Scientometric profile of organic chemistry research in India during 2004–2013

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An analysis of 17,344 papers published by Indian scientists and indexed by Web of Science in the discipline of organic chemistry and its sub-disciplines during 2004–2013 indicates that the Indian output has increased significantly in the later period. Academic institutions contributed about 46% of the total output followed by the Council of Scientific and Industrial Research (CSIR) with 26% of the total output. The most prolific institutions among them mainly belonging to academic institutions and CSIR contributed about 60% of the total output. The value of citation per paper for most of the prolific institutions was higher than the Indian average. Similar trend was observed for the relative citation impact. Indian researchers in the discipline of organic chemistry published their papers in international journals with impact factor greater than 1. About 11% of the papers published by Indian scientists in the discipline of organic chemistry during 2004–2013 remained uncited.

Keywords: Bibliometric indicators, citation analysis, organic chemistry, scientometrics.

ORGANIC chemistry has developed as an important field of research mainly due to its role in drug discovery and for the chemical industry[1]. It has always been an important area of research in chemical sciences in India. Beside the government-funded research agencies and academic institutions (universities and colleges), several private-funded R&D institutions in India are also involved in carrying out research in organic chemistry. Based on the journals indexed by Scopus database during 1987–2002, chemistry research in India constitutes about 6% of world research output in chemical sciences and the share of organic chemistry in this is the highest among all branches of chemical sciences[2].

Scientometrics is a valuable technique for evaluation of research performance of a country or a group of countries or institutions and disciplines. Several scientometric studies dealing with different aspects of organic chemistry research in India have been reported in the literature. For instance, Guay[3] studied the emergence of organic chemistry research in India during 1907–1926 using *Chemical Abstracts* and found that India has a long history of chemical investigations and chemistry is the most popular discipline followed by mathematics and physics. In a study on cross-national assessment of specializations in chemistry, Nagpaul and Pant[4] also found organic chemistry as a strong area of research in the chemical sciences in India. Scientometric assessment of Indian organic chemistry research during 1970s and 1980s by Karki and Garg[5] also showed that its impact has improved during the 80s compared to the 70s. Karki *et al.*[6] also explored the activity and growth of organic chemistry research in India during 1971–1989 using *Chemical Abstracts* and observed that it matched precisely with that of the world during the period 1971–1989. In a bibliometric study, Karki and Garg[7] found that alkaloid chemistry research performed in India was well connected to the mainstream science based on the communication pattern of publications and their citations in the international literature. Kumari[8] analysed research output and citation impact in synthetic organic chemistry (SOC) research for a group of countries and found that China out-performed India in terms of the absolute citations as well as relative citation impact. Jain *et al.*[9] and Garg *et al.*[10] examined the impact of the funding by Science and Engineering Research Council (SERC) of the Department of Science and Technology (DST), New Delhi on research in chemical sciences. Recently, Salini *et al.*[11] compared Indian output in organic chemistry with leading countries of the world and found that the pattern of growth of Indian organic chemistry research was similar to that of the world research output. Nishi *et al.*[12] examined the visibility and impact of the *Indian Journal of Chemistry, Section B* during 2005–2009 and made certain suggestions to improve the same. Following this study, Nagaiah and Srimannarayana[13] analysed Indian papers published in national and international journals in organic chemistry during 2011–2013 and found that Indian scientists prefer to publish in higher ranking international journals, neglecting the Indian journals. The present study examines the status of

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research in organic chemistry and its sub-disciplines in India during 2004–2013 in terms of the publication output and its impact as judged by the number of citations received by these papers.

Objectives of the present study

The focus of the study is on the following aspects:

- To examine the distribution of output and its impact in different sub-disciplines of organic chemistry.
- To examine the pattern of growth of the research publications output during 2004–2013.
- To examine the distribution of output by performing sectors like academic institutions and government-funded R&D institutions.
- To identify the most prolific research institutions in the field of organic chemistry in India and their citation impact.
- To identify the most prolific Indian authors and the impact of their research output.
- To examine the communication pattern of Indian researchers in terms of publishing country of journals and their impact factor and to list the most preferred journals.
- To examine the pattern of citations and identify the highly cited papers.

Methodology

The source of data for the present bibliometric study is Thomson Reuters' *Web of Science* (*WoS*). We downloaded all articles published by Indian authors from *WoS* for the years 2004–2013 in the last week of December 2014 using the search interface 'address'. Using the 'analyze' command available in *WoS*, we culled out 17,614 records from the downloaded data that belonged to the subject category of organic chemistry. 'Search within results' tag was used for downloading data for 11 sub-disciplines of organic chemistry from the downloaded data. The data so downloaded were analysed using MS Excel. The downloaded data included name of all authors with their affiliations, name of the journal with its place of publication, type of publications and citations obtained by each. The data were later enriched with the impact factor of the journals and performing sector to which the institution belonged (academic, research agency, or private). Each record was standardized for its affiliations, as there were variations in it.

Bibliometric indicators used

We have used the total number of publications (TNP), total number of citations (TNC), citations per paper (CPP) and relative citation impact (RCI) as measures of output and impact. The values of TNP and TNC were directly obtained from the downloaded data. CPP is a relative indicator computed as the average number of citations per paper. It has been widely used in bibliometric studies to normalize the large disparity in the volume of published output among disciplines, countries and institutions for a meaningful comparison of research impact. RCI is a measure of both the influence and visibility of a nation's research in the global perspective. It is defined as 'a country's share of world citations in the subspecialty/country's share of world publications in the subspecialty'. RCI = 1 denotes that a country's citation rate is equal to world citation rate; RCI < 1 indicates that a country's citation rate is less than the world citation rate and also implies that the research efforts are higher than its impact; and RCI > 1 indicates that a country's citation rate is higher than the world's citation rate and also implies high-impact research in that country. Here CPP and RCI have been used for a meaningful comparison of the impact of the research output for different sub-disciplines, prolific institutions and authors.

Results and discussion

During 2004–2013, Indian scientists published 17,614 articles on different aspects of organic chemistry and its sub-disciplines. Of these 16,988 (96.4%) were research articles published in journals followed by reviews (269) and conference papers published as journal articles (87). These three types of documents together constitute 17,344 (98.5%) of the research output. Remaining 1.5% records were scattered as editorials (130), corrections (106), book reviews (13), letters (11) and biographies (10) and have not been included in the final analysis. We have analysed 17,344 papers which were published as journal articles, reviews and conference papers published as journal articles, as these constitute the main channels of communication in science. The following paragraphs describe in detail the findings of the study on different parameters.

Distribution of output by sub-disciplines of organic chemistry and its impact

The entire output in organic chemistry was classified into 12 sub-disciplines. The sub-fields are based on the classification used by *Chemical Abstracts*. Table 1 gives the output and impact of Indian research output in terms of TNC, TNP, CPP and RCI for different sub-disciplines of organic chemistry research. The output in different sub-disciplines is about 45% of the total output and the rest 55% is in general/physical organic chemistry. The average value of CPP for the entire Indian output is 11.7. Of the 12 sub-fields listed in Table 1, it can be observed that

Table 1. Distribution of output and its impact in different sub-disciplines of organic chemistry

Sub-discipline	TNP	TNC	CPP	RCI
Aliphatic compounds	2152	32,043	14.89	1.27
Organometallics	1209	17,687	14.63	1.25
Amino acids, peptides, proteins	838	10,307	12.30	1.05
Alicyclic compounds	827	11,820	14.29	1.22
Alkaloids	818	10,456	12.78	1.09
Heterocyclic compounds	802	9683	12.07	1.03
Benzene compounds	457	4788	10.48	0.89
Carbohydrates	393	4877	12.41	1.12
Steroids	148	1295	8.75	0.75
Terpenes and terpenoids	62	715	11.53	0.98
Biomolecules	21	245	11.67	1.00
General/physical organic chemistry	9616	99,271	9.32	0.88
Total	17,344	203,187	11.71	1.00

TNP, total number of publications; TNC, total number of citations; CPP, citations per paper; RCI, relative citation impact forms.

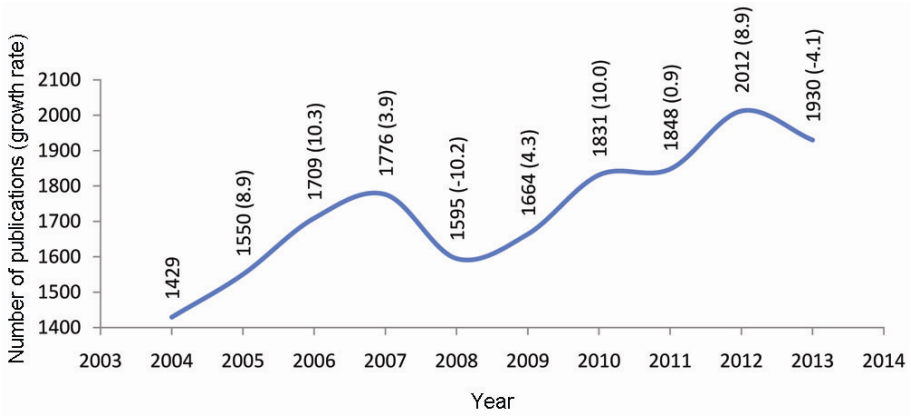

Figure 1. Pattern of publications output (growth rate) in the field of organic chemistry in India during 2004–2013.

nine sub-fields have higher CPP value than the average for Indian output. The three fields which have a lower CPP value are benzene compounds, steroids and general/physical organic chemistry. The lowest value of CPP is for the sub-disciplines of steroids. The value of CPP is significantly higher than the Indian average for the sub-disciplines of aliphatic compounds, organometallics and alicyclic compounds. The values of RCI also follow similar trends for different sub-disciplines.

Pattern of growth during 2004–2013

Figure 1 depicts the pattern and annual growth rate of the output. It indicates that the Indian output in organic chemistry has grown continuously during the period of study, except in 2008. However, the annual rate of growth is inconsistent and has fluctuated during the period of study. The compound annual growth rate (CAGR) (calculated using the formula available at www.investopedia.com/calculator/cagr.aspx) was found to be 3.05% during the period 2004–2013. The output is highest in 2012 with 2012 publications and lowest in the year 2004 with 1429 publications. In blocks of first five years (2004–2008), the number of papers published by Indian scientists was 8059 (46.5%) of the total output, which rose to 9285 (53.5%) during the later period (2009–2013), an increase of 7% over the first block.

Distribution of output by performing sectors

Several agencies are involved in scientific research in India, e.g. academic institutions (universities and colleges), institutes of higher learning like Indian Institutes of Technology (IITs), and medical colleges and hospitals. Besides these, several government-funded laboratories under the aegis of the Council of Scientific and Industrial Research (CSIR), Department of Atomic Energy (DAE), Indian Council of Medical Research (ICMR), Indian Council of Agriculture Research (ICAR), State Agriculture Universities (SAUs), Department of Space (DOS), DST, Department of Biotechnology (DBT) and Defence Research and Development Organization (DRDO) are also

Table 2. Distribution of output in organic chemistry during 2004–2008 and 2009–2013

Performing sectors	2004–2008 (%)	2009–2013 (%)	Change (%)	Total (%)
Academic institutions (universities and colleges)	3729 (46.3)	4351 (46.8)	0.5	8080 (46.6)
Council of Scientific and Industrial Research	2274 (28.2)	2222 (23.9)	(–) 4.3	4496 (25.9)
Indian Institutes of Technology (IITs)	863 (10.7)	1151 (12.4)	1.7	2014 (11.6)
Private institutions	401 (5.0)	442 (4.7)	(–) 0.3	843 (4.9)
Medical colleges and hospitals	215 (2.7)	230 (2.5)	(–) 0.2	445 (2.6)
Department of Science and Technology (DST)	192 (2.4)	205 (2.2)	(–) 0.2	397 (2.3)
Engineering colleges	110 (1.4)	249 (2.7)	1.3	359 (2.1)
Ministry of Chemical and Fertilizers (MCF)	92 (1.2)	89 (0.9)	0.3	181 (1.0)
Department of Atomic Energy	83 (1.0)	100 (1.1)	0.1	183 (1.1)
Other performing sectors contributing < 1% papers	100 (1.2)	246 (2.6)	1.4	346 (2.0)
Total	8059 (100.0)	9285 (100.0)		17,344 (100)

actively engaged in research in different areas of science and technology. Economic ministries under the central/state governments and private institutions approved by the Department of Scientific and Industrial Research (DSIR) also conduct scientific research. To boost the basic research further, the Government of India (GoI) has taken the initiative by setting up several new IITs, National Institutes of Science Education and Research (NISERs) and Indian Institutes of Science Education and Research (IISERs). Table 2 presents data on the distribution of publication output of Indian organic chemistry according to different sectors producing 1% or more of the papers in two blocks for 2004–2008 and 2009–2013. It indicates that academic institutions (universities and colleges) publish the highest number (46.6%) of papers, followed by CSIR with about 26% of papers and IITs with 11.6% of the output. These three performing sectors together publish about 84% of the total output. Remaining 16% output is scattered among the other performing sectors. Here, the highest number of papers is published by R&D institutions funded by private industry. Further analysis of data presented in Table 2 indicates that in absolute terms the output of all performing sectors has increased, except CSIR and the Ministry of Chemicals and Fertilizers (MCF), GoI, which have shown a decrease in 2008–2013 as compared to 2004–2008. However, as seen by the proportional output of these performing sectors in two blocks in case of private R&D institutions, medical colleges and hospitals as well as DST, it has declined marginally. In the case of CSIR, the decrease in output is significant.

Prolific institutions and its impact

Total output came from 867 institutions located in different parts of India. Table 3 lists the 26 most prolific institutions that contributed 1% or more of the total publication output along with the number of citations these papers received during 2004–2014 and the values of CPP and RCI. These institutions produced more than half (59.6%) of the total output and obtained about two-third (64.6%) of the citations. Remaining 841 institutes produced the rest of the output. Of the 26 prolific institutions, 13 were academic institutions, five each belonged to CSIR and IITs, and one each belonged to DST and MCF, GoI. The remaining one, namely Dr Reddy Lab Ltd is a private-funded R&D institution. The value of CPP for all the institutes listed in Table 3 is higher than the average (11.7) value for India, except for the University of Rajasthan, Jawaharlal Nehru Technological University (JNTU), and Kakatiya University. The value of CPP for the University of Rajasthan, JNTU, Hyderabad and Kakatiya University, Warangal, which showed significantly less CPP values than the average for India also had lowest values among all the institutions listed in Table 3. However, the value of CPP for Dr Reddy Lab Ltd is close to the average CPP value for India. The value of CPP is highest (20.58) for IIT Guwahati followed by IIT, Kanpur (18.30) and CSIR-Central Leather Research Institute, Chennai (17.13). The value of RCI also follows similar trends. Based on the low values of RCI for University of Rajasthan, JNTU and Kakatiya University, it can be inferred that the impact of research for these institutes is not commensurate with their output. A raw analysis of data on publishing pattern of papers by these three institutes indicates that more than one-third of their papers appeared in low impact factor journals published from India and other developing and developed countries. This may be a possible reason for low values of CPP and RCI for these institutes.

Prolific authors and the impact of their research output

Total output was produced by more than 24,000 Indian authors. Table 4 lists 33 authors who published 50 or more papers. These authors produced 3408 (19.6%) of the total output and received 46,672 (22.9%) of the total citations. These prolific authors belonged to 21 different institutions. Highest (9) number of authors was from CSIR-IICT, Hyderabad followed by CSIR-NCL, Pune (3), JNTU and Kakatiya University (2 each). Of the 33

Table 3. Most prolific institutions

Institution	TNP (%)	TNC (%)	CPP	RCI
CSIR-IICT, Hyderabad	2158 (12.44)	32677 (16.08)	15.14	1.29
CSIR-NCL, Pune	745 (4.30)	10667 (5.25)	14.32	1.22
CSIR-CDRI, Lucknow	720 (4.15)	10841 (5.34)	15.06	1.29
Indian Institute of Science (IISc), Bengaluru	683 (3.94)	8767 (4.31)	12.84	1.09
IIT Bombay, Mumbai	465 (2.68)	6841 (3.37)	14.71	1.26
IIT, Kanpur	405 (2.34)	7413 (3.65)	18.30	1.56
University of Hyderabad	383 (2.21)	4575 (2.25)	11.95	1.02
University of Delhi	346 (1.99)	4936 (2.43)	14.27	1.22
IIT, Kharagpur	344 (1.98)	3956 (1.95)	11.50	0.98
University of Rajasthan, Jaipur	327 (1.89)	1656 (0.82)	5.06	0.43
JNTU, Hyderabad	314 (1.81)	1246 (0.61)	3.97	0.34
Dr. Reddy Lab Ltd, Hyderabad	283 (1.63)	2446 (1.20)	8.64	0.74
DST-IACS, Kolkata	282 (1.63)	4770 (2.35)	16.91	1.44
University of Kalyani	279 (1.61)	3287 (1.62)	11.78	1.01
University of Madras, Chennai	276 (1.59)	3003 (1.48)	10.88	0.93
IIT Madras, Chennai	248 (1.43)	3341 (1.64)	13.47	1.15
Kakatiya University, Warangal	240 (1.38)	1242 (0.61)	5.17	0.44
NIPER, Chandigarh	237 (1.37)	4264 (2.10)	17.99	1.53
Guru Nanak Dev University, Amritsar	224 (1.29)	3671 (1.81)	16.39	1.40
IIT, Guwahati	220 (1.27)	4528 (2.23)	20.58	1.76
CSIR-NIIST, Thiruvananthapuram	214 (1.23)	3013 (1.48)	14.08	1.20
Banaras Hindu University, Varanasi	201 (1.16)	2636 (1.30)	13.11	1.12
Madurai Kamraj University, Madurai	194 (1.12)	2064 (1.02)	10.64	0.91
Jadavpur University, Kolkata	193 (1.11)	3051 (1.50)	15.81	1.35
CSIR-Central Leather Research Institute, Chennai	180 (1.04)	3083 (1.52)	17.13	1.46
University of Allahabad	179 (1.03)	2143 (1.05)	11.97	1.02
Sub-total	10,340 (59.6)	131,340 (64.6)	12.70	1.08
Other 841 institutions	7004 (40.4)	71,847 (35.6)	10.26	0.87
Total	17,344(100)	203,187 (100)	11.72	1.0

CSIR-IICT, Indian Institute of Chemical Technology; CSIR-NCL, National Chemical Laboratory; CSIR-CDRI, Central Drug Research Institute; JNTU, Jawaharlal Nehru Technological University; DST-IACS, Indian Association for the Cultivation of Science; NIPER, National Institute of Pharmaceutical Education and Research; CSIR-NIIST: National Institute of Interdisciplinary Science and Technology.

authors listed in Table 4, one-third (11) had CPP and RCI lower than the Indian average. It indicates that the impact of the research produced by these 11 authors is not commensurate with their output as the value of RCI is less than 1. Among these authors the lowest CPP and RCI were for Dubey Pramod Kumar of JNTU and Mogilaiah, K. of Kakatiya University. The values of CPP and RCI were highest for Ranu, Brindaban C. of DST-IACS, Kolkata followed by Kantam, M. Lakshmi of CSIR-IICT.

Communication pattern of researchers

The communication pattern of the Indian researchers has been examined using two different indicators. These are the publishing country of journals where the research results were published and impact factor (IF) of these journals, which were obtained from Journal Citation Reports 2012. Journals published from the advanced countries of the West command more respect and mainstream connectivity compared to those published from India or other developing countries. Impact factor is an indicator of the reputation of a journal. Papers published in journals with higher IF by and large have more credit than those published in journals with low IF. The findings based on these two indicators have been described below.

Domestic versus international journals

Analysis of data on papers published in organic chemistry and its sub-disciplines by Indian scientists indicates that these papers were scattered in 62 journal titles published from abroad and two journal titles published from India. Table 5 presents the analysis of data for the distribution of output in domestic and international journals. It indicates that about 15.5% papers were published in domestic journals and the remaining 84.5% appeared in journals published from abroad, which includes both developed as well developing countries. Among the journals published abroad, highest number of papers (44%) appeared in those originating from the UK, followed by USA (23.5%). This indicates that more than two-third (67.4%) of the papers published by Indian scientists in organic chemistry and its sub-disciplines appeared in journals published from these two scientifically advanced countries of the

Table 4. Highly prolific authors

Author	Institution	TNP	TNC	CPP	RCI
Yadav, J. S.	CSIR-IICT, Hyderabad	545	8406	15.42	1.33
Subba Reddy, B. V.	CSIR-IICT, Hyderabad	285	4546	15.95	1.38
Chandrasekhar, S.	CSIR-IICT, Hyderabad	128	2037	15.91	1.38
Majumdar, K. C.	University of Kalyani	126	1465	11.63	1.01
Perumal, Paramasivam	CSIR-CLRI, Chennai	120	2455	20.46	1.77
Dubey, Pramod Kumar	JNTU, Hyderabad	118	310	2.63	0.23
Das, Biswanath	CSIR-IICT, Hyderabad	117	1504	12.85	1.11
Kantam, M. Lakshmi	CSIR-IICT, Hyderabad	107	2565	23.97	2.07
Srikrishna, Adusumilli	IISc, Bengaluru	102	748	7.33	0.63
Sabitha, Gowravaram	CSIR-IICT, Hyderabad	97	1284	13.24	1.14
Mobin, Shaikh M.	IIT Indore	91	1124	12.35	1.07
Misra, Anup Kumar	Bose Institute, Kolkata	91	925	10.16	0.88
Mukkanti, Khagga	JNTU, Hyderabad	91	618	6.79	0.59
Pal, Manojit	Matrix Labs Ltd, Secundarabad	83	1051	12.66	1.1
Yadav, Lal Dhar Singh	University of Allahabad	82	992	12.10	1.05
Puranik, Vedavati G.	CSIR-NCL, Pune	81	974	12.02	1.04
Kamal, Ahmed	CSIR-IICT, Hyderabad	78	1113	14.27	1.23
Ranu, Brindaban C.	DST-IACS, Kolkata	76	2515	33.10	2.86
Mogilaiah, K.	Kakatiya University, Warangal	75	242	3.23	0.28
Perumal, Subbu	Madurai Kamaraj University, Madurai	75	1090	14.53	1.26
Suresh, Eringathodi	CSIR-CSMCRI, Bhavnagar	75	1191	15.88	1.37
Sudalai, Arumugam	CSIR-NCL, Pune	72	963	13.38	1.16
Batra, Sanjay	CSIR-CDRI, Lucknow	71	1440	20.28	1.75
Kotha, S.	IIT Bombay, Mumbai	70	1469	20.99	1.81
Sureshbabu,Vommina Venka	Bangalore University, Bengaluru	69	446	6.46	0.56
Rajanarendar, E.	Kakatiya University, Warangal	69	356	5.16	0.45
Gurjar, Mukund Kumar	CSIR-NCL, Pune	69	730	10.58	0.91
Islam, Syed S.	Visva Bharati University, Shantiniketan	64	909	14.20	1.23
Mohapatra, Debendra K.	CSIR-IICT, Hyderabad	62	646	10.42	0.9
Krishna, Palakodety Radha	CSIR-IICT, Hyderabad	58	622	10.72	0.93
Ray, Jayanta K.	IIT Kharagpur	55	688	12.51	1.08
Prasad, Kavirayani R.	IISc, Bengaluru	54	845	15.65	1.35
Mehta, Goverdhan	University of Hyderabad	52	403	7.75	0.67

CSIR-CSMRI, Central Salt and Marine Research Institute.

Table 5. Distribution of Indian organic chemistry output by journal publishing countries

Journal publishing country	Number of journals	Number of papers (%)
England	18	7613 (43.9)
USA	23	4081 (23.5)
India	2	2687 (15.5)
Germany	8	1940 (11.2)
Switzerland	3	539 (3.1)
United Arab Emirates	4	292 (1.7)
Subtotal	58	17,152 (98.9)
Other four countries	6	192 (1.1)
Total	64	17,344 (100)

Table 6. Distribution of output according to range of impact factor (IF) of journals

Range of IF	Number of papers	% of papers
0–1 (low)	3796	21.9
>1 ≤ 3 (medium)	10,543	61.4
>3 ≤ 5 (high)	2322	13.5
>5 (very high)	683	3.9
Total	17,344	100
Average	2.1	

West. The preference for publishing papers in organic chemistry is similar to the publishing trend for the entire Indian scientific output. However, in the latter case US journals are the most preferred for publishing[14], unlike organic chemistry where the journals published from the UK are preferred. This also corroborates the findings of Nagaiah and Srimannarayana[13] that Indian scientists prefer to publish in international journals. Remaining 32.6% papers appeared in journals originating from other developed and developing countries. Of these, about half appeared *in the Indian Journal of Chemistry, Section B* and *Indian Journal of Heterocyclic Chemistry*. From the pattern of publishing country of journals where Indian scientists published, it can be inferred that the Indian scientific output in organic chemistry is well connected to the mainstream science as more than two-third of the papers was published in journals originating from two most scientifically advanced countries of the West.

Table 7. Most preferred journals used for communicating research results

Journal and country of publication	No. of papers	JIF_{2012}*
Tetrahedron Letters (England)	3051	2.50
Indian Journal of Chemistry Section B (India)	1611	0.69
Synthetic Communications (USA)	1191	1.06
Indian Journal of Heterocyclic Chemistry (India)	1076	0.17
Tetrahedron (England)	953	2.80
Bioorganic and Medicinal Chemistry Letters (England)	942	2.34
Journal of Organic Chemistry (USA)	720	4.56
Synthesis–Stuttgart (Germany)	617	2.50
Synlett (Germany)	589	2.66
Carbohydrate Polymers (England)	476	3.48
Bioorganic and Medicinal Chemistry (England)	470	2.90
Journal of Heterocyclic Chemistry (USA)	466	1.23
Tetrahedron: Asymmetry (England)	455	2.12
Organic Letters (USA)	439	6.14
European Journal Organic Chemistry (Germany)	434	3.35
Journal of Organometallic Chemistry (Switzerland)	428	2.00
Organic and Biomolecular Chemistry (England)	396	3.57
ARKIVOC (USA)	391	1.06
Phosphorus Sulfur and Silicon and Related Elements (England)	365	0.60
Carbohydrate Research (England)	254	2.05
Letters in Organic Chemistry (UAE)	187	0.67
Heterocyclic Communications (Germany)	184	0.52
Organometallics (USA)	172	4.15
Advanced Synthesis and Catalysis (Germany)	158	5.54
Organic Process Research and Development (USA)	129	2.74
Main Group Metal Chemistry (Germany)	124	0.69
Beilstein Journal of Organic Chemistry (Germany)	103	2.80
Total	16,381	
Other remaining 37 journals publishing less than 100 articles	963	
Grand total	17,344	

*Impact factor rounded-off to the nearest whole number.

Distribution of papers according to impact factor

The analysis indicates that the average impact factor of journals where the papers were published is 2.1. Based on the average value, authors divided the impact factor into four categories: 0–1 (low), >1 to ≤ 3 (medium), > 3 to ≤ 5 (high) and > 5 (very high). Distribution of output according to the range of impact factor is given in Table 6, which indicates that about one-fifth (21.9%) papers are published in low impact factor journals. Of these, 15.5% papers appear in two Indian journals which have an impact factor less than one. More than half (61.4%) of papers has been published in medium impact factor journals and the rest (17.4%) in high and very high impact factor journals. Based on this parameter also, one can infer that Indian organic chemistry output is well connected to the mainstream science as more than three-fourth (78%) of the published papers appears in medium, high and very high impact factor journals. Table 7 lists journals most preferred by Indian scientists for publishing their results in organic chemistry and its sub-disciplines along with the name of publishing country and impact factor for 2012. Of the 27 journals listed in Table 7, about one-third (9) from the UK, seven each are from USA and Germany, two each from India, and one each from Switzerland and the United Arab Emirates (UAE).

Citation analysis of output

Citation rates reflect the impact of published work on the international community. Citation counts of authors or a group of authors or an institution indicate the influence or visibility of individuals or groups or institutions. High levels of citation to a scientific publication have been interpreted as signs of scientific influence, impact and visibility. An author's visibility can be measured by finding how often his/her publications have been cited in other publications. The impact of research can thus be assessed by making citation counts of the articles received over a period of time. Table 8 presents the distribution of citations received by papers during 2004–2014. Of the total papers published by Indian scientists in the discipline of organic chemistry and its sub-disciplines, only a small proportion (11.2%) did not get any citation and the rest was cited one or more times. Of the total cited papers, about half (46.25%) was cited between 1 and 5 times and 18.8% was cited 6–10 times. Thus, about

Table 8. Frequency of citations

Range of citations	Number of papers	% of papers	Cumulated % of papers	Total citations
0	1942	11.20	11.20	0
1	1645	9.48	20.68	1645
2	1402	8.08	28.76	2804
3	1137	6.56	35.32	3411
4	1030	5.94	41.36	4120
5	848	4.89	46.25	4240
6	818	4.72	50.97	4908
7	721	4.16	55.13	5047
8	653	3.76	58.89	5224
9	566	3.26	62.15	5094
10	506	2.92	65.07	5060
11–20	3225	18.59	83.66	47,771
21–30	1334	7.69	91.35	33,318
31–40	650	3.75	95.10	22,660
41–50	333	1.92	97.02	14,918
51–100	445	2.57	99.49	29,542
>100	89	0.51	100.00	13,425
Total	17,344	100		203,187

Citations/paper = 11.72.

Table 9. Highly cited authors

Authors	Bibliographic details	No. of citations
Jain, N., Kumar, A., Chauhan, S. and Chauhan, S. M. S., University of Delhi	*Tetrahedron*, 2005, **61**, 1015–1060	553
Verma, A. J., Deshpande, S. V., *Kennedy, J. F. CSIR-National Chemical Laboratory, Pune University of Birmingham	*Carbohydrate Polymers*, 2004, **55**, 77–93	422
Singh, Vijay and Batra, Sanjay, CSIR-Central Drug Research Institute, Lucknow	*Tetrahedron*, 2008, **64**(20), 4511–4574	380
John, Maya Jacob, Thomas, Sabu Mahatma Gandhi University, Kottayam	*Carbohydrate Polymers*, 2008, **71**, 343–364	339
Kotha, S., Brahmachary, E. and Lahiri, K. IIT Bombay, Mumbai	*European Journal of Organic Chemistry*, 2005, **22**, 4741–4767	327
Jose, D. A. *et al.* CSIR-Central Salt & Marine Research Institute, Bhavnagar	*Organic Letters*, 2004, **6**, 45	281
Ranu, B. C. and Banerjee, S. Indian Association for the Cultivation of Science, Kolkata	*Organic Letters*, 2005, **7**, 3049–3052	280
**Nair, Vijay and Suja, T. D. (IISc, Bengaluru) and CSIR-National Institute for Interdisciplinary Science and Technology, Thiruvananthapuram	*Tetrahedron*, 2007, **63**(50), 12247–12275	230
**Karthikeyan *et al.*, Mangalore University and Justice KS Hegde Academy, Mangalore	*Bioorganic and Medicinal Chemistry*, 2006, **14**(23), 7482–7489	223
Vigneshwaran, N. *et al.*, Central Institute for Research on Cotton Technology, Mumbai	*Carbohydrate Research*, 2006, **341**(12), 2012–2018	221
Boruwa *et al.*, CSIR-North East Institute of Science and Technology, Jorhat	*Tetrahedron: Asymmetry*, 2006, **17**, 3315–3326	218
Mhaske, Santosh B. and Argade, Narshinha P. CSIR-National Chemical Laboratory, Pune	*Tetrahedron*, 2006, **62**(42), 9787–9826	214
Gupta, U., Agashe, H. B., Asthana, A. and Jain, N. K., Dr. Hari Singh Gour University, Sagar	*Biomacromolecules*, 2006, **7**(3), 649–658	192
Nair, V. *et al.*, CSIR-National Institute for Interdisciplinary Science and Technology, Thiruvananthapuram	*Tetrahedron*, 2004, **60**, 1959–1982	188
*Li, D., Haneda, H., Hishita, S., Ohashi, N. and Labhsetwar, N. K., CSIR-National Environmental Engineering Research Institute, Nagpur	*Journal of Fluorine Chemistry*, 2005, **126**(1), 69–77	182

*Paper published with international collaboration; **Paper published with domestic collaboration.

two-third (65%) of the papers was cited between 1 and 10 times. Remaining (35%) was cited more than 10 times. Of these, the proportion of papers that received more than 50 citations was approximately 3%. Based on the pattern of citations also, one can infer that the Indian scientific output in organic chemistry and its sub-disciplines is well connected to the mainstream science as more than half (54%) of the papers was cited more than five times.

Highly cited authors

Table 9 lists 15 highly cited papers which received more than 180 citations. Of the 15 highly cited authors, eight are from six different institutions of CSIR, namely National Chemical Laboratory, Pune; Central Drug Research Institute, Lucknow; Central Salt and Marine Research Institute, Bhavnagar; National Institute for Interdisciplinary Science and Technology, Thiruvananthapuram; North East Institute of Science and Technology, Jorhat and National Environmental Engineering Research Institute, Nagpur. Remaining seven papers were published by scientists working at seven different institutions. Of the 15 highly cited authors, two papers each were with domestic and international collaboration, unlike Indian S&T, where a significant number of highly cited papers was published with international collaboration[14]. These 15 papers attracted about 2% of all citations. All the highly cited papers were published during 2004–2008.

Conclusion

Based on the above scientometric analysis of organic chemistry and its sub-disciplines we can conclude the following:

1. Highest number of papers were published in the sub-discipline of aliphatic compounds and it was also the sub-discipline of highest impact in terms of CPP and RCI.
2. The annual rate of growth fluctuated during the period of study, though the output was seen to grow continuously during the period of study.
3. Though academic institutions published the highest number (46.6%) of papers, CSIR made the highest impact as it had the highest number of prolific institutions, prolific authors and highly cited papers.
4. CPP for the entire Indian organic chemistry research output was 11.7. Low values of CPP and RCI for the University of Rajasthan, JNTU and Kakatiya University indicate that the impact of research in these institutions is not commensurate with their output.
5. Based on the distribution of published papers in journals by country, their impact factor as well as the pattern of citations of papers, it can be inferred that the research papers published in organic chemistry and its sub-disciplines form a part of the mainstream science.

1. MacCoss, M. and Baillie, T. A., Organic chemistry in drug discovery. *Science*, 2004, **303**(5665), 1810–1813.
2. Varaprasad, S. J. D. and Ramesh, D. B., Activity and growth of chemical research in India during 1987–2007. *DESIDOC J. Libr. Inf. Technol*., 2011, **31**, 387–394.
3. Guay, Y., Emergence of basic research on the periphery: organic chemistry in India, 1907–1926. *Scientometrics*, 1986, **10**, 77–94.
4. Nagpaul, P. S. and Pant, N., Cross-national assessment of specialization patterns in chemistry. *Scientometrics*, 1993, **27**, 215–235.
5. Karki, M. M. S. and Garg, K. C., Scientometrics of Indian organic chemistry research. S*cientometrics*, 1999, **45**, 107–116.
6. Karki, M. M. S., Garg, K. C. and Sharma, P., Activity and growth of organic chemistry research in India during 1971–1989. *Scientometrics*, 2000, **49**, 279–288.
7. Karki, M. M. S. and Garg, K. C., Bibliometrics of alkaloid chemistry Research in India. *J. Chem. Inf. Comput. Sci*., 1997, **37**, 157–161.
8. Kumari, G. L., Synthetic organic chemistry research: analysis by scientometric indicators. *Scientometrics*, 2009, **80**, 559–570.
9. Jain, A., Garg, K. C., Sharma, P. and Kumar, S., Impact of SERC's funding on research in chemical sciences. *Scientometrics*, 1998, **41**, 357–370.
10. Garg, K. C., Kumar, S. and Dutt, B., Impact of SERC's funding on research. *Curr. Sci*., 2007, **93**, 1114–1121.
11. Salini, C. P., Nishi, P., Vishnumaya, R. S. and Mini, S., A bibliometric evaluation of organic chemistry research in India. *Ann. Lib. Inf. Stud*., 2014, **61**, 332–342.
12. Nishi, P., Parvatharajan, P. and Prathap, G., Visibility and impact of the *Indian Journal of Chemistry Section B* during 2005–2009 using scientometric techniques. *Indian J. Chem. Sect. B*, 2012, **51**, 269–284.
13. Nagaiah, K. and Srimannarayana, G., Publications in organic chemistry from Indian universities and laboratories. *Curr. Sci*., 2015, **105**, 176–183.
14. Garg, K. C. and Kumar, S., Scientometric profile of Indian science as seen through Science Citation Index Expanded 2010–2011, *SRELS J. Inf. Manage.*, 2013, **50**, 529–542.

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