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Research on *Withania somnifera* (Ashwaganda): A Scientometric Assessment of Global Publications Output during 1995-2018

B. M. Gupta[1,*] and K K Mueen Ahmed[2]
[1]Formerly with CSIR-NISTADS, New Delhi 110012, INDIA.
[2]Phcog.Net and SciBioIMed.Org, Bengaluru, Karnataka, INDIA.

ABSTRACT

The present study examined 2008 global publications on *Withania somnifera*, as indexed and covered in international Scopus database during 1995-2018, with a view to understand their publications growth rate, global publication share, citation impact, share of their international collaborative publications, 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 publications. The global publications registered 18.31% annual average growth rate and its citation impact averaged to 18.55 citations per publication. The global share of top 10 countries ranged from 1.34% to 70.42%, with the largest share (70.42%) from India, followed by USA (11.35%) and other 8 countries from 1.34% to 4.03%. More than 100% of the cumulative global publication and citation share comes from top 10 countries during 1995-18. Only four countries among top 10 registered relative citation index above the world average of 1.0: U.K. (2.48), USA (1.80), Germany (1.69) and South Korea (1.08) during 1995-18. Pharmacology, toxicology and pharmaceutics contributed the largest global publications share of 42.33%, followed biochemistry, genetics and molecular biology (32.42%), medicine (30.73%), agricultural & biological sciences (25.45%), etc. during 1995-18. 377 global organizations and 422 global authors participated in global *Withania somnifera* research, of which the 15 most productive global organizations and authors together contributed 25.65% and 14.59% global publication share and 32.31% and 23.82% global citation share respectively during 1995-2018. Amongst 1964 journal publications (in 313 journals) in global *Withania somnifera* research, the top 15 most productive journals together contributed 21.49% global share of total journal publication output during 1995-2018. Sixty Eight (68) publications were found to be high cited, as they registered citations from 100 to 601 during 1995-2018 and they together received 11582 citations, averaging to 170.32 citations per publication.

Key words: *Withania somnifera*, Medicinal plant, Global research output, Scientometrics, Bibliometrics.

Correspondence

B. M. Gupta,

Formerly with CSIR-NISTADS, New Delhi 110012, INDIA.

Phone no: +91 9888378275

Email: bmgupta1@gmail.com

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INTRODUCTION

Withania somnifera (WS), also known as ashwagandha, Indian ginseng, and winter cherry, it has been an important herb in the Ayurvedic and indigenous medical systems for over 3000 years.[1] *Withania somnifera* is an important medicinal plant of the Indian subcontinent. It is widely used, singly or in combination, with other herbs against many ailments in Indian Systems of Medicine since time immemorial.

WS is a small, woody shrub in the Solanaceae family that grows about two feet in height. It can be found growing in Africa, the Mediterranean, and India. Its whole plant, roots, leaves, stem, green berries, fruits, seeds, bark are used. An erect, evergreen, tomentose shrub, 30-150 cm high, found throughout the drier parts of India in waste places and on bunds. Roots are stout fleshy, whitish brown; leaves simple ovate, glabrous, those in the floral region smaller and opposite; flowers inconspicuous, greenish or lubrid-yellow, in axillary, umbellate cymes; berries small, globose, orange-red when mature, enclosed in the persistent calyx; seeds yellow, reniform.[2]

The roots of the plant are categorised as rasayanas, which are reputed to promote health and longevity by augmenting defence against disease, arresting the ageing process, revitalising the body in debilitated conditions, increasing the capability of the individual to resist adverse environmental factors and by creating a sense of mental well-being.[1]

Studies indicate ashwagandha possesses anti-inflammatory, antitumor, antistress, antiantioxidant, anxiolytic, adaptogen, memory enhancing, antiparkinsonian, antivenom, antitumor properties. Various other effects like immunomodulation, hypolipidemic, antibacterial, cardiovascular protection, sexual behaviour, tolerance and dependence have also been studied. It also appears to exert a positive influence on the endocrine, cardiopulmonary, and central nervous systems. The mechanisms of action for these properties are not fully understood. Toxicity studies reveal that ashwagandha appears to be a safe compound.[2-3]

Withania somnifera is in use for a very long time for all age groups and both sexes and even during pregnancy without any side effects. The pharmacological effects of the roots of WS are attributed to the presence of withanolides, a group of steroidal lactones. Its leaves are used in Ayurvedic and Unani systems for treatment of tumors and tubercular glands. A number of withanolide steroidal lactones have been isolated from the leaves of *W. somnifera* and exhibit antibacterial, anti-fungal and antitumor properties. Ashwagandha is used to calm the mind, relieve weakness and nervous exhaustion, build sexual energy and promote healthy sleep. It is also classified as an adaptogen.[4]

Literature Review

Only few bibliometric studies have been carried out on bibliometric assessment of individual medicinal plants research output in the past. However, not a single bibliometric study is available on *Withania somnifera* research output. However similar bibliometric studies were pub-

lished on some of the individual medicinal plants include Aloe Vera,[5] *Azadrachta indica*,[6] *Curcuma longa*,[7] *Glycyrrhiza glabre*,[8] *Nigella sativa*,[9] *Ocimum Santum*,[10] *Phyllanthis emblica*[11] and *Tinospora Cordifolia*.[12]

OBJECTIVES

The study examines research performance, in terms of quantitative and qualitative indicators on *Withania somnifera* plant during 22 years (1997-2016), based on publications covered and indexed in Scopus database. Its objectives are: (i) to study the growth and distribution of global literature on *Withania somnifera*, (ii) to examine the scientometric profile and characteristics of the 10 most productive countries, 15 most productive organizations and to 15 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 *Withania somnifera*.

METHODOLOGY

Withania somnifera global publications of top 10 most productive countries were sourced from Scopus international database (http://www.scopus.com), using two keywords "ashwaganda" or "*Withania somnifera*" for the years 1995-2018. The "Keyword" and "Article Title" tags (as shown in search string below) were searched for the two keywords restricting the hit to the period 1995-2018 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 distribution of publications by subject, collaborating countries, author-wise, organization-wise and journal-wise, etc. were obtained. Citation data was obtained from date of publication till 25 January 2018. Select bibliometric indicators have been used to study the performance of global *Withania somnifera* research.

(KEY("ashwaganda" or "withania somnifera") OR TITLE(ashwaganda or "withania somnifera")) AND PUBYEAR > 1994 AND PUBYEAR < 2019

ANALYSIS

The cumulated global research output on *Withania somnifera* cumulated to 2008 publications in 24 years during 1995-2018. The *Withania somnifera* annual global research output increased from 7 in the year 1995 to 115 publications in the year 2018, registering 18.31% growth per annum. The cumulative world publications output on *Withania somnifera* research in 24 years 1995-2006 increased from 363 to 1645 publications during succeeding ten-year period 2007-2018, registering 353.17% growth. The citation impact of global publications on *Withania somnifera* in 24 years averaged to 18.55 citations per publication (CPP) during 1995-2018; twelve-yearly impact averaged to 42.52 CPP for the period 1995-2006, which sharply declined to 13.26 CPP in the succeeding twelve years 2007-2018 (Table 1).

Of the total global publications output on *Withania somnifera*, 80.13% (1609) appeared as articles, 14.44% (290) as editorials (0.55%), notes (0.50%), erratum (0.30%), articles in press (0.15%) and retracted (0.05%). reviews, 1.49% (30) as book chapters and the rest below 1%: Conference papers and letters (0.85% each), short surveys (0.70%),

Top 10 Most Productive Countries on *Withania somnifera* Research

The global research output in the field of *Withania somnifera* research had originated from as many as 72 countries during 1995-2018, of which, 64 published 1-10 publications each in 24 years, 13 countries 11-50 publications each and 2 countries 228-1414 publications each. The top 10 most productive countries in *Withania somnifera* research contributed 27 to 1414 publications each during 1995-2008 (Table 2). The top 10 most productive countries in *Withania somnifera* research accounted for more than 100% global publication share and more than 100% citation share during 1995-2018. Country-wise, the global publication share of top 10 countries varied widely 1.34% to 70.42% during 1995-2018, with India accounting for the highest publication share (70.42%), followed much behind by USA (11.35%) and other eight countries having global publication share from 1.34% to 4.03% during 1995-2018. Only four of top 10 countries scored relative citation index above the world average of 1.01: U.K. (2.48), USA (1.80), Germany (1.69) and South Korea (1.08) during 1997-16. India has though emerged as one of the world leader in *Withania somnifera* research, its performance in terms of relative citation index (0.84) has below the world average.

International Collaboration

The international collaborative output of top 10 most productive countries on *Withania somnifera* research as a national share in the country-wise output varied widely from 12.16% to 75.51%, with average share of 22.31% during 1995-2018. The highest international collaborative publication share comes from Saudi Arabia (75.51%), followed by Germany (70.37%), Japan (56.25%), U.K. (51.52%), South Korea (50.00%), South Africa (40.63%), USA (39.47%), Pakistan (38.27%), Iran (22.58%) and India (12.16%) during 1995-2018. Most surprisingly, India's international collaborative share in its national output in *Withania somnifera* research has been the lowest among the top 10 countries.

Subject-Wise Distribution of Research Output

The global *Withania somnifera* research output published during 1995-2018 is distributed across nine sub-fields (as identified in Scopus database classification), with pharmacology, toxicology and pharmaceutics accounting for the highest publications share (42.33%), followed by biochemistry, genetics and molecular biology (32.42%), medicine (30.73%), agricultural and biological Sciences (25.45%) and other 5 sub-fields contribution varying from 2.69% to 7.57% during 1995-2018. Its activity index, which computes change in research activity in the discipline over time 1995-2006 to 2007-2018 (world average activity index of a given subject is taken as 100), witnessed increase in biochemistry, genetics and molecular biology (from 84.12 to 103.50), agricultural and biological Sciences (from 63.87 to 107.97), immunology and microbiology (from 67.21 to 107.24), neurosciences (from 82.66 to 103.83), environment sciences (from 84.60 to 103.40) and veterinary science (from 61.46 to 108.50), as against decrease in pharmacology, toxicology and pharmaceutics (from 120.40 to 95.50), medicine (from 105.79 to 98.72) and chemistry (from 116.46 to 96.37). Neuorosciences, among various subjects registered the highest citations impact per publication of 25.17 CPP, followed by biochemistry, genetics and molecular biology (22.01), medicine (21.17), pharmacology, toxicology and pharmaceutics (19.67), chemistry (18.64), agricultural and biological sciences (13.14), immunology and microbiology (12.32) and environmental science (10.01) during 1995-2018 (Table 3).

Profile of Top 15 Most Productive Global Organizations

Three Hundred Seventy Seven (377) organizations participated in global research on *Withania somnifera* during 1995-2018, of which 278 organizations contributed 1-5 publications each, 63 organizations 6-10 publications each, 24 organizations 11-20 publications each, 8 organizations 21-50 publications each and 4 organizations 51-84 publications each.

The productivity of top 15 most productive global organizations in *Withania Somnifera* Research varied from 18 to 84 publications and together

Table 1: Annual World Output on *Withania somnifera* Research during 1995-2018.

Publication Period	World			Publication Period	World		
	TP	TC	CPP		TP	TC	CPP
1995	7	216	30.86	2009	102	2779	27.25
1996	14	671	47.93	2010	127	2334	18.38
1997	10	731	73.10	2011	176	2730	15.51
1998	12	454	37.83	2012	173	2485	14.36
1999	13	679	52.23	2013	184	1987	10.80
2000	32	1813	56.66	2014	163	1203	7.38
2001	32	1597	49.91	2015	161	1154	7.17
2002	32	889	27.78	2016	136	584	4.29
2003	46	1968	42.78	2017	146	372	2.55
2004	43	1988	46.23	2018	115	72	0.63
2005	43	2267	52.72	1995-06	363	15435	42.52
2006	79	2162	27.37	2007-18	1645	21817	13.26
2007	74	3613	48.82	1995-18	2008	37252	18.55
2008	88	2504	28.45				

TP=Total Publications; TC=Total Citations; CPP=Citations Per Publication

Table 2: Global Publication Share of Top 10 Most Productive Countries in *Withania somnifera* during 1995-2018.

S.No	Name of the Country	Number of Publications	Share of Publications	TC	CPP	ICP	%ICP	RCI
		1995-18	1995-18			1995-18		
1	India	1414	70.42	22161	15.67	172	12.16	0.84
2	USA	228	11.35	7593	33.30	90	39.47	1.80
3	Pakistan	81	4.03	1460	18.02	31	38.27	0.97
4	Japan	64	3.19	1937	30.27	36	56.25	1.63
5	South Korea	54	2.69	1079	19.98	27	50.00	1.08
6	Saudi Arabia	49	2.44	434	8.86	37	75.51	0.48
7	United Kingdom	33	1.64	1520	46.06	17	51.52	2.48
8	South Africa	32	1.59	416	13.00	13	40.63	0.70
9	Iran	31	1.54	375	12.10	7	22.58	0.65
10	Germany	27	1.34	844	31.26	19	70.37	1.69
	Total	2013	100.25	37819	18.79	449	22.31	1.01
	World	2008	100.00	37252	18.55			
	Share of 10 Countries in World Total	100.25						

they contributed 25.65% (515) publication share and 32.31% (12036) citation share during 1995-2018. The scientometric profile of these top 15 organizations is presented in Table 4.

- **Six organizations** registered publications output greater than the group average of 34.33: Central Institute of Aromatic & Medicinal Plants, Lucknow, India (84 publications), National Botanical Research Institute, Lucknow, India (62 publications), Banaras Hindu University, Varanasi, India (52 publications), Indian Institute of Integrated Medicine, Srinagar, India (52 publications), Guru Nanak Dev University, Amritsar (40 publications) and Panjab University, Chandigarh, India (36 publications);
- **Five organizations** registered impact and relative citation index above the group average of 23.37 citations per publication and 1.26 during 1995-2018: Savitribai Phule Pune University, Pune, India (57.14 and 3.08), Banaras Hindu University, Varanasi, India (31.23 and 1.68), National Botanical Research Institute, Lucknow, India (30.79 and 1.66), All India Institute of Medical Research, New Delhi, India (30.56 and 1.65) and Indian Institute of Integrated Medicine, Srinagar, India (23.85 and 1.29);
- **Six organizations** contributed international collaborative publications share above the group average of 13.98%: Guru Nanak Dev University, Amritsar (42.50%), Bharathidasan University(38.10%), Banaras Hindu University, Varanasi, India (21.15%), Indian Veterinary Research Institute (21.05%), University of Delhi (19.05%) and Jamia Hamdard University, Delhi (15.79%).

Table 3: Subject-Wise Breakup of Global Publications on Withania Somnifera Research during 1995-2018.

S.No	Subject*	Number of Publications (TP)			Activity Index		TC	CPP	%TP
		1995-06	2007-18	1995-18	1995-06	2007-18		2005-18	
1	Pharmacology, Toxicology & Pharmaceutics	185	665	850	120.40	95.50	16720	19.67	42.33
2	Biochemistry, Genetics & Molecular Biology	99	552	651	84.12	103.50	14330	22.01	32.42
3	Medicine	118	499	617	105.79	98.72	13064	21.17	30.73
4	Agricultural & Biological Sciences	59	452	511	63.87	107.97	6717	13.14	25.45
5	Chemistry	32	120	152	116.46	96.37	2833	18.64	7.57
6	Immunology & Microbiology	13	94	107	67.21	107.24	1318	12.32	5.33
7	Neurosciences	13	74	87	82.66	103.83	2190	25.17	4.33
8	Environmental Science	13	72	85	84.60	103.40	851	10.01	4.23
9	Veterinary Science	6	48	54	61.46	108.50	283	5.24	2.69
	World Output	363	1645	2008			37252	18.55	

- There is overlapping of literature covered under various subjects

TP=Total Publications; TC=Total Citations; CPP=Citations Per Publication

Table 4: Scientometric Profile of Top 15 Most Productive Global Organizations on *Withania somnifera* Research during 1995-2018.

S.No	Name of the Organization	TP	TC	CPP	HI	ICP	%ICP	RCI
1	Central Institute of Aromatic & Medicinal Plants, Lucknow, India	84	1772	21.10	24	4	4.76	1.14
2	National Botanical Research Institute, Lucknow, India	62	1909	30.79	27	6	9.68	1.66
3	Banaras Hindu University, Varanasi, India	52	1624	31.23	18	11	21.15	1.68
4	Indian Institute of Integrated Medicine, Srinagar, India	52	1240	23.85	18	7	13.46	1.29
5	Guru Nanak Dev University, Amritsar	40	532	13.30	13	17	42.50	0.72
6	Panjab University, Chandigarh, India	36	796	22.11	15	1	2.78	1.19
7	All India Institute of Medical Research, New Delhi, India	25	764	30.56	14	3	12.00	1.65
8	University of Rajasthan, Jaipur, India	22	125	5.68	8	0	0.00	0.31
9	Central Drug Research Institute , Lucknow, India	22	267	12.14	8	0	0.00	0.65
10	Savitribai Phule Pune University, Pune, India	22	1257	57.14	14	3	13.64	3.08
11	Bharathidasan University	21	453	21.57	10	8	38.10	1.16
12	University of Delhi	21	316	15.05	10	4	19.05	0.81
13	Indian Veterinary Research Institute	19	284	14.95	7	4	21.05	0.81
14	Jamia Hamdard University, Delhi	19	295	15.53	6	3	15.79	0.84
15	Annamalai University	18	402	22.33	10	1	5.56	1.20
	Total of 15 organizations	515	12036	23.37	202	72	13.98	1.26
	Total of World	2008	37252	18.55				
	Share of top 15 organizations in World output	25.65	32.31					

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

Profile of Top 15 Most Productive Authors

Four Hundred Twenty Two (422) authors participated in global research on *Withania somnifera* during 1995-2018, of which 327 authors contributed 1-5 publications each, 71 authors 6-10 publications each, 20 authors 11-20 publications each and 4 authors 21-43 publications each.

The research productivity in the field of *Withania somnifera* research of top 15 most productive authors varied from 14 to 43 publications. Together they contributed 14.59% (293) global publication share and 23.82% (8875) citation share during 1995-2018. The scientometric profile of these 15 authors is presented in Table 5.

- **Five authors** registered publications output above the group average of 19.53: R.S. Sangwan (43 publications), N.S. Sangwan (30 publications), S.K. Kulkarni and A. Kumar (21 publications each) and R. Tuli (20 publications);
- **Six authors r**egistered impact and relative citation index above the group average of 30.29 citations per publication and 1.63: B.Patwardan (55.74 and 3.0), G.N. Qazi (49.21 and 2.65), G. Kuttan

Table 5: Scientometric Profile of Top 15 Most Productive Authors on *Withania somnifera* Research during 1995-2018.

S .No	Name of the Author	Affiliation of the Author	TP	TC	CPP	HI	ICP	%ICP	RCI
1	R.S. Sangwan	Central Institute of Aromatic and Medicinal Plants, Lucknow, India	43	1456	33.86	22	4	9.30	1.83
2	N.S. Sangwan	Central Institute of Aromatic and Medicinal Plants, Lucknow, India	30	838	27.93	15	3	10.00	1.51
3	S.K. Kulkarni	Panjab University, Chandigarh	21	629	29.95	12	1	4.76	1.61
4	A. Kumar	Indian Institute of Integrated Medicine, Srinagar, India	21	411	19.57	10	0	0.00	1.06
5	R. Tuli	National Agro-Food Biotechnology Institute, Mohali	20	936	46.80	17	1	5.00	2.52
6	A.Ganapathi	Bharathidasan University, Tiruchirapalli	19	423	22.26	10	7	36.84	1.20
7	B.Patwardan	University of Pune	19	1059	55.74	14	3	15.79	3.00
8	K.A. Suri	Indian Institute of Integrated Medicine, Srinagar, India	19	734	38.63	13	0	0.00	2.08
9	G .Kaur	Guru Nanak Dev University, Amritsar	16	226	14.13	9	10	62.50	0.76
10	P.K. Pati	Guru Nanak Dev University, Amritsar	15	93	6.20	6	4	26.67	0.33
11	P.Kumar	University of Rajasthan, Jaipur	14	85	6.07	6	0	0.00	0.33
12	G.Kuttan	Amala Cancer Research Center, Trissur	14	681	48.64	11	1	7.14	2.62
13	G.N.Qazi	Indian Institute of Integrated Medicine, Srinagar, India	14	689	49.21	11	1	7.14	2.65
14	N.Selvaraj	Periyar EVR College (Autonomous), Tiruchirapally	14	315	22.50	9	4	28.57	1.21
15	G. Sivanandhan	Bharathidasan University, Tiruchirapalli	14	300	21.43	7	3	21.43	1.16
		Total of 15 authors	293	8875	30.29	172	42	14.33	1.63
		Total of World	2008	37252	18.55				
		Share of top 15 authors in World total output	14.59	23.82					

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

(48.64 and 2.62), R. Tuli (46.80 and 2.52), K.A. Suri (38.63 and 2.08) and R.S. Sangwan(33.86 and 1.83);

- **Six authors** contributed international collaborative publications share above the group average of 14.33 of all authors: G. Kaur (62.50%), A. Ganapathi (36.84%), N. Selvaraj (28.57%); P.K. Pati (26.67%), G. Sivanandhan (21.43%) and B. Patwardan (15.79%).

Medium of Research Communication

Of the total world output on Withania Somnifera research, 97.81% (1964) during 1995-2018. 1964 journal publications appeared in 313 journals, of which 242 journals published 1-5 publications each, 42 journals 6-10 publications each, 22 journals 11-20 publications each, 5 journals 21-50 publications each and 2 journals 51-72 publications each during 1995-2018.

The top 15 most productive journals reported 17 to 72 publications each on Withania Somnifera research; together they accounted for 21.49% (422 publications) share of total Withania Somnifera output published in journals during 1995-2018. Withania Somnifera research being reported increasingly in journals is gradually becoming a trend; for example, the top 15 most productive journals in twelve years has shown decrease in their Withania Somnifera output from 32.90% to 19.35% share between 1995-06 and 2007-18. The top ranking journal is *Journal of Ethnopharmacology* (with 72 publications), followed by *Phytotherapy Research* (52 publications), *PLOS One* (39 publications), *International Journal of Pharmacy and Pharmaceutical Sciences* (38 publications), *International Journal of Pharmaceutical Sciences Review and Research* (28 publications), etc. during 1995-2018 (Table 6).

Significant Keywords

Around 134 significant keywords having potential to identify comparative research trends in Withania somnifera research studies including pharmacological properties and medicinal uses were discovered from the global literature on Withania somnifera. These keywords are listed in Table 7 in the decreasing order of the frequency of their occurrence in the literature during 1995-2018.

Highly Cited Publications

68 highly cited publications on Withania somnifera research were identified each having 100 to 601 citations (53 publications each in citation range 100-199, 9 publications each in 200-299 citations range,4 publications each in 300-399 citations range and 2 publications 456-601 citations range each) in 24 years during 1995-2018. 68 publications together cumulated a total of 11582 citations, averaging 170.32 citations per publication. Of the 68 highly cited publications, 30 resulted from the participation of research organizations in their role as stand-alone (non-collaborating) institutional authors and remaining 39 from two or more research organizations working in their role as collaborating partners per publication (28 national collaborative and 11 international collaborative). Among 68 highly cited publications, the largest participation was seen from India (36 publications), followed by the USA (17 publications), Japan (4 publications), Germany and U.K. (3 publications each), Australia (2 publications) and Belgium, Canada, Ethiopia, Iran, Netherlands, Pakistan, Palestine, South Korea, Spain, Sweden and Taiwan (1 publication each).

These 68 highly cited publications involved the participation of 289 personal authors and 127 research organizations in total across globe. Of the

Table 6: Top 15 Most Productive Journals on Withania Somnifera Research during 1995-18

S.No	Name of the Journal	Number of Publications		
		1995-06	2007-18	1995-18
1	Journal of Ethnopharmacology	32	40	72
2	Phytotherapy Research	23	29	52
3	PLOS One	0	39	39
4	International Journal of Pharmacy & Pharmaceutical Sciences	0	38	38
5	International Journal of Pharmaceutical Sciences Review & Research	0	28	28
6	International Journal of Pharma & Bio Sciences	0	27	27
7	Indian Journal of Experimental Biology	13	9	22
8	Evidence Based Complementary & Alternate Medicine	1	18	19
9	Phytomedica	19	0	19
10	Phytomedicine	11	8	19
11	Asian Journal of Pharmaceutical & Clinical Research	0	18	18
12	Pharmaceutical Biology	3	15	18
13	Indian Drugs	0	17	17
14	International Journal of Green Pharmacy	0	17	17
15	Pharmacologyonline	0	17	17
	Total of 15 journals	102	320	422
	Total global journal output	310	1654	1964
	Share of top 15 journals in global journal output	32.90	19.35	21.49

Table 7: List of Significant Keywords in Literature on Withania somnifera Research during 1995-18

S.No	Keyword	Frequency	S. No	Keyword	Frequency	S.No	Keyword	Frequency
1	Withania somnifera	1888	46	Drug Structure	77	91	Anti-fungal Activity	35
2	Plant Extract	713	47	Inflammation	76	92	Headque	35
3	Withania	520	48	Placebo	76	93	Arthritis	33
4	Medicinal Plant	604	49	Herb	73	94	Tumor Necrosis	31
5	Plant Root	410	50	Clinical Trial	72	95	Tannin Derivatives	29
6	Withanolide	329	51	Genetics	70	96	Gastrointestinal Disease	28
7	Herbaceous Agent	282	52	Signal Transduction	70	97	Gamma Interferon	27
8	Withaferin A	258	53	Alzheimer Disease	69	98	Dehydrogenase	26
9	Drug Efficacy	247	54	Cytotoxicity	69	99	Cardiovascular Disease	24
10	Ashwagandha	246	55	Escherichia Coli	69	100	Zink	23
11	Plant Leaf	243	56	Ginseng	65	101	Obesity	23
12	Drug Effect	233	57	Stress	68	102	Ulcer	23
13	Antioxidant Activity	222	58	Anti-bacterial Activity	67	103	Paclitaxel	23
14	Phototherapy	222	59	Cell Line Tumor	67	104	Valerian	22
15	Chemistry	205	60	Pathology	67	105	Immunochemistry	22
16	Drug Mechanism	180	61	Alkaloids	66	106	DNA Damage	22
17	Oxidation Stress	179	62	Diet	66	107	Malaria	21
18	Oxidants	170	63	Enzyme Inhibition	66	108	Lung Cancer	21
19	Herbal Medicine	164	64	Ascorbic Acid	65	109	Lawsonia Insermis	20
20	Traditional Medicine	152	65	Alternate Medicine	64	110	Chemotherapy	20
21	Enzyme Activity	151	66	Methanol	64	111	Weight Reduction	18
22	Antineoplastic Activity	140	67	Plant Seed	64	112	Quality of Life	18

Table 7: Con'

23	Phytochemistry	133	68	Gene Expression	63	113	Magnesium	18
24	Anti-inflammatory Activity	133	69	Depression	62	114	Uncaria Tomentosa	17
25	Drug Effects	132	70	Glucose	60	115	Omega 3 Fatty Acids	16
26	Drug Response	131	71	Reactive Oxygen Metabolite	59	116	Hairy Root Culture	16
27	Solanaceae	131	72	Diabetes Mellitus	58	117	Male Infertility	16
28	Lipid Peroxidation	121	73	Diarrhea	58	118	Pancreas Cancer	16
29	Medicinal Plant Products	119	74	Panax Ginseng	58	119	Skin Disease	16
30	Drug Isolation	116	75	Plant Stem	58	120	Leukemia	15
31	Apoptosis	114	76	Anti-microbial Activity	57	121	Abdominal Pain	14
32	Drug Activity	110	77	Drug Potentiation	55	122	Weight Gain	12
33	Drug Safety	110	78	Ethno botany	55	123	Gastritis	12
34	Drug Screening	109	79	Body Weight	53	124	Rasayana	12
35	Immunomodulation	102	80	Ergo sterol	52	125	Radiation Protection	11
36	Ayurveda Drug	95	81	Bark	50	126	Asthma	11
37	Superoxide Dismutase	96	82	Rheumatoid Arthritis	50	127	Anxiety Disorders	11
38	Drug Formulation	90	83	Parkinson Disease	48	128	Obsessive Compulsory Disorder	10
39	Plant Leaves	86	84	Cancer	48	129	Tachy Cardia	10
40	Neuro-protection	85	85	Breast Cancer	45	130	Uterine Cervices Cancer	10
41	Flavonoids	83	86	Neoplasms	38	131	Schizophrenia	9
42	Glutathione	82	87	Cancer Inhibition	37	132	Seizure	8
43	Withanolide A	82	88	Epilepsy	36	133	Insomnia	8
44	Fruit	80	89	Fever	36	134	Leprosy	8
45	Catalase	78	90	Fatigue	36			

68 highly cited publications, 43 were published as articles, 22 as reviews publications and 3 as short surveys. These 68 highly cited publications were published in 37 journals, with 16 publications in *Journal of Ethnopharmacology,* 4 publications in *Phytomedicine, 3 publications each in Life Sciences and Indian Journal of Experimental Biology, 2 publications each in Apoptosis, Cancer Research, Indian Journal of Medical Research, Journal of Clinical Biochemistry and Nutrition and Neurosignals and 1 paper each in other 27 journals.*

CONCLUSION

Published *Withania somnifera* research publications were analysed to understand a quantitative and qualitative assessment of its global research output covering 24 years period (1995-2018) in this study. The data for the study was sourced from Scopus international publications and citations database. The annual and twelve-year cumulative global output of *Withania somnifera* research registered 18.31% and 353.17% growth. Its global citation impact averaged to 18.55 citations per publication during 1995-2018, which decreased from 42.52 during 1995-06 to 13.26 during 2007-2018.

India alone accounted for the highest publication share (70.42%), USA (11.35%) and other 8 countries (from 1.34% to 4.03%) during 1995-2018. The top 10 most productive countries in *Withania somnifera* research together accounted for more than 100% global publication share and more than 100.0% citation share during 1995-2018. Top ranking developing countries on *Withania somnifera* research dominate in quantity of research whereas developed countries in the ranking list dominate more in quality of research. For example, India, Pakistan, Saudi Arabia, South Africa and Iran mainly from developing countries together accounted for 79.79% global publication share and citation impact (averaging 11.13 citations per publication) and comparatively the USA, Japan, South Korea, U.K. and Germany account for only 20.21% global share and citation impact (averaging 32.17 citations per publication) during 1995-2018. Only four of top 10 countries scored relative citation index above the world average of 1.01: U.K. (2.48), USA (1.80), Germany (1.69) and South Korea (1.08) during 1995-2018. The international collaborative publication share of developed countries in *Withania somnifera* was comparatively greater (from 39.67% to 70.37% share) compared to that of major developing countries (12.16% to 40.63% share), with the exception of Saudi Arabia.

Pharmacology, toxicology and pharmaceutics was the most sought after subject area of *Withania somnifera* research accounting for (42.33%) the highest publications share, followed by biochemistry, genetics and molecular biology (32.42%), medicine (30.73%), agricultural and biological sciences (25.45%), etc. during 1995-2018. Among broad subjects, the research activities registered increase in biochemistry, genetics and molecular biology, agricultural and biological sciences, immunology and microbiology, neurosciences and veterinary science, as against decrease in pharmacology, toxicology and pharmaceutics, immunology and microbiology and chemistry during 1995-2006 to 2007-2018.

The top 15 most productive research organizations and the authors on *Withania somnifera* research collectively contributed 25.65% and 14.59% global publication share and 32.31% and 23.82% global citation share respectively during 1997-2016. The leading organizations in terms of publication productivity were: Central Institute of Aromatic and Medicinal Plants, Lucknow, India (84 publications), National Botanical Research Institute, Lucknow, India (62 publications), Banaras Hindu University,

Varanasi, India (52 publications), Indian Institute of Integrated Medicine, Srinagar, India (52 publications), Guru Nanak Dev University, Amritsar (40 publications) and Panjab University, Chandigarh, India (36 publications). The leading organizations in terms of citation impact per publication and relative citation index were: Savitribai Phule Pune University, Pune, India (57.14 and 3.08), Banaras Hindu University, Varanasi, India (31.23 and 1.68), National Botanical Research Institute, Lucknow, India (30.79 and 1.66), All India Institute of Medical Research, New Delhi, India (30.56 and 1.65) and Indian Institute of Integrated Medicine, Srinagar, India (23,85 and 1.29).

The journals medium accounted for 97.81% global share on Withania somnifera research with top 15 most productive journals accounting for 21.49% of total publications output in journals during 1995-2018. Journal of Ethnopharmacology contributed the largest number of publications (724), followed by Phytotherapy Research (52 publications), PLOS One (39 publications), International Journal of Pharmacy and Pharmaceutical Sciences (38 publications), International Journal of Pharmaceutical Sciences Review and Research (28 publications), etc. during 1995-2018.

Of the total Withania somnifera global research output, 68 publications registered high citations, in the range of 100 to 601 citations per publication, and collectively these highly cited publications received a total of 11582 citations, averaging to 170.32 citations per publication. These 68 highly cited publications involved the participation of 289 personal authors and 127 research organizations in total across globe and were published in 37 journals. The leading journals were Journal of Ethnopharmacology (16 publications), Phytomedicine (4 papers), Cancer Research and Life Sciences (3 papers each), etc. Among 68 highly cited publications, the largest participation was seen from India (36 publications), followed by the USA (17 publications), Japan (4 publications), Germany and U.K. (3 publications each), etc.

Conclusively, this research study reveals that developing countries (India India, Pakistan, Saudi Arabia, South Africa and Iran) dominate in *Withania somnifera* search more in terms of quantity of research (with 79.79% global publications share and averaging 11.13 citations per paper), developed countries (USA, Japan, South Korea, U.K. and Germany) dominate instead more in terms of quality of research (with 20.21% global share and averaging 32.17 citation per paper). It concludes that higher priority may be assigned to plant based research in developing countries, particularly in India. In developing countries, the R&D effort needs to be stepped up with comparatively higher investment in terms of both financial and manpower outputs. There is also need to increase the international collaboration, with a view to increase their research output and improved research impact.

Conclude that *Withania somnifera* may be useful in many ailments, including arthritis and other musculoskeletal disorders, stress-induced nervous exhaustion, and hypertension. There are a few preliminary studies available on the effects of WS on the immune system, central nervous system, hemopoetic system, and general growth promotion to form a basis for further studies but not enough evidence to provide a firm scientific basis for definitive therapeutic uses. Preliminary studies have found various constituents of *Withania somnifera* exhibit a variety of therapeutic effects with little or no associated toxicity. These results are very encouraging and indicate this herb should be studied more extensively to confirm these results and reveal other potential therapeutic effects. Clinical trials using ashwagandha for a variety of conditions should also be conducted.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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