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RESEARCH ARTICLE

A Web of Science-based Analysis of Global Research Trends on *Moringa oleifera* from 2010 – 2019

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Abstract

Since time immemorial, people in developing countries relied on herbal folklore to treat different human diseases because of their numerous advantages over conventional drugs. As a result, the applications of medicinal plants are increasing in both advanced and developing countries owing to the emergent popularity of herbal products. *Moringa oleifera* (*M. oleifera*) is one of the most promising floras that have received global attention due to its versatile uses in medicine, industries, agriculture, nutrients, and coagulant in water treatment. Despite the extensive literature on this plant, no document has been reported on the quantity of research that has been carried out on the plant over time and as a result, this present study aimed to in retrospect evaluate the global research outputs on *M. oleifera* from 2010 to 2019. An overall of 989 articles was retrieved from Science Citation Index-Expanded (SCI-Expanded) and a bibliometric package in RStudio and VOS viewer were explored for data analysis and visualization, respectively. The research outputs were observed to have increased relatively over the year, and the most relevant author, institution, country, and journal were Bergamasco R (n = 33), UniversidadeEstadual de Maringá (n = 199), India (n =145) Industrial Crops and Products (n = 29), respectively. Co-authors/documents were 5, while 3.79 for the collaboration index. Findings from this study reveal the research collaboration network among the researchers and trend topics on *M. oleifera* and we believe that this study would provide valuable information for researchers interested in joining the field in the future.

Keywords: Bibliometric Analysis, *Moringa oleifera*, Research Collaboration, Trend Topics

1. Introduction

Moringa oleifera (*M. oleifera*) popularly known as "drumstick" is a multipurpose tree ("miracle tree"), which is one of the 13 species from the family Moringaceae[1,2]. These species have their unique morphological features and India has been recognised to be the lead cultivator of the plant globally[3]. Historically, *M. oleifera* originated from the Himalayans and cultivation of Moringa in several subtropical and tropical geographical regions around the world could be made possible due to its robust drought-resistant potential[1,4–9]. Several studies have reported that all parts of *M. oleifera* have significant multipurpose uses in medicine, nutrition, agriculture, forestry, industries[7,10,11]. In addition, the leaves of *M. oleifera* have been widely explored as food supplements due to their compositions such as vitamins, amino acids, and minerals essential for the growth and development of the human cells and tissues[12–14].

Medicinal plants provide an inexhaustible, cost-effective source of drugs to treat different human life-threatening illnesses[3]. As a result, several studies have reported on the therapeutic applications of *M. oleifera*. These applications include anticancer[8], antibacterial[15,16], antidiabetic[17–19], anti-inflammatory[20], antioxidant[21,22] and hepatoprotective[23]. Previous studies have established that various therapeutic purposes of *M. oleifera* could be associated with the presence of bioactive compounds such as glycosides, flavonoids, alkaloids, vitamins, carotenoids, sterols, minerals, amino acids and phenolics[9,24–26]. Despite the immense uses of *M. oleifera*, the plant is still generally considered unexploited, particularly in countries other than its origin because its multipurpose uses are yet fully exploited[10]. Although, the applications of *M. oleifera* have

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been extensively documented in the literature, however, it is paramount to comprehensively understand the level of research, which have been conducted over the last 10 years on it[27]. As a result, the quest for the study is of high importance.

In 1969, Alan Pritchard proposed the use of bibliometric analysis to evaluate research productivity on a particular topic or subject[28]; and over time, the method has been extensively explored in various fields[29–32]. Through this method, authors' research outputs, the performance of countries and institutions can be analysed, authors' impact, social networking through research collaboration, most relevant documents and the future research hotspots via author keywords analysis can be made possible[33]. To the best of our knowledge, no single bibliometric report has been documented on *M. oleifera* in the literature, hence, the present study aimed to provide a Web of Science-based analysis of global research trends on *Moringa oleifera* from 2010 to 2019. To achieve this aim, we carried out a literature survey from the SCI-Expanded to extract all the research articles on *M. oleifera*.

Subsequently, we determined the annual production over the last 10 years from 2010 to 2019. Most relevant authors/institutions/countries in terms of number of articles and citations were investigated and the research collaboration that exists between them as well as co-occurrence keywords and author co-citations using networks VOSviewer as the map visualization software were assessed.

2. Materials and Methods

2.1 Data Collection, Analysis and Visualization

Research articles on *M. oleifera* were retrieved from SCI-Expanded. We explored title search on Web of Science Core Collections as described by Orimoloye and Ololade[34] "WOS database has a robust indexing technology which minimises the indexer effect with a wider coverage compared to other databases and is a globally acceptable database in the scientific environment". Our title search was "*Moringa oleifera*", and we used a period from 2010 to 2019 in the study. A total of 1508 publications of different types were retrieved which comprise articles (1244), review (49), correction (5), letter (3), meeting abstract (115), early access (9), news item (5), data paper (1), proceedings paper (110), book chapter (6), editorial material (4). These documents were written in English (1162), Portuguese (14), Arabic (2), Indonesian (2), and Spanish (21). These documents were indexed in Science Citation Index Expanded (1,229), Index Chemicus (3), Social Sciences Citation Index (2), Emerging Sources Citation Index (190), Book Citation Index-Science (6), Conference Proceedings Citation Index-Science (163). As highlighted by Deng *et al.*[35], we filtered the documents manually and limited our search to only research articles written in English and indexed in SCI-Expanded to obtain 989 articles and these were exported from WoS in a BibTex file format and saved in a notepad thereafter. The data were analysed with bibliometrix (biblioshiny) in Rstudio (v.3.6.2)[36] and VOS viewer (v.1.6.14) for data visualization of collaboration network that exists among authors/institutions/countries, author co-citation network and author keyword networks.

3. Results and Discussion

All research articles related to *M. oleifera* from SCI-Expanded from 2010 to 2019 was explored in the present study. We evaluated 989 research articles from 432 sources, the average years from publication was 4.22 and average citations/documents and average citations/year/document were 13.9 and 2.301, respectively (Table 1). The total articles comprise 27757 references, keywords plus (2567), author's keywords (2754), authors (3692), authors of single-authored documents (20), authors of multi-authored documents (3672), documents/author (0.268), authors/document (3.73), co-authors/documents (5) with a collaboration index of 3.79. Findings from the present study reveal that the average number of co-authors per paper published by each researcher coupled with the collaboration index signifies that *M. oleifera* research has attracted much attention in the scientific community[37]. The enormous progress observed on the subject could be due tothe research collaboration that exists between the researchers in the field. As highlighted by several studies in the literature, research collaboration brings about mutual benefits, increased productivity, exchange of ideas and resources[38,39].

4. Annual Productivity and Citations

The global productivity trends on *M. oleifera* research articles from SCI-Expanded from 2010 to 2019 were assessed in the present study, and the results are depicted in Figure 1. According to the report of Durieux and Gevenois[40], "the number of articles in a research area can reflect the topic's productivity and development over the years". Similarly, an article citation is a reflection of the

Table 1. Main information on *Moringa oleifera* research from 2010 – 2019

Description	Results
"Timespan"	2010:2019
"Sources (Journals, Books, etc)"	432
"Documents"	989
"Average years from publication"	4.22
"Average citations per documents"	13.9
"Average citations per year per doc"	2.301
"References"	27757
"DOCUMENT TYPES"	
"Article"	989
"DOCUMENT CONTENTS"	
"Keywords Plus (ID)"	2567
"Author's Keywords (DE)"	2754
"AUTHORS"	
"Authors"	3692
"Author appearances"	4941
"Authors of single-authored documents"	20
"Authors of multi-authored documents"	3672
"AUTHORS COLLABORATION"	
"Single-authored documents"	20
"Documents per author"	0.268
"Authors per document"	3.73
"Co-authors per documents"	5
"Collaboration index"	3.79

degree of its dissemination, impact and influence, and this could be used to measure its quality[41]. Our analysis reveals that there is significant growth in *M. oleifera* research over the 10 years study period, as evidenced in the annual productivity. In 2010, 38 articles were recorded with an average total citation per year of 4.76, whereas 58 articles were published in 2011 with a 3.03 average total citation per year. The highest number of articles of 175 was reported in 2019, while the lowest was recorded in 2010 (Figure 1). This means that research on *M. oleifera* has continued to gain popularity among the researchers in the scientific community and this could be due to the multipurpose uses of the plant in medicine, agriculture, water treatment plants, and biotechnology industries[3]. In addition, an increase in the publications on the subject over the year indicates more participation of researchers from different countries, more funding dedication to the research and this development could contribute substantially to the research outputs and attract more skilled researchers to develop an interest in the field[35].

It is remarkable that the citations of published papers on *M. oleifera* research increased with the age of publication year. As stated in the report of Bartneck and Kokkelmans[42] "citation accumulates with time, as a result, papers published earlier have a higher probability of receiving more citations than the new ones, making this an important issue when the citation count is used for the ranking of individual papers". The low citations observed in this study with the most recent publications do not mean that they are less relevant in the field as compared to the older articles. Highly cited papers have a greater chance of visibility, thus attracting greater attention among researchers. Citation analysis helps researchers to obtain a preliminary idea about the articles and research that has an impact in a particular field of interest, and it deals with the examination of the documents cited by scholarly works. Furthermore, it is important that citation does not perfectly reflect the quality of an article (particularly for new publications or publications in areas that are less popular during a particular period), nor is it the only measure[35]. Nevertheless, we suggest an increased amount of multidisciplinary work and the discovery of new applications for *M. oleifera* would enable each article to be fully recognized for its achievements. We believe that the trend of increasing globalization would benefit researchers significantly and multinational cooperation will bring about unexpected changes to *M. oleifera* research in the future.

5. Most Relevant Authors

To determine the most productive authors, we ranked authors based on their total number of articles on *M. oleifera* research from 2010 to 2019 and we carried out other analyses alongside as indicators to provide a more comprehensive view of the scientific impact of the most relevant authors in the field[43]. An overall total of 3692 authors published 989 research articles on the subject, and this analysis was met to identify the most prolific authors among those researchers in the field. The top 20 authors on the subject are presented in Table 2. The top 5 prolific authors with the highest number of articles were Bergamasco R (n = 33), Napoleao TH (n = 16), Muchenje V (n = 15), Nishi L and Vieira MF (n = 14). Similarly, other indicators were also used to measure the

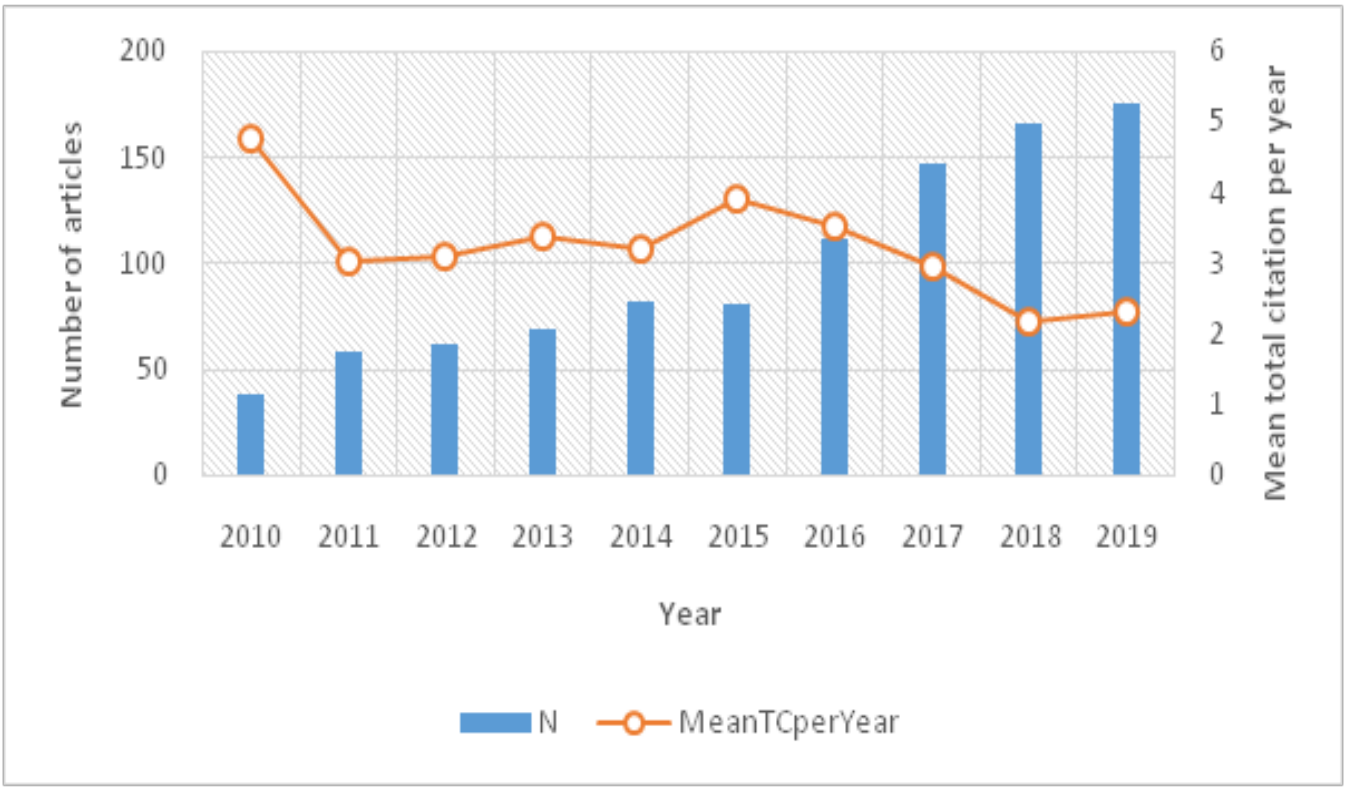

Figure 1. Annual production and citations on *M. oleifera* research from 2010 to 2019.

scientific impact of the authors, and among the authors; Bergamasco R has the highest h-index of 12 followed by Muchenje V (h-index 11), Hassanein AMA (h-index 10), Basra SMA and Shetty NP (h-index of 9). The index was proposed by Hirsch[44] to be used at the individual scientist level, but future work has shown that it also has advantages in measuring publication sets, university research groups, interesting topics, and compounds[45]. Citation counts can be influenced by theself-citations of the authors and several researchers have been found guilty of this in the literature and using citations or h-index to rank a researcher in a particular field could also create some little bias in the assessment[42]. In terms of citations, the topmost 5 authors were Basra SMA (513 citations), Bergamasco R (489 citations), Du Toit ES (439 citations), Muchenje V (349 citations), and Hassanein AMA (294 citations). As earlier mentioned, the citation count does not reflect the quality of an article because several factors could also influence the citations of a paper in a particular field. For example, the publication year is one of the crucial influencers of paper citations, visibility of the articles to other researchers in the field, quality of the content (scientific relevance, novelty, and societal benefits) and the impact factor of the journal in which the paper was published.

6. Top 20 Relevant Journals, Institutions and Countries

The most active journals on *M. oleifera* research from 2010 to 2019 were also investigated, and we depict the results in Table 3. Among these journals, the 7 topmost were Industrial Crops and Products (n = 29), Desalination and Water Treatment (n = 21), International Journal of Agriculture and Biology (n = 18), Journal of Food Science and Technology-Mysore (n = 13), Journal of Environmental Chemical Engineering (n = 12), PlosOne (n = 12). The journals in which they published articles on the subject are of good quality. It is not surprising that research on *M. oleifera* gained attention in the above journals as they are multidisciplinary with good indexing. As novel research on *M. oleifera* continues to unfold gradually, editors of high impact journals gained more interest in the subject. Furthermore, researchers prefer to publish their papers in journals with high quality and visibility as access to publish papers in these journals by other scholars increases the rate at which their papers will be cited, and this consequently influences their h-index. In addition, it is noteworthy to mention that some researchers even are very selective in the papers they cite in their works because they believe that the type of

citations, they have in the bibliographic section of their paper indirectly showcase the quality of their works.

Likewise, the topmost institutions on *M. oleifera* research from 2010 to 2019 in terms of the number of articles published on the subject were assessed and the 7 top-ranked institutions include UnivEstadual Maringa (n = 199), Univ Putra Malaysia (n = 151), Univ Fed Pernambuco (n = 110), UnivAgr Faisalabad (n = 109), South China Agr Univ (n = 102), Univ Fed Ceara (n = 96), Univ Fort Hare (n = 76) (Table 4). As highlighted in the report of Tang *et al.* (2018), "funding agencies play a substantial part in the research progress of a researcher, institution, and countries. To summarize the impetus of funding agencies to this field and to have a better understanding of the historical research on this topic".

The most participated countries on *M. oleifera* research were also assessed and we observed that among the top 7 most relevant countries, India ranked first with 145 articles followed by Brazil (n = 135), China (n = 80), South Africa (n = 69), Pakistan (n = 59), Mexico (n = 53), Nigeria (n = 51) (Table 5). It is incredible that the Asian countries dominated the research, of which, members of the BRICS countries were the top 4 countries and this indicates the level of commitment of these countries on the subject. The BRICS countries have devoted more time, funds, and power to the research and hence they appeared at the top of the list. For the time being, other countries

Table 2. Demographic characteristics of the study sample

Authors	Articles	Authors-Frac	Articles Fractionalized	h_ index	g_ index	m_ index	TC	PY_ start
Bergamasco R	33	Bergamasco R	5.5683	12	21	1.091	489	2010
Bergamasco R	33	Bergamasco R	5.5683	12	21	1.091	489	2010
Napoleao TH	16	Muchenje V	3.4333	11	16	1.1	349	2011
Muchenje V	15	Basra SMA	2.7429	9	15	0.9	513	2011
Nishi L	14	Saini RK	2.5	6	11	0.545	126	2010
Vieira MF	14	Arulselvan P	2.4956	7	14	0.636	249	2010
Arulselvan P	13	Vieira MF	2.4452	8	13	0.889	237	2012
Chen X	13	Fakurazi S	2.4	5	6	1	47	2016
Ahmad S	12	Chimuka L	2.2333	5	8	0.556	69	2012
Basra SMA	12	Masika PJ	2.15	9	12	0.9	238	2011
Coelho LCBB	12	Zhang D	2.119	8	12	0.8	222	2011
Salcedo Vieira AM	12	Nishi L	2.0675	8	12	0.727	230	2010
Fakurazi S	11	Hassanein AMA	2	10	11	1.111	294	2012
Paiva PMG	11	Ahmad S	1.9984	7	11	0.7	199	2011
Nouman W	10	Chen X	1.9854	8	10	0.889	178	2012
Vasconcelos IM	10	Salcedo Vieira AM	1.9774	8	10	0.8	149	2011
Coldebella PF	9	Kwaambwa HM	1.9762	5	9	0.714	87	2014
GuedesPaiva PM	9	Nouman W	1.919	8	9	0.889	191	2012
Masika PJ	9	Du Toit ES	1.9167	7	9	0.7	439	2011
Saini RK	9	Shetty NP	1.9167	9	9	1	289	2012
Wang X	9	Cukrowska E	1.9	4	7	0.667	62	2015

Table 3. Top 20 relevance journals on *M. oleifera* research from 2010 to 2019

Journal	IF	H-index	g-index	m-index	TC	NP	PY start
Industrial Crops and Products	4.244	16	28	1.6	789	29	2011
Desalination and Water Treatment	0.854	6	7	1	81	21	2015
International Journal of Agriculture and Biology	0.822	6	12	0.545454545	156	18	2010
Journal of Food Science and Technology-Mysore	1.946	8	13	0.888888889	174	13	2012
Journal of Environmental Chemical Engineering	4.300	3	6	1	45	12	2018
Plos One	2.776	11	12	1.222222222	400	12	2012
Environmental Technology	2.213	6	10	0.666666667	106	11	2012
Food Science & Nutrition	1.797	4	7	0.8	53	11	2016
Molecules	3.267	6	11	0.666666667	213	11	2012
Food Chemistry	6.306	8	10	0.727272727	360	10	2010
Journal of Ethnopharmacology	3.690	8	10	0.727272727	250	10	2010
Canadian Journal of Chemical Engineering	1.687	4	6	0.666666667	40	9	2015
Journal of Cleaner Production	7.246	6	9	0.857142857	174	9	2014
Journal of Functional Foods	3.701	5	9	0.625	197	9	2013
South African Journal of Animal Science	0.678	4	7	0.5	52	9	2013
South African Journal of Botany	1.792	4	8	0.571428571	78	9	2014
BMC Complementary and Alternative Medicine	2.833	6	8	0.75	148	8	2013
Chemical Engineering Journal	10.652	8	8	0.727272727	328	8	2010
International Journal of Biological Macromolecules	5.162	7	8	0.875	107	8	2013
Journal of Photochemistry and Photobiology B-Biology	4.383	8	8	1.6	282	8	2016

Journal Citation Reports (Clarivate Analytics, 2020), IF- impact factor, TC – total citation, NP – number of publication , PYstart – publication year start.

Table 4. Top 20 relevant institutions on *M. oleifera* research from 2010 to 2019

Affiliations	Articles	Countries	Continent
UniversidadeEstadual de Maringá	199	Brazil	South America
University Putra Malaysia	151	Malaysia	Asia
Federal University of Pernambuco	110	Brazil	South Africa
University of Agriculture Faisalabad	109	Pakistan	Asia
South China Agricultural University	102	China	Asia
Federal University of Ceará	96	Brazil	South America
University Fort Hare	76	South Africa	Africa
University of Veterinary and Animal Sciences	60	Pakistan	Asia
Mahidol University	50	Thailand	Asia
BahauddinZakariya University	49	Pakistan	Asia
King Saud University	48	Saudi Arabia	Asia
National Research Centre	48	Egypt	Africa
Yunnan Agricultural University	46	China	Asia
KhonKaen University	41	Thailand	Asia
Central Food Technological Research Institute	38	India	Asia
Konkuk University	36	South Korea	Asia
UniversitiSains Malaysia	36	Malaysia	Asia
Cairo University	34	Egypt	Africa
University of Limpopo	32	South Africa	Africa
Federal University of Technology Akure	30	Nigeria	Africa

involved in the research whose contributions were not obvious at the present could contribute to the field and their impact felt much later. The predominance of India in Moringa research is because they are the prevalent prime producer of moringa crop, with an annual production of 2.2 million tonnes of tender fruits from an area of 38,000 ha.

We noticed that collaboration of researchers within India is greater than the rate at which they collaborate with researchers from other countries. As a result, the single country publication (SCP) was 129, and while the multiple country publication was 16 (Figure 2). With Brazil, the SCP was recorded to be 130 and MCP was 5. China (64 SCP and 16 MCP), South Africa (59 SCP and 10 MCP), Pakistan (50 SCP and 9 MCP). The prevalence of SCP among these countries could be due to their population. For example, China and India are the top 2 most populated countries with several competent researchers within their countries who can collaborate in research among themselves,hence, international collaboration might not be the game because they have several universities and research institutes with highly prolific researchers. This means that these countries can work independently and that is why we noticed high SCP in some of the countries on the subject. Another possible reason is that the government of these countries have enough funding and resource to encourage research within their countries. It is worth noticing that most of the countries that collaborated with the researchers from the populated countries might form partnerships because of the expert skills or resources from those countries (India and China). *M. oleifera* is an important plant, which can be used as a spice in food or food additives[46]. Keeping in mind with the climatic condition of these countries, Moringa is a dry-resistant plant and India is the most producer of the plant.

Also, the most cited countries on *M. oleifera* research were investigated and the results are represented in Table 6. The top 5 most cited countries were India (n = 2675), followed by Brazil (n = 1781), South Africa (n = 1420), Malaysia (n = 420) and China (n = 671) based on the data retrieved from SCI-Expanded on the subject study.

Table 5. Top 20 relevant countries on *M. oleifera* research from 2010 to 2019

Country	Articles	Freq	SCP	MCP	MCP_Ratio	Population
India	145	0.14721	129	16	0.11	1,380,004,385
Brazil	135	0.13706	130	5	0.037	212,559,417
China	80	0.08122	64	16	0.2	1,439,323,776
South Africa	69	0.07005	59	10	0.145	59,308,690
Pakistan	59	0.0599	50	9	0.153	220,892,340
Mexico	53	0.05381	37	16	0.302	128,932,753
Nigeria	51	0.05178	34	17	0.333	206,139,589
Malaysia	47	0.04772	36	11	0.234	32,365,999
Egypt	45	0.04569	33	12	0.267	102,334,404
Thailand	30	0.03046	26	4	0.133	69,799,978
USA	26	0.0264	15	11	0.423	331,002,651
Saudi Arabia	22	0.02234	7	15	0.682	34,813,871
South Korea	19	0.01929	12	7	0.368	51,269,185
Italy	17	0.01726	9	8	0.471	60,461,826
Iran	10	0.01015	9	1	0.1	83,992,949
Spain	10	0.01015	6	4	0.4	46,754,778
Portugal	9	0.00914	2	7	0.778	10,196,709
Sweden	9	0.00914	1	8	0.889	10,099,265
Germany	8	0.00812	4	4	0.5	83,783,942
France	7	0.00711	5	2	0.286	65,273,511

*SCP – single country publication, MCP – multiple country population. Population source from worldpopulationreview.com

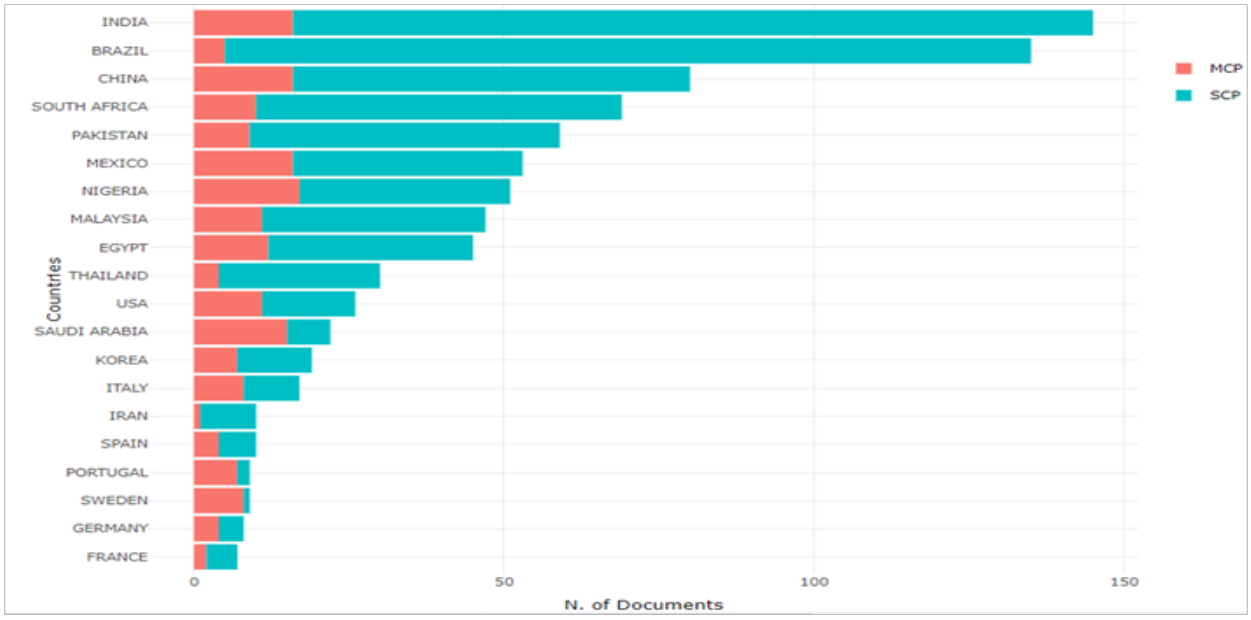

Figure 2. Top 20 relevant countries showing MCP and SCP on *M. oleifera* research from 2010 to 2019.

Table 6. Most cited countries on *M. oleifera* research from 2010 to 2019

Country	Total Citations	Average Article Citations
India	2675	18.448
Brazil	1781	13.193
South Africa	1420	20.58
Malaysia	840	17.872
China	671	8.387
Egypt	539	11.978
Pakistan	534	9.051
USA	518	19.923
Nigeria	498	9.765
Thailand	458	15.267
Mexico	439	8.283
Saudi Arabia	321	14.591
Spain	297	29.7
Korea	258	13.579
Portugal	236	26.222
Italy	222	13.059
Singapore	179	44.75
Germany	125	15.625
Sweden	103	11.444
Australia	101	16.833

7. Authors, Institutions and Countries Collaboration Networks

There are several visualization software such as Bicomb, CitNetExplorer, VOSviewer, BibExcel, Gephi, and Citespace that could enable scholars to determine the relatedness/collaboration, which exists between two or more researchers, institutions and countries to appraise the state-of-the-art research progress and identify hotspots in a particular research field[47]. In the present study, VOS viewer software was explored to map the co-authorship visualization of authors, institutions, and countries. As emphasized by the report of Kamdem *et al.*[48], "co-authorship network identifies the number of publications co-authored by at least two researchers". In this section, we explored VOS viewer software to determine the level of partnership between prolific authors in *M. oleifera* research. We chose fractional counting for the analysis method as described by Kamdem *et al.*[48]. In this approach, as documented by Van Eck and Waltman[49], "the overall weight of each publication is equal to one, and each co-author or each link has a weight of 1/N (where N is the number of co-authors of a publication or the number of links resulting from an action)". Also, it is worthy of note that VOS viewer software designed by Van Eck and Waltman[49] for bibliometric networks is freely available online http://www.vosviewer.com/.

In the present study, for the authors' co-authorship analysis, we set the maximum number of authors per document at 25 and we use the first names of the authors and their initials. We further chose a threshold of 5 to be the minimum number of documents of an author, of which, only 85 authors met the threshold out of 3802 authors and the five 5 top authors were Bergamaso R "(40 documents, 519 citations and 39 total link strength)", Napoleao TH "(22 documents, 389 citations and 22 total link strength)"; Salcedo Vieira AM "(19 documents, 310 citations, 19 total link strength)"; Nishi I "(19 documents, 176 citations, 18 total link strength)" and Vieira MF "(16 documents, 250 citations, 16 total link strength)". Overall, it grouped 85 authors into 22 clusters containing 182 links with 300 total link strength as observed in Figure 3. Authors in a cluster show a related group and the same colour was used to categorize them. The dimension of each circle or node signifies the publications associated with each author, and the level of collaboration between authors is determined by the thickness of the line linking them together[35].

Similarly, institutions' collaboration on *M. oleifera* research was investigated and VOS viewer was used and fractional counting chosen as a method of analysis. The maximum number of institutions per document was set at 25, and a threshold for the minimum number of documents of an author was set at 3 and 173 institutions met the thresholds out of 1115 organizations, and these were further view to determine their relatedness in the field. The 7 topmost institutions on the subject were Univ Fed Pernambuco "(29 documents, 535 citations, 16 total link strength)", Univ Agr Faisalabad "(30 documents, 434 citations, 14 total link strength)", Univ Fort Hare "(19 documents, 539 citations, 13 total link strength)", Bahauddin Zakariya Univ"(15 documents, 157 citations, 12 total link strength)", Univ Estadual Maringa "(42 documents, 536 citations, 9 total link strength)", South China Agr Univ"(19 documents, 252 citations, 10 total link strength)", Natl Res Ctr"(14 documents, 139 citations, 8 total link strength)". The 173 institutions were grouped into 61 Clusters, of which, Cluster 1 had the highest number of items of 13 as represented in Figure

5. The larger the diameter of the sphere, the more the document associated with the institution and the distance between two institutions correlate with their collaboration strength. Univ Estadual Maringa has the sphere diameter followed by Univ Agr Faisalabad.

For the countries' collaboration network, 25 was selected for the maximum number of countries per document, so that the analysis could accommodate many countries and 5 was set as the thresholds, of which 35 countries met the thresholds. The topmost countries were India "(168 documents, 3099 citations, 38 total link strength)", USA "(52 documents, 1080 citations, 32 total link strength)", Saudi Arabia "(40 documents, 637 citations, 31 total link strength)", Egypt "(65 documents, 804 citations, 29 total link strength)", Nigeria "(65 documents, 578 citations, 28 total link strength)", Peoples Republic China "(91 documents, 799 citations, 26 total link strength)", Mexico "(60 documents, 461 citations, 21 total link strength)". However, these 35 countries were grouped into 8 Clusters with 140 links and 210 total link strength. Collaboration is an indispensable aspect of scientific research, and diverse forms of collaboration increase individual researchers' strength and overall influence the total research outputs in a field[50,51]. Science is the name; research collaboration is the game as collaboration brings about an increase in research productivity. It allows resources and ideas to pull together with less labour for the entire individual collaborator because of the division of labour. The government of every country has intensified efforts to encourage research collaborations between researchers within or outside countries. Generally, collaboration has long been acknowledged as one of the crucial factors that greatly influence the scientific impact of a researcher, institution, and country's productivity[39,52]. Even most institutions in the world have created research centres within their domain intending to collaborate with other highly skilled experts in the field of study.One idea is to form interdisciplinary laboratory teams[53].

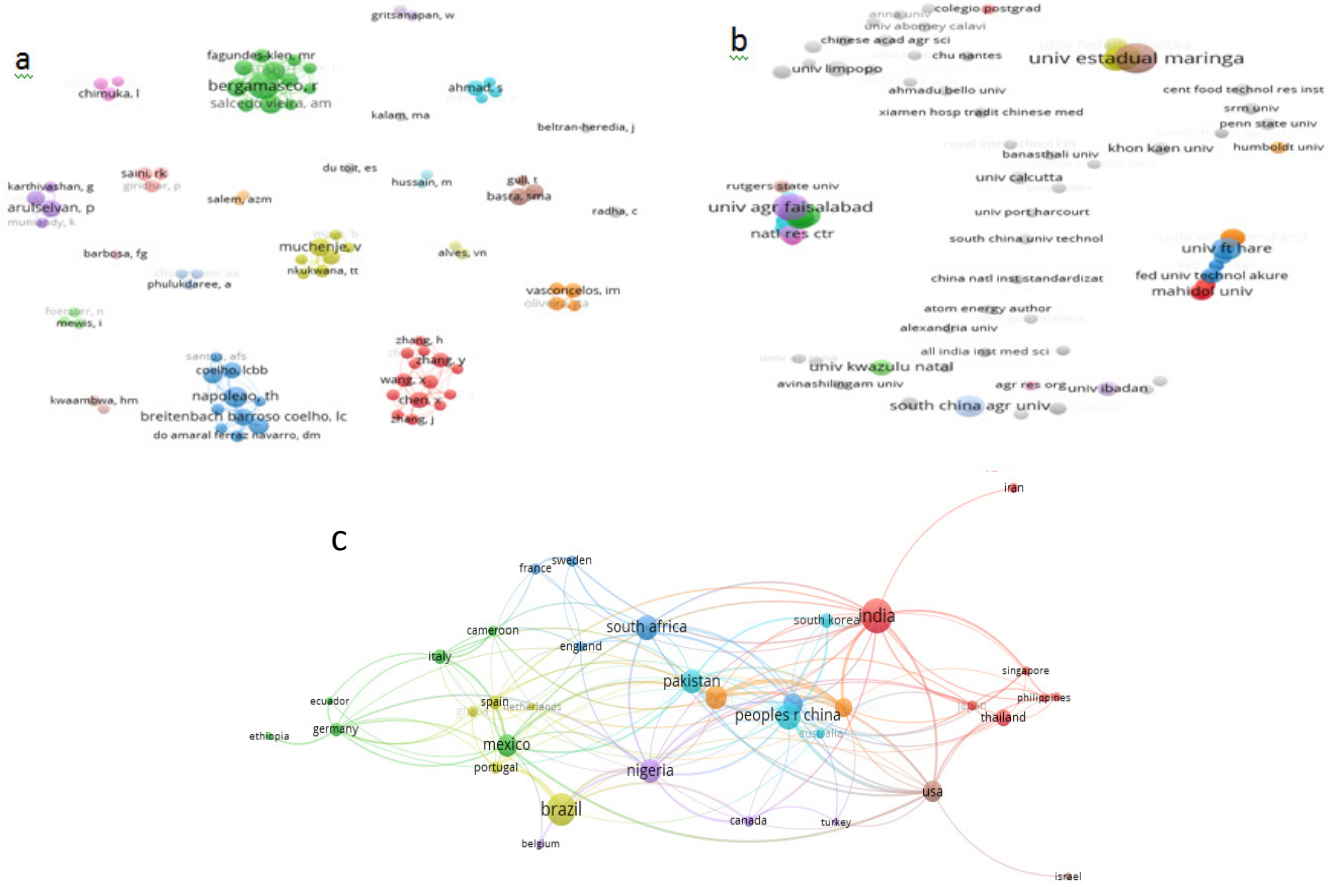

Figure 3. Authors, institutions and countries collaboration networks on *M. oleifera*research from 2010 to 2019.

8. Authors' Co-citation Network

In this section, the scientific relevance of researchers was measured by the number of times that their articles are being cited by another in the same field[48]. Here, we explored the fractional analysis method; we set the threshold of 20 for the minimum number of citations of authors, and 152 authors met the standard out of 22031 authors. The top 7 authors were Anwar F "(397 citations, 366.48 total link strength)", Ndabigengesere A "(192 citations, 174.67 total link strength)", Makkar HPS "(174 citations, 163.06 total link strength)", Fahey JW "(157 citations, 149.35 total link strength)", Siddhuraju P "(131 citations, 128.99 total link strength)", Sreelatha S "(120 citations, 114.34 total link strength)", and Moyo B "(115 citations, 109.05 total link strength)". It grouped the 155 authors into 5 Clusters with 6350 links and 3263.45 total link strength. The size of each circle signifies the total number of citations of the authors on *M. oleifera* research and the software used colour to differentiate each cluster. The relatedness of two co-authorship links is determined by the length of the link between the authors and the thickness of the link signifies the link strength (Figure 4).

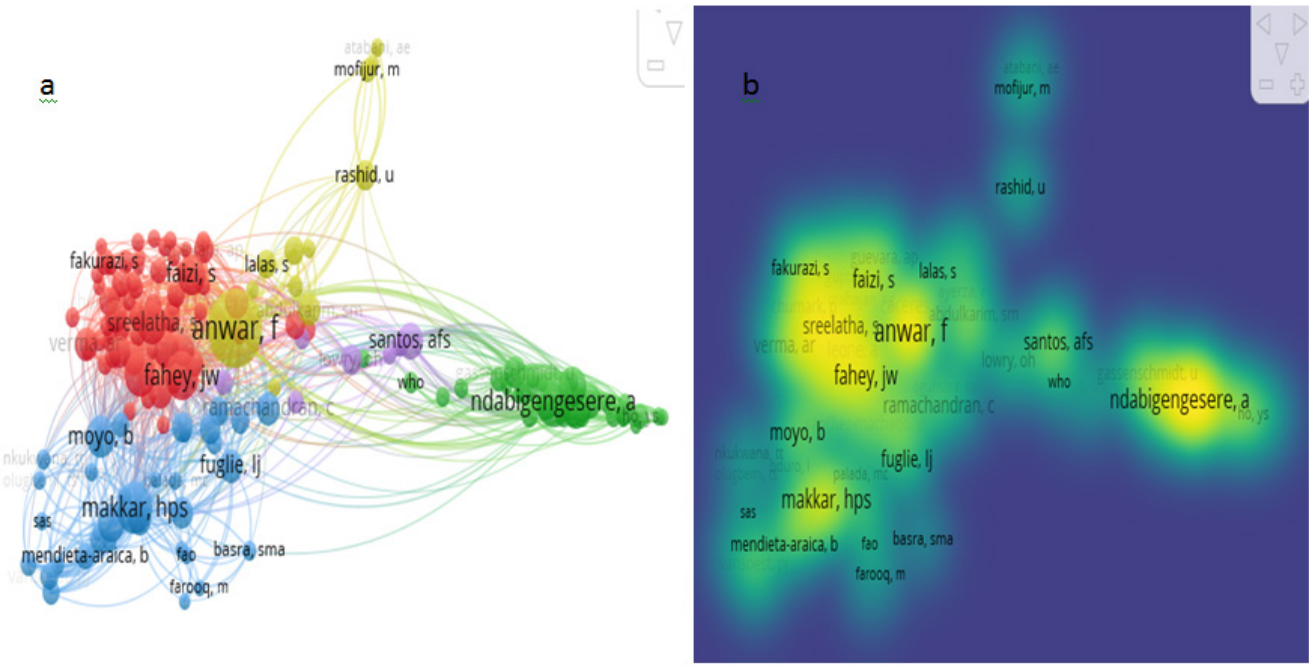

Figure 4. Authors' co-citation network on *M. oleifera* research from 2010 to 2019. **(a)** Network visualization and **(b)** density visualization.

9. Keywords Co-Occurrence Network

Co-occurrence analysis intended to evaluate the connection of keywords established on the number of documents in which they occur together and describe the internal composition relationship and structure in a certain academic domain as well as to reveal the research fronts of that discipline. This type of analysis allows new topics and future directions are easily known and this could be used to monitor research growth in a particular field[54–56]. Author keyword is one of the essential types of information about the research trends from the view of researchers and has been proven to be important for monitoring the development of science. Another metric was used to evaluate the publications based on the title which is known as Keywords Plus. It provides search terms extracted from the titles of papers cited in each new article in the ISI database, is an independent supplement for titlewords and author keywords

In the present study, keyword co-occurrence analysis minutiae the subjects covered in a *M. oleifera* research from 2010 to 2019. For the author's keyword analysis, fractional method analysis was used and 5 was chosen as the minimum number of occurrence of a keyword.

Of this, 99 keywords met the selected thresholds from 2628 keywords identified. The top 8 ranked keywords were *M. oleifera* "(464 occurrences and 265 total link strength)", antioxidant "(38 occurrences and 35 total link strength)", oxidative stress "(31 occurrences and 31 total link strength)", water treatment "(28 occurrences, 26 total link strength)", Moringa "(42 occurrences, 25 total link strength)", biosorption "(21 occurrences, 19 total link strength)", growth "(20 occurrences, 18 total link strength)", coagulation "(22 occurrences, 17 total link strength)". It grouped the 99 author keywords into 12 clusters with 439 links and 531.50 total link strength (Figure 5a). Observed keywords from the articles extracted from SCI-Expanded on the subject indicate research hotspots in the field.

For the past few decades, *M. oleifera* has been an important plant in ethnopharmacology research due to its various medicinal benefits[57–60]. The antioxidant activity of *M. oleifera* has been extensively reported in the literature[22,61–63]. This property could be due to the presence of bioactive compounds in its solvent extracts[64,65]. Apart from its therapeutic potentials, *M. oleifera* has also be used as a coagulant in water treatment which produced great economic benefits in developing countries[65–69].

Keywords have been mandated as part of the criteria for paper submission for all researchers. They are important words from the content of a paper that deals with the focus of the research or topic/subject discussed in the paper. It gives a holistic summary of a paper and enables other researchers to search for a paper on a particular subject[35]. Keywords provide a reasonable description of research hotspots and are very effective in bibliometric analysis when studying knowledge structures in a particular scientific field[35]. Several researchers have used keyword co-occurrence networks for knowledge mapping in the literature[70–72]. The colour of each circle shows keywords in the same cluster and the size of each circle shows the frequency of occurrence of the author keyword[35]. Also, the co-occurrence link is determined by the distance between any two keywords, and the thickness of the connecting line shows the strength of the link. Co-occurrences of title terms show the number of times two terms occur together in a set of documents[48]. In the same way, the frequency of keywords plus among the extracted data was also analysed using the fractional analysis method. A threshold of 5 was the minimum number of occurrences of a keyword, and 251 met the selected measure out of 2533 keywords altogether. The 8 topmost keywords Plus were leaves "(133 occurrences, 127 total link strength)", plant "(81 occurrences, 76 total link strength)", in vitro "(73 occurrences, 71 total link strength)", extract "(71 occurrences, 68 total link strength)", protein "(67 occurrences, 65 total link strength)", removal "(53 occurrences, 52 total link strength)", extracts "(51 occurrences, 50 total link strength)" and antioxidant activity "(50 occurrences, 49 total link strength)". It grouped the 251 keywords plus to 7 clusters with 4369 links and 1708 total link strength (Figure 5b). The keywords highlighted in Figure 5a are the important research hotspots on the subject. This gives a summary of the research works that have been conducted on *Moringa oleifera*. For example, the antioxidant, anticancer, antimicrobial potentials of this plant have been thoroughly investigated.

10. Study Strengths, Limitations and Conclusions

The research trends on *M. oleifera* research were investigated in the present study from the data extracted from SCI-Expanded and analysed through the bibliometric method. The method and the software used for the study are simple, objective, comprehensive, and widely acceptable. However, the articles used in the present study were only written in English from SCI-Expanded and did not include articles written in other languages or other databases that might not give complete coverage of all data on the subject and other quality articles written in other languages might have been missed out. Furthermore, citation analysis was carried out on the authors, since the citations might contain self-citations, and since we did not exclude self-citations of the authors in our analysis, this could probably inflate their ranking scores and thus creating flaws in the h-index of the authors. In addition, we excluded all articles published in 2020 in our analysis because the year is not yet over and could not get the complete publications for the year at this point. Conclusively, the research trends on *M. oleifera* research from 2010 to 2019 were evaluated based on the data retrieved from SCI-Expanded and we observed an increase in annual research outputs over the year. The high research collaboration between the researchers, institutions, and countries in the field could be due to the enormous advantages associated with the plant in various fields that have to attract new researchers to the field. Finally, we hope this study would be a reference source for new researchers that might want to collaborate with existing researchers or join the field in the future to identify trend topics that they could use for their study.

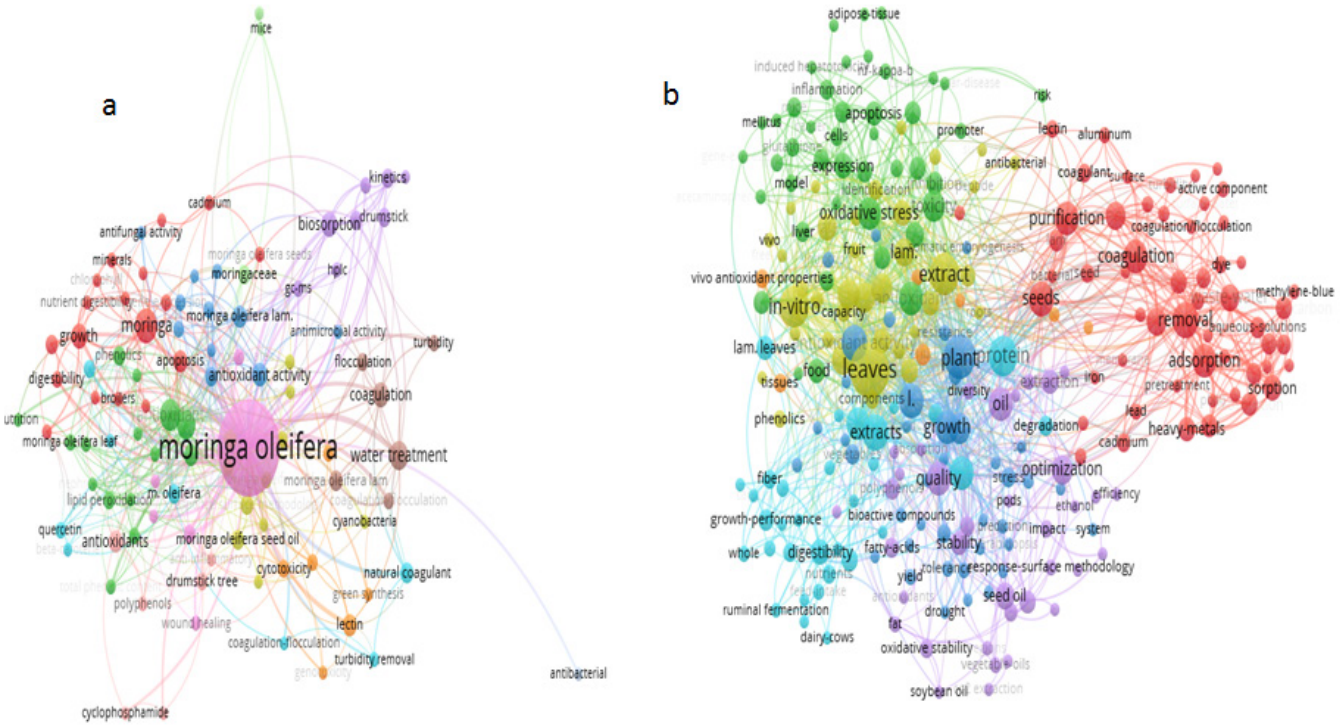

Figure 5. Keywords co-occurrence network. **(a)** Author keywords network and **(b)** keywords Plus on *M. oleifera* research from 2010 to 2019.

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12. Author's Contribution

Conceptualization – K.O and O.O.O.; Data extraction – K.O.; Data analysis – K.O.; Results interpretation – K.O.; Manuscript writeup – K.O; Review – K.O and O.O.O

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