties, including the lack of studies and publications proving its efficacy and safety, which makes it difficult for health professionals and managers to accept it [6]. Ethnobotanical knowledge is fundamental to the discovery of new herbal medicines, as it documents the traditional use of medicinal plants by local communities. This knowledge guides scientific research into the identification of bioactive compounds, validating treatments and speeding up the development of new medicines [7].

The fava- d'anta (*Dimorphandra* spp.) are species of trees native to the semi-arid region of Brazil, especially found in the Chapada do Araripe, in Ceará. They are valued for their fruits, which have a high concentration of bioflavonoids named rutin and quercetin, substances with various pharmacological properties [8]. *Dimorphandra mollis* and *Dimorphandra gardneriana* are the scientific names commonly attributed to specimens known as "fava-d'anta," which face extinction risks due to overexploitation and habitat degradation, making the conservation of these species essential to preserve valuable genetic resources with potential applications in pharmaceutics and cosmetics [9]. The fava d’anta is regarded as a “plant for the future” in Brazil's Center-West and Northeast regions due to its adaptability, economic potential in food industry, ecological role in soil conservation and biodiversity, and cultural significance, making it a sustainable development asset [10,11].

Rutin, a natural flavonoid, has a wide range of biological effects, including antimicrobial, antifungal and anti-allergic properties [12–14]. In addition, it has demonstrated neuroprotective potential, being able to inhibit amyloid-induced cytotoxicity and improve the activity of antioxidant enzymes [15]. Rutin has also been associated with improved bioavailability and therapeutic efficacy when formulated into nanostructures, which may increase its water solubility and facilitate the treatment of various chronic diseases [16].

Quercetin, the non-glycosylated form of rutin, also demonstrates a number of beneficial effects, including antioxidant properties that reduce oxidative stress and anti-inflammatory effects that can help treat conditions such as arthritis [17]. In addition, it has antiviral activity, inhibiting the entry of viruses into cells, and can regulate lipid metabolism, improving insulin sensitivity, which is relevant for type 2 diabetes [18,19]. It is also investigated for its neuroprotective effects, contributing to the preservation of cognitive function [20].

Given the remarkable pharmacochemial potential of rutin and quercetin, derived primarily from *Dimorphandra spp.*, these species emerge as invaluable natural resources for scientific and biotechnological advancements. However, the ongoing risks of overexploitation and habitat loss threaten their availability, further emphasizing the need for comprehensive research and conservation efforts [21,22].

Despite the economic and ecological importance of *Dimorphandra spp.*, a comprehensive understanding of the scientific production, research trends, and applications related to these species remains limited. Bibliometric analysis emerges as a valuable tool to map the state of research and highlight future directions for sustainable use and conservation strategies [23–27].

This study aims to systematically analyze the scientific production surrounding *Dimorphandra* spp., providing insights into research patterns and proposing strategies to harness their potential while ensuring ecological preservation.

MATERIAL AND METHODS

The data analysis for this study was conducted using the Scopus and Web of Science databases, as they are considered high-quality resources and the most useful for collecting publication data for scientific research purposes. The keywords were "Fava d'anta, Dimorphandra gardneriana, and Anta bean" to consider all advancements in the research field related to the topic published between 1969 and 2023. Other included informations were: document types (article and review article), English language, and final publication stage.

A total of 122 publications were acquired following online review for bibliometric analysis, with downloads commencing on April 26, 2024. The PRISMA diagram, with the selected criteria, is summarized in Figure 1.

The Bibliometrix, a package developed in the R statistical language, was used in quantitative studies in scientometrics and bibliometrics [28] to analyze data obtained from Scopus and Web of Science. This tool, known for its robustness and reliability, assisted in constructing maps of journals, countries, institutions, and authors based on co-citation data and keyword maps. Additionally, four tools were employed for data visualization analysis in this study: VOSviewer (v1.6.20, Leiden, South Holland, Netherlands), Microsoft Excel Spreadsheets (Microsoft Office Professional Plus, 2019), OriginPro 2024b (64-bit), and Biblioshiny (version 4.1).

RESULTS & DISCUSSION

Main Information

The dataset consists of 122 documents published between 1969 and 2023, sourced from 92 different journals. It exhibits an annual growth rate of 2.6%, with an average document age of 11.8 years which reveals that most of the literature is recent, which is positive as it reflects current interest and emerging research trends (Table 1). The total number of citations across these documents is 3592, yielding an average of 18.99 citations per document. The dataset includes 1508 Keywords Plus and 389 Author's Keywords. The high number of keywords suggests a considerable diversity of topics covered in the publications. This diversity may indicate a multidisciplinary approach to research involving *Dimorphandra*, covering areas such as phytochemistry, biology, ecology, pharmacology and others.

The documents involve 546 authors, with no single-authored documents. The absence of single-author documents highlights the trend towards collaboration between researchers. The average of 6.68 co-authors per document suggests that larger projects are being carried out, probably requiring a collaborative effort to collect data and analyze information. The average number of co-authors per document is 6.68, and 10.66% of the collaborations are international. Therefore, research on *Dimorphandra* is not limited to a single geographical context, which may indicate a global effort to understand these species, expanding the possibilities for knowledge transfer and the international impact of discoveries.

The majority of the documents (113) are articles, with 9 being reviews, in which species are cited. However, there is no compreensive review addressing the chemical or biological characteristics of *Dimorphandra* species or the *Dimorphandra* genus. The predominance of original articles (113) over reviews (9) suggests that most research is still focused on producing new data and advancing empirical knowledge.This is typical in growing scientific fields, where researchers are more focused on exploring new discoveries than reviewing existing knowledge.

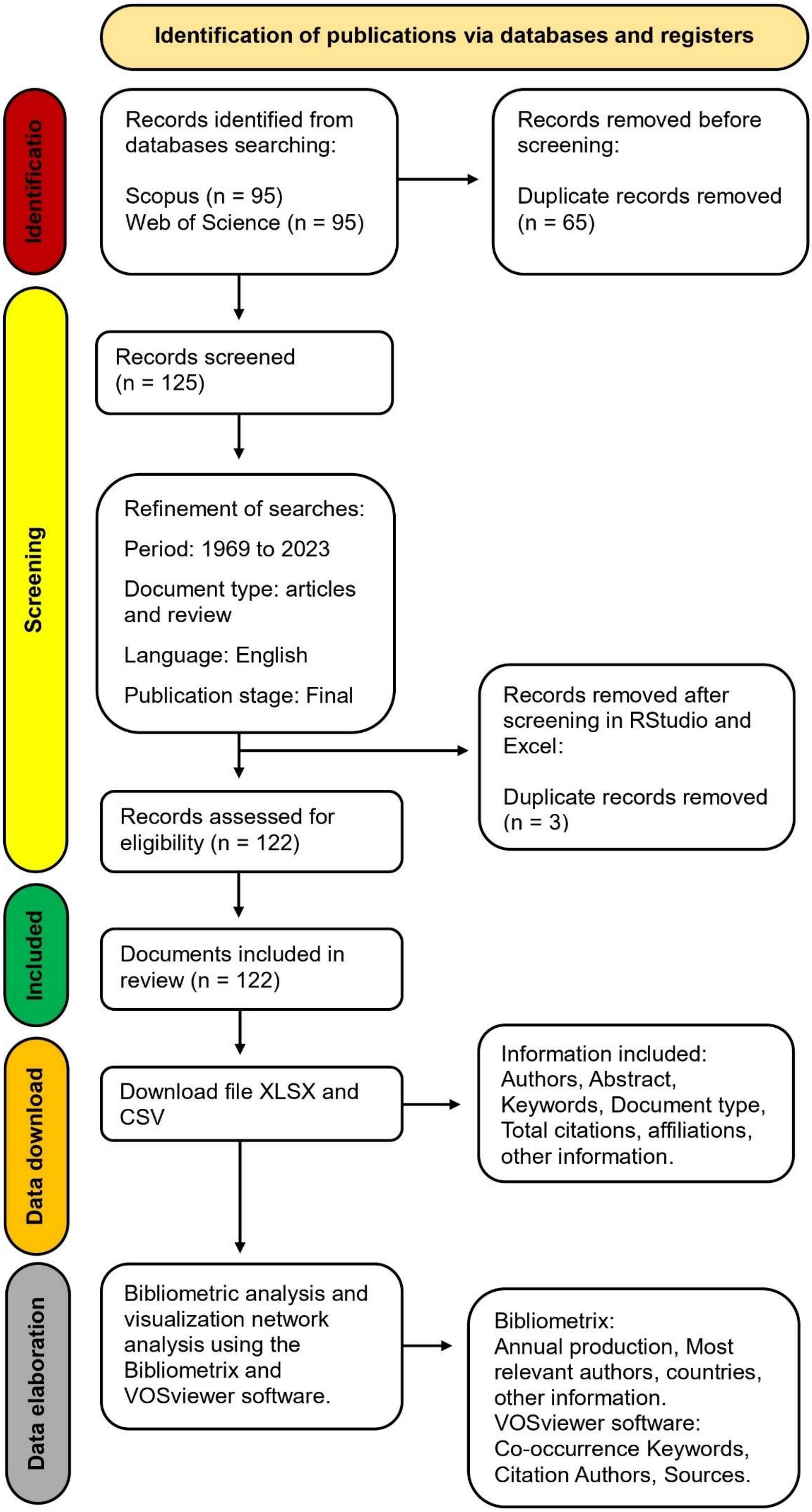

Figure 1. PRISMA diagram, criteria for the current research with Bibliometrix and VOSviewer.

Year-Based Publication Analysis

A total of 122 articles related to fava d'anta were retrieved for review, covering the period from April 1, 1969, to December 31, 2023 (Figure 2). By analyzing the time interval, it can be divided into three trends.

In the first phase or initial stage (1969-1999) there were 4 publications, the first in 1969 and 3 studies about 3 decades later. Our findings are similar to those reported in another bibliometric study conducted in Latin America and the Caribbean, which revealed that between 1970 and 1997, fewer than 100 articles on medicinal plants in general were published annually in major databases, highlighting the underrepresentation and limited progress of research during that period [29]. Factors such as scarce funding, restricted access to phytochemical technologies, and the lack of structured research programs contributed to the underrepresentation of studies. Additionally, traditional knowledge systems were often overlooked, and national policies to support biodiversity-based research were still emerging [30–32].

The second phase (2000-2009) or stage of moderate growth, totaled 35 publications, with a peak of 8 publications in 2009. This gradual increase follows a pattern similar to that reported in a bibliometric analysis of ethnobotanical research in Brazil (1988–2013), which highlighted a steady rise in scientific output during the early 2000s [33]. The use of new technologies, such as the popularization of various chromatographic and non-chromatographic techniques, may have facilitated a more in-depth study of the chemical and pharmacological properties of the species, contributing to the increase in publications from 2000s onwards [34–37].

The third phase (2010-2023) refers to a stage of continuous growth with high annual registrations (for example, 10 articles in 2012 and 2014, and 9 in 2020). This increase can be attributed to enhanced public investment in biodiversity research, the implementation of national policies promoting the sustainable use of native species, and the consolidation of research groups dedicated to bioprospecting and phytotherapy. Moreover, the growing scientific and industrial interest in the valorization of Brazil’s native flora and the development of innovations based on natural products further contributed to the intensification of studies during this phase [37,38].

The fourth phase (2021-2023) is a stabilization stage represented by a reasonable number of publications of 3 to 4/per year. However, many of these studies have focused more on the conservation of the species and botanical descriptions rather than on chemical and pharmacological aspects. This emphasis on a specific topic may hinder a broader understanding of the species’ technological applications, as demonstrated by bibliometric research on *Myrcia splendens.* The analysis, which covered the years 2022, 2023, and 2024, revealed a research bias toward leaf-derived essential oils, to the detriment of other plant parts and related products [39].

Public and private funding for research on native plants and biodiversity likely contributed significantly to the increase in scientific publications on *fava d’anta* since the 2010s. This growth appears to be closely linked to national efforts to promote the sustainable use of Brazilian biodiversity and the investigation of bioactive compounds with therapeutic potential. Notably, the implementation of the National Policy on Medicinal Plants and Herbal Medicines (Política Nacional de Plantas Medicinais e Fitoterápicos – PNPMF) played a central role by encouraging interdisciplinary research, conservation strategies, and the integration of phytotherapy into public health initiatives. Additionally, the expansion of Living Pharmacies (Farmácias Vivas) within the Brazilian Unified Health System (SUS) provided institutional and practical frameworks for the use of native medicinal plants in primary care, which, in turn, stimulated academic interest and research output [40, 41].

These developments were supported by targeted funding programs from institutions such as CNPq, FINEP, and CAPES, which launched specific calls for proposals focused on biodiversity, phytotherapy, and innovation in natural products. Regional public universities, especially in biodiversity-rich areas such as the Northeast and Amazon regions, also received increased support to strengthen research infrastructure and human resources [41–44]. This confluence of public policy, funding incentives, and strategic health initiatives created a favorable environment for the intensification of research on *Dimorphandra* species, particularly *fava d’anta*, aligning scientific production with both conservation goals and health demands.

Table 1. Key statistics regarding the compilation of documents pertaining to *Dimorphandra* spanning from 1969 to 2023.

Description	**Results**
Timespan	1969 - 2023
Sources (Journals)	92
Documents	122
Annual Growth Rate %	2.6
Document Average Age	11.8
Average citations per doc	18.99
References	3592
Document Contents	**Results**
Keywords Plus (ID)	1508
Author's Keywords (DE)	389
Authors	**Results**
Authors	546
Authors of single-authored docs	0
Authors Collaboration	**Results**
Single-authored docs	0
Co-Authors per Doc	6.68
International co-authorships %	10.66
Document Types	**Results**
Original Article	113
Review	9

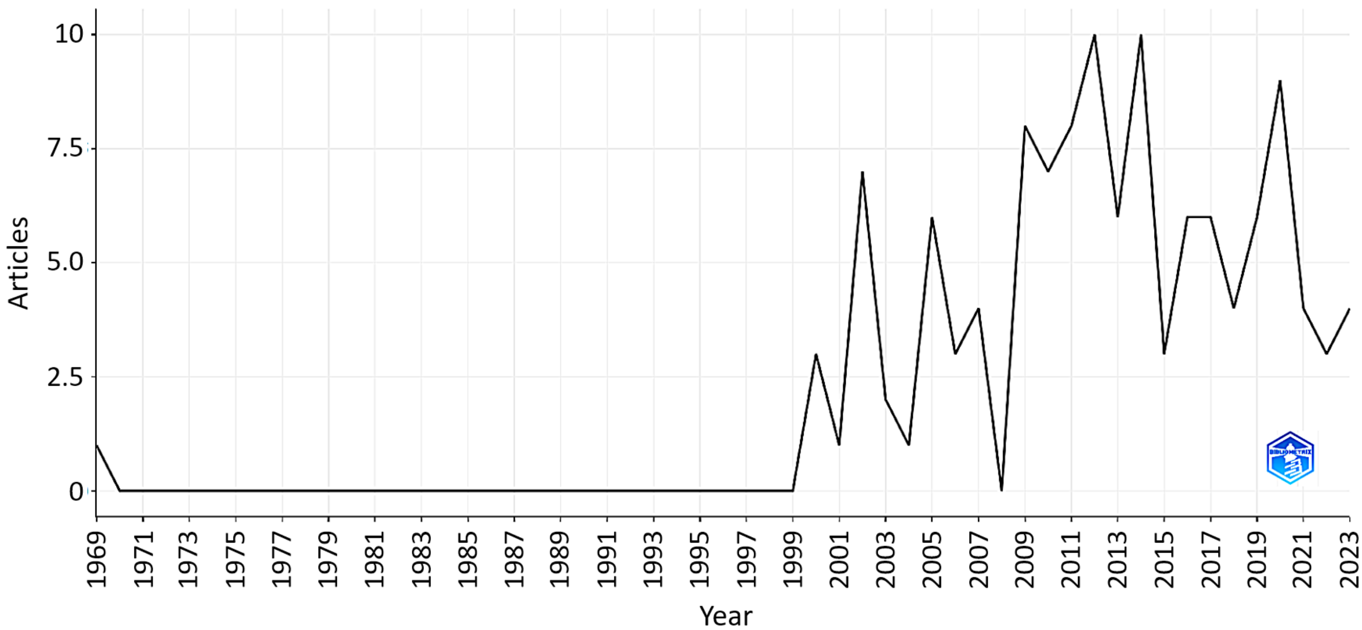

Figure 2. Annual scientific production based on Fava -d'anta (1969 - 2023).

Analysis of Scientific Publications and their Impact

The TC index, or "*Total Citations index*", refers to the total number of citations received by publications in a given period, and is an indicator of academic influence and impact [46]. Based on *Total Citations* (TC), the *Journal of Ethnopharmacology* (*JEP*) is, in fact, the most relevant journal on this list, with 198 citations, which makes it stand out from the rest (Figure 3).

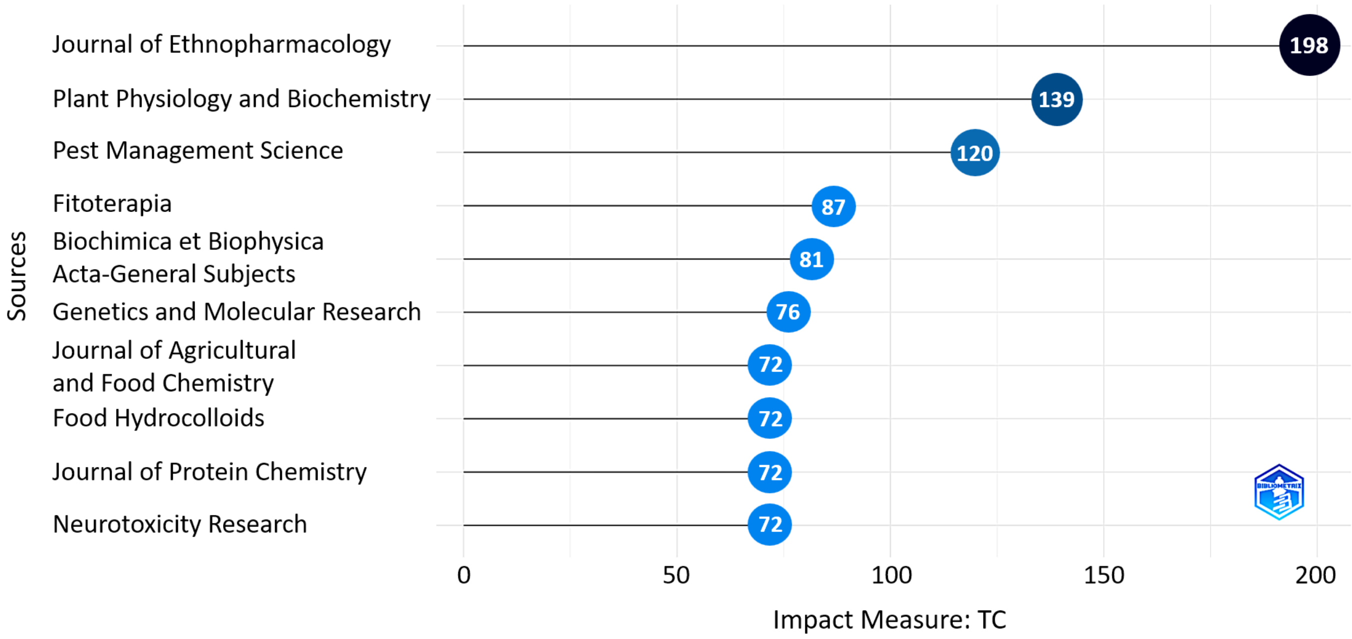

Figure 3. Most Cited Journals in Fava- d'anta Research (1969 - 2023)

Plant Physiology and Biochemistry also stands out, with 139 citations, highlighting its importance in the field of plant physiology and biochemistry. Other journals such *as Pest Management Science* (120 citations) and *Journal of Agricultural and Food Chemistry* (72 citations) also show strong impact, reflecting their essential role in areas such as pest control and the chemistry of food and agricultural products.

JEP is a pioneer publication that brings together research on indigenous medicines and is fundamental to the recognition of ethnopharmacology as an academic discipline. Since its foundation, it has promoted the exchange of interdisciplinary knowledge and strengthened cultural connections, reflecting its importance in being adopted as the official journal of the *International Society for Ethnopharmacology* [46]. In fact, bibliometric analyses focused on medicinal plants and natural products associated with diverse socio-biodiversity systems around the world consistently identify JEP as one of the most frequently cited journals in the field of phytotherapy and medicinal plant research [47–50].

Despite the *JEP* being the clear leader in terms of citations, other journals with lower TC (not individually represented in the Figure 3) are also relevant in their specific areas, excelling in topics such as pharmacology, ecology and phytochemistry. The journals with the lowest TC index, such as *Revista Brasileira de Plantas Medicinais* (7 citations), *Cerne* (7 citations), and *Revista Caatinga* (9 citations), indicate a more restricted impact, which may reflect a more specialized audience or niche or a lower visibility in the area.

The most globally cited paper is by Ribeiro RV (2017), published in *JEP*, with 157 citations, averaging 19.63 citations per year (Figure 4). This study explores the ethnobotanical use of medicinal plants by the Ribeirinha community in the Northern Araguaia microregion, Mato Grosso, Brazil. It underscores the significance of traditional knowledge in health and disease treatment, documenting plant species used by locals. Among these, *Dimorphandra* (fava d'anta) is highlighted for its prominent role in traditional medicine, recognized for its therapeutic properties and potential for pharmacological research, reflecting the region's rich biodiversity and cultural heritage [51].

The two most cited articles locally were studies published by the same author Cintra P (2005) in the journal *Sociobiology*, both with 16 citations (Figure 5).

The first study investigates the toxicity of chemical compounds in *Dimorphandra mollis* on honeybees (*Apis mellifera*) [52]. The plant is noted for its widespread distribution in São Paulo and the potential toxicity of its flowers, peduncles, and bark to bees during the flowering season. The research evaluates the effects of these extracts on bee mortality, emphasizing the importance of plant-pollinator interactions, particularly in the context of the cerrado biome where *Dimorphandra mollis* is a characteristic species.

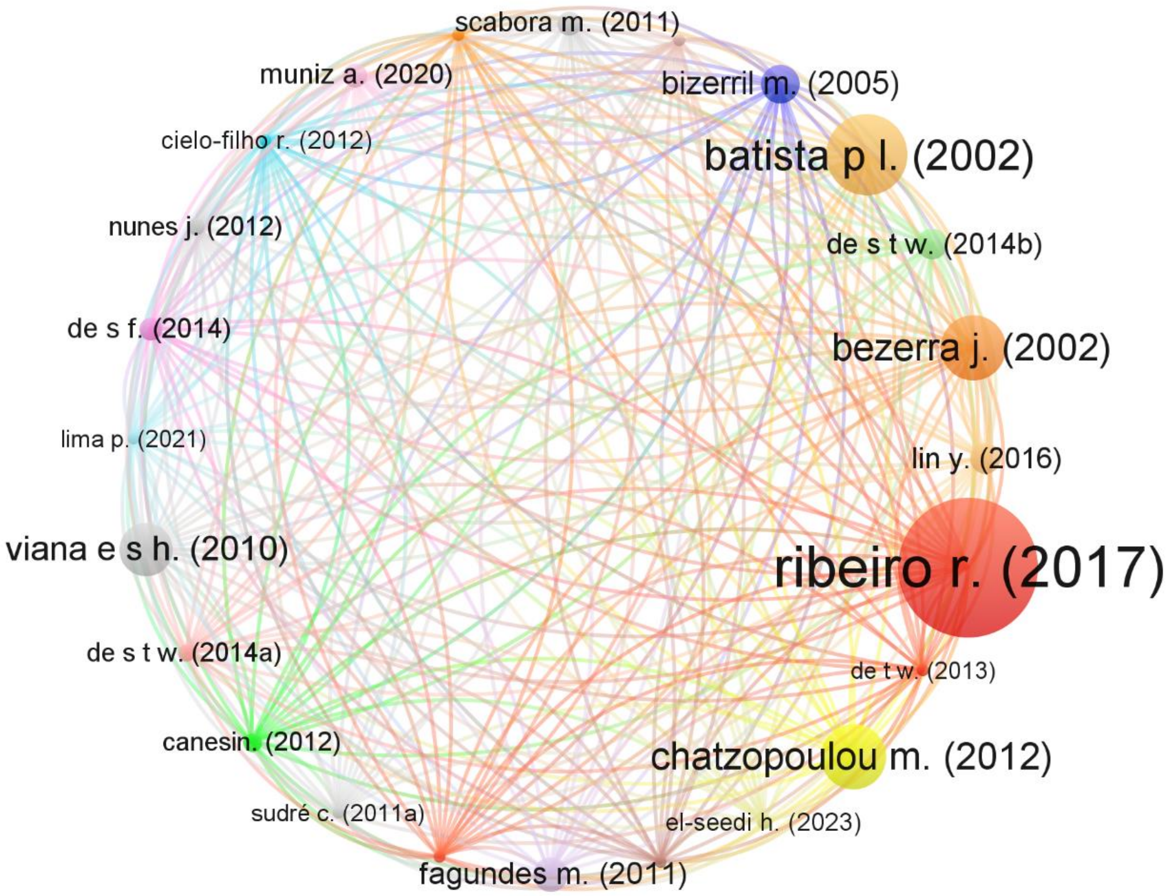

Figure 4. Most cited Global documents on Fava- d'anta (1969 - 2023).

The second study focuses on the toxicity of astilbin, a flavonoid isolated from *Dimorphandra mollis*, on worker ants of *Atta sexdens rubropilosa* [53]. The plant is highlighted for its high concentrations of astilbin in its peduncles and flowers, which exhibit insecticidal properties by increasing ant mortality when incorporated into their diet. This research is significant for developing alternative ant control strategies to mitigate the economic damage caused by these pests in monocultures.

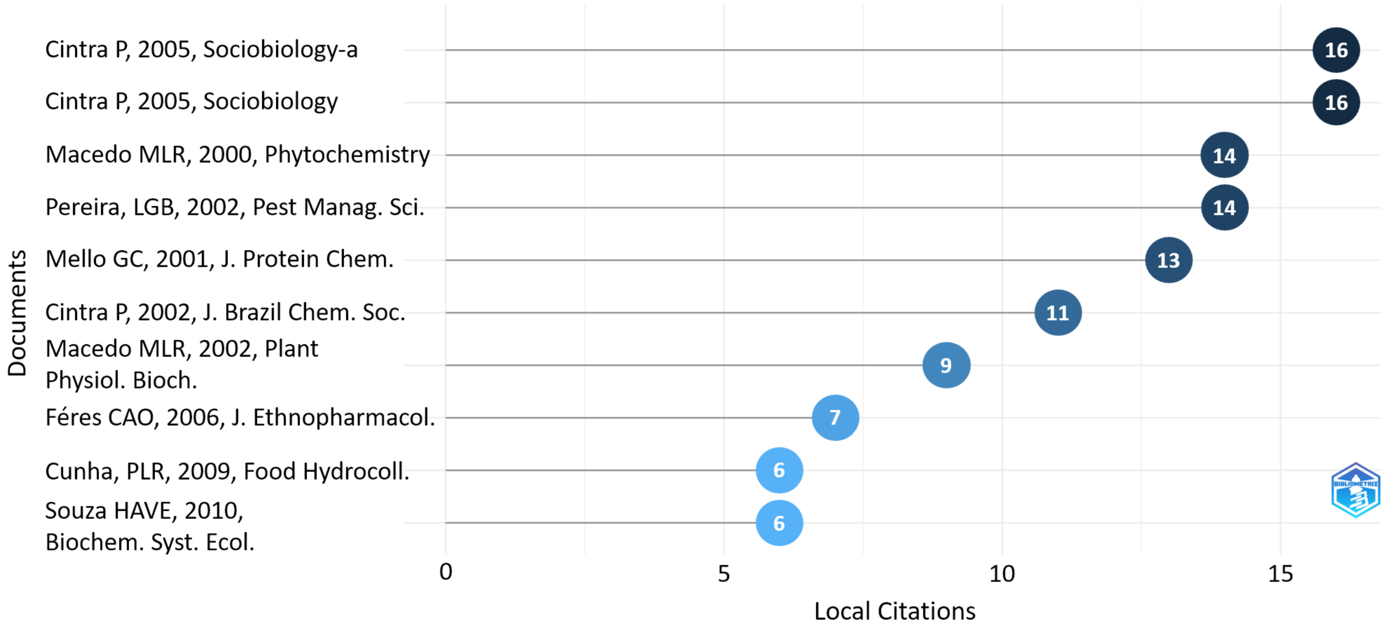

Figure 5. Most cited Brazilian documents on Fava- d'anta.

Trend Identification through Keywords

The word cloud (Figure 6) and Word Network (Figure 7) reveals that the research is strongly focused on cerrado plants, especially *Dimorphandra mollis*, with 24 occurrences, while *Dimorphandra garneriana* was recorded only 4 times, suggesting that *D. mollis* is the main fava d'anta studied scientifically. In addition, the term cerrado appears 11 times, reinforcing the geographical context of the research. The presence of terms referring to polyphenols such as flavonoid (n=8) and flavonoids (n=7) and isolated substances such as rutin (n=9), astilbin (n=9) and quercetin (n=3) indicates a great interest in studying the therapeutic properties of these plants. Flavonoids can act to protect against oxidative stress and regulate the immune response, making them promising as natural therapeutic agents and nutraceuticals for promoting health and well-being [53].

The focus on defense properties, such as trypsin inhibitor (n=9), toxicity (n=6) and insecticidal plants (n=5) points to the study of cerrado plants as potential natural alternatives in pest control, with an emphasis on *Spodoptera frugiperda* [55]. This is reinforced using *Anticarsia gemmatalis* (n=4) and botanical insecticides (n=3) as a promising approach [54]. In addition, the expression conservation genetics (n=4), which indicates that there is a concern for the preservation of cerrado species and their genetic diversity, highlights the role of research in environmental conservation.

Figure 6. Word Cloud on Fava -d'anta (1969 - 2023)

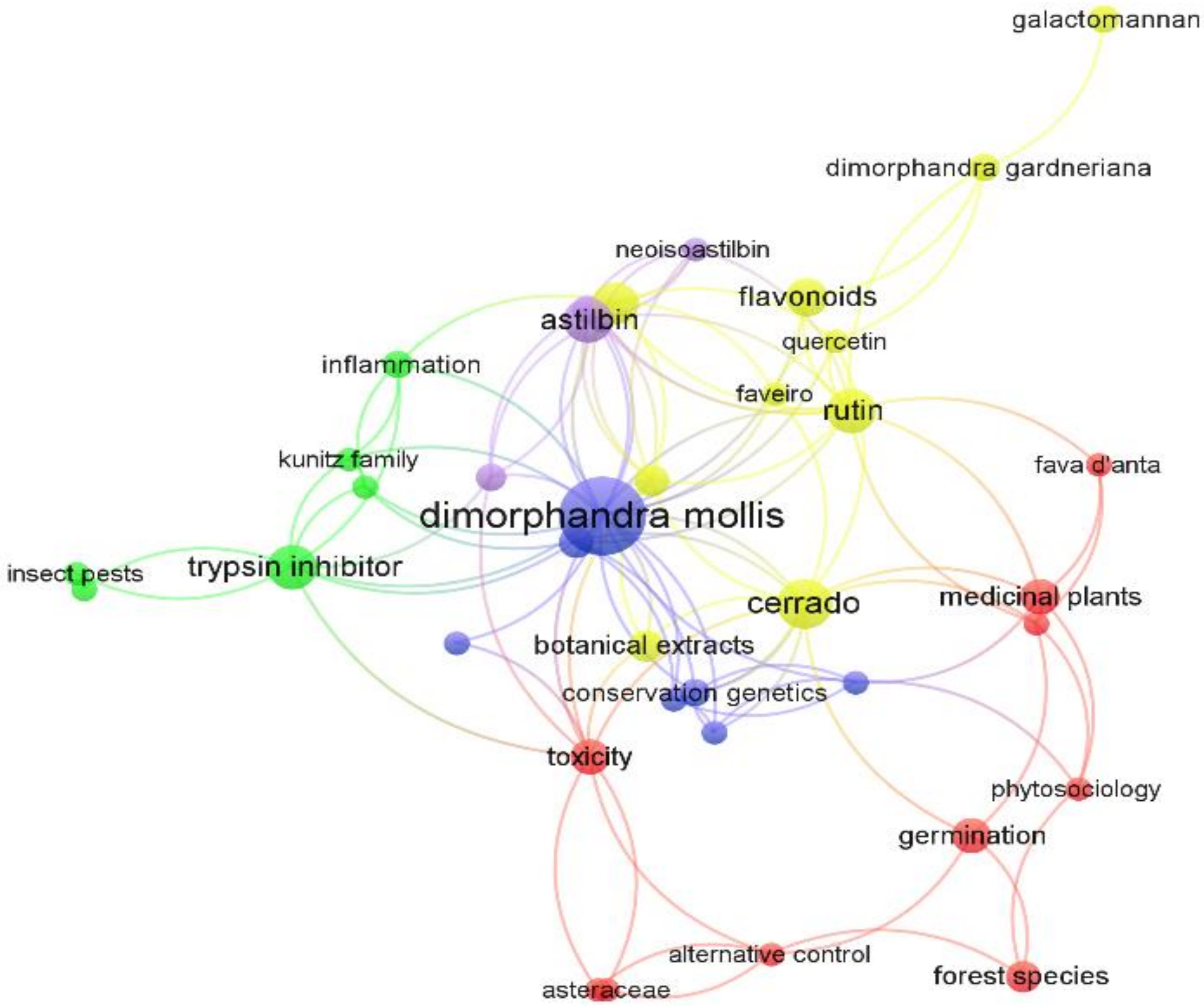

Figure 7. Word Network on Fava- d'anta (1969 - 2023).

Below, Figure 8 presents the thematic evolution of research on *Fava d'anta* over time. Between 1969 and 2009, the most frequent keywords were **flavonoids**, ***Dimorphandra mollis* seeds**, ***Dimorphandra mollis*** and **quercetin**. During this period, the emphasis was on identifying and characterizing the bioactive compounds present in the plant's seeds and, specifically, quercetin, a flavonoid with well-known antioxidant and anti-inflammatory properties. The research therefore focused on the chemical and phytochemical aspects of the plant, with a clear approach towards isolating bioactive compounds and understanding their therapeutic potential.

From 2010 to 2015, the keywords began to include **antioxidant**, **in-vitro**, **nonhuman**, and **condensed tannins**. This indicates a shift in research focus, with an adoption of **in vitro** experimental methods to test the biological and pharmacological properties of compounds, emphasizing **antioxidant** activity and **condensed tannins**. The inclusion of **nonhuman** suggests the use of animal or plant models to test the effects of the compounds, a common trend in pharmacological studies. During this period, the interest in the **antioxidant** activity of *Dimorphandra mollis* increased, reflecting a growing recognition of the role of antioxidants in disease prevention and combating oxidative stress.

Between 2016 and 2023, the most common keywords were **in-vitro**, **cerrado**, **Fabaceae**, **antioxidant**, **flavonoids**, ***Dimorphandra mollis***, **quercetin**, and **plant extract**. The mention of **cerrado** highlights the geographic and ecological context of the plant, which is native to this region, emphasizing interest in local biodiversity and the potential sustainable uses of natural resources. The inclusion of **Fabaceae**, the botanical family of *Dimorphandra mollis*, reflects a broader approach to the study of plants from this family, known for their bioactive compounds. The increased frequency of terms such as **plant extract** reinforces the focus on using plant extracts as sources of bioactive compounds for the development of new drugs or supplements. The consistent presence of **flavonoids**, ***Dimorphandra mollis***, and **quercetin** throughout this period underscores the ongoing interest in flavonoids and their properties, with a focus on the antioxidant and therapeutic effects of the plant, reflecting the growing appeal of bioprospecting and sustainability in scientific research.

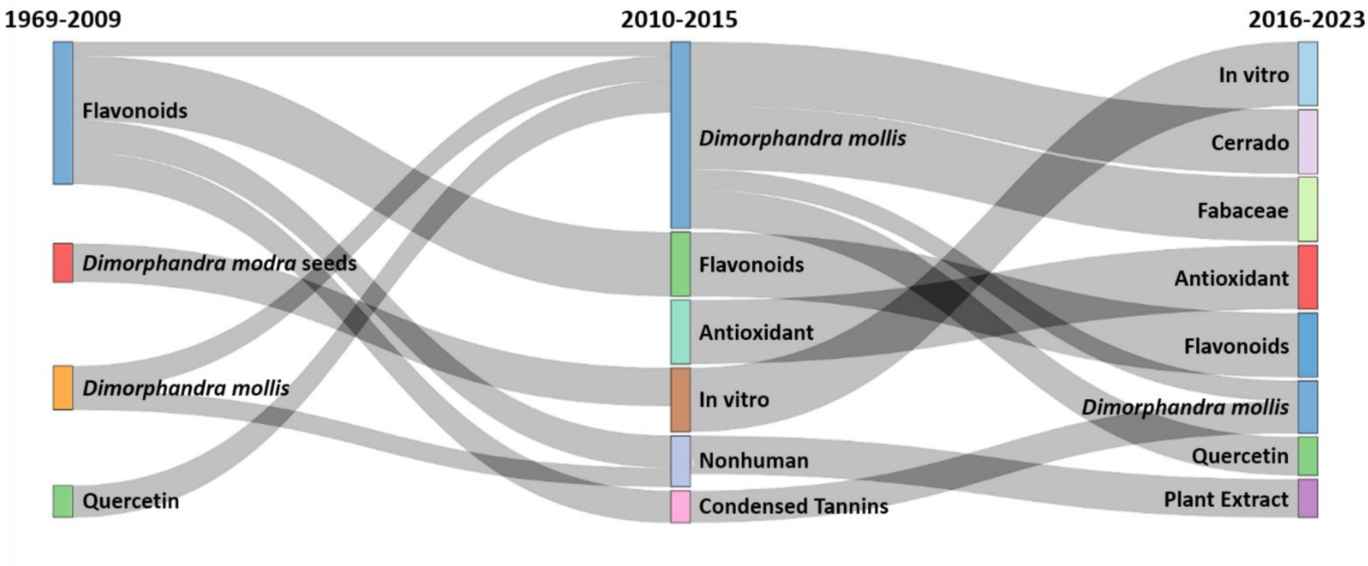

Figure 8. Thematic Evolution of Research on Fava -d’anta (1969 – 2023)

Key authors and their affiliations

Analysis of the bibliometric data shows that the authors listed have different levels of impact in research related to fava -d'anta, with emphasis on metrics such as the h-index, g-index, m-index, total citations (TC), number of publications (NP) and initial year of publication (PY_start).

Authors such as MACEDO M, with an h-index of 6 and 301 total citations, and OLIVEIRA A, with a relatively high m-index of 0.35 and 247 total citations, indicate greater consistency and recognition in their scientific contributions (Figure 9). VIEIRA I, with an m-index of 0.438 and a more recent start of publications (2009), suggests a more relevant scientific output over a shorter period, which reflects a growing impact.

On the other hand, RIBEIRO R have a high m-index (0.364), even with only four publications since 2014, suggesting that their publications have received significant attention in relation to the time they have been active. PETACCI F and MALASPINA O show good stability in the h and g indices, indicating consistent impact and well-cited contributions from the early 2000s.

The analysis of local citations highlights the impact of some authors in specific contexts, such as research networks or thematic areas related to fava d'anta (Figure 10). MALASPINA O leads with 63 local citations, closely followed by PETACCI F (61). This reflects that their publications not only have global relevance (with high h and g indices), but also play a significant role in more focused research networks or communities.

Researchers such as FERNANDES J (58) and BUENO O/CINTRA P (49 each) also have considerable influence in the local context, even if they didn't stand out as much in terms of global citations. MACEDO M, with 44 local citations, consolidates his relevance in both broad and regional contexts. Similarly, VIEIRA I, even with only 11 local citations, maintains a balance between local and global recognition (according to the m and h indices previously analyzed).

In this way, the fava d'anta is likely to attract a diverse network of researchers, with some central figures such as MALASPINA O and PETACCI F dominating both the local and global impact. Authors such as MACEDO M and VIEIRA I stand out for their mixed influence, while others make niche contributions that are relevant to the advancement of the topic. This network reflects an integration between consolidated studies and new research fronts that are yet to reach maturity in terms of citations.

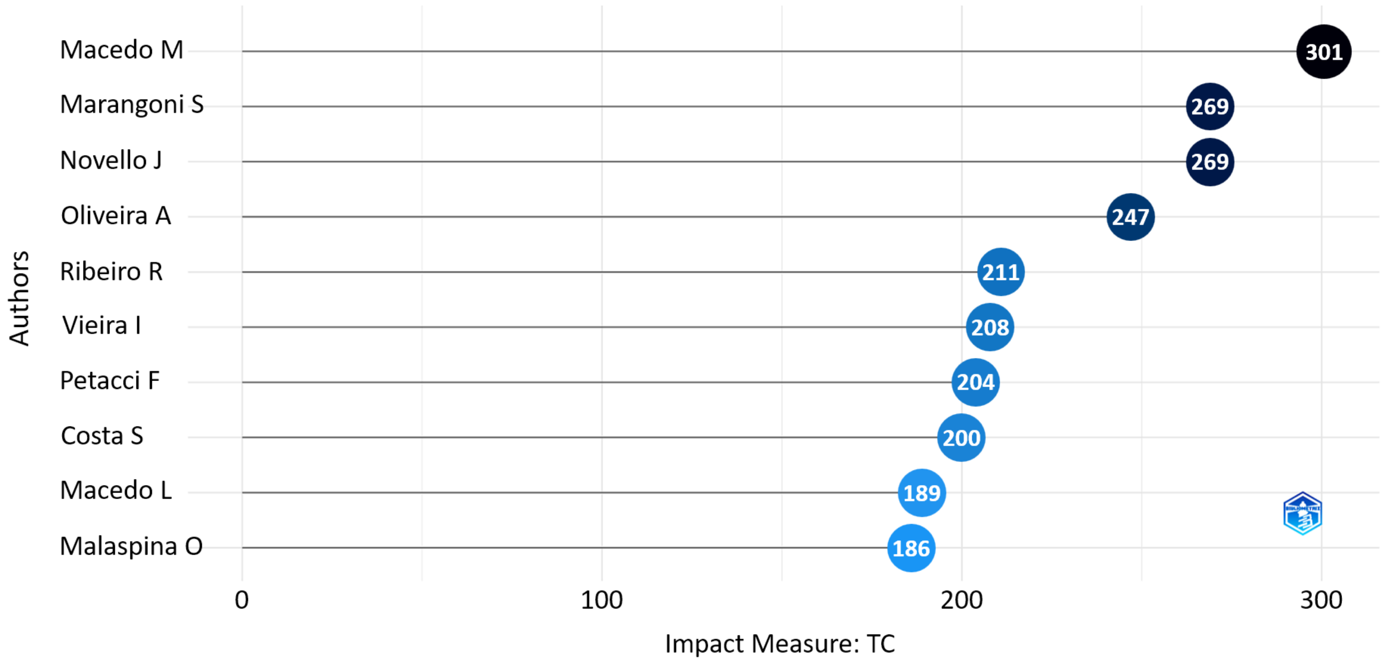

Figure 9. Research Impact of Authors on Fava -d'anta: Total Citation Count

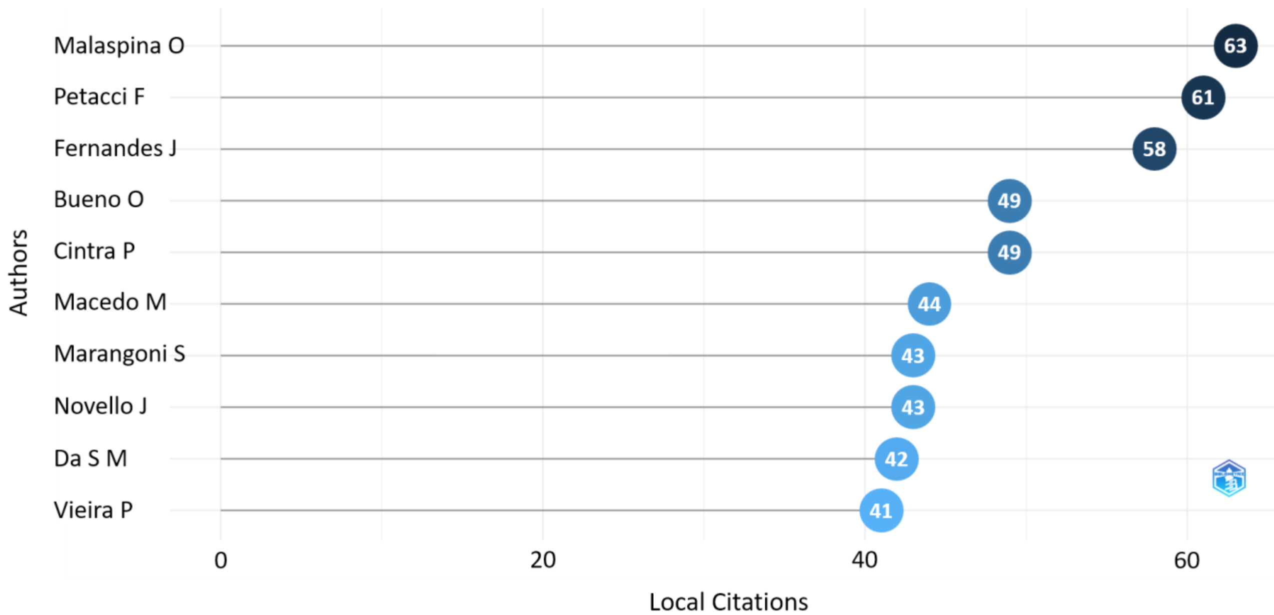

Figure 10. Most Cited Local Authors in Fava- d'anta Research (1969–2023)

The analysis of affiliations (Figure 11 and Figure 12) highlights the prominence of Brazilian institutions in the field studied, with the University of São Paulo (USP) leading the way in terms of the number of articles (21). Such a pattern has also been reported in other bibliometric studies related to natural products, as USP is recognized as one of the most prominent research institutions in Brazil, not only in the field of medicinal plants/phytotherapy but also across a wide range of scientific disciplines. This reflects the institution's strength in scientific production in Brazil and its centrality in topics of national relevance [56–58]. Other notable institutions include the Federal University of Minas Gerais (UFMG), the Federal University of Goiás (UFG), and the Federal University of Viçosa (UFV), all of which have published 14 or more articles, demonstrating their significant contribution to research related to fava-d'anta and related áreas (Figure 7).

The Federal University of Ceará (UFC) also appears with 14 publications, reinforcing the impact of institutions in the Northeast of Brazil in this scientific context. Similarly, the Federal University of Paraíba (UFPB) contributes significantly with 9 publications, highlighting the active participation of Northeastern institutions in advancing research. This regional representation underscores the importance of leveraging the unique biodiversity and cultural heritage of the area to drive scientific discovery and innovation.

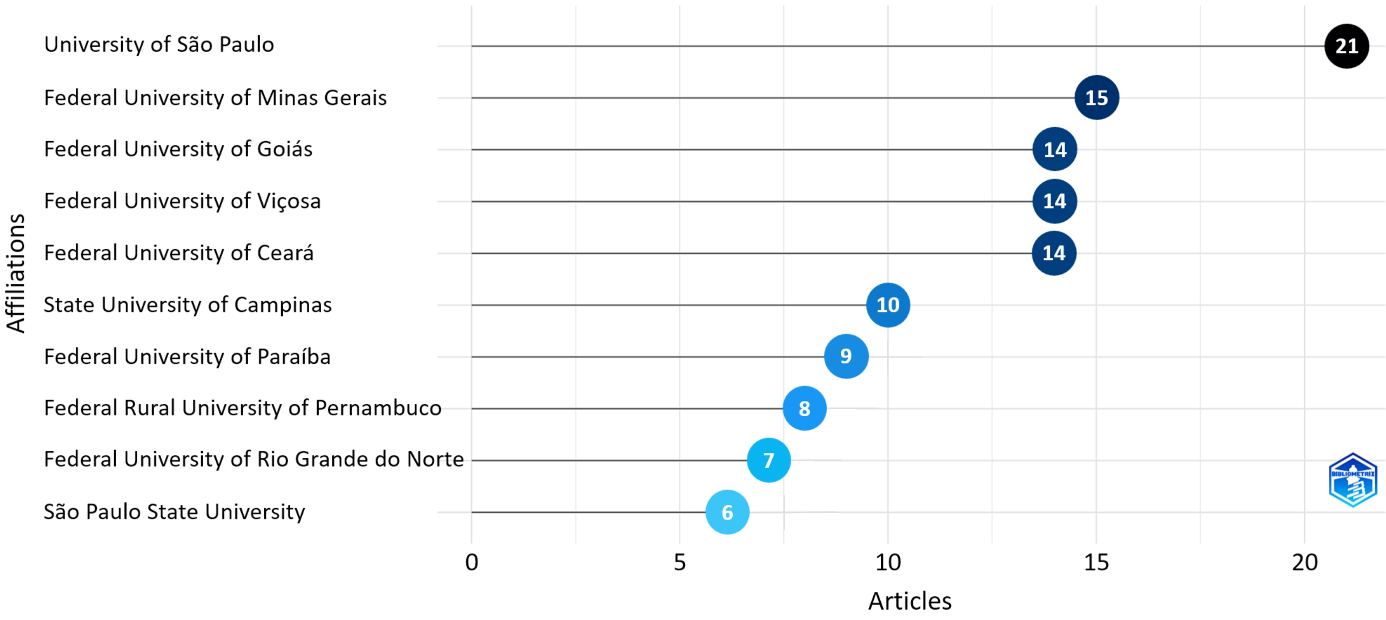

Figure 11. Most Relevant Institutional Affiliations in Fava- d'anta Research (1969–2023)

An analysis of the cumulative number of publications per institution over the years provides an overview of scientific production at the main Brazilian universities (Figure 8). USP stands out as the undisputed leader, maintaining a stable output of 21 publications from 2017 to 2023, consolidating its position as a benchmark in the country. With a consolidated scientific trajectory and robust resources, the university continues to be a center of excellence in various areas of research, remaining ahead of the rest.

UFMG has shown significant growth, particularly after 2020, when its publications increased from 12 to 15. This surge likely reflects increased investment in research and a greater visibility in specific topics. Though slightly behind USP, UFMG has excelled in areas of great scientific impact, justifying its place among the most productive institutions.

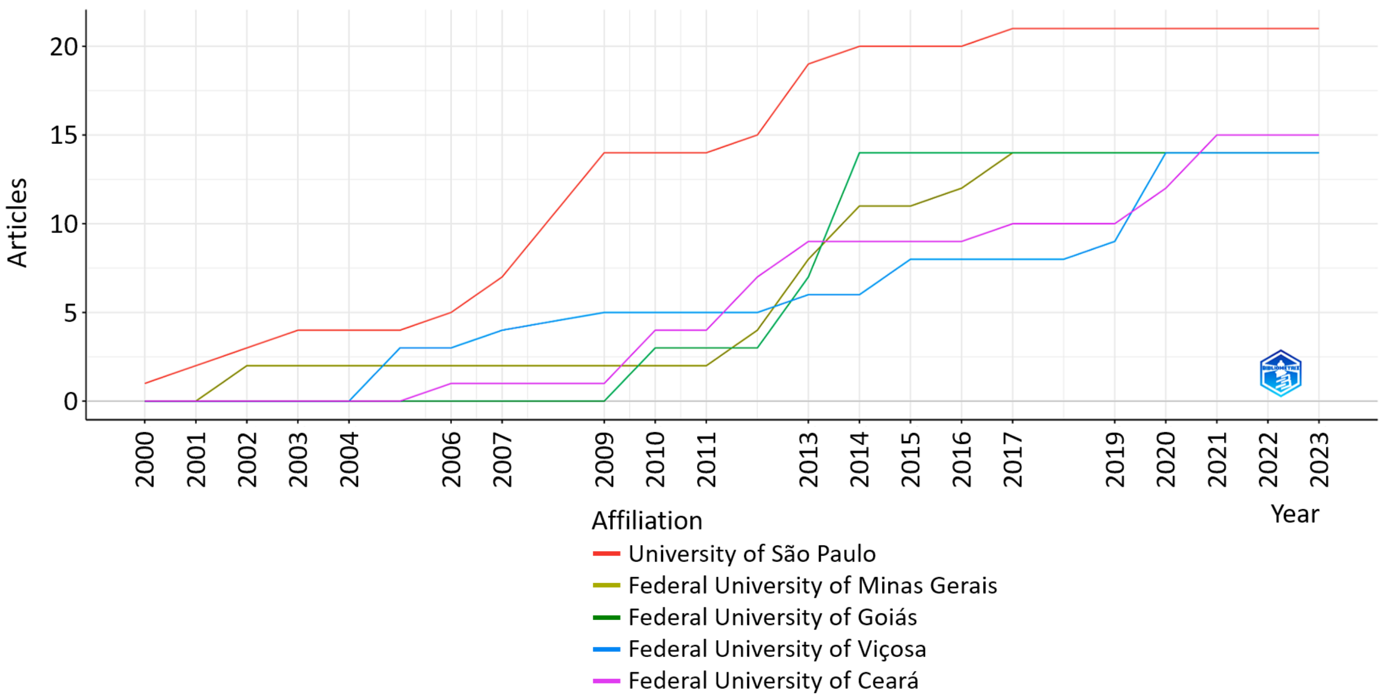

Figure 12. Temporal Evolution of Publications by Institutional Affiliation

In recent years, UFC has seen considerable growth, advancing from 6 publications in 2014 to 14 in 2023. This increase highlights the strengthening of research groups and the growing investment in science and technology in the Northeast, consolidating UFC as an emerging research hub.

UFG has demonstrated steady growth, reaching 14 publications by 2023. Although its expansion has been more gradual compared to UFMG and UFC, UFG has established itself as a relevant institution, maintaining competitive levels of scientific output.

This analysis underscores the growing regional representation in Brazil's scientific landscape, with institutions from different regions contributing significantly to the overall research output. The role of the Northeast, particularly through UFC and UFPB, reflects the importance of investing in local knowledge and innovation to further enrich Brazil's scientific development.

Global Distribution of Scientific Production

A look at the citations of the articles published in the different countries uncovers some important trends in the field studied, particularly the difference in the number of articles published and the impact of the publications, measured by the average number of citations (Figure 13).

The analysis of citations by country reveals that Brazil leads not only in the total number of publications, but also in the total number of accumulated citations, with 1949 citations and an average of 18.60 citations per article. This high number of citations reflects the significant impact of Brazilian scientific productions in the area, indicating that articles produced in Brazil have wide visibility and are frequently referenced in international literature. This trend has also been observed in other bibliometric studies involving botanical taxa with native and endemic representatives in Brazil, such as *Croton* spp., *Copaifera* spp., *Psidium cattleyanum* and *Petiveria alliacea* [60–63].

.The United States, with 48 publications and an average of 16 citations per article, has a considerable impact, although the number of citations is lower than in Brazil.This pattern suggests that, despite the large volume of publications, recognition of US productions is more dispersed than in Brazil.

Greece, with 44 publications and an average of 44 citations per article, stands out for its high average number of citations, indicating that although the number of publications is relatively small, Greek research is highly influential and has been widely referenced in scientific literature.

In summary, Brazil stands out not only for the volume of publications but also for the relevance and impact of its scientific output, being widely cited in international research. Other countries, such as the United States and Greece, also have a significant impact, but Brazil excels in terms of total citations.

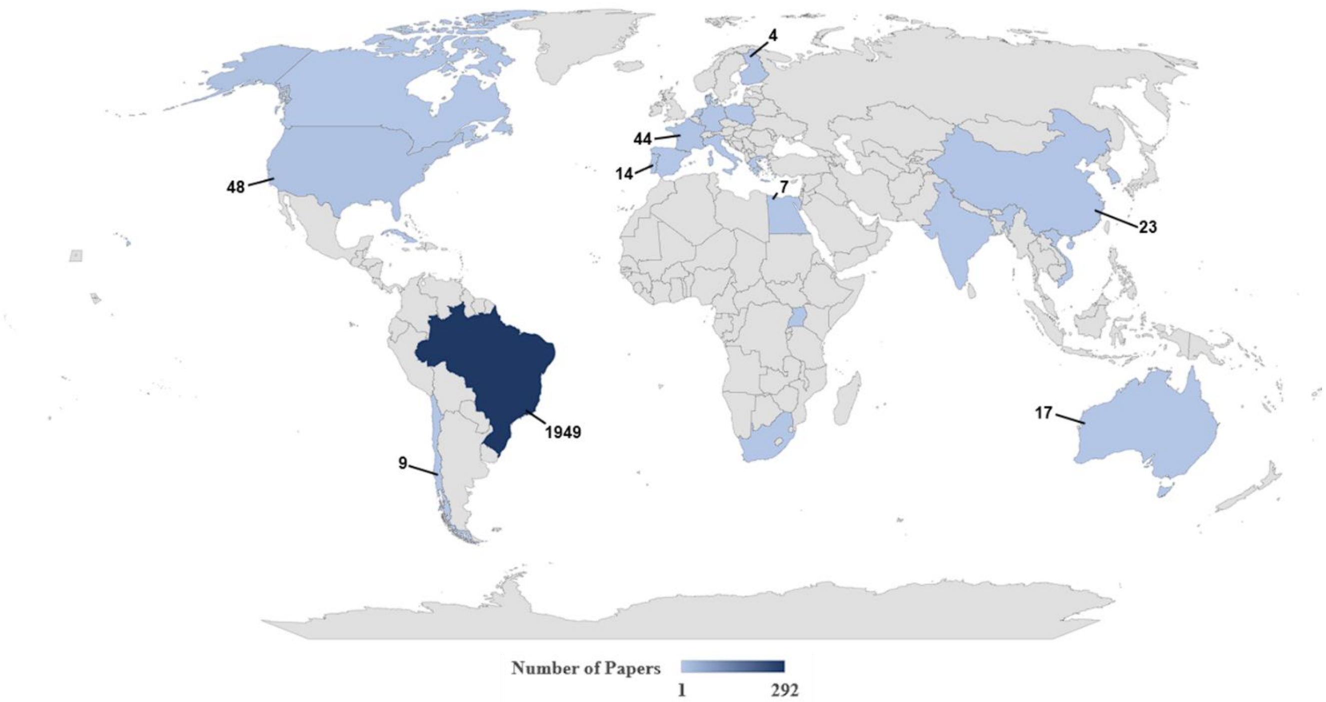

Figure 13. The collaboration network is illustrated on a world map, highlighting publications and the total number of citations by country, with an emphasis on the top 9 countries. Each country is color-coded according to the number of documents, as indicated by the scale bar, and the numbers represent the total citations.

Translational Context and Potential Applications

The bibliometric trends observed in the scientific production on *Dimorphandra* spp., particularly *Dimorphandra mollis*, suggest strong translational potential across multiple applied fields. In the domain of pharmacology, the high frequency of studies focusing on flavonoids such as quercetin, rutin, and astilbin reinforces the plant's value as a natural source of bioactive compounds with recognized antioxidant, anti-inflammatory, and cytotoxic properties [63]. These molecules are frequently associated with the modulation of key biochemical pathways involved in oxidative stress, inflammation, and cellular apoptosis. These mechanisms are highly relevant to the prevention and treatment of chronic diseases, including cancer, metabolic syndromes, and neurodegenerative conditions [64,65]. The emphasis on *in vitro* assays, often followed by *in vivo* validation, as well as the incorporation of pharmacodynamic and toxicological evaluations, reflects a methodological maturity that supports the integration of these phytocompounds into preclinical drug discovery pipelines. Moreover, the potential for developing nutraceutical formulations and functional phytomedicines based on these compounds aligns with current trends in personalized and preventive medicine.

In the field of agriculture, the documentation of insecticidal and toxic effects of extracts from *D. mollis* on pest species such as *Atta sexdens rubropilosa*, *Spodoptera frugiperda*, and *Anticarsia gemmatalis* illustrates the plant's promising role as a source of botanical pesticides. Such findings offer viable and environmentally compatible alternatives to synthetic insecticides, responding to the growing need to balance pest control efficacy with the safety of both ecosystems and human health [66]. The presence of specific allelochemicals with larvicidal and antifeedant effects also opens avenues for the development of formulated bioinsecticides, which could be incorporated into Integrated Pest Management (IPM) strategies. These applications contribute to the reduction of chemical residues in food chains and promote the valorization of native biodiversity in the design of sustainable agricultural technologies [67].

The recurring identification of compounds such as condensed tannins, trypsin inhibitors, and plant-based enzymes broadens the scope of applicability toward biotechnological innovations. These compounds are of interest for the development of enzyme-modulating agents, natural preservatives, and biocatalysts, with potential applications in sectors such as food technology, cosmeceuticals, and bioprocess engineering [69–73]. For example, trypsin inhibitors derived from plants are being investigated for their anticarcinogenic and antibacterial effects [69, 74], while condensed tannins have been studied for their role in ruminant nutrition, including the modulation of gut microbiota and reduction of methane emissions [75]. In addition, the bioprospecting of *Dimorphandra* species may contribute to the production of biodegradable materials, including bioplastics and phytopolymers, supporting the advancement of circular economy models [76,77].

Beyond direct applications, the frequent recurrence of terms such as Cerrado, biodiversity, bioprospecting, and conservation genetics underscores the broader environmental relevance of this body of research. The Cerrado biome, recognized as a global biodiversity hotspot, faces intense anthropogenic pressure. Within this context, *Dimorphandra mollis* functions as both a bioindicator species and a valuable ethnobotanical resource, playing a key role in ecosystem monitoring and restoration strategies [79]. Studies that address the genetic variability, geographic distribution, and ecological functions of *Dimorphandra* spp. contribute to public policy formulation directed at the conservation and sustainable use of native flora [78,79]. They also support the implementation of benefit-sharing mechanisms as outlined by the Nagoya Protocol [80]. Furthermore, the ethnobotanical importance of the plant, especially among traditional communities in Central and Northern Brazil, supports its integration into community-based biodiversity management programs.

From an institutional perspective, the active participation of public universities, particularly those located in the Northeast and Central-West regions of Brazil, such as UFC, UFPB, UFG, and UFMGl, reflects the development of academic infrastructures that support regional scientific autonomy and innovation ecosystems. These institutions play a pivotal role not only in knowledge generation but also in technology transfer, intellectual property development, and the training of specialized personnel for biodiversity-based industries. Their involvement strengthens the connection between academic research and productive sectors, fostering favorable conditions for the emergence of bio-based industries focused on the sustainable use of native species.

In summary, the literature on fava d'anta (*Dimorphandra* spp.) not only contributes to the scientific understanding of the phytochemical and ecological properties of these plants but also aligns with strategic priorities in pharmaceutical innovation, sustainable agriculture, biotechnology, and environmental conservation. The consolidation of research on this genus demonstrates its importance as a multipurpose biological resource with applications that are increasingly relevant to global challenges, including the development of safer therapeutic options, cleaner food production systems, and climate-resilient solutions for sustainable development [81,82].

Fava -d'anta: main phytoconstituents and biological activities

The faveira species (*D. mollis* and *D. gardneriana*) share a comparable phytochemical composition (Figure 8), characterized by a high concentration of polyphenolic compounds (Figure 14), particularly tannins and flavonoids. Key flavonoids identified in these species include isoquercitrin, rutin, and quercetin [83–86]. Other phenolics such as kaempferol, astilbin and neoisoastilbin have also been reported [87–89].

Rutin is a natural flavonoid with significant pharmacochemical potential, especially in the context of inflammation and oxidative stress. Its mechanism of action includes antioxidant properties, which help neutralize free radicals, and anti-inflammatory effects, which are achieved by inhibiting pathways such as NF-κB [91] and reducing cyclooxygenase-2 (COX-2) activity [91]. In addition, rutin can protect cells from damage induced by chemotherapeutic compounds, such as 5-fluorouracil, by reducing inflammation and improving the integrity of the intestinal mucosa [92].

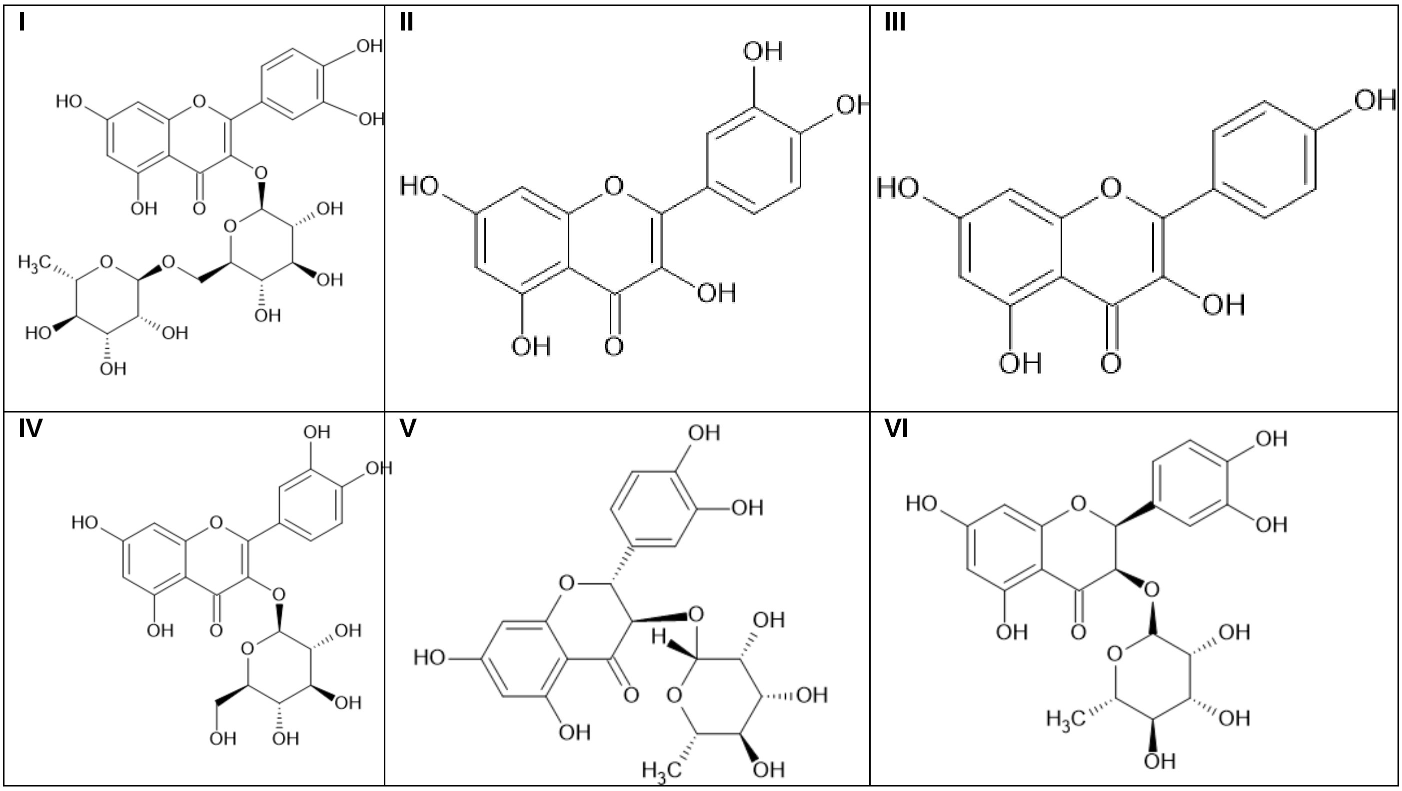

Figure 14. Most common chemical constituents described in Fava- d'anta. I – Rutin. II – Quercetin. III – Kaempferol. IV – Isoquercitrin. V – Astilbin. VI – Neoisoastilbin.

The aglycone of rutin, quercetin, has various bioactive effects, including anti-inflammatory, antioxidant and anti-tumor properties. One of quercetin's mechanisms of action involves modulating the inflammatory response, where it can inhibit the production of pro-inflammatory cytokines such as tumor necrosis factor (TNF) and interleukin-6 (IL-6) [93] . In addition, quercetin can interfere with the signaling of cellular pathways associated with the proliferation and migration of tumor cells, contributing to a reduction in the viability of glioma cells. These effects make quercetin a promising candidate for adjuvant therapies in the treatment of brain tumors, such as gliomas [94].

Kaempferol has also been shown to be a potential drug for use in cancer. Its proposed biochemical mechanisms include inducing apoptosis in cancer cells, inhibiting cell growth and modulating the host's immune response [95]. It acts through intrinsic and extrinsic apoptotic pathways, as well as activating signaling cascades such as PLC, PKC and MEK1/2. In addition, kaempferol can reduce the expression of genes related to mitochondrial biogenesis and glucose uptake, contributing to cell death in various types of cancer.

Isoquercitrin exhibits potent antioxidant properties, effectively scavenging reactive oxygen and nitrogen species (ROS/RNS), inhibiting pro-oxidant enzymes, and enhancing the activity of antioxidant enzymes [96].

It neutralizes free radicals, such as superoxide and hydroxyl radicals, protecting cells from oxidative stress [97]. Additionally, isoquercitrin shows chemoprotective potential, aiding in the prevention of diseases like cancer, diabetes, and cardiovascular disorders [98]. These effects underscore its value in promoting health and reducing the risk of various pathological conditions, positioning isoquercitrin as a promising candidate for dietary supplementation and complementary therapies.

Astilbin is a flavonoid that exhibits a variety of promising mechanisms of action and biological effects. One of its primary attributes is its strong antioxidant capacity, which manifests through the scavenging of reactive oxygen species (ROS). This effect is mediated by an electron transport pathway, helping to protect cells against oxidative stress, a contributing factor to various diseases [100]. Additionally, astilbin demonstrates significant actions on the central nervous system, showing antidepressant effects. These effects are possibly attributed to the stimulation of the Brain-Derived Neurotrophic Factor (BDNF) signaling pathway, a crucial protein for neuroplasticity and mental health [100]. Studies indicate that astilbin can reduce depression-related behaviors in experimental models, suggesting its potential as a therapeutic agent for affective disorders [99]. Regarding neurodegenerative diseases, such as Alzheimer's disease, astilbin has proven effective in enhancing the expression of BDNF and CREB, as well as increasing the activity of the AKT/GSK-3β signaling pathway [101]. Neoisoastilbin is a flavonoid structurally related to astilbin and has the ability to modulate inflammatory pathways and can inhibit the activation of the NLRP3 inflammasome, which is a crucial component in the inflammatory response associated with gouty arthritis [102].

Despite the potential of *Dimorphandra* spp. in various research fields, there are significant gaps in the literature, particularly regarding the extraction of essential oil and the study of the volatilome of the species' flowers. There are no records of studies focused on the extraction and characterization of volatile compounds present in *Dimorphandra* spp., which opens a promising field for future investigations. This aspect is crucial, as the volatilome may contain bioactive compounds with therapeutic properties yet to be explored, or even provide valuable information for chemical ecology, such as understanding plant interactions with floral visitors and pollinators. Techniques such as Headspace or SPME (*Solid Phase Microextraction*) could also be applied, even in cases where the number of volatile compounds is reduced, allowing the detection of compounds at low concentrations and providing a more detailed analysis of the plant's volatile profile.

Additionally, it is notable that there is a lack of studies utilizing advanced techniques, such as LC-MS (Liquid Chromatography coupled with Mass Spectrometry) or UPLC (Ultra Performance Liquid Chromatography), for the detailed chemical analysis of extracts from different parts of the plant, such as leaves, flowers, fruits, roots or stems. These techniques are essential for a deeper understanding of the phytochemical composition and for identifying bioactive compounds at low concentrations. Moreover, there is a scarcity of studies addressing the whole phytocomplex, as most research focuses primarily on isolated plant constituents rather than the interactions and combined effects of the full spectrum of compounds..

In addition to these methodological gaps, an important issue lies in the geographical focus of existing studies. Research on *Dimorphandra* spp. from the Caatinga biome remains scarce compared to the extensive studies conducted on species from the Cerrado biome. This discrepancy underscores the need for comparative analyses to evaluate chemical variation under distinct environmental conditions, particularly those shaped by the geographical and ecological differences between these biomes.

These bibliometric shortcomings highlight the urgent need for studies employing advanced analytical techniques to investigate the metabolome of *Dimorphandra* spp., with particular emphasis on its largely unexplored volatilome. Expanding research in this area is critical to uncovering the diversity of volatile and non-volatile metabolites, which could provide valuable insights into the plant’s bioactive potential and ecological interactions, thereby broadening perspectives for its biotechnological applications.

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