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AUTHORSHIP PATTERN AND COLLABORATIVE MEASURES IN THE FIELD OF CRYSTALLOGRAPHY

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AUTHORSHIP PATTERN AND COLLABORATIVE MEASURES IN THE FIELD OF CRYSTALLOGRAPHY

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Abstract:

The study highlights the authorship pattern and research collaboration in the area of Crystallography based on 45320 scholarly communications appeared in the Crystallography during 1989-2013. Study illustrates various significant aspects like types and trends of authorship, author productivity, degree of collaboration, collaborative index, Collaboration coefficient, Moderate Collaboration. Multiple author papers are more popular among Crystallography literature. There is a significant correlation found between number of authors and number of papers, further, the given data set is verified through Kolmogorov Simonov test. Finally it can be concluded that Crystallography literature does follow the Lotka's law of author productivity and found that there is a Positive Co-relation in Crystallography literature.

Keywords: Authorship Pattern, Degree of Collaboration, Collaborative Coefficient, Collaborative Index, Moderate Collaborate Coefficient

1. INTRODUCTION:

Concept of authorship actually emanated from the anonymity of scholarly communications as, research communications were validate based on the merit of the content and positioned within an anonymous and coherent conceptual system of established truths. In today's highly competitive market place authorship attribution has become even more significant as it is the currency of research credit and primary basis for academic evaluation and reward system like promotions, tenure and salary determination. Study of authorship across the disciple, thus becomes an issue that has frequently been persuaded in bibliometrics.

The Present study is a bibliometric analysis of Crystallography Literature over the period of 1989-2013. An attempt has been made in this study to find out the various

characteristics of Crystallographyliterature such as, authorship pattern and Collaborative research, Lotka's Law etc.

2. REVIEW OF LITERATURE:

Chakraborthy (1981) has studied authorship patterns and collaborative research in Geology based on the data collected from Bibliography and Index of Geology published by the American Geological Institute for the year 1940, 1950, 1960 and 1970. The results showed that the frequency of single authored papers decreased from 84.97 percent in 1940 to 48.36 percent in 1970 and the frequency of papers with two authors increased from 11.75 percent to 32.84 percent for the corresponding years. It is found that multiple authors gradually increased in the field of geology.**Neelamma G and Gavisiddappa Anandhalli (2015).** The study reveals the various aspects of crystallography literature. such as year wise distribution, relative growth rate, doubling time of the literature, geographical wise, organization wise, Language wise, form wise, most prolific authors and funding agency etc. The highest number of articles was published in the year of 2011, while lowest numbers of research articles were reported in the year 1999. Further, the relative growth rate is gradually increases and on the other hand doubling time decreases. Most of the research publications are published in English language and most of the publications published in the form of research articles, China is the highest contributor to the field of Crystallography.**Neelamma and Anandhalli (2016)**have highlighted the authorship pattern and research collaboration in the area of Biology based on 1183 scholarly communication appeared in the Botany during 2005-2014. Study illustrates various significant aspects like types and trends of authorship, author productivity, degree of collaboration, collaborative index, Growth rate of the articles, Relative growth rate and Doubling time, geographical wise distribution. Multiple author papers are more popular among Botany literature. USA is the highest Contributor Country in the field of Botany literature, finally verified through Kolmogorov Simonov test. Finally it can be concluded that Botany literature does not follow the Lotka's law of author productivity and found that there is a negativeCo-relation in botany literature.

Shridevi Prakash Sindagi and Gavisiddappa Bhalappa Anandhalli (2018) this study highlights the authorship trend and collaborative research in the area of lung cancer literature based on 93512 scholarly communications appeared in the lung cancer literature during 1997 to 2016.The study elaborates on various bibliometric components such as year wise distribution of articles, relative growth rate, doubling time, authorship pattern and collaborative coefficients. High degree of collaborative research (0.92) was found in the field of lung cancer which shows there is trend towards collaborative research. The Lotka's distribution is well fitted and followed in the area of Lung cancer which is confirmed with K-S test. The highest number of publication has been contributed by two authors (13301-14.2%) followed by three authors(11869- 12.69%).To examine the trend of research in the area of lung cancer with respect to authorship pattern. There is a high percentage of growth of publication

was observed in case of single author (11.61%) for ten years (2021). The considerable percent of growth was observed (32%) for the period twenty years (2031) in the field of lung cancer. Finally, it can be concluded that, the major research activity is taking place in the area of Lung Cancer.

Shridevi Sindagi And Gavisiddappa Anandhalli (2018)The present study elaborates that Nanotechnology is most emerging subject day by day most of the research taken place in this subject from the year 2000- 2016 the highest number of articles were contributed in the field of nanotechnology was featured in the year 2016, while lowest number of articles were found in the year 2000 i.e. 30 articles (0.38 percent). 5871 publications were in the form of journal articles dominated the highest contribution where the total number of publications were 8000. Among top 50 authors based on publishing maximum no. of publications. The highest number of articles contributed by Wang J. i.e. 51 (4.78%) publications out of 1060 articles. The total research publications (8000) on nanotechnology were published in the seventeen different languages. Among them English language publications were the maximum literature output with a record count of 7655 with citation count of 147859 as global citation score and 2488 local citation score, where Chinese is second highest . The most productive journals in the field of nanotechnology are three (Namely Microelectronic Engineering, Advanced Powder Technology and Journal of Nanoscience and Nanotechnology). 17.04 % of world's share was published in these journals.

3. OBJECTIVES:

1. To observe the nature of Authorship pattern in the literature of Crystallography.
2. To study the collaborative dimensions like Collaborative Index, Degree of Collaboration, Collaborative Co-efficient and Moderate Coefficient in the field of Crystallography
3. To examine the applicability of Lotka's Inverse Square Law in the field of Crystallography.

4. HYPOTHESES

1. The authorship Productivity distribution in the field of Crystallography follow the Lotka Distribution.
2. There is moderate positive correlation found between No of records vs No of authors in the field of crystallography over the period of 25 years (1989-2013).
3. There is moderate positive correlation is found between single author vs multiple authors in the field of crystallography over the period of 25 years (1989-2013.

5. METHODOLOGY:

Web of Science Database was used as major source of data for the present study, based on the objectives; major key words are identified to extract the reliable literature from web of science by using the crystallography as a major main heading and its related sub headings from the year 1989 to 2013. The obtained data was analyzed through the various aspects of document types, publication output, language wise distribution, most productive author and most productive journal etc. Extracted data from the data base was analyzed with help of Ms-Excel and SPSS.

6. ANALYSIS AND INTERPRETATION:

Table- 1 Authorship Pattern in Crystallography (1989-2013)

Year	Total Paper	Number of Papers / Author (s)											Multiple Authored paper	Total no of Multiple Authors	TA
		Single	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	>Ten			
1989	101	27 (0.95%)	28 (0.54%)	17 (0.23%)	9 (0.11%)	7 (0.10%)	4 (0.08%)	2 (0.06%)	3 (0.14%)	1 (0.07%)	1 (0.11%)	2 (0.12%)	74	281	308
1990	141	48 (1.68%)	23 (0.44%)	18 (0.24%)	16 (0.20%)	14 (0.20%)	12 (0.23%)	3 (0.09%)	4 (0.18%)	2 (0.14%)	0 (0.00%)	1 (0.06%)	93	388	436
1991	841	72 (2.53%)	150 (2.89%)	130 (1.75%)	186 (2.32%)	120 (1.70%)	88 (1.71%)	44 (1.28%)	21 (0.96%)	11 (0.79%)	7 (0.78%)	12 (0.71%)	769	3339	3411
1992	979	85 (2.98%)	129 (2.49%)	186 (2.50%)	210 (2.62%)	152 (2.15%)	86 (1.67%)	61 (1.77%)	35 (1.60%)	14 (1.01%)	9 (1.00%)	12 (0.71%)	894	3987	4072
1993	1083	76 (2.67%)	148 (2.85%)	217 (2.92%)	210 (2.62%)	171 (2.42%)	113 (2.20%)	65 (1.89%)	30 (1.37%)	23 (1.66%)	12 (1.34%)	18 (1.07%)	1007	4540	4616
1994	1238	81 (2.84%)	181 (3.49%)	229 (3.08%)	270 (3.36%)	196 (2.77%)	112 (2.18%)	77 (2.23%)	37 (1.70%)	24 (1.73%)	13 (1.45%)	18 (1.07%)	1157	5160	5241
1995	1243	95 (3.33%)	150 (2.89%)	275 (3.69%)	238 (2.97%)	197 (2.78%)	114 (2.22%)	79 (2.29%)	38 (1.74%)	17 (1.22%)	15 (1.67%)	25 (1.48%)	1148	5181	5276
1996	1378	91 (3.19%)	197 (3.80%)	256 (3.44%)	280 (3.49%)	216 (3.05%)	147 (2.86%)	101 (2.93%)	36 (1.65%)	20 (1.44%)	17 (1.90%)	17 (1.01%)	1287	5776	5867
1997	1490	104 (3.65%)	186 (3.58%)	283 (3.80%)	272 (3.39%)	220 (3.11%)	165 (3.21%)	100 (2.90%)	58 (2.66%)	51 (3.67%)	20 (2.23%)	31 (1.84%)	1386	6563	6667
1998	1654	138 (4.84%)	208 (4.01%)	310 (4.16%)	300 (3.74%)	265 (3.75%)	182 (3.54%)	106 (3.08%)	51 (2.34%)	34 (2.45%)	27 (3.01%)	33 (1.96%)	1516	7052	7190
1999	1751	114 (4.00%)	208 (4.01%)	333 (4.47%)	332 (4.14%)	268 (3.79%)	207 (4.03%)	108 (3.13%)	86 (3.94%)	42 (3.03%)	19 (2.12%)	34 (2.02%)	1637	7711	7825
2000	1869	125 (4.39%)	246 (4.74%)	348 (4.67%)	330 (4.11%)	302 (4.27%)	203 (3.95%)	133 (3.86%)	70 (3.21%)	50 (3.60%)	29 (3.24%)	33 (1.96%)	1744	8178	8303
2001	1864	136 (4.77%)	203 (3.91%)	336 (4.51%)	329 (4.10%)	313 (4.42%)	215 (4.18%)	131 (3.80%)	84 (3.85%)	47 (3.39%)	31 (3.46%)	39 (2.32%)	1728	8336	8472

2002	1975	200 (7.02%)	214 (4.12%)	309 (4.15%)	344 (4.29%)	317 (4.48%)	210 (4.09%)	146 (4.24%)	114 (5.22%)	49 (3.53%)	30 (3.35%)	42 (2.49%)	1775	8713	8913
2003	2004	122 (4.28%)	259 (4.99%)	347 (4.66%)	358 (4.46%)	299 (4.23%)	223 (4.34%)	161 (4.67%)	101 (4.63%)	47 (3.39%)	36 (4.02%)	51 (3.03%)	1882	9103	9225
2004	2123	126 (4.42%)	254 (4.89%)	378 (5.08%)	376 (4.68%)	322 (4.55%)	234 (4.55%)	154 (4.47%)	105 (4.81%)	74 (5.33%)	41 (4.58%)	59 (3.50%)	1997	9803	9929
2005	2208	147 (5.16%)	224 (4.32%)	377 (5.06%)	396 (4.93%)	349 (4.93%)	264 (5.14%)	169 (4.90%)	111 (5.09%)	58 (4.18%)	42 (4.69%)	71 (4.22%)	2061	10286	10433
2006	2294	111 (3.89%)	254 (4.89%)	375 (5.04%)	453 (5.64%)	356 (5.03%)	265 (5.16%)	174 (5.05%)	94 (4.31%)	66 (4.76%)	51 (5.69%)	95 (5.64%)	2183	10934	11045
2007	2391	101 (3.54%)	256 (4.93%)	393 (5.28%)	448 (5.58%)	365 (5.16%)	282 (5.49%)	198 (5.74%)	125 (5.73%)	78 (5.62%)	43 (4.80%)	102 (6.06%)	2290	11640	11741
2008	2429	273 (9.58%)	300 (5.78%)	336 (4.51%)	376 (4.68%)	367 (5.19%)	242 (4.71%)	199 (5.77%)	100 (4.58%)	81 (5.84%)	49 (5.47%)	106 (6.29%)	2156	10977	11250
2009	2557	119 (4.18%)	246 (4.72%)	370 (4.97%)	414 (5.16%)	454 (6.42%)	312 (6.07%)	205 (5.95%)	148 (6.78%)	98 (7.06%)	67 (7.48%)	124 (7.36%)	2438	12935	13054
2010	2752	134 (4.70%)	257 (4.95%)	396 (5.32%)	450 (5.61%)	433 (6.12%)	341 (6.63%)	240 (6.96%)	165 (7.56%)	92 (6.63%)	88 (9.82%)	156 (9.26%)	2618	14137	14271
2011	2876	101 (3.54%)	289 (5.57%)	418 (5.62%)	444 (5.53%)	454 (6.42%)	382 (7.43%)	227 (6.59%)	186 (8.52%)	124 (8.93%)	79 (8.82%)	172 (10.21%)	2775	15045	15146
2012	2928	110 (3.86%)	269 (5.18%)	410 (5.51%)	454 (5.66%)	458 (6.47%)	371 (7.22%)	268 (7.77%)	173 (7.93%)	143 (10.30%)	75 (8.37%)	197 (11.70%)	2818	15564	15674
2013	3151	114 (4.00%)	310 (5.97%)	397 (5.33%)	531 (5.62%)	459 (6.49%)	366 (7.12%)	296 (8.59%)	207 (9.49%)	142 (10.23%)	95 (10.60%)	234 (13.90%)	3037	16956	17070
Total	**45320**	**2850**	**5189**	**7444**	**8026**	**7074**	**5140**	**3447**	**2182**	**1388**	**896**	**1684**			
		6.288614	**11.44969**	**16.42542**	**17.70962**	**15.609**	**11.34157**	**7.605914**	**4.814651**	**3.062665**	**1.977052**	**3.715799**			

Table-1 depicts the authorship pattern for the period 1989-2013. The analysis of the table shows that the single author Contribution is 6.28%, two author share is 11.44%, three author share is 16.42%, four author share is 17.70%, five author contribution is 15.60%, six author share is 11.34%, eight share is 4.891%, nine author share is 3.06%, ten author contribution is 3.97%, more than ten author contribution is 3.71% of the total articles 45320. It shows t hat multiple authored research articles have made major contribution in the field of Crystallography literature.

At the same time total author per paper ration was also calculated:

Average author per paper $= \frac{\text{Total no.of authors}}{\text{Total number of papers}} = \frac{215435}{45320} = \mathbf{4.75}$

Figure-1 Authorship Pattern of Crystallography Literature

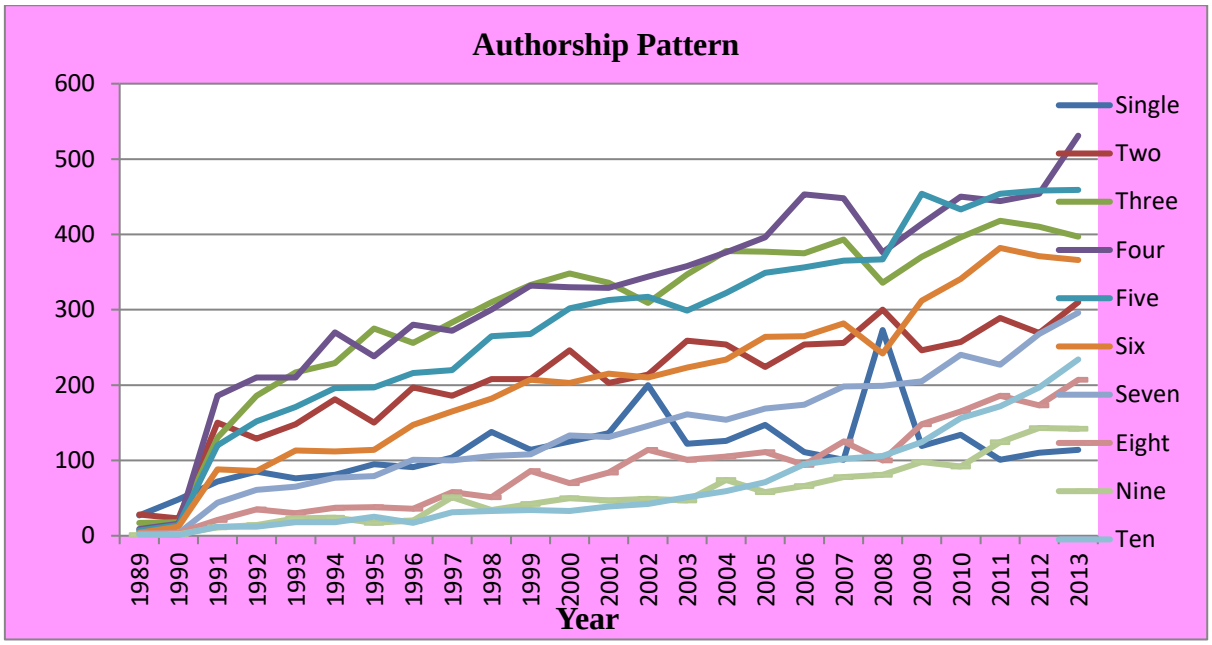

Figure – 2 Total Author vs Total Number of Crystallography Literature

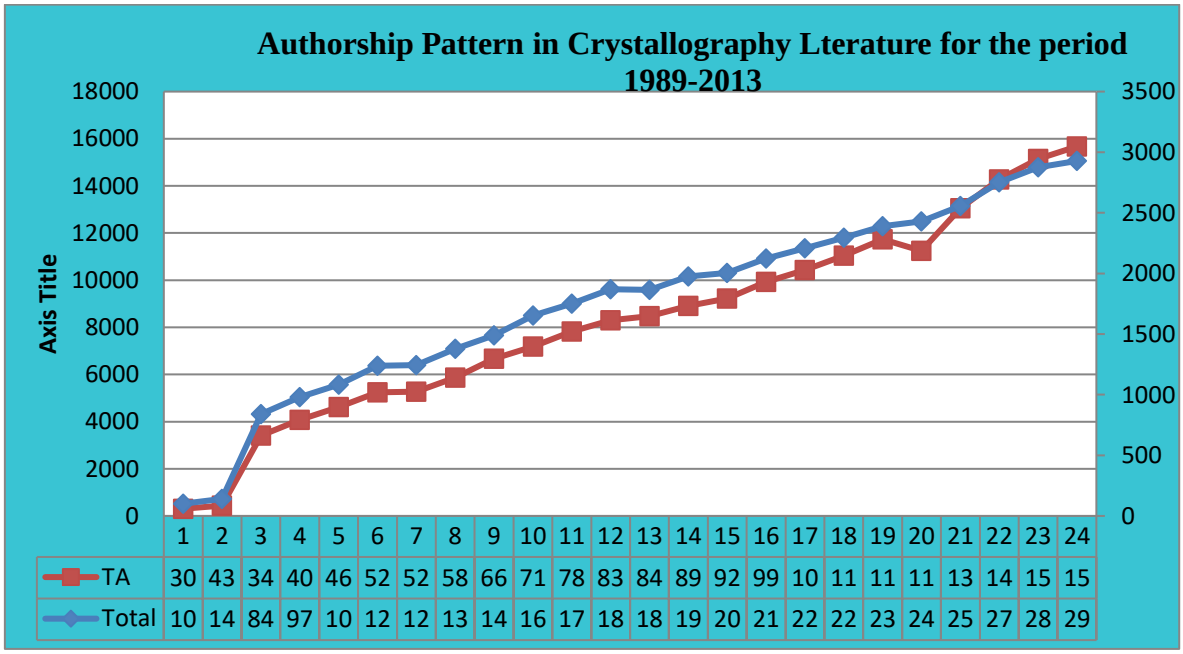

Table – 2 Correlations between number of Articles and number of Authors

		No of Records	No of Authors
no of records	Pearson Correlation	1	.992(**)
	Sig. (2-tailed)		.000
	N	25	25
no of authors	Pearson Correlation	.992(**)	1
	Sig. (2-tailed)	.000	
	N	25	25

** Correlation is significant at the 0.01 level (2-tailed).

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Further, to see the collaboration coefficient between number of articles and number of author with respect to time, there is a positive high significant correlation found between number of records and number of authors (χ=0.992, df=24, P< 0.05). **Hence the null hypotheses is rejected and alternative hypothesis is accepted and indicates that there is moderate positive correlation found between No of records vs No of authors in the field of crystallography over the period of 25 years (1989-2013). (Hypotheses=1)**

Table 3 Correlations between Single author and Multiple author

		Single Author	Multiple Author
single author	Pearson Correlation	1	.520(**)
	Sig. (2-tailed)		.008
	N	25	25
multiple author	Pearson Correlation	.520(**)	1
	Sig. (2-tailed)	.008	
	N	25	25

** Correlation is significant at the 0.01 level (2-tailed).

Further to see the correlation between single author and multiple author distribution for a given data set. There is a moderate to significant correlation found between them (χ =0.520, df=24, P<0.05). **Hence the null hypotheses is rejected and alternative hypothesis is accepted and indicates that there is moderate positive correlation is found between single author vs multiple authors in the field of crystallography over the period of 25 years (1989-2013). (Hypotheses=2)**

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In a similar study conducted by **Chakraborthy (1981)**. studied on authorship patterns and collaborative research in Geology based on the data collected from 'Bibliography and Index of Geology' published by the American Geological Institute for the years 1940, 1950, 1960 and 1970. The results showed that the frequency of single authored papers decreased from 84.97 percent in 1940 to 48.36 percent in 1970, and the frequency of papers with two authors increased from 11.75 percent to 32.84 percent for the corresponding years. It is found that multiple authors gradually increased in the field of geology.

- **Collaborative Measures in Crystallography (1989-2013)**
  - **Measures of Authorship**

The study of authorship is an important aspect and plays a significant role in information dissemination and communication activities. The latest research trends show that they are more data intensive than earlier research due to the proliferation of electronic technologies and the demand for solutions in today's era of fast paced innovation. Similarly the movement towards collaborative innovation is affecting scientific research, bringing scientists from different disciplines together in their pursuit of solutions to today's challenges. This is also found true in the case of Crystallography research, because of the interdisciplinary growth of the subjects. At the same time, it is obligatory on the part of science scientists to come together and complement one another to overcome the challenges. The collaboration is not limited to individual scientists; it is extended even to institutions, communities, and nations and so on. The concept of team work is in vogue because of various funding agencies.

The collaborative Index, degree of collaboration and collaboration coefficient were calculated based on year-wise input of data.

(a). Collaborative index (CI)

This is one of the early measures of degree of collaboration derived by Lawani (1986).

$$\sum_{f}^{A} = \frac{1/fi}{N}$$

It is a measure of mean number of authors. Although it is easily computable, it is not easily interpretable as a degree, for it has no upper limit moreover; it gives a non-zero weight to single-authored papers, which involve no collaboration.

Calculation: $CI = \frac{(f1)1 + (f2)2 + (f3)3 + L + (fk)k}{N}$

Where, f1, f2,f3……= number of authors

N = Number of publications in that year

Using data in Table , during 1989

CC= (27+28x2+17x3+9x4+7x5+4x6+2x7+3x8+1x9+1x10+2x11) / 101

= (27+56+51+36+35+24+14+24+9+10+22) / 101
=308 / 101
= 3.0495

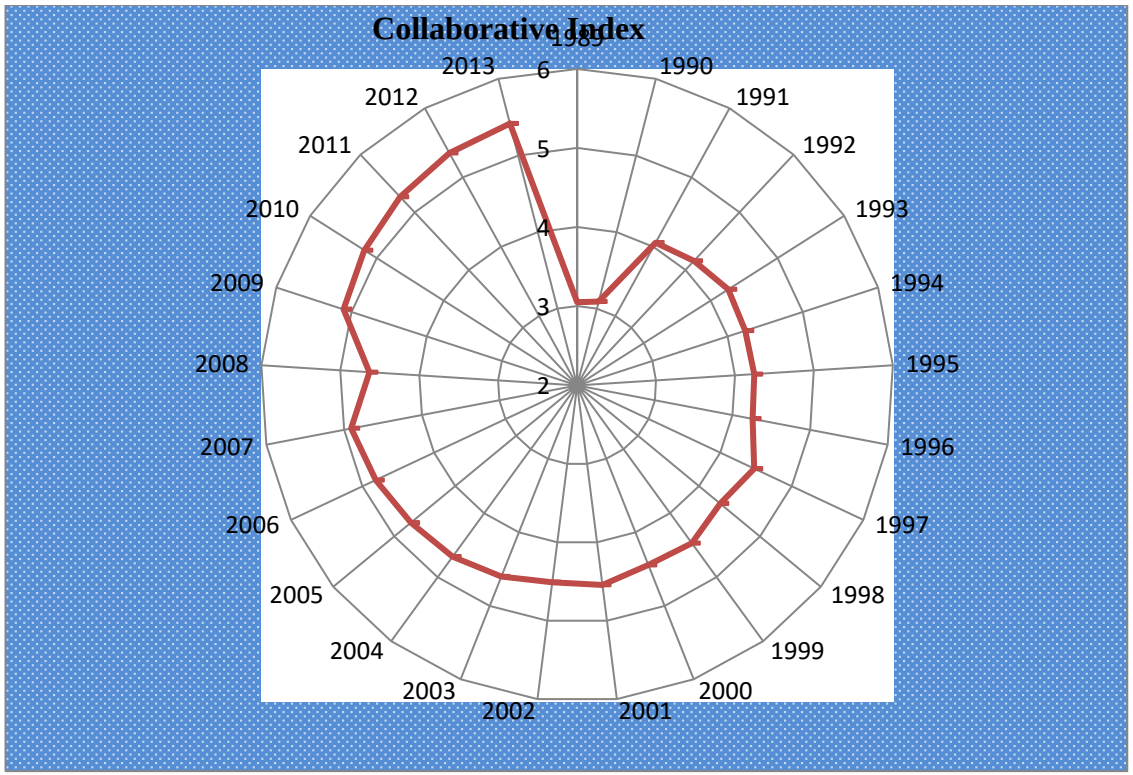
Table shows the authorship pattern and Collaborative Index (CI), in crystallography over the study period of 25 years, (1989-2013). The collaborative index 3.0495 in 1989 has increased to 5.41733 in 2013. The average CI is 4.51 during the study period.

Table- 4Authorship pattern and Collaborative Index (CI) in Crystallography

Year	Single	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	>Ten	Total Articles	CI
1989	27	28	17	9	7	4	2	3	1	1	2	101	3.05
1990	48	23	18	16	14	12	3	4	2	0	1	141	3.09
1991	72	150	130	186	120	88	44	21	11	7	12	841	4.06
1992	85	129	186	210	152	86	61	35	14	9	12	979	4.16
1993	76	148	217	210	171	113	65	30	23	12	18	1083	4.26
1994	81	181	229	270	196	112	77	37	24	13	18	1238	4.23
1995	95	150	275	238	197	114	79	38	17	15	25	1243	4.24
1996	91	197	256	280	216	147	101	36	20	17	17	1378	4.26
1997	104	186	283	272	220	165	100	58	51	20	31	1490	4.47
1998	138	208	310	300	265	182	106	51	34	27	33	1654	4.35
1999	114	208	333	332	268	207	108	86	42	19	34	1751	4.47
2000	125	246	348	330	302	203	133	70	50	29	33	1869	4.44
2001	136	203	336	329	313	215	131	84	47	31	39	1864	4.55
2002	200	214	309	344	317	210	146	114	49	30	42	1975	4.51
2003	122	259	347	358	299	223	161	101	47	36	51	2004	4.60
2004	126	254	378	376	322	234	154	105	74	41	59	2123	4.68
2005	147	224	377	396	349	264	169	111	58	42	71	2208	4.73
2006	111	254	375	453	356	265	174	94	66	51	95	2294	4.81
2007	101	256	393	448	365	282	198	125	78	43	102	2391	4.91
2008	273	300	336	376	367	242	199	100	81	49	106	2429	4.63
2009	119	246	370	414	454	312	205	148	98	67	124	2557	5.11
2010	134	257	396	450	433	341	240	165	92	88	156	2752	5.19
2011	101	289	418	444	454	382	227	186	124	79	172	2876	5.27

2012	110	269	410	454	458	371	268	173	143	75	197	2928	5.35
2013	114	310	397	531	459	366	296	207	142	95	234	3151	5.42
	2850	5189	7444	8026	7074	5140	3447	2182	1388	896	1684	45320	4.51
	6.28861	11.4497	16.4254	17.7096	15.609	11.3416	7.60591	4.81465	3.06267	1.97705	3.7158	100	

Figure-3 Collaborative Index of Crystallography Literature



(b). Degree of Collaboration (DC)

In recent years, most of the countries have realized the importance of scientific research for its Socio-Economic Development, and have initiated programmes that encourage and support collaboration among scientists and researchers, both at the national and the international levels. In order to measure the collaborative research pattern. It can be defined as the number of multi author publications in the discipline published during a year as against the total number of papers (multi author and single author) published during the year.

An indicator known as the Degree of Collaboration has been used as proposed by Subramanyam, K (1983) as below:

$$\text{Degree of collaboration (DC)} = \frac{\text{Nm}}{\text{Nm} + \text{Ns}}$$

Where
Nm = number of multi authors during a specific period in a discipline
Ns = number of single authors publication in a discipline during a given period of time

Based on the data in Table 10, DC stands for multi-authored publications;

Table- 5 Degree of Collaboration (DC) in Crystallography

Year	Single	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	>Ten	Total Articles	DC
1989	27	28	17	9	7	4	2	3	1	1	2	101	0.73
1990	48	23	18	16	14	12	3	4	2	0	1	141	0.66
1991	72	150	130	186	120	88	44	21	11	7	12	841	0.91
1992	85	129	186	210	152	8j6	61	35	14	9	12	979	0.91
1993	76	148	217	210	171	113	65	30	23	12	18	1083	0.93
1994	81	181	229	270	196	112	77	37	24	13	18	1238	0.93
1995	95	150	275	238	197	114	79	38	17	15	25	1243	0.92
1996	91	197	256	280	216	147	101	36	20	17	17	1378	0.93
1997	104	186	283	272	220	165	100	58	51	20	31	1490	0.93
1998	138	208	310	300	265	182	106	51	34	27	33	1654	0.92
1999	114	208	333	332	268	207	108	86	42	19	34	1751	0.93
2000	125	246	348	330	302	203	133	70	50	29	33	1869	0.93
2001	136	203	336	329	313	215	131	84	47	31	39	1864	0.93
2002	200	214	309	344	317	210	146	114	49	30	42	1975	0.90
2003	122	259	347	358	299	223	161	101	47	36	51	2004	0.94
2004	126	254	378	376	322	234	154	105	74	41	59	2123	0.94
2005	147	224	377	396	349	264	169	111	58	42	71	2208	0.93
2006	111	254	375	453	356	265	174	94	66	51	95	2294	0.95
2007	101	256	393	448	365	282	198	125	78	43	102	2391	0.96
2008	273	300	336	376	367	242	199	100	81	49	106	2429	0.89
2009	119	246	370	414	454	312	205	148	98	67	124	2557	0.95
2010	134	257	396	450	433	341	240	165	92	88	156	2752	0.95
2011	101	289	418	444	454	382	227	186	124	79	172	2876	0.96

2012	110	269	410	454	458	371	268	173	143	75	197	2928	0.96
2013	114	310	397	531	459	366	296	207	142	95	234	3151	0.96
	2850	5189	7444	8026	7074	5140	3447	2182	1388	896	1684	45320	0.92
	6.28861	11.4497	16.4254	17.7096	15.609	11.3416	7.60591	4.81465	3.06267	1.97705	3.7158	100	

The analysis of Degree of Collaboration shows that in 1989 it was 0.73 and it has increased to 0.96 in the year 2013. Except a slight decrease in 1990 showing 0.66. The overall Degree of Collaboration in Crystallography is 0.92. This indicates the increasing trend in collaborative publications.

(c). Collaborative Coefficient (CC).

Ajiferuke, Burell and Tague have shown the mean number of authors per publications. The proportion of multiple authorship, as a measure of degree of collaboration in a discipline, according to them, is inadequate, and therefore, they have proposed a measure combining some of the merits of both measures into what is known as Collaborative Coefficient (CC).

Suppose, if a publication has a single author, the author receive one credit; if a publications has a single author the authors receives one credit; if two, each receives ½ credit and in general, if we have 'n' authors each receives 1/n credits. Hence, the average credit awarded to each author of a random publications is E [1/n], a value which lies between 0 and 1. If '0' is to correspond to single authorship, then the Collaborative Coefficient is defined as:

$$\text{CC} = \frac{1-E}{n}$$

$$= 1-\left(\frac{1}{j}\right)p \quad (N=j)$$

And its same $\sum$ rate is

$$= 1 - [\frac{f1 + \left(\frac{1}{2}\right)f2 + \left(\frac{1}{2}\right)f3 + \cdots + \left(\frac{1}{k}\right)fk}{N}]$$

Where: fj = the number of j-authors research publications published in a discipline during a certain period of time.

N = the total number of research papers published in a discipline during a certain period of time: (excluded anonymous authors)

k = the greatest number of authors per paper in a discipline.

Ajiferuke*et.al.*are of the opinion that the Collaborative Co-efficient incorporates the sum of the merits of both collective index and degree of collaboration. It lies between 0 and 1 ($0 \leq CC > 1$). Tends to zero as single authored publications dominate and differentiates among levels of multiple authorship.

$$\text{Calculation: CC} = \frac{1-\left[\, f1 + (1/2)\, f2 + (1/3)\, f3 + \cdots + (1/k)\, fk \right]}{N}$$

Based on the data in Table 15 CC for the year 1999 has been calculated as

$$CC = 1 - (114 + \left(\frac{1}{2}\right) X\ 208 + \left(\frac{1}{3}\right) X\ 333 + \left(\frac{1}{4}\right) X\ 332 + \left(\frac{1}{5}\right) X\ 268 + \left(\frac{1}{6}\right) X\ 207 + \left(\frac{1}{7}\right) X\ 108 + \left(\frac{1}{8}\right) X\ 86 + \left(\frac{1}{9}\right) X\ 42 + \left(\frac{1}{10}\right) X\ 19 + \left(\frac{1}{11}\right) X\ 34)$$

$$= 1 - \frac{(114 + 104 + 111 + 83 + 53.6 + 34.5 + 15.42 + 10.75 + 4.66 + 1.9 + 3.09)}{1751}$$

$$= 1 - \frac{535.9361}{1751}$$

$$= \mathbf{0.69}$$

Table-6 Collaborative Co-efficient (CC) in Crystallography

Year	Single	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	>Ten	Total Articles	CC
1989	27	28	17	9	7	4	2	3	1	1	2	101	0.48
1990	48	23	18	16	14	12	3	4	2	0	1	141	0.46
1991	72	150	130	186	120	88	44	21	11	7	12	841	0.66
1992	85	129	186	210	152	86	61	35	14	9	12	979	0.67
1993	76	148	217	210	171	113	65	30	23	12	18	1083	0.68
1994	81	181	229	270	196	112	77	37	24	13	18	1238	0.68
1995	95	150	275	238	197	114	79	38	17	15	25	1243	0.68
1996	91	197	256	280	216	147	101	36	20	17	17	1378	0.68
1997	104	186	283	272	220	165	100	58	51	20	31	1490	0.69
1998	138	208	310	300	265	182	106	51	34	27	33	1654	0.68
1999	**114**	**208**	**333**	**332**	**268**	**207**	**108**	**86**	**42**	**19**	**34**	**1751**	**0.69**
2000	125	246	348	330	302	203	133	70	50	29	33	1869	0.69
2001	136	203	336	329	313	215	131	84	47	31	39	1864	0.69
2002	200	214	309	344	317	210	146	114	49	30	42	1975	0.68
2003	122	259	347	358	299	223	161	101	47	36	51	2004	0.70
2004	126	254	378	376	322	234	154	105	74	41	59	2123	0.70
2005	147	224	377	396	349	264	169	111	58	42	71	2208	0.70
2006	111	254	375	453	356	265	174	94	66	51	95	2294	0.72
2007	101	256	393	448	365	282	198	125	78	43	102	2391	0.72
2008	273	300	336	376	367	242	199	100	81	49	106	2429	0.67
2009	119	246	370	414	454	312	205	148	98	67	124	2557	0.73
2010	134	257	396	450	433	341	240	165	92	88	156	2752	0.73
2011	101	289	418	444	454	382	227	186	124	79	172	2876	0.74

2012	110	269	410	454	458	371	268	173	143	75	197	2928	0.74
2013	114	310	397	531	459	366	296	207	142	95	234	3151	0.75
	2850	**5189**	**7444**	**8026**	**7074**	**5140**	**3447**	**2182**	**1388**	**896**	**1684**	**45320**	**0.68**
	6.28861	**11.4497**	**16.4254**	**17.7096**	**15.609**	**11.3416**	**7.60591**	**4.81465**	**3.06267**	**1.97705**	**3.7158**	**100**	

Table 6 shows the Collaborative Co-efficient has increased from 0.48 in 1989 to 0.75 in 2013 indicating that research among scientists is fairly collaborative with an average CC of 0.68. There is a constant increase in CC from 1989 to 2013. The over all Collaborative Coefficient is 0.68 (68%). Which shows their high degree of Collaboration observed in Crystallography discipline.

(d). Moderate Collaboration

$$MC=\frac{A}{A-1}\left\{\frac{\sum_{j=1}^{A}(1|j)f_j}{N}\right\}$$

Table7 shows the Moderate Collaboration (MC), we can see the variation in the Moderate Collaboration. It varies from 0.49 in 1989 and notices in 2013 i.e. 0.75. There is an increasing trend found in Moderate Collaboration.

Table-7 Moderate Co-efficient (MC) in Crystallography

Year	Single	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	>Ten	Total Articles	MC
1989	27	28	17	9	7	4	2	3	1	1	2	101	0.49
1990	48	23	18	16	14	12	3	4	2	0	1	141	0.47
1991	72	150	130	186	120	88	44	21	11	7	12	841	0.66
1992	85	129	186	210	152	86	61	35	14	9	12	979	0.67
1993	76	148	217	210	171	113	65	30	23	12	18	1083	0.68
1994	81	181	229	270	196	112	77	37	24	13	18	1238	0.68
1995	95	150	275	238	197	114	79	38	17	15	25	1243	0.68
1996	91	197	256	280	216	147	101	36	20	17	17	1378	0.68
1997	104	186	283	272	220	165	100	58	51	20	31	1490	0.69
1998	138	208	310	300	265	182	106	51	34	27	33	1654	0.68
1999	114	208	333	332	268	207	108	86	42	19	34	1751	0.69
2000	125	246	348	330	302	203	133	70	50	29	33	1869	0.69
2001	136	203	336	329	313	215	131	84	47	31	39	1864	0.69
2002	200	214	309	344	317	210	146	114	49	30	42	1975	0.68
2003	122	259	347	358	299	223	161	101	47	36	51	2004	0.70
2004	126	254	378	376	322	234	154	105	74	41	59	2123	0.70

2005	147	224	377	396	349	264	169	111	58	42	71	2208	0.70
2006	111	254	375	453	356	265	174	94	66	51	95	2294	0.72
2007	101	256	393	448	365	282	198	125	78	43	102	2391	0.73
2008	273	300	336	376	367	242	199	100	81	49	106	2429	0.67
2009	119	246	370	414	454	312	205	148	98	67	124	2557	0.73
2010	134	257	396	450	433	341	240	165	92	88	156	2752	0.73
2011	101	289	418	444	454	382	227	186	124	79	172	2876	0.74
2012	110	269	410	454	458	371	268	173	143	75	197	2928	0.74
2013	114	310	397	531	459	366	296	207	142	95	234	3151	0.75
	2850	**5189**	**7444**	**8026**	**7074**	**5140**	**3447**	**2182**	**1388**	**896**	**1684**	**45320**	**0.68**
	6.28861	**11.4497**	**16.4254**	**17.7096**	**15.609**	**11.3416**	**7.60591**	**4.81465**	**3.06267**	**1.97705**	**3.7158**	**100**	

Table-8 Authorship Pattern and Collaborative Measures in Crystallography

Year	Single authored papers	Multiple authored papers	Total Articles	TA	DC	CC	MC	CI
1989	27	74	101	308	0.73	0.48	0.49	3.05
1990	48	93	141	436	0.66	0.46	0.47	3.09
1991	72	769	841	3411	0.91	0.66	0.66	4.06
1992	85	894	979	4072	0.91	0.67	0.67	4.16
1993	76	1007	1083	4616	0.93	0.68	0.68	4.26
1994	81	1157	1238	5241	0.93	0.68	0.68	4.23
1995	95	1148	1243	5276	0.92	0.68	0.68	4.24
1996	91	1287	1378	5867	0.93	0.68	0.68	4.26
1997	104	1386	1490	6667	0.93	0.69	0.69	4.47
1998	138	1516	1654	7190	0.92	0.68	0.68	4.35
1999	114	1637	1751	7825	0.93	0.69	0.69	4.47
2000	125	1744	1869	8303	0.93	0.69	0.69	4.44
2001	136	1728	1864	8472	0.93	0.69	0.69	4.55
2002	200	1775	1975	8913	0.90	0.68	0.68	4.51
2003	122	1882	2004	9225	0.94	0.70	0.70	4.60
2004	126	1997	2123	9929	0.94	0.70	0.70	4.68
2005	147	2061	2208	10433	0.93	0.70	0.70	4.73
2006	111	2183	2294	11045	0.95	0.72	0.72	4.81
2007	101	2290	2391	11741	0.96	0.72	0.73	4.91
2008	273	2156	2429	11250	0.89	0.67	0.67	4.63
2009	119	2438	2557	13054	0.95	0.73	0.73	5.11
2010	134	2618	2752	14271	0.95	0.73	0.73	5.19
2011	101	2775	2876	15146	0.96	0.74	0.74	5.27
2012	110	2818	2928	15674	0.96	0.74	0.74	5.35
2013	114	3037	3151	17070	0.96	0.75	0.75	5.42
Total	**2850**	**42470**	**45320**	**215435**	**0.92**	**0.68**	**0.68**	**4.51**

TA = Total authors DC= Degree of Collaboration CC = Collaborative coefficient
CI= Collaborative index MC= Modified coefficient

Table 8 shows the Collaborative coefficient research in Crystallography Literature from 1989-2013. The analysis of the table shows that out of 45320 articles published, single author share is 2850 and multiple paper author shares is 42470. This indicates that multiple paper contribution is more than single author papers. Moderate Degree of Collaboration is observed at 0.916, while 0.765 Collaboration coefficients, 0.68, Modified Coefficient and 4.513 Collaborative Index is observed in the Crystallography literature. It can be summarized from the above discussion that very high collaborative research activities are observed in Crystallography literature.

The Lotks's inverse power model, which states the function describing the pattern of productivity of authors publishing in a specified subject field in a fixed time period has been applied and it is mathematically represented as:

$$Y = C \times X^{-n}$$

Where x is the number of publications of interest (1,2,etc.,);
N is an exponent that is constant for a given set of data;
Y is the expected percentage of authors with frequency x of publications; and
C is a constant
The constant C can be calculated by using following formula:

$$C = \sum \frac{1}{x^n}$$

$$C = \sum \frac{1}{x^{2.1}}$$

$$\therefore C = \frac{1}{1.539779}$$

C= 0.649444

The exponent n is often fixed at 2, in which case the law is known as the inverse square law of scientific productivity. However, given that the exponent n predicts the relative number of authors at each productivity level it would seem useful to calculate it (Tamilselvan, 2013). In the present study, least square method has been used. It can be expressed as follows

N can be calculated by using following formula

$$n = \frac{N\sum XY - \sum X \sum Y}{N\sum X^2 - (\sum X)2}$$

Where N is the number of data pairs considered;
X is the logarithm of x (x=number of articles); and
Y is the logarithm of y (y= number of authors)

$$= \frac{31\ x\ (73.95854 - (33.915)x(75.767)}{31\ x\ 41.22323 - \ (33.915)2}$$

$$= \frac{2292.7 - 2569.37}{1277.9 - 1150.22}$$

$$= \frac{276.67}{127.68}$$

N=2.1

Further, the maximum difference between the real and the estimated accumulated frequencies is calculated, and this value is then being compared with the critical value which is calculated by using the following formula:

Hypothesis Ho

The Distribution of publication in the field of Crystallography does not follow Lotka's Distribution.

Table-9 Distribution of Author Productivity Based on Lotka's Law.

X	Y	X	Y	X^2	XY	Yx	Syx	$\frac{1}{x^n}$	c*$\frac{1}{x^n}$	Ckdf	Diff
1	58563	0.000	4.768	0.000	0.000	0.633	0.633	1.000	0.668	0.668	0.035
2	14738	0.301	4.168	0.091	1.255	0.159	0.792	0.222	0.149	0.817	0.024
3	6453	0.477	3.810	0.228	1.818	0.070	0.862	0.092	0.062	0.878	0.016
4	3477	0.602	3.541	0.362	2.132	0.038	0.899	0.049	0.033	0.911	0.012
5	2160	0.699	3.334	0.489	2.331	0.023	0.923	0.030	0.020	0.932	0.009
6	1434	0.778	3.157	0.606	2.456	0.015	0.938	0.021	0.014	0.945	0.007
7	1055	0.845	3.023	0.714	2.555	0.011	0.950	0.015	0.010	0.955	0.006
8	789	0.903	2.897	0.816	2.616	0.009	0.958	0.011	0.007	0.962	0.004
9	580	0.954	2.763	0.911	2.637	0.006	0.964	0.009	0.006	0.968	0.004
10	440	1.000	2.643	1.000	2.643	0.005	0.969	0.007	0.005	0.973	0.004
11	362	1.041	2.559	1.084	2.665	0.004	0.973	0.006	0.004	0.976	0.003
12	317	1.079	2.501	1.165	2.699	0.003	0.977	0.005	0.003	0.979	0.003
13	282	1.114	2.450	1.241	2.729	0.003	0.980	0.004	0.003	0.982	0.002
14	234	1.146	2.369	1.314	2.715	0.003	0.982	0.003	0.002	0.984	0.002
15	203	1.176	2.307	1.383	2.714	0.002	0.984	0.003	0.002	0.986	0.002
16	160	1.204	2.204	1.450	2.654	0.002	0.986	0.002	0.002	0.988	0.002
17	152	1.230	2.182	1.514	2.685	0.002	0.988	0.002	0.001	0.989	0.001
18	112	1.255	2.049	1.576	2.572	0.001	0.989	0.002	0.001	0.990	0.002
19	89	1.279	1.949	1.635	2.493	0.001	0.990	0.002	0.001	0.992	0.002
20	83	1.301	1.919	1.693	2.497	0.001	0.991	0.002	0.001	0.993	0.002
21	56	1.322	1.748	1.748	2.311	0.001	0.991	0.001	0.001	0.993	0.002
22	68	1.342	1.833	1.802	2.460	0.001	0.992	0.001	0.001	0.994	0.002
23	66	1.362	1.820	1.854	2.478	0.001	0.993	0.001	0.001	0.995	0.002
24	51	1.380	1.708	1.905	2.357	0.001	0.993	0.001	0.001	0.996	0.002
25	39	1.398	1.591	1.954	2.224	0.000	0.994	0.001	0.001	0.996	0.003
26	47	1.415	1.672	2.002	2.366	0.001	0.994	0.001	0.001	0.997	0.003
27	38	1.431	1.580	2.049	2.261	0.000	0.995	0.001	0.001	0.997	0.003
28	34	1.447	1.531	2.094	2.216	0.000	0.995	0.001	0.000	0.998	0.003
29	34	1.462	1.531	2.139	2.240	0.000	0.995	0.001	0.000	0.998	0.003
30	37	1.477	1.568	2.182	2.316	0.000	0.996	0.001	0.000	0.999	0.003
31	389	1.491	2.590	2.224	3.863	0.004	1.000	0.001	0.000	0.999	0.001
496	92542	33.915	75.767	41.223	73.959	1.000		1.496	1.000	29.832	

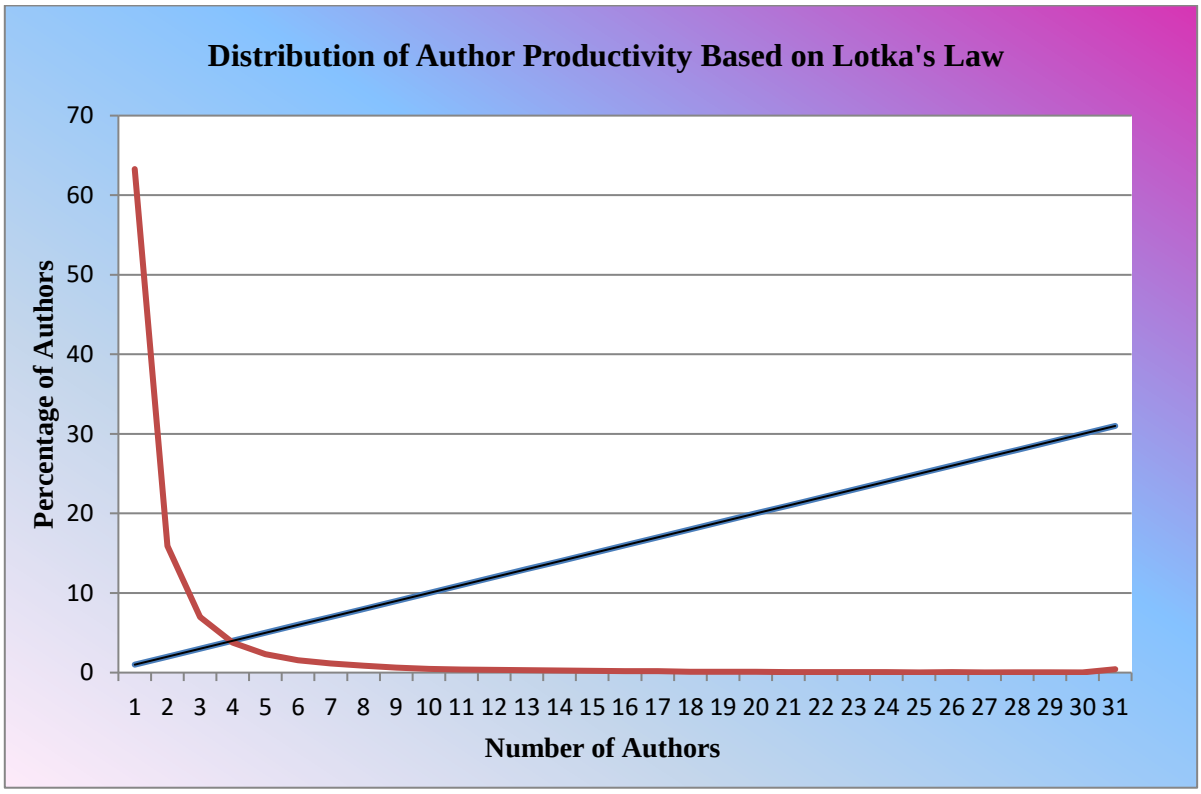
C=0.43336 n=2.169 C.V=0.183942 D=0.000863

The calculated Critical value obtained is 0.183942 and the value of maximum difference (D) between the real and estimated accumulated frequencies is 0.000863. Therefore it is observed that the difference value 0.000863 is less than the critical value 0.183942 indicating that Lotka's law holds well even in case of Authorship productivity in

the field of Crystallography literature. **Hence, the null hypothesis is rejected and Alternative hypotheses is accepted. It means that Distribution Productivity in the field of Crystallography follow the Lotka Distribution (See figure) figure shows the Distribution of Author productivity Based on Lotka's Law.**

Distribution of Author Productivity Based on Lotka's Law

Figure- Distribution of Author Productivity Based on Lotka's Law in Crystallography Literature



7. FINDINGS:

Present study demonstrated some general inferences on the basic bibliometric attributes like authorship pattern, research collaboration of the Crystallography literature. Study increase of publications over the years. With respect to author productivity, present study Fully follow the Lotka's generalized inverse square law with K. S test.

1. The nine and eight author's contribution is very less in the field of Crystallography.
2. Four author contributions are high in the field of Crystallography i.e. (17.70%) which is a clear indication of positive trend towards multi-authorship. Perhaps this may due to interdisciplinary research and team work.
3. The collaboration coefficient between number of records and number author with respect to time found a positive high significant correlation (χ=0.992, df=24, P< 0.05).

4. The correlation between single author and multiple author distribution for a given data set found significant correlation (χ =0.520, df=24, P<0.05).
5. The Degree of Collaboration in 1989 was 0.73 and increased to 0.96 in the year 2013. There is a high degree of collaboration found in Crystallography.
6. The Moderate Co-efficient Collaboration was 0.49 in 1989 and increased to 0.75 in the year 2013.
7. The Collaborative Co-efficient collaboration was 0.48 in 1989 and increased to 0.75 in the year 2013. The overall CI, DC, MC and CC indicate the increasing trend in collaborative publications.
8. Majority of the authors are four and followed by three authors were high in Crystallography Literature.
9. The distribution of Lotka's Law was fully applicable for the Crystallography Literature (Dmax value= 0.000879)

8. CONCLUSION:

Crystallography is one of the emerging subjects in Chemical Sciences and it is one of the thrust areas for research. It is dominated with collaborative research and four and five authorship pattern dominating in this subject. Further high degree of collaboration was observed between number of documents and number of authors. The significant correlation was observed between single versus multiple authors. There is a high degree of collaboration found in Crystallography and The Collaborative Co-efficient measures like CI, DC, MC and CC are gradually increasing trend from 1989 to 2013. Finally it can be concluded that the author productivity distribution well fitted with Lotks distribution.

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