

SCIENTIFIC ARTICLE

Bibliometric Study of Cut Flower Research

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Abstract

Ornamental plants play a fundamental role in diverse applications, from cut flower production to landscape design and space decoration. The ornamental industry, which is part of horticulture, has experienced significant advances and mobilizes billions of dollars in the global economy, being also a totally globalized market. In recent years, this industry has implemented advanced production strategies, from genetic improvement to sustainability and supply chain, promoting scientific research in various areas. However, the dispersion of knowledge has hindered the integration of the various research networks. Therefore, this article seeks to provide an overview of the scientific production in the cut flower sector, establishing a reference line for researchers, using bibliometrics as a tool to identify trends and the scientific structure of this area of knowledge. The results revealed that worldwide since 1983 there have been 975 articles focused on this productive system, generated in more than 69 countries by 2750 authors who published their research in 160 academic journals. Relevant research topics that are already developed and those that need a more intense and integrated research focus on the knowledge already generated were also identified.

Keywords: knowledge networks, research topics, scientific impact, scientific production, sustainability.

Resumo

Estudo bibliométrico da pesquisa sobre flores de corte

As plantas ornamentais desempenham um papel fundamental em diversas aplicações, desde a produção de flores de corte até o projeto paisagístico e a decoração de espaços. O setor de ornamentais, que faz parte da horticultura, tem experimentado avanços significativos e mobiliza bilhões de dólares na economia global, sendo também um mercado totalmente globalizado. Nos últimos anos, esse setor implementou estratégias avançadas de produção, desde o melhoramento genético até a sustentabilidade e a cadeia de suprimentos, promovendo pesquisas científicas em diversas áreas. No entanto, a dispersão do conhecimento tem dificultado a integração das diversas redes de pesquisa. Portanto, este artigo procura fornecer uma visão geral da produção científica no setor de flores de corte, estabelecendo uma linha de referência para pesquisadores, usando a bibliometria como ferramenta para identificar tendências e a estrutura científica dessa área de conhecimento. Os resultados revelaram que, em todo o mundo, desde 1983, houve 975 artigos focados nesse sistema produtivo, gerados em mais de 69 países por 2750 autores que publicaram suas pesquisas em 160 revistas acadêmicas. Também foram identificados tópicos de pesquisa relevantes que já estão desenvolvidos e aqueles que precisam de um foco de pesquisa mais intenso e integrado ao conhecimento já gerado.

Palavras-chave: impacto científico, produção científica, redes de conhecimento, tópicos de pesquisa, sustentabilidade.

Introduction

Ornamental plants play a fundamental role in a wide variety of uses, including the production of cut flowers, landscape and garden design, decoration and aesthetic adaptation of domestic, commercial and industrial spaces

with plants in vases and pots (Carvalho et al., 2022; Villagrán et al., 2021). Likewise, the biodiversity, variability and versatility of cut flowers make them essential elements to embellish multiple environments (Darras, 2020; Dobres, 2011; Kenanoğlu, 2023; Villagrán et al., 2021). The ornamental horticulture industry has generated great

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technological, logistic and commercial developments, and it is currently estimated that this productive sector mobilizes approximately 43,910 million dollars in the world economy (Faust and Dole, 2021; Salachna, 2022).

The cut flower market is a globalized market, the main flower producing countries are located in the Netherlands and South America, while one of the main consumers is the United States, which imports up to 80% of its domestic consumption, however, cut flowers are marketed in more than 100 countries worldwide (Rauter et al., 2022; Ruiz and Mora, 2023; Villagrán and Bojacá, 2020; Villagrán and Bojacá, 2019). In recent years, new production strategies have been implemented in the cut flower industry, starting with the production of plant material, the study of the genome and genetic improvement of the species of interest, crop management, cultivation techniques, irrigation and fertilization, integrated pest and disease management, adaptation of emerging technologies, postharvest activities, as well as issues associated with the supply chain and the sustainability of the production system (Gabellini and Scaramuzzi, 2022; Ingram and Knight, 2019; Krigas et al., 2021). All these new strategies have been driven by the quality demands of international markets, as well as by the dynamics of foreign trade, where there have been economic recessions that undoubtedly have had an impact on this productive sector (Loyola et al., 2019).

On the other hand, this sector is also a great dynamizer of science and, in the different producing regions, multiple research projects are established and published year after year in specialized journals, thus generating new knowledge (Rocha and Medina et al., 2022a). However, all this knowledge is dispersed and sometimes it is very complex to interrelate a group of research on similar topics (Morante-

Carballo et al., 2021). Therefore, one of the strategies used in recent times to generate or know the scientific structure of a field of knowledge is bibliometrics (Raparelli and Bajocco, 2019), as well as studies that rely on quantitative statistics using meta-analysis techniques, such as the work developed by Cunha Neto et al. (2023). Likewise, there are few bibliometric studies or even review articles focused on analyzing the knowledge of the entire cut flower sector.

Therefore, the main objective of this article is to provide an overview of the scientific production in the field of the cut flower ornamental sector. It seeks to establish a baseline that can be used by researchers, academics and professionals involved in this multidisciplinary field. By identifying trends, knowledge gaps and emerging opportunities, it is hoped that this bibliometric review will contribute to the promotion of international collaboration, the advancement of research and the orientation of future research on these plant species of productive and commercial relevance.

Methodology

Currently, one of the most widely used techniques to review and analyze scientific data through a formal, rigorous and transparent method in any field of knowledge is bibliometrics (Zupic and Čater, 2015). This technique relies on various tools that allow for the in-depth analysis of a considerable volume of data, enabling the intellectual and scientific structure of a research topic to be determined (Montalván-Burbano et al., 2021). The development of a bibliometric analysis and the construction of maps of the knowledge network and scientific dissemination is structured in a systematic process that is executed in four phases summarized in Figure 1.

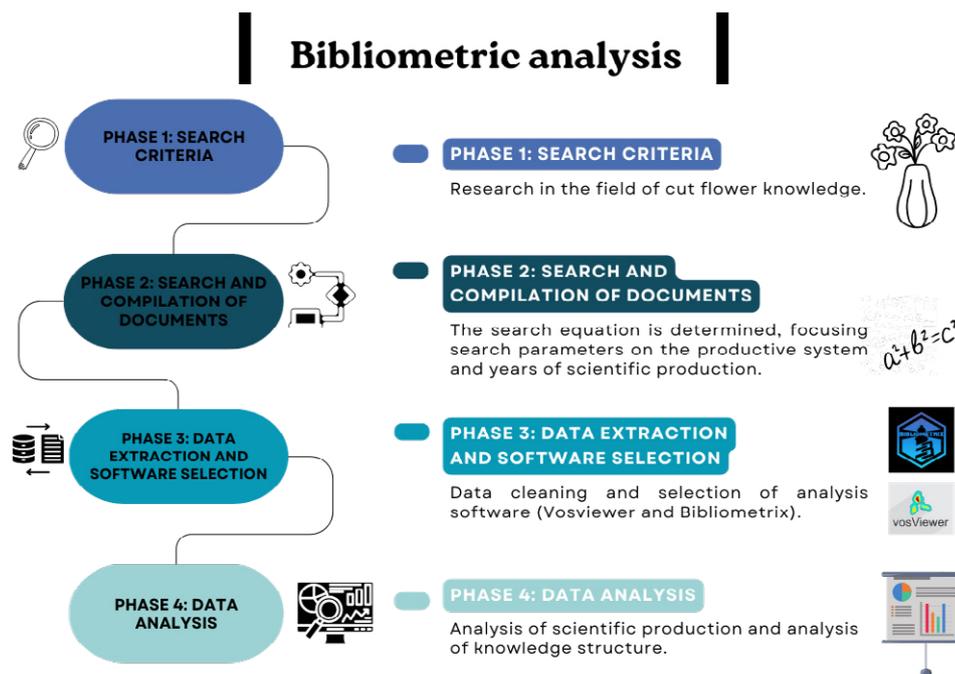


Figure 1. Phases of the academic information search process.

In phase 1, the information search criteria are determined; in our case, the objective was to compile scientific studies related to cut flower production. In phase 2, the search and compilation of documents was carried out, for which it was decided to use the scientific database Scopus, which is a broad and serious database, where extensive information in various fields of knowledge is stored (Carrión-Mero et al., 2020). The search was conducted on July 29, 2023, using basic descriptors or key terms structured in the following search equation:

EQ (1)

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TITLE-ABS-KEY ( "cut flowers" AND ( "technologies 4.0" OR "irrigation" OR "fertilization" OR
"climate monitoring" OR "energy efficiency" OR "postharvest" OR "improvement" OR
"spread" OR "soilless cultivation" OR "climate smart agriculture" OR "greenhouse" OR
"technology" OR "pest and disease management" OR "biologic control" OR
"commercialization" AND NOT "ornamental" ) ) AND PUBYEAR > 1989 AND PUBYEAR <
2024 AND ( LIMIT-TO ( DOCTYPE, "ar" ) OR LIMIT-TO ( DOCTYPE, "re" ) )
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This search equation contains Boolean operators that focus the search on all aspects related to the production system. The search was limited to review or research articles published since 1989 in any language, therefore, from the equation we were able to collect 975 documents. Phase 3 consisted of data extraction and software selection for analysis, the first step was to download the Scopus database in a comma-separated values (CSV) file, with information on the scientific structure. This information was analyzed and reviewed using Microsoft Excel, which allowed preprocessing and quality analysis of the downloaded data, thus guaranteeing the cleaning and elimination of syntax errors or duplicate documents (Ullah et al., 2022). While for the analysis of the database generated in the previous step, the free software Vosviewer and the R software with its Bibliometrix package were used, these programs allow the analysis of the intellectual structure of an academic field through the construction and visualization of networks of co-authorship, citation, among others (Rocha et al., 2022).

Finally, in phase 4, the analysis of the data collected is carried out, focusing on two approaches. The first is an analysis of the performance of the scientific production where the impact and number of publications, areas of knowledge, authors, countries and institutions of origin of the authors of the published documents, among others, are evaluated (Montalván-Burbano et al., 2021). The second analysis corresponds to that of the bibliometric maps, where the intellectual structure of the knowledge field is determined by identifying networks, authorship and co-authorship, as well as growing and declining research topics (Zupic and Čater, 2015).

Results and discussion

Scientific production

A total of 975 documents related to the research topic were collected between 1991 and 2023, which is equivalent to an average value of 29.5 documents generated per year (Figure 2). The year with the highest number of documents published is 2021 with a total of 60, followed by 2015 and 2022, with 58 and 57 documents, respectively. Likewise, it can be observed that during the first four years the number of articles did not exceed 10 documents, which shows that during these years there was little interest in publishing the research carried out in this production system. These documents of the first years focused on technological innovations for the time, such as soilless cultivation systems, where irrigation and fertilization studies predominated, as well as crop management and asepsis and disinfection of flowers during postharvest operations.

On the contrary, since 2010, publications have exceeded 40 documents for all years, which may suggest that this production system is developing research with interest in publication in various areas of work, among the most important of which are issues of genetic improvement, postharvest, and sustainability of the production system. It is also important to mention that of these published documents, 919 correspond to research articles and 56 to systematic and critical review articles.



Figure 2. Scientific production by year.

Subject area

Regarding the thematic areas associated with the published documents, a total of 15 thematic areas were found (Figure 3). It is noteworthy that the largest number of articles are associated with the area of agriculture and biological sciences, where 89.2% of the documents collected are located, because the studies are focused on agronomic management of the production system, genetic improvement, plant physiology and nutrition, irrigation management, technological innovation, and climate optimization of greenhouses. As well as postharvest energy management and the extension of the useful life of spices in the vase through senescence retardants, analyzing the biological, physiological, and biochemical behavior of cut flowers. In a second line, with

14.1% of the documents, is the area of biochemistry, genetics, and molecular biology, where there are studies related to the genetic improvement of some species in cultivation, as well as some genetic studies focused on prolonging the postharvest life of cut flowers. These studies are related to topics associated with the search for greater sustainability of the production system through the optimization of processes such as irrigation and fertilization management, integrated pest, and disease management, as well as the use of water, energy, and chemical agents in unitary postharvest conditioning operations. Finally, other studies have been in different thematic areas, which shows that this area of knowledge can be considered multidisciplinary, analyzed from the approach given to the research work developed.

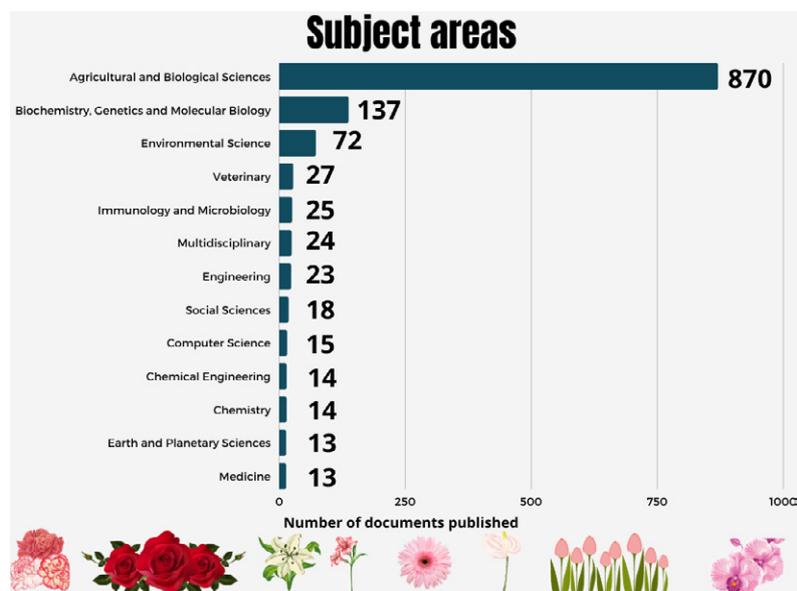


Figure 3. Subject areas involved in the field of knowledge.

Scientific production by countries

Regarding the origin of the 975 documents collected, a total of 69 countries were identified with scientific production associated with the subject, Figure 4 shows the 30 countries with the highest production of documents. The scientific production originated in the United States, Brazil, Iran, China, and India, which together produced 500 documents

equivalent to 51.2% of the documents collected, showing that these countries are at the forefront of research in the cut flower sector. At the regional level, the production originating in Colombia stands out, with 20 documents, accounting for 2% of the total production; it should be remembered that this country is the largest exporter of carnations in the world (Reynafarje et al., 2020; Villagrán and Bojacá, 2019).

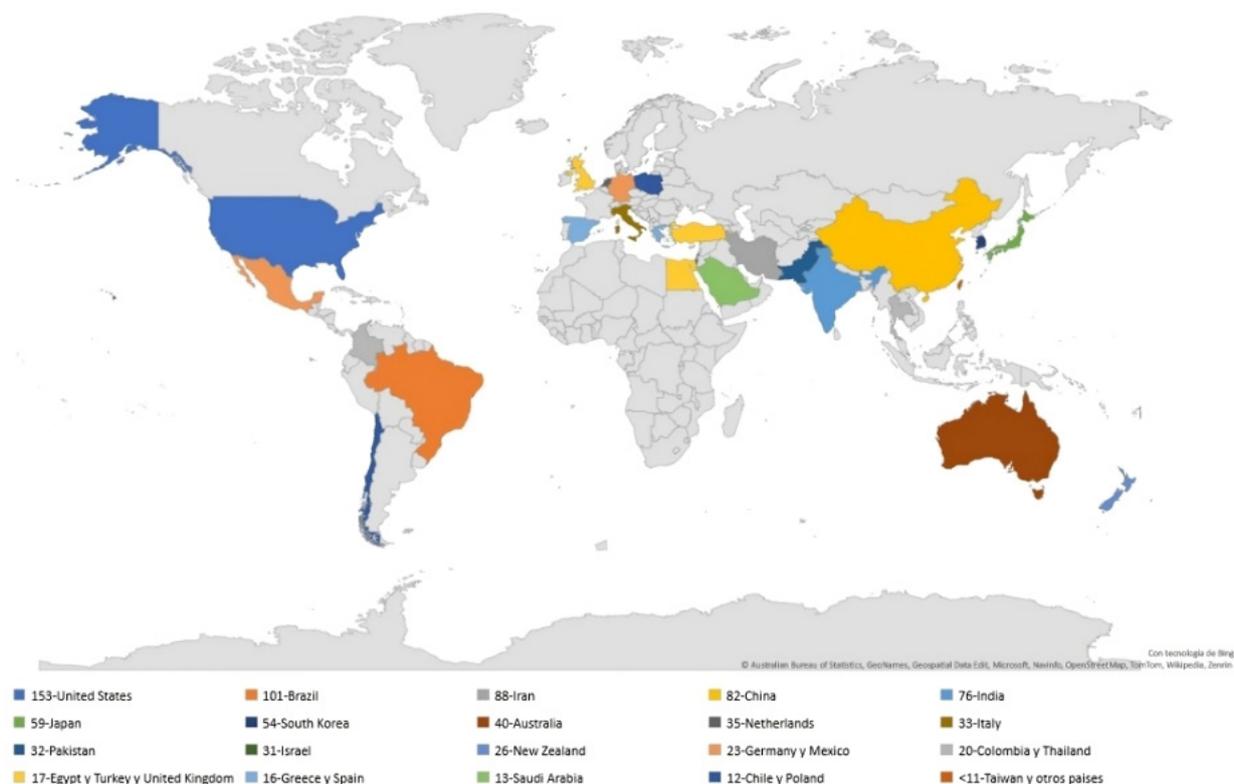


Figure 4. Countries with the highest scientific production.

Most used publication sources

In terms of publication sources, a total of 160 academic journals were identified where the 975 documents collected were published (Table 1). The contribution of documents published in the journal *Acta Horticulturae* (<https://www.actahort.org/>), with 103 documents, leads the production by academic source. This journal is multidisciplinary and publishes all the documents presented and accepted in congresses and symposia organized by the International Society for Horticultural Science (ISHS) (<https://www.ishs.org/>). In second position is the journal *Scientia Horticulturae* (<https://www.sciencedirect.com/journal/scientia-horticulturae>), where 82 documents were published; this journal is published by Elsevier and publishes research related to ornamental crops in temperate, subtropical, and tropical conditions. The journal *Ornamental Horticulture* (<https://www.ornamentalthorticulture.com.br/rbho>) is published by the Brazilian Society of Floriculture and Ornamental Plants (SPFPO) and is intended for the

publication of technical and scientific papers related to the areas of floriculture and ornamental plants, among others.

Additionally, Table 1 includes some scientific impact indicators such as the SJR ranking, which is an index based on the SCOPUS database and through which different weights are assigned to citations depending on the “prestige” of the citing journal, without the influence of the journal’s self-citations, classifying the journals in high impact (Q1) and moderate impact (Q4) (Yuen, 2018). Likewise, the H-index, this reference metric is used to evaluate the influence of a journal’s publications, where h is defined as the value (h) when the journal in question has h publications, each of which has received at least h citations (Garner et al., 2018). *Postharvest Biology and Technology* stands out in this last rating with an index of 161. This journal is published by Elsevier and is dedicated exclusively to the publication of cutting-edge articles on postharvest biological and technological research applied to horticultural products, including cut flower.

Table 1. Main journals selected for publication of papers on cut flowers.

Journal	No. Documents	SJR Ranking	H-index	Country
Acta Horticulturae	103	Q4	68	Belgium
Scientia Horticulturae	82	Q1	134	Netherlands
Postharvest Biology and Technology	51	Q1	161	Netherlands
Hortscience	43	Q2	100	United States
Ornamental Horticulture	39	Q3	10	Brazil
Horttechnology	32	Q2	63	United States
Horticulture Environment and Biotechnology	16	Q1	35	South Korea
New Zealand Journal of Crop and Horticultural Science	16	Q3	44	United Kingdom
Advances In Horticultural Science	14	Q3	27	Italy
Journal Of the Japanese Society for Horticultural Science	14	Q2	39	Japan
Horticultural Science and Technology	12	Q3	16	South Korea

Leading authors in scientific production

The 975 documents were generated by a total of 2750 authors of different nationalities. Table 2 shows the 10 authors with the highest number of publications on this topic. In general, these authors are professors or researchers at universities or research centers in the United States, Brazil, India, China, and Iran. Likewise, these authors are recognized in the research topic and have impact citation indexes higher than 12, which indicates that their works are recognized and are a reference for the area of knowledge. The author with the highest number of publications is

Dole J.M.; who published 27 papers, his works are related to postharvest focused on determining the vase life of cut flowers and foliage and the overall effectiveness of commercial hydration and retention solutions. Next in number of publications is Ahmad, I.; who published 19 papers on the postharvest life of gladiolus, carnations, and roses, as well as topics associated with crop management and physiology of these species. At the regional level, Finger, F.L.; who conducted research focused on postharvest physiological studies of different species of cut flowers, stands out.

Table 2. Authors with the highest scientific production in cut flowers.

Author	Number of documents	Citations	Total citations	H-index	Filiation	Country
Dole, J.M.	27	228	5499	19	Professor- North Carolina State University	USA
Ahmad, I.	19	144	564	13	Professor- Institute of Horticultural Sciences, University of Agriculture.	Pakistan
Finger, F.L.	15	76	7063	42	Professor- Federal University of Viçosa	Brazil
Joyce, D.C.	15	193	6470	41	Researcher- The University of Queensland	Australia
Barbosa, J.G.	13	46	482	12	Professor - Federal University of Viçosa	Brazil
Tahir, I.	12	67	1059	19	Professor - University of Kashmir.	India
Liu J.	6	271	454	10	Researcher- University of Agriculture and Engineering, Guangzhou	China
Grieve C.M.	9	245	7699	43	Researcher- U.S. Department of Agriculture.	USA
Naderi R.	10	240	937	18	Professor - University College of Agriculture and Natural Resources.	Iran
Fanourakis D.	5	219	2000	27	Researcher - Plant Sciences (IBG-2).	Germany.

Most cited documents

The 10 most cited documents were analyzed and are summarized in Table 3. These documents generate a scientific contribution to the field of knowledge, which is considered highly relevant (Carión-Mero et al., 2021; Rocha et al., 2021). The citation rate reflects that these papers contributed a total of 1676 citations, representing 14.3% of the total citations of the 975 papers collected. The document with the highest number of citations is a paper that addresses the aspects developed for 2010 and the prospects of storage under modified atmospheres as a strategy to extend the shelf life of food and cut flowers. In second place is a critical review paper that addresses pre-cooling as an essential component of temperature management, emphasizing the crucial role that this variable plays in prolonging shelf life and maintaining quality, especially for cut flowers.

The third paper addresses issues related to the *in vitro* production of orchids, through micropropagation techniques, where it was identified that the main tissue laboratories worldwide have developed hybrids that are available to different populations, which has allowed these species to become more popular and this industry to be highly profitable. The fourth paper provides a technical review of soilless growing systems, systems that are quite popular in greenhouse production due to their comparative and phytosanitary advantages over natural soil cut flower production. The following paper presents a generalizable exchange model and a framework for analyzing the different stakeholders in the Dutch flower auction market. Cases of success and failure in the introduction of IT-based trading mechanisms are presented, and recommendations for new marketing processes for Dutch flowers are proposed.

The sixth paper makes a comparative analysis of the social impact of rose production in two fictitious companies in Ecuador and the Netherlands, where the

bouquets of roses produced are marketed in the European market through auction in the Netherlands. The results showed that rose production in Ecuador is linked to several negative social effects, such as child labor, unfair wages, and health issues. On the other hand, in the Netherlands, rose production does not present negative social impacts, but it does show impacts with detrimental environmental consequences associated with the energy consumption of technician greenhouses. In the seventh place is a document where a critical review of the factors affecting the vase life of cut roses was carried out, the main findings reported show that preharvest conditions affect the responsiveness of the stomata and influence the vase life of cut roses, likewise in postharvest the factors that affect the life of flowering are the methods of collection and conditioning.

In the eighth paper the authors developed an investigation where the effect of two application frequencies (high and low frequency) of irrigation on the production of cut roses planted on rockwool was studied, the water doses applied were similar at different radiation demands. The results found showed that irrigation frequency influenced the fresh and dry weight of cut flowers, since the total fresh and dry weight of cut flower shoots measured at the end of the experimental period was approximately 33% higher in the high frequency treatment. The ninth paper shows a study of the labor problems faced by women in the Kenyan flower sector, although it mentions that some progress has been made, there are still poor working conditions on some farms. Finally, the tenth paper is a work where genetic improvement is used to improve the organoleptic characteristics of cut flowers. The authors also mention that this biotechnological technique will be key to the generation of new varieties where the color of the flowers can be manipulated, as well as improving the shelf life in the vase, since these are the two characteristics most evaluated by consumers.

Table 3. Top 10 most cited papers in cut flowers.

Title	Citacions	Reference
Modified atmosphere packaging of fresh produce: Current status and future needs	431	(Sandhya 2010)
Precooling techniques and applications for horticultural products - a review	244	(Brosnan and Sun 2001)
Micropropagation of orchids: A review on the potential of different explants.	224	(Chugh et al.,2009)
Application of soilless culture technologies in the modern greenhouse industry - A review	169	(Savvas and Gruda 2018)
Reengineering the Dutch Flower Auctions: A Framework for Analyzing Exchange Organizations	155	(Kambil and Van Heck 1998)
A comparison of cut roses from Ecuador and the Netherlands	123	(Franze and Citroth 2011)
Sources of vase life variation in cut roses: A review	94	(Fanourakis et al., 2013)
Effect of irrigation frequency on rose flower production and quality	81	(Katsoulas et al., 2006)
Humanising the cut flower chain: Confronting the realities of flower production for workers in Kenya	79	(Hale and Opondo 2005)
Novel coloured flowers	76	(Mol et al., 1999)

Knowledge structure analysis

Keyword co-occurrence network

The network of keywords used by each author makes it possible to examine the intellectual structure of the cut flower sector. This analysis makes it possible to identify the keywords that appear most frequently in the documents collected, keywords that are associated in clusters that in turn group the research papers according to their similarity (Morante-Carballo et al., 2021). Figure 5 shows the co-occurrence network of the 329 most used keywords, identifying 7 associated clusters. The green cluster associates studies focused on irrigation, drainage, and nutrition of cut flowers under greenhouse conditions, as well as the study of the growth and development of some specific crop varieties. The purple cluster includes studies focused on postharvest, mainly on the analysis of the vase life of cut flowers, including postharvest physiology and the use of pulsed and preservative solutions.

The Dark blue cluster associates work on topics related to pest and disease management, including studies where management alternatives have an influence on the quality of flowers in postharvest. The red cluster groups studies on genome and genetic improvement, physiology, and crop growth. The Dark blue cluster includes studies on commercial and supply chain issues, as well as problems associated with quality and shelf life in these phases of the commercialization process. On the other hand, the orange cluster groups work

related to the ripening and senescence hormone, such as ethylene, relating physiology, biochemistry, and inhibition of this hormone in postharvest. Finally, in the yellow cluster are associated works where the physiological and biochemical effect generated by ecological pulsed solutions on the quality and vase life of some species of cut flowers such as roses is studied. As for the most used keywords, the list is led by the word “cut flowers” which has a total of 312 co-occurrences and a link strength of 1806, followed by “vase life” with 189 co-occurrences and a link strength of 1024, followed by the words “postharvest” and “water” with 137 and 117 co-occurrences and link strengths of 901 and 1244, respectively, which indicates that the researchers are very focused on the development of studies in the area of postharvest, with the objective of prolonging the shelf life and quality of cut flowers.

Co-authorship network between countries.

The analysis of co-authorship by country makes it possible to determine whether there is any interesting pattern of collaboration between authors from different countries (Morante-Carballo et al., 2021). Countries generating 13 clusters with a total of 225 links. It was also identified that there are 17 co-authorships between the United States and Iran, followed by six co-authorships between Mexico and the United States, and finally 5 co-authorships between Brazil and India.

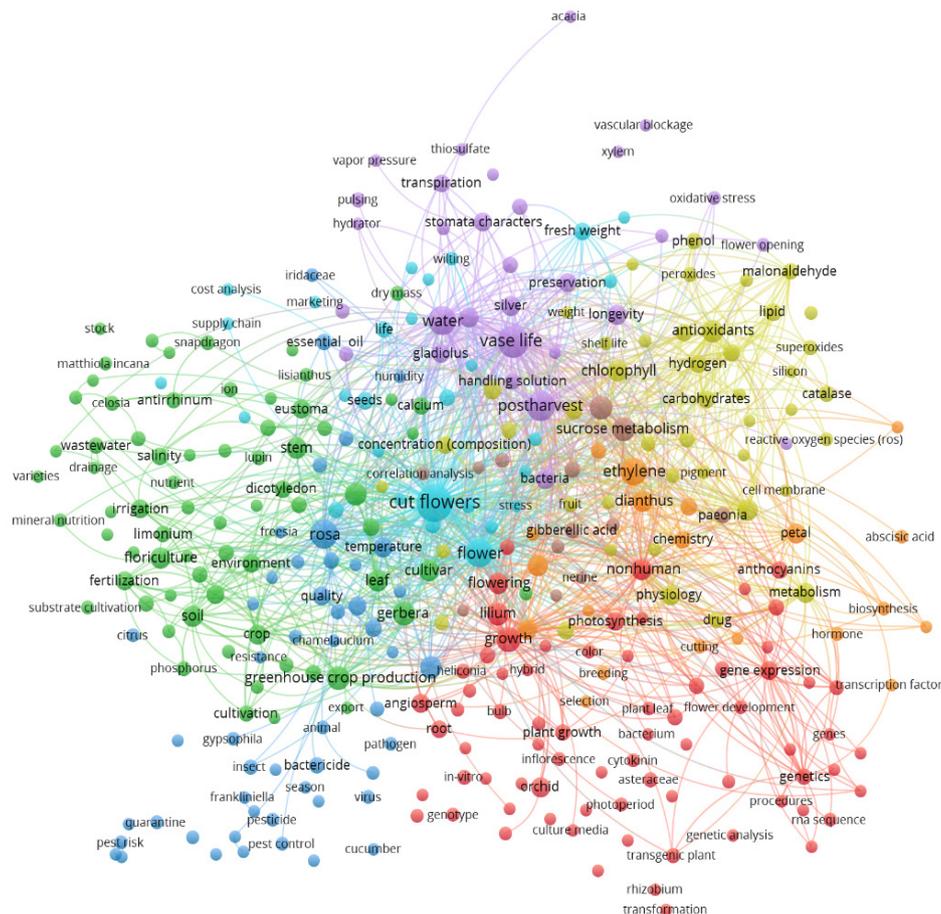


Figure 5. Co-occurrence network of keywords in the scientific area of cut flowers.



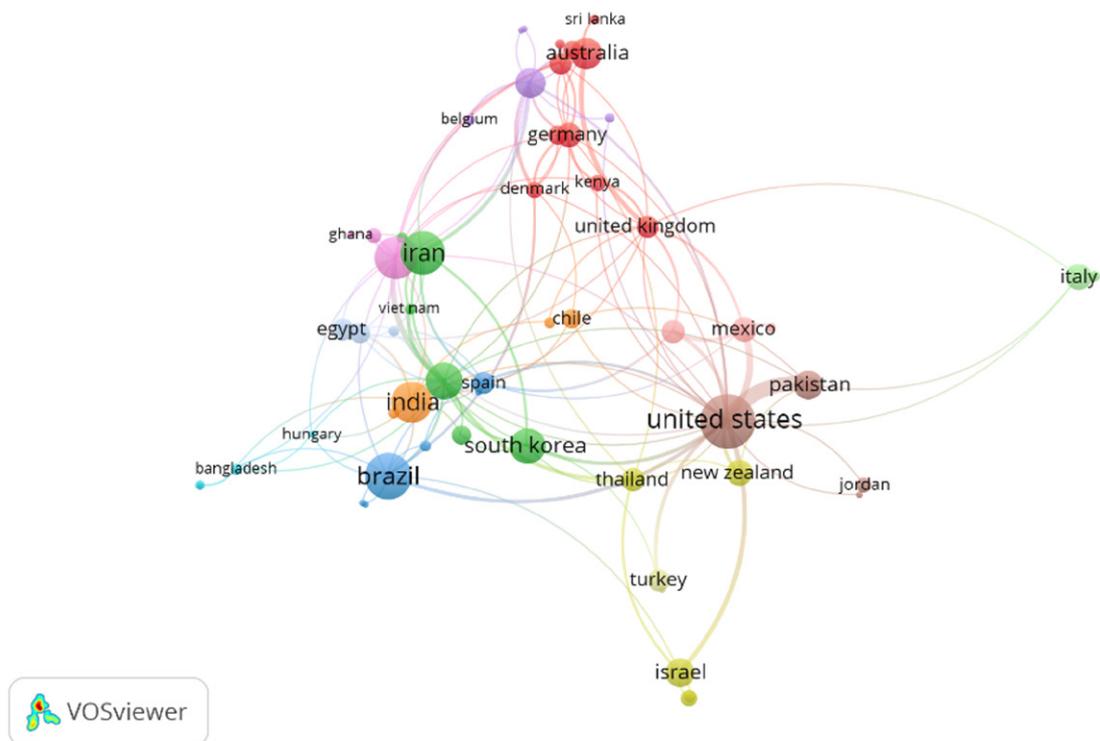


Figure 6. Principal co-authorship network generated between countries.

Author citation network

The network of citations between authors makes it possible to identify whether there is a grouping or conformation of a citation structure between different researchers in the field of knowledge (Rocha et al., 2022b; Rodríguez-Estrada, 2018). Figure 7 shows the main citation network for the 59 main authors of the 2750 that generated the documents, this network has a total of 8 clusters. The central node of the network is occupied by author Dole J.M; author who was cited by a total of 111 authors in his 228 citations, followed by Van Doorn W.G.; who was cited by 44 authors in his 187 citations.

In third place is Grieve C.M.; who obtained 245 citations from 26 different authors, and lastly, Joyce D.C., who was cited by 18 researchers in her 193 citations. Of these authors, it is worth highlighting Van Doorn, W.G.; who has achieved a relevant impact on the citation network with only six published papers, his work has focused on studies of physiology and climatic management in postharvest of roses, postharvest physiology of the Siam tulip, a species originating in Southeast Asia, as well as the development of a computer model to describe the potential vase life of gerberas, roses, carnations, chrysanthem, chrysanthemums and lilies (Alaei et al., 2009; Arrom and Munné-Boch, 2012; Mirjalili et al., 2018).

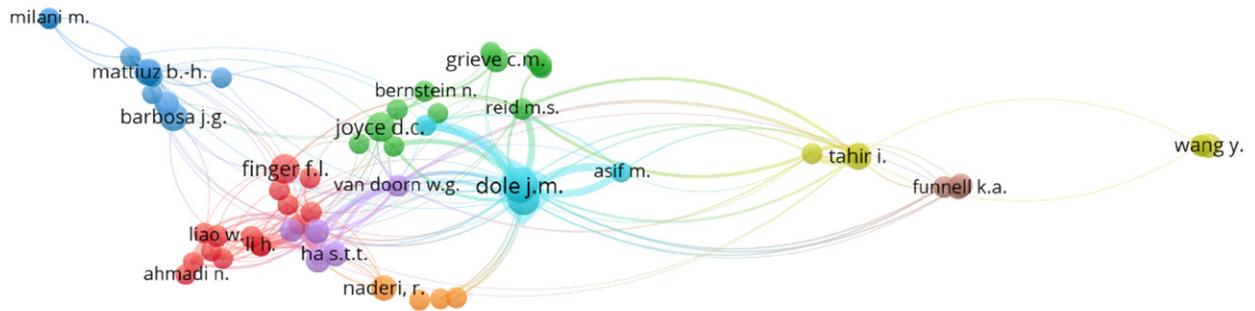


Figure 7. Citation network generated by the authors of the documents collected.

Author cocitation network

Author co-citation analysis allows to evaluate the intellectual structure of the analyzed area of knowledge, this type of analysis proposes that two authors share the same area of research if their papers are cited jointly by one or more papers (Díez-Martín et al., 2021; Montalván-Burbano et al., 2020). Figure 8 shows the network of cocitation between authors of the documents collected and identifies six clusters that are associated with similar research topics. The blue cluster is centered on the author Van Doorn W.G., who works on climate management and water relations and their effect on the quality and life of cut flower vases. The yellow cluster is centered on Reid M.S., which deals with postharvest physiology and the

use of nutritive, antibacterial and pulsant solutions in postharvest of various cut flowers. The purple cluster where the authors Finger F.L and Ahmad. I.; who work on topics associated with crop management and preharvest factors that affect the vase life of various cut flower species.

The blue seawater cluster centralized on Grieve C.M.; in this cluster they work on irrigation, nutrition, crop management under water and salt stress conditions. The red cluster where the central node is Joyce D.C.; they work on quality and pest and disease control in the postharvest stage, and finally, the green cluster centralized in Ketsa S.; where they also work on issues associated with postharvest physiology in various cut flowers.

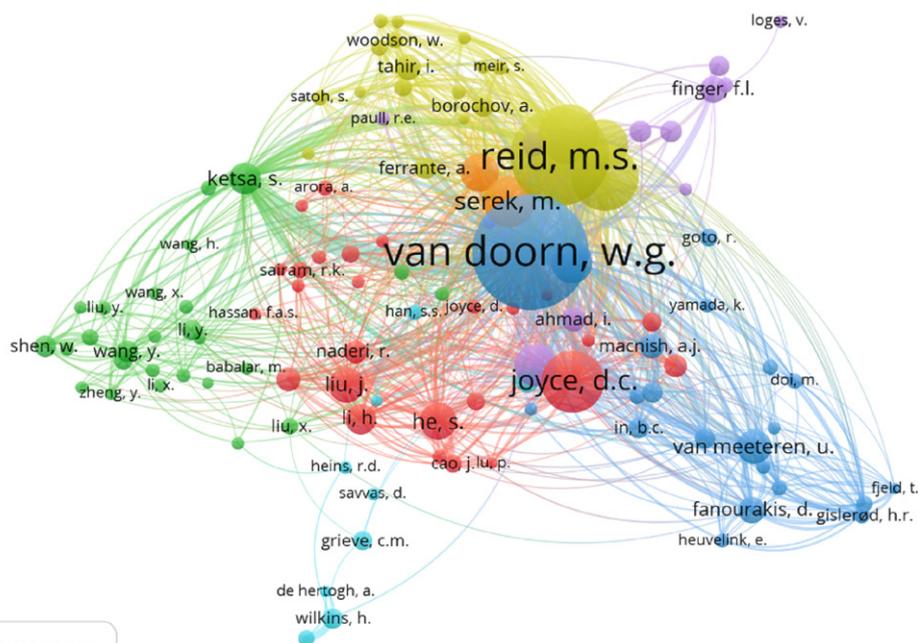


Figure 8. Citation network generated by the authors of the documents collected.

Typologies of relevant research topics.

The map of the intellectual structure and research topics was constructed from the interactions in networks that exist between the keywords used by the authors (Figure 9). This map is based on the centrality that measures the interaction between networks on the y-axis, as well as the density on the x-axis that measures the cohesive strength of each internal network (Madsen et al., 2023; Rocha et al., 2022; Zehra and Urooj, 2022). In the upper right quadrant are located the motor topics, which have already been developed and are important within the scientific area of study. Here we can see that there are topics related to the production of calve, where water management is important both in preharvest work, such as irrigation, and in postharvest work, where this factor is addressed as a key parameter in the water relations of plants and its effect on vase life.

In the same quadrant, with greater integration between each of the knowledge networks, are the works focused on the genetic study of chrysanthemum plants, especially because this species is of great commercial and productive interest worldwide (Liu et al., 2016; Shulga et al., 2011), there is also work related to root and leaf plant diseases, caused by various pathogens (Alaei et al., 2009; Pettitt et al., 2011). As for the lily,

postharvest studies are being carried out to find strategies at the hormonal level to increase its vase life (Arrom and Munné-Bosch, 2012), as well as studies related to culture growth and development in different culture media (Karagüzel, 2020). In the lower right quadrant are located basic topics, which are of high interest for the area of knowledge and that maintain a number of stable research over time, to mention a species is the rose where you can find studies focused on irrigation and fertilization (Shi and Kim, 2014), crop physiology and management (Ghazijahani et al., 2018), genome study and genetic improvement (Nergi and Ahmadi, 2014) and undoubtedly in postharvest (Mirjalili et al., 2018).

In the lower left quadrant there are not very developed topics, here we can observe works related to the well-known wax flower where the floral abscission in postharvest induced by *Botrytis* infection has been an important problem for this industry (Hu et al., 2009). Finally, in the upper right quadrant are the peripheral topics that basically can be quite developed but disconnected from the rest of the themes, there are species that are generally used as accompaniments in floral bouquets such as the wavy sea leaf or are edible flowers such as wool flower or sunflowers, among others.

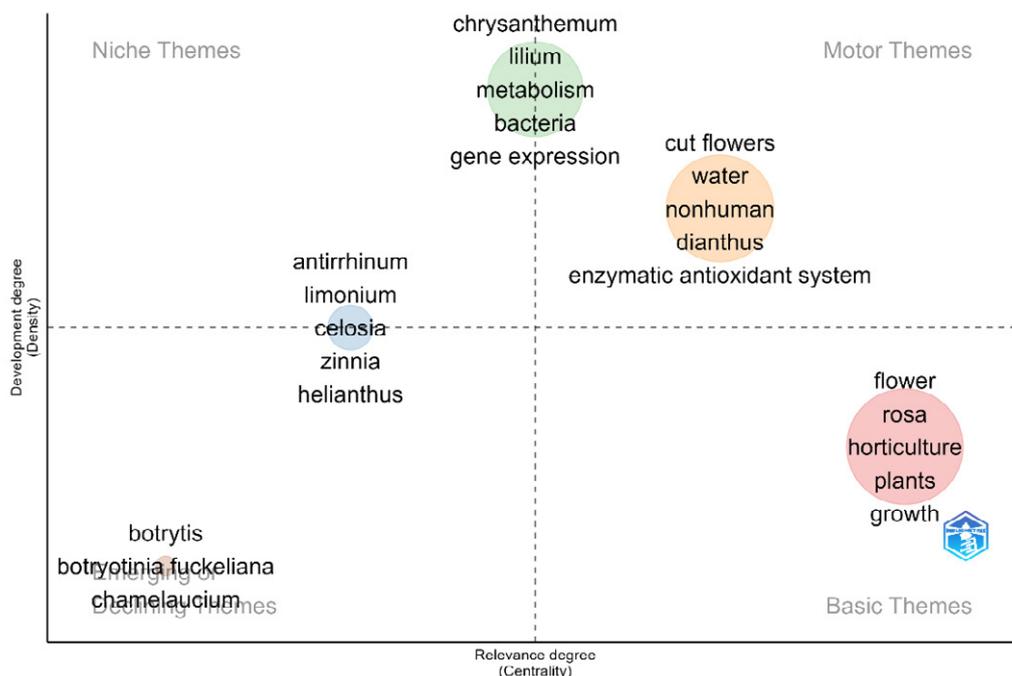


Figure 9. Typologies of research topics in the cut flower sector.

Conclusions

The bibliometric analysis showed a growing interest in research on this production system with a significant increase since 2010, highlighting areas such as genetic improvement, postharvest, and sustainability. This reflects an evolution in scientific interest and a multidisciplinary

approach in the generation of information, associated with more than 15 thematic areas of knowledge.

Sixty-nine countries were identified as the origin of the 975 documents collected, which are published in high and medium impact journals. The United States, Brazil, Iran, China, and India stand out with 500 documents, representing 51.2% of the total and leading research on

cut flowers. Colombia stands out as the main exporter of carnations, and contributed 20 papers, representing 2% of total production at the regional level.

Analysis of the intellectual structure and research topics reveals different categories. The motor topics, such as carnation production and the genetic study of chrysanthemum, are well developed. Basic topics, such as the study of the rose in areas such as irrigation, physiology, and genetics, remain stable over time. On the other hand, there are topics that have been little explored, such as floral abscission in waxflower. Finally, as for peripheral or little explored topics, there are studies on species used in floral bouquets and edible flowers, which are disconnected from the main areas of research. This diversity of approaches shows that there are opportunities for future studies and generation of technological innovations in the field of cut flowers.

Author Contribution

EV, GAO, LM, JFV, CEA, LG, EA, SN: idea creation, data analysis and collection, data analysis, preparation of the manuscript, edition of the manuscript.

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