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Mistletoe in the 21st Century: A bibliometric analysis from a phytosanitary perspective

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Abstract

In recent years, the study of mistletoe has increased notably, with a particular focus on its medicinal properties. However, this has left a gap in the phytosanitary impact of the plant on forest ecosystems. In this study, different bibliometric parameters were analyzed to characterize the research published on mistletoe worldwide between 2004 and 2025. This period was established due to the technological advances and climatic changes that have taken place in the last decade. Two databases were used: one consisting of 253 articles from Web of Science and another database of 104 articles related to forestry topics obtained from Scopus, PubMed, Lens.org, and Google Scholar. The results show that the most studied mistletoe species were *Viscum, Phoradendron,* and *Arceuthobium,* typical of temperate ecosystems, while the most frequently referenced host was *Pinus sylvetris* L. The countries with the greatest scientific production were the United States of America, Mexico, and Brazil. Of the analyzed studies, 48.9 % focused on plant sciences, 22.8 % on forestry sciences, 4.3 % on pharmacology, and 4.1 % on integrative and complementary medicine. It is concluded that research on mistletoe in forest ecosystems remains limited and that new technologies should be integrated into future research. Furthermore, existing studies focus on genera of temperate zones genera, leaving species from subtropical or arid ecosystems underexplored. This represents an area of opportunity area for future research.

Keywords: Pests, hemiparasites, forest ecosystem, bibliometrics, ecology.

Introduction

Forests are vital to the functioning of the Earth, both for the provisioning, regulating, and supporting ecosystem services they provide (Pan et al., 2011) and for their important role in interspecific ecological dynamics (Watson et al., 2018). However, in recent years, factors such as climate change have intensified their vulnerability (Bell et al., 2020), altering their ecological balance (Ndagurwa et al., 2014) and significantly reducing individual vigor (Allen et al., 2015). In turn, they become more susceptible to attack by biotic factors such as insects, pathogens, and hemiparasitic plants (Camarero et al., 2025). Under this scenario, one of the most notable agents due to its wide distribution and notable impact are mistletoes (Ayres & Lombardero, 2000), whose proliferation has increased alarmingly in recent decades globally (Sturrock et al., 2011).

Mistletoe is the common name for hemiparasitic plants that infest trees and shrubs in order to obtain the necessary elements to survive (Endara-Agramont et al., 2022). There are three families of mistletoe species of forest importance: i) *Santalaceae* which includes around 550 species from 40 genera among which some of great importance stand out,

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such as *Viscum* (European mistletoe) (González de Andrés et al., 2024), *Phoradendron* (American mistletoe) (Dawson et al., 1990), and *Arceuthobium* (dwarf mistletoe) (Tinnin et al., 1999) these genera mainly affect woody species of the *Pinus, Juniperus, Arbutus, Populus, Abies*, which are typical of temperate ecosystems (Der & Nickrent, 2008). ii) *Loranthaceae*, a family that includes around 73 genera and 1,000 species, is considered one of the most diverse groups of hemiparasitic plants. *Cladocolea* (Díaz-Limón et al., 2016), *Psittacanthus* (Silva et al., 2021) and *Struthanthus* (González & Morales, 2004) are three important genera in this family and are commonly known as grafts, a term that, although it is not a graft in the traditional horticultural sense, has acquired that name due to the similar way in which it joins another tree (Coria Ávalos et al., 2018). They are mainly distributed in tropical and subtropical areas, although they can also be found in temperate zones, and their main hosts belong to the genera *Quercus, Alnus, Cedrela* and *Ficus* (Grajales et al., 2022). Finally, iii) the *Misodendraceae* family that only has species of *Misodendrum genus* (Henríquez-Velásquez et al., 2012) which are mistletoes confined to South America since they only parasitize individuals of the genus *Nothofagus* (Leadlay & Jury, 2006) (See Supplementary Material 1).

In response to this problem, some recent studies have explored how the dynamics of phytosanitary-important mistletoes alter the physiology of their hosts (Das et al., 2016). Specifically, it has been suggested that their uncontrolled expansion, in addition to diminishing forest health, compromises the resilience of forests, which are already vulnerable to climatic conditions in adverse environments (Rigling et al., 2010).

Despite the ecological importance of these parasitic organisms in forest dynamics (Press & Phoenix, 2005), the study of their impact on forest health is fragmented (Lira-Noriega et al., 2013), both conceptually and geographically (Mellado & Zamora, 2017). This dispersion arises from the diversity of approaches used in the study of mistletoe, many of which transcend the strictly forestry (e.g., medicine, fauna, biology, taxonomy) (Mathiasen et al., 2008). Therefore, the importance of conducting a critical analysis that not only integrates relevant findings on the phytosanitary impact of mistletoe in forests, but incorporates cutting-edge detection and monitoring techniques at the global level is highlighted (Zhang et al., 2020). This comprehensive approach will enrich the amount of available knowledge and facilitate its transfer among affected geographic regions. At the same time it will guide the development of a state-of-the-art approach that provides the community with a broader perspective, enabling the identification of gaps and trends that can guide the development of future research.

Thus, this bibliometric analysis integrates multidisciplinary evidence on mistletoe in forest systems. The main objective of this study is to compile a document that serves as a state of the art of global research on this hemiparasitic plant and its phytosanitary impact. It is hypothesized that existing research has focused primarily on descriptive and geographic distribution approaches (Bilgili et al., 2020), and that it focuses on certain mistletoe genera, thus creating a gap in the study of other genera of phytosanitary importance, revealing areas of opportunity for future research.

Materials and Methods

Compilation of publications

Publications in scientific journals (scientific articles) were considered, excluding gray literature. The purpose was to systematize the state of the art of the study of mistletoe under the current global perspective and conditions, considering publications in the last 21 years (from January 2004 to January 2025) to include relevant scientific studies aligned with the contemporary era. The determination of this period (21 years) is based on the important technological advances developed at the beginning of the XXI century, these advances refer to an increase in the use of remote sensing, programming, etc. for urban, agricultural, and environmental monitoring purposes (Cheng et al., 2024). In addition, climate change in the last decade has fostered the development and spread of pests and diseases worldwide (Sturrock et al., 2011). The research was carried out through different scientific search engines such as Web of Science, Scopus, PubMed, Lens.Org, and Google Scholar.

An extensive search was conducted on all platforms using the following keywords: "mistletoe", *"forest", "Viscum", "Arceuthobium", "Phoradendron", "parasitic plant", "pest", "tree", "forest health"* and *"canopy"*.

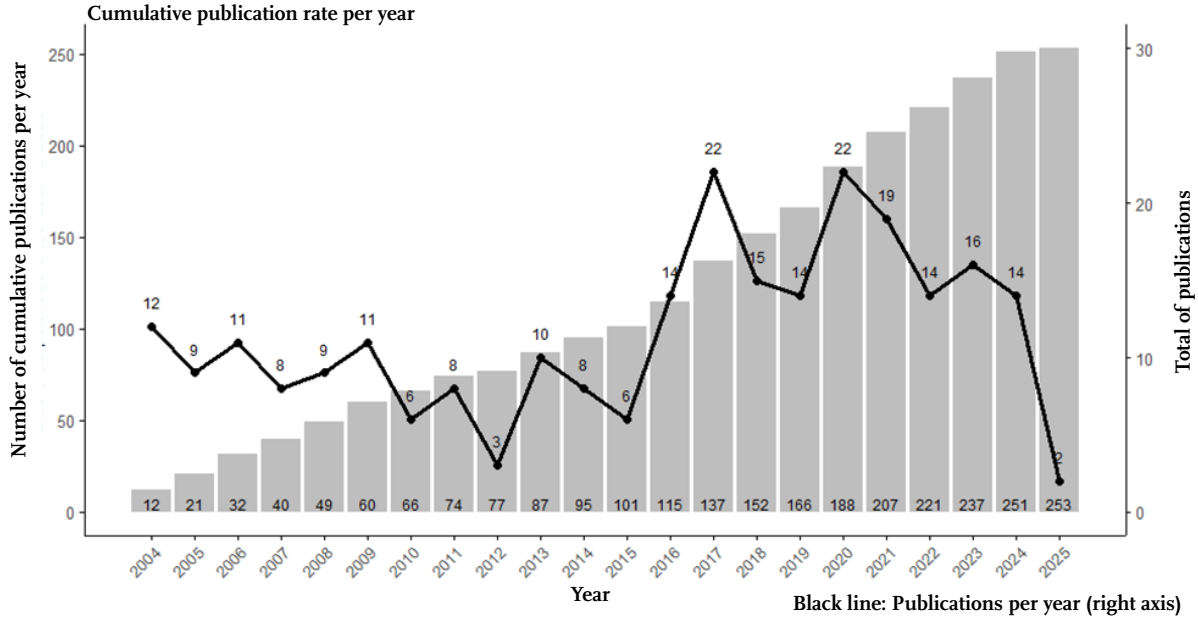
The collected articles were organized into a database (See Supplementary Material 2) in Microsoft Excel®. Within this database, important data were captured for each article found: DOI, bibliographic citations, title, authors, journal of publication, journal impact factor, study objectives, country of origin, tree species studied, mistletoe species studied, methodology used in the study, software and inputs used, drone used (when applicable) and study results. This database consisted of 104 articles.

As a complement to the previous database, a database obtained from the Web of Science platform with the keyword "mistletoe" was used. This database included all publications from 2004 to 2025 in several research areas, yielding a total of 253 articles, this database included more articles than the previous one because it is not limited to forestry studies.

Data analysis

A bibliometric analysis was performed using the Web of Science database (253 articles) using VosViewer software

Figure 1. Cumulative publication rate vs. absolute publication rate for the scientific contribution of mistletoe research for the period 2004-2024. N = 253.



version 1.6.20 (van Eck & Waltman, 2010), where bibliometric networks were created using the "visualization of similarities" analysis algorithm for different parameters (co-authorship, main countries, bibliographic coupling). One of these analyses was the keyword occurrence analysis, to visualize the most notable topics in the consulted literature. This was done for those keywords with more than 5 occurrences. For this same database, RStudio scripts (*R: The R Project for Statistical Computing*, 2010) and such as "ggplot2" (Wickham, 2016) were used to perform the statistical analysis of bibliographically important metrics such as: i) temporal publication rate, the annual and absolute count of the number of articles published was performed. This count helps determine which are the most libraries important years in terms of scientific contributions, ii) research areas in the general study of mistletoe, articles from the Web of Science database were classified within a research area in order to put into perspective which are those topics that capture the most attention within the scientific community and which topics present an area of opportunity for future research, the result was 7 research areas 4 of which are the most notable. iii) publication distribution map, to know the geographic distribution of the scientific contribution to the study of mistletoe and to determine which are the countries that have made the most publications in the studied period in this analysis. iv) main publication journals, for the purpose of getting to know in which articles on this topic are published during the period of the bibliometric analysis. RStudio scripts were also used for the second database of mistletoe studies related to the forestry field (104 articles) in order to obtain graphs of metrics related to: i) research subtopics related to the forestry area; which were classified according to the study objectives and methodology, resulting in the following categories: Ecology, detection and monitoring, impact on plant growth, interaction with climatic effects, biochemical analysis and influence on mortality. And ii) mistletoe genera studied in the forestry field, which were: *Viscum, Phoradendron, Arceuthobium, Amyema, Cladocolea, Loranthus, Misodendrum*, among others unspecified. This grouping and classification of the data eased the preparation of comparative tables and figures which helped meet the objective of this study

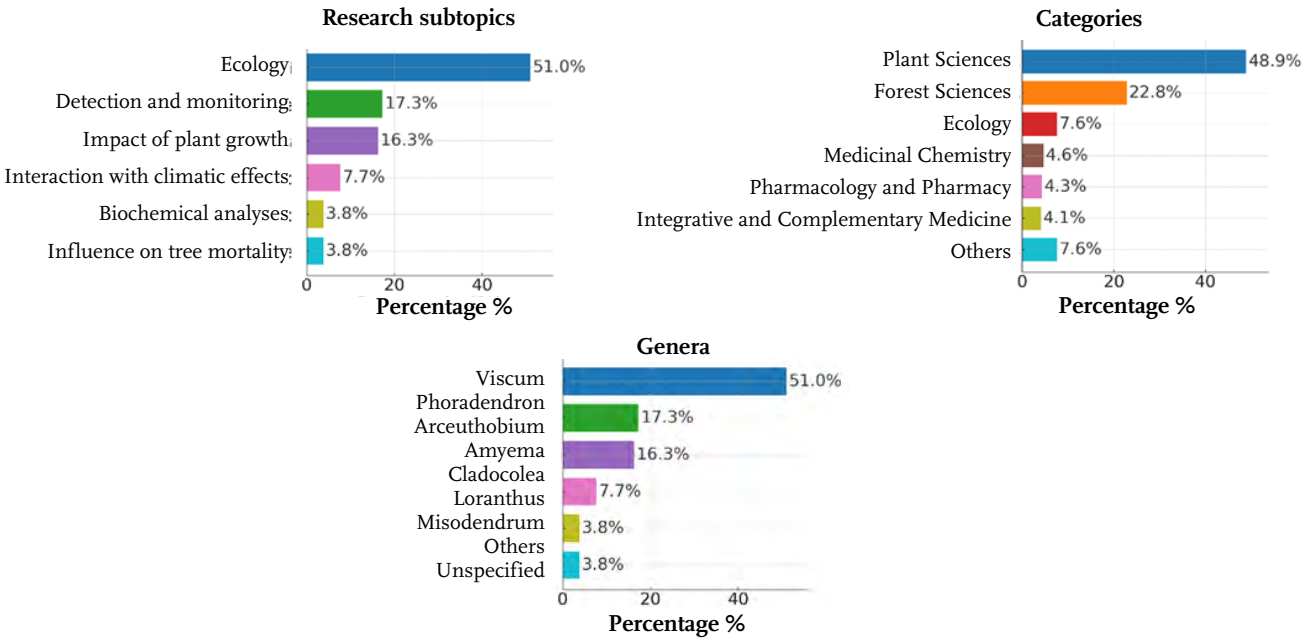
Results

Publications per year and research area

Setting the scientific contribution made over the last 21 years into perspective, cumulative and absolute publication rates were compared (Figure 1). In recent decades the number of publications per year has remained constant with slight increases and decreases. Highlighting 2017 and 2020 as the years with the highest number of publications to date (22 articles).

The publications were classified into four main areas: i) "Plant Sciences" (48.9%), which includes biological studies mostly with descriptive, taxonomic, geographical distribution and population dynamics analyses; ii) "Pharmacology and Pharmacy" (4.3%), with studies focused on the pharmacological properties of the bioactive compounds present in some mistletoe species and which analyzes their effects on the human body; iii) "Integrative and Complementary Medicine" (4.1%), which includes articles that study the use of mistletoe in complementary or alternative medical practices that are combined with conventional medicine, this category is broader since it can cover not only the phar-

Figure 2. Research areas, research subtopics, and most studied mistletoe genera in phytosanitary terms.



macological effects of mistletoe, but also some cultural and spiritual effects of its medicinal use; finally iv) "Forest Sciences," focused on the study of the interaction of these hemiparasitic plants with forest ecosystems, representing 22.8% of all publications found during the period studied. This analysis of the classification of research areas allowed us to identify trends in the studies, revealing an area of opportunity for research into the impacts of mistletoes on forests, since this topic represents less than a quarter of the articles found.

Forest subtopics and main mistletoe genera

To contextualize the state of the art regarding the study of mistletoe in forest ecosystems, articles in this area were classified into research subtopics, with the purpose of visualizing the applications developed in recent years.

The area of ecology is the most studied, hosting works related to the dynamics of mistletoes in ecosystems, their taxonomic description, distribution, interaction with other plant species, etc. Secondly, there is the area of "Detection and Monitoring" which involves studies that have used emerging technologies such as Unmanned Aerial Vehicles (UAVs), satellite images and LiDAR to detect and monitor the presence of mistletoe in forests, highlighting the potential of these technologies which has yet to be fully explored. Finally, the category "Impact on plant growth" includes studies that evaluated the effect of mistletoe on the growth of its host (Figure 2).

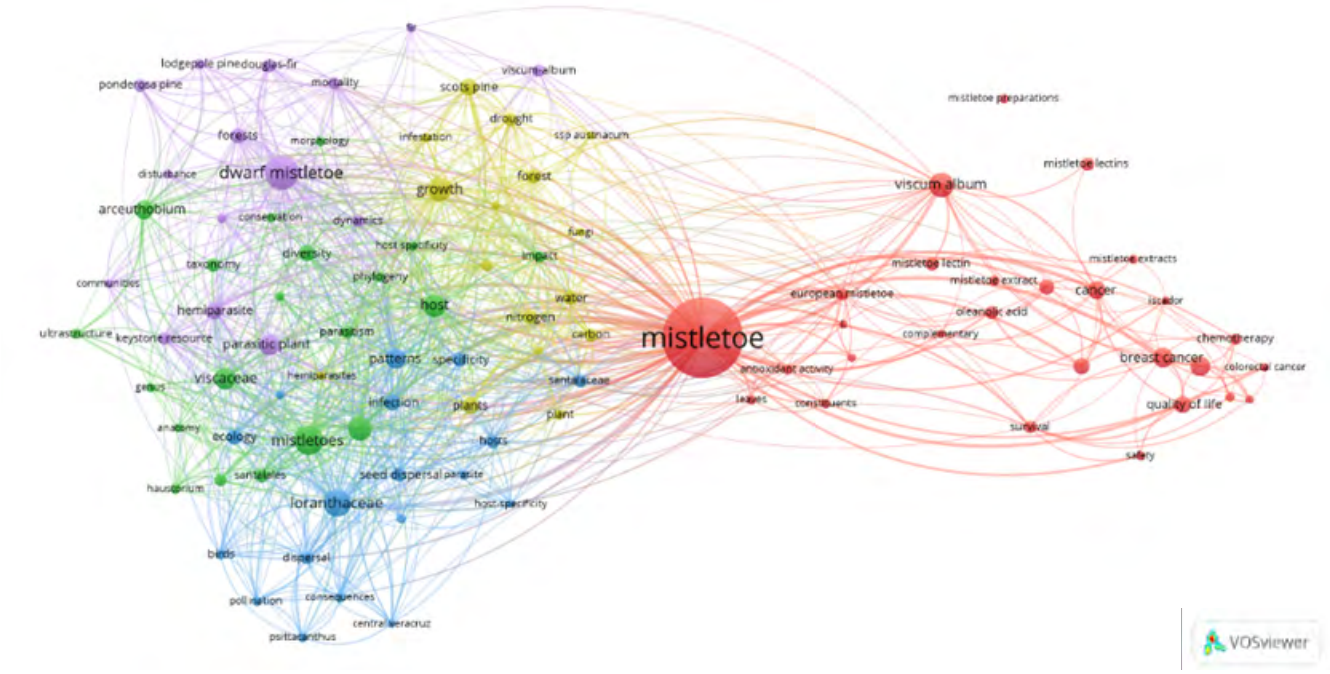
Figure 2 also shows the mistletoe genera that have been studied in forestry publications. The three most important genera were: *Viscum* (29.1%), *Phoradendron* (26.2%), and *Arceuthobium* (23.3%). These genera are representative of temperate ecosystems, whose hosts are coniferous and broadleaf species that inhabit these ecosystems. The most frequently mentioned genus in the literature is *Pinus*, likewise, the main pine species that has been studied for its interaction with mistletoe (of the genus *Viscum*) is *Pinus sylvestris* L., both characteristic of northern European forests. This explains why much of the research has been conducted in this part of the world. In the same way, the genera *Quercus* (*particularly the species Q. douglasii* Hook. & Arn., *Q. lobata* Née and *Q. agrifolia* Née), *Eucalyptus* (*E. fibrosa* F. Muell. and *E. moluccana* Roxb.), *Abies* (*A. alba* (Aiton) Michx., *A. nordmanniana* (Steven) Spach and *A. concolor* (Gordon & Glend.) Lindl. ex Hildebr.), as well as *Juniperus deppeana* Steud are mentioned. Most of these species inhabit temperate forests and are characteristic of ecosystems in the northern hemisphere of the planet, mainly in Europe, some parts of Asia and to a lesser extent in regions of America. This indicates a geographical fragmentation in the study of mistletoe in forests and how this field has developed more in these regions of the world. Finally little-studied mistletoe genera such as *Amyema* (2.9%), *Cladocolea* (1.9%), *Loranthus* (1.9%), and *Misodendrum* (1.9%) were found, which are characteristic of other ecosystems such as tropical and subtropical ones. Such is the case of *Misodendrum* which is limited only to ecosystems in the southern hemisphere, affecting only individuals of the genus *Nothofagus*.

Occurrence of keywords in research

This analysis allowed the generation of a thematic network composed of five clusters that were representative within the field of study (Figure 3).

- Red cluster, with 28 elements, housed the most relevant element in the database, mistletoe (An element with 199

Figure 3. Keyword co-occurrence network for mistletoe studies worldwide from 2004 to 2025. N = 253.



occurrences, the highest in the database), which served as a central node connecting this group with the other clusters in the network, similarly, elements such as "cancer," "quality of life," "breast cancer," and "oleanolic acid" were included. This cluster is the most extensive within the bibliometric network because it has the highest number of elements (28 elements). This is due to the strong trend in the last decade of studies describing the medicinal properties of mistletoe and its effects on human diseases. Another element with high occurrence is also included in the database "*Viscum album*" (29 occurrences), a species of European mistletoe.

- In the green cluster, where 20 elements are grouped together, such as: "host", "viscacae", "mistletoes", "santales", and "anatomy". These elements suggest a grouping in biological terms, indicating that research has focused on describing mistletoe species and their impact on ecosystems.

- Blue cluster contains 18 elements some of which stand out, such as: loranthaceae (with 34 occurrences, one of the most frequently mentioned), seed dispersal, "patterns", "birds", "dispersal" and "pollination." This cluster groups together keywords related to ecological terms such as the dispersal of mistletoes in ecosystems and their interaction with wildlife.

- Yellow cluster, with 16 elements, included notable elements such as: "growth", "plants". "infestation", "forest", and "scots pine". This cluster grouped elements from the forestry field, indicating the studies that have been conducted regarding the impact of mistletoe on forests.

- Purple cluster comprises 15 elements. These include forest related elements such as "dwarf mistletoe", which integrates studies focusing on mistletoes of the genus *Arceuthobium,* one of the most important in phytosanitary terms worldwide. This element is also one of the most frequently occurring in the database (48 occurrences). It is important to note that this cluster (along with the yellow cluster) was one of the smallest (16 and 15 elements, respectively) within the bibliometric network, suggesting limited publication of scientific articles in this field.

Countries and journals that have contributed to the research

The number of publications produced by each country in recent decades was counted in order to analyze in which part of the world mistletoe research in forests has been prioritized. Figure 4 shows the countries that have contributed the most to research in the period studied, being United States the country with the highest number of publications (60), followed by Mexico (25) and in third place Brazil (19). Knowing in which parts of the world mistletoe research has been prioritized puts into perspective those regions where this hemiparasitic plant has significantly impacted different forest ecosystems.

Likewise, the main genus studied was *Viscum*, present in some regions of Europe, Oceania, and part of Africa. The genus *Phoradendron* was the second most studied genus of mistletoe and is distributed in regions of the United States and Mexico, countries with the greatest contribution to the study of this plant.

Figure 4. Publications by country regarding the study of mistletoe in forests in the period 2004 to 2025. N = 253.

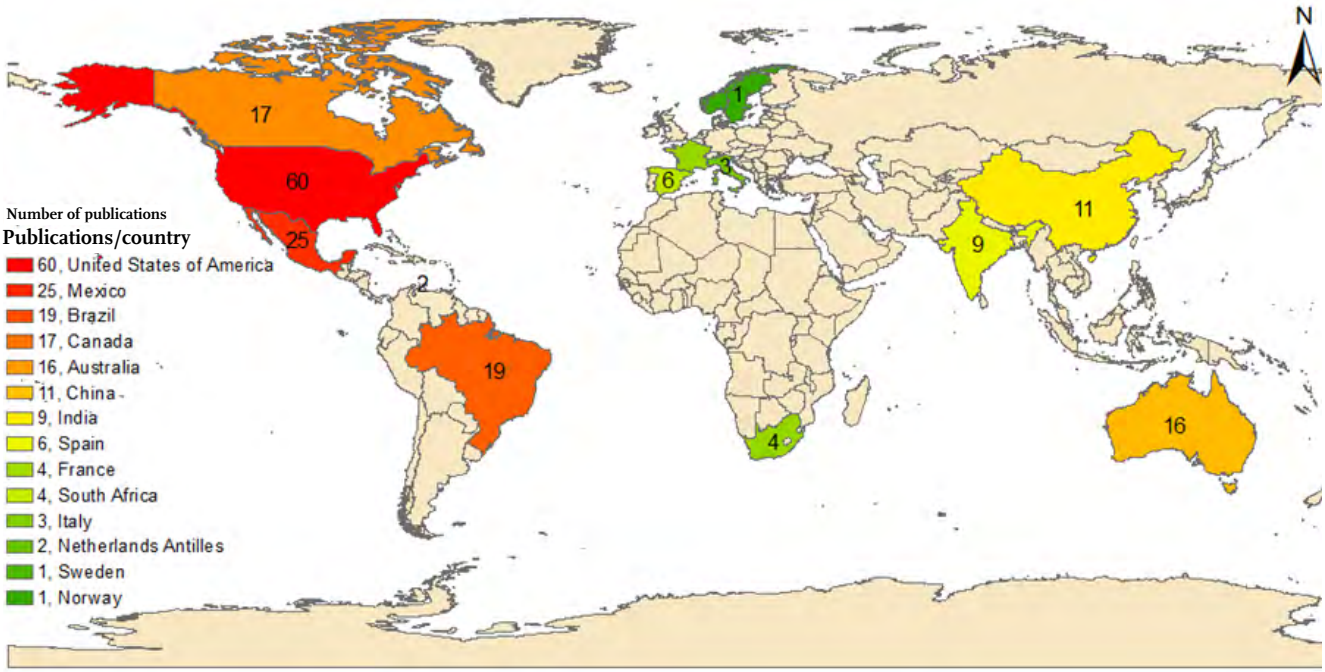


Figure 5 shows the most published journals on mistletoe during the period 2004 to 2025. The analysis included multidisciplinary articles; in medicine, ecology, biology, forestry and zoology, with the aim of identifying the areas where the study of this hemiparasitic plant has been prioritized. The grouping highlights that the journals "Botany", "Plant Basel" and "Forest Ecology and Management" were the main ones in the ecological areas (18 publications), biological (12 publications) and forestry (9 publications) fields. However, the total number of articles in these areas is low, indicating limited scientific production related to these areas of study compared to the 253 publications contained in the database.

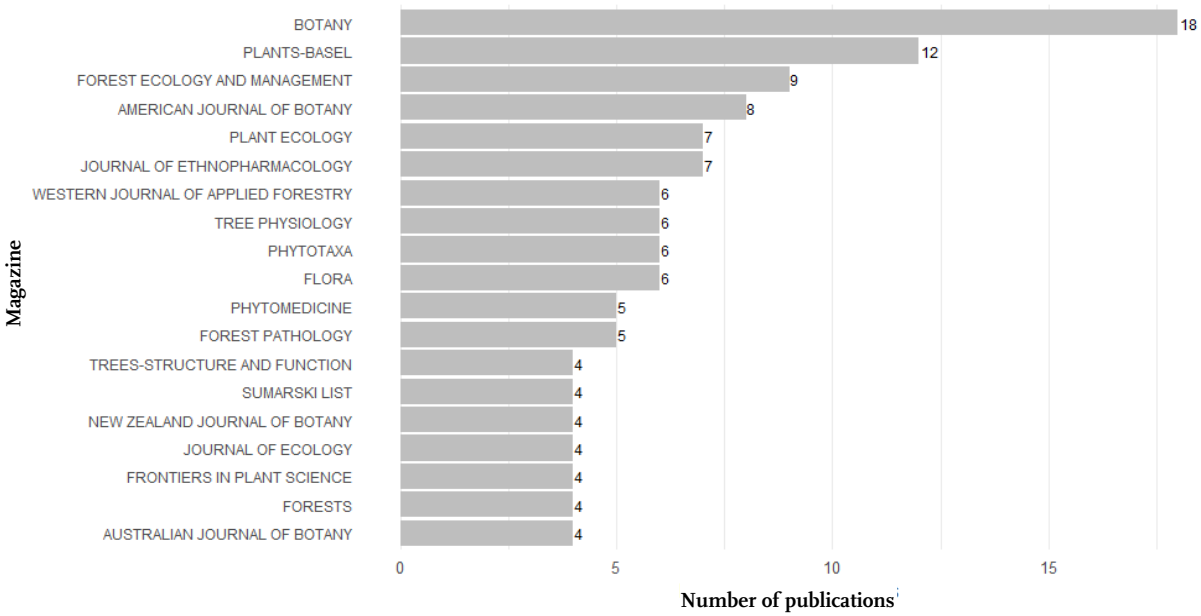
Discussion

This bibliometric analysis revealed a steady growth in scientific interest in the study of mistletoe since 2016, when a period of increased scientific productivity began. This may have been due to technological advances in that year, the trend in the use of new technologies such as UAVs or drones, satellite images, geographic information systems, etc. (Shahi et al., 2023). The scientific community could have been provided with a new line of research in the study of mistletoe beyond the taxonomic description of the species or its geographic distribution. The peaks of scientific contributions (22 publications for each) were found in 2017 and 2020. However, starting in 2020 a decrease in the number of publications per year is observed. This may reveal an area of opportunity for future research seeking to integrate emerging technologies such as artificial intelligence and machine learning algorithms in the study of mistletoe, coupled with the constant climate change that the planet has faced in recent years and which could be directly affecting the ecological development of these hemiparasitic plants. Knowing how scientific contributions to mistletoe research have changed over time, helps to identify trends coupled with other factors such as technological advancement or global climatic conditions that explain the increase in publications.

To our knowledge, this bibliometric analysis is the first to describe the current perspective of mistletoe studies and their limitations in the forestry field. Studies carried out by (Szmidla et al., 2019) and (Shaw & Agne, 2017) focused on a single species of mistletoe and its impact on forest ecosystems, leaving behind the entire group of genera of phytosanitary importance.

A gap was also identified in studies using cuttingedge monitoring and detection tools. As explained in (Missarov et al., 2024), the use of remote sensing for the study of mistletoe, is emerging with great potential; however, it still requires further research due to technical limitations such as the difficulty of implementing diverse methodologies in dense forests and adverse climatic conditions, including its high operating cost. These conditions limit the ability to replicate these techniques globally, isolating this type of study to a limited number of countries that invest sufficient funds in research in this discipline. Despite this, the study focused on systematizing the mistletoe genera of phytosanitary importance that have been studied, uncovering an area of opportunity for future research delving deeper into the interaction of mistletoes with their corresponding ecosystems.

Figure 5. Number of articles on mistletoe, grouped according to the journal where they were published from 2004 to 2025. N = 253.



The author Těšitel, (2016) mentions how mistletoe plays certain important roles within ecosystems such as providing habitat for bird species and acting as a biological control. This undermines the interest in studying the impact of excessive populations of this hemiparasite in forests.

The co-occurrence analysis of keywords provided an overview of the most important topics in the study of mistletoe worldwide. The links between keywords provide insight into which elements tend to appear together in the scientific publications found and which are the most researched subtopics of study with regard to mistletoe. For example, the close connection between the element "mistletoe" and "cancer" indicated a large number of studies analyzing how the medicinal properties of this plant help in the treatment of this disease. In forestry terms, we found a connection between "dwarf mistletoe" and "forests" this means that a large part of the studies published regarding the impact of mistletoe in forests, were those of the genus *Arceuthobium* (commonly known as dwarf mistletoes), which represented a greater degree of distribution and impact on forest ecosystems, as mentioned by Stanton (2006). Another case of similar connection is that of the element "european mistletoe" which has strong connections with "forest", "growth", "scots pine", suggesting that another large part of the studies in this field are linked to mistletoes of the genus *Viscum*, commonly known as european mistletoes (Kollas et al., 2018). Finally, it is possible to see that the impact studies on mistletoe that have been published worldwide between 2004 and 2025 were mostly on the genera *Arceuthobium* and *Phoradendron*.

The analysis of the countries which have contributed the most to the study of mistletoe allows to identify geographical regions such as: United States and Mexico, this explains why *Arceuthobium* and *Phoradendron* are among the most frequently mentioned mistletoe genera in scientific literature, these genera are widely distributed in both countries and represent a potential threat to the forests in this region (Sabrina et al., 2020). The distribution of studies in Europe and Oceania explains why *Viscum* is the most studied genus of mistletoe worldwide and affects a large forest area in european countries (Castagneri et al., 2015). The lack of publications in South American countries indicates a lack of study of *Misodendron* another genus of mistletoe of phytosanitary importance confined to these regions of the world (Tercero-Bucardo & Kitzberger, 2004).

Conclusion

This bibliometric analysis confirmed that global research on mistletoe, during the period 2004–2025, has been dominated by descriptive and ecological approaches, with limited scientific output focused on its phytosanitary impact on forest ecosystems. Furthermore, a significant geographic and taxonomic bias was identified: studies focus on a few mistletoe genera (*Viscum, Phoradendron*, and *Arceuthobium*) and on temperate ecosystems in the northern hemisphere, particularly European and North American coniferous forests.

Results of this bibliometric analysis highlight the need to direct efforts toward mistletoe research in Mexican forest ecosystems, where genera such as *Phoradendron* and *Arceuthobium* represent a red flag of phytosanitary risk, yet their study remains limited compared to their actual impact. This requires the integration of emerging technologies such as remote sensing and artificial intelligence,

among others. These findings highlight critical gaps that represent an immediate opportunity for future research, especially in tropical, subtropical and arid regions, and for the development of modern monitoring methodologies. Thus, this study significantly contributes to redefining priorities in mistletoe research, promoting a more comprehensive and contextualized view of its role as a forest pest in the XXI century.

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APPENDIX 1

Ecological description of genera

Viscum: It is a genus of 70 to 100 species of mistletoes. They are native to temperate and tropical regions of Europe, Africa, Asia and Australia. They belong to the family *Santalaceae*. They are hemiparasitic plants with branches between 15 and 80 cm long, the foliage is dichotomous, with opposite pairs of green leaves that photosynthesize. The flowers are inconspicuous, greenish-yellow, 1 to 3 mm in diameter. The fruit is a white, yellow, orange or red berry when ripe. It has several seeds inside the sticky pulp of the fruit. (Szmidla et al., 2019c).

Phoradendron: includes evergreen shrubs, monoecious or dioecious, with simple, decussate paired leaves of variable shape ranging from falcate to liguliform or lanceolate to narrowly elliptic. Inflorescence of 1 or several axillary spikes, each one with 1 or several fertile articles and each article with 2 or more rows of flowers. Unisexual, sessile, green to yellowish flowers, the staminate ones with 3 or more valvated petals, 3 or 4 bilocular anthers and a rudimentary pistil in the center; the carpellate ones with a unilocular ovary, a straight style originating from a small annular disc and an undifferentiated stigma. The fruit is a whitish, ovoid to globose berry with 1 seed surrounded by a viscid layer. (Gómez-Sánchez et al., 2011).

3. Arceuthobium. It is a genus of 42 plant species, belonging to the Santalaceae family. They parasitize members of the Pinaceae and Cupressaceae families. Commonly known as "dwarf mistletoe," they are small plants (less than 20 cm) with foliage that varies in color from yellow to brown, black, and red. The leaves of this genus of plants are so small that it is sometimes described as a leafless plant, however, the leaves are distributed in the form of scales that begin at the periphery of the shoot apex through periclinal divisions in the subsurface layer (Hawksworth, 1996)

4. Psittacanthus: It is a genus of 42 plant species belonging to the Santalaceae family. They parasitize members of the Pinaceae and Cupressaceae families. Commonly known as "dwarf mistletoes," they are small plants (less than 20 cm) with foliage color that varies between yellow, brown, black,

and red. The leaves of this genus of plants are so small that it is sometimes described as a leafless plant; however, these are distributed in the form of scales that begin at the periphery of the shoot apex through periclinal divisions in the subsurface layer (Hawksworth, 1996).

5. *Misodendrum*. It is a hemiparasitic plant, commonly called Chinese lantern or ñire flower, it is a dioecious species, belonging to a monogeneric family endemic to the forests of southern Argentina and Chile. The Misodendraceae family comprises eight species that specifically infect species of the Nothofagus genus throughout most of their geographical range. The fruits of Misodendrum are small (2 mm) dry achenes with three setae up to 1 cm long that allow them to fly and anchor themselves passively, mainly on small branches and stems of the host. The stems grow sympodially and have reduced photosynthetic tissue with small scale-like leaves. (Tercero-Bucardo & Rovere, 2010).

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