

Curcuma longa (Medicinal Plant) Research: A Scientometric Assessment of Global Publications Output during 1997-2016

K K Mueen Ahmed¹, B. M. Gupta², Ritu Gupta³

ABSTRACT

The present study examined 5351 global publications in *Curcuma longa* as covered in international Scopus database during 1997-2016, with a view to understand 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. The global publications registered an annual average growth rate of 13.40% and its citation impact averaged to 29.04 citations per paper. Among the top 15 countries, the global share ranged from 1.91% to 31.04%, with India contributing the largest share of 31.04%, followed by USA (13.96%), China (11.55%), etc. 92.66% and 96.84% of the cumulative global publication and citation share comes from top 15 countries during 1997-2016, showing increase in publication share from 89.25% to 93.62% from 1997-2006 to 2007-17. Five countries registered relative citation index above the world average of 1.05: USA (2.29), U.K. (2.08), Taiwan (1.81), Italy (1.23) and South Korea (1.10) during 1997-2016. Medicine, among seven broad subjects, contributed the largest publications share of 37.38%, followed by pharmacology, toxicology and pharmaceuticals (32.07%), biochemistry, genetics and molecular biology (31.68%), agricultural and biological sciences (25.53%), chemistry (12.78%), etc. during 1997-16 Among various organizations and authors contributing to global *Curcuma longa* research, the 20 most productive global organizations and authors together contributed 13.89% and 5.59% global publication share and 20.75% and 14.25% global citation share respectively during 1997-2016. Amongst 5157 journal papers (in 2216 journals) in global *Curcuma longa* research, the top 20 most productive journals contributed 15.92% share of total journal publication output during 1997-2016. Three hundred forty (340) publications were found to be high cited, as they registered citations from 100 to 3869 during 1997-2016 and they together received 81274 citations, which averaged to 239.04 citations per paper. It is suggested that developing countries need to increase their efforts in investment in R & D to increase their output and also to perform better in terms of quality of research.

Key words: *Curcuma longa*, Medicinal plant, Global research output, Scientometrics, Bibliometrics.

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INTRODUCTION

Curcuma longa (turmeric) is a small rhizomatous perennial herb of Zingiberaceae (Ginger family) native to southwest India and grow in Africa, especially in Nigeria and South Africa. The plant produces fleshy rhizomes of bright yellow to orange color in its root system, which are the source of the commercially available spice turmeric. In the form of root powder, turmeric is used for its flavoring properties as a spice, food preservative, and food-coloring agent. Turmeric has a long history of therapeutic uses as it is credited with a variety of important beneficial properties. It is considered as one of the golden resources with immense export potential as medicine, beauty aid, cooking spice, and as a dye to color products, such as tanned leather, cotton cloth, thread and palm

fibers to a golden yellow. Turmeric products are also used as a cheap and more environmentally friendly alternative to chemical pesticides already used. The medicinal values of turmeric are known and used by medical practitioners of Siddha, Ayurveda, and Indian systems of medicine and traditional Chinese medicine. It is also used as a home remedy for many disorders. Different forms of preparations, such as stick, powder, paste, liquid, and so on, are available.¹⁻⁶

C. longa rhizomes are being the source of a bright yellow spice and dye with various medicinal applications. Turmeric's finger-like underground rhizomes are dried and used as a spice or taken as a powder in capsule form. The use of the yellow color of turmeric

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Table 1: World Output in *Curcuma longa* Research, 1997-16.

Publication Period	World			World			
	TP	TC	CPP	TP	TC	CPP	
1997	54	2225	41.20	2009	353	10373	29.39
1998	54	3630	67.22	2010	388	9785	25.22
1999	69	9074	131.51	2011	441	9367	21.24
2000	67	3192	47.64	2012	439	7365	16.78
2001	89	7968	89.53	2013	472	7794	16.51
2002	111	6926	62.40	2014	461	5465	11.85
2003	139	7463	53.69	2015	497	3714	7.47
2004	152	7926	52.14	2016	532	1624	3.05
2005	215	12650	58.84	1997-2006	1181	70382	59.60
2006	231	9328	40.38	2007-2016	4170	85007	20.39
2007	272	12974	47.70	1997-2016	5351	155389	29.04
2008	315	16546	52.53				

TP=Total Papers; TC=Total Citations; CPP=Citations Per Paper

rhizome and other plant derivatives as dyes is on the increase toward replacing synthetic additives with natural compounds. This yellow color is due to the presence of three main curcuminoids in the rhizome namely, curcumin, demethoxycurcumin and bis-demethoxycurcumin. Rhizomes are used in Africa and Asia as a cosmetic for body and face. In Asia, turmeric is widely used as an important constituent of curry powder containing up to 25% turmeric. In Western countries, ground turmeric rhizome is widely used in food industry, in particular as a coloring agent in processed foods and sauces.¹⁻⁶

Rhizomes of *C. longa* are part of numerous traditional medicines used as stomachic, stimulant and blood purifier and to treat liver complaints, biliousness and jaundice for arthritic, muscular disorders, biliary disorders, anorexia, cough, diabetic wounds, hepatic disorders, rheumatism and sinusitis. Mixed with warm milk, they are used to cure common cold, bronchitis, and asthma. Juice from fresh rhizomes is applied against many skin infections, whereas a decoction is effective against eye infections. It has promising pharmaceutical activity against cancer, dermatitis, AIDS, inflammation, high cholesterol levels, and dyspeptic conditions. *C. longa* also has also insecticidal, fungicidal, and nematocidal properties.¹⁻⁶

Turmeric can be regarded as a drug for the management of many diseases, such as cancer, inflammations, microbial infections, diabetes, arthritic, muscular disorders, biliary disorders, anorexia, cough, diabetic wounds, hepatic disorders and sinusitis. Curcumin also displayed various pharmacological activities including antioxidant, antineoplastic, antiviral, anti-inflammatory, anti-bacterial, anti-fungal, anti-diabetic, anticoagulant, antifertility, cardiovascular protective, hepatoprotective and immunostimulant activities in animals. Growing evidence shows that an active component of turmeric, curcumin, may be used medically to treat a variety of dermatologic diseases such as acne, alopecia, atopic dermatitis, facial photoaging, oral lichen planus, pruritus, psoriasis, radiodermatitis and vitiligo.¹⁻⁶

Literature Review

There is no scientometric study on *Curcuma longa* research till today. However, few scientometric studies are available which quantitatively analyze global literature on individual medicinal plants, such as Glycyrrhiza glabra,⁷ Aloe Vera,⁸ Artemisinin,⁹ Azadirachta indica¹⁰ and Phlox dactylifera.¹¹⁻¹²

OBJECTIVES

The main objectives of this study are to study the performance and status of global *Curcuma longa* research during the last 20 years (1997-2016), based on publications indexed in Scopus database. The study focuses on the objectives, such as the characteristics of *Curcuma longa*, including growth rate, publication distribution and citation impact by countries, distribution of global research output by broad subject areas and identification of subject trends using keywords, productivity and citation impact of 20 most productive organizations and authors, important medium of communication and prominent journals and the characteristics of its top 340 highly cited papers

METHODOLOGY

Using the Scopus international database (<http://www.scopus.com>), the present study retrieved and downloaded 20-year (1997-2016) global publication data in *Curcuma longa* research. Keywords, such as "*Curcuma longa*" or "curcumin" or "turmeric" were searched in "Title, Abstract and Keyword" tag for the time period '2007-16'. Finally, this search string was applied for searching global publication data on *Curcuma longa* research. When the main search string with restricted to individual top 12 most productive country name in "country tag", the publication data on the individual country in *Curcuma longa* was obtained. The search string was subsequently refined, using analytical functions and tags in Scopus database, by "subject area tag", "country tag", "source title tag", "journal title name" and "affiliation tag", to get data/information on the distribution of publications output by subject, collaborating countries, author-wise, organization-wise and journal-wise, etc. For citation data, citations to publications were also collected from date of publication till 18 May 2018. For the present study, the search on *Curcuma longa* research was carried out on 22 January 2018. A number of select bibliometric indicators have been used to study the performance of global *Curcuma longa* research.

TITLE-ABS-KEY (*Curcuma longa* or curcumin or turmeric) AND PUBYEAR > 1996 AND PUBYEAR < 2017

ANALYSIS RESULTS

The total research output of the world in field of *Curcuma longa* cumulated to 5351 publications in 20 years during 1997-2016. The annual output of the world in *Curcuma longa* research increased from 54 in the year

Table 2: Global Publication Share of Top 15 Most Productive Countries in *Curcuma longa* during 1997-2016.

S.No	Name of the Country	Number of Papers			Share of Papers			TC	CPP	HI	ICP	%ICP	RCI
		1997-2006	2007-2016	1997-2016	1997-2006	2007-2016	1997-2016						
1	India	364	1297	1661	30.82	31.10	31.04	34185	20.58	87	174	10.48	0.71
2	USA	191	556	747	16.17	13.33	13.96	49592	66.39	113	295	39.49	2.29
3	China	106	512	618	8.98	12.28	11.55	11496	18.60	51	124	20.06	0.64
4	South Korea	59	252	311	5.00	6.04	5.81	9930	31.93	49	65	20.90	1.10
5	Japan	98	155	253	8.30	3.72	4.73	7585	29.98	47	89	35.18	1.03
6	Thailand	46	193	239	3.90	4.63	4.47	5289	22.13	39	71	29.71	0.76
7	Iran	6	149	155	0.51	3.57	2.90	2822	18.21	31	34	21.94	0.63
8	Brazil	36	106	142	3.05	2.54	2.65	2576	18.14	25	44	30.99	0.62
9	Malaysia	9	129	138	0.76	3.09	2.58	1966	14.25	24	46	33.33	0.49
10	Germany	43	89	132	3.64	2.13	2.47	3968	30.06	38	68	51.52	1.04
11	Italy	14	114	128	1.19	2.73	2.39	4581	35.79	33	60	46.88	1.23
12	U.K.	46	76	122	3.90	1.82	2.28	7360	60.33	40	53	43.44	2.08
13	Taiwan	19	87	106	1.61	2.09	1.98	5558	52.43	35	22	20.75	1.81
14	Egypt	8	96	104	0.68	2.30	1.94	1870	17.98	21	43	41.35	0.62
15	Pakistan	9	93	102	0.76	2.23	1.91	1708	16.75	21	37	36.27	0.58
	Total	1054	3904	4958	89.25	93.62	92.66	150486	30.35	43.6	1225	24.71	1.05
	World	1181	4170	5351				155389	29.04				
	Share of 15 Countries in World Total	89.25	93.62	92.66				96.84					

TP=Total Papers; TC=Total Citations; CPP=Citations Per Paper; HI=h-index; ICP=International Collaborative Papers; RCI=Relative Citation Index

Table 3: Subject-Wise Breakup of Global Publications in *Curcuma longa* Research during 1997-2016.

S.No	Subject*	Number of Papers (TP)			Activity Index		TC	CPP	%TP
		2007-11	2012-16	2007-16	2007-11	2012-16			
1	Medicine	436	1564	2000	98.77	100.35	62618	31.31	37.38
2	Pharmacology, Toxicology and Pharmaceutics	355	1361	1716	93.73	101.77	51723	30.14	32.07
3	Biochemistry, Genetics and Molecular Biology	380	1315	1695	101.58	99.55	72038	42.50	31.68
4	Agricultural and Biological Sciences	283	1083	1366	93.87	101.74	28763	21.06	25.53
5	Chemistry	163	521	684	107.97	97.74	21444	31.35	12.78
6	Immunology and Microbiology	44	252	296	67.35	109.25	10018	33.84	5.53
7	Environmental Science	48	150	198	109.84	97.21	4835	24.42	3.70
8	Neurosciences	20	116	136	66.63	109.45	7238	53.22	2.54
9	Veterinary Science	22	93	115	86.68	103.77	1268	11.03	2.15
	World Output	436	1564	2000	98.77	100.35	62618	31.31	37.38

* There is overlapping of literature covered under various subjects
TP=Total Papers; TC=Total Citations; CPP=Citations Per Paper

1997 to 532 publications in the year 2016, registering 13.40% growth per annum. The cumulative world output in *Curcuma longa* research in 10 years 1997-2006 increased from 1181 to 4170 publications during succeeding ten-year period 2007-16, registering 253.09% growth. Of the total global publications output, 80.3% (4297) appeared as articles, 13.77% (737) as reviews, 2.49% (133) as conference papers, 1.14% (61) as book chapters, 0.73% (39) as notes, 0.52% (28) as letters, 0.43% (23) as

editorials, 0.41% (22) as short surveys, 0.15% (8) as erratum, 0.02% (1) each as book, conference review and article in press. The citation impact of global publications on *Curcuma longa* research in 20 years averaged to 29.04 citations per publication (CPP) during 1997-2016; ten-yearly impact averaged to 59.60 CPP for the period 1997-2006, which sharply declined to 20.39 CPP in the succeeding five-year 2007-2016 (Table 1)

Table 4: Scientometric Profile of Top 20 Most Productive Global Organizations in *Curcuma longa* Research during 1997-2016.

S.No	Name of the Organization	TP	TC	CPP	HI	ICP	%ICP	RCI
1	Central Food Technological Research Institute, Mysore, India	57	3477	61.00	29	5	8.77	2.10
2	Chiang Mai University, Thailand	55	2040	37.09	21	22	40.00	1.28
3	University of Texas, M.D.Anderson Cancer Centre, USA	54	13022	241.15	44	14	25.93	8.30
4	Mahidol University, Thailand	50	964	19.28	20	16	32.00	0.66
5	Annamalai University, India	43	1556	36.19	18	4	9.30	1.25
6	Universiti Putra Malaysia	40	540	13.50	13	9	22.50	0.46
7	Indian Institute of Spices Research, Calicut, India	39	517	13.26	13	4	10.26	0.46
8	Chulalongkorn University, Thailand	37	760	20.54	14	8	21.62	0.71
9	Banaras Hindu University, Varanasi	36	266	7.39	10	2	5.56	0.25
10	Mashhad University of Medical Science, Iran	33	903	27.36	17	14	42.42	0.94
11	Ministry of Education, China	33	609	18.45	12	8	24.24	0.64
12	Bhabha Atomic Research Centre, Mumbai, India	32	1542	48.19	18	4	12.50	1.66
13	Shenyang Pharm University, China	31	628	20.26	17	4	12.90	0.70
14	Universiti Kebang saan Malaysia	30	366	12.20	10	7	23.33	0.42
15	Universidade desao Paulo-USP, Brazil	30	470	15.67	14	6	20.00	0.54
16	VA Medical Centre, University of Michigan Medical School, USA	30	1711	57.03	18	5	16.67	1.96
17	Kyung Hee University, South Korea	29	558	19.24	12	0	0.00	0.66
18	Yonsei University, South Korea	28	1703	60.82	14	9	32.14	2.09
19	Kasetsart University, Thailand	28	417	14.89	11	9	32.14	0.51
20	Siksha o Anusandhan University, Bhubaneshwar, India	28	188	6.71	8	2	7.14	0.23
	Total of 20 organizations	743	32237	43.39	16.65	152	20.46	1.49
	Total of World	5351	155389	29.04				
	Share of top 20 organizations in World output	13.89	20.75					

TP=Total Papers; TC=Total Citations; CPP=Citations Per Paper; HI=h-index; ICP=International Collaborative Papers; RCI=Relative Citation Index

Top 12 Most Productive Countries in *Curcuma longa* research

The global research output in the field of *Curcuma longa* research had originated from as many as 105 countries in the world during 1997-2016, of which, 64 published 1-10 papers each in 20 years, 21 countries 11-50 papers each, 5 countries 51-100 papers each, 11 countries 101-300 papers each, 3 countries 301-800 papers each and 1 country 1661 papers. The top 15 most productive countries in *Curcuma longa* research contributed 102 to 1661 publications each during 1997-2016 (Table 2). The top 15 most productive countries in *Curcuma longa* research accounted for 92.66% global publication share and 96.84% citation share during 1997-2016. Their ten-yearly output accounted for 89.25% global publication share during 1997-2006 which increased to 93.62% during succeeding ten-year period 2007-16. Country-wise, the global publication shares of top 15 countries varied widely 1.91% to 31.04% during 1997-16, with India accounting for the highest publication share (31.04%), followed by USA (13.96%), China (11.55% share), South Korea, Japan and Thailand (from 4.47% to 5.81%), Iran, Brazil, Malaysia, Germany, Italy and U.K. (from 2.28% to 2.90%), Taiwan, Egypt and Pakistan (from 1.91% to 1.98%) during 1997-2016. The global publication share registered an

increasing publication share varying from 0.28% to 3.30% in 10 countries namely China, Iran, Malaysia, Egypt, Italy, Pakistan, South Korea, Thailand, Taiwan and India, as against decrease from 0.51% to 4.58% in 5 countries, namely Brazil, German, U.K., USA and Japan in ten years period (1997-2006 and 2007-16). Only five of top 15 countries scored relative citation index above the world average of 1.05: USA (2.29), U.K. (2.08), Taiwan (1.81), Italy (1.23) and South Korea (1.10) during 1997-2016. India has though emerged as one of the world leaders in *Curcuma longa* research, its performance in terms of relative citation index has below the world average (0.71).

International Collaboration

The international collaborative output of top 15 most productive countries in *Curcuma longa* research as a national share in the country-wise output varied widely from 10.48% to 51.52%, with average share of 23.97% during 1997-2016. The highest international collaborative publication share comes from Germany (51.52%), followed by Italy (46.88%), U.K. (43.44%), Egypt (41.35%), USA (39.49%), Pakistan (36.27%), Japan (35.18%), Malaysia (33.33%), Brazil (30.49%) and other countries share between 10.48% to 29.71% during 1997-16. Most surprisingly, India's

Table 5: Scientometric Profile of Top 20 Most Productive Authors in *Curcuma longa* Research during 1997-2016.

S.No	Name of the Author	Affiliation of the Author	TP	TC	CPP	HI	ICP	%ICP	RCI
1	B.B.Aggarwal	University of Texas, M.D.Anderson Cancer Centre, USA	47	12430	264.47	41	12	25.53	9.11
2	A. Sahebkar	Mashhad University of Medical Science, Iran	20	764	38.20	15	14	70.00	1.32
3	S. Nayak	Siksha o Anusandhan University, Bhubaneshwar, India	17	110	6.47	6	1	5.88	0.22
4	B. Sasikumar	Indian Institute of Spices Research, Calicut, India	17	307	18.06	9	1	5.88	0.62
5	J.G.Chung	China Medical University, Taiwan	15	688	45.87	11	3	20.00	1.58
6	W.Jun	Chonam National University, South Korea	15	122	8.13	6	0	0.00	0.28
7	K.Komatu	University of Toyama, Japan	15	442	29.47	11	8	53.33	1.01
8	A. Suksamrarn	Rkhamhaeng University, Thailand	15	260	17.33	10	3	20.00	0.60
9	J.K. Hwang	Yonsei University, South Korea	13	361	27.77	12	6	46.15	0.96
10	L. Pari	Annamalai University, India	13	519	39.92	11	1	7.69	1.37
11	K. Srinivasan	Central Food Technological Research Institute, Mysore, India	13	1092	84.00	13	0	0.00	2.89
12	G.B.Maru	Tata Memorial Hospital, Mumbai	12	531	44.25	11	0	0.00	1.52
13	S.Mohanty	Siksha o Anusandhan University, Bhubaneshwar, India	12	91	7.58	6	0	0.00	0.26
14	R.Kuttan	Amala Cancer Research Centre, Trichur, Kerala, India	11	336	30.55	7	0	0.00	1.05
15	J.Lee	Kyung Hee University, South Korea	11	91	8.27	6	0	0.00	0.28
16	P. Limtrakul	Chiang Mai University, Thailand	11	1005	91.36	10	4	36.36	3.15
17	M.Rahmatullah	University of Development Alternatives, Dhaka, Bangladesh	11	299	27.18	6	0	0.00	0.94
18	Y.J.Surh	Seoul National University, South Korea	11	2832	257.45	10	1	9.09	8.87
19	R.K. Joshi	Siksha o Anusandhan University, Bhubaneshwar, India	10	54	5.40	4	1	10.00	0.19
20	B.T.Kurien	University of Oklahoma Health Services Centre USA	10	232	23.20	6	1	10.00	0.80
		Total of 20 authors	299	22566	75.47	10.55	56	18.73	2.60
		Total of World	5351	155389	29.04				
		Share of top 20 authors in World total output	5.59	14.52					

TP=Total Papers; TC=Total Citations; CPP=Citations Per Paper; HI=h-index; ICP=International Collaborative Papers; RCI=Relative Citation Index

international collaborative share in its national output in *Curcuma longa* research has been comparatively small and lowest, 10.48.

Subject-Wise Distribution of Research Output

The global *Curcuma longa* research output published during 1997-16 is distributed across nine sub-fields (as identified in Scopus database

classification), with medicine accounting for the highest publications share (37.38%), followed by pharmacology, toxicology and pharmaceuticals (32.07%), biochemistry, genetics and molecular biology (31.68%), agricultural and biological sciences (25.53%), chemistry (12.78%), and other 4 sub-fields contribution varying from 2.15% to 5.53% during 1997-16. Its activity index, which computes change in research activity

Table 6: Top 20 Most Productive Journals in *Curcuma longa* Research during 1997-2016.

S.No	Name of the Journal	Number of Papers		
		2007-11	2012-16	2007-16
1	Journal of Ethnopharmacology	20	69	89
2	Journal of Agricultural and Food Chemistry	20	43	63
3	Food Chemistry	6	55	61
4	Phototherapy Research	21	39	60
5	International Journal of Pharmacy and Pharmaceutical Sciences	0	46	46
6	Zhongguo Zhongyao Zachi	23	23	46
7	Zhong Yao Cai Zhongyaoacai. Journal of Chinese Medicinal Materials	12	33	45
8	PLOS One	4	35	39
9	Acta Horticulturae	6	32	38
10	Phytomedicine	6	32	38
11	Evidence-based Complementary and Alternative Medicine	2	33	35
12	Food and Chemical Toxicology	8	27	35
13	Planta Medica	12	23	35
14	Biochemical and Biophysical Research Communication	10	22	32
15	International Journal of Pharma and Bio Sciences	0	30	30
16	Pharmaceutical Biology	9	18	27
17	MBC Complementary and Alternate Medicine	3	23	26
18	Cancer Letters	14	12	26
19	Biological and Pharmaceutical Bulletin	13	12	25
20	Indian Drugs	15	10	25
	Total of 20 journals	204	617	821
	Total global journal output	1149	4008	5157
	Share of top 20 journals in global journal output	17.75	15.39	15.92

in the discipline over time 1997-2006 to 2007-16 (world average activity index of a given subject is taken as 100), witnessed increase in medicine (from 98.77 to 100.35), pharmacology, toxicology and pharmaceuticals (from 93.73 to 101.77), agricultural and biological sciences (from 93.87 to 101.74), immunology and microbiology (from 67.35 to 109.25), neuroscience (from 66.63 to 109.45), and veterinary science (from 86.68 to 103.77), as against decline of research activity in biochemistry, genetics and molecular biology (from 101.58 to 99.55), chemistry (from 107.97 to 97.74) and environmental science (from 109.84 to 97.21) from 1997-2006 to 2007-16. Neuroscience, among various subjects registered the highest citations impact per paper of 53.22 CPP, followed by biochemistry, genetics and molecular biology (42.50), immunology and microbiology (33.84), chemistry (31.35), medicine (31.31), pharmacology, toxicology and pharmaceuticals (30.14), environmental science (24.42), agricultural and biological sciences (21.06) and veterinary science (11.03) during 1997-2016 (Table 3).

Profile of Top 20 Most Productive Global Organizations

One thousand five hundred and three (1503) organizations participated in global research on *Curcuma longa* during 1997-2016, of which 1370 organizations contributed 1-10 papers each, 98 organizations 11-20 papers each, 19 organizations 21-30 papers each, 13 organizations 31-50 papers each and 3 organizations 51-57 papers each.

The productivity of top 20 most productive global organizations in *Curcuma longa* Research varied from 28 to 57 publications and together they contributed 13.89% (743) publication share and 20.75% (32237) citation share during 1997-2016. The scientometric profile of these top 20 organizations is presented in Table 4.

- **Seven of these organizations** registered publications output greater than the group average of 37.15: Central Food Technological Research Institute, Mysore, India (57 papers), Chiang Mai University, Thailand (55 papers), University of Texas, M.D. Anderson Cancer Centre, USA (54 papers), Mahidol University, Thailand (50 papers), Annamalai University, India (43 papers), Universiti Putra Malaysia (40 papers) and Indian Institute of Spices Research, Calicut, India (39 papers) during 1997-2016;
- **Five organizations** registered impact above the group average of 43.35 citations per publication during 1997-16: University of Texas, M.D. Anderson Cancer Centre, USA (241.15), Central Food Technological Research Institute, Mysore, India (61.0), Yonsei University, South Korea (60.82), VA Medical Centre, University of Michigan Medical School, USA (57.03) and Bhabha Atomic Research Centre, Mumbai, India (48.19) during 1997-2016;
- **Ten organizations** contributed international collaborative publications share above the group average of 20.46%: Mashhad University of Medical Science, Iran (42.42%), Chiang Mai University, Thailand (40.0%), Yonsei University, South Korea and Kasetsart University, Thailand (32.14% each), Mahidol University, Thailand (32.0%), University of Texas, M.D. Anderson Cancer Centre, USA (25.93%), Ministry of Education, China (24.24%), Universiti Kebangsaan Malaysia (23.33%), Universiti Putra Malaysia (22.50%) and Chulalongkorn University, Thailand (21.62%) during 1997-2016;
- **Five organizations** registered the relative citation index above the group average (1.49) of all organizations: University of Texas, M.D. Anderson Cancer Centre, USA (8.30), Central Food Technological Research Institute, Mysore, India (2.10), Yonsei University, South Korea (2.09), VA Medical Centre, University of Michigan Medical School, USA (1.96) and Bhabha Atomic Research Centre, Mumbai, India (1.66) during 1997-2016

Profile of Top 20 Most Productive Authors

Three thousand and eighty-three (3083) authors participated in global research on *Curcuma longa* during 1997-2016, of which 2914 authors contributed 1-5 papers each, 153 authors 6-10 papers each and 16 authors 11-47 papers each.

The research productivity in the field of *Curcuma longa* research of top 20 most productive authors varied from 10 to 47 publications. Together they contributed 5.59% (299) global publication share and 14.52% (22566) citation share during 1997-2016. The scientometric profile of these 20 authors is presented in Table 5.

- **Eight authors** registered publications output above the group average of 14.95: B.B. Aggarwal (47 papers), A. Sahebkar (20 papers), S. Nayak and B. Sasikumar (17 papers each), J.G. Chung, W. Jun, K. Komatu and A. Suksamrarn (15 papers each) during 1997-2016;
- **Four authors** registered impact above the group average of 75.47 citations per publication: B.B. Aggarwal (264.47), Y.J. Surh (257.45), P. Limtrakul (91.36) and K. Srinivasan (84.0) during 1997-2016;
- **Seven authors** contributed international collaborative publications

share above the group average of 18.73% of all authors: A. Sahebkar (70.0%), K. Komatu (53.33%), J.K. Hwang (46.15%), P. Limtrakul (36.26%), B.B. Aggarwal (25.53%), J.G. Chung and A. Suksamrarn (@0.0% each) during 1997-2016;

- **Four authors** registered the relative citation index above the group average (2.60) of all authors: B.B. Aggarwal (9.11), Y.J. Surh (8.87), P. Limtrakul (3.15) and K. Srinivasan (2.89) during 1997-2016.

Medium of Research Communication

Of the total world output on *Curcuma longa* research, 96.37% (5157) appeared in journals, 1.68% (90) in book series, 1.08% (58) in books, 0.47% (25) in trade publications, 0.36% (19) as conference proceedings and 0.02% (1 each) as multivolume reference work and unidentified during 1997-2016. 5157 journal papers appeared in 2216 journals, of which 1780 journals published 1-5 papers each, 344 journals, 62 journals 11-20

papers each 17 journals 21-30 papers each, 9 journals 31-50 papers each and 4 journals 51-89 papers each during 1997-2016.

The top 20 most productive journals reported 16 to 64 papers each on *Curcuma longa* research; together they accounted for 15.92% (558 papers) share of total *Curcuma longa* output published in journals during 1997-16. *Curcuma longa* research being reported increasingly in journals is gradually becoming a trend; for example, the top 20 most productive journals in ten years has shown decline in their *Curcuma longa* output from 17.75% to 15.45% share between 1997-2006 and 2007-16. The top ranking journal is *Journal of Ethnopharmacology* (with 89 papers), followed by *Journal of Agricultural and Food Chemistry* (63 papers), *Food Chemistry* (61 papers), *Phototherapy Research* (60 papers each), *International Journal of Pharmacy and Pharmaceutical Sciences* and *Zhongguo Zhongyao Zachi* (46 papers each), etc. during 1997-2016 (Table 6).

Significant Keywords

Around 46 significant keywords having potential to identify comparative research trends in *Curcuma longa* research studies including pharmacological properties and medicinal uses were discovered from the global literature on *Curcuma longa*. These keywords are listed in Table 7 in the decreasing order of the frequency of their occurrence in the literature during 2007-2016.

Highly Cited Papers

A total of 340 highly cited papers in *Curcuma longa* research were identified each having 100 to 83869 citations (232 papers each in citation range 100-199, 53 papers each in 200-299 citations range, 18 papers each in 300-399 citations range, 24 papers each in 400-699 citations range, 7 papers each in 700-999 citations range and 6 paper each 1085-3869 citations range) in 20 years during 1997-16. Together 340 papers cumulated a total of 81274 citations, averaging 239.04 citations per paper. Of the 340 highly cited papers, 150 resulted from the participation of research organizations in their role as stand-alone (non-collaborating) institutional authors and remaining 190 from two or more research organizations working in their role as collaborating partners per paper (92 national collaborative and 98 international collaborative). Among 340 highly cited papers, the largest participation was seen from USA (142 papers), followed by the India (68 papers), South Korea (19 paper), China and Japan (18 papers each), U.K. and Taiwan (13 papers each), Thailand (11 papers), Germany and Italy (9 papers each), Paistan (4 papers), Brazil (3 papers), Iran and Malaysia (2 papers each) etc. These 340 highly cited papers involved the participation of 813 personal authors and 548 research organizations in total across globe. The leading organizations participating in high cited papers were University of Texas, M.D. Anderson Cancer Centre, USA (34 papers), Central Food Technological Research Institute, Mysore, India (11 papers), V.A. Medical Centre, University of Michigan Medical School, USA (8 papers), Chiang Mai University, Thailand (7 papers), Bhabha Atomic Research Centre, Mumbai, India (6 papers), Annamalai University, India (4 papers), China Medical University, Taichung, Taiwan, Chinese University of Hong Kong, Panjab University, Chandigarh, India and Peking University, China (3 papers each), Central Drug Research Institute, Lucknow, India, China Medical University Hospital, Taichung, Taiwan, Jamia Hamdard, Delhi and University of Arizona, USA (2 papers each), etc. The leading authors participating in high cited papers were B.B. Aggarwal (32 papers), A.B. Kunnumakkara (7 papers), Y.J. Surh (6 papers), S. Prasad (5 papers), K. Srinivasan, P. Limtrakul, S.C. Gupta, B. Sung, P. Anand and A. Goel (4 papers each), J.G. Chung, M. Dicato, M. Diederich, J.S. Yang, Y.S. Keum and S.S. Han (3 papers each), etc. Of the 340 highly cited papers, 214 were published as articles, 107 as reviews papers, 14 as conference papers, 3 as short surveys and 2 as letters. These 340 highly cited papers were pub-

Table 7: List of Significant Keywords in Literature on *Curcuma longa* Research during 2007-16.

S.No	Keyword	Frequency	S.No	Keyword	Frequency
1	Curcuma Longa	3476	25	Gene Expression	203
2	Curcumin	2442	26	Drug Isolation	189
3	Curcuma	1421	27	Curcuminoids	188
4	Medicinal Plant	762	28	Diabetes Mellitus	188
5	Drug Effect	686	29	Drug Formulation	186
6	Antioxidant Activity	638	30	Cancer Inhibition	184
7	Metabolism	597	31	Antibacterial Activity	172
8	Apoptosis	546	32	Liver	168
9	Rhizome	510	33	Spice	158
10	Drug Mechanism	493	34	Chinese Medicine	157
11	Drug Efficacy	490	35	Genetics	157
12	Antineoplastic Activity	422	36	Alzheimer Disease	145
13	Oxidation Stress	415	37	Flavonoids	142
14	Enzyme Activity	334	38	Neoplasms	142
15	Herbal Medicine	293	39	Antimicrobial Activity	140
16	Tumor Cell Line	287	40	Breast Cancer	135
17	Inflammation	271	41	Placebo	134
18	Drug Structure	258	42	Diarrhea	126
19	Drug Safety	238	43	Cancer	124
20	Drug Screening	237	44	Abdominal Pain	120
21	Pathology	237	45	Bacteria	109
22	Essential Oils	233	46	Bacterial Infection	26
23	Traditional Medicine	220			
24	Phytochemistry	213			

lished in 204 journals, with 10 papers in *Journal of Ethnopharmacology*, 9 papers in *Biochemical Pharmacology*, 8 papers each in *Cancer Letters*, *Food and Chemical Toxicology* and *Journal of Agricultural and Food Chemistry*, 6 papers in *Planta Medica*, 5 papers each in *Cancer Research*, *Journal of Natural Products*, *Molecular Cancer and Therapeutics*, *Phytotherapy Research* and *Phytomedicine*, 4 papers each in *Advances in Experimental Medicine and Biology*, *Anticancer Research*, *Biofactors*, *Biochemistry and Behavior*, *Bioorganic and Medicinal Chemistry*, *Biochemical and Biophysical Research Communication*, *Carcinogenesis*, *Food Chemistry*, *Journal of Biological Chemistry*, *Molecular Nutrition and Food Research*, *Pharmacology and Journal of Nutrition*, 3 papers each in *Alternative Medicine Review*, *Annals of New York Academy of Sciences*, *Clinical Cancer Research*, *European Journal of Pharmacology*, *Free Radical Biology and Medicine*, *International Journal of Biochemistry and Cell Biology*, *International Journal of Pharmaceutics*, *Journal of Chromatography A*, *Life Sciences*, *Mutation Research* and *Oncogene*, 2 papers each in *AAPS Journal*, *Antioxidants and Redox Signaling*, *Atherosclerosis*, *Biochemica et Biophysica Acta-General Subjects*, *Biomaterials*, *Bioorganic and Medicinal Chemistry Letters*, *Bio resource Technology*, *Brain Research*, *Chemical-Biological Interactions*, *FEBS Letters*, *Fitoterapia*, *Frontier in Biosciences*, *International Journal of Food Science and Nutrition*, *International Journal of Medical Research*, *Journal of Cellular Biochemistry*, *Journal of Alternate and Complimentary Medicine*, *Journal of Chromatography B*, *Malaria Journal*, *Medicinal Research Review*, *Nutrition and Cancer*, *Neurochemical Research*, *Nutrients* and *Wound Repair and Regeneration* and 1 paper each in 153 other journals.

CONCLUSION

Research publications data on *Curcuma longa* sourced from the Scopus database was analysed in this study to provide a quantitative and qualitative description of its global research output covering 20 years period (1997-2016). The study showed that annual and ten-year cumulative global output of *Curcuma longa* research registered 13.40% and 253.09% growth. Its global citation impact averaged to 29.04 citations per paper during 1997-2016, which decreased from 59.60 during 1997-2006 to 20.39 during 2007-16.

More than 57% (between 12.28% to 31.04%) of global *Curcuma longa* research output share was mainly from India, USA and China and USA, 9 others top ranking countries accounted for global share of 30.28% (between 2.28% and 5.81%) and 3 other countries contributed global share of 5.83% (between 1.91% to 1.98%) during 1997-2006. The top 15 most productive countries in *Curcuma longa* research together accounted for a high of 92.66% global share during 1997-2016, which increased from 89.25% to 93.62% from 1997-2006 to 2007-16. Top ranking Asian countries in *Curcuma longa* research dominate in quantity of research whereas American and western countries in the ranking list dominate more in quality of research. For example, India, China, South Korea, Japan, Thailand Iran, Brazil, Malaysia, Egypt, Pakistan and Taiwan mainly from Asia together accounted for 72.119% global share and citation impact (averaging 23.92 citations per paper) and comparatively the USA, Germany, Italy and the U.K. account for only 20.47% global share and citation impact (averaging 52.17 citations per paper) during 1997-2016. The global publication share registered an increasing publication share varying from 0.28% to 3.30% in 10 countries namely China, Iran, Malaysia, Egypt, Italy, Pakistan, South Korea, Thailand, Taiwan and India, as against decrease from 0.51% to 4.58% in 5 countries, namely Brazil, German, U.K., USA and Japan in ten years period (1997-2006 and 2007-16). Only five of top 15 countries scored relative citation index above the world average of 1.05: USA (2.29), U.K. (2.08), Taiwan (1.81), Italy (1.23) and South Korea (1.10) during 1997-2016. The international collaborative publication share of American and western countries in

Curcuma longa was greater (39.49% to 51.52% share) compared to that of major Asian countries (10.48% to 36.27% share).

Medicine was the most sought after subject area of *Curcuma longa* research, accounting for (37.38%) the highest publications share, followed by pharmacology, toxicology and pharmaceuticals (32.07%), biochemistry, genetics and molecular biology (31.68%), agricultural and biological sciences (25.53%), chemistry (12.78%), etc. during 1997-16. Among broad subjects, the research activities registered increase in medicine, pharmacology, toxicology and pharmaceuticals, agricultural and biological sciences, immunology and microbiology, neuroscience and veterinary science, as against decline of research activity in biochemistry, genetics and molecular biology, chemistry and environmental science from 1997-2006 to 2007-16.

The top 20 most productive research organizations and the authors on *Curcuma longa* research collectively contributed 13.89% and 5.59% global publication share and 20.75% and 14.25% global citation share respectively during 1997-16. The leading organizations in terms of publication productivity were: Central Food Technological Research Institute, Mysore, India (57 papers), Chiang Mai University, Thailand (55 papers), University of Texas, M.D.Anderson Cancer Centre, USA (54 papers), Mahidol University, Thailand (50 papers), Annamalai University, India (43 papers), Universiti Putra Malaysia (40 papers) and Indian Institute of Spices Research, Calicut, India (39 papers) during 1997-2016. The leading organizations in terms of citation impact per paper were University of Texas, M.D.Anderson Cancer Centre, USA (241.15), Central Food Technological Research Institute, Mysore, India (61.0), Yonsei University, South Korea (60.82), VA Medical Centre, University of Michigan Medical School, USA (57.03) and Bhabha Atomic Research Centre, Mumbai, India (48.19) during 1997-2016;

The journals medium accounted for 96.37% global share in *Curcuma longa* research with top 20 most productive journals accounting for 15.92% of total publications output in journals during 1997-2016. *Journal of Ethnopharmacology* contributed the largest number of papers (89), *Journal of Agricultural and Food Chemistry* (63 papers), *Food Chemistry* (61 papers), *Phototherapy Research* (60 papers each), *International Journal of Pharmacy and Pharmaceutical Sciences* and *Zhongguo Zhongyao Zachi* (46 papers each), etc.

Of the total *Curcuma longa* global research output, 340 publications registered high citations, in the range of 100 to 3869 citations per paper, and collectively these highly cited papers received a total of 81274 citations, averaging to 239.04 citations per paper. These 340 highly cited papers involved the participation of 813 personal authors and 548 research organizations in total across globe and were published in 204 journals, with 10 papers in *Journal of Ethnopharmacology*, 9 papers in *Biochemical Pharmacology*, 8 papers each in *Cancer Letters*, *Food and Chemical Toxicology* and *Journal of Agricultural and Food Chemistry*, 6 papers in *Planta Medica*, 5 papers each in *Cancer Research*, *Journal of Natural Products*, *Molecular Cancer and Therapeutics*, *Phytotherapy Research* and *Phytomedicine* etc.

Conclusively, this research study reveals that developing countries mainly from (India, China, South Korea, Japan, Thailand, Iran, Brazil, Malaysia, Egypt, Pakistan and Taiwan) dominate in *Curcuma longa* research more in terms of quantity of research, whereas western countries (USA, Germany, Italy and the U.K) dominate instead more in terms of quality of research. It is concluded that the developing countries need to put much more efforts in investment (both financial and manpower) in R & D to increase their output and also to perform better in terms of quality of research. In addition, the developing countries need to give higher priority to plant based research and encourage leading academic and research organizations to participate in international collaboration with counterparts from western countries.

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