

Indian Contribution in Immunology and Microbiology 1999-2008: A Scientometric Analysis

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ABSTRACT

The study examines India's performance based on its publication output in immunology and microbiology during 1999-2008, based on several parameters, including the country's annual average growth rate, global publications share and rank, institutional profile of select top 15 institutions, international collaboration profile and major collaborative partners, patterns of communication in national and international journals, and characteristics of its top 15 most productive authors. The study uses 10 years publications data in immunology and microbiology drawn from Scopus international multidisciplinary bibliographical database.

Keywords: Immunology, microbiology, molecular biology, cell biology, microorganisms, DNA technology

1. INTRODUCTION

The world around us is full of organisms, which are too small to be seen with the naked eye. Microbiologists study these tiny life forms. The major groups of microbes are bacteria, viruses, fungi, algae, and protozoa. Microbes live in widely diverse habitats ranging from hot springs, human body, and the depths of the ocean. They affect each and every aspect of life on earth. Microbiology is not a single subject. It has many areas of specialisation. However, it is a science based on the use of pure cultures—looking at one sort of organism at a time. Many of the techniques developed by microbiologists are now used in molecular and cell biology to provide the basis for studying higher organisms. Microorganisms also play a central role in recombinant DNA technology and act as the agents for genetic modification. In India, microbiology is an important area of education and research under biological sciences.

A number of universities and colleges are offering courses at BSc and MSc level in microbiology as well as facilities for doctoral research. Besides universities and colleges, a number of research institutes are engaged in R&D work in this area. Immunology is study of all aspects of the immune system including its structure and

functional disorders of the immune system, blood banking, immunisation, and organ transplantation. It is the study of viruses, at the molecular level, in relationship with the immune system. It means studying how viruses interact with the immune system at the structural level (not studying virus epidemics; rather, the shape of viruses and how they interact with the molecular structure of the immune system). Immunology as a subject of study is concentrated in medical colleges and few universities and is taught as a part of medical degrees.

A number of research institutes, which are part of CSIR, ICMR, DBT, and DST also focus their R&D work in this area. The universities and research institutes besides their own funds, gets extramural research funds from research agencies such as CSIR, ICMR, DST, DBT to carry out research in microbiology and immunology from time to time. Rao [1] had provided a review of the evolution of immunology in India. Similarly, evaluation studies of different subject fields based on their Indian publication output have been carried out by one of the authors in collaboration with other scholars in the field of condensed matter physics, materials science, computer science and pharmacology, toxicology and pharmaceuticals covering different time periods [2-5].

2. OBJECTIVES

The main focus of the study is: (i) to analyse the status, publication share, rank and growth of India's research output among the top 15 productive countries in immunology and microbiology; (ii) to analyse productivity and quality of Indian research output in immunology and microbiology; (iii) to analyse the productivity and quality of 15 major institutions participating in research in immunology and microbiology; (iv) to analyse the pattern of research collaboration in immunology and microbiology; and (v) to analyse the productivity and quality of leading 15 authors in research in immunology and microbiology.

3. METHODOLOGY

The study uses 10 years publications data from 1999 to 2008 on India in the area of immunology and microbiology as defined in Scopus database classification. In addition, it used citations data for measuring quality and visibility of Indian research output. Three years, two year and one year citations windows have been used for computing average citations per paper by India in immunology and microbiology during 1999-2005, 2006 and 2007.

4. ANALYSIS

As reflected in the Scopus database, India published 13,172 research papers during 1999-2008 in immunology and microbiology, with an average output of 1317 papers per year. The cumulative output of India increased from 4669 papers during 1999-03 to 8503 papers during 2004-2008 showing a growth rate of 82.12 per cent. The average citation per paper recorded on a three-year citation window by India was 3.15 during 1999-2008. The average citation per paper decreased from 3.97 during 1999-2003 to 2.98 during 2004-08 (Table 1).

Table 1. Growth of indian research output in immunology and microbiology, 1999-2008

Year	Total papers		
	TP	TC	ACPP
1999	793	3027	3.82
2000	820	3281	4.00
2001	818	2975	3.64
2002	1026	3852	3.75
2003	1212	5638	4.65
2004	1285	5734	4.46
2005	1456	6622	4.55
2006	1603	5806	3.62
2007	1980	3888	1.96
2008	2179	689	0.32
Total	13, 172	41, 512	3.15

TP=Total papers; TC=Total citations; ACPP=Average citations per paper

India was ranked 12th among the top 15 productive countries of the world in immunology and microbiology, with its global publications share of 2.50 per cent as computed from cumulative world publications output data for 1999-2008. India has shown rise in its global publications share, rising from 1.67 per cent to 3.70 per cent from the year 1999 to the year 2008. Correspondingly, India's world ranking improved from 15th position in 1999 to 9th in 2008 (Table 2). India achieved an annual average growth rate of 12.19 per cent per annum during 1999-2008, the second highest after China amongst the top 15 most productive countries (Tables 2, 3 and 4).

4.1 Institutional Profile

Based on publications output data for India in immunology and microbiology, a total of 15 institutions were identified as high productive ones publishing more than 160 papers in the country during 1999-2008. These top 15 institutions together contributed 3664 papers (with 27.82 per cent share) in the total cumulative research output by India during 1999-2008 (Table 5).

The share of these top 15 institutions in the total Indian research output has decreased from 31.08 per cent (1451 papers) in 1999-03 to 26.03 per cent (2213 papers) during 2004-08. These institutions individually published between 179 and 476 papers in 10 years (1999-2008), with an average output of 244 papers per institution. Of these, five institutions each contributed publications output above the 15 institutions average (244 papers per institution). These five institutions along with their publications output are: All India Institute of Medical Sciences, New Delhi with 468 papers, followed by Banaras Hindu University, Varanasi (352 papers), Post Graduate Institute of Medical Education and Research, Chandigarh (319 papers), Indian Institute of Science, Bengaluru (297 papers), and Indian Veterinary Research Institute, Izatnagar (265 papers) (Table 5).

The average growth rate of the top 15 Indian institutions from 1999-03 to 2004-08 was 52.52 per cent. Seven Indian institutions achieved higher growth rate than the average growth rate of the top 15 Indian institutions during this period. These are: University of Delhi, recorded the highest growth rate of 132.4 per cent followed by All India Institute of Medical Sciences, New Delhi (90.68 per cent), Indian Veterinary Research Institute, Izatnagar (84.95 per cent), National Institute of Cholera and Enteric Diseases, Kolkata (82.28 per cent), Banaras Hindu University, Varanasi (70.77 per cent), Central Drug Research Institute, Lucknow (68.67 per cent), and Indian Agricultural Research Institute, New Delhi (65.38 per cent) (Table 5). The average citations received per paper by total papers of this 15 top institutes was 4.20 during 1999-08. Only eight institutions registered higher average

Table 2. Research output and world share of top 15 most productive countries in immunology and microbiology (1999-2008)

Country	Total papers			Per cent share of papers		
	1999	2008	1999-08	1999 (%)	2008 (%)	% (1999-08)
USA	16633	16573	165268	35.04	28.14	31.36
UK	5042	5193	51435	10.62	8.82	9.76
Japan	3912	4073	39181	8.24	6.92	7.43
Germany	3910	4179	38944	8.24	7.10	7.39
France	3459	3435	33456	7.29	5.83	6.35
Italy	1885	2581	21535	3.97	4.38	4.09
Canada	1785	2386	20164	3.76	4.05	3.83
Spain	1631	2374	19578	3.44	4.03	3.71
Netherlands	1566	1886	17043	3.30	3.20	3.23
Australia	1400	1840	15755	2.95	3.12	2.99
China	1199	991	15490	2.53	1.68	2.94
India	793	2180	13173	1.67	3.70	2.50
South Korea	796	1951	12846	1.68	3.31	2.44
Sweden	1282	1246	12068	2.70	2.11	2.29
Russia	897	601	7469	1.89	1.02	1.42
World	47467	58888	527002			

Table 3. Research output and rank of top 15 most productive countries in immunology and microbiology (1998-2007)

Country	Total papers			World rank		
	1997	2007	1997-07	1998	2008	1998-08
USA	16633	16573	165268	1	1	1
UK	5042	5193	51435	2	2	2
Japan	3912	4073	39181	3	4	3
Germany	3910	4179	38944	4	3	4
France	3459	3435	33456	5	5	5
Italy	1885	2581	21535	6	6	6
Canada	1785	2386	20164	7	7	7
Spain	1631	2374	19578	8	8	8
Netherlands	1566	1886	17043	9	11	9
Australia	1400	1840	15755	10	12	10
China	1199	991	15490	12	14	11
India	793	2180	13173	15	9	12
South Korea	796	1951	12846	14	10	13
Sweden	1282	1246	12068	11	13	14
Russia	897	601	7469	13	15	15
World	47467	58888	527002			

citations per paper than the average of 15 institutions. These are: International Centre for Genetic Engineering and Biotechnology, New Delhi with 6.96 citations per paper, followed by Jawaharlal Nehru University, New Delhi (5.70), National Institute of Immunology, New Delhi (5.28), National Institute of Cholera and Enteric Diseases, Kolkata (5.23), Christian Medical College, Vellore (5.22), Institute of Microbial Technology, Chandigarh (4.66), All

India Institute of Medical Sciences, New Delhi (4.47) and Indian Institute of Science, Bangalore (4.45). The average citations per paper decreased from 4.95 during 1999-03 to 3.70 during 2004-08. Except one institution, in all other 14 institutions' average citation per paper decreased during 1999-03 and 2004-08 (Table 6).

The average share of the international collaborative papers of these 15 institutions during 1999-08 was 22.16

Table 4. Annual average publication growth rate of top 15 most productive countries in immunology and microbiology (1999-2008)

Country	Growth rate (%)	Country	Growth rate (%)
USA	0.22	South Korea	10.83
Japan	0.56	India	12.19
UK	0.52	China	15.93
Germany	0.97	Spain	4.36
Canada	3.62	Netherlands	2.43
France	0.09	Australia	3.30
Italy	3.70	Sweden	-0.03
Russia	-3.38	World	2.46

per cent. Only 6 out of 15 institutions have shown higher share of international collaboration papers than the average share of 15 institutions. University of Delhi recorded the highest share (52.21 per cent) of international collaborative papers, followed by Central Food Technological Research Institute, Mysore (40.40 per cent), Jawaharlal Nehru University, New Delhi (35.14 per cent share), International Centre for Genetic Engineering and Biotechnology, New Delhi (26.26 per cent), All India Institute of Medical Sciences, New Delhi (23.29 per cent), and National Institute of Immunology, New Delhi (22.16 per cent) (Table 7).

The average H-Index of these 15 institutions was 19.4. Only nine out of 15 institutions had scored higher H-Index values than the average values of 15 institutions. These are: All India Institute of Medical Sciences, New Delhi with H-Index value of 26, followed by Institute of Microbial Technology, Chandigarh (24), Jawaharlal Nehru University, New Delhi (22), International Centre for Genetic Engineering and Biotechnology, New Delhi (22), National Institute of Cholera and Enteric Diseases, Kolkata (22), Postgraduate Institute of Medical Education and Research, Chandigarh (21), Indian Institute of Science, Bangalore (21), Christian Medical College and Hospital, Vellore (21), and National Institute of Immunology, New Delhi (21).

4.2 Authors Profile

Based on publications output data for India in immunology and microbiology, 15 authors were identified as high productive with more than 45 papers in the country output during 1999-2008.

These 15 authors together contributed 832 papers (with 6.31 per cent share) in the total cumulative research output by India during 1999-2008 with an average of 55.46 papers per author. Only three authors have contributed more than the average output of 15 authors. They are

Table 5. Research output and growth of top 14 major indian institutions in immunology and microbiology (1999-2008)

Affiliation	Number of papers			
	99-03	04-08	99-08	Growth rate
All India Institute of Medical Sciences New Delhi	161	307	468	90.68
Banaras Hindu University, Varanasi	130	222	352	70.77
Postgraduate Institute of Medical Education and Research, Chandigarh	130	189	319	45.38
Indian Institute of Science, Bengaluru	116	171	287	47.41
Indian Veterinary Research Institute Izatnagar	93	172	265	84.95
University of Delhi, Delhi	68	158	226	132.4
National Institute of Cholera and Enteric Diseases, Kolkata	79	144	223	82.28
Central Drug Research Institute, Lucknow	83	140	223	68.67
Indian Agricultural Research Institute New Delhi	78	129	207	65.38
Central Food Technological Research Institute, Mysore	95	103	198	8.42
Christian Medical College, Vellore	80	110	190	37.5
Jawaharlal Nehru University, New Delhi	83	102	185	22.89
Institute of Microbial Technology Chandigarh	85	96	181	12.94
International Centre for Genetic Engineering and Biotechnology, New Delhi	79	100	179	26.58
National Institute of Immunology New Delhi	91	70	161	-23.08
Total institutional output	1451	2213	3664	52.52
Total country output	4669	8503	13,172	
Institutional share in country output	31.08	26.03	27.82	

Table 6. Research output and impact of top 14 major indian institutions in immunology and microbiology

Affiliation	Total papers			ACPP		
	99-03	04-08	99-08	99-03	04-08	99-08
International Centre for Genetic Engineering and Biotechnology New Delhi	79	100	179	8.19	5.99	6.96
Jawaharlal Nehru University New Delhi	83	102	185	7.16	4.51	5.70
National Institute of Cholera and Enteric Diseases, Kolkata	79	144	223	6.19	4.70	5.23
Christian Medical College, Vellore	80	110	190	5.64	4.92	5.22
Institute of Microbial Technology Chandigarh	85	96	181	6.19	3.31	4.66
All India Institute of Medical Sciences, New Delhi	161	307	468	5.39	3.98	4.47
Indian Institute of Science, Bengaluru	116	171	287	5.74	3.57	4.45
Banaras Hindu University, Varanasi	130	222	352	4.44	3.94	4.13
University of Delhi, Delhi	68	158	226	4.54	3.27	3.65
Postgraduate Institute of Medical Education and Research, Chandigarh	130	189	319	3.65	3.53	3.58
Central Drug Research Institute Lucknow	83	140	223	3.76	3.02	3.30
Indian Veterinary Research Institute Izatnagar	93	172	265	3.35	1.94	2.44
Central Food Technological Research Institute, Mysore	95	103	198	2.42	1.85	2.13
Indian Agricultural Research Institute New Delhi	78	129	207	2.36	1.57	1.87
National Institute of Immunology New Delhi	91	70	161	5.23	5.34	5.28
Total	1451	2213	3664	4.95	3.70	4.20

Table 7. Research output and international collaborative papers share of top 14 major Indian institutions in immunology and microbiology

Affiliation	Total papers (1999-2008)			
	TP	TICP	% Share TICP	H-Index
University of Delhi, Delhi	226	118	52.21	17
Central Food Technological Research Institute Mysore	198	80	40.40	13
Jawaharlal Nehru University, New Delhi	185	65	35.14	22
International Centre for Genetic Engineering and Biotechnology, New Delhi	179	47	26.26	22
All India Institute of Medical Sciences New Delhi	468	109	23.29	26
Institute of Microbial Technology, Chandigarh	181	36	19.89	24
Postgraduate Institute of Medical Education and Research, Chandigarh	319	61	19.12	21
National Institute of Cholera and Enteric Diseases, Kolkata	223	41	18.39	22
Central Drug Research Institute, Lucknow	223	41	18.39	17
Indian Agricultural Research Institute, New Delhi	207	38	18.36	12
Indian Veterinary Research Institute, Izatnagar	265	46	17.36	15
Indian Institute of Science, Bengaluru	287	41	14.29	21
Banaras Hindu University, Varanasi	352	38	10.8	17
Christian Medical College, Vellore	190	15	7.89	21
National Institute of Immunology, New Delhi	161	36	22.36	21
Total	3664	812	22.16	19.4

S.C. Arya with 85 papers, followed by S.K. Bhattacharya (82 papers) and S. Sundar (76 papers) (Table 8).

The average citation recorded by these 15 authors was 5.92 during 1999-2008. Only seven authors recorded higher average citations per paper than the average citations of 15 authors. They are S. Sundar with 11.6 citation per paper followed by G.K. Khuller (8.72), S.K. Bhattacharya (8.06), S. Solomon (7.91), N. Kumarasamy (7.73), S. Shivaji (7.33), G.B. Nair (6.89), and N. Ahmed (6.48) (Table 8). The average H-index of these 15 authors during 1999-08 was 12.73.

Of the 15 authors, eight authors showed H-index higher than the 15-authors average. They are: S. Sundar (Banaras Hindu University, Varanasi) with H-index of 19 followed by S.K. Bhattacharya, National Institute of Cholera and Enteric Diseases, Kolkata (18); G.K. Khuller, PGIMER, Chandigarh (17); S. Shivaji, CCMB, Hyderabad (16); S. Solomon, YR Gaitonde Centre for AIDS Research and Education Chennai (15); G.B.Nair, National Institute of Cholera and Enteric Diseases, Kolkata (13); N. Ahmed, Centre for DNA Fingerprinting and Diagnostics, Hyderabad (13); and T.R. Ramamurthy, National Institute of Cholera and Enteric Diseases, Calcutta (13) (Table 8).

4.3 Patterns of Research Communication

The top 20 Indian and foreign journals together contributed 43.42 per cent share to the total cumulative publications output by India in immunology and microbiology during 1999-2008. Their cumulative publications share declined from 43.67 per cent during to 1999-03 to 43.28 per cent during 2004-08 (Table 9).

4.4 Status of India's International Collaboration

Based on publications output data for India in immunology and microbiology (1998-2008), it was found that India's average annual share of international collaborative papers to its total cumulative publication output was 18.55 per cent. India witnessed rise in their share of internationally collaborative papers from 16.71 per cent during 1999-2001 to 18.74 per cent during 2006-08 (Table 10).

Among the 10 top collaborating countries with India during 1999-2008, the largest collaborator was the United States with 1088 papers (44.52 per cent share) followed by the United Kingdom 346 papers, (14.16 per cent), Japan 242 papers (9.90 per cent), Germany 219 papers

Table 8. Research output, impact and H-index of top 15 indian productive authors in immunology and microbiology

Author	Affiliation	H-Index 1999-2008	Total papers, 1999-2008		
			TP	TC	ACPP
S.C. Arya	Sant Parmanand Hospital, Delhi	4	85	40	0.47
S.K. Bhattacharya	National Institute of Cholera and Enteric Diseases, Kolkata	18	82	661	8.06
S. Sundar	Banaras Hindu University, Varanasi	19	76	883	11.6
M.S. Shaila	Indian Institute of Science, Bangalore	10	54	192	3.56
G.B. Nair	National Institute of Cholera and Enteric Diseases, Kolkata	13	53	365	6.89
A.P. Dash	All India Institute of Medical Sciences, New Delhi	6	52	116	2.23
R.K. Jain	Institute of Microbial Technology Chandigarh	12	50	183	3.66
T. Ramamurthy	National Institute of Cholera and Enteric Diseases, Calcutta	13	50	197	3.94
S. Shivaji	Centre for Cellular and Molecular Biology, Hyderabad	16	49	359	7.33
P.R. Narayanan	Tuberculosis Research Centre, Chennai	12	48	244	5.08
A. Pandey	Regional Research Laboratory, Trivandrum	12	50	271	5.42
S. Solomon	YR Gaitonde Centre. for AIDS Research and Education, Chennai	15	46	364	7.91
G.K. Khuller	Postgraduate Institute of Medical Education and Research, Chandigarh	17	46	401	8.72
N. Ahmed	Centre for DNA Fingerprinting and Diagnostics, Hyderabad	13	46	298	6.48
N. Kumarasamy	YR Gaitonde Centre for AIDS Research and Education, Chennai	11	45	348	7.73

TP=Total papers; TC=Total citations; ACPP=Average citation per paper

Table 9. Major productive journals which published papers of Indian authors in immunology and microbiology (1999-2008)

Title	Number of papers		
	1999-08	1999-03	2004-08
<i>Asian Journal of Microbiology Biotechnology and Environmental Sciences</i>	1,097	259	838
<i>Bioresource Technology</i>	664	187	477
<i>World Journal of Microbiology and Biotechnology</i>	514	217	297
<i>Indian Journal of Microbiology</i>	487	243	244
<i>Indian Journal of Biotechnology</i>	482	98	384
<i>Tropical Doctor</i>	270	131	139
<i>Vaccine</i>	211	59	152
<i>Current Microbiology</i>	188	72	116
<i>Journal of Tropical Pediatrics</i>	185	96	89
<i>Journal of Clinical Microbiology</i>	176	77	99
<i>Plant Cell Biotechnology and Molecular Biology</i>	173	51	122
<i>Biotechnology Letters</i>	168	83	85
<i>Transactions of the Royal Society of Tropical Medicine and Hygiene</i>	150	60	90
<i>FEMS Microbiology Letters</i>	147	77	70
<i>Applied Microbiology and Biotechnology</i>	140	37	103
<i>Enzyme and Microbial Technology</i>	140	55	85
<i>Journal of Medical Microbiology</i>	136	52	84
<i>Journal of Molecular Biology</i>	132	55	77
<i>Annals of Tropical Medicine and Parasitological</i>	130	72	58
<i>Letters in Applied Microbiology</i>	129	58	71
Total	5,719	2039	3680
Country output	13172	4669	8503
Share of top 20 journals in country output	43.42	43.67	43.28

Table10. Share of international collaborative papers in total papers in immunology and microbiology (1999-2008)

Year	Total papers		
	TP	TICP	Per cent TICP
1999	793	171	21.56
2000	820	151	18.41
2001	818	83	10.15
2002	1026	140	13.65
2003	1212	263	21.7
2004	1285	261	20.31
2005	1456	303	20.81
2006	1603	322	20.09
2007	1980	374	18.89
2008	2179	376	17.26
Total	13,172	2444	18.55
TP=Total papers; TICP=Total international collaborative papers			

(8.96 per cent), France 155 papers (6.34 per cent), South Korea 131 papers (5.36 per cent), Canada 106 papers (4.34 per cent), Switzerland 95 papers (3.89 per cent), Australia 78 papers (3.19 per cent), and Italy 65 papers, (2.66 per cent) (Table 11).

5. CONCLUSION

India published 13,172 research papers during 1999-2008 in immunology and microbiology, with an average output of 1317 papers per year. India holds 12th rank

Table 11. Leading collaborating countries with india in immunology and microbiology, 1999-08

Country	Period		
	1999-2008	1999-2003	2004-2008
USA	1,088	221	437
UK	346	137	209
Japan	242	90	152
Germany	219	58	161
France	155	34	121
South Korea	131	22	109
Canada	106	30	76
Switzerland	95	21	74
Australia	78	23	55
Italy	65	12	53
Total	2444		

among the top 15 productive countries of the world in immunology and microbiology, with its global publications share of 2.50 per cent as computed from cumulative world publications data for 1999-2008 showing a rise in its global publications share from 1.67 per cent to 3.70 per cent during 1999 to 2008. Correspondingly, India's world ranking improved from 15th position in 1999 to 9th in 2008. India achieved an annual average growth rate of 12.19 per cent per annum during 1999-2008, the second highest after China amongst the top 15 most productive countries. The cumulative output of India increased from 4669 papers during 1999-03 to 8503 papers during 2004-08, showing a growth rate of 82.12 per cent. The average citation per paper decreased from 3.15 during 1999-2003 to 2.98 during 2004-08.

The top 15 most productive institutions together contributed 3664 papers (with 27.82 per cent share) in the total cumulative research output by India during 1999-2008. The publication share of these top 15 institutions in the total Indian research output has decreased from 31.08 per cent (1451 papers) in 1999-03 to 26.03 per cent (2213 papers) during 2004-08. The average growth rate of the top 15 Indian institutions from 1999-03 to 2004-08 was 52.52 per cent. The average citations received per paper, H-Index and the average share of the international collaborative papers by total papers of these 15 top

institutions during 1999-2008 were 4.20, 19.4 and 22.16 per cent, respectively.

The most productive 15 authors together contributed 832 papers (with 6.31 per cent share) in the total cumulative research output by India during 1999-2008 with an average of 55.46 papers per author. The average citations received per paper and the average H-index by total papers of these 15 authors during 1998-2007 was 5.92 and 12.73, respectively. The top 20 productive journals of Indian and foreign origin together contributed 43.42 per cent share to the total cumulative publications output by India in immunology and microbiology during 1999-2008. Their cumulative publications share also showed decline from 43.67 per cent during to 1999-03 to 43.28 per cent during 2004-08. India's average annual share of international collaborative papers to its total cumulative publication output was 18.55 per cent during 1999-08. India witnessed rise in their share of internationally collaborative papers from 16.71 per cent during 1999-2001 to 18.74 per cent during 2006-08

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