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Connecting the Dots: A Bibliometric Review of Worldwide Studies on Basal Stem Rot in Oil Palm

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ABSTRACT

Basal stem rot (BSR) in oil palm, caused by *Ganoderma boninense*, is a global threat with significant economic implications. This bibliometric review uses advanced methods to analyse global BSR research, mapping trends, and contributors. Data from Scopus until 31st December 2023 were evaluated using multiple bibliometric software tools, including the VOSviewer and biblioMagika®. The study identified 528 documents indicating an upward trend since 1965. Notably, 98.1% (518) of the documents were collaborative efforts, with an average collaboration index of 4.67 authors per article. A country-wise analysis highlights Malaysia as the most prolific contributor, accounting for 72.6% (376) of the published documents. The most active author is Idris A.S. with a total number of 101 publications. Paterson R.R.M.'s (2007) article stands out as the most cited, averaging 135 citations per year. Collectively, these patterns illustrate a mature yet evolving research field, emphasizing the importance of continued international collaboration and strategic research directions to address the ongoing challenges posed by BSR in oil palm.

1. Introduction

The pathogenic fungus *Ganoderma boninense* causes a fatal disease to the oil palm called basal stem rot (BSR). The infection and spread of BSR primarily occur through direct contact with the roots of oil palms. During the initial phases of infection caused by *G. boninense*, the pathogen initially acts as a biotroph but subsequently transforms into necrotrophy. This involves the secretion of enzymes that degrade the host's cell walls and stimulate the host's defence mechanisms [1]. To date, BSR disease has remained a severe challenge to oil palm development especially in Southeast Asia. While existing studies contribute valuable insights, ongoing research is essential to comprehensively

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understand the infection process, particularly concerning the progress from root entrance to foliar symptoms. Some studies may have limitations, highlighting the need for continued exploration in this field. However, with technological advancements, such as omics studies, BSR research has become more effective and efficient. As of now, a multitude of studies have utilized these complex methodologies, thereby substantially boosting the knowledge and control of the disease [2].

In order to thoroughly comprehend the research context and patterns in BSR inquiries, it is imperative to utilize bibliometric analysis. Bibliometric analysis is a scientific computerized review process that can identify key research or authors, and their relationships, by analysing all publications on a specific topic or field [3]. This approach enables the quantitative and qualitative assessment of published literature within this field. Despite extensive research on BSR in oil palm, limited attention has been given to systematically synthesising evidence on the ongoing and long-term impacts of pathogenic fungal infections. Findings linking BSR to progressive oil palm yield decline are dispersed across multiple journals, databases, and research contexts, resulting in the absence of a comprehensive overview. This fragmentation constrains a holistic understanding of BSR progression, its influence on long-term yield performance, and the identification of research gaps. Therefore, a bibliometric approach is essential to quantitatively map existing studies, reveal research trends and knowledge structures, and highlight underexplored areas for future investigation.

Accordingly, this bibliometric analysis aims to illustrate the map of the scientific literature of BSR in oil palm. Specifically, the productivity of BSR research across the year and highlights the publication trajectory such as fluctuations, decline and growth. In addition, this study aims to focus on the most productive author, leading contributing countries, institutions with the highest output and high-producing articles in this filed. Key bibliometric indicators, including citation counts, h-index, and g-index, are employed to evaluate research impact. Keyword co-occurrence analysis using VOSviewer is further applied to reveal dominant research themes and emerging topics. Collectively, these objectives provide a structured overview of BSR research and its relevance to pathogenic fungal infection in oil palm.

1.1 Research Question

1. What are the publication trends in the study of the impact of basal stem rot in oil palm , and how have they changed over time?
2. Who are the most prolific authors in the field, and what are the most influential institutions in this topic?
3. What are the most active countries in this applied study, and how does this vary across different regions and periods?
4. What are the most highly cited documents in the field of and what are the key themes and topics that they highlighted?
5. What are the most common keywords in the literature on this related topic, and how have they evolved over time?

The significance of this study lies in providing data from numerous papers associated with BSR disease by performing bibliometric analysis. For example, the trends, patterns, and gaps in the research landscape of this field. Furthermore, the impact of a high-quality paper throughout the years can be thoroughly studied using bibliometric tools, which significantly demonstrate the paper's achievement. The flexibility of bibliometric analysis enables researchers to easily collect and manage abundant data. The results of this study have practical significance as they can identify key contributor and guide oil palm industry to find opportunities for international collaborations. Overall,

this study generates a heavily studied topic and a study that has been largely overlooked by previous studies.

2. Methodology

2.1 Search Strategy

The data collection instrument employed in this study utilized Scopus, a widely acknowledged and extensive research database encompassing diverse subject areas and keywords. Scopus is renowned as one of the largest repositories of scholarly research, making it an apt choice for capturing the breadth of our chosen topic. The search was conducted on December 31, 2023, spanning a single day. The search parameters were meticulously set to encompass the article title, abstract, and keywords, focusing on the combination of "oil palm" and "*Ganoderma*". Meanwhile keywords such as "basal stem rot" were deliberately excluded, as their limited representation in the literature rendered them unsuitable for meaningful bibliometric analysis. The inclusive criteria covered all dates of publication, languages, subject areas, sources, and document types. However, to ensure the relevance and accuracy of the results, stringent inclusion criteria were applied. Specifically, the search results were refined to obligate the presence of keywords directly related to the specified topic. This meticulous approach was undertaken to prevent any potential misinterpretation of the topic. Overall, the inclusion criteria were aligned with the standardized settings of plants and fungi, ensuring a focused and comprehensive exploration of our research domain.

2.2 Data Collection

The data collection was retrieved from the Scopus database. There were 528 document results shown in the Scopus search. All the documents included various scopes like different journals, authors, keywords, and more coverage. However, the required and orderly data must meet the search criteria given. Each title and abstract were reviewed separately to ensure data dependability for outcomes. Thus, there were ten documents excluded from the results and given 518 documents.

2.3 Data Cleaning and Harmonisation

The data results were exported to the CSV (Comma-separated values) text file format. The format includes all the information of the documents such as affiliation, countries, authors, and more details. They were exported into biblioMagika®[4] in Excel, and the results were generated into an information table like authorship analysis, citation metrics, and other appropriate tables. To filter the results, the process of cleaning data was performed by reading each author's name with ID, affiliations, and countries. They must be standardized to improve the quality of results and into common format data. The author's name must have the same ID and their affiliations. The cleaning data proceeded by removing the duplicates of any countries and affiliations. To ensure the data was non-redundant, the author's name, affiliations, and keywords were harmonized by using the OpenRefine software. Each data was reviewed individually to make sure they had the same meaning to prevent data misinterpretation. Figure 1 shows the overall flow diagram of the search strategy.

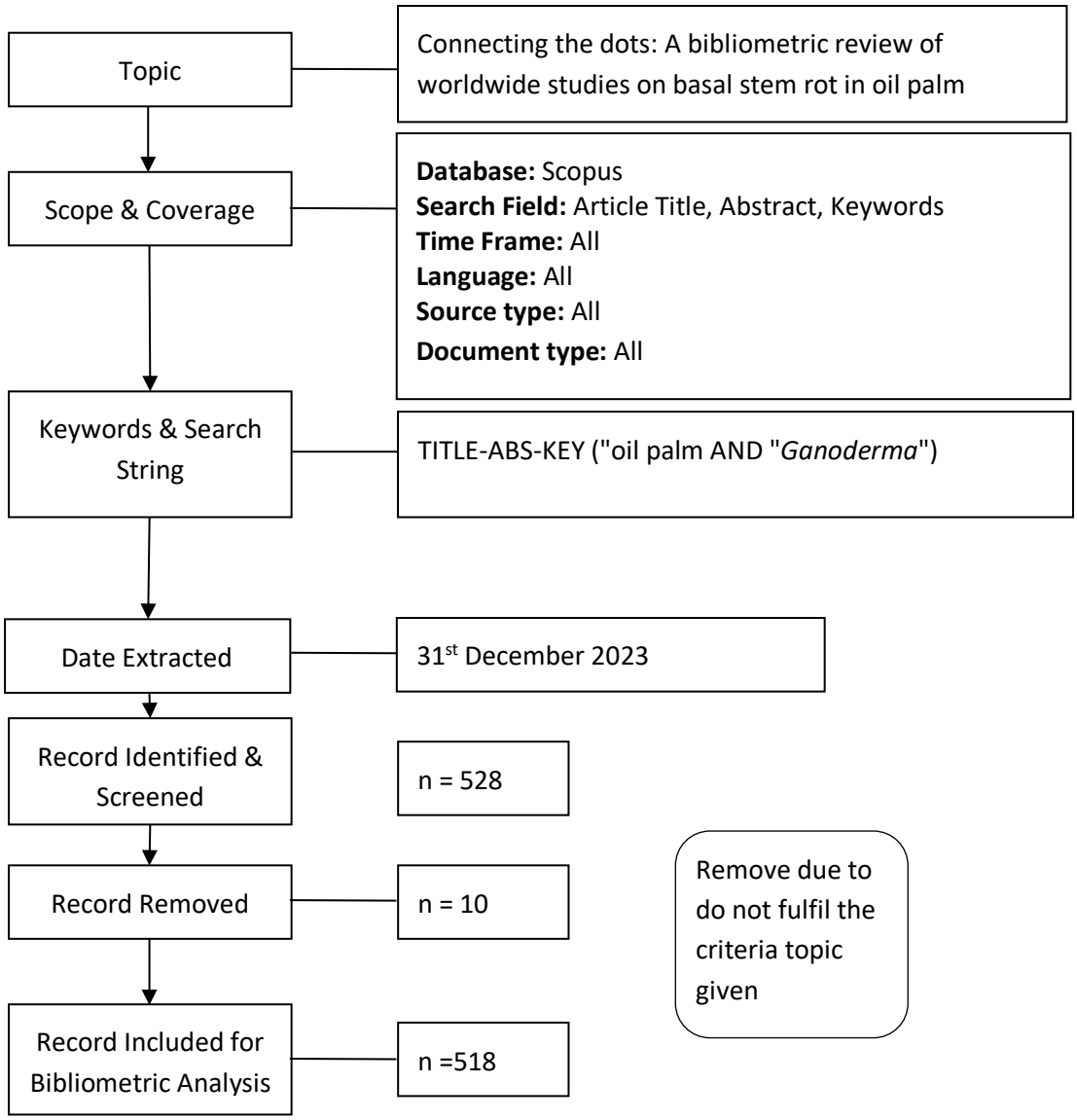

Fig. 1. Flow diagram of the search strategy

2.4 Bibliometric Measures

The bibliometric measures in this topic cover the citation counts, co-authorship, and co-occurrence. Citation counts were determined by collecting the number of times each paper in our dataset was cited by other papers. This basic count gave an idea of a paper's significance in the scientific community. The citation counts can be retrieved and generated from bibliometric software. For instance, the high citation count demonstrates the long-term relevance and significance of the paper. Co-authorship was viewed as the documentation of a cooperation between two or more authors. The co-authorship network is a network that depicts the academic community as well as the structure of our knowledge. Co-occurrence analysis in bibliometrics was used to study the possible association between two bibliographic entries that appear in the same research. They involve the frequencies of keywords used by authors and index keywords. Notably, it will reveal the frequent keywords that can be used to connect various papers, providing valuable insights to researchers. Researchers can acquire significant insights into critical areas of emphasis, emerging trends, and prospective study gaps by detecting notable co-occurring terms.

2.5 Data Analysis

Before analysis, data underwent thorough preprocessing to eliminate outliers and ensure data quality. The data was analysed from different points of view such as tables, graphs, and mapping networks. They were analysed using reliable bibliometric tools such as biblioMagika®[4] and VOSviewer. The study began by doing a thorough literature analysis within our domain of interest to identify significant issues and research themes. This involves doing a thorough search of academic databases and relevant publications to compile an extensive collection of research articles. The data were obtained using the Scopus database resulting in 518 documents. The results were searched within the title, abstract, and keywords. This study used tools for data visualisation such as charts and graphs to explain our findings in an understandable and instructive manner. They were identified using VOSviewer and Biblioshiny. This study can provide an in-depth understanding of the primary issues in our study domain and discover useful insights and patterns within the data via the combination of text mining for thematic analysis with statistical analytics for evaluating hypotheses.

2.6 Tools

Data were analysed and correlated with Microsoft Excel, VOSviewer, OpenRefine, and R, the programming languages that generated Biblioshiny. In Excel (biblioMagika®), the results were sorted and cleaned based on their author's name, ID author, affiliations, and countries. Their results can present all data clearly and they are more practical to store abundance data. OpenRefine was employed to deal with messy data after cleaning in Excel. The messy data includes the author's name, affiliation, author's keywords, and index keywords. Afterwards, VOSviewer was used to visualise the networks between authors, organisations, countries, and keywords.

3. Results and Discussions

3.1 Publication Trends

The publication trends for BSR worldwide are illustrated in Table 1. During our study, we identified 518 publications from the Scopus database, ranging from the years 1965 to 2023. The initial publication on this subject, released in 1965, has the title 'The incidence of *Ganoderma* disease of oil palms in Malaya and its relation to previous crop' authored by P. Turner. This influential publication, which appeared in the Annals of Applied Biology, was novel in its methodology, conducting comprehensive surveys across oil palm plantations to collect data on the prevalence of *Ganoderma* infection [5]. This methodology represented a notable deviation from studies conducted in controlled laboratory settings, offering valuable observations and knowledge on BSR in actual field conditions. Although this study did not utilize experimental techniques, it established the stage for subsequent studies by emphasizing the widespread occurrence and consequences of the condition.

Subsequently, a shift in research emphasis was observed with the increasing adoption of molecular techniques in 1999. The application of these techniques has significantly transformed the research landscape, leading to a change in focus towards various aspects such as molecular diagnostics, pathogen resistance, and enhanced management strategies in the BSR studies. Thus, there was a significant rise in publications as approached the 2000s. The academic community started acknowledging the importance of oil palm diseases, and the paper count surged. It was as though oil palm diseases had appeared in the scientific community conversation, attracting the attention of scientists and scholars. In recognition of the extensive debate and interest in this issue, the total number of citations increased significantly, reaching in 2005. The pattern then changed, with a drastic

fall in 2006, followed by a recovery and a prolonged period of positive growth. Nevertheless, this growing trend stalled in the most recent year, 2020.

The total citation (TC) analysis indicates that publications from the years 2018 (TC=772) and 2005 (TC=541) received notably high citation counts, suggesting their strong influence within the field. These highly cited works likely reflect contributions that became central reference points in subsequent BSR research. The h-index and g-index further illustrate patterns of research impact over time, with prominent influence observed for publications published around 2005, 2007, and 2011.

Higher h-index values (e.g., *h*=12–15) observed during 2016–2019 indicate sustained citation attention across multiple publications, rather than reliance on a small number of highly cited articles. In contrast, higher g-index values, such as those observed in 2018 (*g*=26), suggest the presence of particularly influential studies that accumulated a disproportionately high number of citations compared with other publications.

Table 1
Year of publication

Year	TP	NCP	TC	C/P	C/CP	*h*	*g*
1965	1	1	23	23.00	23.00	1	1
1977	1	1	24	24.00	24.00	1	1
1983	1	1	15	15.00	15.00	1	1
1992	1	1	10	10.00	10.00	1	1
1994	1	1	41	41.00	41.00	1	1
1996	1	1	12	12.00	12.00	1	1
1999	1	1	69	69.00	69.00	1	1
2000	1	1	50	50.00	50.00	1	1
2002	2	2	33	16.50	16.50	2	2
2003	1	1	59	59.00	59.00	1	1
2004	1	1	45	45.00	45.00	1	1
2005	13	13	541	41.62	41.62	12	13
2006	1	0	0	0.00	0.00	0	0
2007	3	3	265	88.33	88.33	3	3
2008	6	6	237	39.50	39.50	6	6
2009	8	8	449	56.13	56.13	8	8
2010	9	9	190	21.11	21.11	6	9
2011	16	16	488	30.50	30.50	12	16
2012	19	19	395	20.79	20.79	12	19
2013	17	17	550	32.35	32.35	14	17
2014	20	20	382	19.10	19.10	12	19
2015	32	31	381	11.91	12.29	12	18
2016	27	25	385	14.26	15.40	12	19
2017	27	26	477	17.67	18.35	14	21
2018	51	46	772	15.14	16.78	15	26
2019	54	49	501	9.28	10.22	13	19
2020	63	56	487	7.73	8.70	13	17
2021	51	44	232	4.55	5.27	8	12
2022	47	35	112	2.38	3.20	6	8
2023	42	11	21	0.50	1.91	2	3
Total	**518**						

Note: TP=total number of publications; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; *h*=h-index; *g*=g-index

3.2 Publication by Countries

Table 2 reveals that Malaysia is the most active country in terms of publication output, contributing 376 articles (TP=376) and a total citation count (TC=5344), indicating its central role in BSR research. This was followed by Indonesia (TP=100) and the United Kingdom (TP=29), indicating broader international involvement in oil palm disease research. Contributions from both producing and non-producing countries reflect the global relevance of BSR as an agricultural and economic concern.

In terms of citation impact, Malaysia exhibited moderate average citations per publication (C/P=14.21) and average citations per cited publication (C/CP=16.05), suggesting that citation influence was distributed across a large volume of publications. Indonesia demonstrated substantial research activity, while contributions from the United Kingdom highlight continued research interest beyond major oil palm-producing regions with comparatively lower average citation values (C/P = 10.67; C/CP = 14.23), while contributions from the United Kingdom showed higher average citation impact (C/P = 26.79; C/CP = 26.79), indicating continued research interest beyond major oil palm–producing regions. Notably, Australia recorded the highest C/P and C/CP values (both 38.83), reflecting strong citation influence at the individual article level despite its lower publication output.

Table 2
The most active countries contributed to the publications

Country	TP	NCP	TC	C/P	C/CP
Malaysia	376	333	5344	14.21	16.05
Indonesia	100	75	1067	10.67	14.23
United Kingdom	29	29	777	26.79	26.79
Portugal	18	17	566	31.44	33.29
Thailand	12	9	80	6.67	8.89
France	10	9	258	25.80	28.67
Papua New Guinea	10	10	266	26.60	26.60
United States	9	7	202	22.44	28.86
Nigeria	9	9	274	30.44	30.44
Japan	8	8	132	16.50	16.50
India	6	5	59	9.83	11.80
Australia	6	6	233	38.83	38.83
Canada	5	4	51	10.20	12.75

Note: TP=total number of publications; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication

3.3 Publication by Institutions

Based on bibliometric analysis, Universiti Putra Malaysia, Malaysian Palm Oil Board, and Universiti Malaysia Sabah were identified as the most productive affiliations in BSR research (Table 3). Universiti Putra Malaysia recorded the highest total publications (TP = 201), reflecting its strong research focus in agriculture and plantation-related studies. This aligns with its role as a major contributor to oil palm research. Meanwhile, the Malaysian Palm Oil Board recorded 128 publications, consistent with its role in supporting the oil palm industry through research and development. Universiti Malaysia Sabah ranked next (TP=58), and it is noteworthy that the majority of the highly productive affiliations were based in Malaysia, as shown in Table 3. These local institutions contributed significantly to the area of study, and their valuable findings received considerable attention from the international scientific community.

Collectively, these bibliometric indicators provide insights into institutional research patterns and impact within the BSR research landscape. Such findings are valuable for researchers seeking to identify influential affiliations, collaborative opportunities, and methodological references for future studies.

Table 3
Most productive institutions with a minimum of five publications

Affiliation	Country	TP	NCP	TC	C/P	C/CP
Universiti Putra Malaysia	Malaysia	201	185	3734	18.58	20.18
Malaysian Palm Oil Board	Malaysia	128	113	1954	15.27	17.29
Universiti Malaysia Sabah	Malaysia	58	51	474	8.17	9.29
Universiti Kebangsaan Malaysia	Malaysia	26	23	213	8.19	9.26
Universitas Sumatera Utara	Indonesia	25	15	60	2.40	4.00
Universiti Malaya	Malaysia	24	20	296	12.33	14.80
Advanced Agriecological Research Sdn Bhd	Malaysia	18	15	153	8.50	10.20
University of Minho	Portugal	18	17	566	31.44	33.29
Institut Pertanian Bogor	Indonesia	16	15	61	3.81	4.07
Sime Darby Sdn. Bhd.	Malaysia	14	14	350	25.00	25.00
University Nottingham Malaysia Campus	Malaysia	14	14	213	15.21	15.21
University of Nottingham	United Kingdom	13	13	235	18.08	18.08
Indonesian Oil Palm Res. Institute	Indonesia	13	12	387	29.77	32.25
FGV R&D Sdn. Bhd.	Malaysia	12	10	108	9.00	10.80
Universiti Sains Malaysia	Malaysia	12	11	154	12.83	14.00

Note: TP=total number of publications; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication

3.4 Publication by Highly Cited Documents

Table 4 lists highly cited documents that have received substantial citation attention within the academic literature. Paterson *et al.,* [6] (2007) represent one of the most highly cited publications in basal stem rot (BSR) research, having accumulated 135 citations. The sustained citation performance of this study indicates its enduring influence within the field, particularly in advancing the understanding of biological mechanisms associated with BSR in oil palm. The affiliation of this publication with Indonesian institutions reflects notable contributions from this country to highly impactful research outputs in oil palm disease studies. Similarly, the work by Hushiarian *et al.,* [7], titled *Detection and control of Ganoderma boninense*: *Strategies and perspectives*, has received substantial citation attention, with a total of 129 citations. This study primarily focused on detection and disease mapping approaches for BSR, providing a comprehensive overview of methodologies employed for early identification and management of infected oil palm trees. In line with Susanto *et al.,* [8], their study investigated biological approaches for identifying the presence of basal stem rot. Given the favourable outcomes, this publication has received a relatively large number of citations (116).

As well, the remaining publications have received many citations, showing the long-term usefulness of their research efforts. The citation count, which represents the number of times an article has been cited by other scholarly publications, demonstrates the importance and influence of these studies. The number of citations indicates that these works have received constant attention

throughout time. Furthermore, measuring a paper's influence based on citation counts gives useful insights into its scholarly relevance. This method also enables a visual representation of citation-based linkages between publications. As a result, both the authors and their publications have more substantial credibility and recognition among academics. For instance, the Scopus database systematically tracks and indexes citations to scholarly literature.

Table 4
Top 20 highly cited documents

No.	Authors	Title	Journal	Total Citation
1	[6]	*Ganoderma* disease of oil palm-A white rot perspective necessary for integrated control	Crop Protection	135
2	[7]	Detection and control of *Ganoderma boninense*: Strategies and perspectives	SpringerPlus	129
3	[8]	Enhancing biological control of basal stem rot disease (*Ganoderma boninense*) in oil palm plantations	Mycopathologia	116
4	[9]	Basal stem rot of oil palm (*Elaeis guineensis*); Mode of root infection and lower stem invasion by *Ganoderma boninense*	Plant Pathology	108
5	[10]	Hyperspectral imagery for mapping disease infection in oil palm plantation using vegetation indices and red edge techniques	American Journal of Applied Sciences	107
6	[11]	Intelligent electronic nose system for basal stem rot disease detection	Computers and Electronics in Agriculture	93
7	[12]	Mapping and identifying basal stem rot disease in oil palms in North Sumatra with QuickBird imagery	Precision Agriculture	90
8	[13]	Stem rots of oil palm caused by *Ganoderma boninense*: Pathogen biology and epidemiology	Mycopathologia	89
9	[14]	Early detection of basal stem rot disease (*Ganoderma*) in oil palms based on hyperspectral reflectance data using pattern recognition algorithms	International Journal of Remote Sensing	81
10	[15]	Effect of endophytic bacteria on growth and suppression of *Ganoderm*a infection in oil palm	International Journal of Agriculture and Biology	81
11	[16]	Early detection of *Ganoderma* basal stem rot of oil palms using artificial neural network spectral analysis	Plant Disease	76
12	[17]	Effects of inoculum potential, shading and soil temperature on root infection of oil palm seedlings by the basal stem rot pathogen *Ganoderma boninense*	Plant Pathology	76
13	[18]	Evaluation of oil-palm fungal disease infestation with canopy hyperspectral reflectance data	Sensors	73
14	[19]	*Ganoderma boninense* basidiospores in oil palm plantations: Evaluation of their possible role in stem rots of *Elaeis guineensis*	73	
15	[20]	Climate change affecting oil palm agronomy, and oil palm cultivation increasing climate change, require amelioration	Ecology and Evolution	70

16	[21]	Genetic diversity of *Ganoderma* in oil palm plantings	Plant Pathology	69
17	[22]	Possible sources of genetic resistance in oil palm (*Elaeis guineensis* Jacq.) to basal stem rot caused by *Ganoderma boninense* - Prospects for future breeding	Mycopathologia	68
18	[23]	De novo transcriptome analyses of host-fungal interactions in oil palm (*Elaeis guineensis* Jacq.)	BMC Genomics	67
19	[24]	How will climate change affect oil palm fungal diseases?	Crop Protection	67
20	[25]	Spectral discrimination of healthy and *Ganoderma*-infected oil palms from hyperspectral data	International Journal of Remote Sensing	64

3.5 Publication by Authors

In the field of BSR research worldwide, it is essential to recognize the significant contributions of prolific authors in shaping the scientific landscape. Table 5 summarises the author with the highest publication output in this respective field. Among the authors analysed, Idris A.S. emerged as the most prolific contributor, with a total of 101 publications (TP=101) related to BSR. Affiliated with the Malaysian Palm Oil Board (MPOB), his publication output reflects sustained research activity in BSR and oil palm–related studies. The presence of multiple highly cited publications further indicates the scholarly influence of his work within the BSR research landscape. Another prominent contributor in the BSR research domain is Chong-K.P. (Universiti Malaysia Sabah), who contributed 40 publications (TP=40) related to BSR. His research output contributes to the understanding of BSR through studies incorporating analytical and biotechnological approaches. Collectively, these findings highlight the role of highly productive authors in advancing BSR research and shaping key research themes within the field.

Thus, C/P and C/CP metrices confirm that each cited article authored by scholars affiliated with UPM contributes a notable impact. Paterson from the University of Minho in Portugal stands out distinctly from the largely Asian contributing authors (e.g., Malaysia and Indonesia). Although Paterson's total publication (TP=18) is comparatively lower than contributors, these articles have achieved exceptionally high citation counts (TC=566). The C/P and C/CP values of author Paterson also reached remarkably high which reflected that almost all of the articles were cited or acknowledged by numerous researchers.

At the author level, different citation metrics highlight distinct patterns of research influence. Meon S. from Universiti Putra Malaysia (UPM) recorded the highest citations per publication (C/P=35.75), indicating strong average citation impact across his published works. In contrast, Sundram S. from MPOB achieved the highest citations per cited publication (C/CP=45.00), reflecting a high level of citation concentration among his cited articles. These differences illustrate how citation influence may be distributed differently across authors, where high C/P values suggest consistently cited publications, while high C/CP values indicate strong impact concentrated within a subset of influential studies.

At the collective level, authors affiliated with Universiti Putra Malaysia (UPM) recorded the highest overall publication output, with a combined total of 129 publications (TP) contributed by multiple affiliated authors, accumulating the highest total citation count (TC = 2165). Overall, this bibliometric analysis highlights the contribution of prolific authors to the development and influence of BSR research in oil palm. Their publication and citation patterns reflect key knowledge sources that continue to shape research directions within this field.

Table 5
Most productive authors

Author's Name	Affiliation	Country	TP	NCP	TC	C/P	C/CP
Idris, A. S.	Malaysian Palm Oil Board	Malaysia	101	91	1445	14.31	15.88
Chong, K. P.	Universiti Malaysia Sabah	Malaysia	40	36	345	8.63	9.58
Bejo, S. K.	Universiti Putra Malaysia	Malaysia	27	24	293	10.85	12.21
Ho, C. -L.	Universiti Putra Malaysia	Malaysia	25	23	398	15.92	17.30
Wong, M. Y.	Universiti Putra Malaysia	Malaysia	22	21	220	10.00	10.48
Paterson, R. R. M.	University of Minho	Portugal	18	17	566	31.44	33.29
Siddique, Y.	Universiti Putra Malaysia	Malaysia	16	15	235	14.69	15.67
Goh, Y. K.	Advanced Agriecological Research Sdn Bhd	Malaysia	16	13	136	8.50	10.46
Basyuni, M.	Universitas Sumatera Utara	Indonesia	15	9	34	2.27	3.78
Sundram, S.	Malaysian Palm Oil Board	Malaysia	15	9	405	27.00	45.00
Yusof, N. A.	Universiti Putra Malaysia	Malaysia	14	13	351	25.07	27.00
Hussein, M. Z.	Universiti Putra Malaysia	Malaysia	13	12	239	18.38	19.92
Goh, K. J.	Advanced Agriecological Research Sdn Bhd	Malaysia	13	11	118	9.08	10.73
Meon, S.	Universiti Putra Malaysia	Malaysia	12	12	429	35.75	35.75
Hayati, R.	Universitas Sumatera Utara	Indonesia	12	6	21	1.75	3.50

Note: TP=total number of publications; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication

3.6 Co-authorship Analysis

Co-authorship analysis is the evaluation of networks that show relationships among authors who have collaborated on papers, allowing us to identify evolving trends and patterns in their collaborations. This section also includes a measurement of the amount of collaboration between authors and organisations. To conduct this research, VOSviewer, a program is used to graphically display these networks. Various components such as nodes, colours, line thickness, and clusters are shown in this illustration to offer a thorough perspective of the connections and linkages within these networks.

3.6.1 Co-authorship by author

Figure 2 depicts the co-authorship relationships among various writers within mapping networks. We initially chose 1069 authors to study their collaborative networks, but only 98 met the threshold. The map shows that authors Idris A., Bejo S.K., and Chong K. have been the most active contributors to publications on BSR in global studies. They appear prominently with the biggest clusters and the most vibrantly coloured nodes, indicating their considerable joint efforts. This paper has highlighted the well-known author which is Idris Abu Seman from Malaysia specifically from the oil palm industry (Malaysian Palm Oil Board). He frequently participates in discussions and contributes publications that are indexed by Scopus. Notably, all of these highly engaged authors are from Malaysia and have collaborated closely. The authors with similar colours highlight their interconnectivity in their study and written activities.

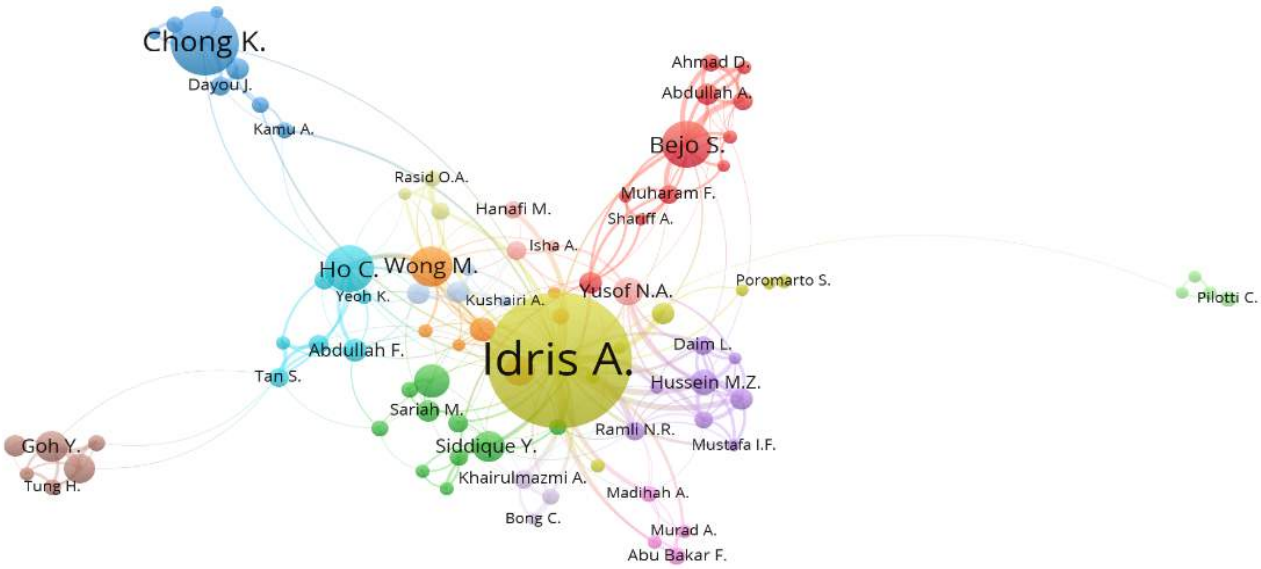

Fig. 2. Network visualisation map of the co-authorship by authors

3.6.2 Co-authorship by organisations

Co-authorship organisations are research relationships between institutes to assist academics in publishing their significant writings. Multiple organisations were engaged in the 518 publications published in Scopus databases. Figure 3 shows that the largest clusters of organisations are Universiti Putra Malaysia and Universitas Sumatera Utara. Although the biggest node, which represents Universiti Putra Malaysia, is easily identifiable due to its significant number of citations, other important contributors such as the Malaysian Palm Oil Board are also included in the mapping although not immediately apparent. This occurs as a result of the constraints of the visualisation tool, which gives preference to showcasing nodes with the most citations, possibly overshadowing other significant contributors. It is crucial to acknowledge that the Malaysian Palm Oil Board holds significant influence in this study field, despite the lack of apparent labels, as demonstrated by its ranking as the second-largest node. This significance is due to their high degree of engagement with publishing scientific articles on the subject. The strong network linkages between organisations emphasize their leadership responsibilities even more, demonstrating that they are the primary affiliations for the authors completing research on this subject matter.

Fig. 3. Network visualisation map of the co-authorship by organisations

3.6.3 Co-authorship by countries

Co-authorship by countries illustrates how they collaborate in publishing scientific publications. Malaysia, as previously stated, leads in the number of published articles, followed by Indonesia, and the United Kingdom. 13 countries were linked through collaboration with Malaysia playing a key role in reflecting a flourishing publishing network. The illustration in Figure 4 demonstrates how collaborations link scholars from different countries. They collaborate on studies and co-author publications, driving worldwide scientific collaboration. Malaysia, in particular, is a key component in this collaborative network, demonstrating its leadership and active engagement in productive collaborations that result in accepted publications.

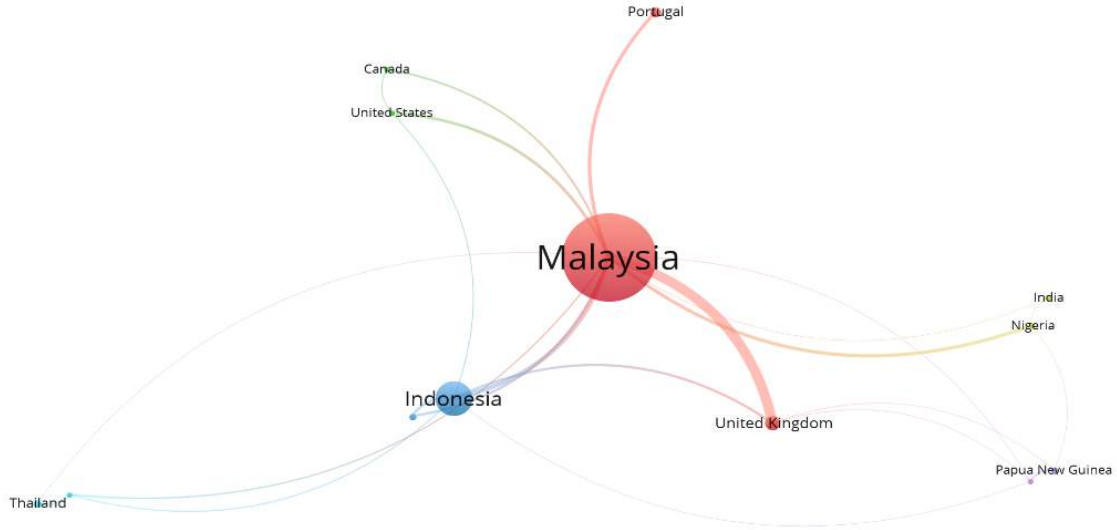

Fig. 4. Network visualization map of the co-authorship by countries

3.6.4 Co-occurrence analysis of author's keywords

Following the co-authorship analysis, we evaluated the co-occurrence of terms. The co-occurrence of keywords reflects how frequently they appear together in research publications. This research included author and index keywords as well as all of the keywords. These keywords were represented as nodes with connections between nodes reflecting their co-occurrence in research publications. Keywords that appeared often together were strongly correlated, generating clusters of related keywords.

Figure 5 shows the co-occurrence of keywords of the author keywords that are related to the topic. The keywords that are frequently used in papers are '*Ganoderma boninense'*, and 'basal stem rot'. *Ganoderma boninense*, the fungus that causes basal stem rot disease, restricts oil palm growth and development, leading to stunted growth. Thus, the term "*Ganoderma boninense*" adequately describes the prevalence of oil palm basal stem rot disease. Meanwhile, the keyword 'Basal Stem Rot' elucidates the reason for oil palm development. Thus, the publications that included these keywords performed procedures and investigated oil palm diseases to prevent their emergence and create novel approaches to lessen their impact.

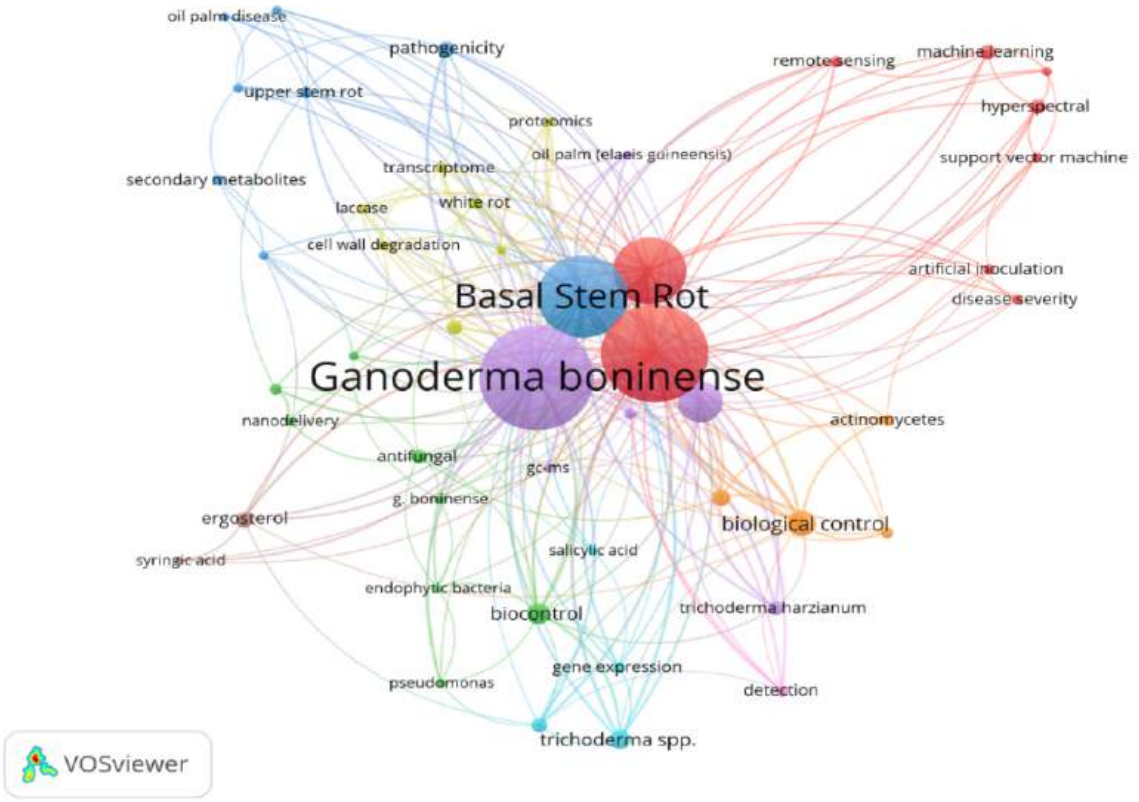

Fig. 5. Network visualisation of the author's keywords

4. Conclusions

This bibliometric analysis provides a comprehensive overview of the evolution and research trends of BSR in oil palm over time. This pattern analysis revealed analysis in the oil palm study has shown continuous growth over recent years and gained a lot of attention from countries worldwide mainly shaped countries with major agricultural outputs such as Malaysia and Indonesia. Consequently, the bibliometrics data showed that the most contributing authors and institutions were from Southeast Asia, reflecting the region's central role in advancing BSR research. The prominence of Malaysia and Indonesia highlights their influence in shaping the scientific landscape of BSR studies, particularly in relation to disease detection, mitigation, and management strategies. In addition, keyword co-occurrence analysis revealed prevailing research priorities and thematic focus areas, while also indicating gaps that extend beyond agronomic and technological perspectives. Addressing these gaps may support a more integrated understanding of oil palm development and disease dynamics. Overall, these findings are beneficial to researchers, oil palm industry stakeholders and policymakers. The researchers would be able to find and locate the most promising author and mentor to collaborate and address the complex research questions. For research and development in oil palm industry sector, the researchers can identify the innovation hotspot and advanced practices like disease management. From a policy perspective, the results highlight opportunities to strengthen regional and international research collaboration, particularly within Southeast Asia. Collectively, this study offers a structured knowledge base that can inform future research directions and support sustainable development efforts in the oil palm industry.

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