eib0985881301

Dactylopius opuntiae (Hemiptera: *Dactylopiidae*) control tactics: a bibliometric analysis

Esperanza García Pascual*
Marco Martín González Chávez**
Avelina Franco Vega**
Esteban Rodríguez Leyva***
Santiago de Jesús Méndez Gallegos*
Juan Angel Morales Rueda****
Angel Bravo Vinaja*

Artículo recibido:
22 de junio de 2023
Artículo aceptado:
6 de noviembre de 2023

Artículo de investigación

ABSTRACT

The objective of this article is to identify the growth, control tactics, collaboration among authors, and emerging trends in scientific research related to the control strategies of *Dactylopius opuntiae* Cockerell (Hemiptera: *Dactylopiidae*) through bibliometric indicators. In order to recover the relevant academic articles on the topic, six referential databases were consulted. The keyword used to retrieve bibliographic information was «Dactylopius opuntiae» in the search fields: title, abstract and keywords. 1 212 bibliographic records were obtained, which

* Colegio de Postgraduados, Campus San Luis, México
garcia.esperanza@colpos.mx jmendez@colpos.mx abravo@colpos.mx
** Facultad de Ciencias Químicas, Universidad Autónoma de San Luis Potosí, México
gcmm@uaslp.mx avelina.franco@uaslp.mx
*** Colegio de Postgraduados, Campus Montecillo, México esteban@colpos.mx
**** Viscoelabs, Materials Research Center ja.morales@viscoelabs.com

were sent to the Zotero software, and subsequently reviewed to discard repeated records unrelated to the topic, obtaining only 99 from 1848 to 2022. These records resulted in four bibliometric indicators using Excel and VOSviewer.
The dynamic of scientific production has been more evident during the last seven years. Biological control, through predators and entomopathogens, was the most studied emergent research theme. From 1848 to 2000, only 12 documents of scientific production about *D. opuntiae* control tactics were found; production has been increasing by a greater proportion from 2016 up to 2022. The most outstanding control tactics were focused on biological control and non-conventional chemical control using various products such as oils, plant extracts, soaps, and detergents. Finally, the most frequently mentioned research topic was «biological control». Among other conclusions, the most researched topics were biological control agents (predators and entomopathogens) and plant resistance, which stood out as the tactic that could be most sustainable.

Keywords: Bibliometric analysis; Pest control; Wild cochineal; Scientific production.

Tácticas de control de Dactylopius opuntiae (Hemiptera: Dactylopiidae): un análisis bibliométrico

Esperanza Garacía Pascual, Marco Martín González Chávez, Avelina Franco Vega, Esteban Rodríguez Leyva, Santiago de jesús Méndez Gallegos, Juan Angel Morales Rueda y *Angel Bravo Vinaja*

Resumen

El objetivo de este trabajo tiene como finalidad identificar el crecimiento, las tácticas de control, la colaboración entre autores y las tendencias emergentes de la investigación científica relacionadas con estrategias de control de *Dactylopius opuntiae* (Cockerell) (Hemiptera: *Dactylopiidae*) por medio de indicadores bibliométricos. Con el fin de recuperar los artículos académicos relevantes sobre el tema, se consultaron seis bases de datos referenciales. Para recopilar la información bibliográfica, se empleó «Dactylopius opuntiae» en los campos de búsqueda: título, resumen y palabras clave. Se rescataron 1 212 registros, los cuales fueron enviados al software Zotero y, posteriormente, se

DOI: http://dx.doi.org/10.22201/iibi.24488321xe.2024.98.58813

revisaron para descartar repeticiones ajenas al tema, con lo que resultaron solo 99 desde el año 1848 al 2022. Estos registros sirvieron para obtener cuatro indicadores bibliométricos utilizando Excel y VOSviewer.
La dinámica de la producción científica fue más evidente durante los últimos siete años. El control biológico, a través de depredadores y entomopatógenos, fue el tema de investigación emergente más estudiado. De 1848 al 2000, sólo se encontraron 12 documentos de producción científica sobre tácticas de control de *Dactylopius opuntiae* (cochinilla silvestre); la producción se incrementó en una proporción mayor de 2016 a 2022. Las tácticas de control más destacadas estuvieron enfocadas al control biológico y al control químico no convencional utilizando diversos productos como: aceites, extractos de plantas, jabones y detergentes. Finalmente, el tema de investigación mayormente mencionado fue el «control biológico». En conclusión, se puede decir que los tópicos más investigados radicaron en los agentes de control biológico (depredadores y entomopatógenos) y la resistencia de las plantas, lo cual destacó como la táctica que podría ser más sostenible.

Palabras clave: Análisis bibliométrico; Control de plagas; Cochinilla silvestre; Producción científica.

Introduction

At the national and international level, the regions or countries where cactus pear, *Opuntia* spp (Caryophyllales: *Cactaceae*), particularly O. *ficus-indica* (L.) Mill. is used or cultivated for human and animal diets, or for the incipient industry; it presents a critical phytosanitary situation because of the recent invasion of *Dactylopius opuntiae* (Hemiptera: *Dactylopiidae*). This insect is considered the main pest of cactus pear due to its reproductive capacity, the severity of its damage in cladodes and fruits, and its socioeconomic impact (Vanegas-Rico *et al.* 2010; 2016; Mazzeo *et al.* 2019). In Mexico, one of the centers of origin of *O. ficus-indica* (Griffith 2004), and its plant feeders, is distributed in more than 20 states, where it infests 15 species of cacti (Chávez-Moreno *et al.* 2011); worldwide, it has been found in more than 29 countries (Méndez-Gallegos and Bravo-Vinaja 2022), and has caused devastating damages from its recent expansion in the basin of the Mediterranean, mainly in northern Africa and the Middle East (Bouharroud *et al.* 2016; Moussa *et al.* 2017; Bader and Abu-Alloush 2019; Mazzeo *et al.* 2019;

Ülgentürk and Hocaali 2019; Bufaur and Bohamdan 2020; El Bouhissi *et al.* 2022), as well as from its potential expansion to new areas in northeastern Brazil (Torres and Giorgi 2018).

Because of the damages caused by D. *opuntiae* on *Opuntia* spp., particularly in Brazil and more recently in northern Africa and the Middle East, the scientific production about the methods to combat this pest has increased during the last 15 years. In a recent study, Méndez-Gallegos and Bravo-Vinaja (2022) found out that during the last decade more than 50 % of the scientific production related to *D. opuntiae* was focused on the application of tactics for its control, this was considered important to identify the types of control tactics that have been carried out to date to focus future lines of research.

The bibliometric approach allows for the analysis of large volumes of scientific documents, identifies the evolutionary changes of a specific field, and provides information on emerging research trends (Donthu *et al.* 2021). Likewise, bibliometrics, defined by Pritchard (1969), represent an essential tool to evaluate scientific production (Moral-Muñoz *et al.* 2020). This study has the objectives of identifying growth, control tactics, co-authorship networks, and emerging trends in scientific research related to control strategies of *Dactylopius opuntiae* Cockerell (Hemiptera: *Dactylopiidae*) using four bibliometric indicators to facilitate decision-making regarding the integrated management strategy of this pest to minimize the damage it causes.

Materials and methods

Sources of information and databases

In order to identify the trends in scientific production related to the strategies used in the control of *D. opuntiae*, the following databases were consulted: Cab Abstracts, Crossref, Google Scholar, Dimensions, Science Citation Index Expanded (SCIE) and Scopus.

Search strategy, refining process and adaptation of bibliographic records

The descriptor used for the extraction of published documents was «*Dactylopius opuntiae*». This was performed in the search fields of *title*, *abstract* and *keywords* to ensure that it had as its main theme the topics of interest. With the search words applied, 1 121 documents were recovered and sent to a database in Zotero software; then, these were subjected to a refining process to eliminate duplicated

DOI: http://dx.doi.org/10.22201/iibi.24488321xe.2024.98.58813

documents or those that did not address the theme. The final database used in the analysis had 99 documents published and indexed until March 2022.

So that this describes the type of control tactic used in the analyzed research, some keywords were added to each bibliographic record in the tags field: 1) Biological control; 2) Conventional chemical control; 3) non-conventional chemical control (plant oils, extracts, essential oils, fatty acids and detergents, among others); 4) Plant resistance; and 5) Others (where legal control, physical control, mechanical control, cultural control and ethological control were included).

Bibliometric analysis and scientific mapping

The documents were processed through four bibliometric indicators. According to Donthu *et al.* (2021), *Growth and behavior of scientific production and Control strategies or tactics classification* were classified as performance techniques, and both were obtained using Zotero and Excel. Instead, *Co-authorship networks and validity through time* were valued as scientific mapping techniques (Noyons 2005); in addition, the first one was recovered from the Co-authorship analysis procedure in VOSviewer software (van Eck and Waltman 2011); *Research themes through time* (1884-2022) was mapped using the co-occurrence of words methodology (van Raan 1993; van Eck and Waltman 2007) through authors or database keywords in VOSviewer. A database of bibliographic records was created in Zotero, and it was imported into VOSviewer in RIS format, which allowed creating and visualizing maps.

Results and discussion

Growth and behavior of scientific production

According to the search strategy, 99 publications were identified and extracted. Scientific production about *Dactylopius opuntiae* control tactics and their regularity increased in a progressive and sustained manner during the last seven years since publications quadrupled; this reflects the growing scientific interest in the theme (*Fig. 1*). This could be associated with the recent invasion of *D. opuntiae* in Brazil in 2001 (Torres and Giorgi 2018), and successively in northern Africa, the Middle East and other countries that exploit Opuntia spp. commercially. Israel and Lebanon stood out at the end of 2013 (Spodek *et al.* 2014), and Morocco in 2015 (Bouharroud *et al.* 2016).

From 1848 to 2000, only 12 documents were found, most of them published in the last two decades. This trend coincides with the importance that *Opuntia*

spp. acquired at the international level, driven by different international agencies during the last 30 years (Méndez-Gallegos and Bravo-Vinaja 2022), as a strategy to combat poverty, food safety and the reduction of desertification; likewise, the discovery of new properties and applications of cactus pear and its byproducts, which motivated the expansion of its cultivation and exploitation (Castellano *et al.* 2021; da Silva *et al.* 2021). The value of the coefficient of determination (R2) indicates, in this case, a moderate growth of scientific production throughout the period studied but in 2016-2022, the growth was higher.

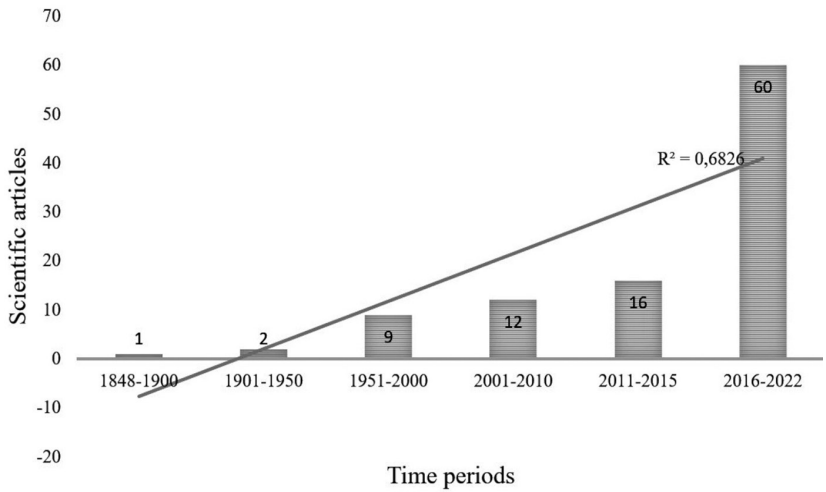

Figure 1. Behavior and evolution of scientific production, regarding control tactics used for *Dactylopius opuntiae*. 1848-2022.
Source: Prepared by the authors, 2023.

Control strategies or tactics classification

Regarding the thematic areas of research addressed by the scientific publications, almost all the control tactics were mentioned in the 99 publications (20 of them were grouped into two research fields). However, there was an emphasis on the application of less invasive tactics, which could be more sustainable than conventional chemical control (*Fig. 2*). The most outstanding areas were focused, primarily, on biological control through predators and entomopathogens (48 %), with the following references: Vanegas-Rico *et al.* (2010; 2016); Bouharroud *et al.* (2018); El Aalaoui *et al.* (2019; 2022); Ramírez-Sánchez *et al.* (2019); Mendel *et al.* (2020); and more. On the other hand, non-conventional

DOI: http://dx.doi.org/10.22201/iibi.24488321xe.2024.98.58813

chemical control used various products such as oils, plant extracts, soaps, and detergents, which represented 21 % (Pérez-Ramírez *et al.* 2014; El Aalaoui *et al.* 2021; López-Rodríguez *et al.* 2021; Ramdani *et al.* 2021, among others). An important number of documents (14 %) corresponded to organo-synthetic insecticides, derived from the urgency of reducing the impact of damage immediately (Pretorius and van Ark 1992; Hernández-Pérez *et al.* 2019; Zeitoun *et al.* 2020).

After the tactics reported as most frequent, studies about plant resistance also stood out, with 13 % (Palacios-Mendoza *et al.* 2004; Vigueras et al. 2009; Passos da Silva *et al.* 2009; Sbaghi *et al.* 2019; Akroud *et al.* 2021; da Silva *et al.* 2021). It is important to highlight that some essential tactics, such as legal control, ethological control, and mechanical control, were also common practices in many areas (Moran and Hoffmann 1987; Macêdo *et al.* 2014; da Silva *et al.* 2010; and El Aalaoui and Sbaghi 2021).

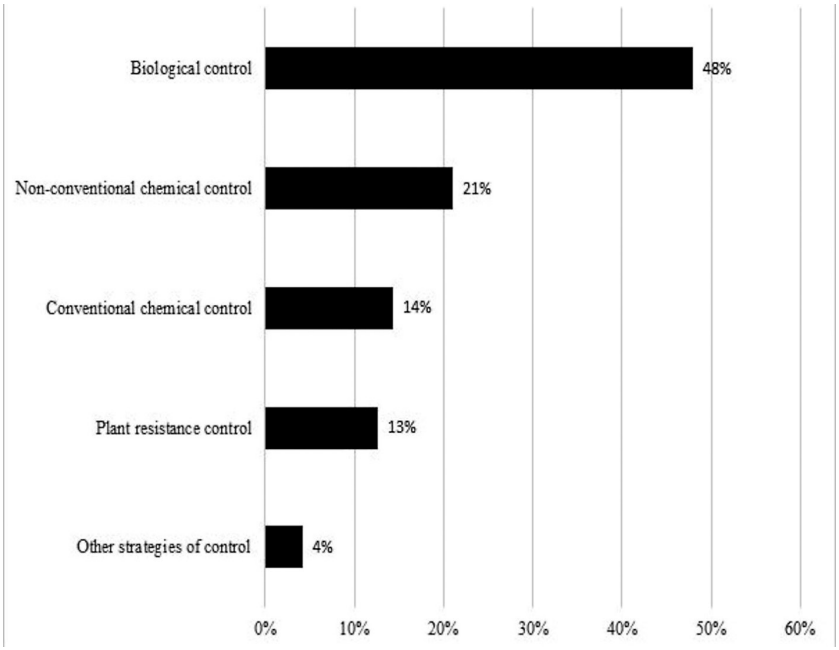

Figure 2. Control strategies of D*actylopius opuntiae* addressed by scientific publications from 1848 to 2022.
Source: Prepared by the authors, 2023.

The bibliometric analysis of scientific literature showed that two control tactics used for *D. opuntiae* could be the most sustainable: 1) the selection and

improvement of resistant varieties represent the most important tactic for management proposals of *D. opuntiae* in the world (Akroud *et al.* 2021), although the reproduction and replanting of these varieties are still a problem, particularly in northern Africa; on the other hand, the process of selection and improvement of varieties that are not destined to fodder, as in Brazil, northern Africa and most of the Middle East, can be longer and more complicated, as in the case of Mexico, with the selection for consumption of fresh vegetable or fruit cultivars with particular characteristics; and 2) classical biological control in Israel (Mendel *et al.* 2020) or conservation in Mexico (Vanegas-Rico *et al.* 2010; 2015; 2016; Cruz-Rodríguez *et al.* 2016; Barreto-García *et al.* 2020) represent the best alternatives. The use of chemical control, particularly non-conventional, is one of the complementary tactics with the highest impact in the strategy of integrated management, together with legal and mechanical control, which should not be dismissed.

Co-authorship networks and their validity through time

The co-authorship patterns of the researchers indicated how these are related and participate in processes of research and publication (*Fig. 3*). For practical purposes, the scientific production was concentrated in three countries, primarily Brazil, Morocco, and Mexico. This could be associated with the fact that they are the countries where damage from *D. opuntiae* on *Opuntia* spp. caused the greatest socioeconomic impact in the last 15 years. In Brazil, the presence of four important research groups of authors: 1) Antonio Felix da Costa, Patricia Vieira Thiago, Luciana Gonçalves de Oliveira; 2) Djalma Cordeiro dos Santos, H. Marinho Falcao, Cavalcanti Vanildo Leal Bezerr; 3) Cesar Auguste Badji, Edcleyton José de Lima, and Keila Aparecida Moreira; 4) Jacinto de Luna Batista, Ivanildo Cavalcanti de Alburquerque, Carlos Henrique de Brito and Edson Lopez Batista. These authors mainly belong to Empresa Pernambucana de Pesquisa Agropecuaria (IPA), Universidade Federal de Pernambuco, the Agronomical Institute of Pernambuco, and Universidade Federal do Agreste de Pernambuco. Likewise, this country also stood out for having the highest number of participating researchers who have published constantly since 2010.

In Mexico, research involves mainly four institutions: Colegio de Postgraduados, Universidad Autónoma Chapingo, Universidad de Guadalajara and Instituto de Investigaciones Agrícolas y Pecuarias (INIFAP). It is also important to highlight that one of the active work groups is represented by Rodríguez-Leyva, and Lomelí-Flores, from Colegio de Postgraduados, which maintains close collaboration with other authors, such as Vanegas-Rico, Méndez-Gallegos, Mena-Covarrubias, and Portillo.

DOI: http://dx.doi.org/10.22201/iibi.24488321xe.2024.98.58813

In addition, they are the researchers that have established, together with Dr. Zvi Mendel and Colegio de Postgraduados, the first international program of classical biological control of *D. opuntiae* in Israel (Mendel *et al.* 2020); this program seems to evidence success that should be corroborated and disseminated among the rest of the countries of the Mediterranean and the Middle East.

In Morocco, the collaboration pattern is constituted by the network of authors of more recent appearance (mainly Bourrahoud, Sbaghi and El Aalaoui) concentrated particularly in two institutions: Institut National de la Recherche Agronomique (INRA) and the International Center for Agricultural Research in the Dry Areas (ICARDA) (*Fig. 3*). The research groups from Brazil and Mexico have remained in force for a longer period, perhaps due to the severity of the damage caused by *D. opuntiae* in those countries and the economic and social importance of *Opuntia* spp.

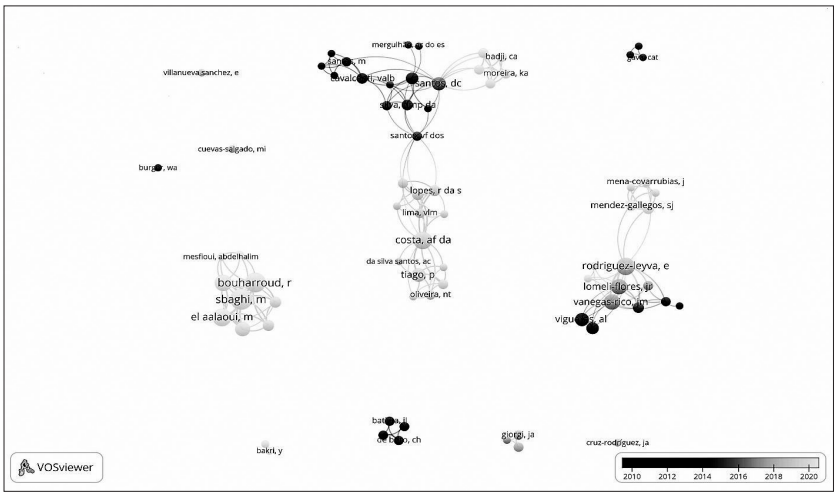

Figure 3. Co-authorship networks, and their distribution throughou time, which addressed the *Dactylopius opuntiae* control tactics, 1848-2022. Source: Prepared by the authors, 2023.

Although there is a collaboration pattern of working groups between education and research institutions at the national level —which established networks to address this problem and take better advantage of its capacities and infrastructure, particularly in Brazil and Mexico— it was observed that there is a reduced rate of international collaboration and publication in high-impact journals. The most recent example of international collaboration, and apparently the most successful, is the program for classical biological control of *D. opuntiae* between Mexico and Israel (Mendel *et al.* 2020).

Research topics through time (1848-2022)

The analysis of the co-occurrence of words in the publications allowed establishing a complete outlook on D. opuntiae control tactics as well as a relationship with the descriptors. To ease the understanding of *Figure 4*, the terms recorded with the highest frequency are shown in the largest circles; in the same way, the closeness between words determines the degree of association, and the lines connecting the words indicate that the terms are related regardless of their closeness or distance. For their part, darker or lighter colors indicate closeness in terms of the time these documents were published. From the 400 terms obtained, 55 appeared at least 5 times during the period 1848–2022 (*Fig. 4*).

The co-occurrence analysis of words created a visualization of the research trends related to the topics of study; this way, it showed that the term that appeared cited most frequently refers precisely to the scientific name of the species: *Dactylopius opuntiae*. The next term that had a high frequency was 'biological control', primarily predators and entomopathogens, which indicates the importance of this tactic in insect control around the world; in addition, it is a term that has remained current through time. Other outstanding nodes refer to the countries that have focused on the theme and developed high scientific productivity: the USA, Spain and Africa were remarkable initially; continuing with Mexico and Brazil; and then the most recently incorporated countries were Morocco and Israel.

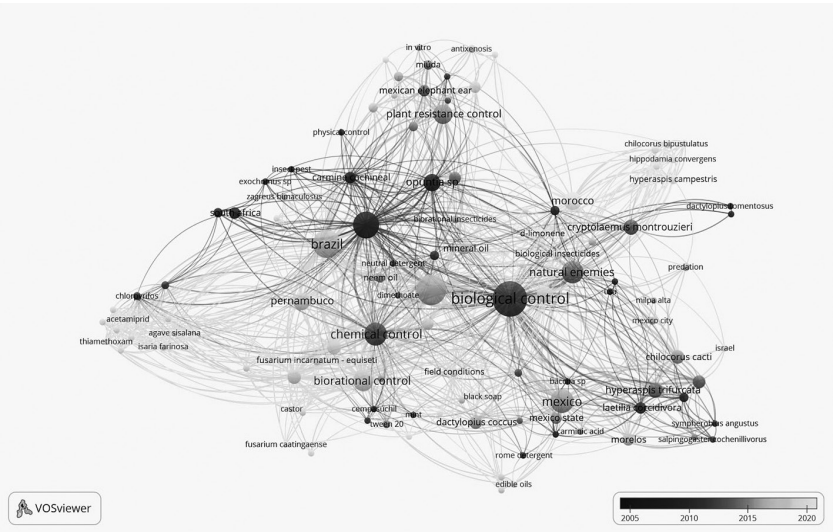

Figure 4. Topic network and its distribution throughout time, which addressed *Dactylopius opuntiae* control tactics, 1848-2022. Source: Prepared by the authors, 2023.

DOI: http://dx.doi.org/10.22201/iibi.24488321xe.2024.98.58813

Figure 4 represents the regions within each country where the problem with *D. opuntiae* is concentrated to a greater degree; for example, Pernambuco in Brazil, Milpa Alta (Mexico City) and Tlalnepantla (Morelos) in Mexico. The following stood out as emerging themes: plant resistance through the selection, improvement, and testing of *D. opuntiae* clones, as well as biological control and non-conventional chemical control using plant extracts, detergents and plant oils, among others.

Although the terms *chemical control, pesticides* and *commercial insecticides* stand out, their use has been applied to indicate the importance of the mentioned tactics, and they represent an alternative to the application of chemical products. Regarding this aspect, there's a need to highlight that a small proportion of the studies addressed conventional chemical control, and that it was focalized at the beginning of the observation period. Deriving from this, the research has been concentrated, at least during the last decade, on the search for more sustainable alternatives, such as biological control and products with a lower environmental impact. Finally, the visualization showed that the highest correlations between these terms were recorded between 2017 and 2019. Derived from this, the strategy for pest control could include some of the tools that are adaptable and replicable in the various regions with this phytosanitary problem.

The research themes with high potential for application could be focalized on the technological development of: new low-toxicity and residual, biodegradable molecules with low risk for health and the environment, as well as a greater selectivity to non-target organisms; identification of secondary metabolites with insecticide activity; selection of entomopathogenic strains and natural enemies, according to each environment in particular where cactus pear is cultivated; and improvement and multiplication of clones with resistance to *D. opuntiae*, primarily.

Conclusions

The bibliometric study of scientific production on *D. opuntiae* control tactics was a relevant and appropriate theme of interest for the international community, evident due to the increase in publications in the last 12 years. The countries that showed leadership regarding scientific production were Morocco, Brazil, and Mexico.

The emerging themes were concentrated in the search and evaluation of biological control agents: predators and entomopathogens were the most studied topics; plant resistance also stood out as the tactic that could be most sustainable. After these two, non-conventional chemical control (oils, plant extracts, soaps, and detergents) was the most reported emergent tactic, in agreement with Sabbahi and Hock (2022) for the case of Morocco.

Through the analysis of the scientific information, it was detected that a common control tactic applicable to all the regions suffered from this problem since each region presents diverse conditions and its control agents would not have the expected successful results.

Considering the imminent globalization of knowledge as a priority, promoting collaboration networks with researchers and institutions at the national and international level is an area of opportunity, that facilitates the adoption and validation of management technologies; they could promote and disseminate the scientific development related to *D. opuntiae* control strategies, which allows taking advantage of synergies, capacities, and resources.

Finally, facing the critical current phytosanitary situation of cactus pear at the international level requires implementing a multidimensional intervention strategy, adaptable and replicable for the management of *D. opuntiae* that should consider the productive, social and climate conditions of each region.

The creation of clusters or research consortia, through the intervention of various institutions related to the subject, could improve the generation of common control alternatives for *D. opuntiae* in less time and with greater impact, such as the one established in Brazil.

References

Akroud, Hayat, Mohamed Sbaghi, Rachid Bouharroud, Tayeb Koussa, Mohamed Boujghagh, and Mustapha El Bouhssini. 2021. Antibioisis and Antixenosis Resistance to *Dactylopius opuntiae* (Hemiptera: Dactylopiidae) in Moroccan Cactus Germplasm. Phytoparasitica 49(4): 623-31. http://doi:10.1007/s12600-021-00897-w

Bader, Ahmad Katbeh and Asem H. Abu-Alloush. 2019. First Record of the Cochineal Scale Insect, Dactylopius opuntiae (Cockerell) (Hemiptera: *Dactylopiidae*), in Jordan. Jordan *Journal of Biological Sciences*. Volume 12, Number 2, June 2019. ISSN 1995-6673: 155-159. https://jjbs.hu.edu.jo/files/vol12/n2/Paper%20number%205.pdf

Barreto-García, Oscar Arturo, Esteban Rodríguez-Leyva, José Refugio Lomelí-Flores, Juan Manuel Vanegas-Rico, Ana Lilia Vigueras, and Liberato Portillo. 2020. *Laetilia Coccidivora* Feeding on Two Cochineal Insect Species, Does the Prey Affect the Fitness of the Predator? BioControl 65(6): 727-36. http://doi:10.1007/s10526-020-10047-6

Bouharroud, Rachid, Abderrahim Amarraque, and Redouan Qessaoui. 2016. First Report of the Opuntia Cochineal Scale *Dactylopius opuntiae* (Hemiptera: Dactylopiidae) in Morocco. *EPPO Bulletin* 46(2): 308-10. http://doi:10.1111/epp.12298

Bouharroud, Rachid, Mohamed Sbaghi, Mohamed Boujghagh, and Mustapha El Bouhssini. 2018. Biological Control of the Prickly Pear Cochineal *Dactylopius Opuntiae* Cockerell (Hemiptera: Dactylopiidae). *EPPO Bulletin* 48(2): 300-6. http://doi:10.1111/epp.12471

Bufaur, Mazen, and Rami Bohamdan. 2020. First Report of the Opuntia Cochineal Scale *Dactylopius opuntiae* (Cockerell, 1896) in Syria. *Arab Journal of Plant Protection* 38(1): 59-63. http://doi:10.22268/AJPP-38.1.059063

Castellano Vera, Jessica, María Dolores Marrero Alemán, Zaida Ortega, Francisco Ramón Romero Artiles, Antonio Nizardo Benítez Vega, and Myriam Rodríguez Ventura. 2021. Opuntia Spp. Fibre Characterisation to Obtain Sustainable Materials in the Composites Field. *Polymers* 13(13): 2085. http://doi:10.3390/polym13132085

Chávez-Moreno, Carla Karina, Alberto Tecante Coronel, Alejandro Casas Fernández, and Lucia Elena Claps. 2011. Distribution and Habitat in Mexico of *Dactylopius* Costa (Hemiptera: Dactylopiidae) and Their Cacti Hosts (Cactaceae: Opuntioideae). *Neotropical Entomology* 40(1), Febrero: 62-71. http://doi:10.1590/S1519-566X2011000100009

Cruz-Rodríguez, Juan Antonio, Emilia González-Machorro, A. Villegas González, M. Rodríguez Ramírez, and Fidel Mejía Lara. 2016. Autonomous Biological Control of *Dactylopius opuntiae* (Hemiptera: Dactyliiopidae) in a Prickly Pear Plantation With Ecological Management. *Environmental Entomology* 45(3): 642-8. http://doi:10.1093/ee/nvw023

Donthu, Naveen, Satish Kumar, Debmalya Mukherjee, Nitesh Pandey, and Weng Marc Lim. 2021. How to Conduct a Bibliometric Analysis: An Overview and Guidelines. *Journal of Business Research* 133, September: 285-96. http://doi:10.1016/j.jbusres.2021.04.070

Eck, Nees Jan van, and Ludo Waltman. 2007. VOS: A New Method for Visualizing Similarities Between Objects. In *Advances in Data Analysis*, ed. Reinhold Decker y Hans J. Lenz, 299-306. Studies in Classification, Data Analysis, and Knowledge Organization. Berlin, Heidelberg: Springer. http://doi:10.1007/978-3-540-70981-7_34.

_____. 2011. Text mining and visualization using VOSviewer. *arXiv:1109.2058 [cs]*, September. http://arxiv.org/abs/1109.2058

El Aalaoui, Mohamed, Rachid Bouharroud, Mohamed Sbaghi, Mustapha El Bouhssini, Lahoucine Hilali, and Khadija Dari. 2019. Comparative Toxicity of Different Chemical and Biological Insecticides against the Scale Insect *Dactylopius opuntiae* and Their Side Effects on the Predator Cryptolaemus *Montrouzieri*. *Archives of Phytopathology and Plant Protection* 52(1-2): 155-69. http://doi:10.1080/03235408.2019.1589909

El Aalaoui, Mohamed, and Mohamed Sbaghi. 2021. Evaluation of Trapping Systems for Cactus Mealybug on Prickly Pear in Greenhouses. *Arthropod Management Tests* 46(1): tsab139. http://doi:10.1093/amt/tsab139

El Aalaoui, Mohamed, Mohamed Sbaghi, Rachid Bouharroud, Mustapha El Bouhssini, and Lahoucine Hilali. 2021. Hyperpredation of Local Adults Ladybirds on the Eggs of *Cryptolaemus montrouzieri* a Potential Predator of Carmine Cactus Cochineal *Dactylopius opuntiae* in Morocco. International Journal of Tropical Insect Science 41(2): 1011-16. http://doi:10.1007/s42690-020-00282-w

El Aalaoui, Mohamed, Fouad Mokrini, Abdelfattah A. Dababat, Rachid Lahlali, and Mohamed Sbaghi. 2022. Moroccan Entomopathogenic Nematodes as Potential Biocontrol Agents against *Dactylopius opuntiae* (Hemiptera: Dactylopiidae). *Scientific Reports* 12(1): 7590. http://doi:10.1038/s41598-022-11709-4

DOI: http://dx.doi.org/10.22201/iibi.24488321xe.2024.98.58813

El Bouhissi, Mayssara, Mohamed Ghefar, Edine Sadine Salah, and Mustapha Gachi. 2022. Note sur la présence de *Dactylopius opuntiae* (Cockerell, 1896) sur le figuier de Barbarie en Algérie (Hemiptera : Dactylopiidae). *Annales de la Recherche Forestière en Algérie* 12(1): 1-6.
https://www.asjp.cerist.dz/index.php/en/article/182825

Griffith, M. Patrick. 2004. The Origins of an Important Cactus Crop, *Opuntia ficus-indica* (Cactaceae): New Molecular Evidence. *American Journal of Botany* 91(11): 1915-21.
http://doi:10.3732/ajb.91.11.1915

Hernández-Pérez, Ricardo, Guadalupe Bravo-Silva, José Martínez-Martínez, Álvaro González González-Hernández, and Teresa de Jesús Ramírez-Pedraza. 2019. Evaluación de la efectividad biológica de bioinsecticida para el control de cochinilla silvestre (*Dactylopius opuntiae* Cockerell), en nopal (*Opuntia ficus-indica* (L.) Mill.), en Totolapan, Morelos, México. *Revista Chilena de Entomología* 45(1).
https://www.biotaxa.org/rce/article/view/46594

López-Rodríguez, Patricia Elizabeth, Gildardo Aquino-Pérez, Francisco Javier Morales-Flores, Jaime Mena-Covarrubias, Esteban Rodríguez-Leyva, and Santiago de Jesús Méndez-Gallegos. 2021. Non-conventional Products as an Alternative to Control *Dactylopius opuntiae* Cockerell (Hemiptera: dactylopiidae). *Revista Fitotecnia Mexicana* 44(3): 417-24.
http://doi:10.35196/rfm.2021.3.417

Macêdo, Helenize Carlos de, Josandra Araújo Barreto de Melo, and Rogério Barbosa Bezerra. 2014. Territory, Public Policies and Rural Development in the Municipality of Caturité, PB. *GeoTextos* 10(2).
http://doi:10.9771/1984-5537geo.v10i2.9285

Mazzeo, Gaetana, Salvatore Nucifora, Agatino Russo, and Pompeo Suma. 2019. *Dactylopius opuntiae*, a New Prickly Pear Cactus Pest in the Mediterranean: An Overview. *Entomologia Experimentalis Et Applicata* 167(1): 59-72.
http://doi:10.1111/eea.12756

Mendel, Zvi, Alexei Protasov, Juan Manuel Vanegas-Rico, José Refugio Lomelí-Flores, Pompeo Suma, and Esteban Rodríguez-Leyva. 2020. Classical and Fortuitous Biological Control of the Prickly Pear Cochineal, *Dactylopius Opuntiae*, in Israel. *Biological Control* 142, March: 104157.
http://doi:10.1016/j.biocontrol.2019.104157

Méndez-Gallegos, Santiago de Jesús, and Ángel Bravo-Vinaja. 2022. *Dactylopius opuntiae* Cockerell (Hemiptera: Dactylopiidae), an Emerging Global Threat for Opuntia Spp: A Bibliometric Analysis. *Journal of the Professional Association for Cactus Development* 24, August: 111-38.
http://doi:10.56890/jpacd.v24i.487

Moral-Muñoz, José Antonio, Enrique Herrera-Viedma, Antonio Santisteban-Espejo, and Manuel Jesús. Cobo-Martín. 2020. Software Tools for Conducting Bibliometric Analysis in Science: An up-to-Date Review. *Profesional de La Información* 29(1). http://doi:10.3145/epi.2020.ene.03

Moran, V. Clifford., and John H. Hoffmann. 1987. The Effects of Simulated and Natural Rainfall on Cochineal Insects (Homoptera: Dactylopiidae): Colony Distribution and Survival on Cactus Cladodes. *Ecological Entomology* 12(1): 61-8.
http://doi:10.1111/j.1365-2311.1987.tb00985.x

Moussa, Zinette, Dany Yammouni, and Dany Azar. 2017. *Dactylopius opuntiae* (Cockerell, 1896), a New Invasive Pest of the Cactus Plants Opuntia ficus-indica in the South of Lebanon (Hemiptera, Coccoidea, Dactylopiidae). *Bulletin de La Société Entomologique de France* 122(2). Persée - Portail des revues scientifiques en SHS: 173-8. http://doi:10.3406/bsef.2017.3194

Noyons, C. M. 2005. Science Maps Within a Science Policy Context. In *Handbook of Quantitative Science and Technology Research: The Use of Publication and Patent Statistics in Studies of S&T Systems*, ed. Henk F. Moed, Wolfgang Glänzel, and Ulrich Schmoch, 237–55. Dordrecht: Springer Netherlands. http://doi:10.1007/1-4020-2755-9_11.

Palacios Mendoza, Celina, Ramón Nieto-Hernández, Celina Llanderal-Cázares, and Héctor González-Hernández. 2004. Efectividad biológica de productos biodegradables para el control de la cochinilla silvestre Dactylopius opuntiae (Cockerell) (Homoptera: Dactylopiidae). *Acta zoológica mexicana* 20(3): 99-106. https://www.scielo.org.mx/pdf/azm/v20n3/v20n3a7.pdf

Passos da Silva, Deise Maria, Laureen Michelle Houllou-Kido, Djalma Cordeiro dos Santos, Rachel Gonçalves Ferreira, Venézio Felipe dos Santos, Wellington Melo Ferreira, Mauricio Silva de Lima, Hiram Marinho Falçao, and F. de Sena Tabosa. 2009. Resistance of in vitro Grown Forage Cactus Clones to *Dactylopius opuntiae* (Hemiptera: Dactylopiidae). *Acta Horticulturae* 811. International Congress on Cactus Pear and Cochineal: 299-302. http://doi:10.17660/ActaHortic.2009.811.40

Pérez-Ramírez, Adriana, Federico Castrejón-Ayala, and Alfredo Jiménez-Pérez. 2014. Potential of Terpenoids and Mealybug Extract to Deter the Establishment of *Dactylopius opuntiae* (Hemiptera: Dactylopiidae) Crawlers on *Opuntia ficus-indica*. *The Florida Entomologist* 97(1): 269-71. https://www.jstor.org/stable/24362465

Pretorius, Marthinus Willem, and H. Van Ark. 1992. Further Insecticide Trials for the Control of Cactoblastis cactorum (Lepidoptera: Pyralidae) as well as *Dactylopius opuntiae* (Hemiptera: Dactylopiidae) on Spineless Cactus. *Phytophylactica* 24: 229-33. https://journals.co.za/doi/pdf/10.10520/AJA03701263_1471

Pritchard, Alan. 1969. Statistical Bibliography or Bibliometrics? *Journal of Documentation* 25(4): 348-49. http://doi:10.1108/eb026482

Raan, Anthony F. J. van. 1993. Advanced Bibliometric Methods to Assess Research Performance and Scientific Development: Basic Principles and Recent Practical Applications. *Research Evaluation* 3(3): 151-66. doi:10.1093/rev/3.3.151.

Ramdani, Chaimae, Karim El Fakhouri, Mohamed Sbaghi, Rachid Bouharroud, Rachid Boulamtat, Abderrahim Aasfar, Abdelhalim Mesfioui, and Mustapha El Bouhssini. 2021. Chemical Composition and Insecticidal Potential of Six Essential Oils from Morocco against *Dactylopius opuntiae* (Cockerell) under Field and Laboratory Conditions. *Insects* 12(11): 1007. http://doi:10.3390/insects12111007

DOI: http://dx.doi.org/10.22201/iibi.24488321xe.2024.98.58813

Ramírez-Sánchez, Carlos Jesús, Francisco Javier Morales-Flores, Raquel Alatorre-Rosas, Jaime Mena-Covarrubias, and Santiago de Jesús Méndez-Gallegos. 2019. Efectividad de hongos entomopatógenos sobre la mortalidad de *Dactylopius opuntiae* (Hemiptera: Dactylopiidae) en condiciones de laboratorio. *Revista Mexicana de Ciencias Agrícolas* 10(22): 1-14. http://doi:10.29312/remexca.v0i22.1854

Sabbahi, Rachid, and Virginia Hock. 2022. Control of the Prickly Pear Cochineal, *Dactylopius opuntiae* (Cockerell), in Morocco: An Overview. *Journal of Plant Diseases and Protection* 129(6): 1323-30. http://doi:10.1007/s41348-022-00655-y

Sbaghi, Mohamed, Rachid Bouharroud, Mohamed Boujghagh, and Mustapha El Bouhssini. 2019. Sources of Resistance to Opuntia spp. against the Carmine Cochineal, Dactylopius opuntiae, in Morocco. Sources de Résistance d'*Opuntia* spp. contre la cochenille à carmin, *Dactylopius opuntiae*, au Maroc. *EPPO Bulletin* 49(3): 585-92. http://doi:10.1111/epp.12606

Silva, Mafalda Alexandra, Tania Gonçalves Albuquerque, Paula Pereira, Renata Ramalho, Filipa Vicente, Maria Beatriz Prior Pinto Oliveira, and Helena Soares Costa. 2021. *Opuntia ficus-indica* (L.) Mill.: A Multi-Benefit Potential to Be Exploited. *Molecules* 26(4): 951. http://doi:10.3390/molecules26040951

Silva, Marta Gerusa Soares da, José Carlos Batista Dubeux, Liz Carolina da Silva Lagos Cortes Assis, Diógenes Luis Mota, Luiz Lúcio Soares da Silva, Mércia Virginia Ferreira dos Santos, and Djalma Cordeiro dos Santos. 2010. Anatomy of Different Forage Cacti with Contrasting Insect Resistance. *Journal of Arid Environments* 74(6): 718-22. http://doi: 10.1016/j.jaridenv.2009.11.003

Spodek, Malkie, Yair Ben-Dov, Alex Protasov, Carlos Jorge Carvalho, and Zvi Mendel. 2014. First Record of *Dactylopius opuntiae* (Cockerell) (Hemiptera: Coccoidea: Dactylopiidae) from Israel. *Phytoparasitica* 42(3): 377-9. http://doi:10.1007/s12600-013-0373-2

Torres, Jorge Braz, and Jose Adriano Giorgi. 2018. Management of the False Carmine Cochineal *Dactylopius opuntiae* (Cockerell): Perspective from Pernambuco State, Brazil. *Phytoparasitica* 46(3): 331-40. http://doi:10.1007/s12600-018-0664-8

Ülgentürk, Selma, and Sema Şişman Hocaali. 2019. Pest Status of *Dactylopius Opuntiae* (Cockerell) (Hemiptera: Dactylopiidae) and New Records of Scale Insects from Northern Turkish Republic of Cyprus. *Munis Entomology & Zoology* 14(1): 294-300. https://www.munisentzool.org/Issue/abstract/pest-status-of-dactylopius-opuntiae-cockerell-hemiptera-dactylopiidae-and-new-records-of-scale-insects-from-northern-turkish-republic-of-cyprus_1272

Vanegas-Rico, Juan Manuel, José Refugio Lomelí-Flores, Esteban Rodríguez-Leyva, and Gustavo Mora-Aguilera. 2010. Natural Enemies of Dactylopius opuntiae (Cockerell) on Opuntia ficus indica (L.) Miller in Central Mexico. *Acta zoologica mexicana* 26(2): 415. http://doi: 10.21829/azm.2010.262718

Vanegas-Rico, Juan Manuel, José Refugio Lomelí-Flores, Esteban Rodríguez-Leyva, Alejandro Pérez-Panduro, Héctor González-Hernández, and Antonio Marín-Jarillo. 2015. Hyperaspis trifurcata (Coleoptera: Coccinellidae) and its parasitoids in Central Mexico. *Revista Colombiana de Entomología* 41(2): 194-9. http://www.scielo.org.co/scielo.php?script=sci_abstract&pid=S0120-04882015000200008

Vanegas-Rico, Juan Manuel, Esteban Rodríguez-Leyva, José Refugio Lomelí-Flores, Héctor González-Hernández, Alejandro Pérez-Panduro, and Gustavo Mora-Aguilera. 2016.. Biology and Life History of *Hyperaspis trifurcata* Feeding on *Dactylopius opuntiae*. BioControl 61(6): 691-701. http://doi:10.1007/s10526-016-9753-0

Vigueras-Guzmán, Ana Lilia, Juan Cibrían-Tovar, and Carlos Pelayo-Ortiz. 2009. Use of Botanicals Extracts to Control Wild Cochineal (Dactylopius opuntiae cockerell) on Cactus Pear. *Acta Horticulturae* 811, February: 229-34. http://doi:10.17660/ActaHortic.2009.811.28

Zeitoun, Rawan, Salem Hayar, Liliane Majed, Khaled El-Omari, and Sylvie Dousset. 2020. Comparison of the Efficacy of Two Insecticides for the Management of Dactylopius opuntiae on Prickly Pear Cactus in Lebanon and Monitoring of the Insecticides Residues Dissipation Rates in Fruits and Cladodes. *Sn Applied Sciences* 2(1): 118. http://doi:10.1007/s42452-019-1910-5

Para citar este texto:

García Pascual, Esperanza, Marco Martín González Chávez, Avelina Franco Vega, Esteban Rodríguez Leyva, Santiago de Jesús Méndez Gallegos, Juan Angel Morales Rueda y Angel Bravo Vinaja. 2024. "Dactylopius opuntiae (Hemiptera: Dactylopiidae) control tactics: a bibliometric analysis". *Investigación Bibliotecológica: archivonomía, bibliotecología e información* 38 (98): 13-29. http://dx.doi.org/10.22201/iibi.24488321xe.2024.98.58813

DOI: http://dx.doi.org/10.22201/iibi.24488321xe.2024.98.58813