

Scientometric Mapping of Pharmaceutical Science Research in India during 2011-2020

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ABSTRACT

This study delineates India's pharmaceutical sciences research landscape from 2011 to 2020 through a scientometric analysis of data from the Scopus database. During this period, India contributed 241,142 publications, constituting 6.90% of the global total of 3,493,821 in the field. The analysis revealed significant variations across different dimensions, including year, country, subject area, funding agency, and leading organizations. Key metrics such as annual growth rate, relative growth rate, doubling time, publication efficiency index, citations per publication, research quality index, research priority index, and *h*-index were employed to assess overall development, research focus, and quality. The production of research output exhibited a steady year-on-year increase, reaching its zenith in 2016, with pharmacology leading at 115,558 publications. The Activity Index reveals increased research activity in India from 2011 to 2016 and in 2020, alongside a significant rise in citations for publications from 2019 and 2020. The quality of Indian contributions from 2011-2014 and 2019-2020 exceeds the global average, with research quality index values range from 1.00 to 1.09. Together, the top ten sponsors have funded 69686 publications, and out of them, 18.80% of publications were funded by the Department of Science and Technology, underscoring government support for scientific research. India's contribution of 6.90% to global pharmaceutical publications is unexpectedly low, given its pivotal role in drug production. This disparity underscores the necessity for improved research capabilities and collaboration. The academic institutions dominate the top contributors, with CSIR as a notable exception. While India's research efficiency has been robust from 2011 to 2016, subsequent years' troubling descent signals an urgent need to address these challenges to revitalise India's position in the global research framework by creating a conducive environment for groundbreaking research. This can be achieved through the strengthening of research infrastructure and providing access to cutting-edge technologies for researchers, thereby ensuring sustained innovation and global competitiveness.

Keywords: Scientometrics, Pharmaceutical Sciences, Publication pattern, Publication efficiency, Co-authorship network, Organizational excellence.

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INTRODUCTION

Pharmacology, one of the scientific disciplines, plays a crucial role in bridging the gap between medicine, biology, and the pharmaceutical sciences.^[1] The discovery, design, and development of new medicines for disease prevention, treatment, and cure represent a critical endeavor in biological research and the pharmaceutical industry. This ongoing process requires substantial investment and commitment to rigorous research, as it is essential for effectively eradicating diseases. Globally, the pursuit of innovative therapies involves significant financial

resources, underscoring the importance of continuous exploration in this vital field. In India, the share of the global pharmaceutical market was merely 1.1% in 1970 since it was a period of early development for the industry but progressively expanded in the subsequent decades due to strategic policy reforms, including patent recognition, tax incentives and grants to the pharma fraternity, and collaborations that have enhanced research in this sector. By 2021, India had emerged as a leader with over 3,000 drug development companies, meeting more than 50% of global vaccine demand. The country exports pharmaceutical products to over 200 nations, with a total export value of \$24.4 billion in the years 2020-21, predominantly to the United States (IBEF, 2021)^[2] and the Indian Economic Survey (2021)^[3] highlights a robust growth trajectory for the domestic market, projecting an increase from \$42 billion in 2021 to \$108 billion by the end of the decade. In response to this burgeoning market and the escalating need



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for innovative treatments, research laboratories, universities, and various institutions are intensifying their investments in pharmaceutical science. These entities are channelling significant resources into the development and clinical testing of new medicines, aiming to uncover effective therapeutic solutions for pressing health challenges.

In recent decades, the field of scientometrics has witnessed the emergence and implementation of diverse methodological approaches, particularly in bibliometrics. These advancements have significantly enhanced the analysis of scientific productivity across various entities, including individual researchers, research laboratories, and nations.^[4,5] Assessing the research landscape of a country necessitates a thorough evaluation of the contributions made by its laboratories and organizations to gauge their performance. Bibliometric analysis is a useful tool for rapidly identifying the state of development and research horizons in a certain field^[6] and it has already been applied for fields of medicine,^[7,8] clinics and hospitals,^[9] biomedical,^[10] drug development^[11] and pharmaceutical care.^[12]

LITERATURE REVIEW

An evaluation of pertinent prior studies was conducted to identify the research gap that informs our investigation. Between 2012-2017, India ranked first among South Asian medical institutions in the quantity and quality of the papers produced.^[13] A predominance of clinical medical publications appeared in biomedical research journals and were highly cited.^[14] A study of adverse drug reactions and pharmacovigilance research during 2004-2015 revealed that the papers on drug safety were increasing significantly in Nepal.^[15] The pharmaceutical research output from institutions and universities between 2008 and 2012 exhibited both high quality and quantity in India^[16] and the research output of University Institution of Pharmaceutical Sciences at Punjab University from 2009 to 2018 exhibited that the United States served as the most significant collaborative partner, contributing to 5.32% of the publications indexed in the Scopus database, and 88.75% of these publications were cited by other researchers.^[17]

Thompson (2019)^[18] examined the publications of US pharmacy schools and college deans gathered from the Web of Science that indicated notable variations in bibliometric indicators, including publication frequency, and highlighted a significant performance gap between male and female academics.

Scopus indexes the journals listed in the Journal Citation Ranking (JCR) along with other high-impact journals that are not included in the JCR. The quantity of articles indexed varies throughout the top databases, including Scopus and Web of Science.^[19] The evaluation of Scopus data for the top 10 NIRF ranked pharma educational institutions in India during 2016-19 reveals that UGC was the leading funding sponsor and the USA was the leading collaborator.^[20] While productivity in pharmacological research

was increasing in India between 2004 and 2018, the quality of the research lagged behind some established and emerging economies.^[21]

The annual growth rate of publications in clinical pharmacology in India stands at 25.89%, contributing to 4.80% of the global share. International collaborations constitute 12.22% of these publications. The top 15 Indian companies contributed approximately 20% of all publications, while the top 10 journals account for 33.82% of the total contributions.^[22] The years 2000-2005 had a tendency to concentrate on institutional norms and clinical policy worldwide, 2005-2010 focussed more on the economies and drug markets due to globalisation. Between 2010-2015, medical services and health systems progressively incorporated and after 2015, pharmaceutical management research started to move toward digitalization.^[23]

Pharmacology publications by Pakistani researchers indexed in the ISI Web of Science from 1975 to 2014 represent 0.25% of the global output. Both publication output and citations have shown steady growth, with annual rates of 29.29% and 34.22%, respectively.^[24]

The growth of United States publications in pharmacology and pharmacy, as recorded in the Web of Science from 2007 to 2016, revealed significant correlations with the economic and demographic conditions of the individual states. The states with elevated GDP levels or a significant concentration of biopharmaceutical industries were associated with more papers.^[25]

Between 2013 and 2020, Qatar's research output in pharmaceutical sciences, as indexed in Web of Science, Scopus, PubMed, and Google Scholar, demonstrated an average annual growth rate of 6.70% with a significant focus on pharmacology and cancer research, highlighting a trend towards applied research within the pharmaceutical sciences with 55.30% of the total output by these two domains.^[26] An evaluation in Iran suggests the mission oriented activities in pharmaceutical research centres may lead them in achieving scientific authority.^[27] Research in pharmacy practice in Qatar from 2005 to 2020 indicates an upward trend in both collaborative efforts and overall publication count. The United Kingdom leads in international partnerships, accounting for 38% of all works.^[28] A study in China highlights that academic institutions are playing a more prominent role in expanding the literature on network pharmacology.^[29] The Pakistan Journal of Pharmaceutical Sciences published 1172 articles between 2006 and 2015, contributed by 951 distinct researchers. Collaborative efforts with India accounted for 11% of the total publications, while the regions of Baluchistan and Azad Jammu and Kashmir contributed fewer papers.^[30] The publication trend of the Journal of Pharmaceutical Education and Research over the years 2007-2018 exhibited a notable increase in both publication and citation rates from 2007 and 2018. Of the 1714 articles published,

30.20% originated from outside US, with Turkey leading as the country with the highest proportion of foreign authors and the published works were diverse, covering various aspects of pharmacology and its associated fields.^[31] A review of articles from the Ichushi-Web, employing interrupted time series analysis (ITSA), revealed a little uptick in the publication numbers following the implementation of the certification system for infection control pharmacists.^[32]

The most frequently cited medical and food science publications from emerging Asian countries indexed in Scopus demonstrated that drug discovery and neuropharmacology have a margin relationship with the extensive range of publications related to antioxidants. Since the turn of this millennium, the majority of these studies have adopted a wider perspective, encompassing a greater variety of plants and foods, diverse biological effects, and multiple strategies for disease prevention.^[33] According to research into the publication landscape for the treatment of contaminated pharmaceutical effluents, China and the United States were the leading contributors to disseminating treatment technologies for pharmaceutical pollution^[34] whereas China, India, and Iran are top three producers respectively in pharmaceutical wastewater research.^[35] Publish or do not graduate approach may also partially explain increased publication in some countries.^[36]

The above review demonstrates that some studies have already been conducted to determine Indian pharma production and export, spending in the pharma market, identifying suitable tools for scientometric studies, research in pharmaceutical science in various countries such as Pakistan, Saudi Arabia, Qatar, the United States, European countries, and the productivity of pharmacology journals. Very few studies were conducted on Indian research performance in the last decade. They have collected data solely using the keywords 'pharmacy' or 'pharmaceutical science', which may not be adequate to retrieve all publications on pharmaceutical sciences. The evaluation discovered no study that used complete bibliographic data in pharmaceutical science to determine the current research performance trend in pharmaceutical sciences in India. Hence, the authors in this study chose to use scientometric indices to assess India's pharmaceutical research performance between 2011 and 2020.

OBJECTIVES

This study spans the period from 2011 to 2020 and focuses exclusively on publications in pharmaceutical sciences from Indian organizations and institutions. Its main objective is to establish a framework for comprehending the advancements made by India in this field. The study specifically seeks to determine the growth patterns of research output, the transformative activity index, citation counts, and the overall quality of the research. Furthermore, it identifies key research areas across various domains, highlights the most productive research topics, and

examines funding sources, contributing organizations, articles, and relevant keywords.

Scope of the Study

The study focuses exclusively on research literature produced by Indian organizations and institutions in the pharmaceutical sciences over a decade, specifically from 2011 to 2020. Only the papers indexed in the Scopus database in these ten years were included in the analysis. The study covers the quantitative and qualitative aspects of the research but does not cover the practical applications. The bibliographical data for the indexed papers was gathered in the last week of December 2022, and the papers indexed thereafter were excluded from consideration.

METHODOLOGY

Data Source

The study exclusively relied on sources from Scopus, an abstract and citation database. It has indexed over 97 million publications from 28000+ peer-reviewed titles worldwide, encompassing a wide range of formats such as journals, books, book series, conference proceedings, reviews, brief surveys, editorials, letters, and business articles.^[37] It is one of the most extensively used databases by researchers and scientists for gathering essential data for bibliometric and scientometric analysis.^[16,17,19,26,28,33] It offers researchers both current and retrospective bibliographic details of the publications it indexes.

Search Strategy

The terms specified below were double quoted to retrieve all the relevant data, applying the 'OR' Boolean operation.

Terms used: Drug Discover*, Drug Screen*, Drug Substanc*, Drug Synthes*, Drug Structur*, Drug Develop*, Drug Design, Pharmacology, Drug Interact*, Drug Absorption, Drug Metabolism*, Drug Cytotoxi*, Drug Respons*, Drug Safety, Drug Mechanis*, Pharmaceutic*, Drug Deliver*, Drug Encapsulat*, Drug Releas*, Drug Dissolution, Drug Nano*, Drug Targetin*, Drug Formul*at*, Drug Carrier*, Transdermal Drug.

The dataset compiled for this analysis encompasses 241142 bibliographic records pertaining to Indian contributions in pharmaceutical sciences, sourced exclusively from articles, reviews, and book chapters within the Scopus database, covering the period from 2011 to 2020. Due to the limitation imposed by Scopus on bulk downloads which caps the number of records to 20000 per request, the collection process necessitated multiple retrieval attempts for each year, ensuring a comprehensive aggregation of relevant literature.

To effectively monitor the development and assess the quality of research in pharmaceutical sciences, a range of scientometric measures such as the annual growth rate, activity index, research

priority index, research quality index, citations per publication, and *h*-index has been employed.

Data Analysis

Quantitative analysis of the retrieved data was conducted utilizing a range of software such as, Microsoft Excel to manage data, and VOSviewer for visualization which were mostly used by the researchers for scientometric research.^[7,23,38] Through the construction of several data tables, interpretations were derived, facilitating a thorough examination of the results.

RESULTS

Publication growth and research activity

Table 1 illustrates the distribution of publications, yearly citation gains, and various indices throughout the study period. While the overall number of publications increased during this timeframe, the growth was not uniform. A significant rise occurred between 2011 and 2016, although this trend has since levelled off with a notable low in 2017. Subsequently, publication output improved until 2020, maintaining an annual growth generally between 100 and 2,000. Various growth rate metrics, including the Annual Growth Rate (AGR), the relative growth rate (RGR), Doubling Time (T_d), Compound Annual Growth Rate (CAGR), and the Activity Index (AI) were employed to determine publication trends. The result reveals that there was no consistent increase in the number of publications produced over the study period. Despite India ranking as the third highest global producer with 241142 publications (6.90%), there was a marked slowdown in growth during the latter half of the study period, as reflected by an increased doubling time and a low CAGR of 0.0627. According to the Indian Pharmaceutical Industry Report (2021), India's nearly 3,000 pharmaceutical R&D industries reportedly met over half of the global vaccine demand in 2021, with the domestic market expected to expand significantly to grow from US\$ 42 billion in 2021 to US\$ 130 billion in the 2030.^[2] However, the data suggest

that research output has not kept pace with drug production efforts.

Relative research activity

In our assessment of India's research contributions over time, we utilized the Activity Index (AI)^[39] to compare both global and Indian outputs in pharmaceutical science. As illustrated in Figure 1, India exhibited a heightened research activity, with an AI exceeding 100 during the periods of 2011-2016 and in 2020, surpassing global efforts. Notably, the year 2014 marked a peak in this activity.

India's top research priority

Using a Research Priority Index (RPI), we conducted a comparative analysis of research focus areas for Indian scholars against their global counterparts. As illustrated in Table 2, data from Scopus reveals that India has contributed 199183 publications across multiple fields out of a total of 2745549 global publications, demonstrating higher activity in 15 of the 27 subject categories. Notably, in the field of "Pharmacology, Toxicology, and Pharmaceutics," India accounts for 86340 contributions compared to 693787 globally. Following this, significant contributions in India were made in Biochemistry, Genetics and Molecular Biology (68019), Chemistry (61850), and Medicine (56428).

The data for the keywords drug discovery, pharmaceutical science, pharmacology, toxicology, and Pharmaceutics has been meticulously retrieved and presented in Table 3. While global trends indicate Pharmacology as the leading area with 1945495 publications, Indian researchers generated 115558 papers in this domain. However, areas such as pharmacology, drug discovery and toxicology are prioritized less in India compared to global averages, but the area pharmaceutical science shows the high priority, suggesting a need for realignment to enhance research impact.

Table 1: Publication Growth.

Year	Total Pub (Global)	Total Pub (India)	AGR	RGR	T_d	CAGR	AI
2011	263500	18716	0.00			0.0627	102.91
2012	286979	20156	0.08	0.73	0.95		101.76
2013	307168	21486	0.07	0.44	1.57		101.35
2014	323378	23522	0.09	0.33	2.11		105.39
2015	340318	24114	0.03	0.25	2.74		102.66
2016	354647	25639	0.06	0.21	3.25		104.74
2017	363944	23454	-0.09	0.16	4.29		93.37
2018	382153	24914	0.06	0.15	4.71		94.46
2019	407912	26791	0.08	0.14	5.05		95.16
2020	463822	32350	0.21	0.14	4.81		101.05
Total	3493821	241142				0.0627	

Table 2: Research Priority Index of Sub Fields.

Subject	Total Pub (Global)	Total Pub (India)	RPI
Agricultural and Biological Sciences	283875	21266	106.15
Arts and Humanities	11667	284	34.49
Biochemistry, Genetics and Molecular Biology	1132085	68019	85.14
Business, Management and Accounting	23933	2551	151.04
Chemical Engineering	282604	24606	123.38
Chemistry	671231	61850	130.57
Computer Science	62771	4639	104.72
Decision Sciences	6472	448	98.09
Dentistry	18491	1710	131.04
Earth and Planetary Sciences	13367	1308	138.66
Economics, Econometrics and Finance	20300	2701	188.54
Energy	34488	5469	224.70
Engineering	203683	18970	131.97
Environmental Science	171407	14583	120.56
Health Professions	42046	2373	79.97
Immunology and Microbiology	215663	11153	73.28
Materials Science	273809	23071	119.39
Mathematics	28784	2161	106.38
Medicine	1381056	56428	57.90
Multidisciplinary	116794	4533	55.00
Neuroscience	203526	4302	29.95
Nursing	66753	1635	34.71
Pharmacology, Toxicology and Pharmaceutics	693787	86340	176.34
Physics and Astronomy	150278	14322	135.04
Psychology	36157	870	34.10
Social Sciences	53512	2563	67.87
Veterinary	40782	2170	75.40
Undefined	49	0	0.00
Total	6239370	440325	

Citations and research quality

The analysis of Indian research contributions reveals a total of 2912770 citations, yielding an average of 12.08 Citations per Paper (CPP), and Table 4 summarizes the details. Notably, publications from 2011 garnered the highest CPP at 19.32. While the volume of annual publications has increased, there is a discernible decline in citation rates, likely attributed to the advancing age of these publications. To better understand this trend, the Citations per Paper per Year (CPPY) were assessed, showing increased citations for works published in 2019 and 2020.

Relative Research Quality of Current Studies

The relative quality of Indian contributions to research was determined using the Research Quality Index (RQI) metric. The

RQI for a given year is the ratio of the proportion of quality papers to the proportion of all papers,^[40] with an RQI of 1 indicating alignment with the global average. The authors set the standard for identifying high-quality papers to arrive at this conclusion. High-quality papers, defined as those meeting or exceeding the year's CPP, totalled 60489 papers with at least 12 citations, demonstrating notable quality. Table 4 depicts the details of total citations, CPP, RQI, and *h*-index for Indian contributions over the years. The RQI metrics given in Figure 2 indicate that contributions from 2011-2014 and 2019-2020 hovered between 1.00 and 1.09, surpassing the global average, while the period from 2015-2017 reflected diminished performance with RQIs between 0.73 and 0.92.

Publication Efficiency

The Publication Efficiency Index (PEI) serves as a valuable quality metric for assessing the cumulative impact of research publications relative to research efforts across different countries over time.

PEI determines whether the impact of publications of a particular country in a given year on a research field corresponds to the research effort. The $PEI > 1$ indicates that a country's publications have a more significant influence on a particular research field than the corresponding research effort.^[41] Although there was a noticeable decline in efficiency, as shown in Figure 3, Indian contributions exceeded the global average from 2011 to 2016, reflecting a previous period of strength in research output.

Co-authorship Network

Among the most prolific authors, the top ten collectively generated 2340 publications, with seven authors contributing over 200 each. Figure 4 illustrates the clusters within the author network of the top 10 prolific contributors. Notably, Kamal, A. leads with a strong network comprising 1597 links, followed by Sriram, D. at 1076 links, and Ahmad, F.J. with 889 links. The remaining contributors are Ali, J. (763), Gupta, V.K. (611), Sridhar, B. (539), Rajeshkumar, S. (439), Gayathri, R. (421), Lakshmi, T. (319), and Vishnu Priya, V. (248). Interestingly, despite ranking 9th and 10th

in publication output, Ali, J. and Gupta, V.K. maintain higher network connectivity, holding 5th and 6th positions respectively.

Leading Partnering Countries

The United States remains the foremost partner in collaborative research, producing 14400 joint papers, followed by Saudi Arabia and the United Kingdom, with China showing a higher growth rate in collaborative papers despite being ranked seventh. The details are shown in Figure 5.

Funding agencies

Funding from various agencies worldwide plays a critical role in advancing research within scientific and technological domains. By funding extensive research across several disciplines, the agencies are instrumental in the widespread dissemination of scientific findings. Table 5 reveals the *h*-index, RQI, and other metrics of the funded papers for 10 of the most prominent pharmaceutical scientific funders. A significant 28.90% of publications during the study period—totaling 69686—received financial support from ten highly productive agencies. Notably, the Department of Science and Technology (DST), India, contributed to 18.80% of these publications, achieving an *h*-index of 125, followed by the Council for Scientific and Industrial Research at 17.21% and the University Grants Commission of India at 14.94%. Interestingly, two non-Indian entities, the University Grants Committee and

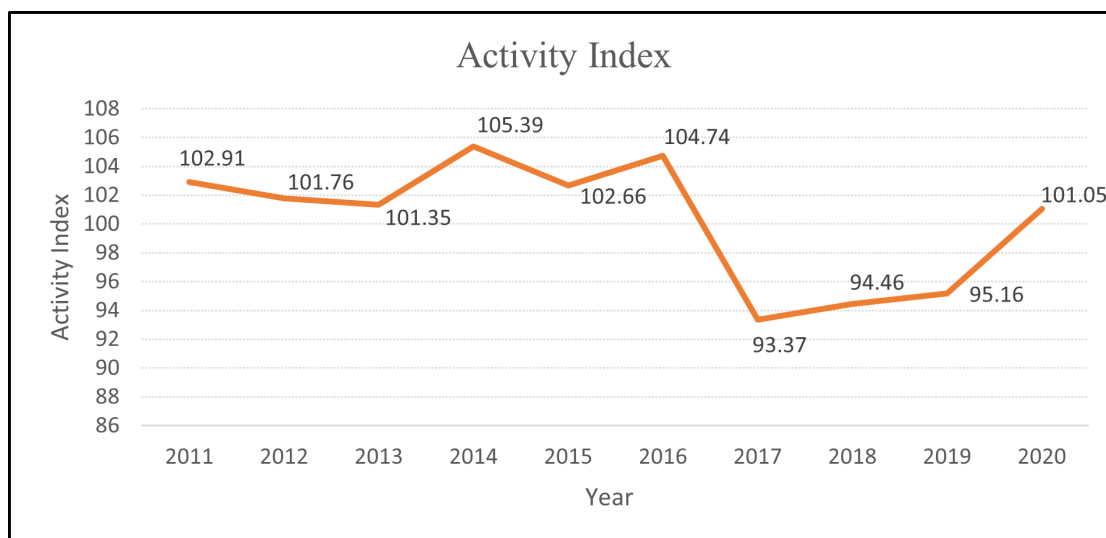


Figure 1: Activity Index.

Table 3: Research Priority Index of pharmacology, toxicology, and pharmaceuticals

Subject	Global	India	RPI
Drug Discovery	505344	37710	97.29
Pharmaceutical Science	482895	74108	200.09
Pharmacology	1945495	115558	77.44
Pharmacology, Toxicology and Pharmaceutics	25	12	625.83
Toxicology	756582	55656	95.91
Total	3690341	283044	

Table 4: Citations and research quality.

Year	Total Pub	Total Citations	CPP	CPPY	RQI	h-Index	PEI
2011	18716	361525	19.32	1.93	1.03	172	1.60
2012	20156	355901	17.66	1.96	1.07	180	1.46
2013	21486	358359	16.68	2.09	1.09	174	1.38
2014	23522	366328	15.57	2.22	1.09	166	1.29
2015	24114	346572	14.37	2.40	0.79	157	1.19
2016	25639	310789	12.12	2.42	0.77	167	1.00
2017	23454	254625	10.86	2.72	0.92	104	0.90
2018	24914	202607	8.13	2.71	0.73	109	0.67
2019	26791	214691	8.01	4.01	1.05	112	0.66
2020	32350	141373	4.37	4.37	1.00	88	0.36
Total	241142	2912770	12.08				

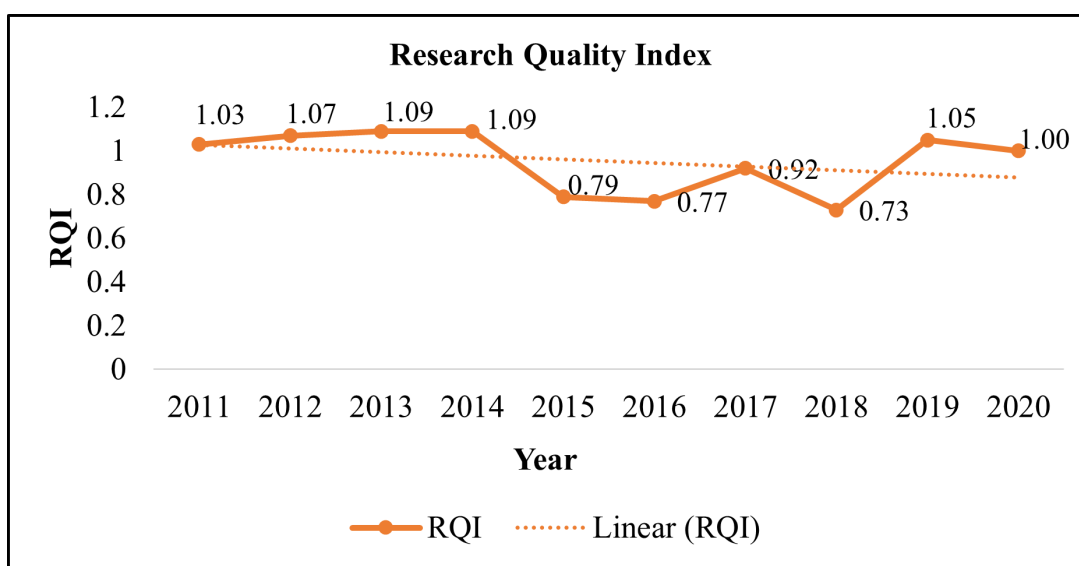


Figure 2: Research Quality Index.

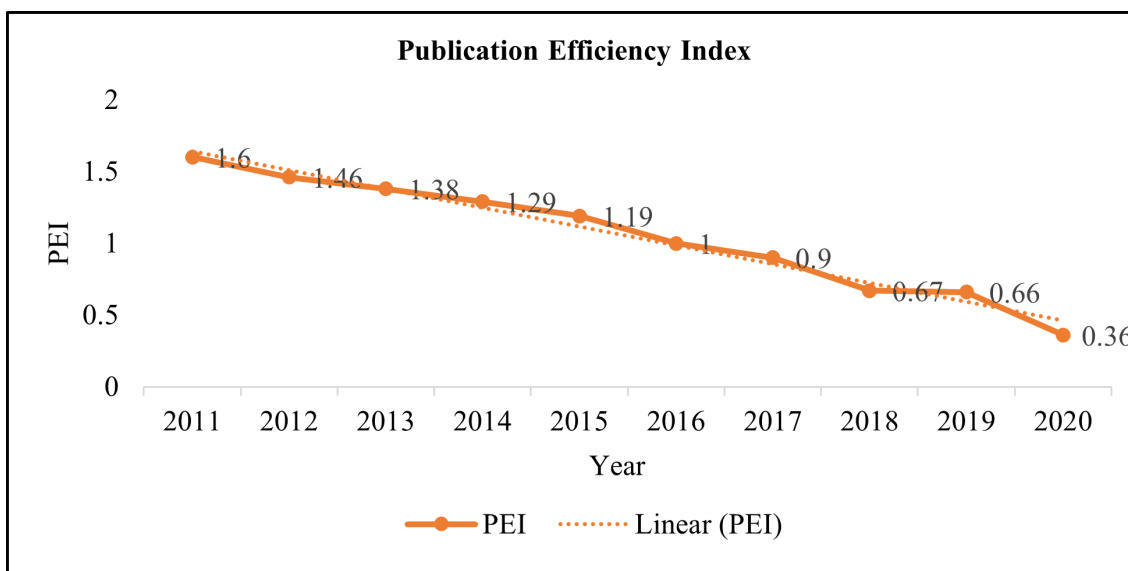


Figure 3: Publication Efficiency Index.

the Bangladesh Council of Scientific and Industrial Research, are also among the top funders.

Publications fostered by these agencies exhibit RQI values ranging from 1.10 to 1.21, surpassing the global average. Although DST ranks highest in output, its RQI stands at 1.12, positioning it

ninth. The UGC and the Department of Biotechnology have the highest-ranked publications, achieving an RQI of 1.21. The Science and Engineering Research Board (SERB) dramatically increased its output from one publication in 2011 to 1816 in 2020, reflecting a compound annual growth rate of 130% and attaining an *h*-index of 79.

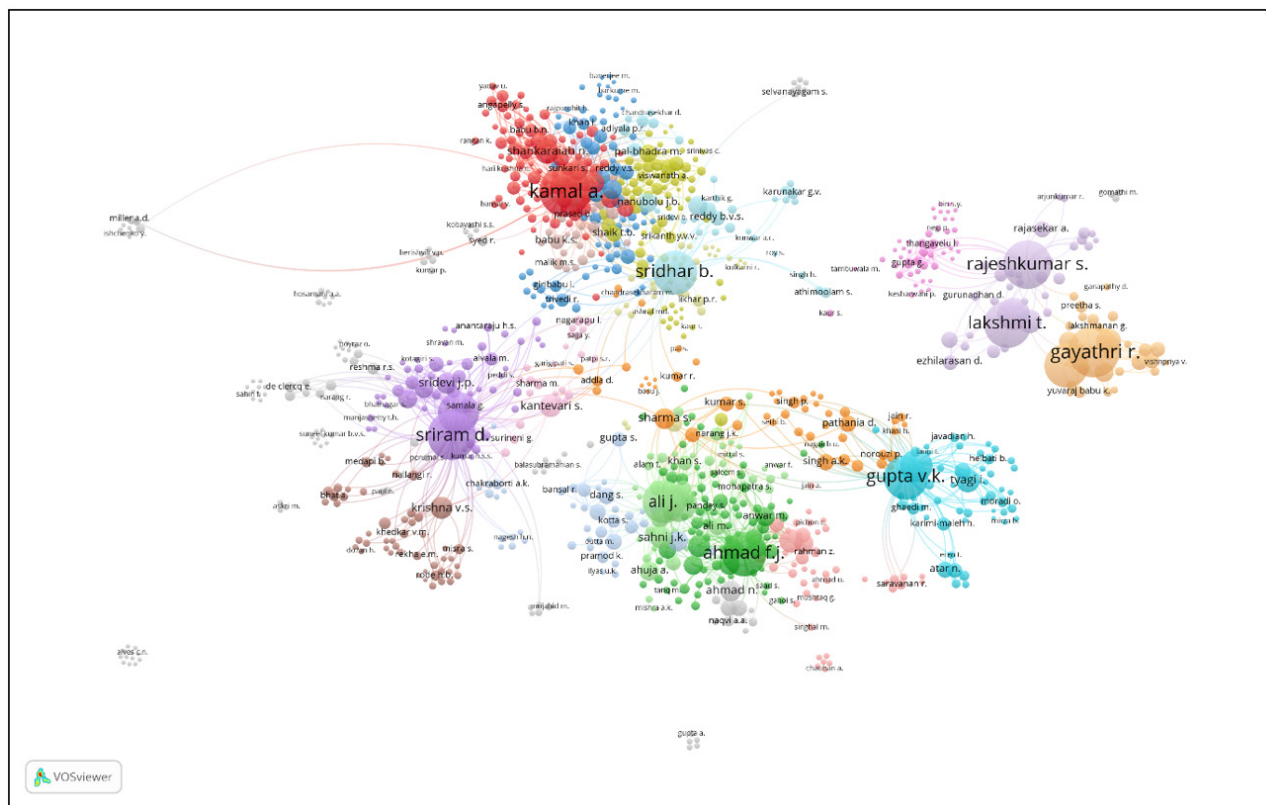


Figure 4: Clusters of Co-authorship Network.

Table 5: Leading Funding Agencies.

Funding Sponsor	2011	2020	Total	CAGR	Citation	h-index	RQI
Department of Sci. &Tech., Ministry of Science and Technology, India.	363	3243	13103	0.28	211139	125	1.12
Council of Scientific and Industrial Research, India.	683	1941	11994	0.12	209930	121	1.20
University Grants Commission (UGC).	395	1498	10408	0.16	162728	110	1.21
University Grants Committee, Hong Kong.	227	1176	6658	0.20	100046	88	1.20
Science and Engineering Research Board.	1	1816	5850	1.30	73442	79	1.20
Department of Science and Technology, Government of Kerala.	132	1137	5221	0.27	82577	89	1.13
Department of Biotechnology, Ministry of Science and Technology, India.	200	1200	4818	0.22	80647	91	1.21
Indian Council of Medical Research.	230	853	4638	0.16	78682	84	1.19
Bangladesh Council of Scientific and Industrial Research.	247	611	3772	0.11	68214	88	1.10
Department of Biotechnology, Government of West Bengal.	91	706	3224	0.26	51563	78	1.17

Highly Performing Subjects

Table 6 highlights the most productive fields of research categorized by Scopus, with 'Pharmacology, Toxicology, and Pharmaceutics' leading in publication volume at 86340 papers and an *h*-index of 190. However, it exhibited the slowest Compound Annual Growth Rate (CAGR) at 0.0058. In contrast, the field of Medicine, with 56428 publications and the highest *h*-index of 245, displayed a lower Research Quality Index (RQI) of 0.90 compared to other top fields, which surpassed the global average (RQI>1), ranging from 1.03 to 1.12.

Organizational Excellence

Table 7 enumerates the ten most productive research organizations, predominantly comprising seven centrally funded government entities from India, with the Council of Scientific and Industrial Research (CSIR) leading in output at 3950 articles and 114455 citations. The academic institutions are leading in producing research output.^[23] Despite its significant publication volume, CSIR's negative CAGR of -3.91% suggests diminished impact. Conversely, the Academy of Scientific and Innovative Research (AcSIR), launched in 2010, has rapidly ascended to prominence with 3669 publications and an RQI of 1.19 and an *h*-index of 76, underscoring its superior research quality. Other institutions, such as IICT, Jamia Hamdard, and Vellore Institute of Technology, exhibit RQI scores exceeding 1, reflecting their commitment to quality research, whilst the notable growth of non-governmental organizations suggests a dynamic shift towards enhanced research productivity across diverse sectors.

Frequently-Cited Works

Throughout the research period, of the total of 241142 papers, yet only 48 (0.020%) received more than 1,000 citations, averaging 2,110 citations each. Among these, 9 publications surpassed 3000 citations, with an average of 4625.11, while 16 papers were cited more than 2000 times averaging 3674.31. Notably, 47 of the top 48 publications were collaboratively authored, with 18992 authors contributing, and only one paper credited to a single author. The most-cited paper, identified as number 1 in Table 8, accrued 7122 citations, although it ranks second based on average citations per year. Conversely, the paper in position 2 achieved the highest average citations per year despite having fewer total citations.

Frequently used Keywords

Table 9 presents the most frequently used top 50 keywords identified in the study. Notably, human, controlled study, nonhuman, and unclassified drug emerged as the predominant keywords, reflecting significant areas of focus in the research. This categorization underscores the prevalence of these concepts in the relevant literature, highlighting their importance in the context of the study.

DISCUSSION

India's pharmaceutical R&D industry has grown significantly, indicating a robust expansion with CAGR of 11% in the domestic market and 16% in export markets over the last two decades (FICCI 2021) and met more than half of the world's demand for vaccines in the year 2021 (Indian Pharmaceuticals Industry Report, 2021). But it does not reflect in publication growth, being a 3rd highest producer (6.90%) worldwide in pharmaceutical science, as the growth rate indicators reveals the unsteady growth

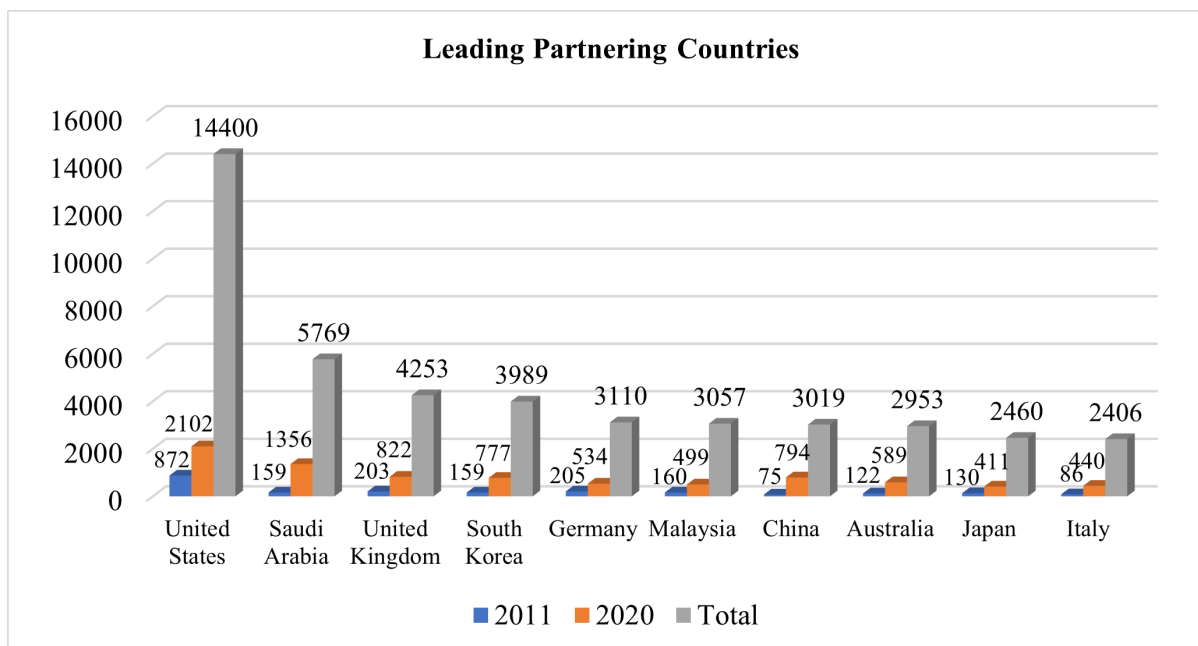


Figure 5: Leading Partnering Countries.

Table 6: Highly Performing Subjects.

Subject	2011	2020	Total	CAGR	Citation	h-index	RQI
Pharmacology, Toxicology and Pharmaceutics	9029	9508	86340	0.0058	828476	190	1.04
Biochemistry, Genetics and Molecular Biology	4847	8645	68019	0.0664	1012558	224	1.12
Chemistry	4582	7682	61850	0.0591	1004254	226	1.10
Medicine	4377	7468	56428	0.0612	831482	245	0.90
Chemical Engineering	1441	3580	24606	0.1064	475597	185	1.09
Materials Science	1137	3772	23071	0.1425	444766	181	1.12
Agricultural and Biological Science	1409	3529	21266	0.1074	278572	145	1.03
Engineering	818	2876	18970	0.1499	273515	156	1.05
Environmental Science	766	2779	14583	0.1539	240121	150	1.05
Physics and Astronomy	758	2120	14322	0.1211	274310	149	1.12

Table 7: Highly performing organizations.

Affiliation	2011	2020	Total	CAGR	Citation	h-index	RQI
Council of Scientific and Industrial Research (CSIR), India.	428	299	3950	-0.0391	114455	108	0.87
Vellore Institute of Technology, Vellore (VIT).	142	470	3896	0.1422	45815	75	1.11
Saveetha Institute of Medical and Technical Sciences (SIMATS).	32	1627	3704	0.5473	14270	58	0.55
Academy of Scientific and Innovative Research (AcSIR).	0	728	3669	NA	55839	76	1.19
Indian Institute of Chemical Technology (IICT).	288	218	3470	-0.0305	62451	79	1.18
University of Delhi (DU).	239	463	3308	0.0762	78395	91	0.81
Banaras Hindu University (BHU).	216	400	3251	0.0708	77533	98	0.86
All India Institute of Medical Sciences, New Delhi (AIIMS).	233	457	3181	0.0777	92923	95	0.56
Manipal Academy of Higher Education (MAHE).	186	539	3117	0.1254	38690	67	0.87
Jamia Hamdard	292	378	2888	0.0291	55059	86	1.17

with CAGR of 6.27%. Also, it does not confirm the results carried out earlier to find the research activity in the pharmacy in India^[21] and Qatar^[28] that found the increasing trend in the literature production. Indian production was increasing in trend in the first half of the study period. The research was more active in most of the study period and comparatively better than the global activity with an AI exceeding 100. Also, the quality of the research from 2011-2014 and again in 2019-2020 was above the average and it partially confirms the findings of the research conducted based on WoS data in India.^[16,21] Even though the Indian research efficiency is greater than the global average during 2011-2016, the values of PEI show the decreasing order over period. The values of *h*-index also indicate the high quality in the first half of the period. Even though the production efficiency was less in the second half of the study period, the CPPY is high.

More papers are dispersed in the pharmaceutical sciences, and allied subjects and more priority is given to the allied subjects with RPI exceeding 100. Among the top 10 most prolific Scopus subject fields, Pharmacology, Toxicology, and Pharmaceutics is

leading in publication volume at 86340 papers and an *h*-index of 190 but it exhibits the slowest CAGR of 0.58%. In contrast, the field of Medicine, with 56,428 publications and the highest *h*-index of 245, displayed a lower Research Quality Index (RQI) of 0.90.

The data retrieved individually using the keywords pharmacology, pharmaceutical science, drug discovery and toxicology without any combination demonstrate more papers appeared under pharmacology (115558), followed by pharmaceutical science (74108), and toxicology (55656). This order of Indian shares deviates from the global and BRICS contribution in the field.^[47]

Kamal, A. stands out with an impressive author network of 1597 links, showcasing exceptional connectivity and likely influence within the field. Sriram, D. and Ahmad, F.J. follows, albeit with notable gaps in their networks, possessing 1076 and 889 links, respectively. Interestingly, network connectivity does not strictly correlate with publication output. For instance, Ali, J. and Gupta, V.K., who rank 9th and 10th in publication productivity respectively,

demonstrate a surprising strength in network connections by ranking 5th and 6th.

The United States remains the foremost collaborator in many research fields.^[12,48,49] In this study it produced 14400 joint papers, followed by Saudi Arabia and the United Kingdom, with China showing a higher growth rate in collaborative papers despite being ranked seventh. This indicates strong collaborative ties between India and countries across multiple continents, enhancing the global impact of pharmaceutical research. The findings show that among the top 10 leading organizations that provided financial support for Indian research in pharmaceutical science, two are not from India such as the University Grants Committee, Hong Kong, and Bangladesh Council of Scientific and Industrial Research. Among the Indian sponsors, the DST, Government of India sponsored 5.43% of the total publications, followed by the CSIR (4.97%) and the UGC of India (4.32%) throughout the study and it reflected in *h*-index also. The research in pharmaceutical science is carried out in all regions in India. Publications fostered by these agencies exhibit RQI exceeding 1, surpassing the global average. The Science and Engineering Research Board (SERB) dramatically increased its output from 1 to 1816 over the period, with a CAGR of 130% and attaining an *h*-index of 79.

The academic institutions are leading in producing research output.^[7,29] Of the top 10 most prolific organizations, 7 are centrally funded government organizations and three are private deemed to be universities. CSIR is the leading organization with 3950 publications and 114455 citations. AcSIR produced 3669 publications in a short period from the inception and it is top in the research quality with an RQI of 1.19. The private institutions perform well in the publication production with a CAGR of 54.73% (SIMATS), 14.22% (VIT) and 12.54% (MAHE) but they, except VIT, failed to get more RQI. The organisation that has low CAGR attained more RQI. The academic institutions are leading in producing research output that confirms the earlier study on trend analysis of pharmaceutical management research.^[7]

It is seen from the findings of the top 10 highly cited publications that a systematic analysis of the Global Burden of Disease Study conducted for different years appears 5 times among the top 10 most frequently cited publications. Most of these studies are related to comparative risk assessment of the burden of disease,^[42] the prevalence of overweight and obesity in children and adults,^[43] age-sex specific all-cause and cause-specific mortality,^[44] the people living with disability for acute and chronic diseases and injuries.^[45,46] The keywords such as human, controlled study, nonhuman, and unclassified drug were predominantly used in the papers reflecting significant areas of focus in the research.

Table 8: Highly Cited Publications.

Sl. No.	Year	Publication	Citation	Avg. Cit/Year
1	2012	Lim S.S. <i>et al.</i> , A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: A systematic analysis for the Global Burden of Disease Study, 2010 ^[42]	7122	890.25
2	2014	Ng M. <i>et al.</i> , Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: A systematic analysis for the Global Burden of Disease Study 2013 ^[43]	6146	1024.33
3	2011	Granger C.B. <i>et al.</i> , Apixaban versus warfarin in patients with atrial fibrillation.	5446	605.11
4	2013	Olesen J. <i>et al.</i> , The International Classification of Headache Disorders, 3 rd edition.	4538	648.29
5	2015	Naghavi M. <i>et al.</i> , Global, regional, and national age-sex specific all-cause and cause-specific mortality for 240 causes of death, 1990-2013: A systematic analysis for the Global Burden of Disease Study 2013. ^[44]	4158	831.60
6	2015	Uhlen M. <i>et al.</i> , Tissue-based map of the human proteome.	3981	796.2
7	2013	Dellinger R.P. <i>et al.</i> , Surviving sepsis campaign: International guidelines for management of severe sepsis and septic shock: 2012.	3959	565.57
8	2015	Vos T. <i>et al.</i> , Global, regional, and national incidence, prevalence, and years lived with disability for 301 acute and chronic diseases and injuries in 188 countries, 1990-2013: A systematic analysis for the Global Burden of Disease Study 2013. ^[45]	3272	654.40
9	2016	Klionsky D.J. <i>et al.</i> , Guidelines for the use and interpretation of assays for monitoring autophagy, 3rd edition.	3004	751
10	2016	Vos T., Global, regional, and national incidence, prevalence, and years lived with disability for 310 diseases and injuries, 1990-2015: a systematic analysis for the Global Burden of Disease Study 2015. ^[46]	2911	727.75

Table 9: Frequently Used Keywords.

Sl. No.	Keywords	Pub.	S. No.	Keywords	Pub.
1	Human	73160	26	Human Cell	12729
2	Controlled Study	70640	27	Antioxidant Activity	11996
3	Nonhuman	70143	28	India	11637
4	Unclassified Drug	53028	29	Oxidative Stress	11430
5	Humans	42023	30	Major Clinical Study	11308
6	Priority Journal	39676	31	Drug Effects	11198
7	Male	39253	32	Drug Structure	11120
8	Female	32239	33	Particle Size	11030
9	Animals	31425	34	Antioxidant	10927
10	Chemistry	30145	35	Infrared Spectroscopy	10661
11	Metabolism	27083	36	Genetics	10549
12	Animal Experiment	26895	37	Antibacterial Activity	10473
13	Animal	24312	38	Synthesis	10423
14	Adult	22807	39	Drug Delivery System	10377
15	<i>In vitro</i> Study	20976	40	Enzyme Activity	10199
16	Animal Model	19963	41	Procedures	9983
17	Rat	19074	42	Drug Formulation	9980
18	Review	18463	43	Scanning Electron Microscopy	9946
19	Drug Effect	16702	44	Nanoparticles	9787
20	Plant Extract	16222	45	Molecular Docking	9723
21	Animal Tissue	15986	46	Escherichia Coli	9370
22	Drug Synthesis	15510	47	Pathology	9179
23	Mouse	13473	48	Rats	9141
24	Drug Efficacy	12889	49	Antineoplastic Agent	8971
25	Drug Screening	12872	50	Apoptosis	8959

The study does not include the publications that have not been indexed in Scopus.

CONCLUSION

The paper reveals the scientometric profile of Indian research in pharmaceutical science, indicating a Compound Annual Growth Rate (CAGR) of 6.27% in publication production throughout study period. However, it also notes a decline in the number of publications during the latter half of the period from 2017 to 2020. India ranks as the third highest global producer of pharmaceutical publications, yet it contributes merely 6.90% to total global production. Despite periods of heightened research activity that exceeded the global average, research output did not align with the country's drug production levels. India's pharmaceutical sector has made remarkable strides, positioning the country among the world's foremost producers of generic medications. With a strong emphasis on innovation, research and development, and regulatory compliance, India is fostering a robust pharmaceutical landscape.

Government initiatives, such as the Scheme for Promotion of Research and Innovation in Pharma MedTech Sector (PRIP), Scheme for Strengthening of Pharmaceuticals Industry (SPI), Production Linked Incentive (PLI) schemes, etc., aim to enhance the nation's manufacturing capability and production in the sector. Especially, the PLI schemes bolster domestic production and reduce dependency on imports.^[50] In addition, India has boosted its regulatory framework, improving the efficiency with which New Drug Applications (NDAs) and Clinical Trials are approved.^[51] The focus on biotechnology and biopharmaceuticals research infrastructure demonstrates India's determination to establish itself as a global leader in pharmaceutical sciences. The collaborative efforts among government, industry, and academia are cultivating a conducive environment for advancements in pharmaceutical sciences, establishing India as a significant player in the global healthcare sector. Concentrating more on research in pharmaceutical science may increase research productivity and the Indian economy. The Indian research in some of the sub-fields was more active than the global average. The thirst area of India differs from global interest in terms of publications based

on sub-fields. More papers (86340) appeared in the sub-fields Pharmacology, toxicology, and pharmaceuticals put together whereas more interest was seen in sub-field medicine at the global level. With 3940 published works, 114455 citations, and an *h*-index of 108, CSIR was the leading producer, but its growth rate shows less growth. The private institutions are leading in the growth rate but in terms of quality, they are lagging. With $RQI > 1$, the papers published during 2011-2014 and 2019-2020 are of high quality. DST was the top funding sponsor, followed by the CSIR, and two non-Indian organizations ranked in the top 10. The researchers in India in pharmaceutical science need to concentrate more on publication production as well as research quality. CSIR is the only organization among the top 10 leading contributors in the field and all others are academic institutions. Government initiatives should focus on establishing new research organisations, strengthening infrastructure, enhancing funding for research and development, providing access to cutting edge technologies, facilitating skill development programmes for researchers, thereby significantly contributing to the improvement of pharmaceutical science in the country. Moreover, creating a regulatory environment that supports innovation will be vital.

The study confined to the publication pattern of pharmaceutical science research in India and did not reveal the state-wise contributions. A thorough evaluation of the research landscape of various states in this field would be helpful to the decision-makers, researchers, and organizations for further improvement. The countries that have collaborated with India for pharmaceutical science research have been identified, but the deep study for the publications produced with the results of this collaboration has not been done. This gap in research assessment limits the understanding of the impact and efficacy of such international partnerships in advancing pharmaceutical science. A comprehensive comparative study of research collaboration with other countries can illuminate India's global positioning and fostering collaboration among organizations in and across India would give more insights to the industries and organizations seeking effective partners for excelling research in this area and enhancing the quality.

Future research in the realm of mapping of pharmaceutical science in India should prioritize several critical areas to deepen the field's understanding. First, conducting longitudinal studies that analyze data beyond 2020 will reveal emerging research themes and evolving funding patterns. Furthermore, exploring collaboration dynamics among academic institutions, industry, and government may provide insights into innovation and knowledge transfer. Finally, examining the influence of specific research outputs on public health policies and practices will help evaluate the practical implications of scientific advancements in the pharmaceutical sector.

ABBREVIATIONS

AGR: Annual Growth Rate; **RGR:** Relative Growth Rate; **Td:** Doubling Time; **CAGR:** Compound Annual Growth Rate; **AI:** Activity Index; **RPI:** Research Priority Index; **CPP:** Citations per Publication; **CPPY:** Citations per Publication per Year; **RQI:** Research Quality Index; **PEI:** Publication Efficiency Index; **DST:** Department of Science and Technology; **CSIR:** Council of Scientific and Industrial Research; **UGC:** University Grants Commission; **SERB:** Science and Engineering Research Board; **IICT:** Indian Institute of Chemical Technology; **AcSIR:** Academy of Scientific and Innovative Research; **VIT:** Vellore Institute of Technology; **SIMATS:** Saveetha Institute of Medical and Technical Sciences; **MAHE:** Manipal Academy of Higher Education; **AIIMS:** All India Institute of Medical Sciences; **DU:** University of Delhi; **BHU:** Banaras Hindu University; **NIRE:** National Institutional Ranking Framework; **PRIP:** Scheme for Promotion of Research and Innovation in Pharma MedTech Sector; **SPI:** Scheme for Strengthening of Pharmaceuticals Industry; **PLI:** Production Linked Incentive; **NDA:** New Drug Application; **JCR:** Journal Citation Ranking; **ITSA:** Interrupted Time Series Analysis.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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