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Publication Output with Citation-based Performance of Selected DBT Institutes in India

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ABSTRACT

This scientometric study examines the publication outputs from six institutes of the Department of Biotechnology (DBT) in India as cited in the Scopus database over the past 24 years, 1996-2019. Research in biotechnology and other allied areas were analysed in terms of their chronological growth, activity index, collaborations, preferred journals for publication, country collaborators, popular keywords and scholarly impact. Scientists from the six institutes published 6, 076 journal articles representing 73.65 per cent of nationally collaborated articles and 25.03 per cent of internationally collaborated articles. Of the DBT institutes, the National Institute of Immunology (NII) published the highest number of articles and the Institute of Life Sciences (ILS) shared most patents. Publication frequency was the highest for Plos One journal and the countries with which scientists collaborated included the United States, Germany, United Kingdom and France in that order. The publishing outputs of DBT institutes suggest a need for greater international collaborative research in order to gain scientific competency and increase the quality of research outputs. Also this study may be helpful to government officials and policy makers in determining allocation of resources to boost the scholarly outputs of DBT institutes.

Keywords: Biotechnology; Publication; Research; Scientometrics; India

1. INTRODUCTION

The term biotechnology was used by the agricultural engineer Karl Erkey[1] from Hungary in 1919. According to him, biotechnology deals with the production methods where products are prepared from raw materials with the aid of living organisms[2]. Although the term was used 100 years ago, it is rooted in traditional applications like selective breeding, hybridisation and fermentation. Today's modern biotechnology also applies techniques involved in such areas as recombinant DNA technology (genetic engineering), the human genome project, and tissue culture. It encompasses aspects of biology, medicine, chemistry and engineering[3]. These techniques have wider scope in varied areas such as food industries, medicine, agriculture and environment[2]. The biotech sector can be broadly divided into five major segments - bio-pharma, bio-agri, bio-services, bio-industrial and bio-informatics[4].

India has the second-largest population in the world. The country possesses a huge market as well as suitable resources for biotechnology products and services. According to Invest India, the Indian biotechnology industry was valued at USD 51 billion in 2018 having a growth rate of almost 15 per cent year-on-year[5] and has the potential to hit USD 100 billion[6] by 2025. Meanwhile, India is among the top 12 biotech destinations in the world and ranks third in the Asia Pacific region[7]. In 1986, the Ministry of Science and Technology, India introduced a separate Department of Biotechnology (DBT) as a major initiative to boost the creation of infrastructural facilities and accelerate research and development[8]. Moreover, the Department also set up the Biotechnology Industry Research Assistance Council (BIRAC) as an Interface Agency to promote and empower the emerging Biotech enterprise to conduct strategic research and innovation[9].

Presently there are 16 autonomous institutes and 3 Public Sector Undertakings under the DBT[10]. Of these, the National Institute of Immunology (NII), Delhi was established in 1981 and it is the first autonomous institute brought under the DBT[8]. Though a lot of metric studies are carried out on biotechnology and allied areas in India, these DBT institutes were not considered among the most productive institutions in Biotechnology research in India[11-12]. Scientometrics is a quantitative methodology used to evaluate scientific output of an institution, discipline or country. Therefore, the present study is an endeavor to investigate the research growth and performance of selected DBT institutes of India using scientometric techniques over the past 24 years.

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2. LITERATURE REVIEW

Biotechnology research covers a broad range of topics. According to Kafarski[13], main areas of research in biotechnology can be differentiated by a rainbow colour code (eg. red denotes medicine and human health, green for processes improving agriculture, blue marine biotechnology, etc). The National Bioinformatics Policy[14] addressed that India's predominantly agrarian economy, the vast biodiversity and ethnically diverse population make biotechnology a crucial determinant in achieving national development.

Patra and Chand[15] studied biotechnology research in India from 1982-2003 and reported on its growth, authorship patterns, productivity, source journals and journal impact factors. The Central Food Technological Research Institute (CFTRI), Mysore was found to be the most productive institute (5.26 %) among Indian institutions. Sevukan and Sharma[16] analysed the research performance of biotechnology faculties in 10 central universities of India for the period of 1997 to 2006 and found that there was a steady growth in biotechnology research publications. Yeung *et al.*[2] examined the trends of biotechnology research from 2017-2019 and reported prominent research themes, major contributors. The United States of America, China and Germany were the leading countries for biotechnology research and India ranked 5th. In another study, Brito and Rodríguez-Navarro[17] confirmed the fact that the USA predominates in research in basic medicine and biochemistry and biotechnology. Further, Sharma et al.[11] also observed a remarkable growth in biotechnology research during 2008-2017 with 7.62 per cent share of the global publications and ranking third. Among the institutions with the highest publishing outputs, the Indian Institute of Technology Delhi contributed the most publications followed by the Council of Scientific and Industrial Research. In another study, Prakash and Arumugam[18] also evaluated India's contribution to biotechnology research and found total 5514 articles from 2002 to 2016. The study showed that two and three authored papers were dominant.

This literature review shows that research in biotechnology in India started during 1980's and since then significant positive growth has been seen. Few analytical studies have been conducted on Indian biotechnology research and the research outputs of the DBT Institutes have not yet been assessed. So, this study fills this research gap by examining the research outputs of six DBT institutes over the past 24 years.

3. OBJECTIVES OF THE STUDY

The present study discloses the research publication productivity of the six oldest DBT institutes in India. The objectives of the study are to:

- assess the publications produced by the selected DBT institutes,
- determine the collaborative research patterns and activity index,
- ascertain the most popular journals for scholarly communication,
- determine the leading collaborative country for publishing outputs,
- reveal the most frequently used keywords and citation impact.

Table 1. Six oldest autonomous institutes under the DBT

Institutes	Year of Establishment
National Institute of Immunology (NII), Delhi	1981
International Centre For Genetic Engineering and Biotechnology (ICGEB), Delhi	1983
National Centre for Cell Science (NCCS), Pune, Maharashtra	1986
Institute of Life Sciences (ILS), Bhubaneshwar, Odisha	1989
Centre for DNA Fingerprinting and Diagnostics (CDFD), Telangana	1990
Rajiv Gandhi Centre for Biotechnology (RGCB), Kerala	1990

4. DATA SOURCE, LIMITATIONS AND METHODOLOGY

The present study focuses on the publication productivity of six DBT affiliates (Table 1). These institutes were selected because they are pioneers among the DBT institutes and are established on or before 1990. So, it can be assumed that the selected institutes are more matured than other DBT institutes in terms of faculty strengths and research infrastructural facilities.

For this purpose, Scopus, an Elsevier multidisciplinary database, was consulted and as a methodology its use was considered consistent with earlier scientometric studies[11, 12, 18]. Each of the DBT institute's names was searched individually using 'Affiliation' search criteria and then the results were refined using the following strategies:

- Document type- Article
- Source type- Journal
- Published between – 1996 to 2019

The search query resulted in 6,076 journal articles and these were exported individually in CSV format. Further, patents were also counted from the institutional affiliation profile and CiteScore of the journals was also identified from the sources[19] of Scopus database. Additionally, the VOSviewer software tool has also been used for sketching network visualisation.

5. RESULTS

The bibliographical details of the retrieved records have been interpreted in the following sub-sections.

5.1 Contribution of the DBT Institutes

Figure 1 depicts the research contribution in terms of journal articles and patents of the six DBT institutes during 1996-2019. Out of 6 institutes, the National Institute of Immunology (NII) published the highest number of articles with 1697 followed by the National Centre for Cell Science (NCCS) with 1363 articles. The Institute of Life Sciences (ILS)

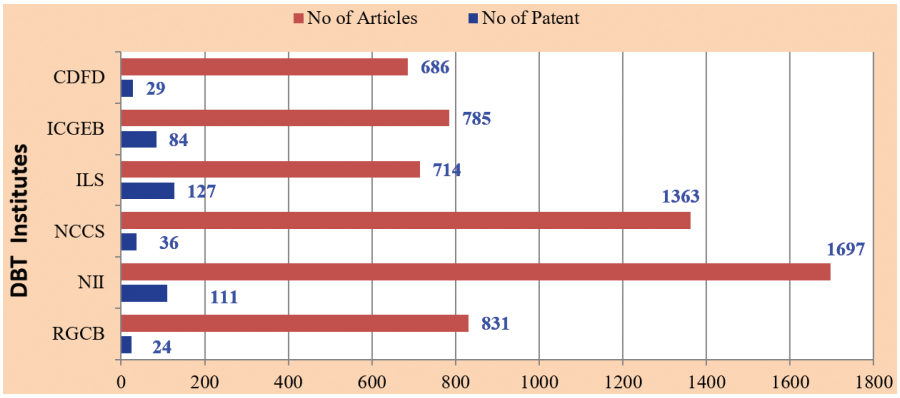

Figure 1. Distribution of research output (articles and patents) by DBT institutes during 1996-2019.

Table 2. Biennial period wise distribution of articles from 1996-2019

Year	DBT Institutes						Total	%	% CAGR
	CDFD	ICGEB	ILS	NCCS	NII	RGCB			
1996-1997	0	44	08	09	113	02	176	2.90	-
1998-1999	10	65	17	32	113	18	255	4.20	**20.37**
2000-2001	19	40	07	43	106	36	251	4.13	-0.79
2002-2003	42	81	14	54	99	28	318	5.23	12.56
2004-2005	71	76	14	70	105	43	379	6.24	9.17
2006-2007	94	37	28	105	120	51	435	7.16	7.13
2008-2009	59	41	43	116	152	53	464	7.64	3.28
2010-2011	58	61	113	171	150	91	644	10.60	17.81
2012-2013	69	79	169	173	195	113	798	13.13	11.32
2014-2015	88	100	105	210	173	117	793	13.05	-0.31
2016-2017	81	92	103	196	209	137	**818**	13.46	1.56
2018-2019	95	69	93	184	162	142	745	12.26	-4.57
Total	686	785	714	1363	1697	831	6076	100	6.5

contributed the most patents with 127 followed by the National Institute of Immunology (NII) with 111 patents. Conversely, the Centre for DNA Fingerprinting and Diagnostics (CDFD) published the lowest number of articles with 686 and the Rajiiv Gandhi Centre for Biotechnology (RBCB) produced only 24 patents.

5.2 Year-wise DBT Institutes' Research Output

Table 2 shows biennial distribution of articles and from 1996 to 2019 the six institutes published 6,076 articles representing a 6.5 per cent Compound Annual Growth Rate (CAGR). The highest number of articles, 818 or 13.46 per cent, were published from 2016 to 2017 and the lowest number, 176 or 2.90 per cent, were published from 1996-1997. Additionally, the maximum research growth occurred from 1998-1999 with 20.37 per cent CAGR and in 2010-2011 with 17.81 per cent CAGR. Hence, it may be stated from the empirical dataset that a consistent growth was seen in the research publication output except for the years 2000-2001, 2014-15 and 2018-2019.

The mathematical formula for calculation of Compound Annual Growth Rate (CAGR)[20] is mentioned below:

$$CAGR = \left(\frac{\text{Ending Value}}{\text{Begining Value}} \right)^{\frac{1}{n}} - 1$$

CAGR%= CAGR × 100; where *n* is the number of interval periods in the dataset.

5.3 Activity Index

Table 3 explores the activity index (AI) of the selected DBT institutes to measure their relative research efforts. Here the study period has been divided into two equal blocks having 12 years each. In the first block, ICGEB (146.35), NII (129.48) and CDFD (115.23) registered contributions that rated higher than the average effort. In the second block, ILS (125), NCCS (109.82) and RGCB (112.03) registered contributions that rated higher than the average effort. In this context, it is worth noting that the contributions of ILS (83.71) increased rapidly in the second block while in the case of ICGEB, the publications (-66.1) reduced significantly in the later years. An AI>100 reflects higher than average effort and AI<100 indicates the lower than average effort; AI=100 confirms the institute's effort precisely to the average.

As suggested by Frame (1977), the AI can be estimated by using following formula[21]:

$$AI = \{(N_{ij}/N_{io}) / (N_{oj}/N_{oo})\} \times 100$$

Where, N_{ij}= Total number of publications of a institute in a particular block (j),

N_{io}= Total number of publications of the institute (i) in all blocks,

N_{oj}= Total number of publications for all institutes in a block (j) and

N_{oo}= Total number of publications for all institutes and for all blocks

5.4 Collaboration Pattern

Table 4 depicts the collaboration trend and scholarly impact of the articles. The scientists of ICGEB produced the largest share with 35.41 per cent of internationally collaborated articles while the RGCB contributed the most with 79.90 per cent of national collaborated articles. Out of the total of 6,076 articles, the six institutes published 4, 475 articles or 73.65

Table 3. Activity index of the selected DBT institutes during 1996-2019

DBT Institutes	1996-2007		2008-2019		Total	Change in AI during 1996-2019
	Articles	AI	Articles	AI		
CDFD	236	115.23	450	93.52	686	-21.71
ICGEB	343	146.35	442	80.27	785	-66.1
ILS	88	41.28	626	125	714	83.71
NCCS	313	76.92	1050	109.82	1363	32.90
NII	656	129.48	1041	87.45	1697	- 42.02
RGCB	178	71.75	653	112.03	831	40.28
Total	1,814	100	4,262	100	6,076	0

Table 4. Collaboration trend and citations impact

Name of the DBT Institute	No Collaboration	%	NCA	%	ICA	%	Total articles
CDFD	20	2.92	480	69.97	186	27.11	686
ICGEB	11	1.40	496	63.18	278	35.41	785
ILS	10	1.40	505	70.73	199	27.87	714
NCCS	16	1.17	1044	76.60	303	22.23	1363
NII	15	0.88	1286	75.78	396	23.34	1697
RGCB	08	0.96	664	79.90	159	19.13	831
Total	80	1.32	4,475	73.65	1,521	25.03	6,076
ACPP	13.25		21.44		25.04		22.24

NCA= National collaborated articles; ICA= International collaborated articles; ACPP= Average citations per paper

per cent of the national collaborated articles and averaged 21.44 citations per paper; and 1,521 articles or 25.03 per cent internationally collaborated articles with an average of 25.04 citations per paper. Further, 80 articles published by single authors accounted for 1.32 per cent of the total articles and these articles were found to have the lowest citation impact.

5.5 Most popular journals used for publishing research results

The 15 most popular journals used for publishing research results, their corresponding share and scholarly impact are shown in Table 5. The scientists of CDFD and NII preferred to publish their articles in the Journal of Biological Chemistry having 33 and 80 articles respectively. Furthermore, the scientists of ILS, NCCS and RGCB published their majority articles in the Plos One journal having 38, 58 and 28 articles respectively. The scientists of the ICGEB contributed 30 articles to the Biochemical and Biophysical Research Communications journal. Overall, the Plos One having the CiteScore of 5.2 was the journal with the most preferred with a total of 249 published articles. The Journal of Biological Chemistry with a CiteScore of 7.4 ranked 2nd with 187 articles and had the largest citation impact.

5.6 Country wise Collaboration Output

Table 6 reveals the data related to the top 10 collaborating countries, corresponding share and scholarly impact. The scientists of United States produced the lion's share of 820 collaborated papers having 32 articles that received at least 100 or more citations. This is followed by Germany with 162 articles (2.67 %) and the United Kingdom with 130 articles (2.14 %). In terms of producing highly cited articles, the collaborated articles of France secured 2nd place and Germany ranked 3rd position having 10 articles. Figure 2 shows the collaboration linkage network of the DBT institutes (India) and those countries with whom they had the greatest number of collaborations.

5.7 Research Trends as Reflected in Keywords

Table 7 and Fig. 3 reflect the most frequently used author keywords. Out of a total 11,548 keywords, 20 keywords have been highlighted and mapped. Of these, 'Apoptosis' was the keyword which occurred most often with 156 times followed by 'Plasmodium Falciparum' and 'India' having 55 times respectively. The 20 most frequent keywords form 5 clusters. The Cluster 1 consists 6 items (Cancer, Curcumin, Diabetes, Inflammation, Nano-particles, Nf-Kb), cluster 2 contains 6 items (Gene Expression, India, Malaria, Phylogeny, Plasmodium falciparum, vaccine), cluster 3 contains 3 items (Apoptosis, autophagy, cytotoxicity), cluster 4 contains 3 items (Breast Cancer, P53, Smar1) and cluster 5 contains 2 items (cytokines, oxidative stress).

5.8 Citation report

Table 8 reports the citation impact and performance of the publications of DBT institutes. The publications of ICGEB received maximum average citations of 28.3 per paper whereas the publications of NCCS gained maximum h-index of 76 and 46 of its publications received at least 100 or more citations. Similarly, the publications of NII gained highest A-index of 142.1 and also received maximum *p*-index score of 93.47. Conversely, the maximum publications i.e. 6.74 per cent of RGCB remain uncited. Overall, the total publications received 22.24 average citations per paper, h-index of 120 and A-index score of 201.33. Only, 4.77 per cent publications remain uncited.

The A-index counts average number of citations of h-core

Table 5. Preferred journals for dissemination of research results

Name of the Journal with CiteScore-2019	DBT Institutes						Total Articles	AC_{100}	AC_{50}
	CDFD	ICGEB	ILS	NCCS	NII	RGCB			
Plos One, 5.2	25	23	38	58	77	28	249	2	13
Journal of Biological Chemistry, 7.4	33	25	2	34	80	13	187	24	27
Scientific Reports, 7.2	11	27	22	30	46	21	157	1	01
Journal of Immunology, 8.3	9	19	2	32	49	0	111	4	13
Biochemical and Biophysical Research Communications, 4.6	6	30	6	29	28	6	105	1	09
Current Science, 1.2	12	8	5	25	16	14	80	0	03
Nucleic Acids Research, 21.1	15	4	2	13	15	6	55	2	01
Journal of Biosciences, 2.1	15	3	1	22	9	1	51	1	3
Biochemical Journal, 7.6	10	11	2	2	20	2	47	1	5
Vaccine, 5.5	3	8	0	2	29	2	44	0	2
Febs Letters, 5.6	8	6	0	10	15	4	43	0	7
Journal of Virology, 7.9	4	14	1	9	13	2	43	7	8
International Journal of Systematic and Evolutionary Microbiology, 4.2	0	0	9	31	1	0	41	2	1
Gene, 4.8	10	4	4	1	15	3	37	0	3
Journal of Bacteriology, 5.4	24	3	1	2	6	0	36	0	3

AC_{100}= Number of articles with at least 100 or more citations; *AC_{50}= Number of articles having 50 to 99 citations.*

Table 6. Country wise distribution of collaborated articles

Country	DBT Institutes						Total articles (N= 6076)	%articles	AC_{100}
	CDFD	ICGEB	ILS	NCCS	NII	RGCB			
United States	89	132	107	161	247	84	820	13.50	32
Germany	21	18	21	37	43	22	162	2.67	10
United Kingdom	14	28	11	29	24	24	130	2.14	8
France	22	32	11	20	23	17	125	2.06	11
Japan	23	13	8	14	24	14	96	1.58	4
Italy	28	24	7	15	6	10	90	1.48	4
Australia	9	18	7	20	12	4	70	1.15	1
Spain	6	30	1	11	2	6	56	0.92	2
Canada	6	7	4	12	13	10	52	0.86	3
China	14	3	5	13	7	7	49	0.81	2

AC_{100}= Number of articles with at least 100 or more citations.

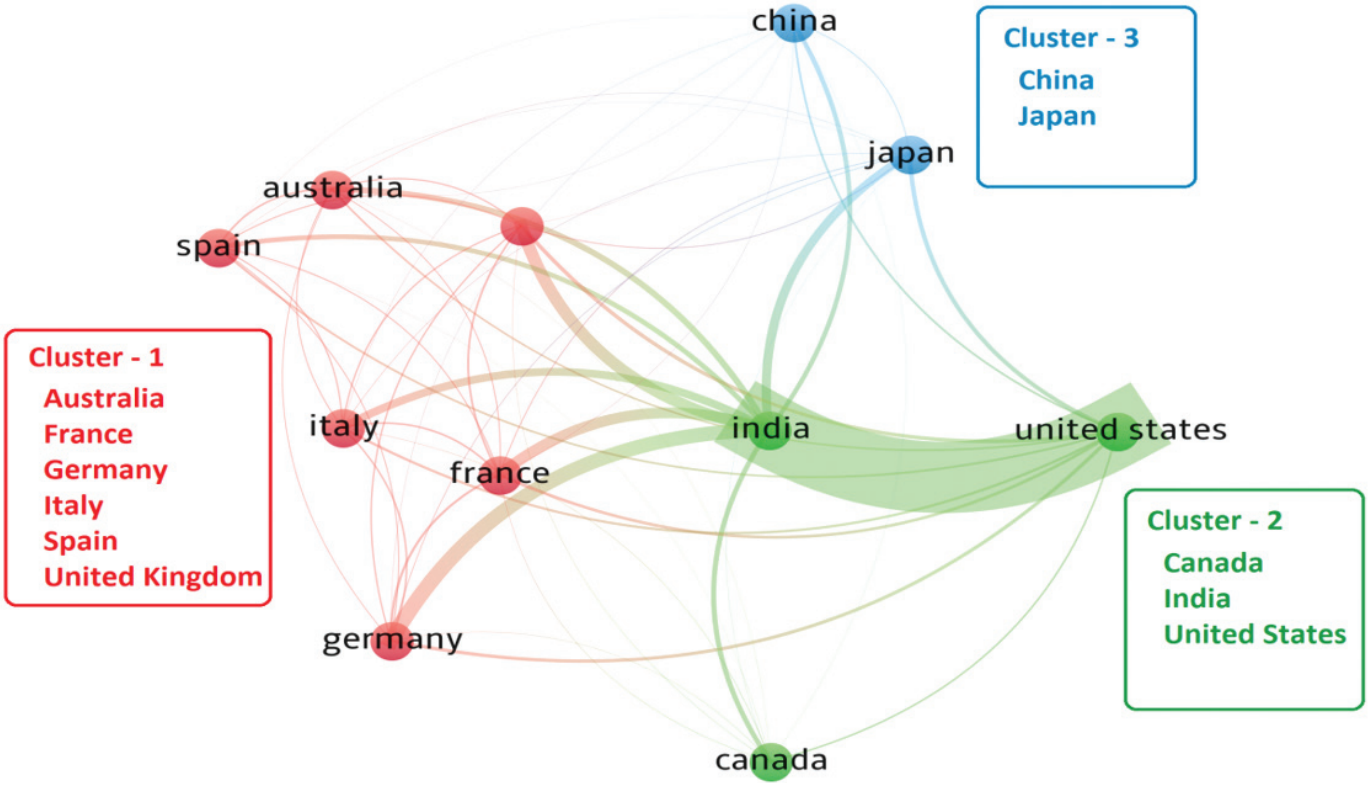

Figure 2. Mapping top 10 countries collaboration linkage with the DBT institutes (India).

Table 7. DBT research trends as reflected by frequency of author keywords

Keyword	Occurrence	Keyword	Occurrence
Apoptosis	156	Curcumin	34
Plasmodium Falciparum	55	Diabetes	34
India	55	Phylogeny	34
Malaria	53	Cytokines	32
Cytotoxicity	52	Cancer	30
Breast Cancer	41	Vaccine	28
Nf-Kb	40	Nanoparticles	27
Gene Expression	40	Inflammation	24
P53	38	Autophagy	22
Oxidative Stress	36	Smar1	22

papers in the h-index and it can be formulated as follows[22]:

$$A-index=\frac{1}{\mathrm{h}}\sum_{\mathrm{j=1}}^{\mathrm{h}}\mathrm{Cit}_{\mathrm{j}}$$

where, h = *h*-index, and cit_j = Total citations counts of h-core papers

The composite performance index (*p*-index) or mock *h*-index was introduced by Prathap[23] and can be computed as follows:

$$p-index=\left(C.\frac{C}{P}\right)^{\frac{1}{3}}$$

Where, C= total number of citations; P= total number of papers

6. CONCLUSIONS

From 1996 to 2019, the publication outputs from six DBT institutes showed steady growth rate and resulted in the publication of 6,076 articles. Initially from 1996-1997, only 176 articles were published and in 2018-2019 this had increased to 745 articles. In the last decade, the publication scenario showed the significant improvement of R&D activities that confirms the recovery from stabilisation of R&D efforts in Biotechnology in India[15]. Among the selected DBT institutes, the National Institute of Immunology (NII) and the National Centre for Cell Science (NCCS) were predominant in terms of producing research papers. It may be argued that despite of producing good quality research papers in reputed journals, these DBT institutes were not counted in the list of prolific Indian institutions in Biotechnology area[11, 12]. Universities were in lead in yielding Biotechnology publications in India[15]. One reason of greater research works at the higher educational institutes, compared to better established national laboratories, is the presence of a large number of doctoral students[15]. Further, the research institutes are more advanced and focused in their subject scope for research and development activities.

In a nutshell, a strong domestic collaboration network

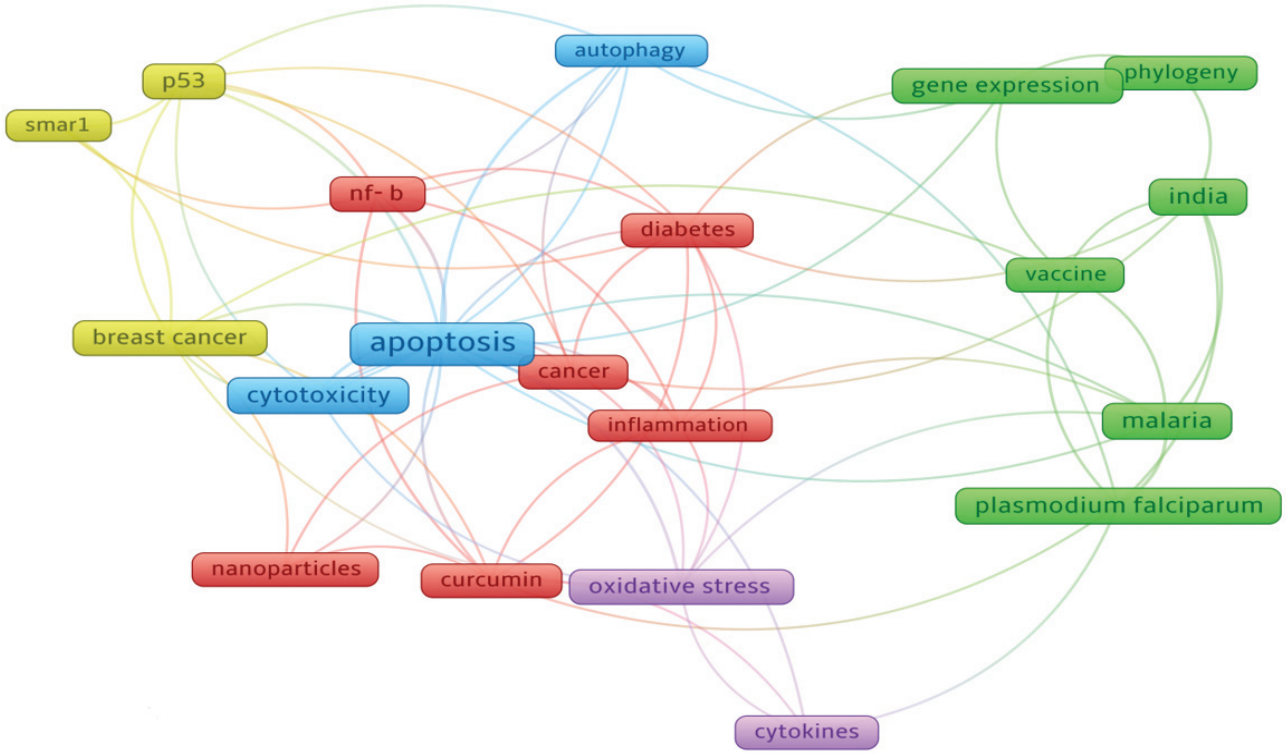

Figure 3. Visualization of top 20 frequently used author keywords.

Table 8. Scholarly impact of the international co-authored publications of IISERs

DBT Institutes	Total Publications	TC (C)	ACPP (C / P)	h-index	A-index	AC_{100}	%uncited	*p-index*
CDFD	686	15223	22.19	57	95.86	16	4.81	69.64
ICGEB	785	22208	28.3	69	131.33	40	3.18	85.66
ILS	714	14186	19.86	49	119.24	23	4.90	65.55
NCCS	1363	32477	23.83	76	135.67	46	5	91.81
NII	1697	37226	21.94	75	142.1	45	4.30	93.47
RGCB	831	13827	16.64	53	90.50	15	6.74	61.27
Total	6076	135147	22.24	120	201.33	185	4.77	144.31

TC= Total times cited; ACPP= Average citations per paper

(73.65 %) has been witnessed along with 25.03 per cent share of international collaborative output. Meanwhile, the United States, a leader in biotechnology research[16] was the major dominating collaborative partner. In order to accelerate biotechnology research and publication, it may be noteworthy to consider more international collaborative research efforts and as a consequence this may have implications for accelerating the scientific competency and efficiency of scientific researchers at the DBT institutes. Additionally, Plos One was the most favored journal for publication of research results. In addition, Apoptosis and Plasmodium Falciparum were most frequently involved keywords in the biotechnology research. The publication of International Centre for Genetic Engineering and Biotechnology (ICGEB) Delhi received maximum average citation impact while in terms of performance index, the National Institute of Immunology (NII) Delhi was dominant. In this context, a citation network study may be done in future to focus on the cited sources and geographical distribution of the knowledge flow.

Research in biotechnology has great potential in India and there is cutting edge research being carried out by scientists at DBT institutes. Such research outputs suggest that the initiatives of the Government of India are to bring together industry and academia to promote entrepreneurship and indigenous manufacturing in the biotech industry having an impact[24]. Given the global pandemic and Coronavirus disease (COVID-19), governments across the world will want to consider greater investments in biotechnology research and direct their focus on infectious diseases, pharmacy, medicine and biotechnology. Hence, the Government of India should concentrate on these

areas by augmenting the budget significantly. This study is timely as the Government of India may want to consider ways of strengthening the capabilities of the DBT institutes in order to give them a fresh impetus to produce quality biotechnology research. Meanwhile, a depth investigation is needed to exhibit the research productivity of all 16 DBT institutions to attract attention from the policy makers/ authorities. As well, further study is also needed to review government policies, regulatory challenges and ways of fostering the growth of India's biotech sector.

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