Characterization of the scientific production of *Moringa oleifera* Lam. for the period 2013-2023

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ABSTRACT

Objective: This study aims to map the scientific production of *Moringa oleifera* in the Scopus database during the period 2013-2023.

Design/methodology/approach: The bibliographic data of moringa publications was downloaded and data was characterized through a bibliometric analysis. The analysis identified key metrics, including the most productive countries, journals and authors with the highest number of publications and citations, topic niche, basic topics, emerging or declining topics, and motor topics.

Results: For the period 2013-2023,a total of 5680 documents were published, categorized as scientific articles (80.21%), bibliographic reviews (8.68%), conference papers (6.78%), book chapters (1.81%) and books (0.11%). Most of the research is embedded in areas such as: agricultural and biological sciences (21.92%), biochemistry, genetics and molecular biology (10.71%) and pharmacology, toxicology and pharmaceuticals (10.51%).

Limitations on study/implications: This study is limited to the Scopus database, which means that additional publications on *Moringa oleifera* from the 2013-2023 period may exist in other databases not included in this analysis.

Findings/conclusions: The bibliometric analysis provided insights into the scientific contributions related to *Moringa oleifera* and supports the development of research on more relevant and hot spots topics.

Keywords: moringa, research trends, bibliometrics.

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INTRODUCTION

Moringa oleifera Lam. is a species domesticated in India (Olson, 2017) and has spread into tropical and subtropical countries (Sanjay and Dwivedi, 2015). This plant is drought-resistance and can be grown in soils with low nutrient availability (Muhl *et al.*, 2013). Its high acclimation capacity and its nutritional, medicinal, forage, biofertilizer, bioinsecticide, flocculant, energy, and bioadsorbent potential have increased its global importance (Abd El-Hack *et al.*, 2018). The leaves contain proteins, lipids, carbohydrates, fiber, vitamins, minerals, and phenolic compounds (Gopalakrishnan *et al.*, 2016). The consumption of

moringa leaves prevents various diseases associated with nutrient deficiencies (Matic *et al.*, 2018). Additionally, moringa is characterized by its content of isothiocyanates, chemical compounds with high medicinal potential (Fahey *et al.*, 2019). The properties of moringa make it an important resource in biotechnology, livestock, medical sciences, and the food industry (Brilhante *et al.*, 2017). Therefore, it has become a cost-effective food production or fortification option in developing countries (Razis *et al.*, 2014) and as a dietary supplement in developed countries. The plant's numerous properties have led various research centers to focus on its study. On the National Center for Biotechnology Information (NCBI) platform, 7,655 publications were identified, along with 6,722 in Scopus and 5,902 in ScienceDirect. In the last two decades, worldwide publications have increased significantly (Gupta and Ahmed, 2020). However, the existing information is outdated, and the trend in research topics may have shifted due to societal needs. This lack of updated information represents a limitation for the development of more accurate research. One tool that facilitates the classification of published information is the bibliometric analysis (Donthu *et al.*, 2021). This analysis involves the classification of publications indexed in various databases and measures the scientific contribution to a particular topic. It has the ability to identify countries, authors, and institutions with the highest number of publications (De Bellis, 2009). It groups research into various areas of knowledge and research topics, establishing trends in the field (Moya-Anegón *et al.*, 2007). Previous bibliometric analyses on moringa cover periods that do not provide updated information and are focused on just a single country (Gupta and Ahmed, 2020) or the type of documents published (George *et al.*, 2021), exclude information from 2020 up to date. Therefore, the aim of this research was to map the scientific production of *M. oleifera* in the Scopus database during the period 2013-2023.

MATERIALS AND METHODS

A bibliographic search was conducted in the Scopus database (http://www.elsevier.com/es-mx/solutions/scopus). The Scopus database was chosen because it contains a large number of journals with high impact factors. The search words used was: *Moringa oleifera*, and no additional filters were applied. This approach aimed to provide a general overview of *M. oleifera* across the various categories managed by Scopus for information classification. The search period ranged from January 2013 to August 12, 2023. A total of 5,680 published documents were identified. The retrieved bibliography was exported into a CSV (commas separated values) file containing all the information provided by the platform for each published document. Using the Bibliometrix package in R 4.2.0, the following variables were determined: number of publications per year, most published document types (scientific articles, reviews, books, book chapters, scientific notes, and other documents), areas with the highest number of publications, annual production in the most researched areas, countries with the most publications, journals with the highest number of publications, authors with the most publications and citations, and the most cited articles. Graphs for annual production, growth in the three most researched areas, and the most published document types were created using Sigmaplot version 10.0. The keyword network was created using the keywords assigned by the authors to their works,

with the most frequent words represented as the largest nodes. A keyword network and the collaboration network between countries were developed using VOSviewer version 1.6.19. The thematic map was generated with the biblioshiny function of the Bibliometrix package in R version 4.2.0.

RESULTS AND DISCUSSION

The bibliometric analysis of moringa highlights the current state of research published on Moringa. Iftikhar *et al.* (2019) state that bibliometric analysis identifies the scientific impact of a particular topic.

Scientific Production Worldwide

Between 2013 and August 12, 2023, 5,680 documents were published, with an average of 516 documents per year and a growth rate of 9.73% anually. The years with the highest and lowest number of publications were 2022 and 2013, with 933 and 213 documents published, respectively (Figure 1). George *et al.* (2021) report 2,345 publications, considering only scientific articles and conference presentations. These researchers also identify an exponential increase in the number of publications. The increase in moringa production can be linked to the promotion by various international organizations, such as the FAO and WWO, regarding its multiple properties (Velázquez-Zavala *et al.*, 2016), as well as the identification and characterization of new phytochemicals in the plant (Chodur *et al.*, 2018). These facts motivate researchers to formulate new studies in various scientific fields to assess and validate its benefits.

Types of Documents Published

The types of documents in which the publications were classified were Research Article (80.21%), Review (8.68%), Conference Paper (6.78%), Book Chapter (1.81%), Book (0.11%), Scientific Note (0.26%), Short Survey (0.23%), Review presented at a conference (0.44%), and Undefined categories (1.48%). George *et al.* (2021) report only publications of scientific articles and conference presentations. This study integrated all the documents included in Scopus to provide a general overview of the topic.

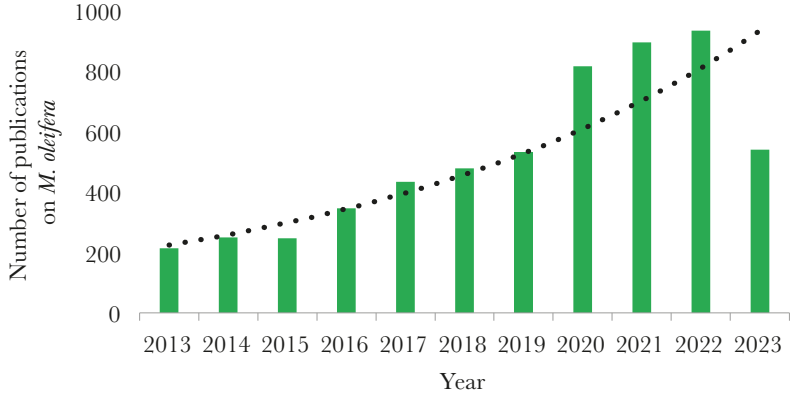

Figure 1. Global scientific production of *M. oleifera* published in Scopus from January 2013 to August 12, 2023. The research trend of *M. oleifera* is shown.

Research by Area of Knowledge

Moringa research has gained significant importance in various scientific fields. Each database defines different scientific categories or areas of knowledge, and each document is classified into one or more categories. Moringa publications in Scopus were classified into the following areas of knowledge: Agricultural and Biological Sciences (21.92%), Biochemistry, Genetics, and Molecular Biology (10.71%), Pharmacology, Toxicology, and Pharmaceuticals (10.51%), Medicine (9.27%), Environmental Science (8.90%), Chemical Engineering (11.70%), Engineering (4.55%), Materials Science (3.23%), Veterinary Science (2.54%), Immunology and Microbiology (2.40%), Energy (2.28%), Nursing (1.73%), Multidisciplinary (1.61%), and other Areas of Knowledge (8.64%). The areas of Agricultural and Biological Sciences; Biochemistry, Genetics, and Molecular Biology; and Pharmacology, Toxicology, and Pharmaceuticals have shown the greatest growth in the last 10 years (Figure 2). The Agricultural and Biological Sciences area ranks first, with the most frequent research focusing on topics such as chemical and organic fertilization, water stress, fruiting, morphological characterization, and agroforestry systems (Muhl *et al.*, 2013; Sarwar *et al.*, 2018; Ruiz *et al.*, 2021). Other topics in this category include the phenological and adaptive study of the species (Förster *et al.*, 2015). Due to its wide agro-climatic adaptability and rapid growth, moringa is considered a viable and low-cost alternative for animal feed (Su and Chen, 2020).

The areas of biochemistry, genetics, and molecular biology occupy the second place. In the field of biochemistry, publications have focused on proximate analysis, vitamin, mineral, amino acid, and fatty acid content in the leaves and seeds (Gopalakrishnan *et al.*, 2016; Dolma and Tashi, 2020). In the areas of genetics and molecular biology, molecular markers such as RAPD, SSRs, ISSRs, AFLPs, and biomarkers have been developed and widely used (Popoola *et al.*, 2014; Hassanein and Al-Soqeer, 2018)

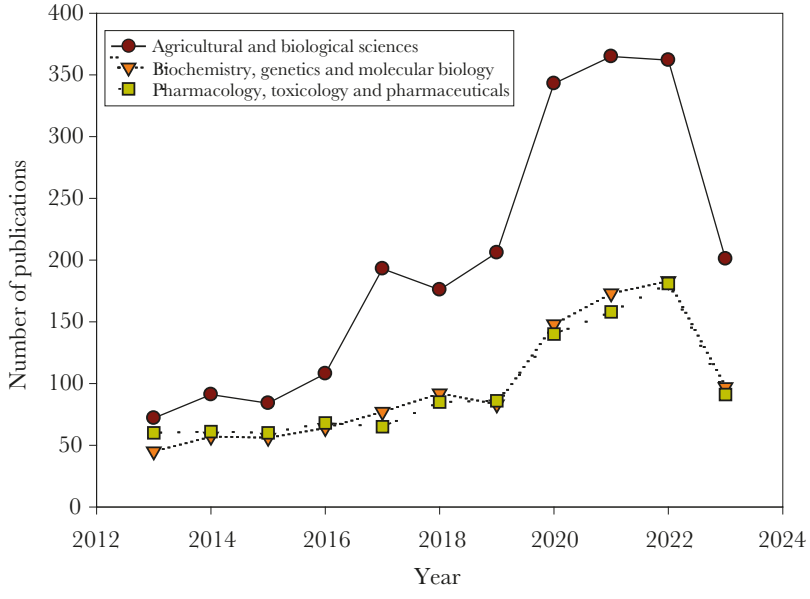

Figure 2. Annual growth of the three areas with the most research on *M. oleifera* in Scopus from January 2013 to August 12, 2023.

to determine the diversity, identity, and genetic structure of moringa populations in various countries (Hassanein and Al-Soqeer, 2018). These areas aim to understand the quantity and function of the genes in its genome (Yang *et al.*, 2015) and their genetic relationship with other species (Abdel-Hameed, 2015). These molecular tools represent an alternative for identifying genetic materials with particular attributes (Popoola *et al.*, 2014). Table 1 shows the countries with the highest number of published documents, with India being identified as the most productive. This high scientific output is due to the fact that moringa is native to India and has high morphological and genetic diversity (Olson, 2017). Mexico's scientific production has amounted to 213 publications, placing it in 11th worldwide position. Despite moringa being cultivated in various states of Mexico (Olson and Alvarado-Cárdenas, 2016) and exhibiting high morphological diversity (Ruiz *et al.*, 2021) and nutritional value (Velázquez-Zavala, 2016), this species is not considered a priority in Mexican research or for livestock or human nutrition. The South African Journal of Botany has published the highest number of documents in the past 10 years. Regarding researchers with the highest number of publications, Berga-Masco, R. holds the first place, while Anwar, F. is the most cited author. This indicates that Anwar, F. is a key figure in the field of moringa research at the international level in recent years. In Mexico, the most cited author is Olson, M. E., with 313 citations for the period 2013-2023.

Collaboration between countries

Figure 3 shows the collaboration network between countries regarding moringa publications. The Scopus database records 134 countries that have researched moringa. India has collaborations with 55 countries, including Saudi Arabia, Egypt, Pakistan, Malaysia, South Korea, South Africa, Italy, and Japan. Mexico has collaborations with 31 countries, with the most frequent being Pakistan, Egypt, India, the United States, and Nigeria. Collaboration between countries indicates the flow of genetic material between various regions and explore the large genetic reservoirs of moringa worldwide.

Each node represents a country. The size of the node refers to the total number of documents published. The width of the line represents the number of collaborations between two countries.

Table 1. Countries, journals, and authors with the highest number of *Moringa oleifera* publications in Scopus from January 2013 to August 12, 2023.

No.	Countries	NP*	Journals with the most publications	NP	Most productive authors	NP	Most cited authors	NC*
1	India	1172	South African journal of botany	106	Bergamasco, R.	84	Anwar, F	1736
2	Indonesia	481	Acta horticulturae	103	Napoleón, TH	44	Becker, K	1343
3	Nigeria	468	Iop conference series: earth and environmental science	98	Paiva, PMG	44	Ashraf, M.	1121
4	China	461	Aip conference proceedings	70	Coelho, LCBB	38	Wang, Y	1076
5	Egypt	446	Journal of ethnopharmacology	57	Tian, Y.	35	Zhang, Y	999

NP*: Number of publications; NC*: Number of citations.

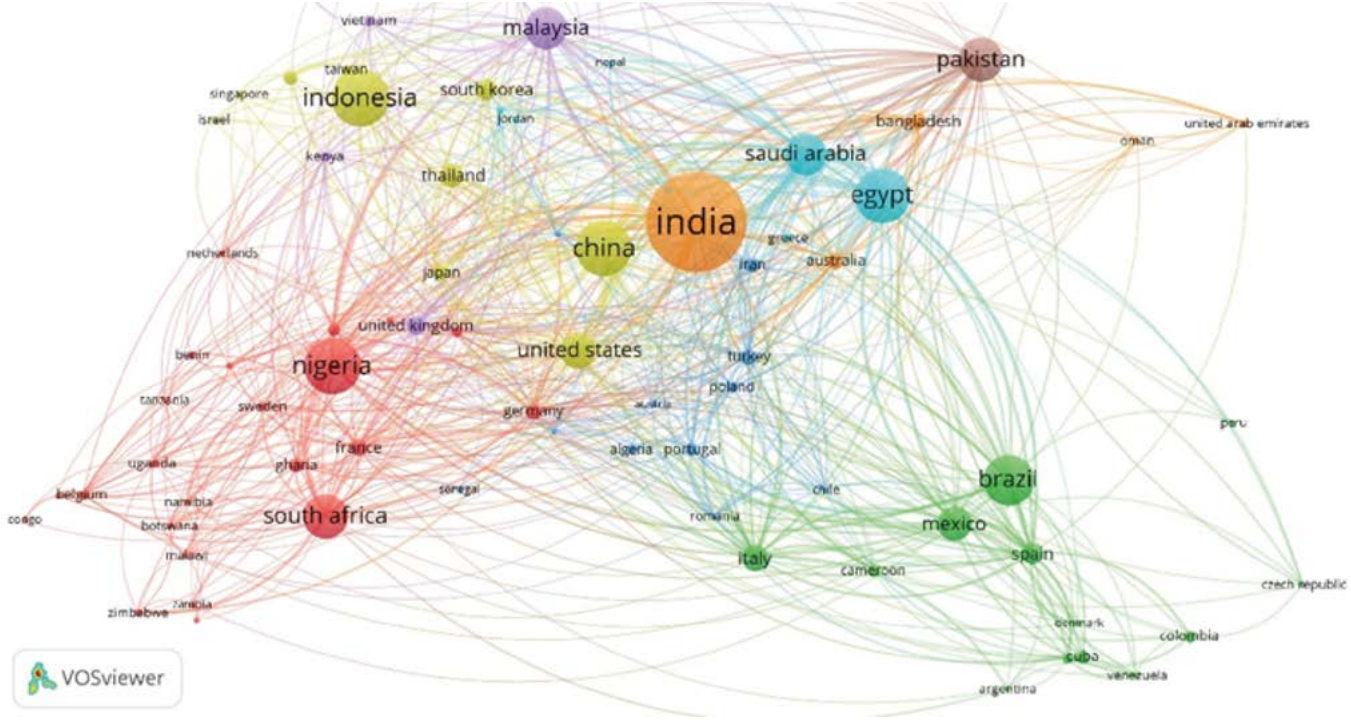

Figure 3. Collaboration between countries regarding *M. oleifera* publications in Scopus from January 2013 to August 12, 2023.

Of the 5680 publications on moringa, the publication by Rafieian-Kopaei M, 2014, in the *International Journal of Preventive Medicine* received a total of 573 citations, ranking first. The article by Gopalakrishnan *et al.*, (2016) has 569 citations, ranking second. Bornmann and Hans-Dieter (2009) mention that the number of citations is proportional to the importance of the study and has a significant influence on readers and the development of future research.

Keywords and Trending Topics

A total of 11,799 keywords were identified by all authors, and 27,733 ID keywords were identified by the Scopus platform. The most frequent ID keywords were: *Moringa oleifera* (4141), plant extract (2062), antioxidants (930), plant chemistry (628), medicinal plant (503), animal experiments (485), plant seeds (467), and oxidative stress (447). Figure 4 shows the relationship between keywords and research frequency over the past 10 years. Cluster 1 includes topics related to performance and meat quality of animals fed with moringa. Cluster 2 groups topics related to flocculation and bioadsorption of potentially toxic elements. Cluster 3 includes topics from the fields of biochemistry and phytochemistry that study the medicinal properties of moringa.

There are 17 clusters, each represented by a different color. The size of each node represents the most frequent keyword. The lines connect the keywords, and the width of the lines shows the frequency of co-occurrence between two keywords. Figure 5 shows the thematic map that summarizes the 5680 published documents on moringa. The map groups the following sections: niche topics, basic topics, emerging or declining

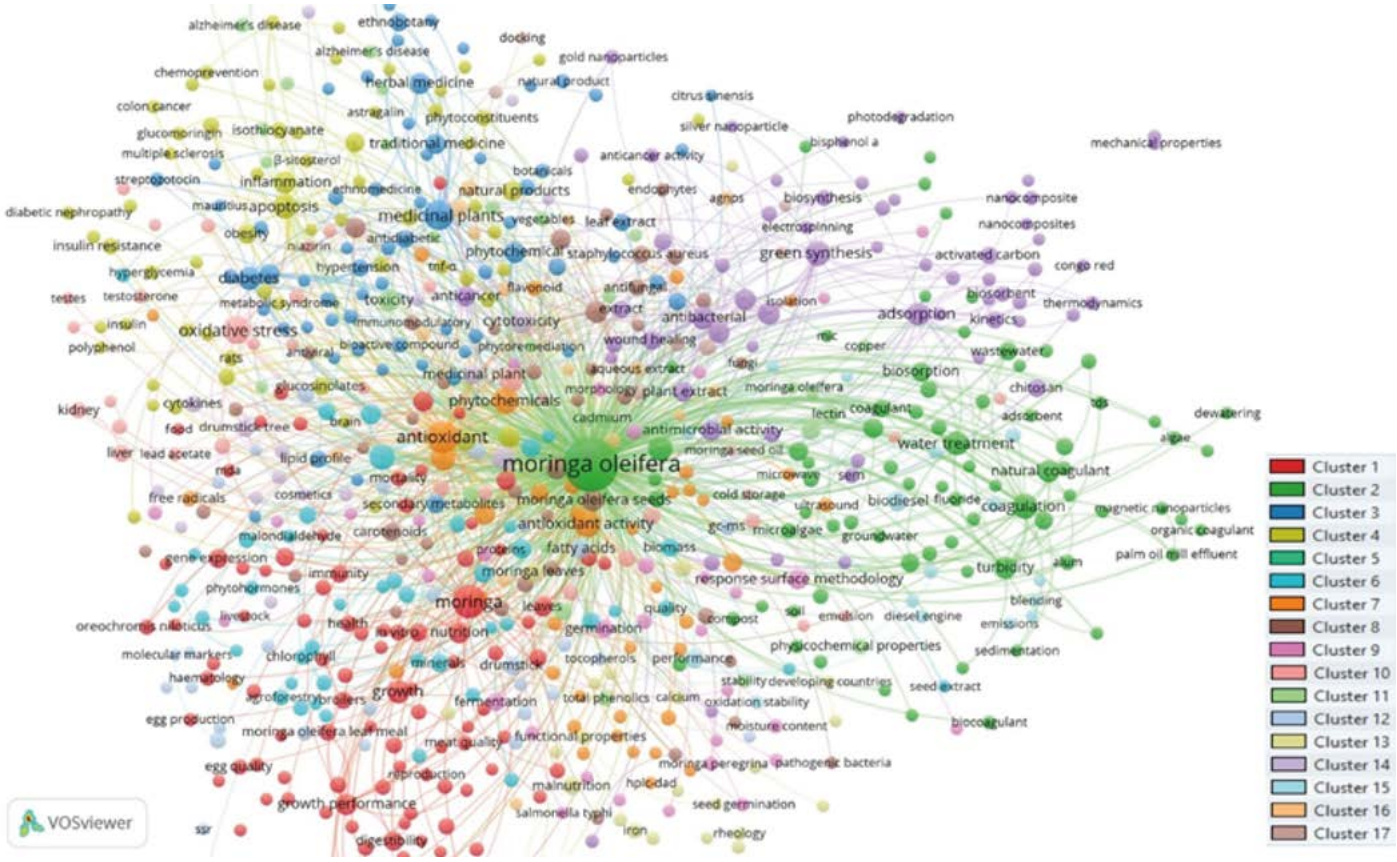

Figure 4. Network of most researched topics on *M. oleifera* in Scopus from January 2013 to August 12, 2023.

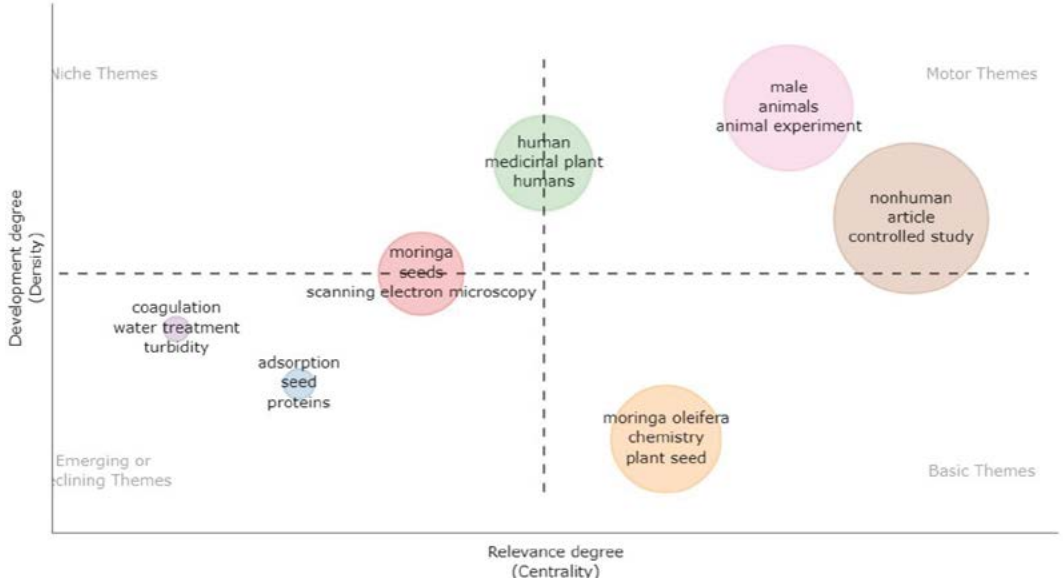

Figure 5. Thematic map of *M. oleifera* research published in Scopus from January 2013 to August 12, 2023.

topics, and core topics. Declining topics include flocculation and adsorption of toxic elements. Basic topics focus on the study of the chemical composition and antibacterial activity of the leaf.

The core topics are divided into two groups: the first focuses on experimentation with animals and oxidative stress, while the second addresses controlled studies on medicinal properties. This is because the leaf contains phytochemicals with antioxidant activity (Azlan *et al.*, 2023). Additionally, moringa contains unique chemical compounds that provide greater therapeutic properties (Chodur *et al.*, 2018) and help prevent cardiovascular and neurodegenerative diseases (Upadhyay *et al.*, 2015).

Moringa research in Mexico

In Mexico, a total of 168 documents were identified, placing the country in the tenth position globally. The individual production consists of 118 publications, with 50 publications being collaborative efforts with other countries. The countries that most frequently collaborate with Mexico are the United States, Spain, Egypt, Italy, Ecuador, and Pakistan. Although other research has been conducted in the country, these were not included in the analysis as only publications in Scopus were considered. This factor limits a more accurate understanding of the current situation of moringa in Mexico. Regarding the number of citations, 1,886 were identified, with an average of 11.22 citations per publication. Both nationally and internationally, an increase in moringa publications was identified in the Scopus database. However, publications not found within the platform could not be analyzed. Descriptive studies, physicochemical characterization, and secondary metabolite profiling have provided important information on moringa in recent years. Topics in the field of omics sciences will provide further information and increase scientific knowledge of the species.

CONCLUSIONS

Moringa has a high scientific production worldwide due to the multiple benefits it offers for human nutrition and health. The scientific contribution on moringa in recent years highlights its economic and ecological importance for the creation of sustainable agri-food systems. Bibliometric analyses help mapping research trends and serve as a foundation for developing research with a high degree of relevance.

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