BIOINFORMATICS RESEARCH DURING 2008-2017: A SCIENTOMETRIC STUDY

Manya R. Gopal
K.G. Sudhier

Dr. Manya R. Gopal
Librarian, Kendriya Vidyalaya, Pangode, Thiruvananthapuram – 695 006, Kerala.
E-mail: manyarajagopal@gmail.com

Dr. K. G. Sudhier
Assistant Professor, Dept. of Library & Information Science Central University of Tamil Nadu, Neelakudi Campus, Kangalancherry Post Thiruvarur, Tamil Nadu - 610005
E-mail: kgsudhier@cutn.ac.in
(Corresponding author)

The article analyses the growth and development of bioinformatics literature in India published between 2008 and 2017 using qualitative and scientometric techniques. A total of 10824 data were drawn from Clarivate Analytic's Web of Science (WoS) in January 2019. During the period of study, the share of Indian contribution in bioinformatics research found to be 3.49%. with biochemistry and molecular biology accounting for the highest publications share. University of Delhi and Indian Institute of Science were the most productive institutes in the country. The journal *PLoS One* was found to have published the most papers from India followed by *International Journal of Systemic and Evolutionary Microbiology* and *Gene*. The article contributed by Ravi K Patel of NIPGR, New Delhi in the *PLoS One* journal received the highest number of citations followed by Milee Agarwal with 249 citations. Among the top ranked authors, Sanjay Kumar Singh of Bose Institute, Kolkata topped the list with 28 papers followed by George Priya Doss of VIT University, Vellore with 24 papers. Department of Biotechnology (DBT), Government of India is the major funding agency for the majority of research followed by DST and CSIR.

KEYWORDS: Bioinformatics, Computational Biology, Scientometrics, India, Web of Science

INTRODUCTION

Bioinformatics is a computer-assisted interface discipline dealing with the acquisition, storage, management, access and processing of molecular biology data. It is an interdisciplinary field that develops and applies computational methods to analyse large collection of biological data, such as genetic sequences, cell populations or protein samples, to make new predictions or discover new biology (Tripathi, 2000). The computational methods used include analytical methods, mathematical modelling and simulation. It deals with methods for storing, retrieving and analyzing biological data, such as nucleic acid (DNA/RNA) and protein genomic, biological and chemical data to support the drug discovery

process (Madhani, 2011). The discipline bioinformatics has become a frontline applied science and is of vital importance to the study of new biology, which is widely recognized as the defining scientific endeavor of the twenty-first century. The rapid expansion of the field was seen in the mid 1990s and early 2000 which were powered by the worldwide internet boon. The early contributors to the field of bioinformatics were from either life sciences or physical sciences who had realized the potential of computational approaches in the study of biology. As the discipline evolved and its scope became broader, the implementation of bioinformatics has grown in various fields (Gupta *et al.*, 2015).

The single most important event to give a big thrust to the development of bioinformatics was the Human Genome Project (HGP) initiated in 1988. Extensive developments in computer algorithm writing and database management paralleled this growth giving an impetus to the field of bioinformatics (Barik et al., 2020).The explosion of information resulting from the human genome project has propelled the rapid development of bioinformatics as a discipline. The growth in full genomic sequencing, structural genomics, proteomics, micro-array etc. will be very slow without application of bioinformatics (Fenstermacher, 2005).

India has experienced an extensive growth in the area of bioinformatics in the past decades since 1960s. The field of bioinformatics has undergone significant evolution in India. The number of publications has been increasing significantly during the years within the field of life science. Various bioinformatics courses were organised by universities and institutions in India to improve academic scenario. In addition to formal degree programmes, many universities organise national and international conferences to train bench scientists to use bioinformatics databases, tools and software. These programmes are mainly funded by the central government agencies like: CSIR, DBT, DST, ICMR, ICAR, and UGC.

The spread of bioinformatics centers across India is primarily due to the extensive infrastructure and network that was initiated way back in 1980s by S. Ramachandran, the first Secretary, DBT, Government of India, and is being supported at 168 locations across the country. According to Krishnaswamy and Madhan Mohan (2016)[6], 'India was the first country to conceptualise and establish, during 1986–87, a national distributed bioinformatics network, which is now the largest in the world . Even as the term 'bioinformatics' was just coined, the DBT took a bold step in initiating the Biotechnology Information System Network' (BTISNET) [7]. The network centres are in various levels viz Centres of Excellence (CoEs), Distributed Information Centres (DICs), Distributed Information Sub-Centres (Sub-DICs) and Bioinformatics Infrastructure Facilities (BIFs) and North Eastern Bioinformatics Network (NEBInet).

REVIEW OF LITERATURE

A good number of scientometric studies have been carried out on diverse subject fields where as very few studies have so far been conducted on bioinformatics research both at global and country level. Amongst such studies, Gopal and Sudhier (2017) presented the

authorship pattern and collaborative research in the field of bioinformatics in India as indexed in web of science for a period of 2010-2014. The study was based on 6187 publications and found a remarkable increase in the number of multi-authored publications. Again Gopal and Sudhier (2015) examined the growth and development of bioinformatics research in India in terms of the publication output as reflected in Web of Science (2006-2010). Song *et al* (2014) measured the influence and productivity of bioinformatics by mining full-text articles retrieved from *PubMed* Central. Magana (2014) provided an overview of the state of bioinformatics education and identified current approaches of bioinformatics education at the undergraduate and graduate levels. Based on these findings, they described the landscape of scholarly work in this area and, as a result, identify opportunities and challenges in bioinformatics education. Liu, Li and Guao (2014) conducted a study based on the Science Citation Index Expanded to provide insights into research activities on bioinformatics in China. Song and Kim (2013) collected full-text articles from *PubMed* Central and computed their citation relation. They infer the knowledge structure and understand the trend of the bioinformatics field. Vijayan *et al*. (2011) compiled Indian research publications in computational biology and bioinformatics. The publication covering a list of 2118 documents will be useful to the researchers in this area as well as to the DBT for assessing the tangible output of its endeavours.

Molatudi, Molotja and Pouris (2009) reports on the practises of bioinformatics research in South Africa using bibliometric techniques for the period 1990-2006 by using Science Citation Index Expanded (SCIE) data from the Web of Science database. Guan and Gao (2008) studied the comparison and evolution of Chinese research performance in the field of bioinformatics using SCI- Expanded database during the period of 2000-2005. The study found that the number of Chinese papers in bioinformatics has been increasing during the period of study. Patra and Mishra (2006) analyzed the growth of the scientiûc literature in bioinformatics collected from NCBI *PubMed* using standard bibliometric techniques.. The existing literature analysis revealed that very few studies were present in the field of bioinformatics research in the global as well as in the national level. In this background, the present study attempts to look into this area of research in the Indian context and understand how various institutional actors have performed during the past two decades. Hence, the proposed study could enable to bridge the research gap on scientometric output of bioinformatics, particularly in India.

OBJECTIVES OF THE STUDY

The specific objectives are to:

1. Examine the growth of bioinformatics research
2. Study the document forms, subjects and the relative growth of publications
3. Identify the top ranked authors, the pattern of authorship and co-authorship index
4. Identify the leading institutions and funding agencies involved in the research
5. Examine the state- wise productivity

6. Determine the core journals and highly cited articles

METHODOLOGY

The study was undertaken based on the data downloaded from Web of Science database for the period 2008-2017 using the following search strategy.

TS= (("Bioinformatics" OR "Computational biology" OR "Biology, Computational" OR "Computational Molecular biology" OR "Biology, computational molecular" OR "Biologies, Computational Molecular" OR "Computational Molecular Biologies"OR "Molecular biology, computational" OR "Molecular Biologies, Computational" OR "Bio-informatics" OR "Bioinformatic" OR "Bio Informatics" OR "Bio-Informatic" OR "Sequence analysis" OR "Genomics")) AND CU= India AND PY = 2009-2018. Refined by: [excluding] Countries/ territories: All other in the WoS database. The key words used for searching was taken from MeSH (Medical Subject Headings). First author count is employed for the author counting. All the searched results are first saved in text files and then imported into Microsoft Excel latest version and Statistical Package for Social Science (SPSS) version17.0 was used for analysis.

RESULTS AND DISCUSSION

India's share of Research Output

The growth of Indian bioinformatics literature corresponding to the world literature indexed by Web of Science during the period of study is presented in table 1. The table1 clearly indicates the growth of literature in the world as well as in India during the period of study. A steady and consistent growth is visible in the case of world output with a remarkable increase in the publication output. Whereas in India, a steady growth was seen upto the year 2011, but later years shows a greater increase except in the year

Table 1: Share of Indian Bioinformatics research output

Year	World output	Indian output	% of Indian output	% Share of India's research output
2008	24042	672	2.8	0.22
2009	25017	686	2.74	0.22
2010	25954	740	2.85	0.24
2011	26858	792	2.95	0.26
2012	29030	897	3.09	0.29
2013	32105	1157	3.6	0.37
2014	33760	1402	4.15	0.45
2015	35861	1397	3.9	0.45
2016	38130	1602	4.2	0.52
2017	39230	1479	3.77	0.48
Total	309987	10824	3.49	0.035

2014 and 2016. This plot clearly indicates that the bioinformatics research in India is growing and the publication output is increasing each year. It is observed that the Indian output is also increasing consistently with that of the world output.

Relative Growth Rate and Doubling Time

Relative Growth Rate (RGR) is a measure to study the increase in the number of articles of time and Doubling time (Dt.) is directly related to RGR. It is the time required for articles to become double of the existing amount (1985). Table 2 shows that 672 research publications in the year 2008 increased to 1479 by the end of 2017. From the result it is clear that the relative growth rate of total research output has decreased gradually for all the years. The growth rate is 0.7 in 2009 which decreased upto 0.15 in 2017. The study period of 10 years is divided into three blocks such as 2008-

Table 2: Relative Growth Rate and Doubling Time

Year	Count	Cumulative	W1	W2	R(a) W2-W1	Mean R(a) (1-2)	Doubling time Dt. (a)	Mean Dt. (a)
2008	672	672		6.51				
2009	686	1358	6.51	7.21	**0.7**	0.57	0.99	1.29
2010	740	2098	7.21	7.65	0.44		1.58	
2011	792	2890	7.65	7.97	0.32		2.17	
2012	897	3787	7.97	8.24	0.27	0.29	2.57	2.44
2013	1157	4944	8.24	8.51	0.27		2.57	
2014	1402	6346	8.51	8.76	0.25		2.77	
2015	1397	7743	8.76	8.95	0.19	0.2	3.65	3.67
2016	1602	9345	8.95	9.14	0.19		3.65	
2017	1479	10824	9.14	9.29	**0.15**		4.62	
Total	10824					0.35		2.46

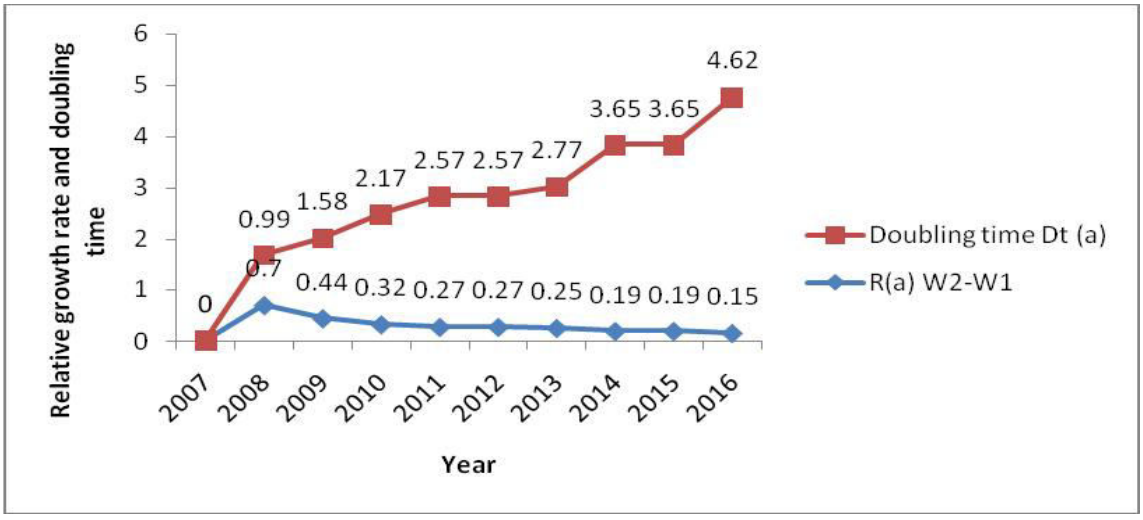

Figure 1: Relative Growth Rate and Doubling time of publications

2010, 2011-2013 and 2014-2017. The mean relative growth rates for these periods were 0.57, 0.29 and 0.2 respectively whereas the period of study witnessed a mean relative growth of 0.35. The doubling time for the above three blocks is 1.29, 2.44 and 3.67 respectively and the mean is 2.46.

From the figure 1, it is clear that the relative growth rate of literature in the field of bioinformatics shows a declining trend. Contrastingly, the doubling time for publications shows an increasing trend.

Subject- wise Distribution

The bioinformatics research output published during 2008-2017 is distributed across twenty sub-fields, with Biochemistry and Molecular Biology accounting for the highest publications share (16.18%) followed by Biotechnology and Applied Microbiology (15.15%). Medicine (14.26%) occupies the third position followed by Computer Science (7.41%) and Plant Sciences (6.31%). The number of contributions in these subject fields varied from 68 to 1751 papers and the first four subjects together contributed 53 % of the total output. The list of subject categories itself gives proof of the multidisciplinary nature of bioinformatics.

Major Contributing States

It is found that authors from all the states and union territories in the country have

Table 3: Subject Distribution

Sl. No.	Subject	TP	%
1	Biochemistry and Molecular Biology	1751	16.18
2	Biotechnology and Microbiology	1640	15.15
3	Medicine	1543	14.26
4	Computer Science	802	7.41
5	Plant Sciences	683	6.31
6	Multidisciplinary Sciences	674	6.23
7	Genetics and Heredity	448	4.14
8	Engineering	431	3.98
9	Agriculture	387	3.58
10	Biology	295	2.73
11	Veterinary Sciences	287	2.65
12	Virology	238	2.19
13	Immunology	207	1.91
14	Infectious Diseases	186	1.72
15	Geology	158	1.46
16	Environmental Sciences	141	1.3
17	Chemistry	101	0.93
18	Mathematical and Computational Biology	97	0.89
19	Materials Sciences	69	0.64
20	Pharmacology and Pharmacy	68	0.63
21	Others	618	5.71
Total		10824	100.00

contributed to bioinformatics research output. Sixteen states and union territories have contributed more than one paper. Union territories lead the list by contributing 21.55% (2330) papers. Other productive states are Uttar Pradesh (11.19%), Tamil Nadu (10.03%) and Karnataka (9.77%). Among the union territories, the highest contributions are from New Delhi and Chandigarh. Karnataka (9.77%), Maharashtra (9.04%) and Andhra Pradesh (7.93%) are the other most productive states with more than 500 publications. The analysis shows that the union territories and the other three states viz. Uttar Pradesh, Tamil Nadu and Karnataka together contribute more than 50 % of the total research output of bioinformatics research in the 10 years. There is a tremendous concentration of research institutions and funding in the capital city and few selected states.

Table 4: Geographical Distribution

Sl. No.	States	R	TP	%
1	Union Territories	1	2330	21.53
2	Uttar Pradesh	2	1211	11.19
3	Tamil Nadu	3	1086	10.03
4	Karnataka	4	1057	9.77
5	Maharashtra	5	978	9.04
6	Andhra Pradesh	6	858	7.93
7	West Bengal	7	569	5.25
8	Kerala	8	388	3.58
9	Gujarat	9	313	2.89
10	Odisha	10	277	2.56
11	Punjab	11	257	2.37
12	Haryana	12	250	2.31
13	Assam	13	189	1.75
14	Uttarakhand	14	175	1.62
15	Rajasthan	15	161	1.49

(R- Rank, TP- Total no. of Papers)

Indian Institutions involved in Bioinformatics Research

The total output of bioinformatics research from the country is contributed by 961 institutions belonging to different sectors scattered in various parts of India. Table 5 lists the 13 most prolific institutions that contributed more than 100 publications. The table 5 indicates that the University of Delhi is the top ranked institute with 2.32% of the total papers (251 papers) followed by, Indian Institute of Science (IISc, 229 papers) and Indian Agriculture Research Institute (IARI, 199 papers). On further analysis it is found that

among the institutions, 10 are universities under central or state governments. Two medical colleges which contribute more in the area of bioinformatics research are All India Institute of Medical Science (AIIMS) and Post Graduate Institute of Medical and Educational Research (PGIMER) with 124 and 61 publications each. IIT Rourkela and IIT Kharagpur are the other institutions which contributed 121 and 86 papers respectively. The remaining 19 contributions are by scientific research institutions coming under CSIR, ICAR, ICMR, IISc, DRDO, DBT, ISI and Bose Institute.

Table 5: Prolific Institutions

Institutions	TP	P	R
University of Delhi	251	2.32	1
Indian Institute of Science (IISc), Bengaluru	229	2.11	2
Indian Agriculture Research Institute (IARI), New Delhi	199	1.84	3
Indian Vetinary Research Institute (IVRI), Uttarakhand	162	1.49	4
Centre for Cellular & Molecular Biology (CCMB), Hyderabad	158	1.46	5
National Institute of Plant Genome Res. (NIPGR), New Delhi	137	1.26	6
Vellore Institute of Technological University (VIT), Vellore	128	1.18	7
Institute of Microbial Technology (IMTECH), Chandigarh	127	1.17	8
All India Institute of Medical Sciences (AIIMS), New Delhi	124	1.15	9
Indian Institute of Technology (IIT), Rourkela	121	1.12	10
Institute of Genomics &Integrative Biology (IGIB) , New Delhi	120	1.11	11
Banaras Hindu University (BHU), Varanasi	112	1.03	12
Jawaharlal Nehru University (JNU), Delhi	105	0.97	13

(R- Rank, P- Percentage, TP- Total no. of Papers)

Funding Agencies

Based on the number of projects and the amount spent for the research, the major funding agencies which are directly responsible for the sponsorship of bioinformatics research in the country are ranked and the results are shown in the table 6. Department of Biotechnology (DBT), Government of India is the major funding agency for the majority of research (14.53%). Department of Science and Technology (DST) and Council for Scientific and Industrial Research (CSIR) are the other agencies which are sponsoring bioinformatics research with 10.9% and 9.20% of the research output respectively. It is evident that almost all the agencies under the Government of India are spending enough money for the research and development activities in the area of bioinformatics.

Top ranked Journals

The researchers in the field of bioinformatics communicate their research output in the form of articles through different journals within the country and outside. During the period of study, the researchers published 8732 papers scattered over 1723 journals. Bibliographic form- wise analysis of the bioinformatics research shows that 80.67 % of the contributions are in the journals. The table 7 lists the top ten journals in which the

Table 6: Funding Agencies

Sl. No	Funding Agencies	TP	Percentage
1	Department of Biotechnology (DBT)	1573	14.53
2	Department of Science and Technology (DST)	1180	10.9
3	Council for Scientific and Industrial Research (CSIR)	996	9.2
4	University Grant Commission (UGC)	907	8.38
5	Indian Council of Agricultural Research(ICAR)	417	3.85
7	Indian Council of Medical Research (ICMR)	335	3.1
8	Science and Engineering Research Board (SERB)	59	0.54
9	National Agricultural Innovation Project (NAIP)	56	0.51
10	Defence Research and Development Organisation (DRDO)	37	0.35
11	Board of Research in Nuclear Science (BRNS)	30	0.28
12	All India Council for Technical Education (AICTE)	23	0.21
13	Others	346	3.2
14	Not mentioned	4865	44.95
Total		10824	100.00

Table 7: Top ranked journals

Sl. No	Journals	Year	Country	Publisher	IF	Rank	Count
1	PLoS One	2006	USA	PLoS	2.806	1	380 (4.35%)
2	International Journal of Systematic & Evolutionary Microbiology	1951	USA	IUMS	2.134	2	166 (1.9%)
3	Gene	1976	Netherlands	Elsevier	2.319	3	149 (1.71%)
4	Molecular Biology Reports	1974	Netherlands	Springer	1.828	4	103 (1.18%)
5	Indian Journal of Biotechnology	2002	New Delhi	NISCAIR	0.287	5	93 (1.07%)
6	Infection Genetics & Evolution	2001	Netherlands	Elsevier	2.885	6	90 (1.03%)
7	BMC Genomics	2000	U K	Biomed Central	3.867	7	88 (1.01%)
8	Applied Biochemistry & Biotechnology	1976	Netherlands	Springer	1.751	8	84 (0.96%)
9	Scientific Reports	2011	U K	Nature publishing group	5.228	9	77 (0.88%)
10	Current Science	1932	India	Indian Academy of Sciences	0.833	10	73 (0.84%)

researcher are publishing their output. *PLoS One* (380 papers) is the most productive journal in which bioinformatics researchers like to publish their articles.*International Journal of Systemic & Evolutionary Microbiology* (166 papers) and *Gene with* 149 papers are in the next two position. It is interesting to note that the top ranked journal with highest number of publications is *PLoS One* (IF= 2.806) and it was started in the year 2006. The remarkable feature of the results is the high status of multi- disciplinary journals in the core journal list of bioinformatics literature. It is also noted that among the first 10 journals, two are from India, *Indian Journal of Biotechnology* published by CSIR-NISCAIR and *Current Science* by Current Science Association along with Indian Academy of Sciences.

Authorship Pattern and Degree of Collaboration

It is observed from the analysis that, the single papers constitute only 4.40% whereas the multiple authors constitute 95.60% of the total output. It is inferred that the bioinformatics research community is in favour of collaborative work rather than single creativity. From the figure 2 it is clear that out of the total 10824 publications, 471 (4.35%) papers are contributed by single authors while 2044 papers (18.88%) are contributed by two authors. It is interesting to note that more than 56% of the total papers are contributed by four or more authors. From the analysis it can be interpreted that there is an increasing trend towards multiple authorship. It also throws light towards the increase of collaborative research in the field of bioinformatics. Figure 3 shows the productivity pattern of authors.

The degree of collaboration in different years is calculated and is presented in the table 9. To determine the degree of collaboration in quantitative terms, the formula given by Subramanyam (1983) is used. It is seen that the

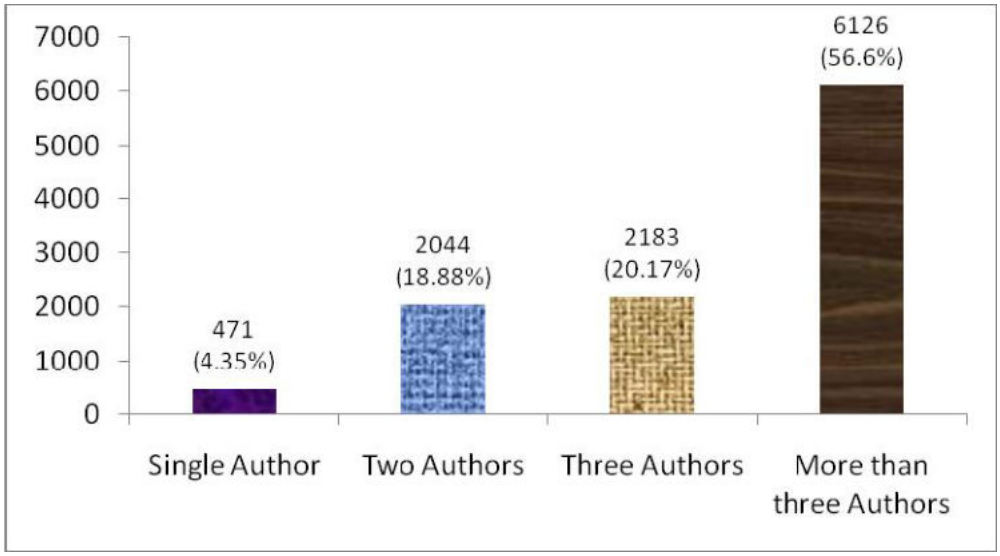

Figure 2: Authorship pattern of contributions

Table 8: Year- wise Degree of Collaboration

Year of publication	Single Author	Multiple authors	Total	Degree of Collaboration
2007	56	616	672	0.92
2008	52	634	686	0.92
2009	29	688	717	0.96
2010	35	780	815	0.96
2011	55	842	897	0.94
2012	46	1111	1157	0.96
2013	63	1339	1402	0.96
2014	52	1345	1397	0.96
2015	39	1563	1602	0.98
2016	44	1435	1479	0.97
Total	471	10353	10824	0.95 (Mean)

degree of collaboration over the years varies from 0.92 to 0.97. The mean value is found to be 0.95.

Co-Authorship Index

Co-Authorship Index (CAI) is a possible way of analysing the author collaboration patterns. It is obtained by calculating proportionally the number of single, two, multi and mega- authored papers for different nations or sub disciplines or years (2003). It is observed from the table 9 that the CAI of single authors shows a decline from 191.5 in the year 2008 to 68.4 in the year 2017. On the other hand, there is a fluctuation trend of CAI for two, three and more than three authored contributions. The table also suggests that the number of multi- authors is greater when compared with the single authors. The results clearly indicate the increase of collaborative research in the field of bioinformatics.

Table 9: Pattern of CAI

Year	Single Author	CAI	Two Authors	CAI	Three Authors	CAI	More than three Authors	CAI	Total
2008	56	191.5	149	117.4	144	81.5	323	25.2	672
2009	52	174.2	166	128.1	146	87.7	322	27.2	686
2010	29	92.9	115	84.9	159	53.4	414	12.9	717
2011	35	98.7	132	85.8	157	54.6	491	11.1	815
2012	55	140.9	159	93.9	162	58	521	11.1	897
2013	46	91.4	226	103.4	243	42.6	642	6.6	1157
2014	63	103.3	255	96.3	276	34.9	808	4.3	1402
2015	52	85.5	272	103.1	284	36.3	789	4.6	1397
2016	39	55.9	315	101.1	323	31.3	925	3.3	1602
2017	44	68.4	255	91.3	289	31.6	891	3.5	1479
Total	471		2044		2183		6126		10824

Most productive authors

The total output of bioinformatics research was contributed by 47643 Indian authors. Based on the first author count, the table 10 lists prolific authors who have published ten or more papers during the period of study. Sanjay Kumar Singh of Bose Institute, Kolkata with 28 papers topped the list followed by George Priya Doss of VIT University, Vellore published 24 papers and Virendra Gomase of Padmashree Dr DY Patil University, Navi Mumbai with 22 papers. Among the top ranked authors, four are from CSIR institutions and the others belong to institutions of national importance.

Table 10: Most Productive Authors

Authors	Affiliation	TP	P	R
Sanjay Kumar Singh	Bose Institute, Kolkata	28	0.26	1
George Priya Doss. C	VIT University, Vellore	24	0.22	2
Virendra Gomase. S.	Padmashree Dr DY Patil Univ, Navi Mumbai	22	0.2	3
Manoj Kumar	AIIMS, New Delhi	19	0.17	4
Anil Kumar. P	Institute of Microbial Technology, Chandigarh	18	0.16	5
Pradipta Maji	Indian Statistical Institute, Kolkata	12	0.11	6
T N R Srinivas	National Institute of Oceanography, Kochi	11	0.1	7
Asokan. R.	Indian Institute of Horticulture Research, Bangalore	10	0.09	8
Srimoni Dutta	Behala College, Kolkata	10	0.09	8
Suresh Govatati	Sri Krishnadevaraya University, Andhra Pradesh	10	0.09	8
Jitendra Kumar	IIT, Kharagpur	10	0.09	8
Mukesh Jain	National Institute of Plant Genomics Research , New Delhi	10	0.09	8
Amit Kumar	Central Institute of Medical and Aromatic Plants , Lucknow	10	0.09	8
Shri Krishna Raj	National Botanical Research Institute, Lucknow	9	0.83	9
V. Venkataravanappa	Indian Institute of Horticulture Research, Bangalore	9	0.83	9

Highly Cited Papers

Since citation counts can be considered as the indicator of the impact of a paper, papers receiving more citations show a positive trend towards high global visibility of Indian research output. Based on the publication output of the researchers of Indian bioinformatics field, the highly cited papers are analysed and is presented in Table 11. It is clear that top 10 papers were

identified as highly cited papers with 90 or more citations. These 20 papers together received 2800 citations and three papers have received more than 200 citations each. The article contributed by Ravi K Patel of NIPGR, New Delhi in the *PLoS One* journal received the highest number of citations (325) followed by Milee Agarwal with 249 citations. It is interesting to note that all the highly cited papers are published in foreign journals and none from India. All the 20 highly cited papers are published in 20 different journals. Out of the 10 highly cited papers, four are contributed by the scientists of NIPGR, New Delhi followed by three papers from University of Delhi and two

Table 11: Highly cited papers

Author	Affiliation	No. of citations	Source	Publisher
Ravi K Patel	NIPGR, New Delhi	325	PLOS one	Public Library of Science
Milee Agarwal	BV Patel Pharmaceutical Education & Research Development, Ahmadabad	249	Plant Cell Reports	Springer
Rohini Garg	NIPGR, New Delhi	228	DNA Research	Oxford University Press
Rita Arora	University of Delhi	183	BMC Genomics	Biomed Central
Samritil Dhawan	Punjab University, Chandigarh	161	Critical reviews in Biotechnology	Taylor and Francis
Aashima Nijhawan	University of Delhi	142	Plant Physiology	American Society of Plant Biologists
Banishree Saha	Indian Institute of Science (IISc), Banglore	136	Citokines	Academic press
D.Saravanakumar	Tamil Nadu Agricultural University, Coimbatore	125	Journal of Applied Microbiology	Blackwell publishing
Ramesh K Aggarwal	Center for Cellular and Molecular Biology, Hydrabad	118	Theor. Appl. Genet.	Springer
Upendra. N Dwivedi	University of Lucknow, Uttar Pradesh	112	Journal of Molecular Catalysis B-Enzymatic	Elsevier Science

papers from IISc, Bengaluru. The rest are produced by scientists from different universities and institutes. Among the highly cited authors, Rohini Garg of NIPGR, New Delhi contributed two papers.

CONCLUSION

Using publications data from *Web of Science* database, this study provides a quantitative and qualitative description of Indian bioinformatics research covering a period of 10 years (2008-2017). During the period of study, the share of Indian contribution in bioinformatics research is found to be 3.49%. with biochemistry and molecular biology accounting for the highest publications share followed by biotechnology and applied microbiology. Among the most productive states, Union territories lead the list by contributing 21.55% papers followed by Uttar Pradesh and Tamil Nadu. The University of Delhi is found to be the most contributing institution with 2.32% of the total papers where as IISc, Bengaluru gains the second position. *PLoS One* is the most productive journal in which bioinformatics researchers like to publish their articles. DBT, Government of India is the major funding agency for the majority of research (14.53%). The study is significant since such a study incorporating all facets of Indian bioinformatics research output based on WoS has never been conducted so far. The results of this study will help to assess and promote the bioinformatics research process in India and help to make a better understanding of the information needs of bioinformatics researchers. The study provided useful information to the scientists and researchers working in this area. The features that emerged were that the bioinformatics literature is growing and recorded an increased trend throughout the years.

REFERENCES

1. Barik, S., Rai, N., Mishra, P., Singh, S. K., & Gautam, V. (2020). Bioinformatics: how it helps to boost modern biological research. *Current Science,* 118 (5), 698-699.
2. Biotechnology Information System Network. Retrieved March 11, 2020, from http://www.btisnet.gov.in/
3. Fenstermacher, D. (2005). Introduction to bioinformatics. *Journal of American Society of Information Science & Technology,* 2(8), 440-446.
4. Garg, K. C. & Padhi, P. (2003). Scientometrics of Laser Research in India during 1970-1994. *Scientometrics,* 56 (1), 81-93.
5. Gopal, M. R., & Sudhier, K. G. (2015). A quantitative analysis of bioinformatics literature in India. *Information Studies*, 21 (2 & 3), 93-110.
6. Gopal, M.R., & Sudhier, K. G. (2017). Authorship Pattern and Collaborative Research in Indian Bioinformatics Research. *The Journal of Indian Library Association*, 2017, 53 (1), 5-13.
7. Guan, J., & Gao, X. (2008). Comparison and evolution of Chinese research performance in the field of bioinformatics. *Scientometrics*, 75(2), 357-379.

8. Gupta, S., Chavan, S., Deobagkar, D. N., & Deobagkar, D. D. (2015). Bio/ chemoinformatics in India: an outlook. *Briefings of Bioinformatics*, 16(4), 710-731. doi: 10.1093/bib/bbu028.

9. Krishnaswamy, S., & Madhan Mohan, T. (2016). The largest distributed network of bioinformatics centres in the world: Biotechnology Information System Network (DBT-BTISNET). *Current Science,* 110 (4), 556-561

10. Liu, Ai-Yuan., Li, Shi-Ying, & Guo, Yu-Qing (2014). Characteristics of research on bioinformatics in China assessed with Science Citation Index Expanded. *Scientometrics,* 99, 371–391.

11. Madhani, P. M. (2011). Indian Bioinformatics: Growth Opportunities and Challenges. *PRERANA- Journal of Management Thought& Practices*, 3(2), 7-17.

12. Magana, A. J., Taleyarkhan, M., Alvarado, D. R., Kane, M., Springer, J., & Clase, K. (2014). A survey of scholarly literature describing the field of bioinformatics education and bioinformatics educational research. *CBE Life Science Education*, 13(4), 607–623. doi:10.1187/cbe.13-10-0193

13. Mahapatra, M. (1985). On the validity of the theory of exponential growth of scientific literature. IASLIC National Conference, IASLIC, Calcutta, 1985.

14. Molatudi, M., Molotja, N., & Pouris, A. (2009). A bibliometric study of bioinformatics research in South Africa. *Scientometrics*, 81(1), 47-59

15. Patra, S. K., & Mishra, S. (2006). Bibliometric study of bioinformatics literature. *Scientometrics***,** 67(3), 477-489.

16. Song, M., & Kim, S.Y. (2013). Detecting the knowledge structure of bioinformatics by mining full-text collections. *Scientometrics,* 96 (1), 183–201.

17. Song, M., Kim, S. Y., Zhang, G., Ding, Y., & Chambers, T. (2014). Productivity and influence in bioinformatics: A Bibliometric analysis using PubMed Central. *Journal of the Association of Information Science & Technology*, 65(2), 352-371.doi: 10.1002/ asi.22970

18. Subramanian, K. (1983). Bibliometric studies of research in collaboration: A review. *Journal of Information Science,* 6(1), 33-38.

19. Tripathi, K. K. (2000). Bioinformatics: The foundation of present and future biotechnology. *Current Science,* 79 (5), 570–575.

20. Vijayan, M. (2011). *Bioinformatics and Computational biology: A compendium of research publications from India (2002-2010*), New Delhi: DBT, BTIS Bioinformatics Centre, Central Drugs Research Institute, Lucknow.

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