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Article

Bibliometric analysis of the scientific production on *Maconellicoccus hirsutus* (1971-2021)

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Abstract

Maconellicoccus hirsutus is a polyphagous insect that attacks a wide range of woody plants. This pest has caused large agricultural losses of 10 to 18 million dollars. This study aimed to evaluate the research trend on *M. hirsutus*. Articles were retrieved from the Web of Science Core Collection (WoSCC) database and network maps were made using the VOSviewer software. A bibliometric analysis of 122 research papers published from 1971 to 2021 was carried out. The bibliographic coupling between countries was 20, mainly with the United States. The co-citations of references was 69. The analysis of the co-occurrence of 35 keywords showed that the studies on *M. hirsutus* split into four groups. Four of the top six articles with more than 50 accumulated citations were published in Bulletin of Entomological Research, Proceedings of the National Academy of Sciences of the United States of America, and Biological Control. In general, research on *M. hirsutus* has been directed mainly towards biological control with *Anagyrus kamali* and the search for predators, pheromones, and entomopathogenic fungi.

Keywords:

biological control, literature review, pests, pink hibiscus mealybug.

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Introduction

Maconellicoccus hirsutus (Green, 1908) (Hemiptera: Pseudococcidae - Eppo A1 and A2 Lists) or pink hibiscus mealybug (PHM) is an insect originally reported in South Asia and has dispersed to Australia, Africa, the Middle East, the United States of America, Central America, and the northern region of South America (EPPO, 2021). In Mexico, *M. hirsutus* was first detected in 1999 in the state of Baja California Norte (Miller, 1999). An outbreak of *M. hirsutus* was confirmed in Nayarit in February 2004. Currently, this pest is widespread in Campeche, Chiapas, Colima, Guerrero, Hidalgo, Jalisco, Morelos, Oaxaca, Quintana Roo, San Luis Potosí, Sinaloa, Tabasco, Tamaulipas, Veracruz, and Yucatán (SENASICA, 2019).

PHM is a pest for which a detailed analysis of economic losses has been carried out (Kairo *et al*., 2000). This pest has caused great agricultural losses with estimates of 10 and 18 million dollars. However, for Mexico, only a few projections have been made of the possible impact on avocados and mangoes, and its economic impact could be $106 758.77 million pesos in a planted area of 3 668 534.05 ha (SENASICA, 2019).

Maconellicoccus hirsutus is a polyphagous insect that attacks a wide range of woody plants, causing damage in commercial plantations and nurseries; it has been recorded to feed on 73 families and more than 200 genera of plants (EPPO, 2021). Typical feeding symptoms include leaf curling and shortening of internodes, resulting in a bump (Williams, 1996). In addition, the insect in its nymph stage excretes a honeydew, which serves as a substrate for the growth of sooty mold, which reduces the photosynthetic area of the plant (EPPO, 2021).

Maconellicoccus hirsutus is a quarantine pest in several countries and also of regulatory interest to other regional plant protection organizations (EPPO, 2021) due to the fact that it presents a potential risk to a variety of crops. It will make sense to perform a bibliometric analysis on *M. hirsutus* to determine trends in publications and research on this pest.

Bibliometric analyses contribute to systematizing the information on topics. In the agricultural area, the topics studied include rice (Peng, 2017), corn (Yuan and Sun, 2020), melon (Yuan *et al*., 2021) and pest management (Salustino *et al*., 2021). Thus, this study will be a new contribution to the literature on *M. hirsutus* in general. This study aimed to evaluate and map the results of research published in the Web of Science Core Collection (WoSCC) from 1900 to July 2021.

Materials and methods

Database used

For the bibliometric analysis, the Web of Science (WoS) -Clarivate Analytics platform database (https://webofknowledge.com/) was used, following the review methodology, as shown in (Figure 1). This paper considers the Web of Science Core Collection (WoSCC) as a database to achieve the objective of this work. This option searched all databases on the WoS platform. This allowed us to identify the citation connections between various authors.

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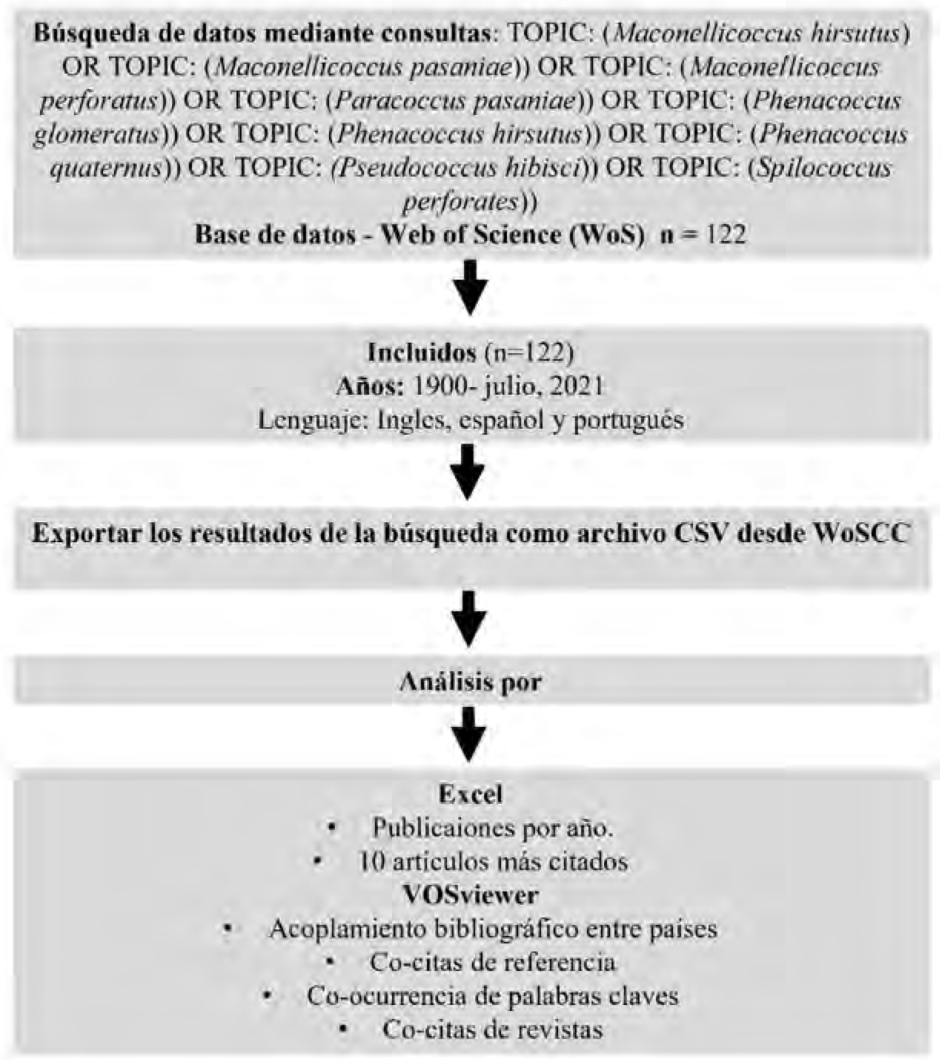
Figure 1. Flow chart of the collection and processing of information on *Maconellicoccus hirsutus*.



Search strategy

To select the sample articles analyzed in this study, a search for papers with a time period from 1900 to July 2021 was run. First, the recovery topic was established as: topic: (*Maconellicoccus hirsutus*) or topic: (*Maconellicoccus pasaniae*)) or topic: (*Maconellicoccus perforatus*) or topic:(*Paracoccus pasaniae*) or topic: (*Phenacoccus glomeratus*) or topic: (*Phenacoccus hirsutus*) or topic: (*Phenacoccus quaternus*) or topic: *(Pseudococcus hibisci*) or topic: (*Spilococcus perforates*).

Inclusion and exclusion criteria

The inclusion criterion for the literature presented was to consider publications in peer-reviewed scientific journals. Articles written in English, Spanish and Portuguese were also considered. Documents without a rigorous review process, such as editorial material, meeting, book, patent, abstract, case report, report, and others, were excluded. Review articles were excluded to avoid duplication in the sample.

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Export of bibliometric data and indicators

The search resulted in a total of 122 documents, which were downloaded and saved as a plain text file (*.TXT) in the format 'full record and cited references' for the analyses. The data were processed using the 'analysis of results' tool of the Web of Science® platform. The exported data included authors, titles, journals, year of publication, total citations, countries, and keywords. Microsoft Excel was used to analyze the characteristics of the publication by years.

Network maps

Analyses were performed with network maps with the VOSviewer software (version 1.6.5, Leiden University, Leiden, Netherlands). The VOSviewer technique allowed us to run a clustering algorithm to position and classify the keywords that will be mapped. Thus, the software was used to show bibliographic coupling between countries, reference co-citations, and keyword co-occurrence using the measure of 'association' (van Eck and Waltman, 2010).

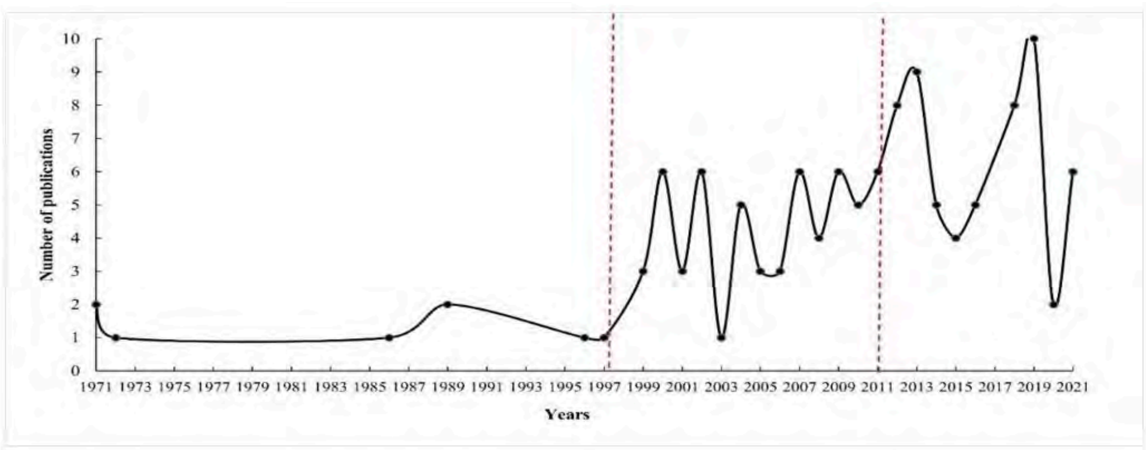
To relatively assess the impact of the six articles with the most citations for *M. hirsutus* in the scientific community, quantitative indicators were considered: Hirsch's index (H-index) and quartile presented on the SCImago platform (http://www.scimagojr.com). In addition, the impact factor (IF) obtained from the Journal Citation Report (2020) was also considered, which showed the strength of the journals that published these papers.

Results and discussion

Articles published by year

In the indicated period from 1900 to 2021 (July 2021), 122 publications on *M. hirsutus* were identified in the WoSCC database. The first publications on *M. hirsutus* in the WoSCC were in 1971; therefore, the bibliometric analysis was carried out from this year. In 1971, the first articles on *M. hirsutus* were published on nymphal stage (Ghose, 1971b), yield loss (Ghose, 1971a), damage (Ghose, 1972) and control (Das and Singh, 1986). Thus, the trends in the number of identified papers are shown in Figure 2, experiencing three defined periods.

Figure 2. Number of papers on *Maconellicoccus hirsutus* published by year in WoSCC from 1971 to July 2021 (n= 122 publications).



The first period presented unchanged production (1971-1998), with an average of 1.33 ±0.51 articles per year. The second period (1999-2011) shows an average of 4.38 ±1.66 articles per year; in this period, there was a marked increase in the year 2000 and despite the peaks in the number of publications, with a maximum of 6 (in the years 2002, 2007, and 2009) and a minimum of 2 (2003), it resulted in an increasing trend in scientific production within the period.

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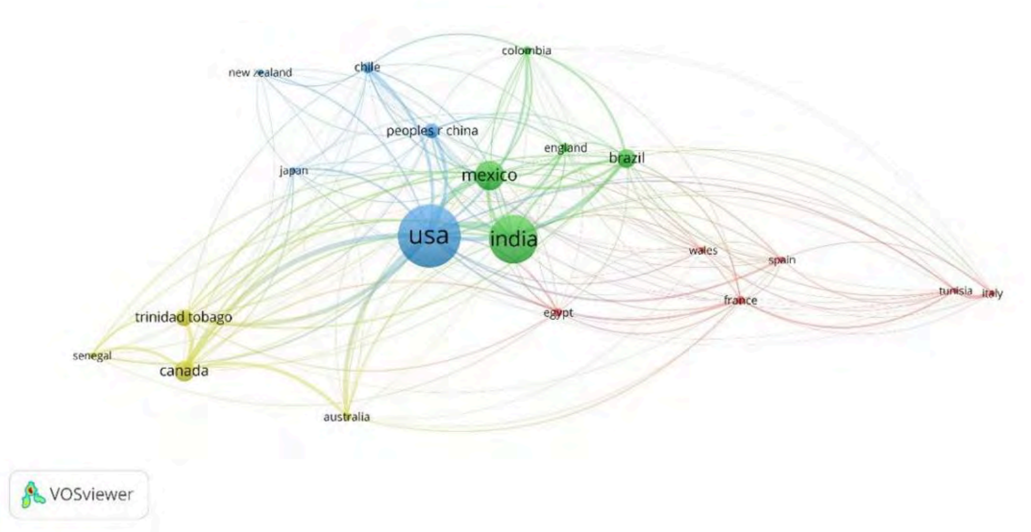
In the third period (2012-2021), an average of 5.77 ±3.15 papers were observed; the beginning of the data series was preceded by a peak in 2013 (nine articles), with a decrease in the next two years, followed by a second increase that was the highest value in the series in 2019 (10 papers), with a subsequent decrease to two articles. In the 2020-2021 study period, the number of papers published represented 6.5% of the total number of articles published, with the participation of 49 authors.

Network visualization maps

Bibliographic coupling between countries

Country bibliographic coupling occurs when publications from two countries refer to publications from a third country. The strength of the bibliographic coupling depends on the number of references that the two papers have in common. In this study, the bibliographic coupling between 20 of 33 countries (the minimum number of documents in a country was set at 2) was divided into four clusters (Figure 3).

Figure 3. Bibliometric map for bibliographic coupling between countries.



In this way, it was observed that the United States of America (USA) has a central influence on *M. hirsutus* and other countries, such as India, Mexico, Canada, Brazil, China, among others, are coupled to the USA. Thus, the first cluster (red) is made up of Wales, Tunisia, Spain, Italy, France, and Egypt; the second cluster (green) is made up of the USA, China, New Zealand, Japan, and Chile. The third cluster (blue) is made up of India, Mexico, Brazil, England, and Colombia; the fourth cluster (olive green) is made up of Canada, Trinidad and Tobago, Senegal, and Australia.

Reference co-citations

Co-citation is a co-occurrence relationship that occurs when two items from the existing literature are cited together by a third. A total of 3 112 co-cited references on *M. hirsutus* were found. Figure 4 shows 69 reference co-citations (with a minimum number of citations for one reference= 5).

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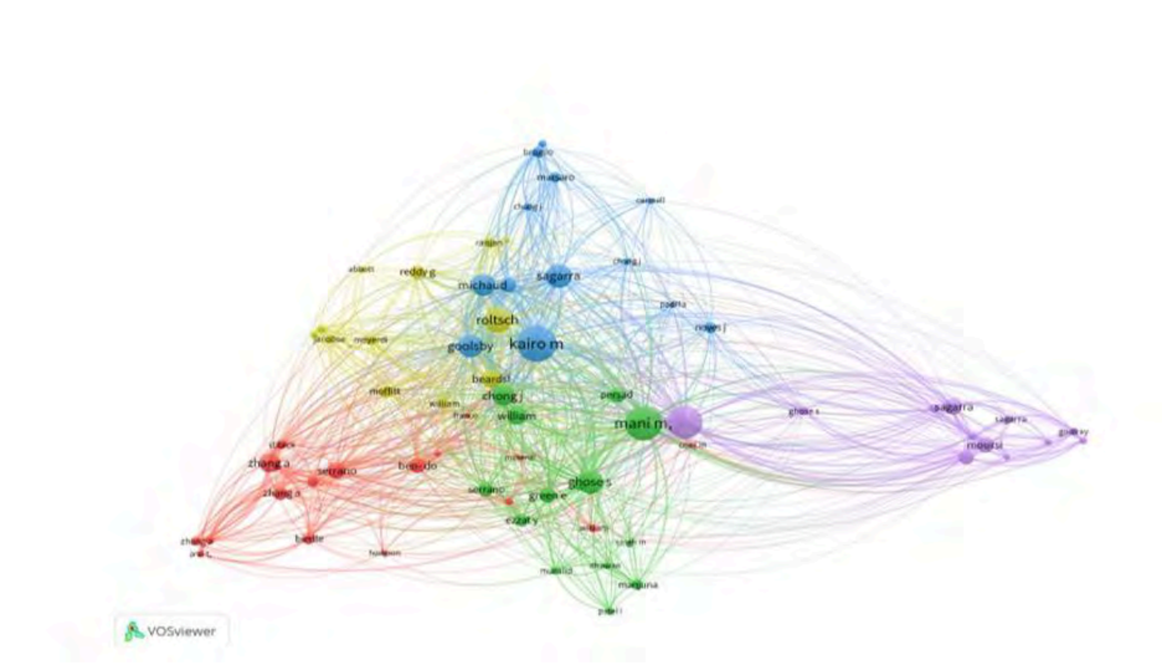
Figure 4. Networks of reference co-citations about *Maconellicoccus hirsutus*.



These references formed five clusters. Cluster 1 (red) is made up of 17 references, the main one being Zhang *et al*. (2004b). The second one (green) groups 14 references, led by Mani (1989). The third cluster (blue) with 13 references led by Kairo *et al*. (2000). The fourth one (olive green), composed of 13 references, whose main author was Roltsch *et al*. (2006). Cluster five (purple) was made up of 12 references, led by Williams (1996).

Keyword co-occurrence

In this analysis, 640 different keywords were obtained. Figure 5 showed the network of the top 35 keywords (minimum number of occurrences of a keyword= 5) of the total WoSCC database data series.

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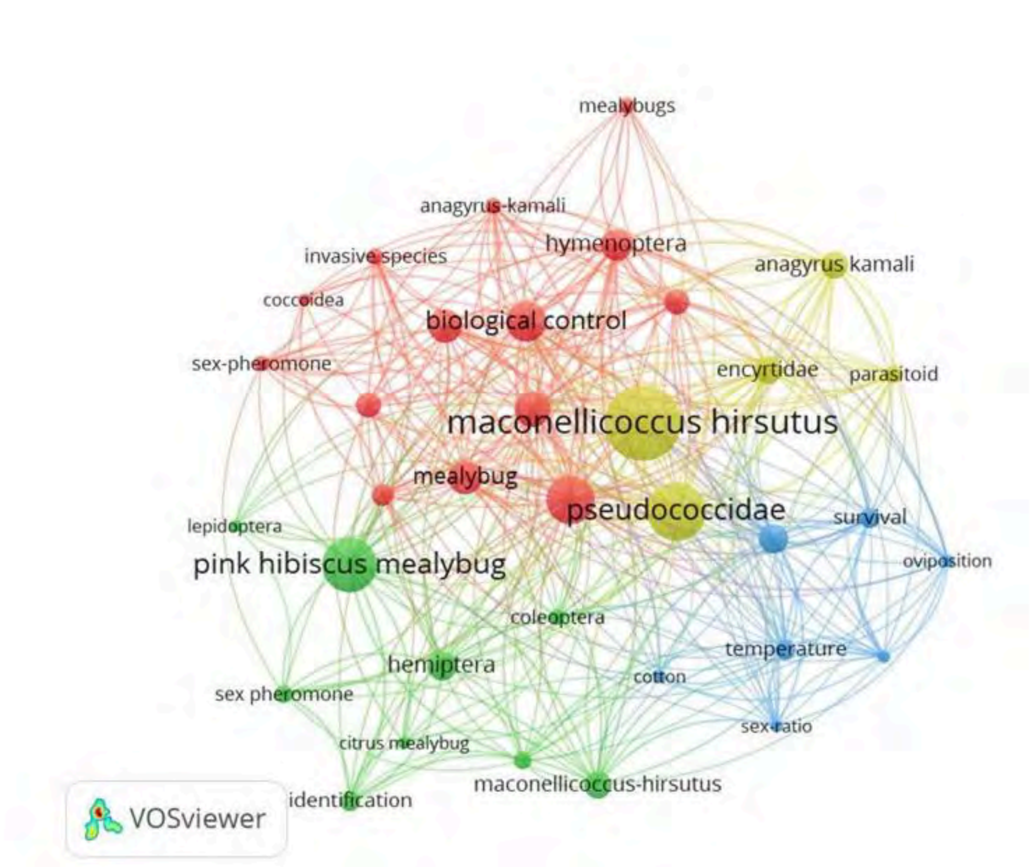
Figure 5. Visualization map of co-occurrences of main keywords. The volume of the node corresponds to the number of occurrences.



The first cluster (red) consists of 14 words about biological control of *M. hirsutus*; for example, natural enemies, pheromones, and *A. kamali*. The second cluster (green) is made up of nine words related to the taxonomy of *M. hirsutus*, common name, and pest. The third cluster (blue) was made up of seven terms on the reproductive aspect, such as fertility, sex ratio, oviposition, temperature, and survival. Finally, the fourth one (olive green) included five terms about the use of the parasitoid *A. kamali*. More studies have recently been published focusing on the search for natural enemies, biological control, and work with *A. kamali* continues.

Main areas of research and gaps in literature

The distribution of the 122 articles published on *M. hirsutus* was in 52 different journals. The top four papers with more than 50 cumulative citations were published in Bulletin Of Entomological Research, Proceedings of the National Academy of Sciences of the United States of America (PNAS), and Biological Control.

In general, the papers address topics such as entomopathogenic fungi, parasitoids, predators, and the use of sex pheromones. The two papers on *M. hirsutus* with the most citations (#100 citations) were published in the journal Bulletin of Entomological Research, which is in the second quartile of its category within the Scimago Journal Rank (SJR). In this sense, the third article with the most citations (63 citations) was published in the PNAS journal, which is in the first quartile within the SJR. The three journals with the highest visibility were PNAS, (H= 737, IF= 9.4), followed by Biological Control (H= 9, IF= 2.7) and Environmental Entomology (H= 81, IF= 1.5); the rest of the journals have H-values lower than those mentioned (Table 1).

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Table 1. The six most cited papers for *Maconellicoccus hirsutus* from 1971 to 2021 (July).

Authors	Journal	TC	IF	Q	H
Sagarra *et al.* (2001)	Bulletin Of Entomological Research	104	1.8	Q1	67
Nagrare *et al.* (2009)	104	1.8	Q1	67	
Zhang *et al.* (2004a)	Proceedings of the National Academy of Sciences of the United States of America	63	9.4	Q1	737
Daane *et al.* (2004)	Biological Control	60	2.7	Q1	93
Williams (1996)	Bulletin Of Entomological Research	47	1.8	Q2	67
Chong *et al.* (2008)	Environmental Entomology	42	1.5	Q2	81

TC= total citations; Q= quartile; H= H index.

Discussions

Bibliometric analyses are not trivial (Ellis *et al*., 2020). In the present study, the analysis provided information on the development of *M. hirsutus* research over the past 50 years, so it is not possible to discuss them all. Therefore, the important areas of interest that arise from these analyses were highlighted. In addition, they project frontiers of knowledge graphically, which allows a scientific evaluation of the research based on the information provided, including the academic value of the reference, citations, keywords, and level of production of the relevant research.

Topics on the biological cycle of *M. hirsutus* formed the first lines of research on the pest since 1971. This is due to biogeographic factors since *M. hirsutus* is native to South Asia and its distribution in that period was limited to Africa (Williams, 1996). Another fact was its dispersion to new areas. By 1994, the pest had spread from Guyana and Venezuela to the Bahamas and Belize. Thus, in 1995, the United States Department of Agriculture, the Animal and Plant Health Inspection Service-Plan Protection and Quarantine (USDA-APHIS-PPQ) initiated a pest mitigation project based on classical biological control.

At the time of the arrival of *M. hirsutus* in California in 1999, the effectiveness of two species of parasitoids, *A. kamali* and *Gyranusoidea indica* Shafee, had already been proven. From this moment on, the analysis considers a second period (1999-2011), where publications on the biological control of *M. hirsutus* increased, mainly the generation of knowledge on parasitoids such as *A. kamali* (Sagarra *et al*., 2000), *A. pseudococci* (Daane *et al*., 2004) and *A. subalbipes* (Arai and Mishiro, 2004; Roltsch *et al*., 2006).

During this period, research on the use of pheromones was also conducted (Zhang *et al*., 2004b). This search for *M. hirsutus* control options has led to economic losses of more than 700 million dollars for the agricultural, forestry, and nursery industries, caused by this pest in the United States (Ranjan, 2006).

During the third period (2012-2021), publications on biological control were expanded in the search for other alternatives for the control of *M. hirsutus*. Thus, research focused on the search for predators, such as *Cacoxenus campsiphallus* (Gitonides) (Raspi *et al*., 2015), *Cryptolaemus montrouzieri* Mulsant (Mani, 2018), *Scymnus* Kugelann (Poorani and Lalitha, 2018) and *Rhynocoris marginatus* (Kitherian *et al*., 2018).

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Citations reflect the follow-up and relationships of the development of idea research when an author cites another author (Osareh, 1996). Thus, the identification of the most cited articles in the field serves as an indicator of the impact of research (Kinnin *et al*., 2019). In this study, the most cited papers are Sagarra *et al*. (2001) and Nagrare *et al*. (2009), with 101 and 100 citations, respectively.

For the biological control of *M. hirsutus*, the use of *A. kamali* stands out both in the co-occurrence of keywords and co-citations of authors who have addressed this topic. The genus *Anagyrus* comprises more than 350 described species of primary endoparasitoids from various mealybug hosts.

Conclusions

The evaluation and network mapping on the scientific production of *M. hirsutus* (1971-2021) until July 2021 covered a large number of publications that allows us to build a complete vision. In addition, the results obtained from this study are useful for researchers and institutions working extensively in this area.

The annual production of scientific articles varied during the period considered. Nevertheless, the publication of papers was mainly on topics of biological control of *M. hirsutus* given the low efficiency of chemical insecticides to combat it. In this sense, the map of bibliographic coupling between countries corroborates that the USA laid the foundations for the biological control of this pest from 1995 onwards.

After this year, 9 of the 10 articles with the highest citations were published. During the last ten years, the number of publications was 57 papers, which present other alternatives for the control of *M. hirsutus*, such as predators and entomopathogens. The use of the parasitoid *A. kamali*, as well as the efficiency of other species of the genus *Anagyrus*, has prevailed in research. More recently, to increase the efficiency of biological control, research has led to hypotheses for the use of combinations of parasitoid with a predator, entomopathogenic fungus or nematode.

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