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Top 100 most cited papers on medicinal plants research: A bibliometric review

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***Abstract*---**Background: The idea of the paper is to identify trends and examine the characteristics of the top 100 cited papers on medicinal plants research. Methods: Web of Science citation database was

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queried to identify the citations of the top 100 most cited papers on medicinal plants research. R and Excel statistical software were employed to extract bibliographic data on various parameters such as number of authors, publication year, journal name, country of origin, research collaboration, trend of research *etc*. The top 100 cited papers were extracted for further statistical and visual analysed on various grounds. Results: 100 top-cited articles were identified where these papers published in 51 journals, led by *Journal of Ethnopharmacology* (36 papers) and other journals. All most cited papers were published during 1993 to 2020. The common areas of study were categorized as radical scavenging activities of medicinal plants, antioxidant behaviour of medicinal plants, antiviral and anti-bacterial application, use of medicinal plants in diagnosis and treatment of various diseases such diabetes and cancer *etc.* India and China emerged as leading nations performing medicinal plants research and greater author's collaboration were witnessed in medicinal plants research with an overall collaboration index of 4.39. Conclusion: The top-cited articles published in medicinal plants research can help us recognize the qualitative research, identifications, and trends of research. The analysis provides an insight to the prevalent areas of study being cited within the discipline and interdisciplinary field of practice.

***Keywords*---**Medicinal Plants, Bibliometric, Keyword Co-occurrence, VoSviewer.

Introduction

Medicinal plants and medicines made from plants-derivatives are commonly and widely used in traditional cultures across the globe. They are in widespread use as an alternative to synthetic and chemical drugs [1]. Looking the global importance of the term medicinal plants, a proper definition can be summarized as follows "all higher plants that have been alleged to have medicinal properties, i.e., effect that relates to health or which can be proven to be useful by western standards or which contains constituents that can be used as drugs." [2]. Since ancient times, Medicinal plants have been a vital resource for the global community in terms of healing and creating of many life-saving drugs. Now a days also due to their medicinal importance they are as importance as a primary healthcare mode for approximately 85% of the world's population [19], and as a resource for drug discovery, with around 80% of all synthetic drugs deriving from them [20]. But it is only from the last few hundred years since there is a prolific rise has been recorded in the area of medicinal plants research. Also, due to continuous research and innovation, especially in last two decades, scientific community have witnessed an exponential rise in the publications on medicinal plants research. Therefore, it is very much essential to review most influential publications concerning medicinal plants in terms of citations and related matrix characteristics. For this, 100 most cited papers concerning medicinal plants have been analysed through various authors and journals level metrices using bibliometric means.

Bibliometrics studies comprises set of tools and analysis procedures to map the published and recorded knowledge in a defined field of study [12, 13] and can be used to overview the state-of-the-art status and development trends of a research field, providing ideas and directions for future research [14, 15]. Bibliometric approaches are commonly employed to many areas of research to map their research trend and foci [16–18]. The Web of Science (WoS) Core Collection is the most commonly used platform for bibliometric analyses. To the best of the author's knowledge till date, there has been no comprehensive bibliographic review of studies on medicinal plants using bibliometric utilities have been conducted. Therefore, in this current study we have conducted a bibliometric study to analyse the 100 most cited papers on medicinal plants research using Web of Science citation database as source for retrieving published papers from the year 1989 to 2020. The data provides a comprehensive perspective on the research status of medicinal plants by considering the analysis units such as publication years, total number of citations counts, most relevant authors, most relevant countries/regions, most prolific journal sources, most relevant organizations, and network visualizations such as author's keyword co-occurrences and co-authorship network.

The present study attempts to analyse the top 100 most cited papers on medicinal plants using bibliometric and visualization means. The paper tries to answer following research question:
Q: What is the publication landscape and intellectual structure of top 100 most cited papers on medicinal plants?
In order to answer this main research question, many unitary questions need to answer such as (1) Which were the most prominent countries, authors and affiliations in terms of publications and citations and other metrices? (2) Which were most occurred and linked keywords to analyse the various research fronts? (3) What are the themes and trend of medicinal plants research based on keywords clusters analysis?

Methods

Data Sources and extraction

100 most cited papers on medicinal plants research have been extracted from Web of Science Core collection citation database and the time frame was set from the origin to 2020. The advance search option was selected for querying the search term and under that "Title" as access point has been selected. The keyword TI = ("medicinal plants") has been searched under title only column and all types of documents were selected for displaying the result. Altogether 10505 papers were displayed in search result from which top 100 most cited papers were ranked, selected and downloaded along with their full bibliographic item record [8].

Statistical and visual Analysis

Microsoft Excel and R- Statistical Software [21] was used for descriptive statistical analyses of the publication year, publication types, number of citations, authors, countries/regions, organizations, and journals and their metrices. The VOSviewer

software [22-23] has been used to perform the network analysis on various bibliographic network**.** While creating co-authorship-based map, author's names have been used as unit of analysis, and they were further linked with each other based on their collaboration with each other.

In this map, a threshold of minimum 2 times occurred keywords have been selected**.** The software assigns the nodes to form a cluster which are jointly group together and depends upon the resolution parameter [24]. Each cluster is represented by a colour. More important terms had larger circles represents more important keywords, and strongly related keywords were closer to each other. The connecting curved lines between two terms shows the relationship between them and lines thickness represents a stronger link between two keywords [24].

Results

100 most cited papers along with other metrices

A total of 10505 papers were displayed with medicinal plants as a keyword in their titles. Papers were scrutinized and extracted from WoS database and organized in their descending number of citations. Thus, 100 most cited papers from top have been sorted and downloaded for further analysis. Altogether, all these papers are cited 33991 times, ranging between 186 and 1597 citations each, and 14 papers out of them were cited at least 500 times. Table 1 presents the 100 most cited papers along with their core journals.

Table 1
The 100 most cited papers on Medicinal Plants Research

Rank	TC	TCPY	NTC	Authors	Title	Journals/Sources
1	1597	88.72	2.605	Yizhong Cai [et al.], 2004	Antioxidant activity and phenolic compounds of 112 traditional Chinese medicinal plants associated with anticancer	Life Sciences
2	1083	60.17	1.766	G. Miliauskas, P.R.Venskutonis and T.A.van Beek., 2004	Screening of radical scavenging activity of some medicinal and aromatic plant extracts	Food Chemistry
3	873	72.75	2.148	Shilin Chen [et al.], 2010	Validation of the ITS2 Region as a Novel DNA Barcode for Identifying Medicinal Plant Species	PLOS ONE
4	871	43.55	2.102	J.K.Grover, S.Yadav and V.Vats, 2002	Medicinal plants of India with anti-diabetic potential	Journal of Ethnopharmacology
5	862	53.88	2.254	A. Djeridane [et al.], 2006	Antioxidant activity of some Algerian medicinal plants extracts containing phenolic compounds	Food Chemistry
6	846	49.76	2.089	J. L. Ríos and M.C. Recio, 2005	Medicinal plants and antimicrobial activity	Journal of Ethnopharmacology
7	838	49.29	2.069	Marcy J. Balunasa and A. Douglas	Drug discovery from medicinal plants	Life Sciences

				Kinghorn, 2005		
8	691	46.07	1.976	Farooq Anwar [et al.], 2007	Moringa oleifera: a food plant with multiple medicinal uses	Phytotherapy Research
9	681	40.06	1.681	H. O. Edeoga [et al.], 2005	Phytochemical constituents of some Nigerian medicinal plants	African Journal of Biotechnology
10	645	40.31	1.687	V. Katalinic.[et al.], 2006	Screening of 70 medicinal plant extracts for antioxidant capacity and total phenols	Food Chemistry
11	530	26.50	1.279	Chang W Choi [et al.], 2002	Antioxidant activity and free radical scavenging capacity between Korean medicinal plants and flavonoids by assay-guided comparison	Plant Science
12	518	24.67	1.683	Iqbal Ahmad and Arina Z. Beg, 2001	Antimicrobial and phytochemical studies on 45 Indian medicinal plants against multi-drug resistant human pathogens	Journal of Ethnopharmacology
13	516	32.25	1.35	Yi-Zhong Cai [et al.], 2006	Structure–radical scavenging activity relationships of phenolic compounds from traditional Chinese medicinal plants	Life Sciences
14	513	23.32	1.736	Frank R. Stermitz [et al.], 2000	Synergy in a medicinal plant: Antimicrobial action of berberine potentiated by 5′-methoxyhydnocarpin, a multidrug pump inhibitor	Proceedings of the National Academy of Sciences of the United States of America
15	488	40.67	1.201	W.Y.Huang, Y.Z. Cai and Y.Zhang, 2010	Natural phenolic compounds from medicinal herbs and dietary plants: potential use for cancer prevention	Nutrition and Cancer-an International Journal
16	475	19.79	1.591	Michael Heinrich [et al.], 1998	Medicinal plants in Mexico: healers' consensus and cultural importance	Social Science & Medicine
17	471	31.40	1.347	Leonardo Gobbo-Neto and Norberto P. Lopes, 2007	Medicinal plants: factors of influence on the content of secondary metabolites	Quimica Nova
18	463	19.29	1.551	Iqbal Ahmad, Zafar Mehmood and Faiz Mohammad, 1998	Screening of some Indian medicinal plants for their antimicrobial properties	Journal of Ethnopharmacology
19	461	35.46	1.69	Bushra Sultana, Farooq Anwar and Muhammad Ashraf, 2009	Effect of extraction solvent/technique on the antioxidant activity of selected medicinal plant extracts	Molecules
20	437	27.31	1.143	F. Pourmorad, S.J. Hosseinimehr and N. Shahabimajd, 2006	Antioxidant activity, phenol and flavonoid contents of some selected Iranian medicinal plants	African Journal of Biotechnology
21	365	24.33	1.044	Siddharthan Surveswaran [et al.], 2007	Systematic evaluation of natural phenolic antioxidants from 133 Indian medicinal plants	Food Chemistry
22	361	18.05	0.871	Carmen W. Huie, 2002	A review of modern sample-preparation techniques for the extraction and analysis of medicinal plants	Analytical and Bioanalytical Chemistry
23	358	21.06	0.884	Marta Cristina Teixeira Duarte [et al.], 2005	Anti-Candida activity of Brazilian medicinal plants	Journal of Ethnopharmacology
24	348	23.20	0.995	Ulysses Paulinode Albuquerque [et al.], 2007	Medicinal plants of the caatinga (semi-arid) vegetation of NE Brazil: A quantitative approach	Journal of Ethnopharmacology
25	344	17.20	0.83	M. C. Sabu and Ramadasan Kuttan, 2002	Anti-diabetic activity of medicinal plants and its relationship with their antioxidant property	Journal of Ethnopharmacology
26	343	24.50	1.361	Maria de Fátima	Survey of medicinal plants used in the	Revista Brasileira de

				Agra [et al.], 2008	region Northeast of Brazil	Farmacognosia Brazilian Journal of Pharmacognosy
27	343	17.15	0.828	K Cimanga [et al.], 2002	Correlation between chemical composition and antibacterial activity of essential oils of some aromatic medicinal plants growing in the Democratic Republic of Congo	Journal of Ethnopharmacology
28	342	15.55	1.157	A. Nostro [et al.], 2000	Extraction methods and bioautography for evaluation of medicinal plant antimicrobial activity	Letters in Applied Microbiology
29	341	17.05	0.823	K.M. Solimana and R.I. Badeaa, 2002	Effect of oil extracted from some medicinal plants on different mycotoxigenic fungi	Food and Chemical Toxicology
30	339	17.84	1.345	Lena Galvez Ranilla [et al.], 2010	Phenolic compounds, antioxidant activity and in vitro inhibitory potential against key enzymes relevant for hyperglycemia and hypertension of commonly used medicinal plants, herbs and spices in Latin America	Bioresource Technology
31	332	27.67	0.817	Naheed Ahmad [et al.], 2010	Rapid synthesis of silver nanoparticles using dried medicinal plant of basil	Colloids and Surfaces B: Biointerfaces
32	329	27.42	0.81	Hua-Bin Li.[et al.], 2008	Antioxidant properties in vitro and total phenolic contents in methanol extracts from medicinal plants	LWT - Food Science and Technology
33	305	21.79	1.21	Chi-Chun Wong [et al.], 2006	A systematic survey of antioxidant activity of 30 Chinese medicinal plants using the ferric reducing antioxidant power assay	Food Chemistry
34	300	18.75	0.785	M.Eddouks [et al.], 2002	Ethnopharmacological survey of medicinal plants used for the treatment of diabetes mellitus, hypertension and cardiac diseases in the south-east region of Morocco (Tafilalet)	Journal of Ethnopharmacology
35	300	15.00	0.724	Kittisak Likhitwitayawuid [et al.], 1993	Cytotoxic and Antimalarial Bisbenzylisoquinolme Alkaloids from Stephania erecta	Journal of Natural Products
36	300	13.64	1.015	Alan C. Hamilton, 2004	Medicinal plants, conservation and livelihoods	Biodiversity and Conservation
37	294	10.14	1	Chellaiah Muthu [et al.], 2006	Medicinal plants used by traditional healers in Kancheepuram District of Tamil Nadu, India	Journal of Ethnobiology and Ethnomedicine
38	292	16.22	0.476	Ajit Kar, B.K. Choudhary and N.G. Bandyopadhyay, 2003	Comparative evaluation of hypoglycaemic activity of some Indian medicinal plants in alloxan diabetic rats	Journal of Ethnopharmacology
39	281	17.56	0.735	Muhammad Tahir ul Qamar [et al.], 2020	Structural basis of SARS-CoV-2 3CLpro and anti-COVID-19 drug discovery from medicinal plants	Journal of Pharmaceutical Analysis
40	281	14.79	1.115	C. Leigh Broadhurst, Marilyn M. Polansky, and Richard A. Anderson, 2000	Insulin-like biological activity of culinary and medicinal plant aqueous extracts in vitro	Journal of Agricultural and Food Chemistry
41	279	139.50	1	D. Srinivasan [et al.], 2001	Antimicrobial activity of certain Indian medicinal plants used in folkloric medicine	Journal of Ethnopharmacology
42	279	12.68	0.944	Cailean Clarkson [et al.], 2004	In vitro antiplasmodial activity of medicinal plants native to or naturalised in South Africa	Journal of Ethnopharmacology
43	278	13.24	0.903	Peter M Bork [et	Sesquiterpene lactone containing Mexican	FEBS Letters

				al.], 1997	Indian medicinal plants and pure sesquiterpene lactones as potent inhibitors of transcription factor NF-κB	
44	275	15.28	0.448	Jung, Mankil [et al.], 2006	Antidiabetic agents from medicinal plants	Current Medicinal Chemistry
45	274	10.96	1.006	Toni Rabe and Johannes van Staden, 1997	Antibacterial activity of South African plants used for medicinal purposes	Journal of Ethnopharmacology
46	272	17.00	0.711	A. Ferreira [et al.], 2006	The in vitro screening for acetylcholinesterase inhibition and antioxidant activity of medicinal plants from Portugal	Journal of Ethnopharmacology
47	271	10.84	0.994	L. Tona [et al.], 1998	Antiamoebic and phytochemical screening of some Congolese medicinal plants	Journal of Ethnopharmacology
48	269	16.81	0.704	G.A. Ayoola [et al.], 2008	Phytochemical screening and antioxidant activities of some selected medicinal plants used for malaria therapy in Southwestern Nigeria	Tropical Journal of Pharmaceutical Research
49	263	10.96	0.881	Suheyla Karatas Dugenci, Nazlı Arda and Akın Candan, 2003	Some medicinal plants as immunostimulant for fish	Journal of Ethnopharmacology
50	262	18.71	1.04	Dong-Ping Xu [et al.], 2017	Natural antioxidants in foods and medicinal plants: Extraction, assessment and resources	International Journal of Molecular Sciences
51	260	13.68	1.032	Sukran Kultur, 2007	Medicinal plants used in Kırklareli province (Turkey)	Journal of Ethnopharmacology
52	259	51.80	1	D. Ivanova [et al.], 2005	Polyphenols and antioxidant capacity of Bulgarian medicinal plants	Journal of Ethnopharmacology
53	259	17.27	0.741	Andrea Lubbe and Robert Verpoorte, 2011	Cultivation of medicinal and aromatic plants for specialty industrial materials	Industrial Crops and Products
54	259	15.24	0.64	Tian-yang Wang, Qing Li and Kai-shun Bi, 2018	Bioactive flavonoids in medicinal plants: Structure, activity and biological fate	Asian Journal of Pharmaceutical Sciences
55	248	22.55	1.105	Sheng Qin [et al.], 2009	Isolation, diversity, and antimicrobial activity of rare actinobacteria from medicinal plants of tropical rain forests in Xishuangbanna, China	Applied and Environmental Microbiology
56	248	9.19	1.039	Peter H. Canter, Howard Thomas and Edzard Ernst, 2005	Bringing medicinal plants into cultivation: opportunities and challenges for biotechnology	Trends in Biotechnology
57	245	61.25	1	H Goker [et al.], 2008	Haemostatic actions of the folkloric medicinal plant extract Ankaferd Blood Stopper®	Journal of International Medical Research
58	244	18.77	0.895	H. Jouad [et al.], 2001	Ethnobotanical survey of medicinal plants used for the treatment of diabetes, cardiac and renal diseases in the North centre region of Morocco (Fez–Boulemane)	Journal of Ethnopharmacology
59	241	14.18	0.595	T. Essawi and M.Srour, 2000	Screening of some Palestinian medicinal plants for antibacterial activity	Journal of Ethnopharmacology
60	238	17.00	0.944	Pulok K. Mukherjee [et al.], 2006	Leads from Indian medicinal plants with hypoglycemic potentials	Journal of Ethnopharmacology
61	238	11.33	0.773	Enzo A. Palombo, 2011	Traditional medicinal plant extracts and natural products with activity against oral bacteria: potential application in the prevention and treatment of oral diseases	Evidence-Based Complementary and Alternative Medicine
62	238	8.81	0.997	Si Eun Lee [et al.],	Screening of medicinal plant extracts for	Life Sciences

				2003	antioxidant activity	
63	237	10.77	0.802	A.J.Vlietinck [et al], 1995	Screening of hundred Rwandese medicinal plants for antimicrobial and antiviral properties	Journal of Ethnopharmacology
64	236	14.75	0.617	Duduku Krishnaiah, Rosalam Sarbatly and Rajesh Nithyanandam, 2011	A review of the antioxidant potential of medicinal plant species	Food and Bioproducts Processing
65	233	21.18	1.038	Cleyton Marcos de M. Sousa [et al.], 2007	Total phenolics and antioxidant activity of five medicinal plants	Quimica Nova
66	230	12.11	0.913	Tilahun Teklehaymanot and Mirutse Giday, 2007	Ethnobotanical study of medicinal plants used by people in Zegie Peninsula, Northwestern Ethiopia	Journal of Ethnobiology and Ethnomedicine
67	230	8.52	0.964	Letitia M. McCune and Timothy Johns, 2002	Antioxidant activity in medicinal plants associated with the symptoms of diabetes mellitus used by the Indigenous Peoples of the North American boreal forest	Journal of Ethnopharmacology
68	229	20.82	1.02	H.Y.Sohn [et al.], 2004	Antimicrobial and cytotoxic activity of 18 prenylated flavonoids isolated from medicinal plants: Morus alba L., Morus mongolica Schneider, Broussnetia papyrifera (L.) Vent, Sophora flavescens Ait and Echinosophora koreensis Nakai	Phytomedicine
69	225	15.00	0.644	Takuo Okuda, 2005	Systematics and health effects of chemically distinct tannins in medicinal plants	Phytochemistry
70	225	15.00	0.644	Bushra Sultana and Farooq Anwar, 2008	Flavonols (kaempeferol, quercetin, myricetin) contents of selected fruits, vegetables and medicinal plants	Food Chemistry
71	225	11.25	0.543	Anna K.Jager, Anne Hutchings and Johannes van Staden, 1996	Screening of Zulu medicinal plants for prostaglandin-synthesis inhibitors	Journal of Ethnopharmacology
72	222	12.33	0.362	K. Das, R. K. S. Tiwari and and D.K. Shrivastava, 2010	Techniques for evaluation of medicinal plant products as antimicrobial agents: Current methods and future trends	Journal of Medicinal Plants Research
73	221	13.00	0.546	B.Kumar [et al.], 2007	Ethnopharmacological approaches to wound healing—Exploring medicinal plants of India	Journal of Ethnopharmacology
74	216	15.43	0.857	Ngo Van Hai, 2015	The use of medicinal plants as immunostimulants in aquaculture: A review	Aquaculture
75	215	8.27	1	M.R.Gonzalez-Tejero. [et al.], 2008	Medicinal plants in the Mediterranean area: Synthesis of the results of the project Rubia	Journal of Ethnopharmacology
76	213	17.75	0.524	C. W. Fennell [et al.], 2004	Assessing African medicinal plants for efficacy and safety: pharmacological screening and toxicology	Journal of Ethnopharmacology
77	213	14.20	0.609	Mohammed S. Ali-Shtayeh, Zohara Yaniv and Jamal Mahajna, 2000	Ethnobotanical survey in the Palestinian area: a classification of the healing potential of medicinal plants	Journal of Ethnopharmacology
78	212	30.29	1	Luiz Rodrigo, Saldanha Gazzaneo, Reinaldo Farias Paiva de Lucena	Knowledge and use of medicinal plants by local specialists in a region of Atlantic Forest in the state of Pernambuco (North eastern Brazil)	Journal of Ethnobiology and Ethnomedicine

				and Ulysses Paulino de Albuquerque,2005		
79	210	15.00	0.833	Indrani Mitra, Achintya Saha and Kunal Roy, 2010	Exploring quantitative structure–activity relationship studies of antioxidant phenolic compounds obtained from traditional Chinese medicinal plants	Molecular Simulation
80	210	11.67	0.342	B.Auddy [et al.], 2003	Screening of antioxidant activity of three Indian medicinal plants, traditionally used for the management of neurodegenerative diseases	Journal of Ethnopharmacology
81	209	9.50	0.707	Mahmud Tareq Hassan Khan [et al.], 2005	Extracts and molecules from medicinal plants against herpes simplex viruses	Antiviral Research
82	206	12.12	0.509	Xue Qing Yang [et al.], 2013	Maxent modeling for predicting the potential distribution of medicinal plant, Justicia adhatoda L. in Lesser Himalayan foothills	Ecological Engineering
83	203	16.92	0.5	Michael A. Huffman, 2003	Animal self-medication and ethno-medicine: exploration and exploitation of the medicinal properties of plants	Proceedings of the Nutrition Society
84	203	10.68	0.806	Piergiorgio Pietta, Paolo Simonetti, and Pierluigi Mauri, 1998	Antioxidant Activity of Selected Medicinal Plants	Journal of Agricultural and Food Chemistry
85	202	11.88	0.499	Joao B. Calixto, 2005	Twenty-five years of research on medicinal plants in Latin America: A personal view	Journal of Ethnopharmacology
86	199	22.11	1	A.H. Atta and A. Alkofahi, 1998	Anti-nociceptive and anti-inflammatory effects of some Jordanian medicinal plant extracts	Journal of Ethnopharmacology
87	199	10.47	0.79	N.A.Awadh Ali [et al.], 2001	Screening of Yemeni medicinal plants for antibacterial and cytotoxic activities	Journal of Ethnopharmacology
88	199	8.29	0.667	V. Prashanth Kumar [et al.], 2006	Search for antibacterial and antifungal agents from selected Indian medicinal plants	Journal of Ethnopharmacology
89	198	11.65	0.489	S. Chanda and R. Dave, 2009	In vitro models for antioxidant activity evaluation and some medicinal plants possessing antioxidant properties: An overview	African Journal of Microbiology Research
90	198	8.25	0.663	Allison L. Adonizio [et al.], 2006	Anti-quorum sensing activity of medicinal plants in southern Florida	Journal of Ethnopharmacology
91	197	9.38	0.64	Werner Fabry, Paul O. Okemo and Rainer Ansorg, 1998	Antibacterial activity of East African medicinal plants	Journal of Ethnopharmacology
92	195	12.19	0.51	Kamonnate Srithi...[et al.], 2009	Medicinal plant knowledge and its erosion among the Mien (Yao) in northern Thailand	Journal of Ethnopharmacology
93	194	14.92	0.711	W.Y. Huang [et al.],2008	Biodiversity of endophytic fungi associated with 29 traditional Chinese medicinal plants	Fungal Diversity
94	193	12.06	0.505	Tania Maria de Almeida Alves [et al.], 2000	Biological Screening of Brazilian Medicinal Plants	Memorias Do Instituto Oswaldo Cruz
95	193	8.04	0.647	Lin Zhang [et al.], 2011	Antioxidant and Anti-inflammatory Activities of Selected Medicinal Plants Containing Phenolic and Flavonoid Compounds	Journal of Agricultural and Food Chemistry
96	192	14.77	0.704	Karen Hardy [et al.], 2012	Neanderthal medics? Evidence for food, cooking, and medicinal plants entrapped in dental calculus	Naturwissenschaften

97	190	13.57	0.754	S. A. A. Jassim and M.A. Naji, 2003	Novel antiviral agents: a medicinal plant perspective	Journal of Applied Microbiology
98	189	8.59	0.639	Donald P. Briskin, 2000	Medicinal Plants and Phytomedicines. Linking Plant Biochemistry and Physiology to Human Health	Plant Physiology
99	188	17.09	0.837	E. Roeder, 1995	Medicinal plants in Europe containing pyrrolizidine alkaloids	Pharmazie
100	186	18.60	1	T.M. Kutchan, 1995	Alkaloid Biosynthesis[mdash]The Basis for Metabolic Engineering of Medicinal Plants.	Plant Cell

The most cited paper was the "*Antioxidant activity and phenolic compounds of 112 traditional Chinese medicinal plants associated with anticancer*" authored by Cai Yz; et.al. (2004) published in '*Life Sciences*' Journal. The paper was cited 1597 times. Majority of the papers were published during the 2000-2010. The oldest paper,*" Cytotoxic and antimalarial bisbenzylisoquinoline alkaloids from stephania-erecta*" was published in 1993 in Journal of Natural Products and has been cited 300 times. The newest paper is related to corona virus by MT ul Qamar et al. (2020) cited 281 times.

Most relevant sources and their diversity

The top 100 cited papers were covered by 51 journal sources. Journal of Ethnopharmacology (36) an interdisciplinary journal devoted to indigenous drugs, came out as the most productive journal covering alone 36% papers from the top 100 list. The other top 4 *sources were Food Chemistry, Life Sciences, Journal of Agricultural and Food Chemistry* and *Journal of Ethnobiology and Ethnomedicine with six, four, three and three papers respectively.* Top 7 journals covered 56% of the 100 most cited papers. The rest 46 journals published one paper each making nature of medicinal plant research landscape diverse and interdisciplinary. It is interesting to note that the diversity of papers published on medicinal plants research also comprises the field of Basic Sciences such as, Chemistry and Microbiology(*Analytical and Bioanalytical Chemistry,* 1 paper & *Applied and Environmental Microbiology*, 1 paper), the field of Food Sciences and Agriculture (*Journal of Agricultural and Food Chemistry, 3 papers*), the field of medicine and pharmacology (*Antiviral research, 1 paper & Asian Journal of Pharmaceutical sciences, 1 paper*) and also the field of Ecological Engineering & Conserving the Biodiversity *(Ecological Engineering, 01 paper & Biodiversity and Conservation, 01 paper*).

Most Productive Countries and Affiliations

The two biggest Asian countries India and China emerged as the most productive countries (based on corresponding author's country) publishing majority of the top cited papers on medicinal plants. The two nations have jointly topped the list with first and second in terms of the greatest number of highly cited papers with 14 and 13 papers respectively, however, China came out as the most cited country with 6022 citations followed by India (4572 citations), Brazil (08 papers, 2338 citations) and United States (07 papers, 2680 citations).

A total of 148 affiliations were identified, where the universities were the most participative. Among them, the top ten most productive affiliations/institutions

with the highest number of papers were The University of Hong Kong has the leadership (12 papers), followed by the University of Agriculture, Pakistan (5 papers), University of Illinois, USA (4 papers) Aligarh Muslim University, India (3 papers), The National Research Centre, Egypt (03 papers), University of Freiburg, Germany (03 papers), University of Kinshasa, Congo (03 papers), Western Sydney University, Australia (03 papers) and Andong National University, South Korea (02), and Jadavpur University, India (02 papers).

Most Productive authors and author's productivity

There was total 402 authors appearances were recorded with 4.02 average authors per paper while 4.37 co-authors per papers ranging from 1 to 17. A total of 11 Single authored papers were recorded while number of multi-authored papers were 391 (97.26%) which speaks the sound collaboration in medicinal plants research with an overall collaboration index of 4.39. Figure. 1 shows the tree-map of 50 most frequently used author's keywords in medicinal plants research papers. The keyword medicinal plants occurred 34 times, consequently, antioxidant activity 11 times, Flavonoids and antibacterial activity occurred 8 and 7 times respectively. The frequency of the keyword indicates the hot research topics within the field [5], [6], [7].

Table 2 presented with the top 10 most productive authors who contributed in 100 most cited papers. China's dominance can easily be observed as 6 out of top 10 authors were from China. Yizhong Z. Cai from, Department of Botany, The University of Hong Kong came out as the most contributed author in 100 most cited papers with 3156 Total Citations (TC) across his 5 Total Publications (TP), followed by Harold Corke from Shanghai Jiao Tong University, China with 2668 total citations across his 4 papers with publication start years 2004. Since, their first publication year a greater number of papers were written by these authors but the study only covers those papers which falls in the category of 100 most cited papers.

Table 2
Top 10 most productive authors

S.No.	Keywords	Occurrences	Links	Total Link Strength	Cluster
1	medicinal plants	34	27	53	2
2	antioxidant activity	11	15	27	3
3	flavonoids	08	16	27	6
4	antibacterial activity	07	04	06	1
5	antioxidants	6	10	14	1
6	antimicrobial activity	6	5	10	2
7	diabetes	6	8	11	4
8	ddph	5	15	20	3
9	indian medicinal plants	5	10	13	1
10	ethnobotany	5	4	7	5

Tree-Map of Author's Keywords

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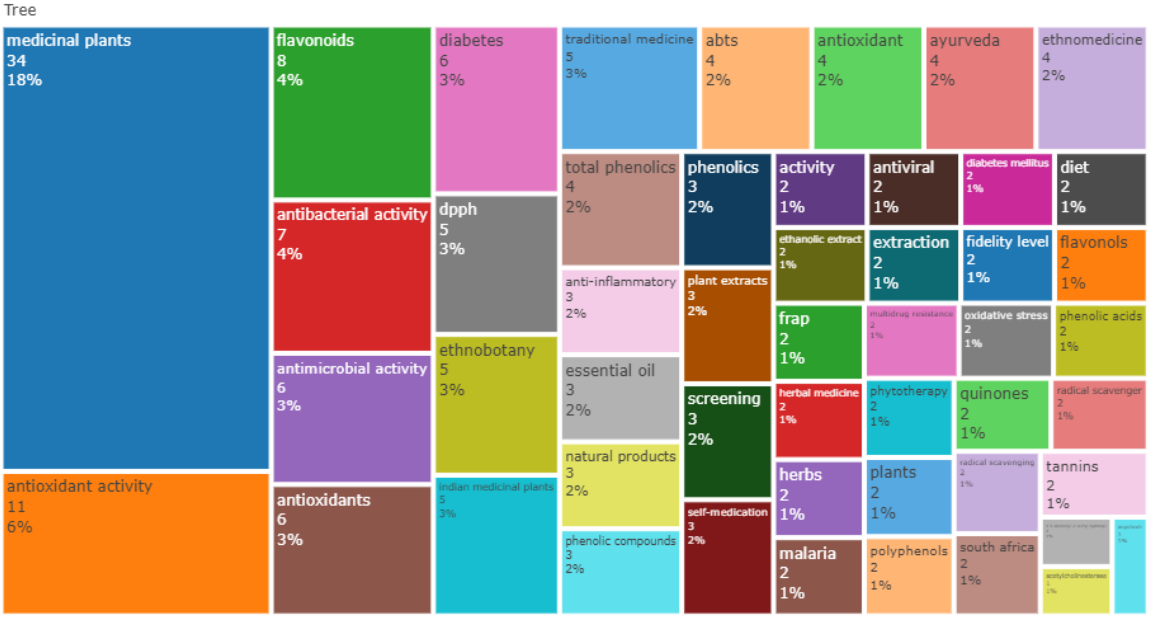

Figure 1. Tree-map of 50 most occurred author's keywords in medicinal plant research

Keyword Co-occurrence of Author's Keywords and Visualization

A keyword co-occurrence network-based mapping is a technique of examining occurrences and links between the keywords in order to get an insight about the knowledge structure of a scientific domain [25]. Figure 2. is a keyword co-occurrence analysis map of 47 most occurred author's keywords in medicinal plants research papers. In order to map the link strengths and total occurrences of each keyword, a cluster-based analysis has been performed. For this, full counting method has been adopted and in order to cover more keywords in the mapping, a threshold of minimum 2 times occurred keywords have been selected. Out of all 304 author's keywords 47 met the threshold and further co-occurrence map has been drawn using these 47 keywords only. All together these 47 keywords were distributed in 8 clusters with their respective number of occurrences, links and link strengths. The keywords with the most total link strength were selected. More important keywords had bigger node size while the most connected keywords were placed very near to each other. Cluster one contained 10 keywords, cluster two and three with 8 keywords, cluster four with 6 keywords, cluster five with 5 keywords, cluster six with 5 keywords, cluster seven with 4 keywords and cluster eight contained only 1 keyword. The map

drawn in figure 2 is an overlay network co-occurrence analysis in which bigger nodes represents the most occurred terms, and thickness of the curved lines represent their links with another keyword and strength of total links in their respective clusters. Table 2 is provided with top ten most occurred author's keywords along with their link and total link strength. The overlay analysis demonstrates occurrences of terms over the years. The keywords with blue nodes depicting trend of research during early 2002 and onwards while keywords with yellow nodes were from recent years topics. Research on oxidative stress, antioxidant behaviour of medicinal plants were such recent research topics around 2008 and onwards.

Table 3

Top 10 most occurred author's keywords along with their links and link strength

Author	Affiliation	TP	TC	h_index	g_index	Pub. Fractionalized	PY_start
CAI YZ	The University of Hong Kong, Hong Kong	5	3156	5	5	1.23	2004
CORKE H	Shanghai Jiao Tong University, China	4	2668	4	4	0.90	2004
SUN M	The University of Hong Kong, Hong Kong	4	2668	4	4	0.90	2004
ANWAR F	University of Agriculture, Pakistan	3	1368	3	3	1.08	2007
LI HB	The University of Hong Kong, Hong Kong	3	864	3	3	0.63	2006
VLIETINCK AJ	University of Antwerp, Belgium	3	836	3	3	0.45	1995
AHMAD I	Aligarh Muslim University, India	2	981	2	2	0.83	1998
ASHRAF M	University of Agriculture, Pakistan	2	1152	2	2	0.58	2007
CHEN F	The University of Hong Kong, Hong Kong	2	605	2	2	0.50	2006
CHENG KW	The University of Hong Kong, Hong Kong	2	605	2	2	0.50	2006

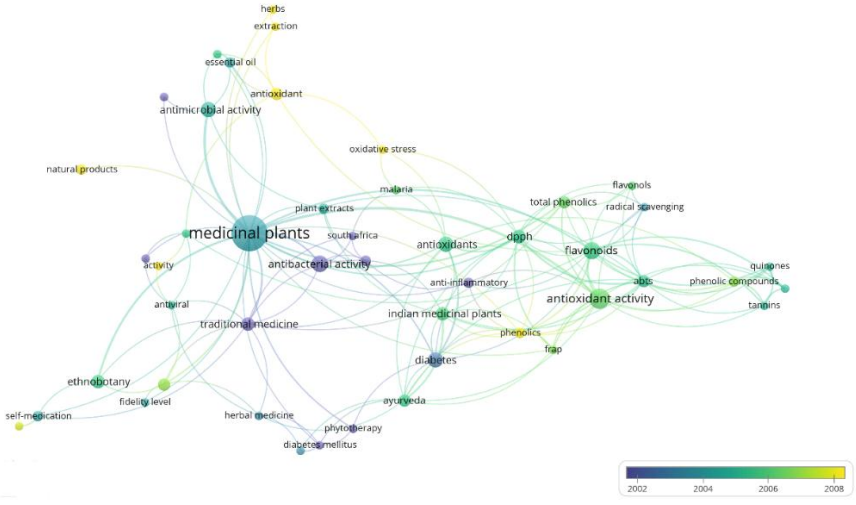

Figure 2. Keyword Co-occurrence map of author's keywords in medicinal plant research

Thematic mapping in medicinal plants research

A thematic map is presented In Figure 3, based on the keywords clustering. This thematic map is a method based on the observations proposed by Cobo et al. [26]. The map can be used to find out and analyse the themes, evolution and trend of a research domain. The map is designed in to four quadrants in which topical themes were defined and placed. The first quadrant (1) contains themes known as motor themes. On a X-Y graph these motor themes possess greater centrality and density and hence, considered essential and evolved quadrant in a research domain. The main themes from quadrant 1 were Traditional medicine, Fidelity level, Flavonoids, Antibacterial activities. These themes-based papers were already reported in 100 most cited list in table 1.

The second quadrant is known as the Niche quadrant characterized by high density but low centrality, means themes have more internal links in here than external links. The theme Natural products was identified in this quadrant on which papers such as *"Traditional medicinal plant extracts and natural products with activity against oral bacteria: potential application in the prevention and treatment of oral diseases"* has been recorded where application of natural products have been discussed for prevention and treatment of several oral diseases.

The third quadrant is called as the emerging or declining themes characterized with low density and low centrality and no theme was identified under this quadrant. At the last, the 4th quadrant consists of basic themes having low density but higher centrality. Themes under this quadrant are very important and concerns basic themes transversal to different area and themes of the research domain. Themes such as anti-inflammatory, self-medication, antioxidants and medicinal plants were basic but core themes on which several numbers of highly cited papers were published and categorized under this study.

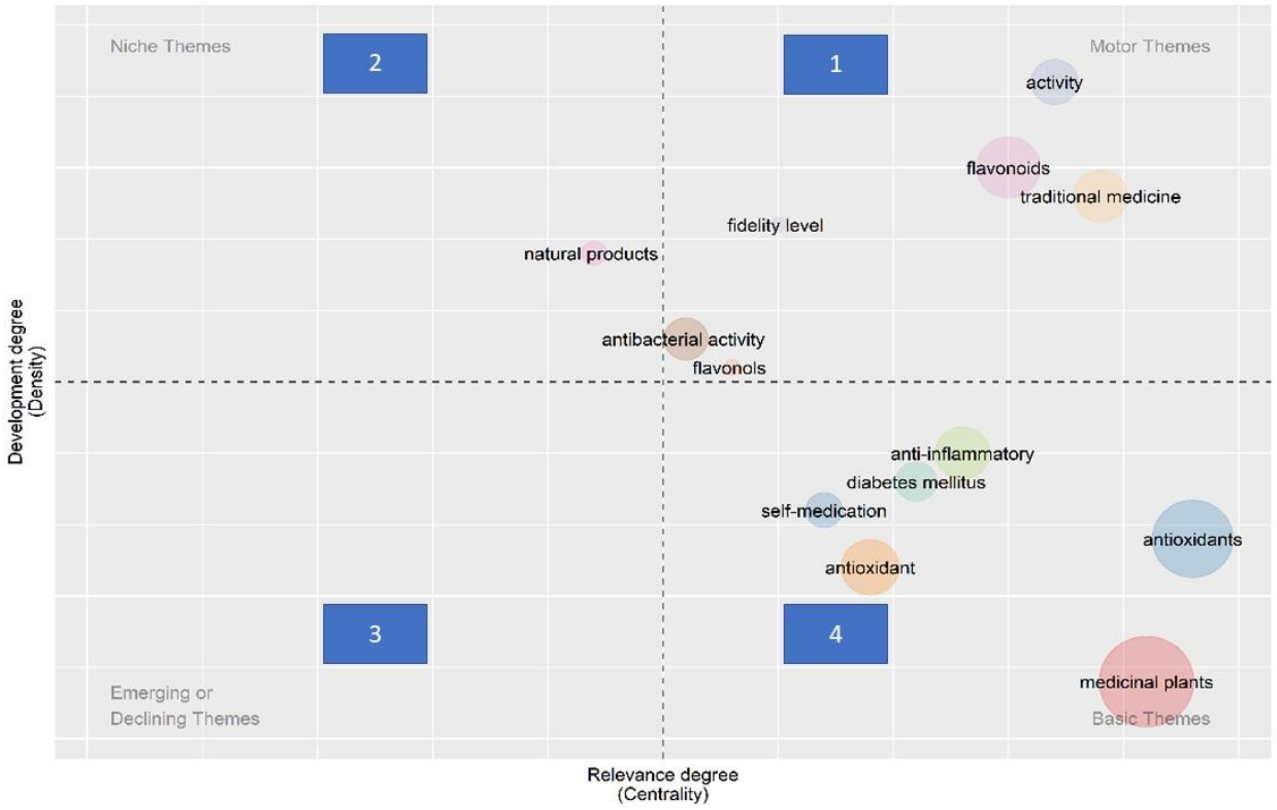

Figure 3. Thematic Map of Author's Keywords distributed in four quadrant

Conclusion

In this study we performed a bibliometric analysis on the 100 most cited papers citing medicinal plants based on various bibliometric and citation metrices. The study revealed that majority of these highly cited papers were performed in two Asian countries India and China and most of them were published in diversified domains such as journal of Ethnopharmacology [3], Life Sciences [4], Journals related to Food Chemistry, Medicine and Agricultural Sciences. The highly cited papers on medicinal plants covered multiple research aspect such as, antioxidants attributes of medicinal plants, identifying medicinal plant species using DNA barcoding, identifying medicinal plants having antimicrobial and antiviral attributes, Potential use of medicinal plants in treating various diseases including cancer *etc.* Although topics such as metabolic engineering of medicinal plants, use in dental calculus are of great importance in recent years, they tend to get less citations.

Analysis of these top cited papers can act as a guide for researchers and frame their policy with respect to exploring new trends in medicinal plant research, funding allocations and to assess the areas of further research. This study can also be very helpful for journal editors to better understand the relevance of research in medicinal plant and its international scientific scenario.

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