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Phytoremediation with *Cucumis Sativus*: A Bibliometric Study

Mario Francisco Santoyo de la Cruz[1], Abel Quevedo Nolasco[1], Paulina Janneth Pérez Peralta[1], Peter Virgen[2]*

[1]Postgraduate College, campus, Montecillo, México.
[2]California State University Fresno, Industrial Technology Agriculture Systems Management, USA.
*Correspondence: E-mail: santoyo.mario@colpos.mx

ABSTRACT

Phytoremediation is a technique to treat contaminated soils and waters which has allowed the discovery of plants that hyperaccumulate heavy metals. To know the evolution of research in phytoremediation with Cucumis sativus, the main areas of study and the most influential authors and institutions in the field, it is important to state that the objective of this study was to analyze the scientific production associated with the phytoremediation of contaminated water and soil using *Cucumis Sativus* using the Biblioshiny statistical software in RStudio. Based on the use of BIB electronic files from the Scopus online page with the keyword "Phytoremediation Cucumis sativus" from 2014 to 2023, it was observed that in 2017, the publication of articles had an upward trend with a total of three articles published. The years 2020 and 2021 stood out as the most productive in publications. "Environmental Pollution" was the journal with the most publications with four articles from 2014 to 2023. Jian Wu and Jie Wu stood out with two publications each in 2019 and 2020, which reveals a wealth of communities and groups within academic collaboration. It is recommended to expand phytoremediation studies. Research with modern technologies and with low environmental impact should be considered. Production over a relatively short period could indicate sustained interest in Cucumis sativus phytoremediation research.

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1. INTRODUCTION

Soil and water pollution are caused by natural forces or chemically manufactured products related to industrial activity, agricultural chemicals, or inadequate waste disposal. There are nearly 90 substances considered persistent, toxic, and capable of accumulating in the soil. The most common substances involved in soil pollution are heavy metals (Trojanowska, 2023). Heavy metals pose a serious threat to the environment and food security. Soil and water act as important sinks for heavy metals. Heavy metals are non-biodegradable and can persist in the environment. For the most part, they exist in the atmosphere as aerosols that can be deposited in the soil and water through rainfall. Heavy metals in the soil can leak into groundwater (Shen *et al*., 2022).

In agriculture, yields increase thanks to fertilizers, but have negative effects on the environment when they are not applied correctly. Contamination of soil and groundwater by lead (Pb), cadmium (Cd), copper (Cu) zinc (Zn), and chromium (Cr) are some of the results found among others. Therefore, critical levels in many regions for agricultural soils have been exceeded. Although these metals are essential for plants such as Cu and Zn, excessive quantities represent a high risk for the health of living organisms (Ortiz *et al*., 2023).

Phytoremediation is considered the only eco-sustainable alternative for the in-situ treatment of soils contaminated with potentially toxic elements. This is an environmentally friendly, non-invasive technology that allows the recovery of the structure and function of the soil (González *et al*., 2017).

In the last two decades, phytoremediation researchers have reviewed the distribution of hyperaccumulator plants, their ecology, and the photochemical processes involved in the accumulation of heavy metals. The ability of plants to tolerate high concentrations of toxic metals in the soil and thrive in contaminated conditions is highlighted. The discovery of these plants with unique abilities to accumulate heavy metals opened new possibilities for phytoremediation (Baker & Brooks, 1989).

The ex-situ bioremediation method involves the removal of contaminated soil and its subsequent transportation to another site for treatment. Factors such as the geographical location of the contaminated site, the cost of treatment, the type of contaminant, and the severity of the contamination are the main criteria for carrying out this investigation (Sabreena *et al*., 2022).

On the other hand, phytoextraction aims to eliminate contaminants, such as heavy metals, from the soil through absorption by the roots and accumulation in the harvestable parts of the plants. Many articles consider phytoextraction as a low-cost method to clean contaminated soils (Neaman, 2022). However, some authors deny short-term efficiency.

Therefore, it is considered that the growth rate of plants in phytoremediation is important due to the number of heavy metals extracted from the soil since any method that increases plant growth and biomass also increases the absorption of heavy metals captured by the plant and its structure (Santoyo *et al*., 2023).

Currently, few studies are locatable in databases when using terms such as "phytoremediation bibliometrics", "phytoremediation citation analysis", "phytoremediation bibliometric analysis" or "phytoremediation scientometric study", and even fewer with the terms "Phytoremediation Cucumis sativus". By doing this type of research, bibliometric analyses can be carried out that provide a more detailed vision of the evolution of research in phytoremediation, the main areas of study, and the most influential authors and institutions in the field.

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Some features of Bibliometrix are: a) Co-authorship analysis: analyzes collaboration between authors and research groups; b) Citation analysis: citation analysis to evaluate the influence of scientific works and authors; c) Scientific maps: allows the creation of scientific maps, and visualizations that demonstrate the relationships between authors, keywords, documents and topics; d) Journal evaluations: estimation of quality and relevance of scientific journals; e) Research trends: Identification of emerging trends and patterns in scientific literature over time; d) Data visualization: Graphic representation of the results of bibliometric analysis; g) Export of results: Export of analysis results in compatible formats (https://www.bibliometrix.org/home/).

Therefore, the objective of this study was to analyze the bibliometric software package, in R language, of the scientific production of the topic of phytoremediation of contaminated water with the use of Cucumis Sativus between the years 2014-2023, using metrics and statistics to analyze the production, dissemination, and impact of scientific publications.

2. METHODS

2.1. Data collection

The Scopus website was accessed and the keywords: “Phytoremediation Cucumis sativus” were searched to generate BIB electronic files. The electronic BIB files were then entered into the Bibliometrix software package to analyze and visualize the bibliometric data. the software is mainly used in the field of scientific research to analyze scientific production, evaluate the productivity of authors, journals, and organizations, and explore trends in scientific literature.

2.2. Bibliometric analysis

In combination with the statistical software RStudio (Biblioshiny online), the advanced bibliometric analysis was carried out, which included the annual scientific production, the production of sources over time, the most relevant authors, the most relevant keywords, and the collaboration network.

The system detected 25 publications which were analyzed to compare: The plant species, the method used, the contaminant, the medium analyzed, and the most relevant results.

3. RESULTS AND DISCUSSION

3.1. Annual scientific production

Scientific production is a fundamental aspect of measuring the progress and contribution of certain disciplines in the academic and scientific community. In this analysis, the scientific production of ten years, between 2014 and 2023, is examined using the Bibliometrix tool. The results (**Figure 1**) reveal interesting patterns in publication frequency over these years.

The year 2014 marked the beginning of the research, with the publication of two articles. This may be considered a modest, but important starting point to establish the basis of scientific production. However, in 2015, a significant decrease was observed, with no publications. In 2016, the pace of publications resumed with the appearance of two articles. The upward trend continued in 2017, with three articles published. This suggests a possible increase in investment in research and development, as well as greater interest in the discipline. In contrast, 2018 once again experienced a decline in production, without any publications.

As of 2019, scientific production began to grow again, with three articles published. The years 2020 and 2021 stood out as the most productive years with each year publishing six articles (**Figure 1**). This sustained increase in production may be indicative of greater

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recognition of the discipline, much like the consolidation of research projects, and an increase in international collaboration. Likewise, the significant increase in publications in 2020 and 2021 may be due to the implementation of strategies to improve production, such as interdisciplinary collaboration, participation in conferences, and the active search for publication opportunities on the topic of phytoremediation with Cucumis sativus.

A bibliometric analysis was carried out in the Web of Science (WoS) on the topic of "phytoremediation of cadmium in contaminated soil" and a rapid growth in publications was found during the period 1994 to 2021 with 5494 articles. However, starting in 2006, the annual number of publications showed an upward trend and exceeded 100 publications. In 2017, annual publications reached 383, indicating that on average, one relevant article was published each day. Furthermore, almost half (45.12%) of the articles were published between 2017 and 2021. The trend variation in the annual number of publications indicated that this field has received increasing attention in the last three decades, especially in recent years.

This coincides with the results of the present study since an increase to nine publications was observed between 2019 and 2021 with the words "Phytoremediation Cucumis sativus". It should be noted that the analysis of scientific production over the last ten years reveals intermittent patterns in the number of articles published, possibly associated with external factors such as funding, data availability, and global events.

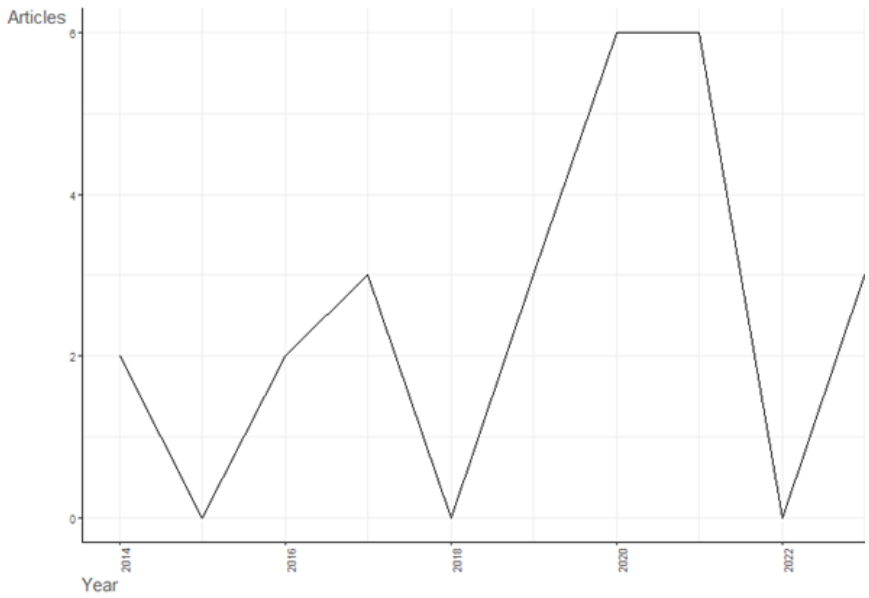

Figure 1. Annual scientific production.

3.2. Source production over time

Bibliometric analysis of scientific publications in environmental journals provides valuable insight into research trends and the evolution of research in the field of phytoremediation with Cucumis sativus which are presented in **Figure 2**. Patterns and trends in scientific production over time were identified through data collection from Scopus on publications in different journals (**Figure 3**).

It is noted that the journal "Environmental Pollution" published four articles in the years 2014, 2016, 2017, and 2023 for a total of four articles. The irregularity in the frequency of publication could indicate specific research approaches at different times, perhaps in response to emerging issues in environmental pollution.

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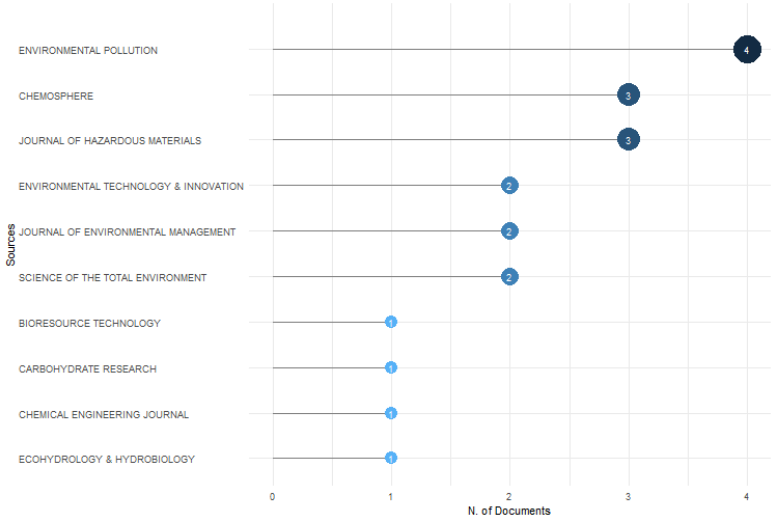

Figure 2. Most relevant sources.

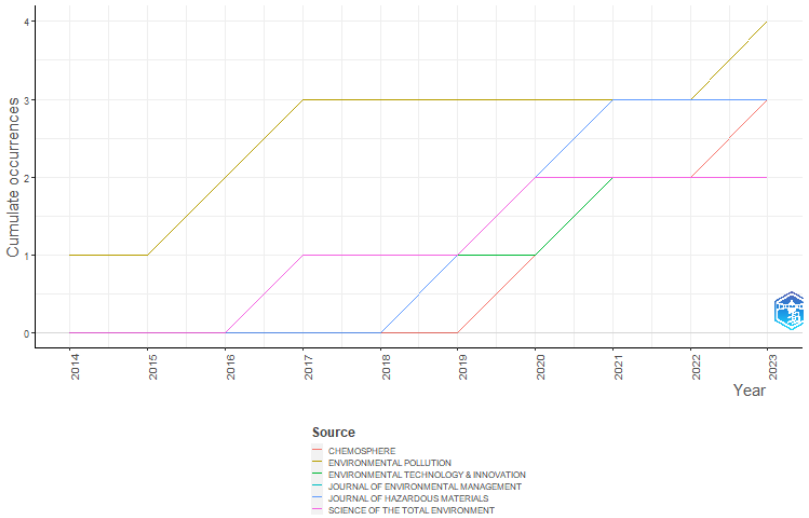

Figure 3. Source production over time.

The journal "Chemosphere" also presented variability in the frequency of publications, with three articles distributed in the period 2020-2023. The concentration of publications during recent years suggests the growing trend in phytoremediation research, possibly related to technological advances or innovative approaches in the area.

Likewise, the publications of the Journal of "Hazardous Materials" were distributed in the years 2019, 2020 and 2021. This suggests a concentration of research in a relatively short period. Given the specific focus on "hazardous materials", it is plausible that emerging issues in the regulation and management of these materials have influenced the publication pattern.

The "Environmental Technology & Innovation" magazine featured publications in 2016 and 2021, which could indicate a focus on innovative technologies and environmental solutions over time. The five-year separation between publications could reflect an emphasis on the maturity and viability of new technologies before their presentation in scientific literature.

Regarding the Journal of "Environmental Management", two publications were observed in 2019 and 2020. This production pattern could be related to the strategic planning of

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research projects throughout these specific years while possibly also reflecting a continuity in the approach of environmental management in different contexts.

In the years 2017 and 2020, the journal "Science of the Total Environment" covered a wide range of environmental topics, which could explain the variability in the years of publication. The specific topics of interest in those years influenced the choice of this journal as a publishing platform.

In a different investigation, the analysis that was carried out using the HistCite tool provided a deep insight into the distribution and impact of phytoremediation research in a specific period. The 12,436 articles retrieved in 1802 journals reflect the amplitude and diversity of phytoremediation research. The 20 most productive journals have published approximately 41% of the total production, suggesting leadership in the promotion and dissemination of research in the field of phytoremediation. The journals titled "The International Journal of Phytoremediation", "Environmental Science and Pollution Research", and "Chemosphere" have proven to be particularly influential by publishing various articles. Similarly, journals such as "Journal of Hazardous Materials", "Environmental Science and Technology", and "Bioresource Technology" influence the dissemination of research in this field in highly impacting factors. In this investigation, the journals "Chemosphere", "Journal of Hazardous Materials", and "Environmental Pollution" are among the six main ones that published on phytoremediation with Cucumis sativus (**Figure 2**).

3.3. Most relevant authors

The bibliometric study reveals the participation of several prominent authors in research on the phytoremediation of Cucumis sativus. During the last decade, in **Figures 4 and 5**, Jian Wu and Jie Wu stand out for having published each two articles in 2019 and 2020. This consistency in the production of articles in a relatively short period suggests significant interest or discoveries in that period about the phytoremediation of this plant.

On the other hand, it was observed that each of the authors Nava, Saeed, Nasir, Grobelak, Anran Behnam, and Behnas all published an article during the time frame of 2019 to 2023 (**Figure 4**). This broader distribution of publications over four years could indicate interdisciplinary collaboration or attention to various aspects of Cucumis sativus phytoremediation. Furthermore, the more uniform distribution of these other authors could reflect constant attention to the long-term evolution of Cucumis sativus phytoremediation.

The main authors who published in WoS on phytoremediation of cadmium-contaminated soil from 1994 to 2021 were Xiaoe Yang with 72 publications, Shuhe Wei with 42 publications, and Longhua Wu and Shafaqat Ali with 41 publications. None of the authors mentioned coincide with the main authors of this study, which means that they have not worked with Cucumis sativus.

Valdiviezo *et al*. (2023) conducted a scientometrics study on soil pollution treatment technologies, identifying a total of 78 authors with at least 10 publications each. Among the main ones were the first author: Yong Sik Ok, with 28 published documents; the second author: Daniel Tsang, also with 28 published documents and the third author: Ravi Naidu, with 27 published documents. These authors emerge as top leaders in terms of the number of publications.

The hierarchy of leading authors was based on the number of publications each has contributed to the field of study. However, despite the notable number of authors reported in WoS, this wide distribution does not indicate the excessive concentration of publications per author. This suggests that the field of research on soil pollution and treatment is diverse.

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Similarly, there are probably collaborations between authors found in the article, but they would not be the main ones concerning this work.

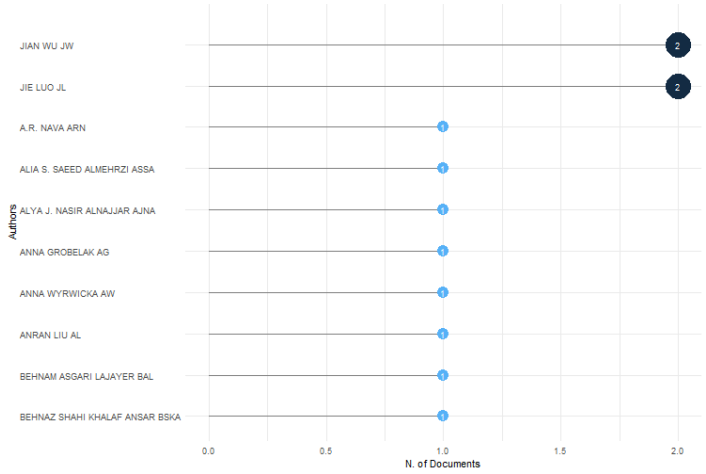

Figure 4. Most relevant authors.

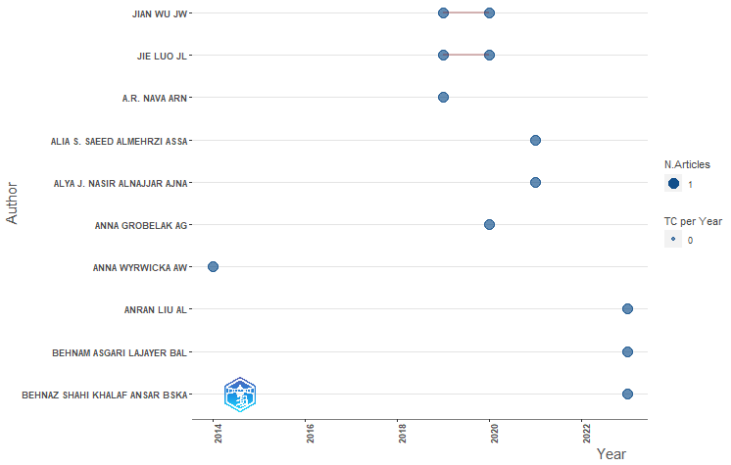

Figure 5. Most relevant authors over time.

3.4. Most relevant keywords

The results of the bibliometric analysis reveal interesting patterns in the frequency of keywords in Cucumis sativus phytoremediation studies. They are displayed in (**Figures 6-9**). The keyword "phytoremediation" is the most recurrent, with a total of 11 occurrences in the period studied, that is, 15% of the total words found. This keyword shows an upward trend, with a single occurrence in 2014 and a constant increase over the years, reaching four occurrences in 2020. This indicates an increase in research and interest in phytoremediation with Cucumis sativus and an advance in understanding its bioremediation capacity.

The keyword "bioremediation" also appears in the articles, with three occurrences in the period from 2019 to 2021 (**Figure 6**). Although its frequency is lower compared to "phytoremediation", its presence indicates a continued interest in exploring multiple approaches to the remediation of contaminated soils. The keyword “plants” also had three occurrences, spread across different years. This suggests the importance of understanding the role of plants, such as Cucumis sativus, in environmental remediation. These two words represent only 4% of each of the total words found.

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The keywords "antioxidant", "organic pollutants", "photosynthesis", and "contaminated soil" had two occurrences between 2019 to 2023 (**Figure 6**). This represented 8% of the total words found. Although these keywords have a lower frequency compared to the main ones, their appearance suggests specific attention to aspects such as the antioxidant effects of plants, the removal of organic contaminants, the role of photosynthesis, and the restoration of contaminated soils.

The bibliometric analysis of Zhang *et al*. (2022) on phytoremediation of potentially toxic elements in soil, from 2008 to 2021, found that the keyword "phytoremediation" was identified as the most used in the articles, suggesting that it is a central and fundamental term in the field of study. After “phytoremediation,” the five most frequently used keywords were “accumulation,” “plants,” “tolerance,” “Cd,” and “Pb” (**Figure 6**). These keywords likely reflect key aspects of the researchers' focus and depth of research on the topic of phytoremediation. For example, "accumulation" could be related to the ability of plants to accumulate contaminants, while "tolerance" could indicate the resistance of plants to these contaminants, and "Cd" and "Pb" to specific toxic elements such as cadmium and lead. Comparing the previous data with that of this work, a similarity is identified in the keyword’s “phytoremediation” and “plants”, being one of the main words found.

The issue of heavy metal phytoremediation from 1989 to 2018 is addressed. Certain critical points that have emerged as areas of priority focus were found. Key terms such as “soil,” “hyperaccumulator,” “enrichment process-mechanism,” and “technology improvement” highlight essential aspects that researchers consider crucial to advancing heavy metal phytoremediation. Likewise, new research outlooks that are gaining ground were identified. Such as the consideration of "wastewater", "field crops", "microbes genetically modified plants", and "agro-mining". These fundamental areas provide the conceptual framework and context for the development of effective phytoremediation approaches. In the same way, the transition was observed towards more specific and specialized categories, such as "Engineering, multidisciplinary", "Engineering, chemistry", and "Sustainable Science and Technology". These trends reflect the evolution and constant search for innovative and effective solutions in the phytoremediation of contamination mainly by heavy metals.

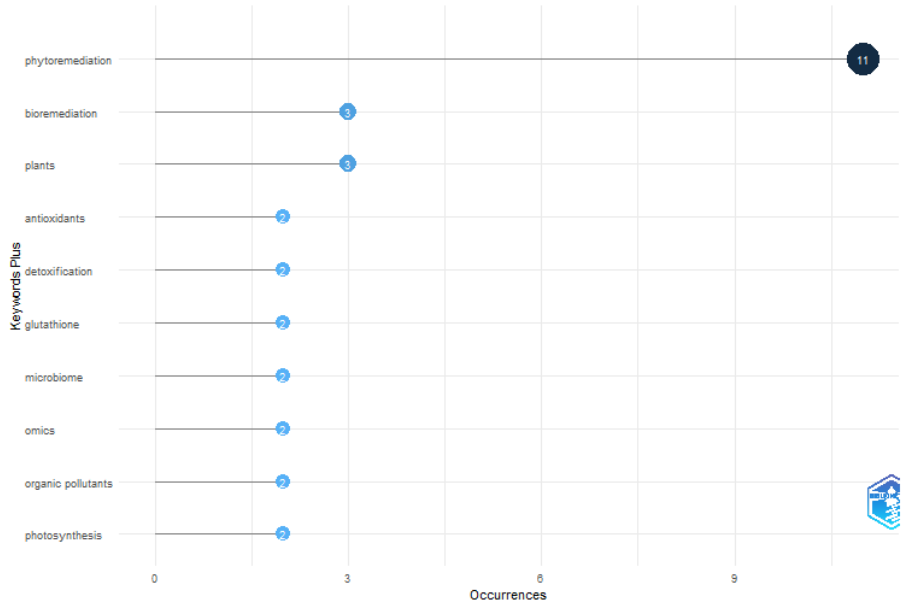

Figure 6. Most relevant words.

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Figure 7. Word cloud.

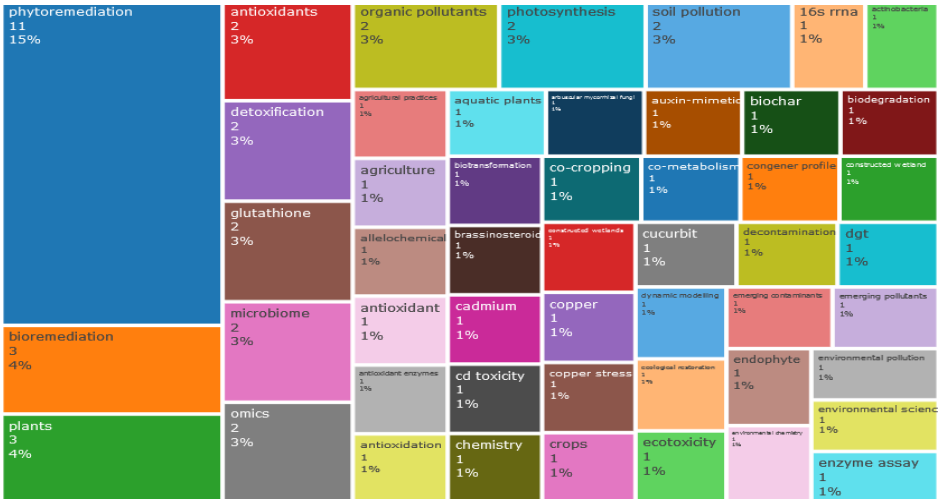

Figure 8. Word map in percentage.

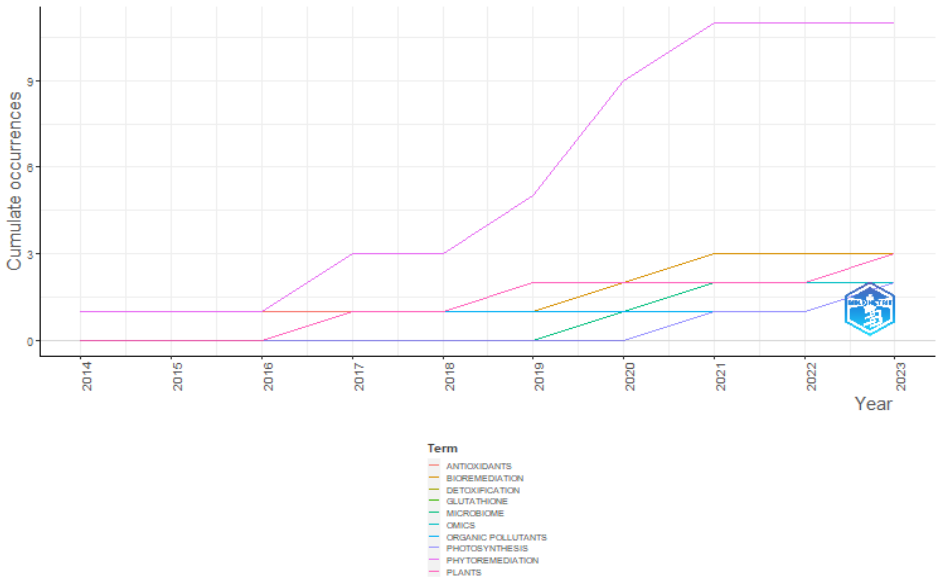

Figure 9. Frequency of words over time.

3.5 Collaboration network

The visual representation of **Figure 10** indicates the collaboration networks between various authors. These networks have been created from the collaboration of authors who have published articles. The number of published works provides information on how academics have interacted in the field of research. The Bibliometrix clustering algorithm was used to generate these collaborative networks and helped identify patterns and groups within

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the academic community. By establishing a minimum of two numbers of edges for cluster formation, the analysis focuses on authors who have collaborated on at least two articles. This highlights the strongest and most significant relationships.

By segmenting the networks into 18 distinct sets, each set is colored and designated with a name that reveals the plentifulness of communities and groups within the academic collaboration. Prominent authors such as Jian Wu J. W., Jie Lou J. L., and Chunming Zhang OZ. appear with the first two nodes, being the most representative among them. This hierarchy in node size could indicate an exceptional contribution of these authors to the research, which is reflected in their prominence in the network.

A fascinating aspect that emerges from this representation is the significant influence that the residents of certain countries exert on the formation and structure of collaboration networks. For example, it was observed that the collaboration network around Jian Wu J. W. and Jie Lou J. L. is composed of authors from China. This reflects how geographical and cultural barriers can influence academic relationships, giving rise to collaborative groups that share a common geographical base.

However, despite the abundance of connections present in these networks, the overall density of the collaboration network is low, suggesting that while there are some strong and well-established collaborations, most scholars show limited cooperation. This could be due to a variety of factors. Factors such as divergent research interests, resource limitations, or the highly specialized nature of certain fields.

In the case of Rabelo (2023), he prepared the bibliometric analysis of bacteria and fungi in the phytoremediation of hydrocarbons, which highlighted two scientific collaboration groups. The first group was the largest with seven researchers, suggesting a large and diverse network of collaboration. Names like Ali Nedaa Yousef A., Radwan Samir S. A., Khanafer Majida M, and Narjes Dashti stand out due to their strong literary bond. The second group, composed of three authors (Li Yiming, Bao Mutai, and Chen Qingguo), displayed a more selective and focused collaboration. It highlights the collaboration in scientific research and the different levels of collaboration that influence the course and impact of research in the field of phytoremediation.

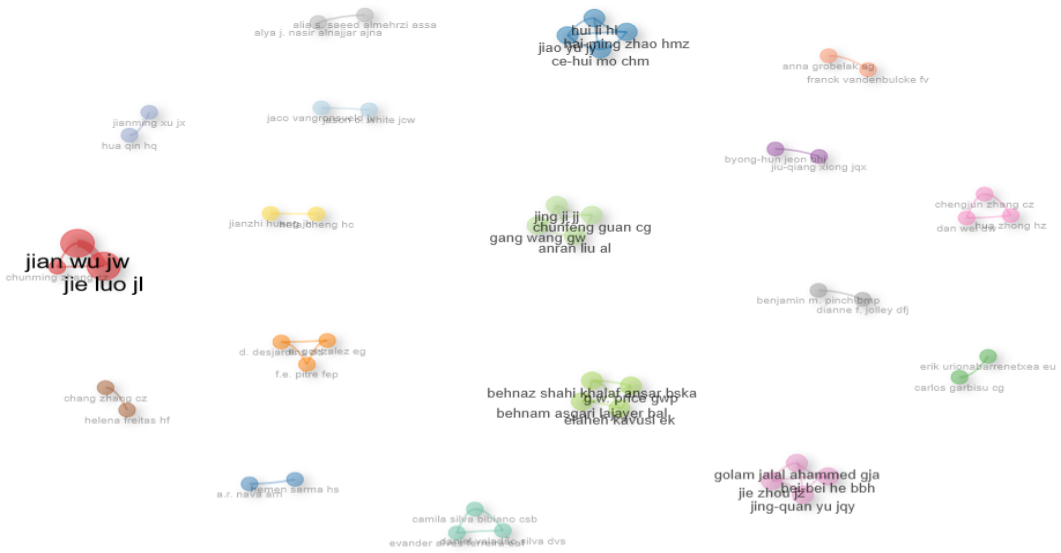

Figure 10. Map of the collaboration network.

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3.6. Post Comparison

The publications produced by the Biblioshiny software are analyzed (**Table 1**) finding Cucumis sativus as the main plant species in phytoremediation studies due to its rapid growth, adaptability, and ability to accumulate a variety of contaminants. Analysis of the publications reveals a diversity of phytoremediation approaches used. From traditional methods such as hyperaccumulation and phytoaccumulation to more innovative approaches such as biofiltration and biodegradation, these methods cover a range of strategies to address contamination. Heavy metal issues, such as cadmium, lead, copper, and nickel, have been prominent in phytoremediation studies with Cucumis sativus. Additionally, the inclusion of metalloids such as arsenic and antimony, along with organic compounds, broadens the spectrum of contaminants treated. Water and soil have been the main media in which phytoremediation experiments have been carried out. A key observation in these publications is the favorable decontamination success rate, which ranges from 50% to 85%. These results suggest phytoremediation with Cucumis sativus as being an effective method for reducing the concentration of contaminants in the experimental media.

Table 1. Comparative analysis of the publications obtained by the biblioshiny software.

Especies	Method	Pollutant	Medium	Results	Reference
Cucumis sativus L. *and Sedum alfredii*	Hyperaccumulation	Cadmium	Soil	Reduction from 30 to 47%	Lin *et al*., 2021
Nicotiana tabacum L.	Exogenous application of β-carotene.	Bisphenol A	Soil	82% removal	Wenting *et al.,* 2023
Eichhornia crassipes and Lemna minor	Review: Mathematical models of phytoremediation	Heavy metals	Soil	N/A	Jaskulak *et al*., 2020
vegetation in general	Review: Phytofiltration	Poly perfluoroalkyl	Water and soil	N/A	Kavusi *et al*., 2023
Brassica napu and Eisenia fetida	Biostimulation, bioaugmentation, phytoremediation, and vermiremediation	Chromium VI and lindane	Soil	Reduction of Cr VI to trivalent t reduction of lindane.	Lacalle *et al*., 2020
Eucalyptus globulus	Phytoremediation and red and blue light	Cadmium, lead, and copper	Soil	50%-70% decrease	Jie *et al*., 2019
Vegetation in general	Review: Phytoremediation and biofortification	Selenium	Soil	N/A	Trippe *et al*., 2021
Cucumis sativus L.	Biofiltration	Polychlorinated biphenyls	Soil	27%-38% reduction	Wyrwicka *et al*., 2014
Cucumis sativus L.	Bio absorption	Picloram Herbicide	Soil	Reduction in the topsoil layer.	Braga *et al*., 2016
Cucumis sativus L.	Glucose in plant	Copper	In plant	Copper reduction by enzymes	Mohammad *et al*., 2021

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Table 1 (continue). Comparative analysis of the publications obtained by the biblioshiny software.

Especies	Method	Pollutant	Medium	Results	Reference
sHelianthus annuus, Pseudomonas libanensis, Claroideoglomus claroideum	Bioaugmentation	Nickel	Saline soils	Accumulation in plants of 82%, 38% and 45%	Ying *et al.*, 2019
General vegetation	Review: Bioretention and phytoextraction	Insecticides, herbicides and fungicides	Soils and waters	N/A	Nele *et al.*, 2017
Cucumis sativus L.	Phytoremediation	2,4,6-trichlorophenol, chlorpyrifos and oxytetracycline	Hydroponics	Strengthening metabolism	Ahammed *et al.*, 2017
General vegetation	Review: Enzymatic biotransformation	Pharmaceutical products	Water	N/A	Mayur *et al.*, 2019
Degrading endophytes	Review: Phytoremediation	Organic material	Soil	N/A	Nai *et al.*, 2017
Cucumis sativus L.	Bioaccumulation	Lead	In plant	Pb decrease	Samira *et al.*, 2021
Plants and microorganisms	Review: Bioremediation	Polycyclic aromatic hydrocarbons	Soil	N/A	Hemen *et al.*, 2019
Plant and bacteria	Review: Phytoremediation	Heavy metals	Soil and water	N/A	Pooja *et al.*, 2021
Festuca arundinacea, Salix miyabeana y *Medicago sativa*	Phytoremediation	Trace metals and organic contaminants	Soil	Pollutant degradation	Brereton *et al.*, 2020
Cucurbita spp. Cucumis sativus	Biodegradation	polychlorinated biphenyl	Soil	Degradation of 19.5%-42.7%	Hua *et al.*, 2014
Aquatic plants	Review: Biotransformation	Metal nanoparticles and metal oxide	Water	N/A	Parisa *et al.*, 2020
Noccaea caerulescens	Light irradiation and phytoremediation	Heavy metals	Soil	Accumulation of > 100 mg kg^{-1}	Jie *et al.*, 2020
General vegetation	Review: Phytoaccumulation	Cadmium	Soil	N/A	Li *et al.*, 2023
Raphanus sativus	Bioaccumulation	Arsenic and antimony	Soil	Accumulated more as in roots and accumulated more Sb in shoots	Lien *et al.*, 2016

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4. CONCLUSION

Starting in 2014, the research marked a modest yet significant starting point with the publication of two articles. However, 2015 presented a notable decrease by not registering any publications.

The journals studied presented variability in the frequency of publication throughout the period analyzed (2014 to 2023). The journal "Environmental Pollution" was published over years dispersed throughout the period, which could indicate an adaptation to emerging issues in environmental pollution such as climate change, air pollution, and loss of biodiversity among others, and specific research approaches in different moments. Similarly, “Chemosphere” experienced a concentration of publications in recent years indicating technological advances.

Jian Wu and Jie Wu have been identified as prominent authors, who have demonstrated consistency in publishing two articles. The production of articles over a relatively short period indicates a sustained interest in Cucumis sativus phytoremediation.

The emergence of “phytoremediation” as a keyword gradually increased from 2014 to 2020, reflecting an increase in attention and interest in this field. This increasing trend can be interpreted as a response to continuous advances in the understanding of the remediation capabilities of Cucumis sativus and possibly its effectiveness in the recovery of soils and waters with contamination problems.

The bibliometric analysis has allowed the capture of a series of fluctuations in scientific production throughout these years in the phytoremediation of soil and water with Cucumis sativus, however, research remains limited.

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6. AUTHORS’ NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

7. REFERENCES

Ahammed, G. J., He, B. B., Qian, X. J., Zhou, Y. H., Shi, K., Zhou, J., Yu, J. Q. and Xia, X. J. (2017). 24-Epibrassinolide alleviates organic pollutants-retarded root elongation by promoting redox homeostasis and secondary metabolism in Cucumis sativus L. *Environmental Pollution*, *229*, 922-931.

Baker, A. J. M., and Brooks, R. R. (1989). Terrestrial higher plants which hyperaccumulate metallic elements. A review of their distribution, ecology and phytochemistry. *Biorecovery*, *1*(2), 81–126.

Braga, R. R., dos Santos, J. B., Zanuncio, J. C., Bibiano, C. S., Ferreira, E. A., Oliveira, M. C., Silva, D. V. and Serrão, J. E. (2016). Effect of growing Brachiria brizantha on phytoremediation of picloram under different pH environments. *Ecological Engineering*, *94*, 102-106.

Brereton, N. J. B., González, E., Desjardins, D., Labrecque, M., and Pitre, F. E. (2020). Co-cropping with three phytoremediation crops influences rhizosphere microbiome community in contaminated soil. *Science of the Total Environment*, *711*, 135067.

González, C. M. C., Carrillo, G. R., Sánchez, L. A. S., and Ruiz, O. (2017). Phytoremediation alternatives for sites contaminated with potentially toxic elements. *Agroproductivity*, *10* (4), 8-14.

Hemen, S., Nava, A. R., and Prasad, M. N. V. (2019). Mechanistic understanding and future prospect of microbe-enhanced phytoremediation of polycyclic aromatic hydrocarbons in soil. *Environmental Technology and Innovation*, *13*, 318-330.

Hua, Q., Philip, C. B., and Jianming, X., (2014). Cucurbita spp. and Cucumis sativus enhance the dissipation of polychlorinated biphenyl congeners by stimulating soil microbial community development. *Environmental Pollution*, *184*, 306-312.

Jaskulak, M., Grobelak, A., and Vandenbulcke, F. (2020). Modelling assisted phytoremediation of soils contaminated with heavy metals – main opportunities, limitations, decision making and future prospects. *Chemosphere*, *249*, 126196.

Jie, L., Min, C., Chunming, Z., Jian, W., and Sophie X. W. G. (2020). The influence of light combination on the physicochemical characteristics and enzymatic activity of soil with multi-metal pollution in phytoremediation. *Journal of Hazardous Materials*, *393*, 122406.

Jie, L., Wenxiang, H., Jian, W., and Xiaowen, S. G. (2019) Sensitivity of Eucalyptus globulus to red and blue light with different combinations and their influence on its efficacy for contaminated soil phytoremediation. *Journal of Environmental Management*, *241*, 235-242.

Kavusi, E., Ansar, B. S. K., Ebrahimi, S., Sharma, R., Ghoreishi, S. S., Nobaharan, K., Abdoli, S., Dehghanian, Z., Lajayer, B. A., Senapathi, V. and Price, G. W. (2023). Critical review on phytoremediation of polyfluoroalkyl substances from environmental matrices: Need for global concern. *Environmental Research*, *217*, 114844.

Lacalle, R. G., Aparicio, J. D., Artetxe, U., Urionabarrenetxea, E., Polti, M. A., Soto, M., Garbisu, C. and Becerril, J. M. (2020). Gentle remediation options for soil with mixed chromium (VI) and lindane pollution: Bio stimulation, bioaugmentation, phytoremediation and vermiremediation. *Heliyon*, *6*(8), E04550.

Li, Y., Rahman, S.U., Qiu, Z., Shahzad, S.M., Nawaz, M.F., Huang, J., Naveed, S., Li, L., Wang, X. and Cheng, H. (2023). Toxic effects of cadmium on the physiological and biochemical attributes of plants, and phytoremediation strategies: A review. *Environmental Pollution*, *325*, 121433.

Lien, K. N., Benjamin, M. P., William, W. B., Peter, R. T., and Dianne, F. J. (2016). Assessing the uptake of arsenic and antimony from contaminated soil by radish (Raphanus sativus) using DGT and selective extractions. *Environmental Pollution*, *216*, 104-114.

Lin, T., Yasir, H., Zhiqin, C., Qiang, L., Jahidul, I. S., Zhenli, H., and Xiaoe, Y. (2021). A phytoremediation coupled with agro-production mode suppresses Fusarium wilt disease and alleviates cadmium phytotoxicity of cucumber (Cucumis sativus L.) in continuous cropping greenhouse soil. *Chemosphere*, *270*, 128634.

Mayur, B. K., Yoon, H. H., Jiu, Q. X., Sanjay, P. G., Min, J., and Byong. H. J. (2021). Phytoremediation as a green biotechnology tool for emerging environmental pollution: A step forward towards sustainable rehabilitation of the environment. *Chemical Engineering Journal, 415*, 129040.

Mohammad, Y., Alia, S. S. A., Alya, J. N.A., Pravej, A., Nesma, E., Radwan, K., and Shamsul, H. (2021). Glucose modulates copper induced changes in photosynthesis, ion uptake, antioxidants and proline in Cucumis sativus plants. *Carbohydrate Research*, *501*, 108271.

Nai, X. F., Jiao, Y., Hai, M. Z., Yu, T. C., Ce. H. M., Quan, Y. C., Yan, W. L., Hui, L., and Ming, H. W. (2017). Efficient phytoremediation of organic contaminants in soils using plant–endophyte partnerships. *Science of the Total Environment*, *583*, 352-368.

Neaman, A. (2022). Phytoextraction of metals from contaminated soils: A utopian idea. *IDESIA*, *40*(4), 2-5.

Nele, E., Jason, C. W., Jaco, V., and Nele, W. (2017). Chapter seven - bio- and phytoremediation of pesticide-contaminated environments: A review. *Advances in Botanical Research*, *83*, 277-318.

Ortíz, O. A. M., Hernández, N. E., Lara, V. F., Granados, E. C. A., Landero, V. N., and Andrade, H. P. (2023). Bioaccumulation of heavy metals in cucumber plants inoculated with Trichoderma strains (Hypocreaceae) in the Mezquital Valley, Hidalgo, Mexico. *Revista Internacional de Contaminación Ambiental*, *39*, 54525.

Parisa, E., Weeradej, M., and John, P. (2020). Phytoremediation of engineered nanoparticles using aquatic plants: Mechanisms and practical feasibility. *Journal of Environmental Sciences*, *93*, 151-163.

Pooja, S. (2021). Efficiency of bacteria and bacterial assisted phytoremediation of heavy metals: An update. *Bioresource Technology*, *328*, 124835.

Rabelo, F. R. A., (2023). Bacteria and fungi used in the biodegradation of hydrocarbons: A literature review and bibliometric analysis. *Revista EIA*, *20*(39), Reia3913: 1-35.

Sabreena, Shahnawaz, H., Sartaj, A. B., Vineet, K., Bashir, A. G., and Fuad, A. (2022). Phytoremediation of heavy metals: An indispensable contrivance in green remediation technology. *Plants*, *11*(9), 1255.

Samira, K., Muhammad, I., Wajeeha, Y., and Rizwan, R. (2021). The exogenous menadiol diacetate enhances growth and yield by reducing Pb uptake, translocation and its toxicity through tissue nutrients acquisition in cucumber (Cucumis sativus L.). *Environmental Technology and Innovation*, *23*, 101666.

Santoyo-de la Cruz, M. F., Khalil-Gardezi, A., Carrillo-Castañeda, G., Ortega-Escobar, H. M., Mancilla-Villa, O. R., Rubiños-Panta, J. E., López-Buenfil, J. A., Larque-Saavedra, M. U., Haro-Aguilar, G. and Ali-Gamboa, C. A. (2023). Effect of plant growth-promoting bacteria (Medicago sativa L.) on two types of soil, copper and compost. *Acta Universitaria*, *33*, 1-14.

Shen, X., Dai, M., Yang, J., Sun, L., Tan, X., Peng, C., Ali, I. and Naz, I. (2022). A critical review on the phytoremediation of heavy metals from environment: Performance and challenges. *Chemosphere*, *291*(3), 132979.

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Trippe, R. C., and Pilon, S. E. (2021). Selenium, transport and metabolism in plants: Phytoremediation and biofortification implications. *Journal of Hazardous Materials*, *404*, (Part B), 124178.

Trojanowska, M., (2023). Reclamation of polluted land in urban renewal projects. Literature review of suitable plants for phytoremediation. *Environmental Challenges*, *13*, 100749.

Valdiviezo, G. L. G., Castañeda, O. C. A., Cabello, T. R.J., García, A. F. F., Munive, C. R. V., and Alfaro, P. E. A. (2023). Scientometric study of treatment technologies of soil pollution: Present and future challenges. *Applied Soil Ecology*, *182*, 104695.

Wenting, F., Xiaoyan, Z., Xiancao, C., Wenjing, W., Anran, L., Jing, J., Gang, W., and Chunfeng, G. (2023). The potential roles of carotenoids in enhancing phytoremediation of bisphenol A contaminated soil by promoting plant physiology and modulating rhizobacterial community of tobacco. *Chemosphere*, *316*, 137807.

Wyrwicka, A., Steffani, S., and Urbaniak, M. (2014). The effect of PCB-contaminated sewage sludge and sediment on metabolism of cucumber plants (*Cucumis sativus L*.). *Ecohydrology and Hydrobiology*, *14*(1), 75-82.

Ying, M., Mani, R., Rui, S. O., Chang, Z., and Helena, F. (2019). Potential of plant beneficial bacteria and arbuscular mycorrhizal fungi in phytoremediation of metal-contaminated saline soils. *Journal of Hazardous Materials*, *379*, 120813.

Zhang, Y., and He, G. (2022). Bibliometrics-based: Trends in phytoremediation of potentially toxic elements in soil. *Land*, *11*, 2030.

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