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An Institutional Collaboration and Application of Lotka's Law to the Research Output of Rashtrasant Tukadoji Maharaj Nagpur University

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Abstract

The article presents a scientometric picture of Rashtrasant Tukadoji Maharaj Nagpur University. The analysis was carried out on the data extracted in the form of 1908 records extracted from Web of Science during 2001-2019. However for testing of Lotka's law all the records i.e. 4212 available 1989 were used. An annual growth is highlighted in the study period. The article draws attention to annual growth of publication output, co-authorship network, distribution of publication output on the basis of various subject categories, leading collaborative institutes and countries. Further, the co-authorship network and co-occurrence of keyword analysis have been depicted through VOS-viewer.

Keywords: Scientometrics; Research output; Scientific productivity; Rashtrasant Tukadoji Maharaj Nagpur University; Co-authorship network; Keyword occurrence; Lotka's Inverse Square Law

1. Introduction

Institutional collaboration and testing of Lotka's law both these part belong to scientometrics which aims to map out the research output of an academicians, document or group of documents or institutions. It is synonymous term for 'bibliometrics' and 'informetrics' (Rao, 2014). In any case it measures and interprets the research output. In the present article an attempt has been made to study institutional collaboration and validation of Lotka's law on the research output of Rashtrasant Tukdoji Maharaj Nagpur University (RTMNU).

RTMNU, Nagpur is one of the eminent universities in Maharashtra state of India. It was established on 4th August, 1923 with six affiliated colleges and 927 students. During more than nine decades of its existence, the University has progressed satisfactorily and has touched many mile stones. The retrospective administrative nature of the university has made this progress possible. Presently University comprises of Forty-Four Postgraduate Teaching Departments (PGTD), three Constituent Colleges/Institutions (Law College, Laxminarayan Institute of Technology, and College of Education). Five hundred and three colleges are affiliated. The department and conducted college/institution buildings are spread over in 11 campuses with an overall area of 318 acres. More than four Lakh students are enrolled under different courses in the university (RTMNU).

2. Review of Literature

Some pertinent reviews have been concisely given as below.

Ortega, J. L., & Aguillo, I. F. (2013) described the typological properties of the institutional and national collaboration network from the profile extracted from Google Scholar Citation. The scientists from the United States formed their dominant collaborative networks. It reflected two geographical poles: The Asian one was connected to the United States while the European one and the United State formed reciprocal network. Dhiman & Sibasankar, (2018) studied collaborative trend in leading Indian LIS journals during 2012-2017. Out of 900 articles 48% were two authored, 33.17% single authored and 14% three authored articles. The maximum collaboration was seen in the year 2014. The collaborative index and collaborative coefficient indicated collaborative authorship trend. Further author productivity distribution followed the Lotka's law.

Kshirod & Mahapatra, (2018) did the collaborative and knowledge sharing study through the posing of LIS community. The study showed that LIS communities were active on Facebook group for sharing their knowledge collaborating with others.Sudhier K. G., (2013) tried to apply Lotka's law and pattern of author productivity in the domain of physics. The sample consisted of 1665 first authors as straight count method and 3367 authors in complete count appended in the doctoral theses in physics. The ultimate result showed that Lotka's law was not applicable to physics literature.

Jalal, Samir Kumar (2019) carried out co-authorship and collaborative study based on1156 papers published jointly by authors from India and Bangladesh. USA, UK, Japan, Australia and Canada were found to be top collaborating countries. After 2012 a strong growth was seen in the collaborative output between both these countries. Mortality, strain, prevalance and diseases were highly observed keywords among the country wise collaboration. The Lotka's law was also reestablished by using R package for bibliometrics. Kumar, Suresh (2017) tested Lotka's law on 2106 publications to test its applicability in LIS publication. He used Kolmogorov-Smrinov goodness-of-fit test to compare the functions describing the observed and theoretical distribution at 10% level of significance by adopting the method of Blank. The test revealed that the law was applicable in LIS publications.

3. Objective

The study has been carried out with the following objectives

1. To study the co-authorship network of the authors
2. To study the institutional collaboration
3. To measure out distribution of research output on the basis of the various subject areas
4. To analyze the co-occurrence of keywords
5. To verify Lotka's Inverse Square Law of Scientific Productivity

4. Methodology

The research output from academicians of RTMNU required for the present study was drawn from the Web of Science database. The research output from 2001 to 2019 has been considered for the study. In order to get appropriate data, 'Organization-Enhanced' search was carried out by selecting the organization 'Rashtrasant Tukadoji Maharaj Nagpur University' from the index. It contained all the possible variations available with the name of the university. The time span was customized as per the years selected for the study which resulted generation of 1908 records. The data was mined on 16 July 2019. The same data was filtered as per publication year, web of science subject categories, organizations, authors, and countries. The data of 1908 records was also used as an input to VOSviewer for data visualization co-authorship network and co-occurrence of keywords analysis.

Nevertheless, for the validation of Lotka's law, a whole research output in the form of 4212 records available in WoS from 1989 to 22 October 2019 was used. Kalmogorov-Smirnov test i.e. K-S test suggested by Pao (Pao, 1985) is applied for the verification of the dataset. While re-examining the Lotka's law, in the dataset, the number of contributors who had contributed single article is identified. In same way the numbers of contributors who had contributed two, three, four and so on articles are also being identified. These numbers of contributors are named as 'Observed Values'. The 'Expected Values' against each Observed Values are calculated with the help of Lotka's formula. The deviation between these observed and expected values/frequencies are examined through K-S test. The maximum deviation between the cumulative frequencies of the observed and expected value is determined by the following formula

$$D = \text{Max} \mid Fo(X) - Sn(X) \mid$$

Where Fo(X) is the cumulative frequency of expected value
Sn(X) is the cumulative frequency of observed value

5. Hypothesis

The following hypothesis was set for the present study.
Lotka's Inverse Square Law of Scientific Productivity is fit for the selected dataset

6. Data Analysis and Interpretation

6.1 Growth of Publications

Table no. 1 show how there is continuous growth in publication output of RTMNU. Out of total output, around 73% percent outputs came during 2010 to 2019. These years are remarkable in that maximum research output came during this period. All the publication output has been cited for 17952 times. 93 publications in 2008 have received maximum 1674 citations followed by 1655 and 1638 in the year 2011 and 2012 respectively. The average citation is high (23.21%) in 2002 the year in which 39 documents are quoted for 905 times.

Table 1. Growth of publication

Publication Year	TP	TC	ACPP
2001	24	261	10.88
2002	39	905	23.21
2003	26	318	12.33
2004	41	829	20.22
2005	59	641	10.86
2006	56	770	13.75
2007	75	1134	15.12
2008	93	1674	18
2009	95	1111	11.69
2010	112	1422	12.7
2011	141	1655	11.74
2012	130	1638	12.6
2013	155	1283	8.28
2014	138	1196	8.67
2015	175	1334	7.62
2016	149	851	5.71
2017	164	623	3.8
2018	169	293	1.73
2019	67	14	0.21
Total	1908	17952	9.41

6.2 Co-authorship network

Co-authorship is result of research collaboration. It increases research productivity, citedness and research impact (Noruzi & Abdekhoda, 2014). The following figure (Fig.1) shows the co-authorship network based on full counting method of VOS-viewer. The authors who have at least minimum five documents to their credit have and minimum 25 co-authors per document have been chosen to form the network. Of 2406 authors, 331 met the thresholds. Dhoble S J has 403

documents to his credit and 775 is his total network link strength. Moharial, S V stands at the second position with 301 links strength (documents 301). Among the other authors who are significant in co-authorship network are Kokare, D. M. (documents 65, link strength 196), Subhedar N K (documents 56, link strength 180), Dhoble, N S (documents 53, link strength 142), Dhopte S M (documents 36, link strength 124), Muthal P L (documents 36, link strength 124), Joshi C P (documents 39, link strength 112) and Singh V (documents 25, link strength 206)

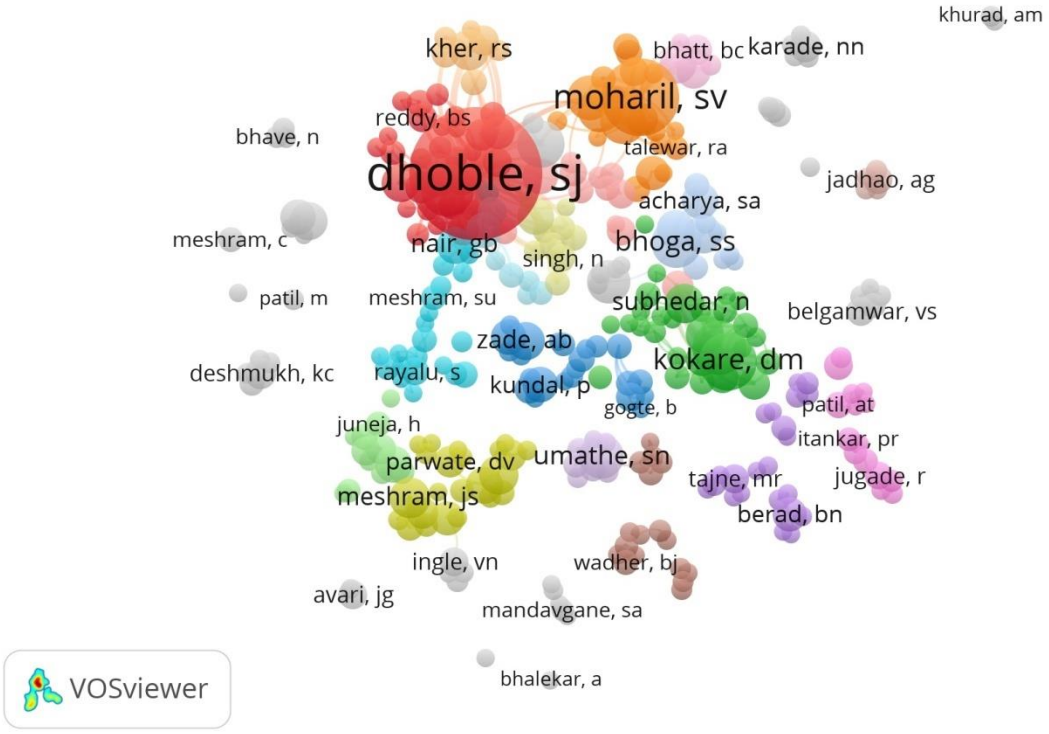

Fig. 1 Co-authorship network

6.3 Collaborative institutes and organizations

Table 2. Leading institutional collaborators

Sr. No	Organization	Total Publications	Total Citation	ACPP	H-index	Self Citation
1.	Council of Scientific and Industrial Research	140	2285	16.32	27	72
2.	National Environmental Engineering Research Institute, India	105	2047	19.5	27	67
3.	Visvesvaraya National Institute of Technology, Nagpur	90	681	7.57	14	13
4.	Bhaba Atomic Research	54	414	7.67	10	42

	Centre					
5.	Indian Institute of Science Education Research (IISER), Pune	54	843	15.61	19	207
6.	Kamla Nehru College	53	622	11.74	15	73
7.	Indian Institute of Technology (IIT) System	47	640	13.62	15	11
8.	KZS SCI College, Nagpur	42	330	7.86	10	169
9.	Sant Gadge Baba Amravati University, Amravati	38	547	14.39	14	16
10.	Sevaldal Mahila Mahavidyalaya, Nagpur	36	226	6.28	9	32
11.	Savitribai Phule Pune University	29	174	6	7	13
12.	Hislop College, Nagpur	28	255	9.11	10	14
13.	Institute of Science, Nagpur	28	225	8.04	9	34
14.	N.S. Science & Arts College, Bhadravati	25	310	12.4	10	55
15.	SK Porwal College, Kamptee	25	308	12.32	11	42

The authors in RTMNU seemed to collaborate mostly with the authors in Council of Scientific and Industrial Research. Jointly 140 papers were published with 2285 citations. H-index is also high (27) for this partnership. The second organization in the list is National Environmental Engineering Research Institute with which RTMNU collaborated in 105 publications. The organization is also ahead in terms of highest citation per paper (19.5%) and h-index (27). Among the list of top 15 organizations, 7 institutions are from the Nagpur city itself while 2 institutes are from adjacent regions. Ten organizations are from Maharashtra. Sant Gadge Baba Amravati University which is also among the list of prominent collaborator used to be part of RTMNU got separated and established itself as the new university in 1983. The state universities in Maharashtra have been identified with tendency to develop collaboration within state and they need to extend their research partnership beyond geographical boundaries (Bapte & Gedam, 2018).

6.4 Distribution of Research Output Based on Subject Areas

Table 3. Subject wise distribution of research output and citations received

Sr. No	Subject Area	Share of Document	Citations Received	ACPP	H-index
1	Material Science Multidisciplinary	214	1903	8.89	23
2	Pharmacology Pharmacy	183	2964	16.2	30

3	Optics	172	1742	10.13	22
4	Biochemistry Molecular Biology	163	1140	6.99	15
5	Chemistry Multidisciplinary	162	1045	6.45	16
6	Physics Condensed Matter	134	945	7.05	17
7	Chemistry Physical	128	1394	10.89	20
8	Neurosciences	96	1913	19.93	27
9	Physics Applied	92	737	8.01	15
10	Chemistry Organic	88	682	7.75	88
11	Engineering Chemistry	70	871	12.44	16
12	Chemistry Medicinal	69	1441	20.88	21
13	Physics Multidisciplinary	68	280	4.12	10
14	Engineering Electrical Electronic	66	344	5.21	8
15	Geosciences Multidisciplinary	60	310	5.17	10
16	Nuclear Science Technology	60	314	5.23	10
17	Polymer Science	55	624	11.35	1
18	Thermodynamics	52	450	8.65	12
19	Chemistry Allied	48	554	11.54	14
20	Environmental Sciences	45	944	20.98	13

As per the Web of Science classification of subjects, most of the papers (214) have been published in the domain of Multidisciplinary Material Science which is followed by Pharmacology Pharmacy (183), Optics (172), Biochemistry-Molecular Biology (163) and Chemistry Multidisciplinary. However, most of the citations (2964) were seen in the field of Pharmacology Pharmacy, Neurosciences (1913) and Material Science Multidisciplinary (1903). The average citation per paper (ACPP) was high (8.01%) in the field of Environmental Sciences. Medicinal Chemistry and Neuroscience were also in the lead to register higher ACPP. Organic Chemistry, Pharmacology Pharmacy and Neurosciences registered the highest h-index. There was hardly any paper in the field of Social Science and Humanities in the distribution of leading subject areas. A quite similar result was found in the study carried out by Bapte & Gedam, (2018).

6.5 Co-occurrence of keyword

Figure 4 shows co-occurrence of keywords with greatest total links strength based on full counting method given in the VOSviewer. The criteria of the keywords having appeared five times or more than five times have been selected. Out of 8558 keywords, 635 met the threshold. Out of 635, leading 50 keywords were chosen. The keywords most frequently occurred and having more links keywords are photoluminescence (occurrence-280, link strength (1126), luminescence (occurrence-199, link strength (763), phosphor (occurrence-145, link strength-634), thermo luminescence (occurrence-121, link strength-413), xrd (occurrence-88, link-395), emission (occurrence-91, link strength-394 and phosphors (occurrence-86, link strength-387). Besides these keywords are followed by energy transfer, ce3+, combustion synthesis, and dy3+

and luminescence properties. These keywords throws light on the research areas in which faculty members are engrossed with. The prominent keywords directly show their relation with leading journals and prolific authors.

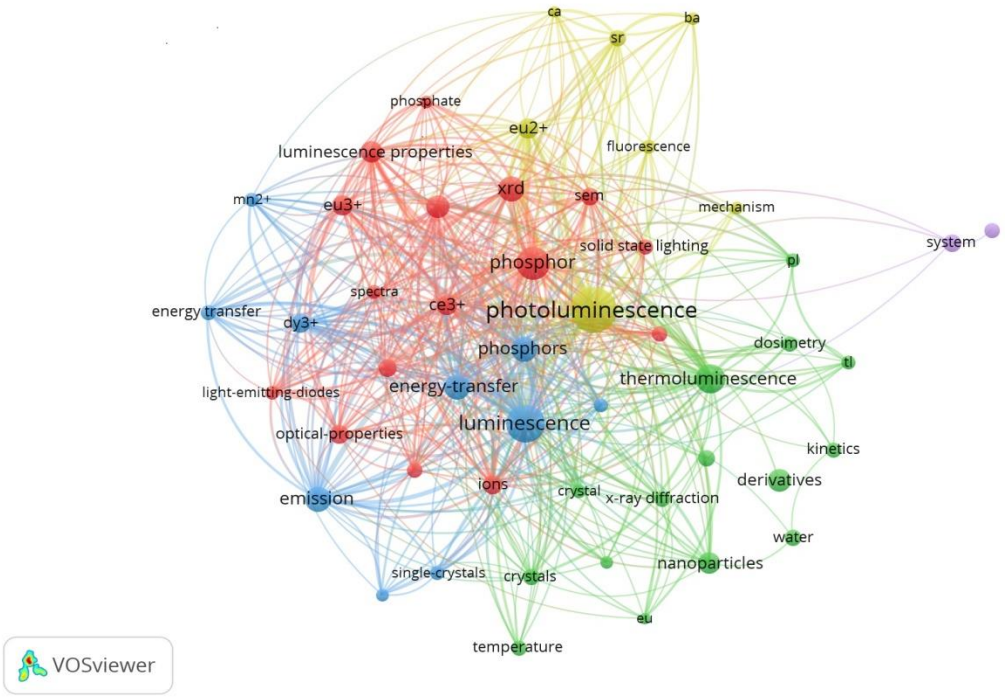

Fig 3 Co-occurrence of keywords

6.6 Validation of Lotka's Law

Alfred Lotka presented an analysis of the number of publications listed in Chemical Abstracts from 1907 to 1916 with the frequency of publications by particular authors (Maheshwarappa, 1997). In analysis he excluded the names of corporate authors but only considered the name of author beginning with A and B as listed in the Index. On the same line Lotka made a similar study in the field of Physics. On the basis of these two data sets he quoted following statement popularly known as Lotka's Inverse Square Law of Scientific Productivity (Maheshwarappa, 1997).

'The number of authors making 'n' contribution is about $1/n^2$ of those making one contribution, and the proportion of all contributors who make a single contribution is about 60 percent.'

Mathematically, the first part of this law i.e. 'the number of authors making 'n' contributions is about $1/n^2$ of those making one contribution' can be stated as.

$$a(n) = a(1)/n^2$$

Where, a(1) is the number of authors contributing one article
a(n) is the number of authors contributing 'n' number of articles
'n' is number of articles

Considering the objectives of the present study the Lotka's Inverse Square Law of Scientific Productivity is tried to satisfy in the dataset on following both the conditions given in the law.

- The number of authors making 'n' contribution is about $1/n^2$ of those making one contribution, and
- The proportion of all contributors who make a single contribution is about 60 percent.

Taking in to consideration above points and after analyzing the collected data presented in the tables the following facts are observed.

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- If we consider the second part of Lotka's law i.e. the proportion of all contributors who make a single contribution is about 60 percent from table 1 it is observed that the law is fit for the data. Because out of 2739 identified contributors 1594 (58.2%) have contributed a single article during the period.

Table 4. No. of observed and expected authors along with no. of articles

Sr. No.	No. of Articles	No. of Authors Observed	No, of Authors Expected
1	1	1594	1594
2	2	451	399
3	3	221	177
4	4	94	100
5	5	75	64
6	6	49	44
7	7	45	33
8	8	30	25
9	9	27	20
10	10	20	16
11	11	17	13
12	12	14	11
13	13	13	9
14	14	12	8
15	15	6	7
16	16	3	6
17	17	10	6
18	18	6	5

19	19	5	4
20	20	2	4
21	21	1	4
22	22	1	3
23	23	4	3
24	24	2	3
25	26	2	2
26	27	6	2
27	29	1	2
28	30	1	2
29	31	2	2
30	32	2	2
31	33	1	1
32	34	2	1
33	35	3	1
34	36	1	1
35	38	1	1
36	41	2	1
37	43	1	1
38	44	1	1
39	51	1	1
40	52	1	1
41	55	1	1
42	58	1	0
43	60	1	0
44	67	1	0
45	68	2	0
46	78	1	0
47	194	1	0
48	439	1	0
		2739	**2581**

Table 5 Frequency of observed and expected authors

Sr.No.	No, of Authors (Observed)	Frequency of Authors (Observed)	No, of Authors (Expected)	Frequency of Authors (Expected)
1	1594	0.582	1594	0.6176
2	451	0.1646	399	0.1546
3	221	0.0807	177	0.0686
4	94	0.0343	100	0.0387
5	75	0.0273	64	0.0248
6	49	0.0179	44	0.017
7	45	0.0164	33	0.0128

8	30	0.0109	25	0.0096
9	27	0.0098	20	0.0077
10	20	0.0073	16	0.0062
11	17	0.0062	13	0.005
12	14	0.0051	11	0.0043
13	13	0.0047	9	0.0035
14	12	0.0043	8	0.0031
15	6	0.0021	7	0.0027
16	3	0.0011	6	0.0023
17	10	0.0037	6	0.0023
18	6	0.0022	5	0.0019
19	5	0.0018	4	0.0015
20	2	0.0007	4	0.0015
21	1	0.0004	4	0.0015
22	1	0.0004	3	0.0012
23	4	0.0015	3	0.0012
24	2	0.0007	3	0.0012
25	2	0.0007	2	0.0008
26	6	0.0022	2	0.0008
27	1	0.0004	2	0.0008
28	1	0.0004	2	0.0008
29	2	0.0007	2	0.0008
30	2	0.0007	2	0.0008
31	1	0.0004	1	0.0004
32	2	0.0007	1	0.0004
33	3	0.0011	1	0.0004
34	1	0.0004	1	0.0004
35	1	0.0004	1	0.0004
36	2	0.0007	1	0.0004
37	1	0.0004	1	0.0004
38	1	0.0004	1	0.0004
39	1	0.0004	1	0.0004
40	1	0.0004	1	0.0004
41	1	0.0004	1	0.0004
42	1	0.0004	0	0
43	1	0.0004	0	0
44	1	0.0004	0	0
45	2	0,0007	0	0
46	1	0.0004	0	0
47	1	0.0004	0	0
48	1	0.0004	0	0
	2739		**2581**	

Table 6. Cumulative frequency of observed and expected authors

Sr. No.	Frequency of Authors (Observed)	Cumulative Frequency (Observed) Sn(X)	Frequency of Authors (Expected)	Cumulative Frequency (Expected) Fo(X)	D=|Fo(X) - Sn(X)|
1	0.582	0.582	0.6176	0.6176	**0.0356**
2	0.1646	0.7466	0.1546	0.7722	0.0256
3	0.0807	0.8273	0.0686	0.8408	0.0135
4	0.0343	0.8616	0.0387	0.8795	0.0179
5	0.0273	0.8889	0.0248	0.9043	0.0154
6	0.0179	0.9068	0.017	0.9213	0.0145
7	0.0164	0.9232	0.0128	0.9341	0.0109
8	0.0109	0.9341	0.0096	0.9437	0.0096
9	0.0098	0.9439	0.0077	0.9514	0.0075
10	0.0073	0.9512	0.0062	0.9576	0.0064
11	0.0062	0.9574	0.005	0.9626	0.0052
12	0.0051	0.9625	0.0043	0.9669	0.0044
13	0.0047	0.9672	0.0035	0.9704	0.0032
14	0.0043	0.9715	0.0031	0.9735	0.002
15	0.0021	0.9736	0.0027	0.9762	0.0026
16	0.0011	0.9747	0.0023	0.9785	0.0038
17	0.0037	0.9784	0.0023	0.9808	0.0024
18	0.0022	0.9806	0.0019	0.9827	0.0021
19	0.0018	0.9824	0.0015	0.9842	0.0018
20	0.0007	0.9831	0.0015	0.9857	0.0026
21	0.0004	0.9835	0.0015	0.9872	0.0037
22	0.0004	0.9839	0.0012	0.9884	0.0045
23	0.0015	0.9854	0.0012	0.9896	0.0042
24	0.0007	0.9861	0.0012	0.9908	0.0047
25	0.0007	0.9868	0.0008	0.9916	0.0048
26	0.0022	0.989	0.0008	0.9924	0.0034
27	0.0004	0.9894	0.0008	0.9932	0.0038
28	0.0004	0.9898	0.0008	0.994	0.0042
29	0.0007	0.9905	0.0008	0.9948	0.0043
30	0.0007	0.9912	0.0008	0.9956	0.0044
31	0.0004	0.9916	0.0004	0.996	0.0044
32	0.0007	0.9923	0.0004	0.9964	0.0041
33	0.0011	0.9934	0.0004	0.9968	0.0034
34	0.0004	0.9938	0.0004	0.9972	0.0034
35	0.0004	0.9942	0.0004	0.9976	0.0034
36	0.0007	0.9949	0.0004	0.998	0.0031
37	0.0004	0.9953	0.0004	0.9984	0.0031
38	0.0004	0.9957	0.0004	0.9988	0.0031
39	0.0004	0.9961	0.0004	0.9992	0.0031
40	0.0004	0.9965	0.0004	0.9996	0.0031
41	0.0004	0.9969	0.0004	1	0.0031

42	0.0004	0.9973	0	1	0.0027
43	0.0004	0.9977	0	1	0.0023
44	0.0004	0.9981	0	1	0.0019
45	0,0007	0.9988	0	1	0.0012
46	0.0004	0.9992	0	1	0.0008
47	0.0004	0.9996	0	1	0.0004
48	0.0004	1	0	1	0

From Table 3, it is observed that D= Max | Fo(X) –Sn (X) | = 0.0356

At the 0.01 level of significance,

K-S Statistics = $\frac{1.63}{\sqrt{n}}$

Here n is number of authors observed during the study which is 2739 (from Table 1)

$$\text{K-S Statistics} = \frac{1.63}{\sqrt{2739}}$$

$$= \frac{1.63}{52.34} = 0.0311$$

Here, it is cleared that the value of D i.e. 0.0356 is greater than the value of K-S statistic i.e. 0.0311 and therefore it becomes factual that the given data does not fit to Lotka's Law.

7. Conclusion

The article is based on the scientometric analysis of Rashtrasant Tukadoji Maharaj Nagpur University which is one of the eminent state universities in Maharashtra state. A continuous growth was observed during 2001-2009. The distribution of the output revealed that most of the papers published in the area of Material Science Multidisciplinary, Pharmacology Pharmacy and Optics. The Social Sciences and Humanities lagged behind in terms of research output. Not a single subject was found in the list of top most subject categories. RTMNU mostly collaborated with Council of Scientific and Industrial Research, National Environmental Engineering Research Institutes and Visvesvaraya National Institute of Technology, Nagpur. While USA, South Korea, South Africa were the leading foreign collaborators with RTMNU. Further, the value of D was found greater than the value of K-S statistic; the Lotka's law did not fit over the study. The article is helpful to have a thoughtful reflection on overall research output of RTMNU. However more studies on the same line are required to trace the nature expansion of the research activity of state universities in Maharashtra.

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