MATHEMATICS RESEARCH BY INDIANS IN BRITISH INDIA: A BIBLIOMETRIC ANALYSIS

Sanku Bilas Roy

The study analyses the publication pattern of Indian researchers in mathematics during the first half of twentieth century. Authorship pattern, Collaborative Coefficient, Prolific researchers, the appropriateness of Lotka's law and Bradford's law and Geographical distributions of publications have been studied. The Quinquennial distribution of publications indicates that there is a gradual growth in the number of publications. The Lotka's law seems to be accepted for the present data set, but not the Bradford's law.

Keywords: Sulbasutras; Aryabhatta; Authorship Pattern; Lotka's Law; Bradford's Law; Collaborative Coefficient.

INTRODUCTION

India has had a tradition of science from ancient times. The mathematical tradition in India has been robust since the time of Aryabhatta. Indian mathematics finds its beginning in the Sulbasutras of the Vedic time. In the early Indian mathematics, trigonometry formed an integral part of astronomy. References to trigonometric concepts and relations are found in astronomical texts such as Suryasiddhanta (CE 400), Varahamihira's Pancha Siddhanta (ca. CE 500), Brahmagupta's Brahma Sputa Siddhanta (CE 628) and the great work of Bhaskara II called 'Siddhanta siromoni' (CE 1150) [1]. The symbol for zero was discovered by Aryabhatta I (476 AD) in connection with the decimal expression of numbers.

Modern mathematics had persuaded over the indigenous mathematics during the colonial rule in India. The study and research in mathematics on modern line began in India rather late. The 20th century saw the real exploration of knowledge in mathematics teaching and mathematical researches, the major effort being made by the Indian themselves. Calcutta University started first in 1907, Madras started also in 1907 but systematic research in Madras University began in 1927, while Bombay University began its research program in mathematics as late as 1941 [2].

The present study makes an in-depth survey of the contributions of Indians in the mathematics research during 1901-1947. The study is confined to the articles/papers written in English by Indians published in the journals only. The geographical limit of the coverage is confined to British India only

Sanku Bilas Roy
Gobardanga Hindu College,
24 Parganas (N),
West Bengal
libraryghc2015@gmail.com

OBJECTIVES

The main objectives are as follows:

- To enumerate the growth, proliferation and changes of mathematics research during the period under study.
- To study the chronological distribution of contributions.
- To analyse the author productivity patterns in the field of mathematics.

- To examine the validity of Lotka's law using total counting of authors.
- To assess the validity of Bradford's law.
- To depict geographical distribution of mathematics research.

METHODOLOGY

The data for this study was collected from Biographical memoirs of the fellow of the Indian National Science Academy, Indian Science Abstract, and MathScinet database for the period of 1901 to 1947. The bibliographical points of all relevant articles/papers on the concerned aspects were noted and put into Excel sheets from which a simple working database was prepared. The data was tabulated and then analyzed by various quantitative methods in order to satisfy the above mentioned objectives of this study.

REVIEW OF LITERATURE

Many scholars highlighted the origin and development of mathematics in India through their noteworthy publications. But, their writings mostly dealt with historical background of the development of mathematics in India. A few quantitative analyses on mathematics research in India were conducted. Singh [3] made a discussion about the use of series in Hindu Mathematics. The author claimed that the existence of arithmetic and geometric series in Vedic literature as early as 2000 B.C. and in Jain literature as early as the fourth century B.C., or even earlier were found.

Srinivasiengar [4] presented a chronological account of the contributions of some prominent workers of mathematics in ancient India together with certain special and allied topics of interest thereto, such as, the decimal system of numerations, the Sulbasutras, the mathematics of the Jainas, the Bakhshali manuscript, Indian mathematics after Bhaskara, etc.

Gupta [5] dealt with both the statements and derivations of the exact value of the Sine of 18° as found in India upto the first half of the eighteenth century A.D. This exact value, which is equivalent to the modern value, namely $\sin 18^0 = (\sqrt{5}-1)/4$ was found, apparently for the first time in India, in the Jyotpatti of Bhaskara II (12th century A.D.). A few proofs which were found in the works of Munisvara, Kamalamara (both flourished in seventeenth century) and Jagannatha (eighteenth century) was also highlighted. These proofs were mostly geometrical in nature but analytical treatment in terms of trigonometrical and algebraic steps was also involved.

Kapur [6] stated the role of various individuals and professional societies in the development of pure and applied mathematics in India in the twentieth century. Some related developments in mathematics education were also considered. The various recommendations of the National Committee on Mathematics Education and Research have also been considered. Some suggestions for an in-depth study of the history of mathematical science in the modern period were also made.

Quantitative study on the mathematics research in India during 1988-1998 as reflected in MathScinet was undertaken by Arunachalam [7]. Indian Statistical Institute and Tata Institute of Fundamental Research were the two leading publishers of research papers. Unlike in many other fields, Calcutta published the largest number of papers in mathematics, followed by Mumbai, New Delhi, Chennai and Bangalore. About 92% of these papers have appeared in 877 journals published from 62 countries. Journals published in the USA, UK and the Netherlands were popular with Indian mathematicians.

A description about some eminent mathematicians such as Ramanujan, Ananda Rau, Vaidyanathaswamy, Pillai, Chowla who have contributed significantly to mathematics in the twentieth century and have had considerable influence on mathematics in India was provided by Raghunathan [8].

Emch et al. [9] discussed the mathematics of the classical and medieval periods. The contribution of Brahmagupta, Bhaskara II and the Kerala School of Mathematics were also highlighted. Further stress was made on the features of algorithms, the concept of proofs and the practice of Upapattis in mathematics and astronomy in

India. The study also dealt with the Indian mathematics in modern period including the contribution of Srinivasan Ramanujan on partial fractions and contributions of Indian mathematicians to quantum statistics.

The publication productivity of mathematics in some select Universities of Chandigarh and Punjab during the year 2004-2013 was studied by Chakravarty and Sharma [10]. The source database was Scopus. The study dealt with 532 publications of Panjab University, Chandigarh (PU), Punjabi University, Patiala (PUP) and Guru Nanak Dev University, Amritsar (GNDU) in the field of Mathematics. It examined the Mathematics output by different ways like document type, source type, authorship pattern and degree of collaboration. The study also focused on the relative growth rate of publications, doubling time for publications and participative index rate of Universities.

Sinha [11] focused on the development of mathematical sciences in India during the Second World War. This study mainly described India's indigenous tradition in mathematics and the ongoing freedom struggle in the country. The influences coming from all over the world on Indian science during the aforesaid period has also been highlighted.

ANALYSIS AND INTERPRETATION

Distribution of literature in Mathematics during 1901-1947

It is convenient to analyze the collected data in five year intervals so that a comprehensive discussion can be carried out. In this section we tried to depict a picture of distribution of publications on mathematics during the period of 1901-1945.

Table Quinquennial distribution of publications in mathematics (1901-1945)

Period	**1901-05**	**1906-10**	**1911-15**	**1916-20**	**1921-25**	**1926-30**	**1931-35**	**1936-40**	**1941-45**
Paper	1	58	111	149	230	219	343	678	537
Average Publication Per Year	0.2	11.6	22.2	29.8	46	43.8	68.6	135.8	107.4

Table 1 gives a picture of quinquennial accumulation of papers distribution. Only one paper is published in the first five years. Thereafter a rapid rise in the number of publications during 1905-1910 has been noticed. This rise may be due to establishment of two mathematical societies, namely Indian Mathematical Society (1907) and Calcutta Mathematical Society (1908); both were started to publish its journal in 1909. Then a continuous growth has witnessed in the next two decades, at the rate of 25 papers per year and 45 papers per year respectively. By the 1930s, both the number of publications and researchers are increased. It has noticed that the number of papers published in 1936-1940 is almost double than previous five years period (1931-35). However, retardation instead of an acceleration of publications has occurred in the last decade under study. The publication density of mathematics for the period under study of is 24.23.

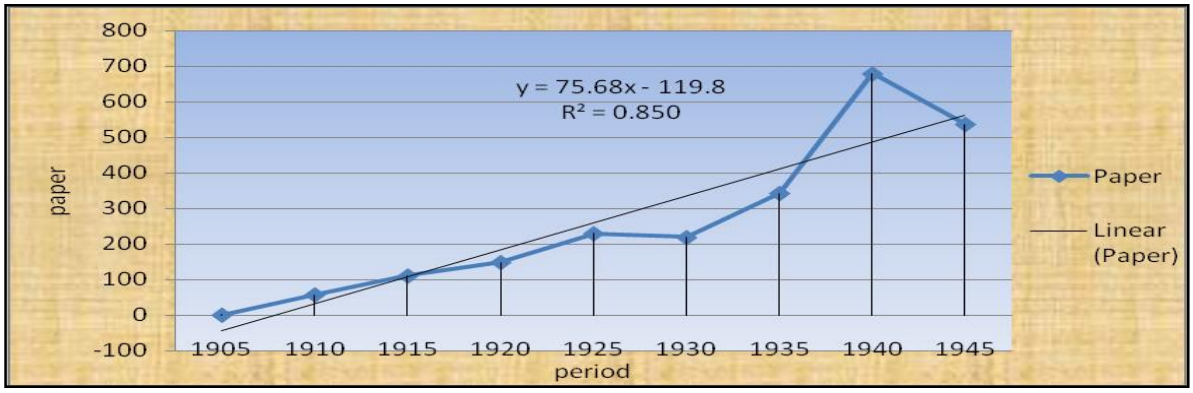

Figure 1: Growth of Literature in Mathematics (1901-1945)

On a brief study of the above graph, we may say that an increase has been recorded after the first five years, the growth of mathematical publications since then manifests more or less steady up to 1925, but lack of progressive increase being accounted for during 1926-30. Then the flow begins to increase and reach at saturation plateau at the end of 1930s but again showed a mild de-growth in 1940s.

The reasons of these conditions may be are: there is more than double increase in the number of researchers and correspondingly the number of publications increase more than three times during 1931-40 than the previous decades of this century. Only 13 PhD theses were accepted until 1930, whereas about 30 theses were accepted by the Indian universities from 1931 to 1947 [12].

A simple trend line gives the following regression equation y=75.68x-119.8 and R^2=0.85, that means, the curve does not fits very well with linear trend of growth as the value of R-squared not so close to 1

Authorship Pattern

The data revealed (table 2) the authorship pattern of mathematics research during the period under study.

Table 2: Authorship Pattern

Authorship	Paper
1	2346
2	177
3	15
4	3

It found that the dominancy of solo research was prevalent in case of mathematics research in British India. About 92% papers were authored by single author.

Application of Lotka Laws of Authors Productivity

The simplest equation to represent Lotka's law is

$$x^{a} y = c$$

Where x stands for the contributions; y stands for the number of authors, and c is constant.

Using the above equation, the value of c will be determined according to Sen's method [13].

Take in account the value of as given in the first row of the following table 2, we get

$$1^{a}. 252 = c \quad [\text{as } 1^{a} = 1]$$

$$252 = c$$

Now, using the data of the second row (table 3), we can find out the value of 'a'.

$$2^{a}. 83 = 252$$

- $2^{a} = 252/83$
- $2^{a} = 3.0361$
- a log 2 = log 3.0361
- a. 0.301 = 0.482
- a = 0.482/0.301
- a = 1.602

Using the value of 'a' the expected values of 'y' has been determined in the following table. It may be observed from table that the value of 'y' are quite close to the actual

values when calculated with a = 1.602. Hence, it may be said that by and large the data set derived from this study follows Lotka's law.

Table 3: Distribution of the Number of Papers According to Authors

Number Of Paper	Number Of Authors (Y) (Observed Value)	Number Of Authors (Y) (With The Value Of Authors I.E. A=1.602)
1	252	252
2	83	83
3	38	43
4	25	27
5	18	19
6	8	14
7	13	11
8	12	9
9	10	7
10	9	6
11	5	5
12	6	4
13	6	4
14	4	3
15	2	3
16	7	3
17	5	2
18	2	2
20	1	2
21	3	2
22	2	2
24	3	1
25	1	1
26	1	1
27	1	1
28	2	1
29	1	1
32	2	1
35	2	0.8
37	1	0.7
38	1	0.7
40	1	0.6
46	1	0.5
49	1	0.5
52	1	0.4
63	1	0.3
70	1	0.2
160	1	0.06

Prolific Researchers

We noticed (table 4) that about 25.3% papers have been published by the ten most prolific Indian researchers in mathematics during this period.

Table 4: Prolific researchers in Mathematics

Name	No. of Papers	% of Share in Total Contribution	Rank	Affiliation
S Chowla	160	6.21	1	Lahore, Govt. College
Hansraj Gupta	70	2.75	2	Hosiarpur Govt. College, Punjab
S S Pillai	63	2.28	3	Annamalai University
M T Naraniengar	52	2.04	4	Bangalore, Central college
R S Varma	49	1.84	5	Lucknow University
Ganesh Prasad	46	1.8	6	University of Calcutta
D D Kosambi	40	1.57	7	Poona, Ferguson college
P C Mahalanobis	38	1.49	8	Calcutta, ISI
A Narasinga Rao	37	1.45	9	Annamalai University
T Vijayaraghavan	35	1.37	10	Andhra University
R Vaidyanathaswamy	35	1.37	10	Madras University

We observed that S. Chowla (6.21%) was the most prolific researcher, followed by H. Gupta (2.75%), S. S. Pillai (2.28%), M. T. Naraniengar (2.04%), R. S. Verma (1.84%) and Ganesh Prasad (1.8%) respectively.

Collaborative Coefficient (CC)

To measure the strength of collaboration among the authors, the Collaboration Coefficient method is used. It is based on fractional productivity defined by Price and Beaver [14]. The following formula suggested by Ajiferuke [15] has been used.

$$CC = 1 - \sum_{j=1}^{j=k} (1/j)\, fj/N$$

Collaboration Coefficient is a number between 0 and 1. The more it is bigger than 0.5 the better is the collaboration rate among the authors [16].

It has seen from this study that the Collaborative Coefficient (CC) in mathematics research is 0.03.

Application of Bradford's Law of Scattering and Identification of Core journals

"If scientific periodicals are arranged in order of decreasing productivity of articles on a given subject that may be divided into a nucleus of periodicals more particularly devoted to the subject and several groups or zones containing the same number of articles as the nucleus and succeeding zones". Bradford expressed this relationship of the number of journals as 1: n : n^2… [17].

The graphical representation of this law plotted a bibliography with cumulative number of papers (R) against logarithm of the cumulative number of journals (log n). It is popularly known as "Bradford Bibliograph" [18].

The following figure is the representation of Bradford's Bibliograph using the data set of this study.

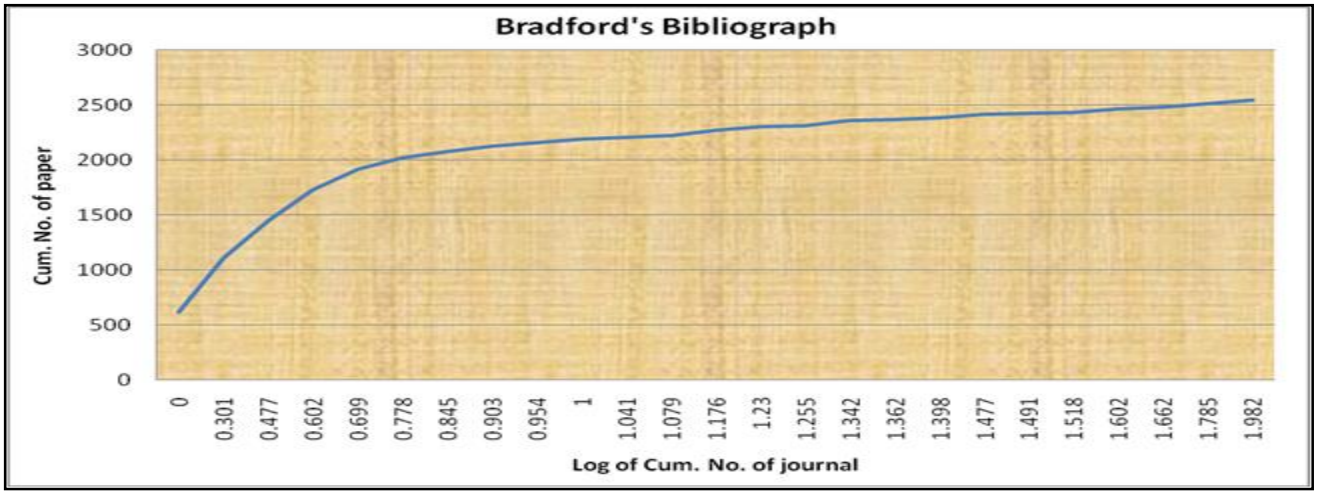

Figure 2: Bradford's Bibliograph

In the present study, by the help of following Table, 96 journals were divided into three zones according to their frequency of occurrence. In the first zone only 2 journals carried 1112 papers; in the second zone 4 journals carried 910 papers and the third zone consist of 90 journals carrying 519 papers accordingly.

Table 5: Ranking of Journals

S. No.	Name of Journals	Rank	Papers	Cum no. paper	Cum % of papers
1	The Journal of the Indian Mathematical Society	1	620	620	24.39
2	Bulletin of the Calcutta Mathematical Society	2	492	1112	43.745
3	The Mathematics Student	3	340	1452	57.12
4	Proceedings of the Indian Academy of Science	4	276	1728	67.977
5	Sankhya: the Indian Journal of Statistics	5	188	1916	75.412
6	Calcutta University Journal of Department of Science	6	106	2022	79.581
7	Journal of the University of Bombay	7	52	2074	81.626
8	Current Science	8	46	2120	83.435
9	Journal of the London Mathematical Society	9	37	2157	84.89
10	Journal of The Annamalai University	10	29	2186	86.03
11	Tohoku Mathematical Journal	11	18	2204	86.738
12	Proceedings of the London Mathematical Society	12	17	2221	87.406
13	Proceedings of the Benares Mathematical Society	13	16	2237	88.035
14	Proceedings of the National Academy of Sciences	13	16	2253	88.664
15	Proceedings of the National Institute of Sciences of India	13	16	2269	89.293
16	The Journal of the Osmania University College	14	14	2283	89.844
17	The Philosophical Magazine and Journal	14	14	2297	90.395
18	Science and Culture	15	12	2309	90.867
19	Indian Physico-Mathematical Journal	16	11	2320	91.299
20	Proceedings of the Lahore Philosophical Society	16	11	2331	91.731
21	Mathematische Zeitschrift	16	11	2342	92.163
22	The Quarterly Journal of Mathematics	16	11	2353	92.595
23	Journal of Bengal Asiatic Society	17	10	2363	92.988

24	Proceedings of Bengal Mathematical Society	18	8	2371	93.302
25	The Half-Yearly Journal of the Mysore University	18	8	2379	93.616
26	Indian Journal of Physics	19	7	2386	93.891
27	American Mathematical Monthly	19	7	2393	94.166
28	Bulletin of the American Mathematical Society	19	7	2400	94.441
29	Proceedings Cambridge Philosophical Society	19	7	2407	94.716
30	Proceedings of Edinburgh Mathematical Society	19	7	2414	94.991
31	Nature	20	6	2420	95.227
32	Comptes rendus de l'Académie des Sciences	21	5	2425	95.423
33	Quarterly Journal of Mathematics, Oxford Series	21	5	2430	95.619
34-40	7 journals have four papers	22	28	2458	96.718
41-46	6 journals have three papers	23	18	2476	97.426
47-61	15 journals have two papers	24	30	2506	98.606
62-96	35 journals have one paper	25	35	2541	100
	Total= 96 Journals		**2541**	**2541**	**100**

The three zones of journal scattering are as follows:

2: 4: 90 == 2: 2*2: 2*2*2 ==2: 2n: $2n^2$

Here, n = 2 i.e. Bradford multiplier

Here, the Bradford's law is not justified.

Table 6: Bradford's Zones of Journal Scattering

Zones/Groups	No. of Journals	No. of Papers	% of Papers
1	2	1112	43.74
2	4	910	35.84
3	90	519	20.42
All Zones	96	2541	100

Geographical Distribution of Contributions

Table 7 provides data of only ten high performing places from where at least 70 papers were published. These top ten places account for 72.47 % of total research output.

Table 7: Geographical Distribution of Contributions

Rank	Place	% of Contributions
1	Calcutta	23.22
2	Madras	10.34
3	Annamalainagar	8.40
4	Banagalore	6.25
5	Waltair	6.04
6	Lahore	5.13
7	Dacca	3.64
8	Poona	3.26
9	Delhi	3.22
10	Mysore	2.93

Data in the above table reveals that Calcutta is on the top with highest contribution of 23.22 % papers; followed by Madras (10.34 %), Annamalainagar (8.4%), Bangalore (6.25%), Waltair (6.04%) and Lahore (5.13%) respectively.

FINDINGS AND CONCLUSION

From the above study, the following facts have been noted:

The year-wise distribution of publications follows an increasing tendency. The publication density of mathematics for the period under study of is 24.23. It is also clear from the study that solo authorship (92%) is prevalent in mathematics research. The Collaborative Coefficient (CC) in mathematics research is 0.03. About 25.3% papers have been published by the ten most prolific Indian researchers. Lotka's generalized law is more or less fit the author productivity distribution pattern. On the other hand, the distribution of papers over different journals does not satisfy the verbal formulation of Bradford's Law of Scattering. The ten most productive places account for 72.47 % of total research output. The highest level of contribution has found during the decade of 1931-1940 due to the active participation of Indian researchers in mathematics research along with British researchers increase to a considerable extent. This may be the indication of transformation of colonial science to national science in India.

REFERENCES

[1] Joseph, G. G. Mathematics. In Selin, H. & Narasimha, R. (Eds.). *Encyclopaedia of classical Indian sciences: natural science, technology, medicine.* Hyderabad: Universities Press, 2007, pp.244-249.

[2] Bag, A. K. Mathematics and mathematical researches in India during Fifth to Twentieth centuries-profile and prospects. *Indian Journal of History of Science,* 47(3), 2012, 473-512.

[3] Singh, A N. On the use of series in Hindu mathematics. *Osiris*, 1, 1936, 606-628.

[4] Srinivasiengar, C. N. (1967) .*The History of Ancient Indian Mathematics*. Calcutta: World Press.

[5] Gupta, R. C. Sine of Eighteen degrees in India upto the eighteenth century. *Indian Journal of History of Science,* 11(1), 1976, 1-10.

[6] Kapur, J. N. Development of mathematical sciences in India during the twentieth century. *Indian Journal of History of Science*, 27(4), 1992, 389-407.

[7] Arunachalam, S. Mathematics Research in India Today: What Does the Literature Reveal? *Scientometrics*, 52(2), 2001, 235-59.

[8] Raghunathan, M. S. Artless innocents and ivory-tower sophisticates: some personalities on the Indian mathematical scene. *Current Science*, 85(4), 2003, 526-36.

[9] Emch, G. G., Sridharan, R. & Srinivas, M. D. (Eds.). *Contributions to the history of Indian mathematics.* New Delhi: Hindustan Book agency, 2005.

[10] Chakravarty, R. & Sharma, J. Publication Productivity of Mathematics in Select Universities of Chandigarh and Punjab: A Scientometric View. *International Journal of Information Library and Society*, 4(1), 2015, 27-33.

[11] Sinha, J. N. Features of mathematical sciences in India during the Second World War. *Indian Journal of History of Science*, 50(3), 2015. 521-32.

[12] Inter University Board of India. *Mathematics, astronomy, statistics: a bibliography of doctoral dissertations accepted by Indian universities 1857-1970*. New Delhi: Author, 1973.

[13] Sen, B. K. Lotka's law: a viewpoint. *Annals of Library and Information Studies*, 57(2), 2010, 166-67.

[14] Price, D. S. & Beaver, D. B. Collaboration in an invisible college. *American Psychologist*, 21, 1966, 1011.

[15] Ajiferuke, I. Collaborative Co-efficient: a single measure of the degree of collaboration in research. *Scientometrics*, 14(5-6), 1988, 421-433.

[16] Elango, B. & Rajendran, P. Authorship trends and collaboration pattern in the marine sciences literature: a scientometric study.

International Journal of Information Dissemination and Technology, 2(3), 2012, 166-169.

[17] Deshmukh, P. P. Citation analysis of Ph.D thesis submitted to Punjabrao Krishi Vidyapeeth during 1990-94 (Ph.D thesis, Department of Library and Information Science, Amravati University, Amravati), 1998. Retrieved from: http://shodhganga.inflibnet.ac.in/handle/10603/11178.

[18] Gupta, J. Bradford's law of scattering in Ph.D. theses of LIS at Bundelkhand University, Jhansi. Journal of Indian Library Association, 50(1), 2014, 21-30.