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Research Evolution on Medicinal Plant from Myrtaceae Family (*Callistemon genus*): Five Decades of Research (a Bibliometric Review)

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Abstract: This study carried out a bibliometric analysis centered on Callistemon research, spanning five decades, disclosing their trend and limitations. Published works related to Callistemon between 1966 and 2020 were retrieved from Web of Science (WoS) and SCOPUS databases using the search term Callistemon. A total of 239 documents comprising 237 research and two review articles were obtained from the hybrid databases. The 239 articles were authored by 680 researchers across the globe with an article/author and author/article ratio of 0.351 and 2.85, respectively. An average citation number of 9.657 was recorded per document; the most recurrent keywords obtained in this analysis were Myrtaceae, *Callistemon citrinus*, *Callistemon lanceolatus*, 1, 8-cineole, essential oil, essential oil composition, antibacterial, and antioxidants. This analysis offered a comprehensive and general overview of the Callistemon genus from 1966 to 2020 with an insight into the frequency of citations for most cited publications in addition to the trend of articles, journals, countries, top researchers, and the quality of works steering from research on Callistemon genus. This bibliometric study will help researchers in this field of interest understand Callistemon's growth trajectory, identify the scientific areas of evidence, and find exceptional analysis centers for scientific interchange and collaboration.

Keywords: *Callistemon* genus; bibliometric analysis; review; web of science; SCOPUS; Myrtaceae; *Callistemon citrinus*; *Callistemon lanceolatus*)

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1. Introduction

Plants are indispensable because they play a vital role in the continued existence of life on planet Earth due to their activities in supplying oxygen to different organisms and humans.

They also provide non-nutritional components better-called plant secondary metabolites, which do not participate in cell metabolism and are formed from different precursors like amino acids or through various enzymatic reactions. The building blocks of many pharmaceutical medications are derived from these plant secondary metabolites, which are essential for maintaining human health. Small molecules have a variety of chemical and biological functions. The most widely used medication made from plant secondary metabolites is morphine, quinine, aspirin, artemisinin, dititoxin, etc. [1]. Inquiry into bioactive compounds acquired from plants as a basis of alternative medicine to synthetic drugs has received much cognizance and attention [2]. Aromatic plants have been utilized since ancient times for their preservative and curative properties and to impart aroma and flavor to food and beverages or to reinstate back to health both body and mind [3, 4]. Herbal medicines derived from plant sources serve as a substitute for health treatment among several people, particularly in developing countries [5, 6]. The therapeutic properties of aromatic plants are partly ascribed to their secondary metabolites. The functions of these secondary metabolites in plants are as follows: for chemical signals enabling plants to manage or control their environment (ecological role); to attract pollinating insects and repel predators, inhibition of seed germination, or communication between plants by emitting chemical substances as an indicator of the presence of herbivores [7].

Callistemon obtained its name from a Scottish botanist named Robert Brown (1773–1858), who contributed significantly to the study of Botany by utilizing a microscope. Callistemon genus is classified among the Myrtaceae family and is made up of about thirty-four species; it is an aromatic plant with a very strong fragrance. The word Callistemon is from two Greek words (Kallistos meaning most beautiful, and stema meaning a stamen) [8]. This evergreen shrub possesses lanceolate and aromatic leaves and is widespread in Australia, although a couple of them have been introduced to other countries and continents like the USA and Africa. The plant is known as a bottle brush due to its traditional brush that looks like a conventional bottle brush [9, 10]. Naturally, Callistemon is commonly found either along a watercourse or at the edge of a swamp. This plant enjoys moist conditions and grows very well in gardens when watered regularly, although some of its species do not tolerate drought. It can be planted either by cutting or from its seeds, and the flowering time of the plant is usually in spring or early summer (October-December). Other circumstances may make this plant bring out flowers at other times of the year. They are grown as decorative plants in gardens, houses, streets, or offices because of their red attractively colored flowers. The leaf of this plant releases a refreshing fragrance when crushed with hands [11, 12]. Callistemon genus has about 140 genera with approximately 3800 species and has been employed as an anti-pertussis and anti-bronchitis in traditional rural settings. The antiparasitic, antithrombotic, antimicrobial properties and antioxidant activities of the volatile oils of the genus Callistemon have been widely documented [13-16]. The aerial parts of this plant have been used in frequent remedies for the management of diarrhea, dysentery, and rheumatism. [15], while the nanoparticles obtained from the leaves of this plant had been documented to be effective against parasites, bacteria, trypanosomes, malaria parasites, and benign prostatic hyperplasia (BPH) [17-19]. Traditional healers in India use the plant to treat respiratory ailments such as cough and bronchitis and are also employed as insecticides, while its essential oil is used as an antimicrobial herbal drug [19, 20-21]. About 500 mL of the fresh leaves decoction of *Callistemon citrinus* is drunk by adults in Uganda to treat cough [21]. It is commonly used in conventional Chinese medicine pills for taking care of hemorrhoids in China [22]. Callistemon

is used in farmlands to control weeds and as a biomarker for ecological management [23, 24]. It is also used for tool handles and as fuel [25].

The literature on Callistemon is very strewn and versatile, spanning different geographic areas of the world. Also, this plant's scientific, commercial, and popular demands give room for a thorough awareness of the publication patterns of its literature. A bibliographic analysis is therefore needed to analyze the developments in the therapeutic studies of Callistemon. This is a common research tool used to quantify the scientific productivity of a particular subject area using indices such as productive journals, most prolific authors, commonly used keywords, most cited publications, and article collaboration networks. In this review, we used studies indexed in the Web of Science and Scopus databases to project research trends of Callistemon. These hybrid databases were selected due to their easy accessibility and availability of a wide range of multifaceted literature.

Moreover, they provide an extensive collection of excellent and high-impact scientific publications. Therefore, this paper aims to offer a comprehensive and general overview of the Callistemon genus from 1966 to 2020 using bibliometric indices such as frequency of citations, most cited publications, most productive journals, most prolific countries, top researchers, and most used keywords. This article will aid researchers in this field of interest to discover the research needs, identify the scientific areas of evidence of Callistemon studies, and find exceptional centers of analysis for scientific communications and collaboration.

2. Materials and Method

The literature on Callistemon is versatile and thus dispersed across an array of sources. To study the research productivity of this genus, published peer-reviewed articles on Callistemon were obtained via a query in the Web of Science (WoS) and Scopus databases depicted by a method described by Olisah *et al*. (2022) [26]. In summary, "*Callistemon*" was used as the search term in the title module to retrieve documents indexed in the WoS database (articles and reviews) from 1 January 1966 to 28 June 2020. This gave a total of 141 articles consisting of 139 research articles and two reviews. For Scopus, the same search term was used to mine articles from 1 January 1966 to 28 June 2020, and it yielded a total of 205 documents (articles, 204) (Figure 1). The title search for both databases was used because it improves retrieval and specificity with a negligible loss of sensitivity [27-29]. Documents such as meetings, abstracts, books, conference papers, news items, corrections, letters, editorial materials, notes, and retractions were excluded from the search engine in both databases. All documents were downloaded in BibTex file format and uploaded into R Studio (v.3.4.1) for further analysis. Codes were used to merge duplicate documents, and after this, a total of 239 documents were used for analysis. Commands for the annual figure of publications, countries' productivity, journal sources, teamwork networks, and other citation metrics were retrieved from http://www.bibliometrix.org and Aria and Cuccurullo (2017) [30]. Bibliometric networks and bibliographic combinations such as author, author keyword, citation, co-citation, teamwork, country, co-word analysis, keyword plus networks, and keyword co-occurrences were captured with bibliometrix R-package. Journal and keyword co-occurrence networks were also visualized using VosViewer (version 1.6.15 -© 2009 – 2020). Journal impact factor (IF) was retrieved from the 2020 Journal Citation Report. (https://jcr.incites.thomsonreuters.com).

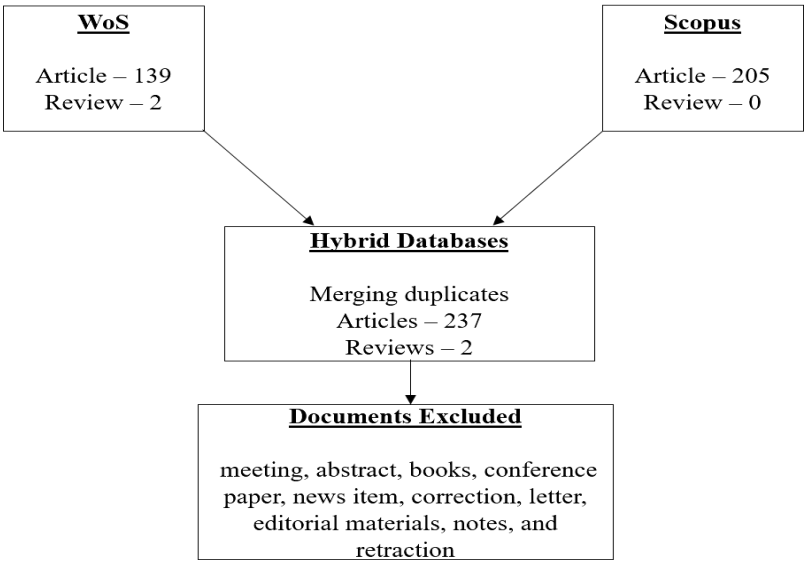


Figure 1. Bibliographic documents retrieval criteria.

3. Results and Discussion

3.1. Global evolution of Callistemon literature.

With the objective of determining the periodic growth of literature on *Callistemon* genus, an array of the study was conducted, which shows in entirety that a total of 239 publications with 237 articles and 2 reviews were published on this genus. These were recovered from the WoS and Scopus databases during the period under survey. Documents retrieved include the following: Myrtaceae, *Callistemon lanceolatus*, *Callistemon viminalis*, *Callistemon citrinus*, antibacterial activity, essential oils, chemical composition, antioxidant, cytotoxicity, green synthesis, nanoparticles, GC-MS, and thin-layer chromatography. The timeline was delineated into a period of six years each (Figure 2). Between the years 1966 - 1972, only four articles were published on the genus *Callistemon*; in 1975 (n = 4), there was an upsurge in articles published compared to the other publications years (one each). There was, however, a downward trend with just one published article from 1977-1988, except for the four articles recorded again in 1982 (Figure 2). The production of articles improved immensely within the range of 2 - 9 articles between 2004 - 2009; although this trend was erratic, 2010 and 2012 witnessed a steady increase in publications on *Callistemon* genus from 11 to 13, respectively. The year 2016-2017 were the most productive years recording 23 and 25 publications each, respectively, and nose-dived again in 2018 to 11 articles. Published articles in 2016 alone (23) were equal to the whole publication from 1966-1993. Eleven authors were involved in single-authored documents, while the remaining 669 authors engaged in collaborative work, as seen in Table 1. It is important to examine the partnership index in addition to the frequency of single-authors and multiple-authored articles. These data will facilitate helpful information on the scope and consequences of research work done on *Callistemon*, the number of authorship per article, which signify the international collaboration index was 2.93, which was consistent with a similar study conducted on polybrominated biphenyl ethers [31] thus connoting a high trend of co-authorship [32]. An average citation number of 9.657 was recorded per document in this study. Scientific output associated with *Callistemon* study by Lotka's law [33] showed a beta coefficient and goodness of fit of 2.69 and 0.95 correspondingly, with Kolmogorov-Smirnoff p-value of 0.07 ($p < 0.05$) (Figure 3).

The yearly percentage growth rate of articles stood at 4.71%. Other significant bibliometric indices investigated include the sum total of publishers engaged in printing articles associated with *Callistemon* interrelated research, as revealed in (Figure 4).

3.2. Journals dominance.

Elsevier ranked first with 25% of publications among the top 20 most relevant sources and a cumulative article number of 18. Fitoterapia recorded the highest number of published articles of 6, with 8% of the total 25% of the cumulative percentage recorded for Elsevier. Besides, Taylor and Francis occupy the second category of the top 20 most relevant sources, with the Journal of Essential Oil Research and Journal of Essential Oil-Bearing Plant having 10 and 5 articles amounting to 14 and 7%, respectively. Despite the dominance of Elsevier journals on Callistemon research, the Journal of Essential Oil Research still had the highest number of articles (n = 10), consequently depicting that authors prefer journals affiliated with Taylor and Francis compared to Elsevier as regard research on *Callistemon* genus. Springer ranked 3rd position with 10% among the top 20 most relevant sources, with BMC (n =3), Apidologieand Antonie Van Leeuwenhoek International Journal of General and Molecular Microbiology (n = 2, each) dominating this publisher (Figure 4 & 10).

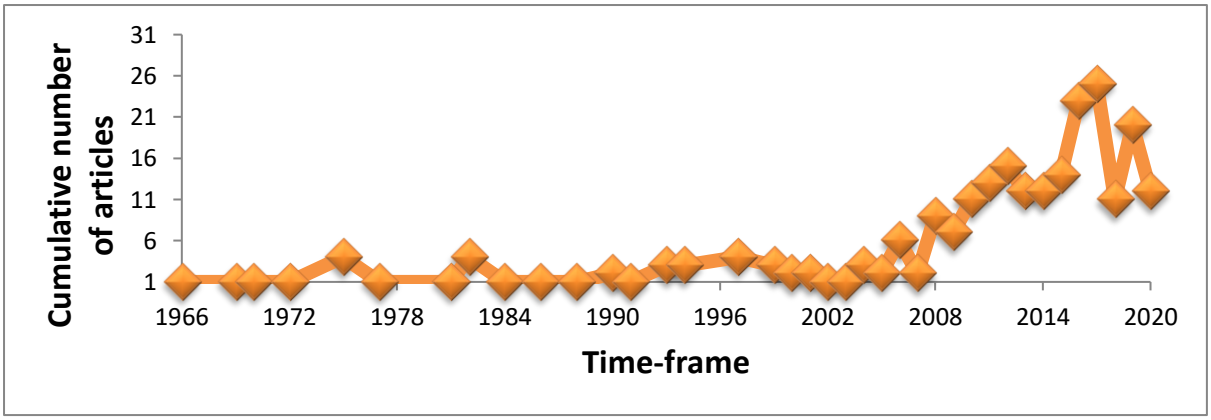


Figure 2. The international trend of *Callistemon* research (1966-2020).

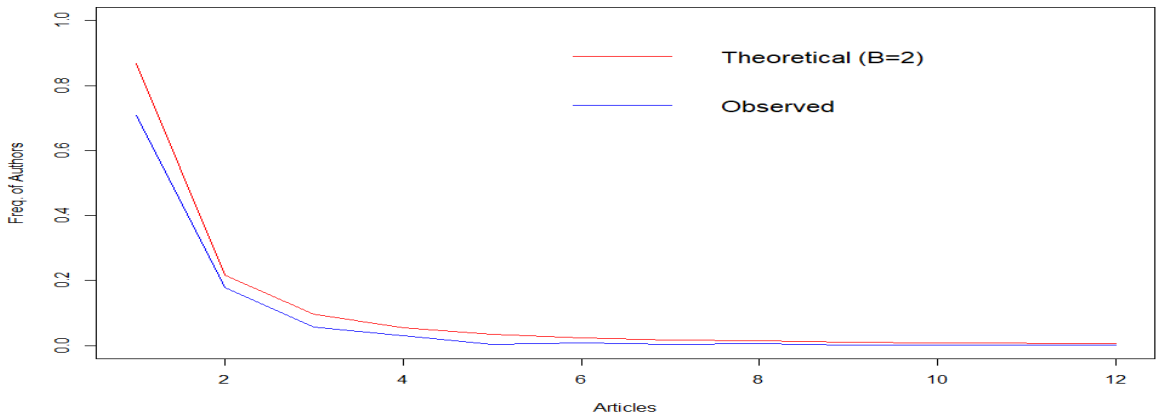


Figure 3. Scientific output based on *Callistemon* research as revealed by Lokta distribution.

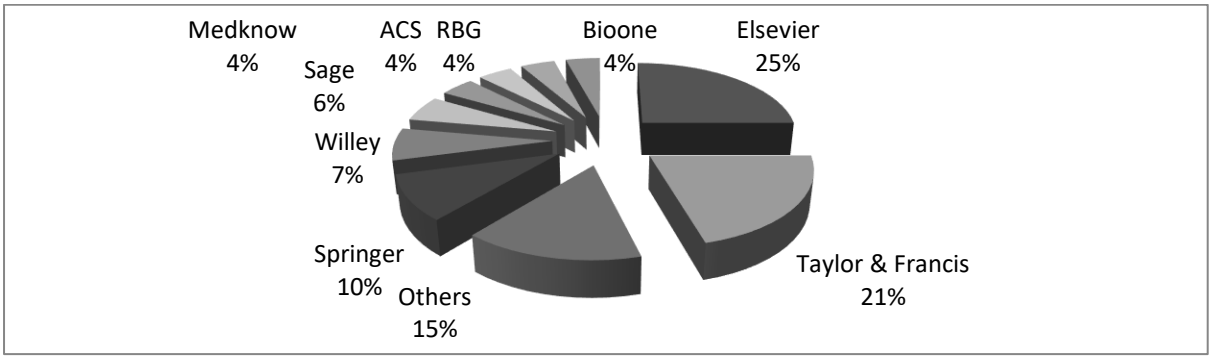


Figure 4. Percentage of distribution of the top twenty publishers on *Callistemon*-related research (1966-2020).

Table 1. Brief data on the comprehensive analysis of the *Callistemon* genus recovered from published journals in WoS.

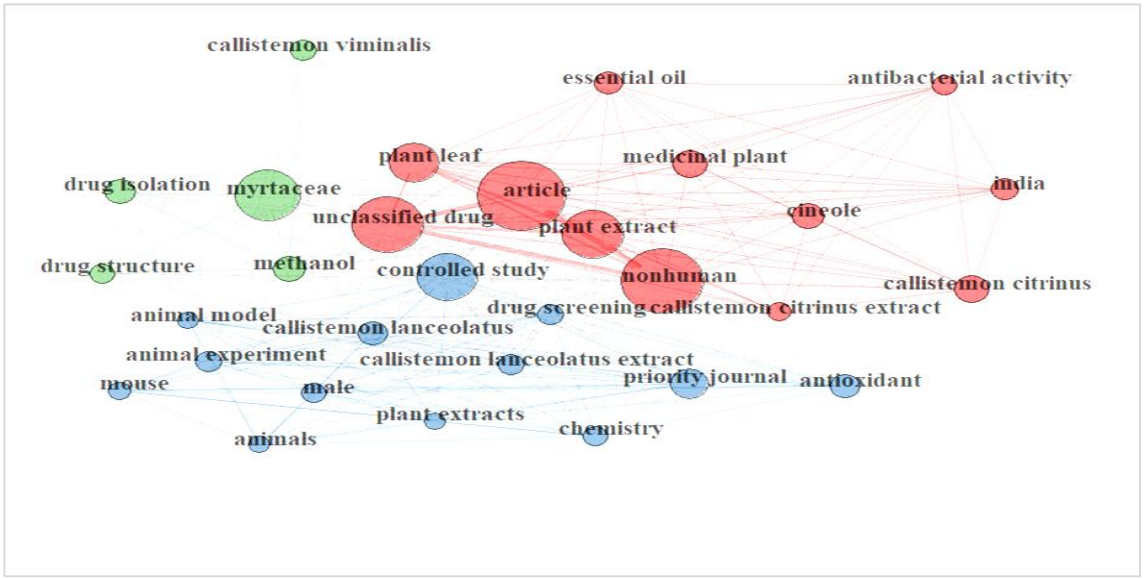
Depiction	Rates
Documents	239
Journal source	163
Keywords plus (ID),K_p	1238
Author's Keywords (DE), A_k	556
Period	1966-2020
Average citations per documents, $A_{c/d}$	9.657
Authors, A_u	680
Authors appearance,A_a	1053
Authors of single-authored documents,A_{sad}	11
Authors of multi-authored documents, A_{mad}	669
Single-authored documents, S_{ad}	11
Documents per Author, $D_{/a}$	0.351
Authors per Document, $A_{/d}$	2.58
Co-Authors per Documents, $C_{a/d}$	4.41
Collaboration Index, C_i	2.93

3.3. Keywords employed in Callistemon research.

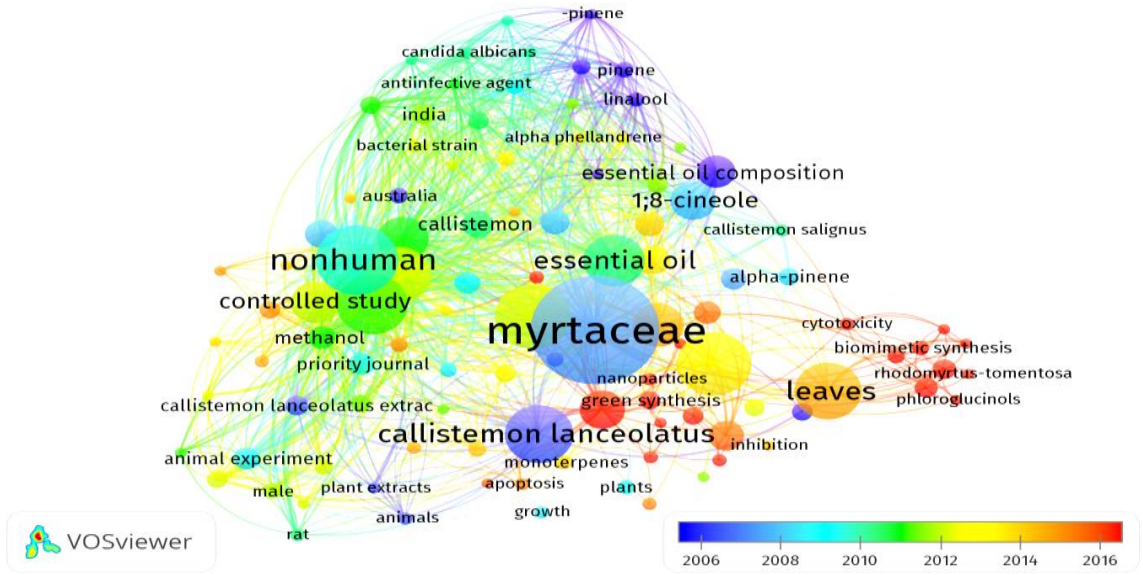
Keywords are often used in publications to spot the research domain the articles belong to and consequently reveal the idea articulated by the author. Before a draft manuscript can be submitted for publication, journals always require a certain number of keywords to accompany the manuscript. This helps to aid online searches by other researchers or scholars all over the world. This study considered keyword and keyword-plus to ascertain the research progression of *Callistemon*. Twenty of the most significant keywords used by researchers to depict research work on Callistemon were retrieved from the hybrid databases and presented in (Table 2). Based on the keyword frequencies, *Myrtaceae*, *Callistemon lanceolatus* (*C. lanceolatus*), *Callistemon viminalis* (*C. viminalis*), *Callistemon citrinus* (*C. citrinus*), and 1, 8 cineole occupies the first, second, third, fourth and fifth category of keywords used by authors (n=21, 16, 16, 11 & 10; 18.10%, 13.79%, 13.79%, 9.48%, & 8.62%). The first keyword, 'Myrtaceae' is frequently used by authors to depict the family to which *Callistemon* belongs [34], while the other keywords, like *C. lanceolatus, C. viminalis* and *C. citrinus* describe the various species in the genus of *Callistemon* from the family *Myrtaceae*. They comprise about 34 species that are endemic to Australia, but some of them have been naturalized in India and some parts of Africa. These species are found growing in almost every province of South Africa [34].

The keyword-plus represent the plant parts used, the component of the plant part used, and the biological activity carried out in the specific research [16] (Figure 5a), showing the co-occurrence and correlation between the top twenty keywords linked to the study of *Callistemon* with each colored loop indicating a term. Some terms represented in the loop are leaves,

constituents, extracts, essential oils, gas exchange, plants, etc. They all summarized ideas expressed by the authors of *Callistemon* research.



(a)



(b)

Figure 5. (a) Co-occurrence arrangement of the top-twenty terms on *Callistemon*. The Coloured circle loops signify the rate of occurrence in articles. The thicknesses of the line sandwiched between any two terms demonstrate the degree of cooperation. **(b)** Network of keywords in *Callistemon* research. Cluster between1966 to 2020.

The thickness of the line connecting two terms shows the extent of collaboration between them, while the degree of thickness in networks connecting leaves, constituents, diel-alder adducts, *viminalis*, and *Myrtaceae* shows the extent of similarity between these terms. Conversely, 1, 8 cineole is predominantly present in all species of *Callistemon* genus globally [15], while terms like leaves, chemical composition, constituents, antibacterial and antimicrobial activity (n=30, 14, 8, 6, 6; 25.86%, 12.07%, 6.89%, 5.17%, & 5.17%) are used to express the researcher area of interest in research related to *Callistemon*. A correlation exists between keywords employed by authors in their published articles, as seen in (Figure 5b) where the circle-colored node depicts a term; for example, the big-blue circle-colored loop in (Figure 6) are *Myrtaceae* and *C .lanceolatus*; these represent the family and the species of *Callistemon*

while pinane, linalool, pinene alpha-pinene represented in the small circled deep blue loop are used to depict the components of essential oils obtained from various species of *Callistemon* (Figure 5b)". In contrast, pinane, linalool, and pinene alpha-phellandrene, represented in the small circled deep blue loop, are used to depict the components of essential oils obtained from various species of *Callistemon* (Figure 5b). The keyword plus represent the plant parts used, the component of the plant part used, and the biological activity carried out in the specific research [16]. (Figure 5a) shows the co-occurrence and correlation between the topmost twenty keywords linked to the study of *Callistemon*, with each colored loop indicating a term. Some of the terms represented in the loop are leaves, constituents, extracts, essential oils, gas exchange, plants, etc; they all summarized ideas expressed by the authors of *Callistemon* research. The thickness of the line connecting two terms shows the extent of collaboration between them, while the degree of thickness in networks connecting leaves, constituents, diel-alder adducts, *viminalis*, and *Myrtaceae* shows the extent of similarity between them.

Table 2. Twenty most significant keywords employed for *Callistemon* Research.

Rank	N_{AK} (DE)	N_A	(% of 239)	N_{KP}	Articles	Articles (% of 239)
1	Myrtaceae	45	18.82	Article	43	17.99
2	*Callistemon viminalis*	30	12.55	Myrtaceae	41	17.15
3	*Callistemon citrinus*	29	12.13	Non-human	40	16.74
4	*Callistemon lanceolatus*	28	11.71	Unclassified drug	34	14.22
5	1, 8 cineole	24	10.04	Leaves	32	13.38
6	Essential oil	18	7.53	Plant Extract	32	13.38
7	Essential Oil Composition	16	6.69	Plant Leaf	24	10.04
8	Antibacterial activity	12	5.02	Controlled Study	23	9.62
9	Antioxidant	12	5.02	Chemical Composition	22	9.20
10	*Callistemon rigidus*	10	4.18	Antibacterial activity	17	7.11
11	α Pinene	9	3.76	*Callistemon citrinus*	16	6.69
12	Antibacterial	8	3.34	*Callistemon lanceolatus*	16	6.69
13	*Callistemon*	7	2.92	*Callistemon viminalis*	16	6.69
14	Antifungal	6	2.51	Essential oil	15	6.27
15	Apoptosis	6	2.51	Medicinal Plant	15	6.27
16	Pinene	6	2.51	Antimicrobial Activity	14	5.85
17	Acylphloroglucinols	5	2.09	Antioxidant	13	5.43
18	Antimicrobial	5	2.09	Cineole	13	5.43
19	Antioxidant Activity	5	2.09	*Escherichia coli*	13	5.43
20	*Callistemon salignus*	5	2.09	Methanol	12	5.02

3.4. Authors' output.

The overall number of authors that participated in studies related to the Callistemon genus between 1966-2020 was 680. Table 3 shows the first 20 prolific authors, ranked from greater to lesser contributions to published articles. The overall number of papers published by an author can be used to calculate the overall impact in a research field, although it may be overblown by an undersized number of a big hit that may not necessarily reflect the researcher's output if they are a co-author on a paper with many more authors. Zhang Y and Maaza M were the most prolific authors contributing 12 articles each (5.0%) from the total of 239 articles. In recent years, many developing nations, like China, Brazil, India, and Mexico, have declared their obligation to science and technology (S&T) as an elemental pillar of their economic development [35]. This may explain why Zhang Y from China, who started publishing articles on this subject in 2010, was tied in the first position with Maaza from South Africa with 12 articles each, accumulating 5% of the total articles published. These authors were followed by Sone BT, also from South Africa (9, 3.8%), in the third position, as seen in Table 3. The dominance of South African scholars may be attributed to the fact that most Callistemon species are naturalized in South Africa, thus attracting studies from several scientific

disciplines [34]. The high use of plant materials for clinical medicine and biomedical studies by South African scholars may be responsible as a factor (Gonzalez *et al*., 2016) [35]. Luo J (n=10, 4.2%) also from China and Alvarez S (n=10, 4.2%) from Spain ranked 2nd position. It has been documented that the economic potency of a country affects the research output of that country [28, 36-38] since Spain's economy is the sixth-largest in Europe, following countries like Germany, United Kingdom, France, Italy, and Russia with a GDP growth rate of 2.4 % in 2018 and 2.0 % in 2019. Other top authors are Kong L (n=8, 3.3%), ranked 4th position, Srivastava S, 5th position (n=8, 3.3%), Wang X, 6th position (n=8, 3.3%), Wu L, 7th position (n=8, 3.3%), although all these authors have the same number of publications, their total citation from (Table 3) differs. It is fascinating to see a researcher from Nigeria occupying the 13th position among the most prolific 20 authors in Table 3, Larayetan R (n=6, h-index of 4) has a total number of citations of 22. This might be due to the recent effort of the Nigerian Federal Ministry of Science and Technology with the 2012 launching of the Science, Technology, and Innovation (ST&I) adjusted policy that was geared at building a virile Science, Technology, Innovation capability, and potentials necessary to produce a modern economy; some detailed objectives were brought to light by the agency".

These objectives consist of facts acquisition, sustaining the Nigerian higher institutions via adequate financial support, innovation, sustaining the dispersal of local technology, enhancement of ST&I database, producing and sustaining reliable mechanisms for funding, initiation and strategizing on bilateral and multilateral partnership in ST&I among others. Additionally, the significance of staff training and development cannot be ignored; this role is carried out by the Tertiary Education Trust Fund (TETFund), which is meant to give opportunities to lecturers in Nigeria University, Polytechnic and College of Education to be educated abroad thus enabling them to interrelate with other researchers international and benefits from such contact and interaction to the advantage of research productivity in Nigeria educational system [39]. Larayetan, a researcher from Nigeria, was given the ample opportunity to study at the University of Fort Hare, South Africa, as seen from most of his publications on Callistemon-related work that was done in South Africa in collaboration with his home university (Kogi State University, Nigeria) could be another factor why this Nigeria researcher was listed among the top 20 productive authors. Furthermore, citation analysis (a process that evaluates the quality of an article by calculating the number of times other researchers cited a particular author's work in their published article) was obtained from WoS (1966-2020) and used for this bibliometric examination. Citation per paper makes it possible to compare different research across the globe irrespective of age or country of origin. As regard citation, these twenty top prolific authors have an overall cumulative citation of 1604, as shown in Table 3, and the seven most prolific authors referred to above have citations of 112, 179, 109, 138, 158, 109, 59, and 109, respectively. H-index, a tool used to determine the scientific research efficiency of researchers [40], was also recorded in Table 3 with Zhang Y, Maaza M, Luo J, Kong L, Wang X, and Wu L having the highest h-index in research about Callistemon species. The summation of the whole h-index for the most productive authors was 104, with an average of 4.33. Authors like Ahmad K, Athar F, Kumar A, Liu H, Alam M, Syamsundar K, Larayetan R, Darokar M, Khanuja S, Qiu S, Abdelhady M, Chen Y, Gupta S, and Gaddam B all fell below the average h-index score of 4.33.

Table 3. Bibliometric evaluation of the twenty most productive authors of *Callistemo*n genus (1966-2020) based on the frequency of articles and total citations.

S/N	Author	Institution	Country	Articles	TC	NP	h-index	g-index	Start Date
1	Zhang Y	‘State Key Laboratory of Natural Medicines, Department of Natural Medicinal Chemistry, China Pharmaceutical University, Nanjing’.	China	12	112	10	7	10	2010
1*	Maaza M	‘College of Graduate Studies, University of South Africa, Pretoria’.	South Africa	12	179	9	7	9	2015
2	Luo J	‘State key Laboratory of Natural Medicines, Department of Natural Medicinal Chemistry, China Pharmaceutical University, Nanjing’.	China	10	109	8	7	8	2015
2*	Alvarez S	‘Departamento de Riego, Centro de Edafología y Biología Aplicada del Segura (CSIC)’.	Spain	10	138	4	4	4	2011
3	Sone BT	‘Nanosciences African Network (NANOAFNET), Materials Research Department, iThemba LABS, National Research Foundation, P.O. Box 722, Somerset West 7129, Western Cape Province, South Africa’.	South Africa	9	158	6	5	6	2015
4	Kong L	‘State Key Laboratory of Natural Medicines, Department of Natural Medicinal Chemistry, China Pharmaceutical University, Nanjing’.	China	8	109	8	7	10	2015
5	Srivastava S	‘Central Institue of Medicinal and Aromatic Plants, Lucknow’.	India	8	59	8	3	7	2001
5*	Linga V	‘Department of Microbiology, Osmania University, Hyderabad, Telangana State’.	India	8	25	6	4	5	2014
6	Wang X	‘State Key Laboratory of Natural Medicines, Department of Natural Medicinal Chemistry, China Pharmaceutical University, Nanjing’.	China	8	109	8	7	8	2015
6*	Vaddavalli R	‘Department of Botany, Osmania University, Hyderabad, Andhra Pradesh’.	India	8	25	6	4	5	2014
7	Wu L	‘State key Laboratory of Natural Medicines, China Pharmaceutical University, Nanjing’.	China	8	109	8	7	8	2015
7*	Ahmad K	‘Jamia Hamdard University, Department of Pharmaceutical Chemistry, New Delhi’.	India	8	23	4	2	4	2017
8	Kumar A	‘Laboratory of Herbal Pesticides, Center of Advanced Study in Botany, Banaras Hindu University, Varanasi.’	India	7	62	7	3	7	2008
8*	Athar F	‘Center for Interdisciplinary Research in Basic Science, Medicinal Chemistry Laboratory, Jamiav Millia Islamia, New Delhi’.	India	7	23	4	2	4	2017
9	Liu H	‘State Key Laboratory of Phytochemistry and Plant Resources in West China, Kunming Institute of Botany, Chinese Academy of Sciences, Kunming’.	China	7	45	6	4	6	2016
10	Yang M	‘State Key Laboratory of Natural Medicines, China Pharmaceutical University, Nanjing’.	China	7	92	7	5	7	2015
11	Alam M	‘Jamia Hamdard University, Department of Phytochemistry and Pharmacognosy, Faculty of Pharmacy, New Delhi’.	India	6	19	3	2	3	2011
12	Syamsundar K	‘Central Institute of Medicinal and Aromatic Plants, Banglore’.	India	6	14	6	3	3	2008
13	Larayetan R	‘Kogi State University, Department of Chemistry, Anyigba, Nigeria’.	Nigeria	6	22	4	2	4	2017
14	Darokar M	‘Genetic Resource and Biotechnology Division, Central Institute of Medicinal and Aromatic Plants, Lucknow’.	India	5	13	5	3	3	2008

S/N	Author	Institution	Country	Articles	TC	NP	h-index	g-index	Start Date
15	Khanuja S	‘Central Institute of Medicinal and Aromatic Plants, Banglore’.	India	5	35	5	3	5	2003
16	Qiu S	‘Program for Natural Products, Chemical Biology, Key Laboratory of Plant Resources Conservation & Sustainable Utiliation, Guangdong’.	China	5	32	5	3	5	2016
17	Abdelhady M	‘Department of Pharmacognosy, Falcuty of Pharmacy, Umm Al-Qura University, Saudi Arabia’.		4	6	4	2	2	2012
18	Chen Y	‘State key Laboratory of Natural Medicines, China Pharmaceutical University, Nanjing’.	China	4	64	4	3	4	2015
19	Gupta S	‘Analytical Chemistry Division, Central Institute of Medicinal and Aromatic Plants, Lucknow’.	India	4	10	3	3	3	2008
20	Gaddam B	‘Department of Botany, Osmania University, Hyderabad, Andhra Pradesh’.	India	4	12	4	2	3	2014

3.5. Collaborative authorship and countries.

The collaborative network among the top countries on *Callistemon*-related research is portrayed in (Figure 6). A relationship is established between the size of the lobe and the degree of collaboration among different countries. The larger the colored circle, the greater the number of teamwork among countries. Furthermore, a line having a thicker diameter in-between two circles reveals the teamwork strength between the two countries. It is fascinating to observe that India, China, Australia, Egypt, South Africa, Korea, Pakistan, and Nigeria have the highest collaborative network with other countries. Also, the clustered diagram in Figure 6 revealed that India, China, Australia, Egypt, South Africa, Korea, and Pakistan are at the apex of the collaborative network with other countries. Six of these seven countries mentioned above are also ranked 1^{st,} 2nd, 3rd, 4th, 5th, and 7th on the list of most productive countries Table 4. Their effectiveness and efficiency may be accredited to a high level of international participation and perhaps a multinational partnership with other countries, which is capable of impacting research visibility and citation rate [28, 39, 41]. India, with the highest degree of collaborative strength, is seen as having a strong alliance with Korea, which might be because the two countries are from the same Asian region, while Egypt, an African country, is also found in alliance with about three countries, namely Saudi Arabia, Pakistan, and Germany. The first two countries with a strong collaborative alliance with Egypt may be due to the Islamic relationship that these three countries enjoy together. The collaborative alliance seen in the clustered network diagram (Figure 6 and Figure 7) for Nigeria with South Africa, Cameroon, and Germany may be due to the giant stride displayed by the Tertiary Education Trust Fund (TETFund) designated by the Nigerian government to provide ample opportunity to lecturers across Nigeria University, Polytechnic and College of Educations to be trained abroad thus enabling them to interact and enter into a partnership with other researchers worldwide and benefits from such exposures and interaction to the advantage of research output in Nigeria educational system. Doing research with associates from different institutions and across different countries of the world brings about a positive influence on the value of productivity and also accelerates the research process [42]. Advantages of this collaboration include access to human and equipment resources, swapping of ideas, particularly across disciplines, pooling of skills to resolve difficult problems, augmentation of productivity, and better access to funding [43-44]. These factors play a very important concerted effort between Kogi State

University, Nigeria, and the University of Fort Hare, South Africa (Figure 7). The size of the lobe and the degree of collaboration in (Figure 8) between Oyedeji and Chane-Ming, who are both authors on *Callistemon* research, is a result of Oyedeji citing Chane-Ming in his published journals titled 'Chemical Composition and antibacterial activity of the volatile oils of *Callistemon citrinus* and *Callistemon viminalis* from South Africa.'

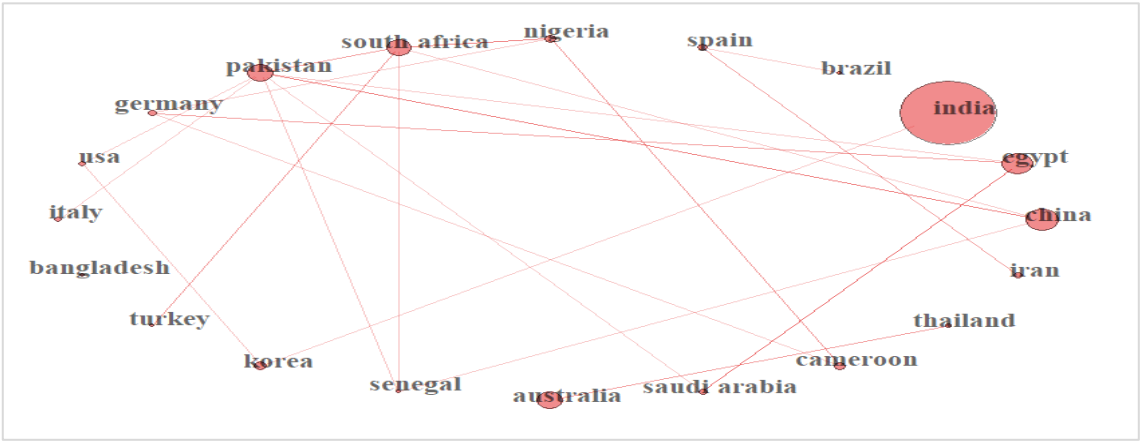


Figure 6. Top 20 countries collaboration network.

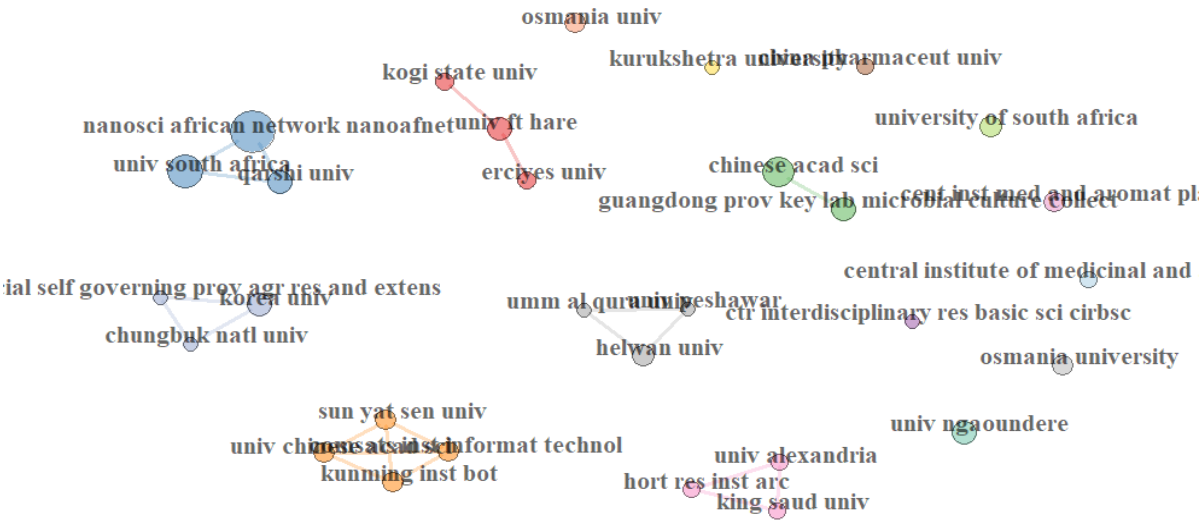


Figure 7. Top 30 Institutes collaboration network.

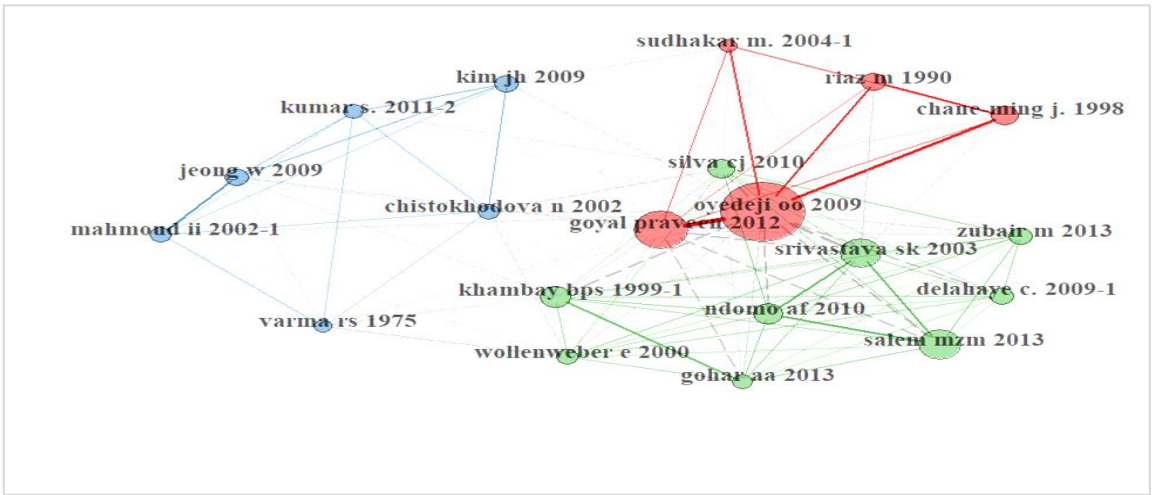


Figure 8. Top 20 author's co-citation network.

Table 4. Twenty-five most cited manuscripts on *Callistemon* obtained from 1966 to 2020 from the WoS and Scopus Databases.

Rank	First Name, Initials, Year	Title of Articles	Journal	TC	TC/Y
1	Salem MZM, 2013	"Evaluation of Extracts And Essential Oil From *Callistemon viminalis* Leaves: Antibacterial And Antioxidant Activities, Total Phenolic And Flavonoid Contents"	Asian Pac J Trop Med	75	9.4
2	Sone BT, 2015	"SM2O3 Nanoparticles Green Synthesis Via *Callistemon viminalis'* Extract"	J Alloy Compd	60	10.0
3	Oyedeji OO, 2009	"Chemical Composition and Antibacterial Activity of the Essential Oils of *Callistemon citrinus* and *Callistemon viminalis* from South Africa"	Molecules	59	4.9
4	Shukla R, 2012	"Antifungal, Aflatoxin Inhibition and Antioxidant Activity of *Callistemon lanceolatus* (SM.) Sweet Essential Oil and its Major Component 1,8-Cineole Against Fungal Isolates from Chickpea Seeds"	Food Control	57	6.3
5	Kumar S, 2011	"Pharmacognostic Study and Anti–Inflammatory Activity of *Callistemon lanceolatus* Leaf"	Asian Pac J Trop Biomed	49	4.9
6	Alvarez S, 2011	"Transpiration, Photosynthetic Responses, Tissue Water Relations and Dry Mass Partitioning in Callistemon Plants During Drought Conditions"	SciHortic	48	4.8
7	Kim JH, 2009	"Compounds with Elastase Inhibition and Free Radical Scavenging Activities from *Callistemon lanceolatus*"	J Med Plants Res	42	3.5
7	Pandey DK, 1982	"Volatile Fungitoxic Activity of Some Higher Plants with Special Reference to that of *Callistemon lanceolatus* DC"	J Phytopathol	42	1.1
8	Cao JQ, 2016	"Callistrilones A and B, Triketone-Phloroglucinol-Monoterpene Hybrids with a New Skeleton from *Callistemon rigidus*"	Org Lett	38	7.6
9	Alvarez S, 2014	"Long-Term Effect Of Salinity On Plant Quality, Water Relations, Photosynthetic Parameters And Ion Distribution in *Callistemon citrinus*"	Plant Biol	35	5.0
9	Seyydnejad SM, 2010	"Antibacterial Activity of Hydroalcoholic Extract of *Callistemon citrinus* and Albizia Lebbeck"	Am J ApplSci	35	3.2
10	Alvarez S, 2013	"Changes in Growth Rate, Root Morphology and Water Use Efficiency of Potted *Callistemon citrinus* Plants in Response to Different Levels of Water Deficit"	Sci Hortic	32	4.0
10	Kumar P, 2011	"A Green Approach for the Synthesis of Gold Nanotriangles Using Aqueous Leaf Extract of *Callistemon viminalis*"	Mater Lett	32	3.2
11	Brown GK, 2001	"Molecular Phylogeny and Biogeography of Melaleuca, Callistemon and Related Genera (Myrtaceae)"	Aust Syst Bot	30	1.5
11	Huq F, 1997	"An Alkenol and C-Methylated Flavones from *Callistemon lanceolatus* Leaves"	Planta Med	30	1.3
12	Kobayashi K, 2006	"Constituents of Stem Bark of *Callistemon rigidus* Showing Inhibitory Effects on Mouse Alpha-Amylase Activity"	Biol Pharm Bull	29	1.9
13	Mahmoud II, 2002	"Polyphenolic Constituents of *Callistemon lanceolatus* Leaves"	Pharmazie	28	1.5
13	Sone BT, 2016	"Single-Phase Alpha-CR2O3 Nanoparticles' Green Synthesis Using *Callistemon viminalis'* Red Flower Extract"	Green Chem Lett Rev	28	5.6
14	Ndomo AF, 2010	"Insecticidal Activities of Essential Oil of *Callistemon viminalis* Applied as Fumigant and Powder Against Two Bruchids"	J Appl Entomol	27	2.5
14	Riaz M, 1990	"The Chemical Composition of Pakistani *Callistemon citrinus* Oils	J Essent Oil Res	27	0.9
15	Rattanaburi S, 2013	"Acylphloroglucinols from *Callistemon lanceolatus* DC"	Tetrahedron	26	3.3
15	Wu L, 2015	"Isolation and Biomimetic Synthesis of ()-Calliviminones A And B, Two Novel Diels-Alder Adducts, From *Callistemon viminalis"*	Tetrahedron Lett	26	4.3
15	Lounasmaa M, 1977	"Phloroglucinol Derivatives of *Callistemon lanceolatus* Leaves"	Phytochemistry	26	0.6
16	Sone BT, 2016	"Single-Phase Alpha-Cr2O3 Nanoparticles' Green Synthesis Using *Callistemon viminalis*' Red Flower Extract"	Green Chem Lett Rev	25	5.0
16	Shukla R, 2011	"Efficacy of Essential Oils of Lippia Alba (Mill.) ne Brown and *Callistemon lanceolatus* (sm.) Sweet and their Major Constituents on Mortality, Oviposition and Feeding Behaviour of Pulse Beetle, Callosobruchus Chinensis L"	J Sci Food Agric	25	2.5

TC – Total citations; TC/Y – Total citation per year

The more an article is cited, the more influence it generates in the circle of the scientific community [45], which depicts the journal's weight on the subject matter [46]. On the other hand, the number of times a publication is cited could be linked with the negative criticism generated by its content [47]. The 20 most quoted publications in Callistemon's research works are listed in (Table 5). These publications are hierarchically arranged from the highest to the smallest number of citations. Citations of the 20 most dominant publications were between 25 and 75, and only 50 articles were cited more than 50 times. Since researchers working on Callistemon work published in different journals and the years of publications were different,

as seen in Table 5, it will be difficult to give the journal with the highest citation; rather, we examined the author with the highest citation irrespective of the journals they published their work in. The most cited article [48] was cited 75 times, with an average of 9 citations per year. Articles authored by Sone *et al*. (2015) (n = 60) [49] and Oyedeji *et al*. (2009) (n =59) [50] were ranked second and third, respectively, averaging a total citation per year of 10 and four times respectively. Sone *et al*. (2015) [49] majorly worked on the green synthesis of Callistemon nanoparticles and published in high and moderately impact factor journals such as Journal of Alloys and Compounds (IF of 4.350) and Green Chemistry Letters & Reviews (IF of 2.820). Oyedeji *et al*. work was centered on the Callistemon plant's essential oils and documented his work in Molecule with a good IF of 3.010. Only two articles (each) of the 25 most cited were published in the same journals (Scientia Horticulturae and Green Chemistry Letters and Reviews). The top 25 most cited articles were from 23 journal sources, thus indicating a clear author preference. Older articles are liable to acquire citations after a while; recent analytical equipment, modification in the research plan, progress in scientific information, and importance of the research in addition to the scholar's first choice may possibly augment the average citation of more current literature. In addition, the bigger colored circle loop with different colors depicting the Journal of essential oil research, Phytochemistry, Fitoterapia, Journal of essential oil bearing, tetrahedron, and Natural Product Communication clearly reveals the author's preference in the choice of the journal (Figure 9).

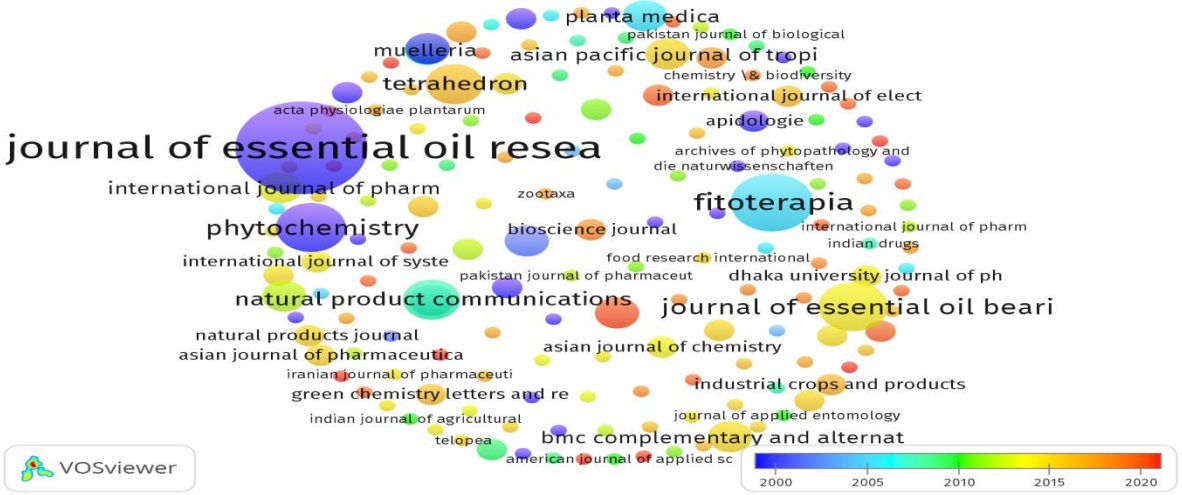


Figure 9. Network cluster of Journals where research on the Callistemon genus was published.

3.6. Publication division by country.

To study this variable, countries were categorized from larger to smaller in terms of productivity. Asian countries were found among the list of 25 most prolific countries. They include India, China, and Korea, with a total citation per country of 642, 220, and 136, while African countries like Egypt, South Africa, Cameroon, Zimbabwe, and Benin also made the list with varying numbers of publications (17, 11, 8, 2, 1 & 1 respectively) and a total citation of 456 representing 20.53% of the overall citation of the 25 most productive countries. The 25 most prolific countries were categorized based on the number of articles published and the total number of citations per country (Table 5). Australia, found among the world's most industrialized and developed nations [51], ranked 3rd on the list with 18 publications, as seen in (Table 5). It is poignant to know that Australia is the only country where the genus Callistemon is found 'wild' (to grow naturally without being planted or cared for by humans);

this plant is native to the Australian states of New South Wales and Queensland and by this virtue supposed to have one of the highest numbers of publication in the genus Callistemon since it is first known in this country before been introduced or naturalized in other countries of the world. However, this country can only boast 18 publications making it the 3rd most productive country on the list despite its strategic advantage. It is pertinent to note that this plant was introduced to India several years back [52], but India topped the 25 most prolific countries in the genus Callistemon with 70 publications between 1966 and 2020 (Table 5). It has been documented in 'the scientific impact of developing nations of the world by Gonzalez *et al*. (2016) [35] that the most used tool to evaluate a nation's scientific feet is an international comparison with peers [53-55], the scientific input based on publications and citations of each country was compared with their relative impact, it was concluded that India, which was among the other eight developing countries of the world, is reducing her science gap with research and development (R & D) investment and her scientific impact is rising at more than double the rate of the developed world [36]. This may be why India, a newly industrialized country (NIC) would have the largest number of publications than Australia, which is among the world's developed nations. Secondly, it could be that in the last few years, an increasing number of developing countries, like India, South Africa, and China, etc. have publicly declared their dedication to science and technology as a primary pillar of their economic development, making them rank one of the topmost prolific countries [35]. The categorized order of these countries was slightly altered when efficiency was calculated based on the number of citations for every country; India and China, among the three Asian countries, still maintained the list of the 1st and 3rd top prolific countries, but an African country, South Africa was seen ranking 2nd in this list with a total number of citation per country of 225 pushing Australia to the 4th position in this category as depicted in Table 5.

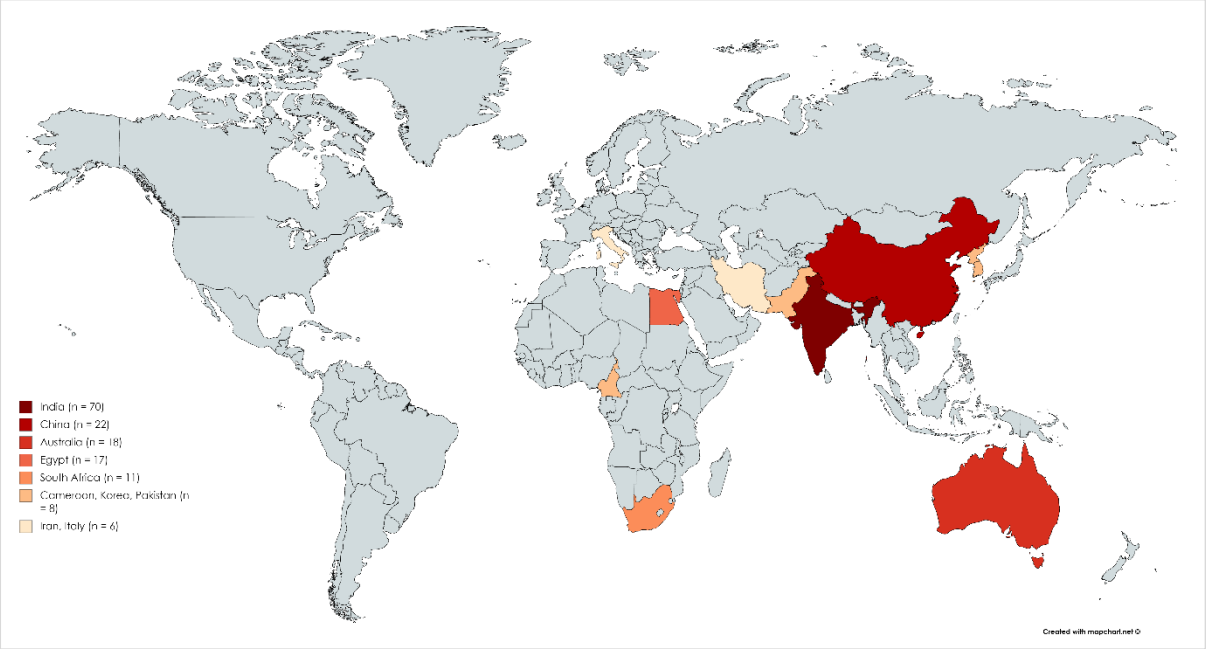


Figure 10. Heat maps of the top 10 most prolific areas on *Callistemon* research. Dark brown shading depicts areas with a higher number of publications. Grey color shading shows the areas that are not part of the top 10. *Map created with mapchart.net.*

Table 5. Productivity of different Countries and citations on *Callistemon* derived from articles from 1966-2020.

Rank	M_{PA}							$T_{C/C}$			
	Country	**Articles**	**(% of 239)**	**Freq**	**SCP**	**MCP**	**MCP Ratio**	**Rank**	**Country**	**T_C**	**A_{AC}**
1	India	70	29.28	0.31	68	2	0.02	1	India	642	9.17
2	China	22	9.20	0.10	20	2	0.09	2	South Africa	225	20.45
3	Australia	18	7.53	0.08	17	1	0.05	3	China	220	10.00
4	Egypt	17	7.11	0.07	13	4	0.02	4	Australia	166	9.22
5	South Africa	11	4.60	0.05	7	4	0.36	5	Egypt	159	9.35
6	Cameroon	8	3.34	0.03	3	5	0.62	6	Spain	138	34.50
7	Korea	8	3.34	0.03	6	2	0.25	7	Korea	136	17.00
8	Pakistan	8	3.34	0.03	6	2	0.25	8	Iran	76	12.66
9	Iran	6	2.51	0.02	4	2	0.33	9	Pakistan	67	8.37
10	Italy	6	2.51	0.02	5	1	0.16	10	Cameroon	58	7.25
11	Spain	4	1.67	0.01	4	0	0.00	11	Japan	53	17.66
12	Bangladesh	3	1.25	0.01	2	1	0.33	12	Thailand	42	21.00
13	Brail	3	1.25	0.01	2	1	0.33	13	Mexico	32	10.66
14	Cuba	3	1.25	0.01	2	1	0.33	14	Italy	29	4.83
15	Japan	3	1.25	0.01	3	0	0.00	15	Finland	26	26.00
16	Mexico	3	1.25	0.01	1	2	0/66	16	United Kingdom	25	25.00
17	Turkey	3	1.23	0.01	0	3	1.00	17	France	21	21.00
18	USA	3	1.25	0.01	3	0	0.00	18	Serbia	15	15.00
19	Saudi Arabia	2	0.83	0.00	1	1	0.50	19	USA	14	4.66
20	Thailand	2	0.83	0.00	0	2	1.00	20	Zimbabwe	14	7.00
21	Zimbabwe	2	0.83	0.00	2	0	0.00	21	Iraq	12	12.00
22	Argentina	1	0.86	0.00	0	1	1.00	22	Saudi Arabia	11	5.50
23	Austria	1	0.41	0.00	1	0	0.00	23	Austria	9	9.00
24	Benin	1	0.41	0.00	1	0	0.00	24	Bangladesh	9	3.00
25	Colombia	1	0.41	0.00	1	0	0.00	25	Colombia	5	5.00

M_{PA}: Most productive countries, SCP: Single Country Publications, MCP: Multiple Country Publications $T_{C/C}$: Total citations per country, A_{AC} Average Article Citations, T_C: Total Citations.

4. Conclusions

Plants employed for research to explore important active ingredients for medicines have been established to possess a momentous scientific output. This work happens to be the first bibliometric analysis on the *Callistemon* genus spanning five decades wherein annual scientific productions, most productive authors, top manuscript citations, most prolific countries, top citation per country, most relevant sources, and the most significant keywords were examined and discussed. This study provides a summary of and output and visibility of research findings in the *Callistemon* genus. The result and conclusion arrived at in this work might be employed for classifying and prioritizing prospective research in *Callistemon*-related work.

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Conflicts of interest

The authors declared that this manuscript has no conflict of interest.

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