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Biological control of termites: a bibliometric and state-of-the-art review

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ABSTRACT: Termites are considered pests and biological control is an environmentally friendly alternative to reduce pesticide contamination. It was aimed with this study to compile the publications indexed in the Scopus platform referring to biological control of termites between 1981 and 2019. A total of 143 publications were found, each of which was read and filtered according to the selection criteria. The studies analyzed were conducted in 16 countries, with the United States leading the way (44%). A total of 55 termite species and seven families were recorded in the papers. For the control agents tested, more than 140 species were identified and classified. Plant insecticides were the most cited, with emphasis on oils and extracts from *Azadirachta indica* and *Chamaecyparis obtusa*. It was noted that most research was conducted on a laboratory scale in the form of experimental designs. This may limit more comprehensive discussions of the biological termite control agents tested. Although the use of other control agents is increasing, there is a wide range of insecticides and plant-derived compounds that can be studied.
Keywords: pesticides; Xylophagous agent; control agents; ecosystem engineers; systematic review.

Controle biológico de cupins: uma revisão bibliométrica e estado da arte

RESUMO: Os cupins são considerados pragas e o controle biológico é uma alternativa ecologicamente correta para reduzir a contaminação por pesticidas. Objetivou-se com este estudo compilar as publicações indexadas na plataforma Scopus referentes ao controle biológico de cupins entre 1981 e 2019. Foram encontradas 143 publicações, cada uma delas foi lida e filtrada de acordo com os critérios de seleção. Os estudos analisados foram realizados em 16 países, com os Estados Unidos liderando (44%). Um total de 55 espécies de cupins e sete famílias foram registradas nos trabalhos. Para os agentes de controle testados, mais de 140 espécies foram identificadas e classificadas. Os inseticidas vegetais foram os mais citados, com ênfase em óleos e extratos das espécies *Azadirachta indica* e *Chamaecyparis obtusa*. Foi observado que a maioria das pesquisas foram conduzidas em escala laboratorial na forma de delineamentos experimentais. Isto pode limitar discussões mais aprofundadas sobre os agentes biológicos de controle de cupins testados. Embora o uso de outros agentes de controle esteja aumentando, há uma vasta gama de inseticidas e compostos derivados de plantas que podem ser estudados.
Palavras-chave: pesticidas; agente Xilófago; agentes de controle; engenheiros de ecossistema; revisão sistemática.

1. INTRODUCTION

Termites are terrestrial social insects, classified in the Neoptera superorder, polymorphic and hemimetabolous, with lengths varying from 3 to 25 mm (CONSTANTINO, 2012; GULLAN; CRANSTON, 2017). Termites are cosmopolitan but are most often present in Oriental, Neotropical, and Ethiopian areas, being especially diverse in tropical forests and savannas (CONSTANTINO, 2012). The infraorder Isoptera is part of Blattodea order and comprises nine families: Archotermopsidae, Hodotermitidae, Kalotermitidae, Mastotermitidae, Rhinotermitidae, Serritermitidae, Stolotermitidae, Stylotermitidae and Termitidae (ENGEL, 2011; KRISHNA, 2013).

These insects feed on different forms and sources of lignocellulosic (alive, dead, or rotten), grasses, hummus, manure, roots, leaves, stems, and soil detritus (EGGLETON, 2010; KRISHNA, 2013). Some termites feed on fungi, by obtaining contaminated material and growing the fungus inside their nests, feeding on the spores and mycelium produced (BIGNELL, 2006). Except for a few arboreal species, termites spend most of their lives building, foraging, and feeding in or on soil (HOLT; LEPAGE, 2000). They are known as ecosystem engineers, being especially important in harsh environments and depleted soils. To modify the minerals, present in the soil, they dig enormous galleries and channels that can enhance the stability and absorption of organic matter (BIGNELL, 2006; GULLAN; CRANSTON, 2017).

This indicates that termites require a lot of attention in the forestry and industrialized timber sectors. Studies indicate the damage that termites can cause to solid wood structures as well as their by-products (BATISTA et al., 2022; MEDEIROS NETO et al., 2022). In addition, increased seedling mortality and reduced productivity in *Eucalyptus* spp. and *Pinus* spp. plantations, which are among the most widely cultivated wood species in the world, is reported (GOVORUSHKO, 2019; PRASTYANINGSI et al., 2020; EVANS, 2021). These aspects are fundamental for the timber market in tropical regions, especially in Brazil, which stands out worldwide in the area of native and planted forests with robust tropical timber production (MASCARENHAS et al., 2021; MEDEIROS et al., 2021).

Overall, only a minority of species are considered pests, by attacking trees, wooden structures, and crops, causing substantial damage (BIGNELL et al., 2014; GULLAN; CRANSTON, 2017). Most insects are classified by the United Nations Environment Programme (UNEP) as pests due to the losses caused and whether their removal is economically beneficial. Beyond organic materials like crops, forests, and pastures, termites can also significantly damage structures such as buildings, bridges, and dams, along with furniture, paper, and food (UNEP, 2003).

The traditional method for pest control consists of applying insecticides based on synthetic organic compounds. Among these insecticides, POPs (Persistent Organic Pollutants) stood out for many years. Although effective in controlling pests, POPs pose risks to the environment and human safety, due to their capacity for long-range transport, bioaccumulation, and bioamplification (UNEP, 2003).

Biological control can be a viable alternative to reduce the impacts caused by pesticides on the environment. Controlled application of entomopathogens and botanical insecticides are examples of control agents with low risk of contamination. Despite being a topic of interest to agricultural sciences, few studies have been published on the biotic mechanisms of pest control.

One of the ways to evaluate the scientific production on these topics is through a systematic review, evaluating bibliometric data and the state of the art. A bibliometric review is by the choice of papers through a database that brings together publications, making it possible to identify gaps in knowledge and analyze research trends over time (DONTHU et al., 2021; ARAUJO et al., 2023). Thus, the objective of the present study was to compile data presented by scientific publications stored in the Scopus platform about the biological control of termites, in addition to carrying out the state-of-the-art on the subject.

2. MATERIALS AND METHODS

2.1. Bibliometric Review

Using the Scopus (Elsevier) database, we searched under the terms "termite" and "biological control" in titles, abstracts, and keywords of publications from 1981 to 2019. The string generated was: TITLE-ABS-KEY ("termite" AND "biological control") AND (EXCLUDE (PUBYEAR, 2020, 2021, 2022)). The search generated a list of 143 publications, which were identified and accessed individually through Google Scholar and other specific indexation platforms. Every publication was read and filtered, with those aligned with the following criteria being maintained: 1 – investigation of biological control of termites, even if it is not the main theme of the production; and 2 – testing of at least one agent for biological control of termites, except for review publications. We considered biological control agents to be: a) those directly extracted from plants, such as essential oils, extracts, plant tissue, ashes from plant material, or chemical compounds isolated from plants; b) agents with entomopathogenic potentials, such as fungi, bacteria, viruses, nematodes and acari; and c) predators such as ants and larvae of various species.

After filtering, the remaining papers were classified by: I) type of publication; II) year of publication; III) authors; IV) research institution affiliation; V) funding agency; VI) journal or other publication; and VII) science area (as in Scopus). Data were tabulated and graphs generated with spreadsheet management software.

2.2. State of the Art

Aiming to point out efficient methods for termite control, as well as possibilities for new experiments in the area, we conducted a systematic review using the filtered documents. Information was extracted and divided into: a) site of collection; b) species of termites collected; c) termite targets; d) study venue (field x laboratory); e) tested control agents; and f) application spots.

3. RESULTS

3.1. Bibliometric Review

After screening, 68 articles related to the topic were identified. The documents are classified by Scopus into four types: article; review (6%); book chapter (3%); and conference paper (1%). "Article" was the most numerous categories, corresponding to 85% of publications. Considering the whole period of this review (1981-2019), the number of publications addressing the biological control of termites was rising but is still low. The peaks were in 2017, with six publications, and 2004-2005, with five publications each (Figure 1). There were also periods with no publications indexed in the Scopus database on the subject (1984 to 1989 and 1991 to 1996), giving an average of 1.74 publications/year.

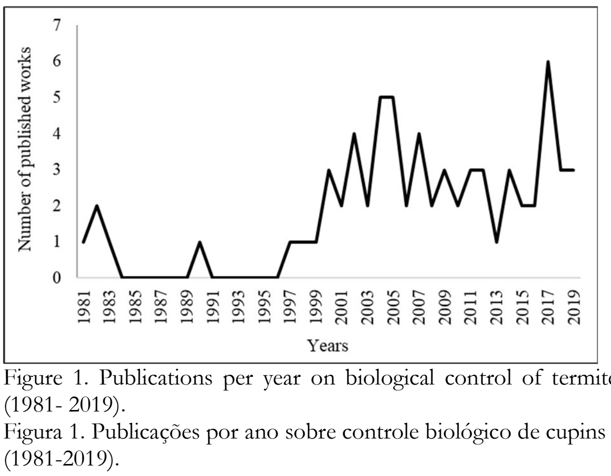

Figure 1. Publications per year on biological control of termites (1981- 2019).
Figura 1. Publicações por ano sobre controle biológico de cupins (1981-2019).

A total of 155 authors participated in the publications about biological control of termites. Of these authors, those with the highest number of publications are cited below (Figure 2A). The integration cluster revels that the three top authors worked together (Figure 2B).

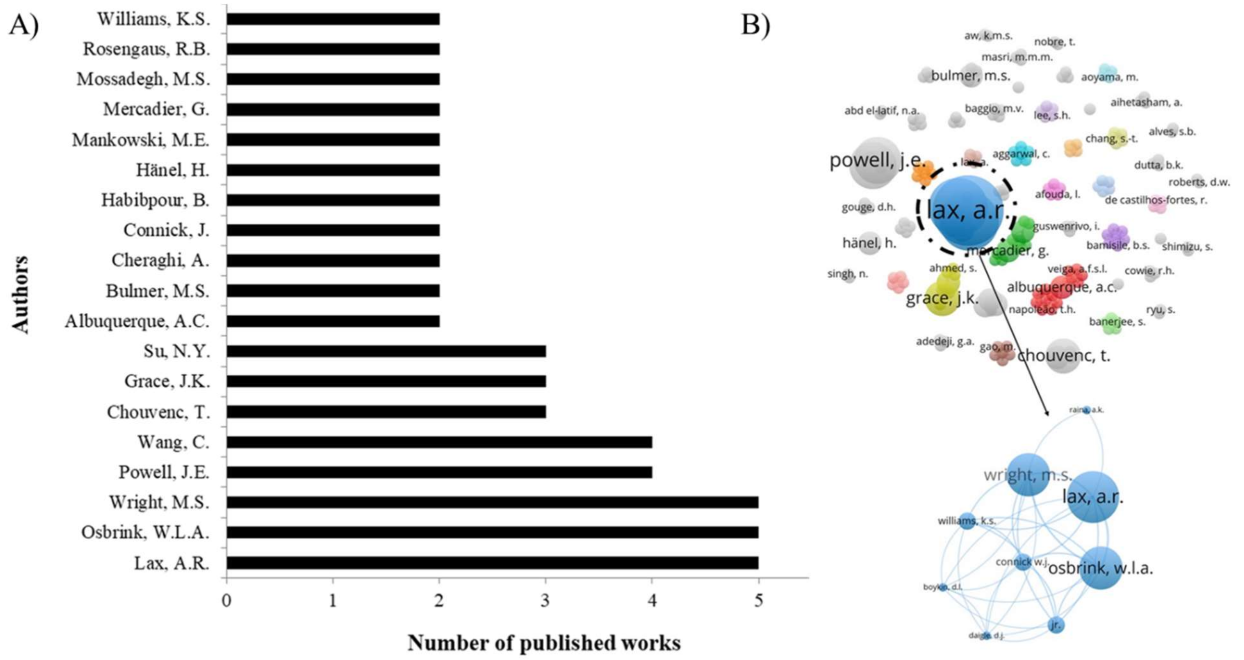

Figure 2. A) The 22 authors with the highest number of publications on the biological control of termites (1981-2019). B) Integration clusters and main clusters among authors with publications on biological control of termites (1981-2019).
Figura 2. A) Os 22 autores com maior número de publicações sobre controle biológico de cupins (1981-2019). B) Clusters de integração e clusters principais entre autores com publicações sobre controle biológico de cupins (1981-2019).

Among the 84 institutions with affiliated authors, the standout was the United States Department of Agriculture (USDA), with more than 30%, represented by the Agricultural Research Service (ARS) and Forest Service (FS) (Figure 3). The United States was the country with the largest portion of institutions and authors (43%), followed by Brazil (11%), India (10%), Malaysia (5%), and China (4%). Identification of institutions/agencies and nationalities indicates where the subject is being analyzed the most.

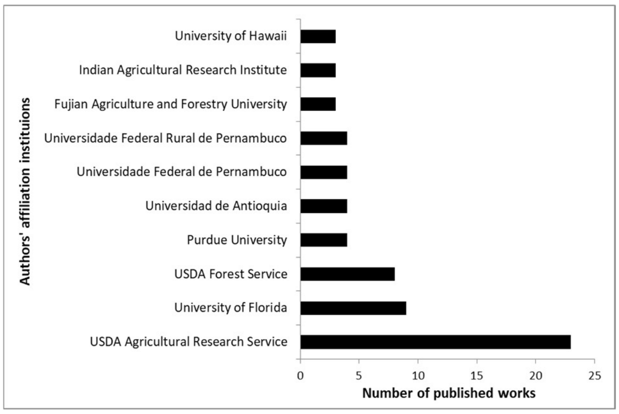

Figure 3. Institutions with numbers of affiliated authors who published papers on biological control of termites (1981-2019).
Figura 3. Instituições com números de autores afiliados que publicaram artigos sobre controle biológico de cupins (1981-2019).

Out of the 11 funding agencies presented by Scopus (Figure 4), the three that funded the most research were Brazilian governmental agencies, denoting the importance of public funding for the development of Brazilian research.

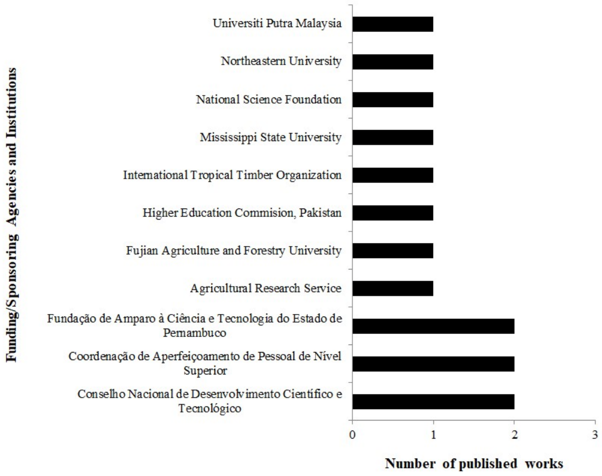

Figure 4. Publications on biological control of termites by funding agencies and institutions, (1981-2019).
Figura 4. Publicações sobre controle biológico de cupins por agências e instituições de fomento, (1981-2019).

The theme was addressed by 43 journals, with *International Biodeterioration and Biodegradation* having the most publications (9%). Most journals (46%) only published one study. Figure 5 identifies those with at least two documents published (Figure 5). As for nationalities, there were studies from 14 countries, with 30% of journals being American, 21% British and 14% Dutch.

There was a huge difference between the nationalities of journals and authors' affiliation institutes. Even though less than 8% of authors were affiliated with European institutions, more than 55% of studies were published in journals from Europe. The pattern was the opposite in Asia, where almost 30% of institutions were based, but corresponded to less than 7% of publications by nationality of the journal.

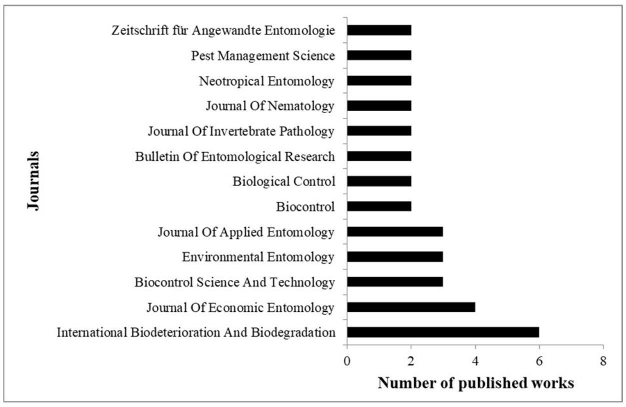

Figure 5. Journals with higher publishing numbers on biological control of termites (1981-2019).
Figura 5. Periódicos com maior número de publicações sobre controle biológico de cupins (1981-2019).

Scopus classified studies into 15 categories regarding the area of science (Figure 6). Areas with the highest occurrence within publications were: "Agricultural and Biological Sciences" (48%); "Environmental Science" (17%); "Immunology and Microbiology" (10%); and "Materials Science" (7%). This classification is in full accordance with the subject, as: 1 – The potential of termites as agricultural and forest pests; 2 – The relevant ecological function performed by termites in their natural and introduced habitats; 3 – Biological control methods executed with the introduction of pathogenic microorganisms, parasites or through the attack of symbionts present in the guts of termites; 4 – Especially on urban areas, where the damage caused by termite attack can have a direct relationship with the material attacked.

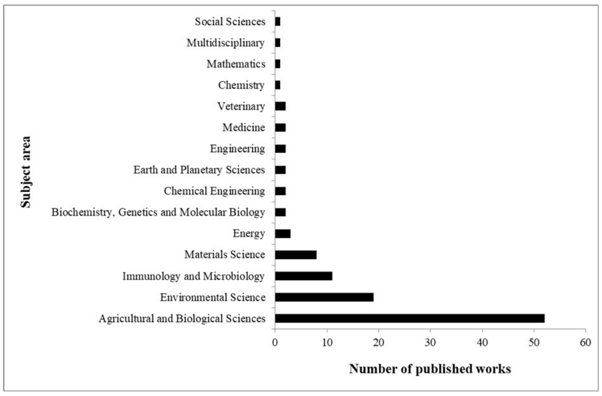

Figure 6. Publications on biological control of termites, classified by areas of science, according to Scopus (1981-2019).
Figura 6. Publicações sobre controle biológico de cupins, classificadas por áreas da ciência, segundo Scopus (1981-2019).

3.2. Collection sites

Collections were made in 63 areas. The sites were described with different levels of specificity. Some articles gave full description of the area, presenting geographic coordinates, while some only identified the region where the collection took place. Some studies were conducted in multiple collection sites while others focused on a single collection site. Among the 16 countries, the one with the most collections was the United States, representing 44% (Figure 7).

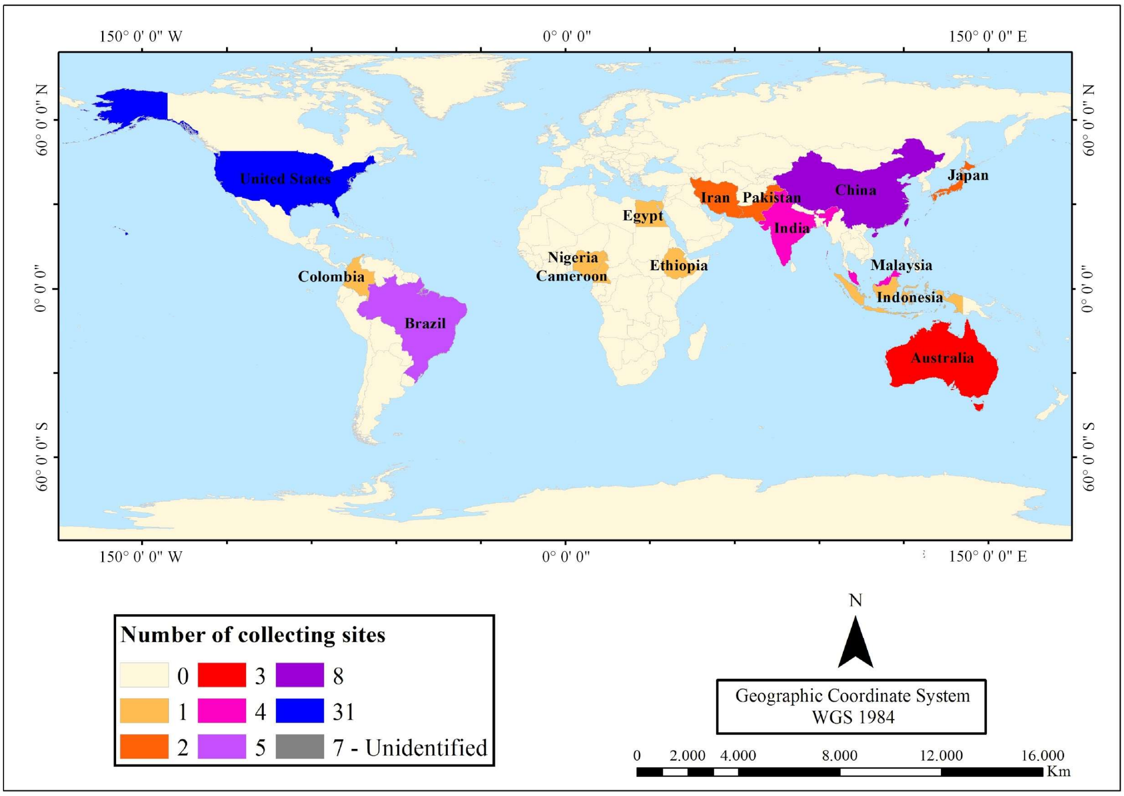

Figure 7. Termite collecting sites by country in publications on biological control of termites (1981-2019).
Figura 7. Locais de coleta de cupins por país em publicações sobre controle biológico de cupins (1981-2019).

3.3. Termite species collected

A total of 55 termite species, from 35 genera and seven families were counted. Of the 183 reports of termites, 178 identified the isopteran genus and 136 the genus and species. The families were Rhinotermitidae, Termitidae, Kalotermitidae, Archotermopsidae, Hodotermitidae, Stolotermitidae and Mastotermitidae, while the genera were *Coptotermes, Reticulitermes, Nasutitermes, Odontotermes,* and *Macrotermes*. The most frequent species were *Coptotermes formosanus*, *Reticulitermes flavipes* and *Coptotermes curvignathus* (Figure 8).

It is possible to observe a concentration of studies on five species, representing more than 40% of the studies with identified species. The genera *Coptotermes* and *Reticulitermes* represented almost 40% of mentions by genus, and 45% of the studies were on the *Rhinotermitidae* family. Through the information gathered, a map was formed representing the collected species of each country (Figure 9). The diversity of species was greatest in Brazil, United States and the Asian continent.

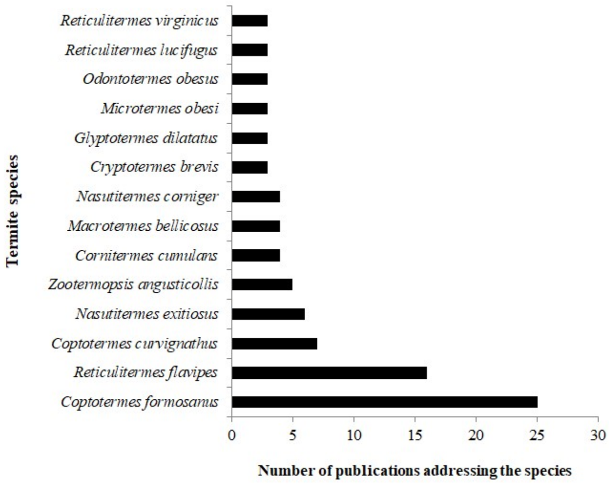

Figure 8. Number of publications on termite biological control addressing each species.
Figura 8. Número de publicações sobre controle biológico de cupins abordando cada espécie.

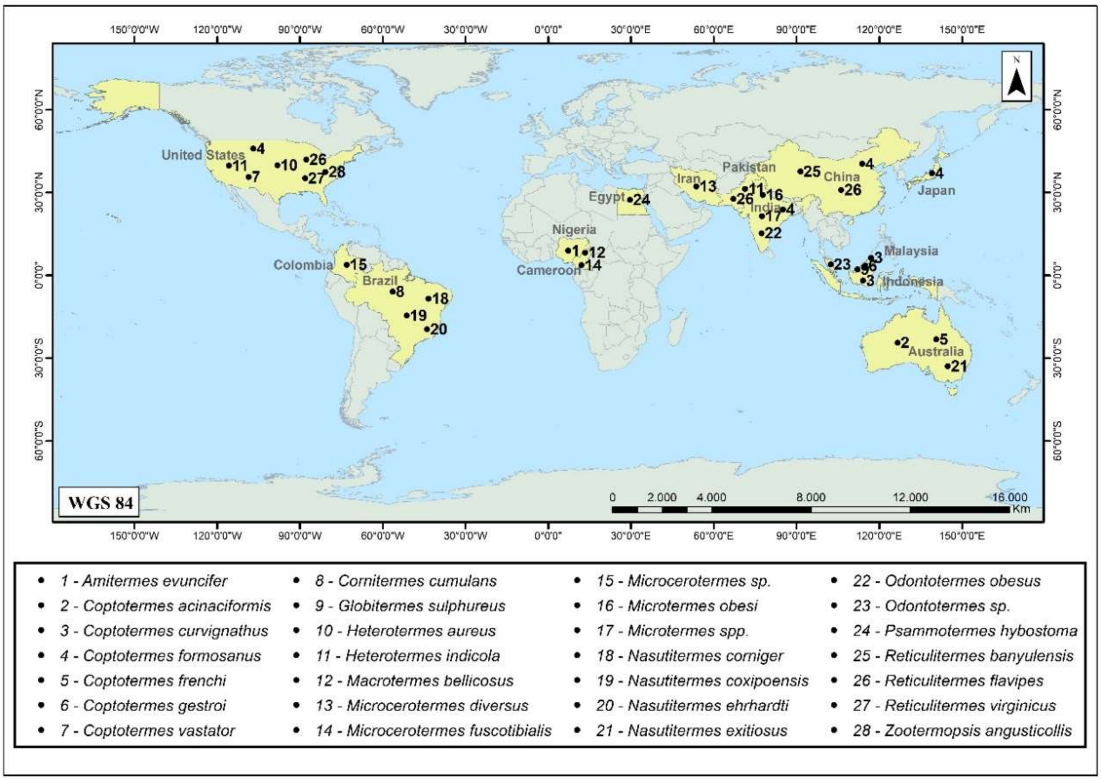

Figure 9. Species collected by country mentioned in publications on biological control of termites (1981-2019).
Figura 9. Espécies coletadas por país citadas em publicações sobre controle biológico de cupins (1981-2019).

3.4. Termite targets and evaluation site (Field x Laboratory)

More than 30 targets of termite attacks were registered. These included urban trees, clothing, plastics, paper, and more frequently structural wood and crops.

The studies used for comparison of the evaluation site did not include publications categorized by Scopus as "reviews" or "book chapters". The experiments were divided between: experiments that took place in the field, experiments that took place in a laboratory, or experiments that took place in both places.

Laboratory experiments represented the vast majority of studies, with 89%. Simulating the environment of a termite nest is complex. The cryptic habit of termites, their different kinds of nests, mechanisms of defense and hygiene, and also the different kinds of microorganisms that dwell in termite nests constitute particular habitats for various species. Among the few studies carried out in the field, only two reported effective results, one of them through the coating of a wood piece and the other through spraying of mounds.

3.5. Tested control agents

More than 140 species tested for biological control of termites were identified and divided into three categories: pathogens, botanical insecticides, and predators. Botanical insecticides were the most cited, also representing the highest number of species (Figure 10).

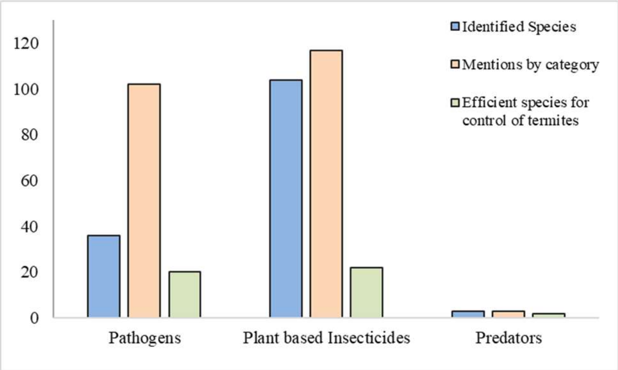

Figure 10. Identified species, number of references, and number of effective species by category of biological control agent.
Figura 10. Espécies identificadas, número de referências e número de espécies efetivas por categoria de agente de controle biológico.

All told, 24 control agents were utilized more than once. Also, 11 of these were found to be effective in two or more studies (Table 1). Among the botanical insecticides, plant oils and extracts were most frequent. Among the plant sources, Cupressaceae and Pinaceae were the main families and *Azadirachta indica* and *Chamaecyparis obtusa* were the most cited species (Figures 11 and 12).

As for pathogens, the most frequent representatives were fungi and nematodes, particularly the species *Metarhizium anisopliae*, *Beauveria bassiana* and *Steinernema carpocapsae* (Figures 13 and 14).

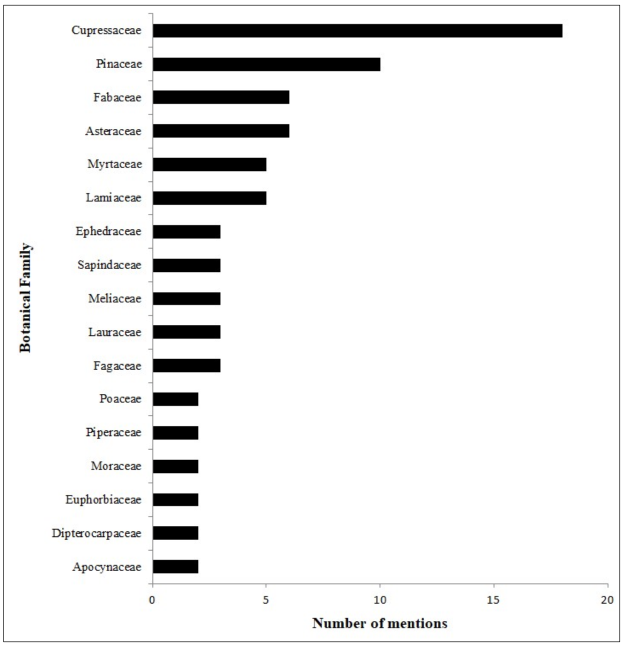

Figure 11. Main families utilized to produce botanical insecticides for termite control.
Figura 11. Principais famílias utilizadas na produção de inseticidas botânicos para controle de cupins.

Table 1. Effectiveness of tested agents for biological control of termites.
Tabela 1. Eficácia dos agentes testados para controle biológico de cupins.

Control agents	Type	Total applications	Effective applications	Effectiveness (%)
Metarhizium anisopliae	Fungus	33	28	84.9
Beauveria bassiana	Fungus	11	8	72.7
Steinernema carpocapsae	Nematode	6	4	66.7
Heterorhabditis indica	Nematode	5	4	80.0
Serratia marcescens	Bacterial	4	4	100.0
Azadirachta indica	Plant	4	3	75.0
Bacillus thuringiensis	Bacterial	4	3	75.0
Isaria fumosorosea	Fungus	3	3	100.0
Steinernema riobrave	Nematode	3	2	66.7
Heterorhabditis sonorensis	Nematode	2	2	100.0
Jatropha curcas	Plant	2	2	100.0

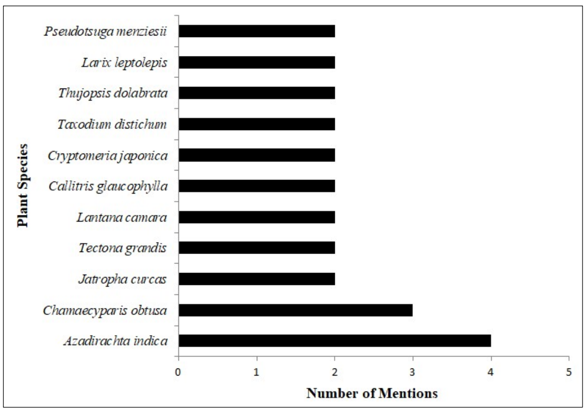

Figure 12. Number of mentions by the most cited plant species used to produce botanical insecticides.
Figura 12. Número de menções das espécies vegetais mais citadas para produção de inseticidas botânicos.

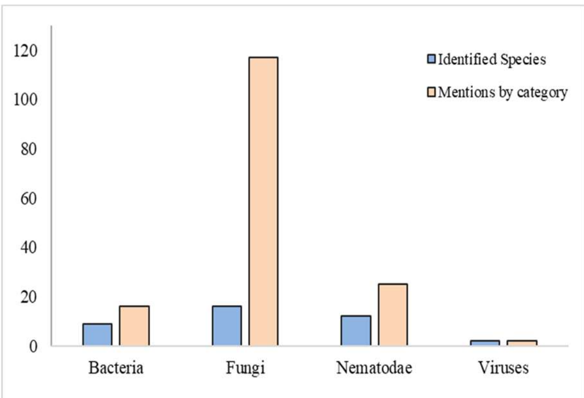

Figure 13. Number of identified species and mentions by group of pathogens.
Figura 13. Número de espécies identificadas e menções por grupo de patógenos.

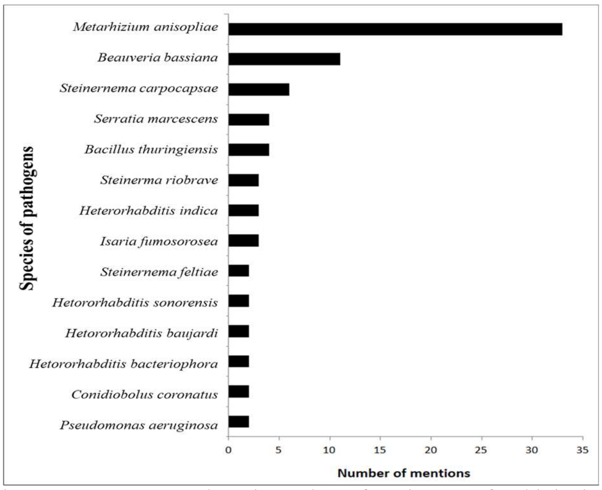

Figure 14. Most mentioned species of pathogens for biological control of termites.
Figura 14. Espécies de patógenos mais citadas para controle biológico de cupins.

3.6. Application places

The places were divided into four categories with applications to substrate being much more frequent than the others (Figure 15). Effectiveness was superior to 50% for all the methods used. Overall, the experiments were conducted in small spaces (commonly Petri dishes). Also, experimental designs often involved no-choice assays, and even those with multiple-choice assays did not have ample space. This reinforces what was pointed out in topic "d", that the experimental designs frequently limit the defensive alternatives for termites and fail to show effective actions of the tested control agents.

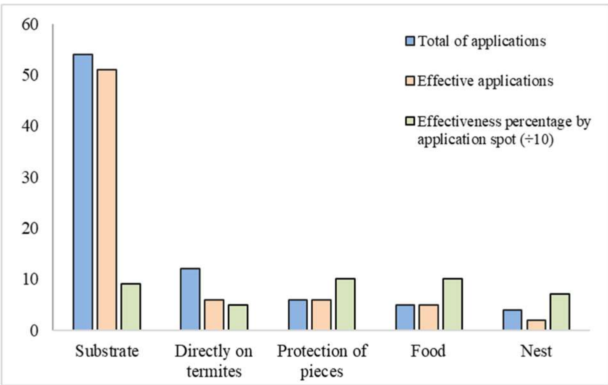

Figure 15. Total and effectiveness of applications by location.
Figura 15. Total e efetividade das aplicações por localidade.

4. DISCUSSION

The survey found several types of publications. According to Scopus, articles are documents that provide original research or opinions, which can be published as full papers in peer-reviewed journals, case reports, research/technical notes, short communications, and conference papers, which consist of articles published in the annals of a conference or symposium (ELSEVIER, 2020). Publications defined as "Reviews" are those in which there is significant coverage of previous documents, generally presenting extended bibliographies and without sections common to articles, such as "materials and methods" and "results" (ELSEVIER, 2020). Also, according to Elsevier (2020), "Book Chapter" is a publication contained in a book or collection of books.

According to Krishna et al. (2013), studies of termitology started with classifications published by Linnaeus in the 18th century and continued with the works of Hagen and Frogatt in the 19th century, while the leading authors in the 20th century were Snyder, Emerson, and Grassé. However, historical records of termites (and the damage caused by them) date from more than 2200 years ago. Their attack on dams and dikes was recorded in China (GUI-XIANG et al., 1994). Research on the biological control of termites started around 1916, as indicated in the pioneering study of Merril and Ford, in which parasitic nematodes were found inside termite heads (PAUL et al., 2018). Since Merril and Ford discovery, many other biological control agents have been tested. The oldest one present in this review date to 1981, conducted by Hänel with the utilization of the fungus *Metarhizium anisopliae* (Hänel, 1981).

Identification of the authors of articles of great importance for bibliometric reviews, since this contributes to data collection about the subject (SILVA et al., 2020; ARAUJO et al., 2023). The authors Lax, Osbrink, and Wright frequently collaborated on each other's works, making them the leading research team on the topic (Figure 2). A similar pattern was found for Wang and Powell, who were co-authors of four studies presented here. Lax et al. studied the effects of different control agents, among them fungi, bacteria, nematodes, and plant extracts on the termite species *Coptotermes formosanus*. Wang and Powell targeted *C. formosanus*, but also included *Reticulitermes flavipes*, utilizing the four previously cited control agents and mites.

Also, Silva et al. (2020) and Araujo et al. (2023) stated that the identification of institutions/agencies and their nationalities can contribute to the formation of networks of institutions and favor the exchange of experiences and information at different levels, from local to international. The existence of agencies and mechanisms of funding is of great importance for the development of scientific research throughout a region. Hottenrott; Lawson (2014) observed that academic production is directly affected by funding, not only on the number of publications but also in the subjects that are being studied. Areas with significant termite impact can nevertheless have low academic production on the subject. Systematic reviews can provide visibility of the problem and the area.

Termites vary according to habits. Rhinotermitidae are xylophagous termites commonly living in subterranean nests. They build large, fast expanding, and diffuse nests in soil or directly in wood (CONSTANTINO, 2012). Genera are scattered around the world, especially *Coptotermes, Reticulitermes*, and *Heterotermes* (Bourguignon, 2016). Also known as the "Formosan subterranean termite", *C. formosanus* is mentioned in the list from the International Union for Conservation of Nature (IUCN) as "100 of the World's Worst Invasive Alien Species". *R. flavipes* is also classified as an invasive species in various countries, such as France (BAOUDOUIN et al., 2018), Italy (GHESINI et al., 2011), Pakistan (HASSAN et al., 2017), Germany, Uruguay and Chile (CONSTANTINO, 2022).

The representatives of the Kalotermitidae family generally have small colonies do not make direct contact with soil (CONSTANTINO, 2012). It is a termite basal family and is dispersed around the globe, with higher numbers in Oriental and Neotropical zones (Krishna et al., 2013). The genera mentioned the most in the articles reviewed were *Cryptotermes* and *Neotermes*, while the most common species was *Cryptotermes brevis*. It originated in Peru and Chile, but has been introduced in a series of other countries in South America, Europe, Africa, and Oceania (CONSTANTINO, 2022).

Termitidae is the most modern termite family and corresponds to more than 70% of registered species (CONSTANTINO, 2022). Their habits and morphology are varied, normally composed of big colonies and complex nests, which can be internal or external (CONSTANTINO, 2012). The numbers of species and genera identified in this review were smaller than those of the Rhinotermitidae. The most frequent genera were *Nasutitermes* and *Microcerotermes*, with *Nasutitermes exitiosus* being the most frequent species.

Termites are commonly known for their capacity for cellulose digestion. This cellulose comes from different sources, according to each species, and varies from sound wood to hummus and even fungi (LIMA; COSTA-LEONARDO, 2007). Although they generally feed on cellulosic material, the damage caused by termites extends to other materials as well.

Chouvenc; Su (2010) listed mechanisms that hinder the biological control of isopterans, pointing out: i) alarm response/repellency/avoidance behavior; ii) chemical defense by use of volatile compounds produced by microorganisms associated with termites; iii) grooming (cleaning of members and nest); iv) antifungal activity of the digestive tract; v) humoral immunity; vi) necrophagy /burial/avoidance of corpses; and vii) competition among microorganisms.

Observing each point, the utilization of space is an evident problem. Most isopteran defensive practices are related to the relocation or isolation of contamination sources, a practice that is difficult in the small spaces of laboratories. Therefore, laboratory studies involving biological control agents of termites mostly consist of tests of the lethality of the agent (CHOUVENC et al., 2011), since the simulated environment does not match field conditions.

Botanical insecticides are control agents derived from plants, and as such, they pose a small risk to the environment when compared to traditional insecticides (ISMAN, 2014).

The review by Chouvenc et al. (2011), covering studies from 1960 to 2010, pointed out problems involving the biological control of termites through the use of fungi, nematodes, viruses, and bacteria. Some of their observations were:

1. Reduced experimental protocol, incompatible with the complex biology of termites. Especially ones developed in Petri dishes and/or experiments based on no-choice assays, because they do not provide support for field applications.
2. The data provided were insufficient to define treatment as effective.
3. High variability of results, suggesting that these experiments were inconsistent and lacked reliability.
4. The concentrations used were too high (above 10^7). Since the microorganisms would not be able to maintain that concentration level in the field, it makes them unavailable for field trials.

We also observed the same points, particularly the incomplete experimental protocol of no-choice assays and Petri dish evaluations. As for the insufficiency of data, some publications did not present information on the effectiveness of tested control agents or did not use control treatment. Other similarities found between this review and that of Chouvenc et al. (2017) were the concentration of studies on *Coptotermes* and *Reticulitermes* species. Pathogens used were also similar; fungi and nematodes were particularly frequent, with *Metarhizium anisopliae* and *Beauveria bassiana* being the most common control agents.

5. CONCLUSIONS

Through parameters utilized in this review, we observed that the number of publications per year has been growing. This shows that research interest in the area is increasing. Authors affiliated with American research centers and colleges were responsible for the largest share of publications, but termite attacks were noticed in multiple points of the globe. Even though the use of other control agents is rising, the use of entomopathogens is still predominant. There is a vast set of plant-based insecticides and compounds that can be tested for the control of termites. Differences between field conditions and laboratory conditions can explain the distinct results of each control agent tested. There is a need to test control methods that represent nest conditions more accurately.

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ATTACHMENT

Table 2. Titles, authors, journals and access to the 68 publications used on this review.
Tabela 2. Títulos, autores, periódicos e acesso aos 68 trabalhos utilizados na presente revisão.

Title	Authors	Journal	DOI or Link
Diversity, Roles, and Biotechnological Applications of Symbiotic Microorganisms in the Gut of Termite	Zhou J., Duan J., Gao M., Wang Y., Wang X., Zhao K.	Current Microbiology	10.1007/s00284-018-1502-4
Evaluation of the virulence of entomopathogenic fungus, Isaria fumosorosea isolates against subterranean termites Coptotermes spp. (Isoptera: Rhinotermitidae)	Jessica J.J., Peng T.L., Sajap A.S., Lee S.H., Syazwan S.A.	Journal of Forestry Research	10.1007/s11676-018-0614-9
Prospects in sustainable control of oil palm pests and diseases through the enhancement of ecosystem services - The way forward	Kamarudin N., Seman I.A., Masri M.M.M.	Journal of Forestry Research	10.21894/jopr.2019.0030
Potential fungal control of the subterranean termite heterotermes indicola (Wasmann)	Aihetasham A., Shariq S., Qazi J.I.	Pakistan Journal of Zoology	10.17582/journal.pjz/2018.50.6.2093.2098
Toxicity Bacillus thuringiensis-based Bio Insecticide Enriched with Golden Snail Meat Flour Against Worker and Soldier Castes of Coptotermes Curvignathus (Isoptera: Termitidae)	Pujiastuti Y.	E3S Web of Conferences	10.1051/e3sconf/20186801029
Isolation and characterization of Metarhizium anisopliae TK29 and its mycoinsecticide effects against subterranean termite Coptotermes formosanus	Keppanan R., Sivaperumal S., Ramos Aguila L.C., Hussain M., Bamisile B.S., Dash C.K., Wang L.	Microbial Pathogenesis	10.1016/j.micpath.2018.06.040
The diversity of soil fungus in and around termite mounds of Globitermes sulphureus (haviland) (blattodea: Termitidae) and response of subterranean termite to fungi	Guswenrivo I., Nagao H., Lee C.Y.	Sustainable Future for Human Security: Environment and Resources	10.1007/978-981-10-5430-3_4
The potential of Isaria spp. as a bioinsecticide for the biological control of Nasutitermes corniger	Lopes R.D.S., Lima G.D., Correia M.T.D.S., da Costa A.F., Lima E.Á.D.L.A., Lima V.L.D.M.	Biocontrol Science and Technology	10.1080/09583157.2017.1380163
Effects of heartwood extractives on symbiotic protozoan communities and mortality in two termite species	Hassan B., Mankowski M.E., Kirker G., Ahmed S.	International Biodeterioration and Biodegradation	10.1016/j.ibiod.2017.05.023
Mode of infection of metarhizium spp. Fungus and their potential as biological control agents	Aw K.M.S., Hue S.M.	Journal of Fungi	10.3390/jof3020030
Microbial Control of Structural Insect Pests	Pereira R.M., Oi D.H., Baggio M.V., Koehler P.G.	Microbial Control of Insect and Mite Pests: From Theory to Practice	10.1016/B978-0-12-803527-6.00029-9
Quantifications of phytochemicals and biocide actions of Lawsonia inermis linn. Extracts against wood termites and fungi	AdedejI G.A., Ogunsanwo O.Y., Elufioye T.O.	International Biodeterioration and Biodegradation	10.1016/j.ibiod.2016.10.026
Control of primary reproductives of Microtermes spp. in soil treated with Galleria cadavers infected with Heterorhabditis indica	Mohan S., Upadhyay A., Gupta R.	Nematology	10.1163/15685411-00003019
Entomopathogenic nematodes for the management of subterranean termites	Khan M.A., Ahmad W., Paul B., Paul S., Khan Z., Aggarwal C.	Plant, Soil and Microbes: Volume 1: Implications in Crop Science	10.1007/978-3-319-27455-3_16
Variation in subterranean termite susceptibility to fatal infections by local Metarhizium soil isolates	Denier D., Bulmer M.S.	Insectes Sociaux	10.1007/s00040-015-0394-6
Behaviour and ecological impacts of termites: Fecundity investigations in mounds	Wako S.E.	Ekologia Bratislava	10.1515/eko-2015-0008
Foraging activity of the subterranean sand termite, psammotermes hybostoma (Desneux) and its associated fungus metarhizium anisopliae under natural environmental conditions in El-Fayoum governorate, egypt	Abd El-Latif N.A., Solaiman R.H.A.	Egyptian Journal of Biological Pest Control	www.cabdirect.org/cabdirect/abstract/20153131034
Insecticidal activities of Cunninghamia konishii Hayata against Formosan subterranean termite, Coptotermes formosanus (Isoptera: Rhinotermitidae)	Cheng S.-S., Lin C.-Y., Chen Y.-J., Chung M.-J., Chang S.-T.	Pest Management Science	10.1002/ps.3673

Characterization of biocontrol traits of heterorhabditid entomopathogenic nematode isolates from South Benin targeting the termite pest Macrotermes bellicosus	Zadji L., Baimey H., Afouda L., Moens M., Decraemer W.	BioControl	10.1007/s10526-014-9568-9
Application of bait treated with the entomopathogenic fungus Metarhizium anisopliae (Metsch.) sorokin for the control of microcerotermes diversus Silv.	Cheraghi A., Habibpour B., Mossadegh M.S.	Psyche (London)	10.1155/2013/865102
Horizontal transmission of the entomopathogen fungus metarhizium anisopliae in microcerotermes diversus groups	Cheraghi A., Habibpour B., Mossadegh M.S., Sharififard M.	Insects	10.3390/insects3030709
Antitermitic activity of plant essential oils and their major constituents against termite Odontotermes assamensis Holmgren (Isoptera: Termitidae) of North East India	Pandey A., Chattopadhyay P., Banerjee S., Pakshirajan K., Singh L.	International Biodeterioration and Biodegradation	10.1016/j.ibiod.2012.09.004
When subterranean termites challenge the rules of fungal epizootics	Chouvenc T., Su N.-Y.	PLoS ONE	10.1371/journal.pone.0034484
Effect of lectins from Opuntia ficus indica cladodes and Moringa oleifera seeds on survival of Nasutitermes corniger	Paiva P.M.G., Santana G.M.S., Souza I.F.A.C., Albuquerque L.P., Agra-Neto A.C., Albuquerque A.C., Luz L.A., Napoleão T.H., Coelho L.C.B.B.	International Biodeterioration and Biodegradation	10.1016/j.ibiod.2011.05.008
Subterranean termite prophylactic secretions and external antifungal defenses	Hamilton C., Lay F., Bulmer M.S.	Journal of Insect Physiology	10.1016/j.jinsphys.2011.05.016
Potential of Metarhizium anisopliae and Beauveria bassiana in the control of tea termite Microtermes obesi Holmgren in vitro and under field conditions	Singha D., Singha B., Dutta B.K.	Journal of Pest Science	10.1007/s10340-010-0328-z
Apparent synergy among defense mechanisms in subterranean termites (Rhinotermitidae) against epizootic events: Limits and potential for biological control	Chouvenc T., Su N.-Y.	Journal of Economic Entomology	10.1603/EC09407
A novel strain of Steinernema riobrave (Rhabditida: Steinernematidae) possesses superior virulence to subterranean termites (Isoptera: Rhinotermitidae)	Yu H., Gouge D.H., Shapiro-Ilan D.I.	Journal of Nematology	www.ncbi.nlm.nih.gov/pmc/articles/PMC3380470/
Infectivity of Metarhizium anisopliae (Deuteromycotina: Hyphomycetes) isolates to the arboreal termite Odontotermes sp. (Isoptera: Termitidae)	Balachander M., Remadevi O.K., Sasidharan T.O., Sapna Bai N.	International Journal of Tropical Insect Science	10.1017/S1742758409990294
Evaluation of metarhizium anisopliae var. anisopliae (Deuteromycotina: Hyphomycete) isolates and their effects on subterranean termite coptotermes curvignathus (Isoptera: Rhinotermitidae)	Hoe P.-K., Bong C.-F.J., Jugah K., Rajan A.	American Journal of Agricultural and Biological Science	10.3844/ajabssp.2009.289.297
Biological alternatives for termite control: A review	Verma M., Sharma S., Prasad R.	International Biodeterioration and Biodegradation	10.1016/j.ibiod.2009.05.009
Anti termite activity of Jatropha curcas Linn biochemicals	Singh N., Sushilkumar	Pestology	10.4314/jasem.v12i3.55498
Interaction between the subterranean termite Reticulitermes flavipes (Isoptera: Rhinotermitidae) and the entomopathogenic fungus Metarhizium anisopliae in foraging arenas	Chouvenc T., Su N.Y., Elliott M.L.	Journal of Economic Entomology	10.1603/0022-0493(2008)101[885:IBTSTR]2.0.CO;2
Non-traditional approaches to subterranean termite control in buildings	Nobre T., Nunes L.	Wood Material Science and Engineering	10.1080/17480270801945413
Susceptibility and behavioral responses of the dampwood termite Zootermopsis angusticollis to the entomopathogenic nematode Steinernema carpocapsae	Wilson-Rich N., Stuart R.J., Rosengaus R.B.	Journal of Invertebrate Pathology	10.1016/j.jip.2006.11.004
Resistance of the termite, Coptotermes formosanus Shiraki to Metarhizium anisopliae due to grooming	Yanagawa A., Shimizu S.	BioControl	10.1007/s10526-006-9020-x
Effect of natural products on gut microbes in Formosan subterranean termite, Coptotermes formosanus	Doolittle M., Raina A., Lax A., Boopathy R.	International Biodeterioration and Biodegradation	10.1016/j.ibiod.2006.06.023

Chroniodiplogaster formosiana sp. n. (Rhabditida: Diplogastridae) from Chinese populations of Odontotermes formosanus Shiraki (Isoptera: Termitidae)	Poinar Jr. G., Meikle W., Mercadier G.	Journal of Nematology	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2586454/
Estimating tree resin dose effect on termites	Qian L., Ryu S.	Environmetrics	10.1002/env.761
Evaluation of an entomopathogenic fungus, Paecilomyces fumosoroseus (Wize) Brown and Smith (Deuteromycota: Hyphomycetes) obtained from Formosan subterranean termites (Isop., Rhinotermitidae)	Meikle W.G., Mercadier G., Rosengaus R.B., Kirk A.A., Derouané F., Quimby P.C.	Journal of Applied Entomology	10.1111/j.1439-0418.2005.00976.x
Differential susceptibility of subterranean termite castes to entomopathogenic nematodes	Mankowski M.E., Kaya H.K., Grace J.K., Sipes B.	Biocontrol Science and Technology	10.1080/09583150400016951
Pathogenicity of paecilomyces lilacinus and metarhizium anisopliae on microcerotermes sp. termites (isoptera: Termitidae) [Patogenicidad de paecilomyces lilacinus y metarhizium anisopliae sobre termitas microcerotermes sp. (isoptera: Termitidae)]	Ana Isabél Gutiérrez G., Yamillé Saldarriaqa O., Sandra Uribe S., Zuluaqa A M.P., Fabio Pineda G.	Revista Colombiana de Entomologia	http://www.scielo.org.co/scielo.php?pid=S0120-04882005000100003&script=sci_abstract&tlng=pt
Pathogenicity of Metarhizium anisopliae var. anisopliae and Metarhizium anisopliae var. acridum on Nasustitermes coxipoensis (Holmgren) (Isoptera: Termitidae) [Patogenicidade de Metarhizium anisopliae var. anisopliae e Metarhizium anisopliae var. acridum sobre Nasutitermes coxipoensis (Holmgren) (Isoptera: Termitidae)]	Albuquerque A.C., Pereira K.C.A., Cunha F.M., Veiga A.F.S.L., Athayde A.C.R., Lima E.A.L.A.	Neotropical Entomology	10.1590/S1519-566X2005000400008
A strain of the fungus Metarhizium anisopliae for controlling subterranean termites	Wright M.S., Raina A.K., Lax A.R.	Journal of Economic Entomology	10.1093/jee/98.5.1451
Termite feeding deterrent from Japanese larch wood	Chen K., Ohmura W., Doi S., Aoyama M.	Bioresource Technology	10.1016/j.biortech.2004.02.014
Potential of entomopathogenic fungi as biological control agents against the Formosan subterranean termite	Wright M.S., Osbrink W.L.A., Lax A.R.	ACS Symposium Series	10.1021/bk-2004-0887.ch012
External events related to the infection process of Cornitermes cumulans (Kollar) (Isoptera: Termitidae) by the entomopathogenic fungi Beauveria bassiana and Metarhizium anisopliae [Eventos externos relacionados ao processo de infecção de Cornitermes cumulans (Kollar) (Isoptera:Termitidae) pelos fungos entomopatogênicos Beauveria bassiana e Metarhizium anisopliae]	Neves P.M.O.J., Alves S.B.	Neotropical Entomology	10.1590/S1519-566X2004000100010
Antimicrobial activity of certain essential oils against hindgut symbionts of the drywood termite Kalotermes flavicollis Fabr. and prevalent fungi on termite-infested wood	Alfazairy A.A.M.	Journal of Applied Entomology	10.1111/j.1439-0418.2004.00886.x
Cellulose bait improves the effectiveness of Metarhizium anisopliae as a microbial control of termites (Isoptera: Rhinotermitidae)	Wang C., Powell J.E.	Biological Control	10.1016/j.biocontrol.2004.02.007
United States Department of Agriculture - Agriculture Research Service research on targeted management of the Formosan subterranean termite Coptotermes formosanus Shiraki (Isoptera: Rhinotermitidae)	Lax A.R., Osbrink W.L.A.	Pest Management Science	10.1002/ps.721
Isolation and evaluation of Beauveria bassiana for control of Coptotermes formosanus and Reticulitermes flavipes (Isoptera: Rhinotermitidae)	Wang C., Powell J.E.	Sociobiology	https://entomology.rutgers.edu/personnel/changlu-wang/docs/11-Beauveria-
Transfer of entomopathogenic fungi among formosan subterranean termites and subsequent mortality	Wright M.S., Osbrink W.L.A., Lax A.R.	Journal of Applied Entomology	10.1046/j.1439-0418.2002.00604.x
Susceptibility of Nasutitermes ehrhardti (Isoptera: Termitidae) to Bacillus thuringiensis subspecies	De Castilhos-Fortes R., Matsumura A.T.S., Diehl E., Fiuza L.M.	Brazilian Journal of Microbiology	10.1590/s1517-83822002000300006

Mites and nematodes associated with three subterranean termite species (Isoptera: Rhinotermitidae)	Wang C., Powell J.E., O'Connor B.M.	Florida Entomologist	10.1653/0015-4040(2002)085[0499:MANAWT]2.0.CO;2
Laboratory evaluations of four entomopathogenic nematodes for control of subterranean termites (Isoptera: Rhinotermitidae)	Wang C., Powell J.E., Nguyen K.	Environmental Entomology	10.1603/0046-225X-31.2.381
Increased mortality of Coptotermes formosanus (Isoptera: Rhinotermitidae) exposed to eicosanoid biosynthesis inhibitors and Serratia marcescens (Eubacteriales: Enterobacteriaceae)	Connick W.J. Jr., Osbrink W.L.A., Wright M.S., Williams K.S., Daigle D.J., Boykin D.L., Lax A.R.	Environmental Entomology	10.1603/0046-225x-30.2.449
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