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Review Article

A Bibliometric Analysis of Global Research on Ticks, their Distribution and Epidemiology from 1970 to 2023

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Abstract

Ticks are ectoparasites that inflict significant direct and indirect harm upon their hosts. They are distributed throughout the world but are more prevalent in tropical and subtropical regions. The purpose of this bibliometric analysis is to scrutinize the research conducted on ticks to date. Data were retrieved from Web of Science (WoS) for this study. A total of 309 records were downloaded in Plaintext, Excel and BIB format. For data analysis and visualization, the researchers employed various software tools such as MS Access, MS Excel, Notepad++, Biblioshiny, Vosviewer, Python, florishStudio, *etc*. Results show that the year 2021(25, 8.09%) had the highest number of publications. Notably, De La Fuente (13, 4.2%) was the most prominent author. Of all journals, Parasites Vectors (18, 5.8%) contributed the most to this literature. With 81 publications (26.21%), the USA had the highest number of publications in this field. Oklahoma State University was the most productive institution, having published 20 papers (6.47%). The most frequently used keywords were "tick" and "ticks", "cattle", "prevalence", "risk factors", and "vaccine". This study reveals the current trends, hot topics and research gaps in the field of tick research, which can help researchers to develop a roadmap for future studies. The findings of this analysis may prove useful to businesses and academics alike, as they provide an understanding of the current state of research in ticks and tick-borne diseases.

Keywords: Tick; Distribution; Epidemiology; Bibliometrics; Research topic analysis

Introduction

Ticks are ectoparasites that feed on the blood of a wide variety of vertebrates, including reptiles, birds and mammals. They are obligate hematophagous, meaning they require a blood meal to survive (Foley *et al.* 1999; Parola and Raoult 2001; Meyer-Kayser *et al*. 2012; Elati *et al.* 2018; Ahbara *et al*. 2022; Zając *et al.* 2022). The negative impact of ticks and tick-borne diseases results in an economic loss of US$ 13.9 to 18.7 billion annually (Ghosh *et al.* 2019). This also leads to a reduction of milk yield by up to 30% and the value of hides and skins by 29-30% (Ahbara *et al.* 2022). These parasites are ubiquitous, but they are most commonly found in tropical and subtropical regions (Ghosh *et al*. 2007). They are considered the second most important vector of diseases in humans and the first most important in animals (Parola and Raoult 2001; Maharana *et al*. 2011). Ticks belong to the order Acarina and suborder Ixodida (Walker 2003) and more than 800 species of ticks have been reported so far (Walker 2003; Steen *et al*. 2004).

The life cycle of ticks includes four developmental stages: egg, larvae, nymph, and adult. The larvae hatch from eggs and attach themselves to the host using their mouthparts (Pearce *et al.* 1987; Walker 2003; Fisher 2008; Ferrer and Morandini 2019). These parasites usually attach themselves to the ears, tail, perineum, hind legs, neck, and udder in animals, while they attach themselves to the eyelid and chin in birds (Pearce *et al.* 1987; Parola and Raoult 2001; Fisher 2008; Ferrer and Morandini 2019; Zając *et al.* 2022). After feeding for 3 to 5 days, the larvae fully engorge with blood and then leave the host to molt into nymphs. The nymphs then attach themselves to a new host and repeat the process. The feeding stage of the nymph and adult female ticks lasts for 4 to 5 days and 5 to 20 days, respectively. Male ticks of most species do not feed much like females and spend most of their time searching for females. The life cycle of ticks usually completes in two years on various hosts and is attached to each host for only a few days

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(Pearce *et al.* 1987; Walker 2003; Fisher 2008; Ferrer and Morandini 2019).

Ticks can cause a range of health issues to the hosts they feed on. When ticks pierce the host skin during their feeding stage, they result in lesion formation, irritation, redness, swelling, itching, abscess formation and dermatitis (Pearce *et al.* 1987; Ghosh *et al*. 2019). Heavy tick infestation can lead to weight loss, anemia, blindness (if ticks accumulate around the eyes), pelage loss, paralysis, behavioral abnormalities and even death (Durden *et al*. 1991; Andreotti *et al*. 2018). Additionally, ticks can transmit a variety of pathogens, including *Borrelia* spp., *Bartonella* spp., *Babesia* spp., *Ehrlichia* spp., *Anaplasma* spp., *Rickettsia* spp., *Theileria* spp., *Candidatus* spp., tick-borne encephalitis virus, Crimean Congo virus and many others that can cause serious diseases such as Lyme disease, relapsing fever, granulocytic ehrlichiosis, Rocky Mountain fever, Q fever, theilosis, anaplasmosis and tick-borne encephalitis. Some of these diseases are zoonotic and can be transmitted to humans (Dumpis *et al*. 1999; Keklikçi *et al*. 2009; Matulis *et al*. 2023). In some cases, ticks have even been found to infest humans directly, such as on the aural or eyelid areas (Dumpis *et al*. 1999; Keklikçi *et al*. 2009).

Ticks are known to be more prevalent during the monsoon season, followed by summer and winter (Debbarma *et al*. 2018; Ghosh *et al*. 2019). Young hosts are particularly vulnerable to tick infestations due to their lower immunity levels compared to adults and juveniles. Furthermore, female hosts of the same species tend to have higher rates of tick infestations than their male counterparts.

Ticks are commonly controlled through the use of acaricides, which include synthetic pyrethroid compounds like deltamethrin, cypermethrin, Decamethrin and Amitraz, as well as macrocyclic lactone products like ivermectin, epinomectin, moxidectin and doramectin. Other chemical compounds like organophosphates (such as malathion, coumaphos and chlorpyrifos), organochlorines, and phenyl pyrazoles are also used (Chhabra 1992; Davey *et al*. 2005; Malik *et al.* 2021). However, the use of these chemical compounds has detrimental effects, including anti-drug resistance in ticks and contamination of milk, meat and the environment (Novick and Reitano 1986). Biological control of ticks using hymenopteran insects (chalcid) has also been reported in some states (Chhabra 1992). Although the anti-tick vaccine can be a promising anti-tick agent, vaccines made so far do not confer protection against multiple tick species (Ahbara *et al.* 2022). Vaccines have been made using Bm86/Bm95, FER2, longistatin, subolesin antigen, Salp14 and BMTIs and cDNA clones of 4F8, 4D8 and 4E6 (Almazán *et al.* 2005; Hajdusek *et al.* 2010; Islam *et al.* 2012). The genotype (STX5, STXBP6 & SLOCO2A1 genes) of tick-resistant animals is also being exploited to control ticks (Ahbara *et al*. 2022).

Bibliometric analysis is a quantitative research method that provides valuable insights into various aspects of scholarly publications. It enables researchers, institutions, and policymakers to evaluate productivity, influence, and trends in scientific and academic literature within a particular field, discipline, or set of publications. Although bibliometric analysis has been carried out for some economically important arthropod species, such as mites and honeybees (Sweileh *et al*. 2016; Lei *et al*. 2019; Demir *et al*. 2020; Ziegler *et al*. 2021; Palacino-Rodríguez *et al*. 2022; Barbero *et al*. 2023), no such analysis has been conducted for ticks. Therefore, the objective of this study is to assess the research output and identify knowledge gaps in tick-related studies. This document presents a comprehensive analysis of the author, country and institution research profiles on ticks' relevant studies. Additionally, it includes a year-wise publication analysis, citation analysis, international collaboration, most influential articles, extensively used keywords and the impact of journal publishing on ticks. This bibliometric analysis aims to contribute to the literature related to ticks and provide a better understanding of the emerging trends within this field.

Modus Operandi of Data Acquisition

The researchers conducted a study utilizing bibliometrics methods to quantitatively analyze data and identify research productivity and co-word relationships. A comprehensive literature review was conducted to identify all relevant keywords for the research topic. These keywords were combined using Boolean operators and used to execute the query in the title field of the WoS database.

TI= ("Tick prevalence" OR "Tick Distribution" OR "Tick Diversity" OR "Tick intensity" OR "Tick infestation" OR "Tick epidemiology" OR "Tick molecular characterization" OR "Tick Economic loss" OR "Tick Acaricides").

A total of 377 records were retrieved without applying any filter (Fig. 1). The document types meeting abstract, proceeding paper, editorial material, note, correction and news items were excluded from the data. The document type's article, review, book chapter and early access were finally included for the analysis. Later, Citation Management Software, Endnote, was used for the duplication check. A match on the author, title and year was applied and no duplicate record was found. Finally, a total of 309 documents were left for analysis. The refined data was imported in Plain text, Excel, and BIB format to perform bibliometric analysis with the help of Visualization Software. After downloading data in the RStudio software and then exporting it in Excel format, the researchers employed various software tools such as MS Access, MS Excel, Notepad++, Biblioshiny, vosviewer, Python, florishStudio, *etc.* Further, Co-word analysis was performed using vosviewer to identify emerging research trends. This technique involved calculating co-occurrences of keywords in publications and then creating clusters based on themes and subthemes.

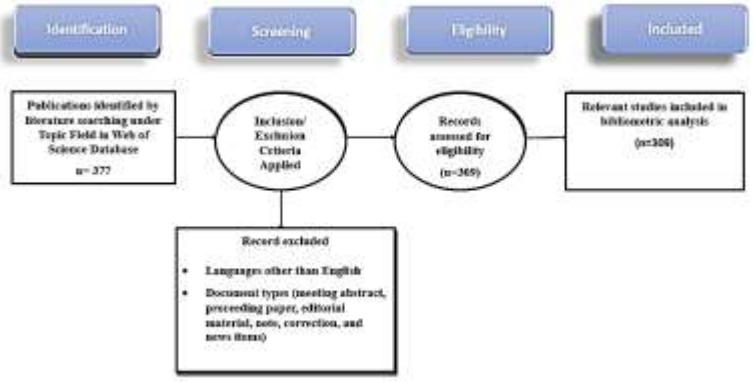

Fig. 1: Data extraction and filtration process

Fig. 2: Annual scientific production during each year

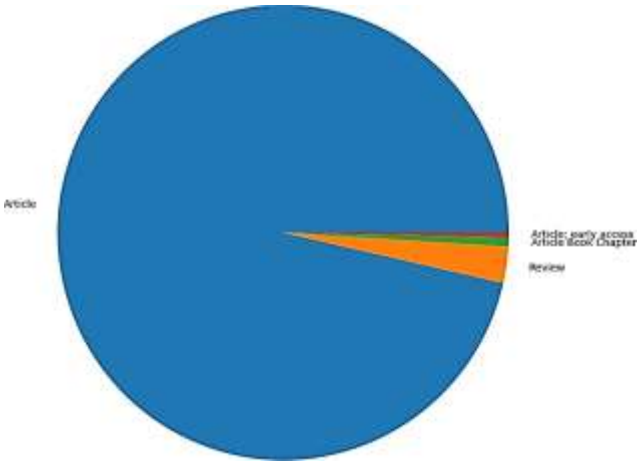

Fig. 3: Graph showing type of document published on ticks and its relevant fields

Bibliometric Approaches

Year-wise analysis

Fig. 2 shows that a total of 309 publications were published in the Web of Science database from 1970 to 2023. The highest numbers of publications were published in the years 2021 and 2022 respectively. Interestingly, the publications from 1999 received the highest number of citations, followed by those from 2012 and 2014, respectively. Surprisingly, no citations were received in the year 2023. The researcher also noted that the years 1986 and 1988 had the same number of publications and received an equal number of citations. Similarly, the years 1991 and 1999 had the same number of publications, but 1991 received the highest number of citations among them.

Table 1: Impact of Different journal shown by bibliometric analysis

Sources	NCP	CP	TP	TC
Parasites Vectors	0	18	18	459
Veterinary Parasitology	1	14	15	705
Vaccine	0	14	14	498
Ticks and Tick-Borne Diseases	0	13	13	198
Journal of Medical Entomology	0	9	9	161
Onderstepoort Journal of Veterinary Research	1	8	9	161
Tropical Animal Health and Production	1	8	9	70
Indian Veterinary Journal	3	5	8	14
Journal of Wildlife Diseases	0	6	6	135
PLoS One	1	5	6	113
Insect Science and its Application	0	6	6	62
Veterinary World	1	5	6	35
Experimental and Applied Acarology	0	6	6	90
Parasitology Research	0	5	5	197
Buffalo Bulletin	3	0	3	0

Note: NCP = Non cited publications, CP = Cited publications, TP = Total publications, TC = Total Citations

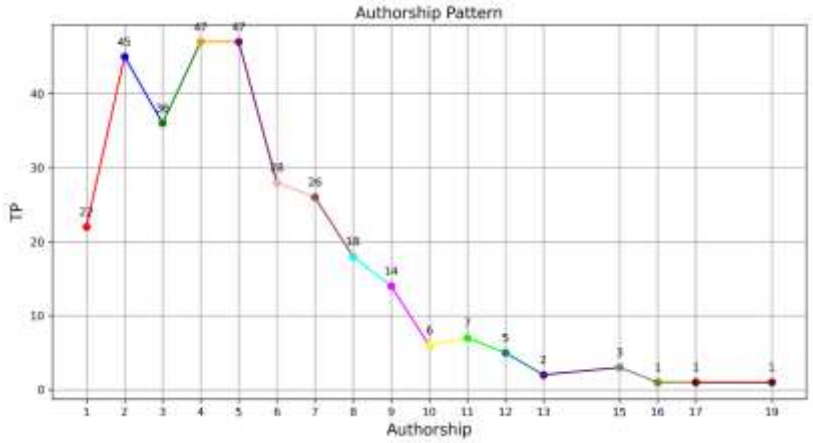

Fig. 4: A graph showing co-authorship by researchers in tick field

Document types

In Fig. 2, 3 the researchers found that "articles" were the most commonly used document type for research, with 298 publications. Following closely behind, "reviews" were the second most favored type with 8 publications. In terms of citation analysis, "articles" ranked highest with 5620 citations, followed by "reviews". Interestingly, "book chapters" had only two publications and two citations.

Authorship pattern

Fig. 4 displays the authorship patterns utilized by researchers in the tick field. The patterns range from single-author to 19-author collaborations. The findings reveal that the most prevalent collaboration patterns are those involving four and five authors, closely followed by two-author collaborations. Interestingly, joint research conducted by groups consisting of 16, 17 and 19 authors led to only one publication each. Furthermore, there is an exceptional case where a single author has managed to publish a total of 22 publications.

Top sources

In Table 1, the impact of various journals is evaluated based on their publication and citation counts. Among journals with over 15 publications, Parasites Vectors holds the top position with 18 publications. Veterinary Parasitology and Vaccine secure the second and third ranks with 15 and 14 publications, respectively. Interestingly, Veterinary Parasitology leads in terms of citations, followed closely by Vaccines. Strikingly, the Journal of Medical Entomology and Onderstepoort Journal of Veterinary Research share the same number of publications and citations. However, despite having identical publication counts, these five journals exhibit varying citation counts.

Top articles

Table 2 presents the top 15 highly cited articles in Bibliometric research. Topping the list is the article titled "Incidence from Coincidence: Patterns of Tick Infestations on Rodents Facilitate Transmission of Tick-Borne Encephalitis Virus," published in 1999, which has garnered

Table 2: Top 15 highly cited revealed by bibliometric analysis

Title	PY	TC
Incidence from coincidence: Patterns of tick infestations on rodents facilitate transmission of tick-borne encephalitis virus	1999	259
World association for the advancement of veterinary parasitology (WAAVP) second edition: guidelines for evaluating the efficacy of parasiticides for the treatment, prevention and control of flea and tick infestations on dogs and cats	2013	166
Biology, treatment and control of flea and tick infestations	2009	123
Successive tick infestations selectively promote a T-Helper 2 cytokine profile in mice	1999	116
Risk factors to tick infestations and their occurrence on horses in the state of Sao Paulo, Brazil	2001	102
Distribution of ticks infesting ruminants and risk factors associated with high tick prevalence in livestock farms in the semiarid and arid agro-ecological zones of Pakistan	2017	98
Identification and characterization of *Rhipicephalus (Boophilus) Microplus* candidate protective antigens for the control of cattle tick infestations	2010	97
Characterization of Ferritin 2 for the control of tick infestations	2010	95
Molecular characterization of a *Haemaphysalis longicornis* tick salivary gland-Associated 29-Kilodalton protein and its effect as a vaccine against tick infestation in rabbits	1999	95
Breed-associated resistance to tick infestation in *Bos indicus* and their crosses with *Bos taurus*	1998	90
Decorin-binding protein A (Dbpa) of *Borrelia burgdorferi* is not protective when immunized mice are challenged *via* tick infestation and correlates with the lack of DbpA expression by *B. burgdorferi* in ticks	2000	87
Characterization of three ixodes scapularis cDNAs protective against tick infestations	2005	80
World association for the advancement of veterinary parasitology (WAAVP) guidelines for evaluating the efficacy of parasiticides for the treatment, prevention and control of flea and tick infestation on dogs and cats	2007	78
Tick infestation on Roe deer in relation to geographic and remotely sensed climatic variables in a tick-borne encephalitis endemic area	2008	76
Prevalence, distribution and risk associated with tick infestation of dogs in Great Britain	2011	73

Note: PY = Publication Year, TC = Total Citations

Fig. 5: Most influential countries in terms of publications

the highest number of citations. Following closely is the article titled "World Association for The Advancement of Veterinary Parasitology (WAAVP) Second Edition: Guidelines for Evaluating the Efficacy of Parasiticides for the Treatment, Prevention, and Control of Flea and Tick Infestations on Dogs and Cats," published in 2013, securing the second-highest number of citations.

Top countries

Fig. 5 presents the country-wise analysis. According to the country-wise analysis, the USA emerges as the leading contributor with 81 publications, closely followed by Spain with 29 publications. Brazil holds the third position with 26 publications, although at a considerable distance from the top two. On the other end of the spectrum, Mexico, Ethiopia, and Kenya rank at the bottom, with 9, 8 and 6 publications, respectively. Regarding the number of citations, the USA stands out securing the top position among all countries. The USA maintains its dominance in citations, showing the highest number. Spain takes the second position with 893 citations, and South Africa follows with 674 citations. Ethiopia, unfortunately, lags significantly with only 47 citations, holding the last position in this aspect.

Top keywords

A cartographic map was presented in Fig. 6, highlighting the most commonly used authors' keywords. The purpose of the analysis was to identify the keywords under each

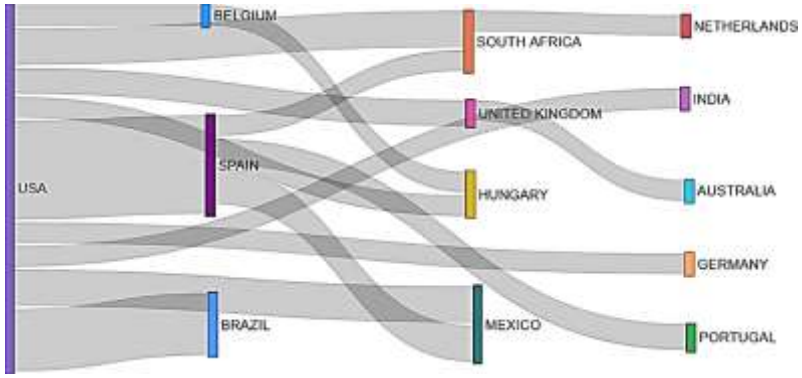

Fig. 8: Country Collaboration pattern for research on ticks related research

research stream. A criterion of a minimum of three occurrences of the keywords was set for the keywords to appear on the map. Different colors represent different clusters. Nine clusters presenting different research themes from the map. The keywords like ticks, tick, prevalence, cattle and tick infestation are their respective research themes. The size of the frequency of the occurrences of the keywords.

Top organizations

Fig. 7 reveals the top-performing organizations in terms of productivity. Oklahoma State University Stillwater and Oklahoma State University System stand out as the most productive, both having 20 publications. Following closely behind is Consejo Superior De Investigaciones Cientificas, Almazan C, with a significant number of 18 publications. It is worth noting that certain organizations share the same publication count, indicating similar levels of productivity. Notably, EUROPE has the lowest number of publications among the listed organizations.

Country collaboration

Fig. 8 highlights the fruitful research collaborations among different countries. Notably, researchers from the USA and Spain jointly published 18 papers, marking the highest number of collaborative publications between any two nations. Additionally, the USA and Brazil collaborated on 11 publications, while Spain and Mexico, USA and Mexico, and the USA and South Africa each contributed six publications through their joint efforts.

Comparative Analytical Framework

Over the past five decades, there have been a total of 309 publications related to ticks, their distribution, and prevalence. Interestingly, the number of publications per year wasn't more than 10 until 2008. However, the average number of publications per year has been 15 since 2008 until now. The maximum number of publications was recorded in the year 2021, with most of them being related to tick infestation and their control. This sudden increase in trend could be correlated with the rise in awareness about ticks, tick-borne diseases, and economic loss due to ticks. The most cited publication was from the year 1999 by Dumpis *et al*. (2019) which reviewed tick-borne encephalitis, a zoonotic disease transmitted by ticks that clearly recognized the potential risk of ticks and tick-borne pathogens to humans.

De La Fuente, from the University of Castilla-La Mancha, is the leading author on ticks, with an impressive 13 publications, all of which have been cited. He also holds the distinction of having the highest citation impact. Most of his publications are related to the control of ticks, *Anaplasma marginale*, and *Ixodes scapularis*. One of his most notable publications provides an extensive overview of tick-borne pathogens, their vectors, geographical distribution and host species affected (Fuente *et al*. 2008). Three of his publications are among the top articles related to ticks, which report the use of recombinant tick FER2 protein as a suitable antigen for vertebrate vaccination and protection against ticks (Hajdusek *et al*. 2010), the use of RNAi for the selection of candidate tick-protective antigens and the use of cDNA clones that encode for UBQ and SUB as cattle vaccination and infestation with *R. microplus* and *R. annulatus* (Almazán *et al*. 2010) and vaccination of mice with recombinant 4F8, 4D8 and synthetic 4E6 against Ixodes scapularis (Almazán *et al*. 2005). The second most productive author is Consuelo Almazán from the Autonomous University of Tamaulipas. Although she has only seven publications, her work has been cited a total of 415 times. Notably, most of her publications are collaborative with De La Fuente.

According to the analysis, the journal 'Parasites Vectors' has the highest number of publications (N = 18), followed by 'Veterinary Parasitology' which has the maximum number of citations. Despite ranking third in terms of publications, "Vaccine" has a greater number of citations than "Parasites Vectors," indicating that publication count does not necessarily reflect a source's impact. The second most cited article, published in "Veterinary

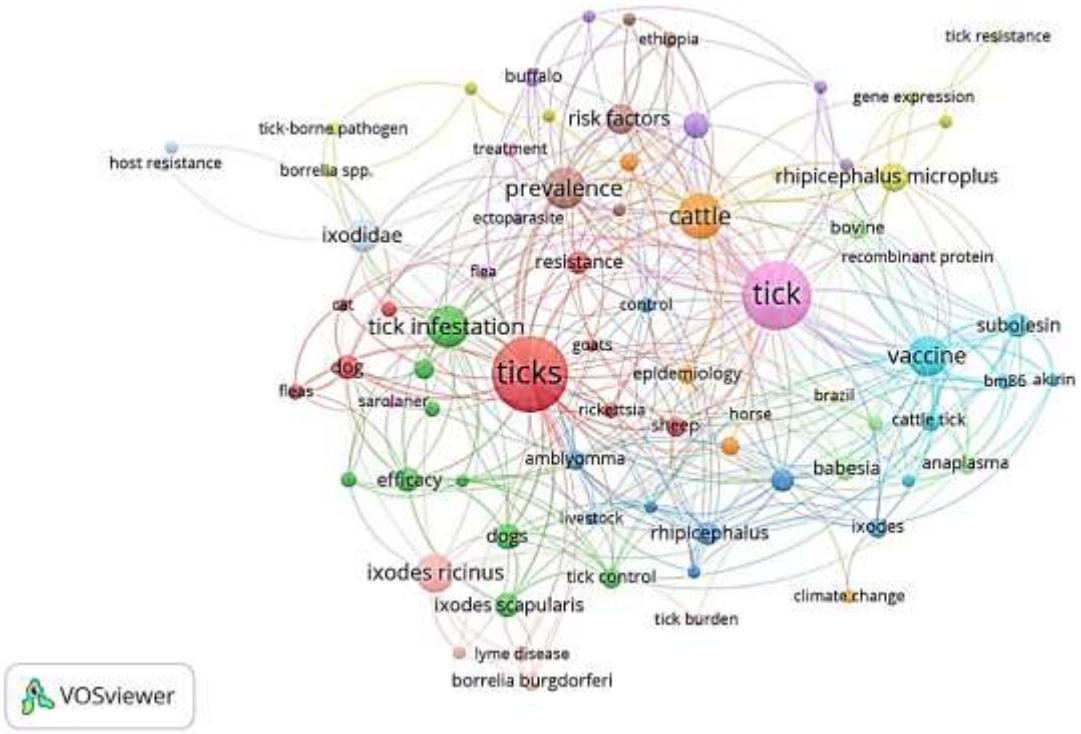

Fig. 6: Co-occurrence map based on the Web of Science category; ball represents the frequency of the occurrences ofthe keywords

Fig. 7: Leading organizations working on Ticks

Parasitology," provides guidelines for assessing the effectiveness of acaricides for tick control (Marchiondo *et al*. 2013). The top author, De La Fatura has most of his publications in the journals 'Vaccines' and 'Veterinary Parasitology' and one-third of his top articles related to ticks are also published in 'Veterinary Parasitology'.

The prominent organizations with the maximum number of publications since 2000 are the "Oklahoma State University" and the "Oklahoma State University System" from the USA. Notably, De Le Fuente's research on ticks is

primarily affiliated with "Oklahoma State University," with three of his most influential articles in collaboration with the institution. Shakya *et al*. (2014) from India, in affiliation with "Oklahoma State University," suggested the use of subolesin to develop a vaccination for controlling tick infestations on cattle (Shakya *et al.* 2014). This institution has also collaborated with researchers from Italy, Spain, India, Netherlands, Tunisia, and Mexico for research on ticks, tick-borne pathogens, and their control, indicating its keen interest in this area. Following these institutions is "Consejo Superior De Investigaciones Cientificas" from Spain, with 18 publications. It is noteworthy that the majority of these publications (11 out of 18) were affiliated with "Oklahoma State University," highlighting the significance of collaborative research efforts.

The present study also highlights the contributions of various countries in the field of tick and tick-borne pathogens research. Analysis of the data reveals that the United States (USA) has contributed approximately one-third (81/309) of the publications, followed by Spain, with less than half of the USA's contribution (29/309). The USA's first publication on this subject was in 1984, and until 2000, only five articles were published. However, from 2000 to 2022, there has been an average of three publications per year, with the maximum number of publications (six) in the years 2021, 2014, 2012 and 2009. Spain, on the other hand, published its first article in 1998, followed by the second in 1999. Nonetheless, there was a four-year hiatus in research after the second publication. From 2005 to 2022, Spain has had an average of one publication per year, with a maximum of five publications in the years 2014 and 2012. Overall, the USA has remained active in research related to ticks and tick-borne pathogens. The collaboration pattern between the USA and Spain is the most prominent pattern of collaboration, with a total of 15 publications, which is even more than half of Spain's total publications. Ticks and tick-borne diseases are more prevalent in tropical and subtropical regions, such as Pakistan, India, and Bangladesh, due to the conducive climatic conditions for the growth of these pathogens. Extensive research is needed in these developing countries to combat the spread of these diseases. While India, Pakistan, South Africa, Ethiopia, and Kenya have made though not sufficient but notable contributions in this field, but Bangladesh lags with just one publication in 2011 reporting the infestation rate of ticks on cattle in Chittagong district to be 36.31% (Kabir *et al*. 2011). Insufficient research in developing countries could be attributed to poor economic conditions, as economic resources are the most significant factor that impacts both the diseases and research related to them. However, bridging the gap between developed and developing countries is essential to enhance global health. Currently, such collaboration patterns have been observed between the USA and Brazil, USA and Mexico, USA and South Africa, USA and India, and USA, Spain, and South Africa, and USA, Spain and Mexico.

In bibliometric analysis, a network graph of keywords sheds light on the trending topics in research. This particular analysis reveals the most commonly used keywords are "tick" and "ticks", which is not surprising considering the research focus. Other frequently used keywords include "cattle", "prevalence", "risk factors", and "vaccine". The higher occurrence of the keywords "Ticks" and "Cattle" can be attributed to the fact that ticks are the primary parasite of cattle and can cause significant losses in their weight, milk, hides, and other products. Moreover, they can transmit various pathogens to them. The keyword "Vaccine" is more frequently combined with other keywords like "subolesin" and "bm86", indicating the importance of these two vaccines as promising treatments against tick infestations in cattle (Vos *et al*. 2001; Shakya *et al*. 2014).

Although this is the first bibliometric analysis on the tick, the author admits that there are some limitations that merit attention. Firstly, the literature was solely retrieved from the Web of Science, while other databases such as Scopus and PubMed have not been investigated. Secondly, the study only considered publications in the English language, resulting in the potential loss of valuable information from other languages. Thirdly, only research articles, review articles, and book chapters have been included in this study. Furthermore, despite using all relevant keywords and manually checking for the retrieval of articles, there is still a possibility of a limited number of false positives or negatives. Lastly, the information extracted from Web of Science is used for ranking, but due to different spellings of authors and institutions, it is possible that authors or institutions have multiple affiliations that authors are not aware of and hence, the ranking might not be 100% accurate. The authors were cognizant of these limitations and endeavored to minimize their impact.

Conclusion

This study provides a comprehensive review of articles and book chapters on ticks, highlighting research subjects, prominent countries and organizations, research gaps, and current trends. The findings reveal an upward trend in publications on ticks over the past decade. Notably, researchers from the United States and Spain have demonstrated significant contributions and collaborations in this field. This study underscores the need for further research and international collaboration to control ticks and tick-borne pathogens, particularly in agricultural countries where livestock plays a significant role in the economy.

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Author Contributions

MA and SM drafted the initial manuscript, including writing the introduction, methodology, result, and discussion, S.A conducted data collection by gathering and organizing the bibliometric data from relevant databases, AG performed data analysis, including statistical analysis and interpretation of bibliometric indicators, HA revising draft for important intellectual content and provided critical feedback, GSS Coordinated the research project and ensured the accuracy and integrity of the entire work, providing oversight throughout the study.

Conflicts of Interest

All authors declare no conflict of interest.

Data Availability

Data presented in this study will be available on a fair request to the corresponding author.

Ethics Approval

Not applicable to this paper.

Funding Source

Not applicable

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