Original Research Article

Research on *Azadirachta indica*: A scientometric assessment of global publications output during 1997–2016

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Abstract

Aim: The present study aimed to perform scientometric assessment of global publications output of research on *Azadirachta indica* during 1997–2016.

Methodology: The present study examined 4900 global publications on *A. indica,* as indexed and covered in international Scopus database during 1997–2016 with a view to understanding their growth rate, global publication share, citation impact, international collaborative papers share, distribution of publications by broad subjects, productivity and citation profile of top organizations and authors, preferred media of communication, and bibliographic characteristics of high cited papers.

Results: The global publications registered 7.61% annual average growth rate, and its citation impact averaged to 13.91 citations per paper. The global share of top 10 countries ranged from 1.91% to 31.04%, with the largest share (53.49%) from India, followed by Brazil (6.12%), USA (6.02%), etc., About 86.82% and 85.81% of the cumulative global publication and citation share comes from top 10 countries during 1997–2016. The cumulative global share of top 10 countries increased from 85.89% to 86.35% from 1997–2006 to 2007–2017. Only top three countries registered relative citation index above the world average of 1.0: UK (1.95), USA (1.71), and Germany (1.42) during 1997–2016. Agricultural and biological sciences contributed the largest global publications share of 48.41%, followed by pharmacology, toxicology and pharmaceutics (22.04%), biochemistry, genetics and molecular biology (17.35%), medicine (16.80%), environmental science (13.39%), and other three sub-fields contribution varying from 4.90% to 8.22% during 1997–2016. Eight hundred and forty-eight global organizations and 1589 authors participated in global *A. indica* research, of which the 25 most productive global organizations and authors together contributed 20.65% and 8.92% global publication share and 22.43% and 12.66% global citation share, respectively, during 1997–2016. Among 4387 journal papers (in 959 journals) in global *A. indica* research, the top 20 most productive journals together contributed 43.63% global share of total journal publication output during 1997–2016.

Conclusion: Totally, 78 publications were found to be high cited, as they registered citations from 100 to 1441 during 1997–2016 and they together received 18,498 citations, averaging to 237.15 citations per paper.

Keywords: *Azadirachta indica,* bibliometrics, global research output, medicinal plant, scientometrics

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INTRODUCTION

For centuries, agents derived from natural sources, especially plants have been the primary source of medicine. Neem, also referred to as *Azadirachta indica* is one such plant that has been so named because it provides freedom from all diseases and used for thousands of years in Indian and African continents.[1] The United States has also recognized the significance of research on neem and published a report entitled "Neem-a tree for solving global problems."[2]

A. indica A. Juss (Neem) is a tropical evergreen tree (Fam. Meliacae; Subfam. Melioideae) has universally been accepted as a wonder tree because of its diverse utility and multitude of human benefits in various fields. Multidirectional therapeutic uses of neem have been known in India since the Vedic times. Different parts of the plant including flowers, leaves, seeds, and bark have been used to treat both acute and chronic human diseases; and used as insecticide; antimicrobial, larvicidal, antimalarial, antibacterial, antiviral, and spermicidal. It is widely used also for its cosmetic, medicinal, and agricultural uses.[3]

A. indica, commonly known as neem, has attracted worldwide prominence in recent years. Neem has been extensively used in Ayurveda, Unani, and Homoeopathic medicine and has become a cynosure of modern medicine. More than 140 compounds have been isolated from different parts of neem. All parts of the neem tree have been used conventionally for the treatment of inflammation, infections, fever, skin diseases, and dental disorders.[4]

Different parts of the neem tree are used to treat pyrexia, headache, ulcer, respiratory disorders, cancer, diabetes, leprosy, malaria, dengue, chicken pox, and dermal complications. The tree is popular for its pharmacological attributes such as hypolipidemic, antifertility, microbicidal, antidiabetic, anti-inflammatory, hepatoprotective, antipyretic, hypoglycemic, insecticidal, nematicidal, antiulcer, antioxidant, neuroprotective, cardioprotective, and antileishmaniasis properties. *A. indica* is also rich in various phytochemicals for pharmaceuticals such as alkaloids, steroids, flavonoids, terpenoids, fatty acids, and carbohydrates.[5]

The chemopreventive and anticancer therapeutic efficacy of *A. indica* fractions and compounds could be explained by multiple cellular and molecular mechanisms, including free radical scavenging, carcinogen-detoxification, DNA repair, cell cycle alteration, programmed cell death (apoptosis) and autophagy, immune surveillance, anti-inflammatory, anti-angiogenic, anti-invasive, and anti-metastatic activities as well as their ability to modulate several dysregulated oncogenic signaling pathways.[6]

Literature review

Few bibliometric studies made a bibliometric assessment of Azadirachta research in the past. Thirumagal and Ramesh[7] explored global neem research (392 papers) during 2006–2010. It used PubMed database and focused on various aspects: growth rate, authorship pattern-number of authors, productivity and degree of collaboration, bibliographic format, language-wise and country-wise distribution, identification of core journals using Bradford law, and depicting a clustering view of neem research. Singh[8] examined global Azadirachta research (1198 papers) during 1901–2014. It also used PubMed and focused on chronological growth of literature, authorship pattern and author productivity, fitness of distribution of papers to Bradford's law of scattering, country-wise contribution and identification of core journals. Vijayakumar and Shehbaz[9] studied the authorship pattern of *A. indica* literature, which revealed that collaborative research is more favored than the solo research with a degree of collaboration as 0.94. Similar bibliometric studies have been published on other individual medicinal plants such as *Aloe Vera*,[10] *Curcuma longa*[11] *Glycyrrhiza glabra*,[12] *Ocimum Santum*,[13] *Pheonix dactylifera*,[14] *Tinospora cordifolia*,[15] and *Phyllanthis emblica*.[16]

Objectives

The study examines global *A. indica* research performance, in terms of quantitative and qualitative indicators during 22 years (1997–2016), based on publications indexed in the Scopus database. Its objectives are as follows: (i) to study the growth and distribution of global literature on *A. indica*, (ii) to examine the scientometric profile and characteristics of the 10 most productive countries, 25 most productive organizations, and to 25 most productive authors, (iii) to study the distribution of publication output by broad subject areas and identification of significant keywords, (iv) to identify the medium of communication and the bibliographic characteristics of global highly cited publications on *A. indica*.

METHODOLOGY

The top 10 most productive countries global publications on *A. indica* were sourced from Scopus international database (http://www.scopus.com), using two keywords "*Azadirachta indica*" or "neem" for the years 1997–2016. The TITLE-ABS-KEY (as shown in search string below) tag was searched for the two keywords restricting the hit to the period 1997–2016 in "date range" tag. The

statement becomes the main search string. The main search string was further restricted to individual 10 countries in "country" tag one by one for obtaining publication data of these countries. On further restricting global search string by "subject area tag," "country tag," "source title tag," "journal title name" and "affiliation tag," statistics on the distribution of publications by subject, collaborating countries, author-wise, organization-wise and journal-wise, etc., were obtained. Citation data were obtained from the date of publication to January 25, 2018. Select bibliometric indicators have been used to study the performance of global *A. indica* research.

TITLE-ABS-KEY (*Azadirachta indica* or neem) AND PUBYEAR > 1996 AND PUBYEAR < 2017.

Analysis

The total research output of the world in the field of *A. indica* cumulated to 4900 publications in 20 years during 1997–2016. The *A. indica* annual global research output increased from 95 in the year 1997 to 321 publications in the year 2016, registering 7.61% growth per annum. The cumulative world output in *A. indica* research in 10 years 1997–2006 increased from 1375 to 3525 publications during succeeding 10-year period 2007–2016, registering 156.36% growth. The citation impact of global publications on *A. indica* in 20 years averaged to 13.91 citations per publication (CPP) during 1997–2016; ten-yearly impact averaged to 25.98 CPP for the period 1997–2006, which sharply declined to 9.21 CPP in the succeeding 5-year 2007–2016 [Table 1].

Of the total global publications output, 89.53% (4387) appeared as articles, 6.35% (311) as reviews, 2.29% (112) as conference papers and the rest below 1%: book chapters (0.47%), letters and notes (0.37% each), short surveys (0.22%), editorial (0.14%), erratum (0.12%), conference reviews (0.06%), articles in press (0.04%), and book and retracted (0.02% each).

Top 10 most productive countries in *Azadirachta indica* research

The global research output in the field of *A. indica* research had originated from as many as 112 countries in the world during 1997–2016, of which, 64 published 1–10 papers each in 20 years, 31 countries 11–50 papers each, 9 countries 51–100 papers each, 7 countries 101–300 papers each, and 1 country 2621 papers. The top 10 most productive countries in *A. indica* research contributed 84–2461 publications each during 1997–2016 [Table 2]. The top 10 most productive countries in *A. indica* research accounted for 86.22% global publication share and 85.81% citation share during 1997–2016. Their ten-yearly output accounted for 85.89% global publication share during 1997–2006 which increased to 86.35% during succeeding 10-year period 2007–2016. Country-wise, the global publication share of top 15 countries varied widely 1.71%–53.49% during 1997–2016, with India accounting for the highest publication share (53.49%), followed by Brazil (6.12%), USA (6.02%), Nigeria (5.57%), Pakistan (4.71%), and other countries, namely UK, Germany, China, Egypt, and Malaysia (from 1.71% to 2.45%) during 1997–2016. The global publication share registered an increasing publication share varying from 0.45% to 3.01% in six countries, namely Pakistan, Egypt, Nigeria, India, Malaysia, and China, as against decrease from 0.39% to 4.57% in four countries, namely Brazil, German, UK, and USA in 10 years (1997–2006 and 2007–2016). Only three of the top 10 countries scored relative citation index above the world average of 1.00: UK (1.95), USA (1.71), and Germany (1.42) during 1997–2016. India has though emerged as one of the world leaders in *A. indica* research, its performance in terms of relative citation index (0.96) has below the world average.

Table 1: World output in *Azadirachta indica* research, 1997-2016

Publication period	World			Publication period	World		
	TP	TC	CPP		TP	TC	CPP
1997	95	1463	15.40	2009	325	5314	16.35
1998	107	2151	20.10	2010	392	4105	10.47
1999	98	2402	24.51	2011	441	4136	9.38
2000	118	2552	21.63	2012	419	3617	8.63
2001	96	2597	27.05	2013	361	2982	8.26
2002	122	3895	31.93	2014	402	1992	4.96
2003	158	3716	23.52	2015	351	1156	3.29
2004	175	6221	35.55	2016	321	623	1.94
2005	183	4660	25.46	1997-2006	1375	35,719	25.98
2006	223	6062	27.18	2007-2016	3525	32,459	9.21
2007	237	4406	18.59	1997-2016	4900	68,178	13.91
2008	276	4128	14.96				

TP: Total papers, TC: Total citations, CPP: Citations per paper

International collaboration

The international collaborative output of top 10 most productive countries in *A. indica* research as a national share in the country-wise output varied widely from 7.97% to 65.09%, with an average share of 17.44% during 1997–2016. The highest international collaborative publication share comes from Germany (65.09%), followed by UK (60.0%), USA (56.95%), Egypt (44.44%), Malaysia (39.29%), China (25.91%), Pakistan (19.05%), Nigeria (16.12%), Brazil (10.33%), and India (7.97%) during 1997–2016. Most surprisingly, India's international collaborative share in its national output in *A. indica* research has been comparatively small and lowest, 7.97%.

Subject-wise distribution of research output

The global *A. indica* research output published during 1997–2016 is distributed across eight sub-fields (as identified

in Scopus database classification), with agricultural and biological sciences accounting for the highest publications share (48.41%), followed by pharmacology, toxicology and pharmaceutics (22.04%), biochemistry, genetics, and molecular biology (17.35%), medicine (16.80%), environmental science (13.39%), and other three sub-fields contribution varying from 4.90% to 8.22% during 1997–2016. Its activity index, which computes change in research activity in the discipline over time 1997–2006 to 2007–2016 (world average activity index of a given subject is taken as 100), witnessed increase in pharmacology, toxicology, and pharmaceutics (from 84.47 to 106.06), biochemistry, genetics, and molecular biology (from 95.17 to 101.88), medicine (from 72.31 to 110.80), immunology and microbiology (from 85.77 to 105.55), and veterinary science (from 81.67 to 107.15), as against decrease in agricultural and biological sciences (from 111.99 to 95.32), environmental science (from 124.4 to 90.48), and chemistry (from 111.8 to 95.40) from 1997–2006 to 2007–2016. Chemistry, among various subjects registered the highest citations impact per paper of 19.51 CPP, followed by immunology and microbiology (17.80), pharmacology, toxicology, and pharmaceutics (17.38), medicine (15.55), environmental science (15.49), biochemistry, genetics, and molecular biology (14.57), veterinary science (11.25), and agricultural and biological sciences (10.61) during 1997–2016 [Table 3].

Profile of Top 25 Most Productive Global Organizations

Eight hundred and forty-eight organizations participated in global research on *A. indica* during 1997–2016, of which 715 organizations contributed 1–10 papers each, 85 organizations 11–20 papers each, 41 organizations 21–50 papers each, and 5 organizations 51–64 papers each.

The productivity of top 25 most productive global organizations in *A. indica* research varied from 27 to 64 publications and together they contributed 20.65% (1012) publication share and 22.43% (15,293) citation share during 1997–2016. The scientometric profile of these top 25 organizations is presented in Table 4.

- Ten organizations registered publications output greater than the group average of 40.48: Banaras Hindu University, Varanasi, India (64 papers), Indian Agricultural Research Institute, New Delhi, India (63 papers), University of Karachi, Pakistan (60 papers), Annamalai University, India (55 papers), Tamil Nadu Agricultural University, India (51 papers), Indian Veterinary Research Institute, India and King Saud University, Saudi Arabia (49 papers each),

Table 2: Global publication share of top 10 most productive countries in *Azadirachta indica* during 1997-2016

Serial number	Name of the country	Number of papers			Share of papers			TC	CPP	ICP (%)	RCI
		1997-2006	2007-2016	1997-2016	1997-2006	2007-2016	1997-2016	1997-2016			
1	India	721	1900	2621	52.44	53.90	53.49	34,917	13.32	209 (7.97)	0.96
2	Brazil	88	212	300	6.40	6.01	6.12	3109	10.36	31 (10.33)	0.75
3	USA	128	167	295	9.31	4.74	6.02	7018	23.79	168 (56.95)	1.71
4	Nigeria	60	213	273	4.36	6.04	5.57	2797	10.25	44 (16.12)	0.74
5	Pakistan	35	196	231	2.55	5.56	4.71	2449	10.60	44 (19.05)	0.76
6	U.K.	62	58	120	4.51	1.65	2.45	3256	27.13	72 (60.00)	1.95
7	Germany	47	59	106	3.42	1.67	2.16	2097	19.78	69 (65.09)	1.42
8	China	25	80	105	1.82	2.27	2.14	1021	9.72	27 (25.71)	0.70
9	Egypt	5	85	90	0.36	2.41	1.84	1016	11.29	40 (44.44)	0.81
10	Malaysia	10	74	84	0.73	2.10	1.71	823	9.80	33 (39.29)	0.70
Total		1181	3044	4225	85.89	86.35	86.22	58,503	13.85	737 (17.44)	1.00
World		1375	3525	4900				68,178	13.91		
Share of 10 countries in world total								85.81			

TC: Total citations, CPP: Citations per paper, ICP: International collaborative papers, RCI: Relative citation index

Table 3: Subject-wise breakup of global publications in *Azadirachta indica* research during 1997-2016

Serial number	Subject*	Number of papers (TP)			Activity index		TC	CPP	TP (%)
		1997-2006	2007-2016	1997-2016	1997-2006	2007-2016	2007-2016		
1	Agricultural and biological sciences	747	1630	2377	111.99	95.32	25215	10.61	48.51
2	Pharmacology, toxicology and pharmaceutics	256	824	1080	84.47	106.06	18767	17.38	22.04
3	Biochemistry, genetics and molecular biology	227	623	850	95.17	101.88	12387	14.57	17.35
4	Medicine	167	656	823	72.31	110.80	12798	15.55	16.80
5	Environmental science	229	427	656	124.40	90.48	10159	15.49	13.39
6	Immunology and microbiology	97	306	403	85.77	105.55	7172	17.80	8.22
7	Chemistry	112	245	357	111.80	95.40	6965	19.51	7.29
8	Veterinary science	55	185	240	81.67	107.15	2700	11.25	4.90
World output		1375	3525	4900					
There is overlapping of literature covered under various subjects									

TP: Total papers, TC: Total citations, CPP: Citations per paper

Table 4: Scientometric profile of top 25 most productive global organizations in *Azadirachta indica* research during 1997-2016

Serial number	Name of the organization	TP	TC	CPP	HI	ICP (%)	RCI
1	Banaras Hindu University, Varanasi, India	64	1601	25.02	21	9 (14.06)	1.80
2	Indian Agricultural Research Institute, New Delhi, India	63	865	13.73	16	5 (7.94)	0.99
3	University of Karachi, Pakistan	60	469	7.82	2	5 (8.33)	0.56
4	Annamalai University, India	55	1472	26.76	24	1 (1.82)	1.92
5	Tamil Nadu Agricultural University, India	51	410	8.04	11	4 (7.84)	0.58
6	Indian Veterinary Research Institute, India	49	664	13.55	14	3 (6.12)	0.97
7	King Saud University, Saudi Arabia	49	884	18.04	17	39 (79.59)	1.30
8	UNESP-Universidade EStadual Paulista, Brazil	48	414	8.63	12	2 (4.17)	0.62
9	University of Agriculture, Faisalabad, Pakistan	43	964	22.42	12	10 (23.26)	1.61
10	Federal University of Viscosa, Brazil	41	289	7.05	10	6 (14.63)	0.51
11	Bharathiar University, Coimbatore, India	40	1164	29.10	17	24 (60.00)	2.09
12	Panjab University, Chandigarh, India	37	339	9.16	13	2 (5.41)	0.66
13	Chittaranjan National Cancer Institute, Kolkata, India	37	683	18.46	17	8 (21.62)	1.33
14	University of Ibadan, Nigeria	36	554	15.39	12	7 (19.44)	1.11
15	University of Mysore, India	36	308	8.56	9	2 (5.56)	0.62
16	Universidade de Sao Paulo-USP, Brazil	35	247	7.06	9	3 (8.57)	0.51
17	Indian Institute of Technology, New Delhi	34	473	13.91	12	6 (17.65)	1.00
18	Ahmadu Bello University, Nigeria	32	205	6.41	8	3 (9.38)	0.46
19	Vellore Institute of Technology, India	31	558	18.00	11	3 (9.68)	1.29
20	University of Agricultural Sciences, Bangalore, India	30	103	3.43	5	1 (3.33)	0.25
21	Arid Forestry Research Institute, Jodhpur, India	29	140	4.83	6	1 (3.45)	0.35
22	Aligarh Muslim University, India	29	900	31.03	12	2 (6.90)	2.23
23	Universidade Federal Rural de Pernambuco, Brazil	28	169	6.04	8	1 (3.57)	0.43
24	Central Arid Zone Research Institute, Jodhpur, India	28	684	24.43	8	1 (3.57)	1.76
25	Wageningen University and Research Centre, Netherlands	27	734	27.19	13	23 (85.19)	1.95
Total of 25 organizations		1012	15293	15.11	11.96	171 (16.90)	1.09
Total of world		4900	68178	13.91			
Share of top 25 organizations in world output		20.65	22.43				

TP: Total papers, TC: Total citations, CPP: Citations per paper, HI: h-index, ICP: International collaborative papers, RCI: Relative citation index

UNESP-Universidade Estadual Paulista, Brazil (48 papers), University of Agriculture, Faisalabad, Pakistan (43 papers) and Federal University of Viscosa, Brazil (41 papers) during 1997–2016

- Eleven organizations registered impact and relative citation index above the group average of 15.11 CPP and 1.09 during 1997–2016: Aligarh Muslim University, India (31.03 and 2.23), Bharathiar University, Coimbatore, India (29.10 and 2.09), Wageningen University and Research Centre, Netherlands (27.19 and 1.95), Annamalai University, India (26.76 and 1.92), Banaras Hindu University, Varanasi, India (25.02 and 1.80), Central Arid Zone Research Institute, Jodhpur, India (24.43 and 1.76), University of Agriculture, Faisalabad, Pakistan (22.42 and 1.61), Chittaranjan National Cancer Institute, Kolkata, India (18.46 and 1.33), King Saud University, Saudi Arabia (18.04 and 1.30), Vellore Institute of Technology, India (18.0 and 1.29) and University of Ibadan, Nigeria (19.44 and 1.11) during 1996–2016
- Seven organizations contributed international collaborative publications share above the group average of 16.90%: Wageningen University and Research Centre, Netherlands (85.19%), King Saud University, Saudi Arabia (79.59%), Bharathiar University, Coimbatore, India (60.0%), University of Agriculture, Faisalabad, Pakistan (23.26%), Chittaranjan National Cancer Institute, Kolkata, India (21.62%), University of Ibadan, Nigeria (19.44%), Indian Institute of Technology, New Delhi (17.65%) during 1997–2016.

Profile of top 25 most productive authors

A total of 1589 authors participated in global research on *A. indica* during 1997–2016, of which 1414 authors contributed 1–5 papers each, 141 authors 6–10 papers each, 29 authors 11–20 papers each, and 5 authors 21–37 papers each.

The research productivity in the field of *A. indica* research of top 25 most productive authors varied from 13 to 37 publications. Together they contributed 8.92% (437) global publication share and 12.66% (8628) citation share during 1997–2016. The scientometric profile of these 20 authors is presented in Table 5.

- Seven authors registered publications output above the group average of 17.48: R. Baral (37 papers), A. Bose (31 papers), S. Nagini (30 papers), A. Koul, K. Murugan and B. S. Siddiqui (20 papers each), A. K. Srivastava (18 papers) during 1997–2016
- Ten authors registered impact and relative citation index above the group average of 19.74 CPP and 1.42: K. G. Bhattacharyya (52.15 and 3.75), S. Nagini (38.40 and 2.76), V. C. Verma (37.77 and 2.72), K. Murugan (29.29 and 2.11), N. Chandrasekaran (29.08 and 2.09),

Table 5: Scientometric profile of top 25 most productive authors in *Azadirachta indica* research during 1997-2016

Serial number	Name of the author	Affiliation of the author	TP	TC	CPP	HI	ICP (%)	RCI
1	R. Baral	Chittranjan National Cancer Institute, Kolkata, India	37	683	18.46	17	8 (21.62)	1.33
2	A. Bose	Chittranjan National Cancer Institute, Kolkata, India	31	477	15.39	15	8 (25.81)	1.11
3	S. Nagini	Annamalai University, India	30	1152	38.40	9	0 (0.00)	2.76
4	A. Koul	Panjab University, Chandigarh, India	24	279	11.63	11	1 (4.17)	0.84
5	K. Murugan	Bharathiar University, India	24	703	29.29	15	21 (87.50)	2.11
6	B.S. Siddiqui	University of Karachi, Pakistan	20	306	15.30	11	0 (0.00)	1.10
7	A.K. Srivastava	Indian Institute of Technology, New Delhi, India	18	317	17.61	10	1 (5.56)	1.27
8	G. Gopalakrishnan	SPIC Science Foundation, Chennai, India	17	222	13.06	8	3 (17.65)	0.94
9	F. Abdel-Ghaffar	Cairo University, Egypt	16	441	27.56	13	15 (93.75)	1.98
10	M.R. Forim	Universidade Federal de Sao Carlos, Brazil	15	107	7.13	7	1 (6.67)	0.51
11	K. Sarkar	National Cancer Research Institute, Kolkata, India	15	280	18.67	12	6 (40.00)	1.34
12	V.R.B. Sastry	National Institute of Animal Nutrition and Physiology, Bangalore, India	15	67	4.47	4	2 (13.33)	0.32
13	J.D. Vendramim	ESALQ/USP, Brazil	15	137	9.13	8	0 (0.00)	0.66
14	S. Barik	National Cancer Research Institute, India	14	128	9.14	7	6 (42.86)	0.66
15	X.M. Peng	Research Institute of Resource Insects of Chinese Academy of Forestry, China	14	12	0.86	2	0 (0.00)	0.06
16	H.M. Poehling	Kasetsart University, Germany	14	191	13.64	9	6 (42.86)	0.98
17	Y.X. Zheng	Research Institute of Resource Insects of Chinese Academy of Forestry, China	14	21	1.50	2	0 (0.00)	0.11
18	K.G. Bhattacharyya	Guwahati University, India	13	678	52.15	8	0 (0.00)	3.75
19	N. Chandrasekaran	Vellore Institute of Technology, India	13	378	29.08	7	2 (15.38)	2.09
20	S. Ignacimuthu	Loyola College, Chennai, India	13	359	27.62	8	2 (15.38)	1.99
21	Z. Iqbal	University of Agriculture, Faisalabad, Pakistan	13	290	22.31	9	2 (15.38)	1.60
22	H. Mehlhorn	Heinnch Heine University, Germany	13	341	26.23	11	3 (23.08)	1.89
23	A. Mukherjee	Vellore Institute of Technology, India	13	378	29.08	7	2 (15.38)	2.09
24	G. Suresh	SPIC Science Foundation, Chennai, India	13	190	14.62	8	3 (23.08)	1.05
25	V.C. Verma	Banaras Hindu University, India	13	491	37.77	9	7 (53.85)	2.72
Total of 25 authors			437	8628	19.74	9.08	99 (22.65)	1.42
Total of world			4900	68,178	13.91			
Share of top 25 authors in world total output			8.92	12.66				

TP: Total papers, TC: Total citations, CPP: Citations per paper, HI: h-index, ICP: International collaborative papers, RCI: Relative citation index

A. Mukherjee (29.08 and 2.09), S. Ignacimuthu (27.62 and 1.99), F. Abdel-Ghaffar (27.56 and 1.98), H. Mehlhorn (26.23 and 1.89), and Z. Iqbal (22.31 and 1.60) during 1997–2016

- Nine authors contributed international collaborative publications share above the group average of 22.65% of all authors: F. Abdel-Ghaffar (93.75%), K. Murugan (87.50%), V. C. Verma (53.85%), S. Barik (42.86%), H. M. Poehling (42.86%), K. Sarkar (40.0%), A. Bose (25.81%), H. Mehlhorn (23.08%), and G. Suresh (23.08%) during 1997–2016.

Medium of research communication

Of the total world output on *A. indica* research, 97.14% (4387) appeared in journals, 1.55% (76) in book series, 0.51% (25) in trade publications, and 0.31% (15) in conference proceedings during 1997–2016. 4387 journal papers appeared in 959 journals, of which 770 journals published 1–5 papers each, 104 journals 6–10 papers each, 50 journals 11–20 papers each, 29 journals 21–50 papers each, 3 journals 51–100 papers each, and 2 journals 101–134 papers each during 1997–2016.

The top 20 most productive journals reported 29–134 papers each on *A. indica* research; together they accounted for 43.63% (1037 papers) share of total *A. indica* output published in journals during 1997–2016. *A. indica* research being reported increasingly in journals is gradually becoming a trend; for example, the top 20 most productive journals in 10 years has shown increase in their *A. indica* output from 18.63% to 76.31% share between 1997–2006 and 2007–2016. The top ranking journal is *Journal of Ethnopharmacology* (with 134 papers), followed by *Pestology* (130 papers), *Archives of Phytopathology and Plant Protection* (85 papers), *Indian Journal of Agricultural Sciences* (74 papers), *Journal of Biopesticides* (62 papers), etc., during 1997–2016 [Table 6].

Significant keywords

Around 44 significant keywords having the potential to identify comparative research trends in *A. indica* research studies including pharmacological properties and medicinal uses were discovered from the global literature on *A. indica*. These keywords are listed in Table 7 in the decreasing order of the frequency of their occurrence in the literature during 1997–2016.

Highly cited papers

Seventy-eight highly cited papers in *A. indica* research were identified each having 100–1441 citations (50 papers each in citation range 100–199, 23 papers each in 200–499

Table 6: Top 20 most productive journals in *Azadirachta indica* research during 1997-2016

Serial number	Name of the journal	Number of papers		
		2007-2011	2012-2016	2007-2016
1	Journal of Ethnopharmacology	44	90	134
2	Pestology	52	78	130
3	Archives of Phytopathology and Plant Protection	4	81	85
4	Indian Journal of Agricultural Sciences	24	50	74
5	Journal of Biopesticides	0	62	62
6	International Journal of Pharma and Bio Sciences	0	49	49
7	Parasitology Review	2	41	43
8	Research Journal of Pharmaceutical Biological and Chemical Sciences	0	42	42
9	Crop Protection	17	23	40
10	International Journal of Pharmaceutical Sciences Review and Research	0	38	38
11	International Journal of Pharmacy and Pharmaceutical Sciences	0	38	38
12	Pakistan Journal of Botany	3	35	38
13	Phytotherapy Research	24	12	36
14	Journal of Economic Entomology	24	11	35
15	Phytoparasitica	0	35	35
16	African Journal of Biotechnology	6	28	34
17	Ecology Environment and Conservation	7	26	33
18	Indian Journal of Animal Sciences	19	14	33
19	Asian Journal of Microbiology Biotechnology and Environment Sciences	12	17	29
20	Current Science	13	16	29
Total of 20 journals		251	786	1037
Total global journal output		1347	1030	2377
Share of top 20 journals in global journal output		18.63	76.31	43.63

Table 7: List of significant keywords in literature on *Azadirachta indica* research during 1997-2016

Serial number	Keyword	Frequency	Serial number	Keyword	Frequency
1	*A. indica*	3883	23	Drug isolation	165
2	Neem	768	24	Bacteria (microorganism)	156
3	Plant leaf	720	25	Plant root	156
4	Medicinal plants	720	26	Antimicrobial activity	152
5	Azadirachta	403	27	Antioxidant activity	151
6	Chemistry	323	28	Drug mechanism	147
7	Drug effect	320	29	Enzyme activity	141
8	Insecticide	309	30	*E. coli*	140
9	Neem oil	309	31	Malaria	136
10	Herbaceous agent	278	32	Essential oils	130
11	Plant seed	266	33	Terpenes	130
12	Plant leaves	260	34	Anti-ineffective agents	126
13	Phytotherapy	249	35	Bio-pesticides	121
14	Drug efficacy	246	36	Ethno-botany	118
15	Traditional medicine	238	37	Pesticides	118
16	Pest control	222	38	Flavonoids	112
17	Phytochemistry	194	39	*E. coli*	110
18	Ant0bacterial activity	181	40	Anti-fungal activity	109
19	Drug screening	181	41	Anti-neoplastic activity	107
20	Bark	179	42	Antioxidants	105
21	Herbal medicine	169	43	Integrated pest management	93
22	Diabetes mellitus	169	44	Insect control	88

A. indica: *Azadirachta indica, E. coli*: *Escherichia coli*

citations range, 3 papers each in 500–999 citations range and 2 papers 1000–1441 citations range each) in 22 years during 1997–16. Seventy-eight papers together cumulated a total of 18498 citations, averaging 237.15 citations per paper. Of the 78 highly cited papers, 45 resulted from the participation of research organizations in their role as stand-alone (noncollaborating) institutional authors and remaining 33 from two or more research organizations working in their role as collaborating partners per paper (20 national collaborative and 13 international collaborative). Among 78 highly cited papers, the largest participation was seen from India (42 papers), followed by the USA (11 papers), UK (7 paper), Canada (5 papers), Brazil, Germany, and Nigeria (3 papers each), Bangladesh, Kenya, and Pakistan (2 papers each), Croatia, Costa Rica, Denmark, Ghana, Hong Kong, Japan, Malaysia, South Africa, South Korea, Spain, Thailand, Tongo, and Uganda (1 paper each). These 78 highly cited papers involved the participation of 242 personal authors and 116 research organizations in total globally. Of the 78 highly cited

papers, 56 were published as articles, 20 as reviews papers, and 2 as conference papers. These 78 highly cited papers were published in 63 journals, with 11 papers in *Journal of Ethnopharmacology, 2 papers each in Biomass and Bioenergy, Chemical Engineering Journal, Food Chemistry, Journal of American Mosquito Control Association and Journal of Hazardous Materials* and 1 paper each in 57 other journals.

RESULTS AND CONCLUSION

Research and publications data on *A. indica* sourced from the Scopus database were analyzed in this study to provide a quantitative and qualitative description of its global research output covering 20 years (1997–2016). The study showed that annual and 10-year cumulative global output of *A. indica* research registered 7.61% and 156.36% growth. Its global citation impact averaged to 13.91 citations per paper during 1997–2016, which decreased from 25.98 during 1997–2006 to 9.21 during 2007–2016.

India alone accounted for the highest publication share (53.49%), followed by Brazil (6.12%), USA (6.02%), Nigeria (5.57%), Pakistan (4.71%), and other countries, namely UK, Germany, China, Egypt, and Malaysia (from 1.71% to 2.45%) during 1997–2016. The top 10 most productive countries in *A. indica* research together accounted 86.22% global publication share and 85.81% citation share during 1997–2016. Their 10-year cumulated global publication share increased from 85.89% to 86.35% global publication share during 1997–2006 to 2007–2016. Top ranking developing countries in *A. indica* research dominate in quantity of research, whereas American and western countries in the ranking list dominate more in quality of research. For example, India, Brazil, Nigeria, Pakistan, China, and Egypt mainly from developing countries together accounted for 75.58% global publication share and citation impact (averaging 12.45 citations per paper) and comparatively the USA, UK, and Germany account for only 10.63% global share and citation impact (averaging 23.74 citations per paper) during 1997–2016.

The global publication share registered an increasing publication share varying from 0.45% to 3.01% in 6 countries namely Pakistan, Egypt, Nigeria, India, Malaysia, and China, as against decrease from 0.39% to 4.57% in 4 countries, namely Brazil, German, UK and USA in 10 years period (1997–2006 and 2007–2016). Only three of the top 10 countries scored relative citation index above the world average of 1.0: UK (1.95), USA (1.71) and Germany (1.42) during 1997–2016. The international collaborative publication share of American and western countries in *A. indica* was greater (56.95%–65.09% share) compared to that of major developing countries (7.97%–44.44% share).

Agricultural and biological sciences was the most sought after subject area of *A. indica* research, accounting for (48.41%) the highest publications share, followed by pharmacology, toxicology and pharmaceutics (22.04%), biochemistry, genetics and molecular biology (17.35%), medicine (16.80%), environmental science (13.39%) and other three sub-fields contribution varying from 4.90% to 8.22% during 1997–2016. Among broad subjects, the research activities registered increase pharmacology, toxicology and pharmaceutics, biochemistry, genetics and molecular biology, medicine, immunology and microbiology, and veterinary science, as against decrease in agricultural and biological sciences, environmental science, and chemistry during 1997–2006 to 2007–2016.

The top 25 most productive research organizations and the authors on *A. indica* research collectively contributed 20.65% and 8.92% global publication share and 22.43% and 112.66% global citation share, respectively, during 1997–2016. The leading organizations in terms of publication productivity were: Banaras Hindu University, Varanasi, India (64 papers), Indian Agricultural Research Institute, New Delhi, India (63 papers), University of Karachi, Pakistan (60 papers), Annamalai University, India (55 papers), Tamil Nadu Agricultural University, India (51 papers), Indian Veterinary Research Institute, India and King Saud University, Saudi Arabia (49 papers each), UNESP-Universidade Estadual Paulista, Brazil (48 papers), University of Agriculture, Faisalabad, Pakistan (43 papers) and Federal University of Viscosa, Brazil (41 papers) during 1997–2016. The leading organizations in terms of citation impact per paper were Aligarh Muslim University, India (31.03 and 2.23), Bharathiar University, Coimbatore, India (29.10 and 2.09), Wageningen University and Research Centre, Netherlands (27.19 and 1.95), Annamalai University, India (26.76 and 1.92), Banaras Hindu University, Varanasi, India (25.02 and 1.80), Central Arid Zone Research Institute, Jodhpur, India (24.43 and 1.76), University of Agriculture, Faisalabad, Pakistan (22.42 and 1.61), Chittaranjan National Cancer Institute, Kolkata, India (18.46 and 1.33), King Saud University, Saudi Arabia (18.04 and 1.30), Vellore Institute of Technology, India (18.0 and 1.29) and University of Ibadan, Nigeria (19.44 and 1.11) during 1996–2016.

The journals medium accounted for 97.14% global share in *A. indica* research with top 20 most productive journals accounting for 43.63% of total publications output in journals during 1997–2016. *Journal of Ethnopharmacology*

contributed the largest number of papers (134), *followed by Pestology (130 papers), Archives of Phytopathology and Plant Protection (85 papers), Indian Journal of Agricultural Sciences (74 papers), Journal of Biopesticides (62 papers), etc., during 1997–2016.*

Of the total *A. indica* global research output, 78 publications registered high citations, in the range of 100–1441 citations per paper and collectively these highly cited papers received a total of 18498 citations, averaging to 237.15 citations per paper. These 78 highly cited papers involved the participation of 242 personal authors and 116 research organizations in total across globe and were published in 63 journals. The leading journals were Journal of Ethnopharmacology (11 papers), Biomass and Bioenergy, Chemical Engineering Journal, Food Chemistry, Journal of American Mosquito Control Association and Journal of Hazardous Materials (2 papers each) and 1 paper each in 57 other journals.

Conclusively, this research study reveals that developing countries (India, Brazil, Nigeria, Pakistan, China, Egypt, and Malaysia) dominate in *A. indica* search more in terms of quantity of research, whereas western countries (USA, UK, and Germany) dominate instead more in terms of quality of research. It is suggested that the developing countries and India, in particular, need to give higher priority to plant based research and needs to coordinate, monitor and prioritize their R and D efforts, with higher investment (both financial and manpower) in R and D and increase their international collaboration, with a view to increase their research output and improved research impact.

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Conflicts of interest

There are no conflicts of interest.

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