

Scientometric Analysis of Research Output of Two Eminent Scientists of India

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Abstract - The paper examines the contribution of G.N.R and C.N.R. The results of the study indicate that mostly he published journal articles with collaborators and his span of productivity lies with in twenty years. During his productivity age, in an average he produced more than 40 journal articles in reputed journals. The study found that both scientists have contributed significantly to the academic literature. Further, CNR has high citation and more papers publication.

Keywords: Scientometric, Authorship pattern, Collaborative co-efficient, Research Productivity.

Introduction

The universe of Knowledge is ever growing and dynamic that results into emergence of new disciplines or subjects. The newly emerged subjects are also growing uncontrollably due to the rigorous scientific research. Thus, the measurement of the growth of a discipline is known as statistical bibliography or bibliometrics. Further, the terms like 'Librametrics', 'Bibliometrics', 'Informetrics' and 'Scientometrics' have been used synonymously in order to study the growth of literature in a discipline and other aspects of literature quantitatively. This type of measurement is essential to asses the directions in which the subject grows and pros and cons of the factors related to obscelence. Russians used the term scientometrics in late sixties for quantitative aspects of studies in science. Scientometrics means study of quantitative aspects of science and technology and would include "technometrics" also. There has been ever-growing interest among scientometrists to publish data on individual scientists who are role model scientists or mentors. In this context, this study also made an attempt to study the contribution of Prof.G.N.Ramachandran nobelarate and Prof. C.N.R.Rao an icons of Biophysics and chemistry especially in the field of nanoscience and nanotechnology. He is basically a chemical scientist of our contemporary.

Scientific publications seem to have provided the best available basis for measuring the outputs of individual scientists as there is a good correlation between the eminence of scientists and their sustained scholarly publications⁷⁻⁸. One of the first writers to suggest scientific publications as a measure of research productivity was Willium Stockley, a Nobel laureate who was interested in measuring research productivity among individuals within a group by analysing their publications⁹. Scientometric studies are highly valued by historians of science, biographers of scientists, science policy makers, administrators of scientific

establishments, R&D managers, educationists, scientometricians, young scientists, documentalists, information scientist and science journalists¹⁰. Like G.N.Ramachandran and C.N.R Rao the protagonist of this study, many more Indian scientists contributing much in the arena of R&D of different disciplines. In order to prove the metal of Indian contributions in various disciplines similar scientometric studies of an individual scientist are also to be carried out. It is hoped that this study may give ideas to the researchers who are intend to carry out similar scientometric studies on individual scientists.

Literature review

Review of literature is a significant and primary component of any research investigations. It enables to understand earlier research interest research pattern and the magnitude of the research output in the field of knowledge. Though there is countless number of literatures available on scientometrics, the study has reviewed here very important studies which are of immediate relevant to the study.

Kalaiappan and Kaliyaperumal¹³ studied the works of G.N.Ramachandran, a legendary crystallography is our country which reveals solo research authorship pattern and collaboration ratio along with the yearly productivity. Kalyane and samanta¹⁴ have done a scientometric study of articles published by K.Ramaiah, an agricultural scientist of India, which throws light on history of science, scientific development, interaction in a research group and organization of research systems.

Kalyane and Sen¹⁵ studied the contributions published by Nobel laureate Pierre-Gilles de Gennes published during 1956-1995, which revealed that scattering of publications did not follow Bradford's Law, but assumptions about author productivity formed to be more or less correct.

Kulkarni¹⁶ analysed the works of M.V. Bhole, a pioneer on Yoga, who contributed 147 papers during 1965-1995. The study revealed that about 60 per cent of his contributions were based on collaborative research and did not confined to solo type of research.

A similar study was also conducted by Vijay Kumar, Kalyane, and Kademani¹⁷ on the publications of Ahmed Hassan Zewail, Nobel laureate in Chemistry, who had collaborated with one or two colleague and published 246 papers during 1976-1994.

Methods and Materials

The curriculum vitae, which includes list of them publications and from available web resources are used as sources of information for this study. Along with this few of the data are collected from back issues of leading news papers and journal such as 'The Hindu' and 'current science'. Thus, this study used secondary data. For the purpose of the analysis, Fox Pro database software was used to classify and quantify the extracted data from web resources. The following statistical tools and bibliometric indicators were employed during the process of analysis and interpretation of data. For analysis of data, the following methods given by Lancaster¹⁸ Leydesdroff¹⁹ Kalyane²⁰ Sen and Gan²¹ were used

- Authorship pattern
- Collaboration Coefficient
- Fifty percentile age
- Productivity co-efficient
- Core collaborators

- Productivity of Life

Results and Discussion

The following tables show the result of the study. The below table explains the contribution of GNR and CNR contribution in the academic output.

Table 1: Contribution of GNR and C.N.R Rao

S.NO	DESCRIPTION	Number of Contribution G.N.R	Number of Contribution C.N.R
1	Books	1 (0.33)	14
2	Monographs and Reviews	5(1.64)	-
3	Edited Vol.	7 (2.30)	38
4	Journal Articles	184 (60.53)	1696
5	Conference / Symposium	9 (2.96)	-
6	Books Articles	21(6.91)	-
7	Mathematical Philosophy Article	77 (25.33)	-
	1.1.1 TOTAL	304 (100)	

It can be observed from Table 1 shows that 184 articles (60.53%) were the research papers published in 'Journals', 77 articles (25.53%) in 'Mathematical Philosophy' and followed by 'Books Articles' accounts to 21 (6.91%) Among the 304 articles, 214 articles published as 'journal articles'; in 'conference proceedings' and 'book articles' contributed by G.N.R. Contributions of Prof.C.N.R.Rao, it is seen from the table that Prof.C.N.R.Rao published journal articles of 536 up to 2010, among his publications of 578. It is interesting to note that the journal articles constituted more than 92 percent. Remaining are edited books that constituted 5 percent and his original books constituted to 14 percent of over all his productivity. It is also observed that many articles are published in reputed international journals with high impact factors. For the analysis of this study only his journal articles are alone taken up.

Table 2: Authorship patterns

S.No.	Description	Total No. of G.N.R	Total No. of C.N.R.Rao
1	Single Author	76 (35.51)	13 (2.61)
2	Two Authors	108 (50.46)	74 (13.62)
3	Three Authors	21 (9.81)	163 (30.41)
4	Four Authors	2 (0.95)	169 (31.53)
5	Five Authors and above	7 (3.27)	117 (21.83)
	1.2 Total	214 (100)	536 (100)

In order to evaluate further whether Prof. G.N.R. contributions are in individual capacity or collaborative research, the contributions are grouped based on authorship and the same is shown in table 2. It can be seen that 35.51% (76 articles) are contributed as single author. 108 articles (50.46%) are contributed with one joint author and 21 articles with three authorship. Nearly 64.49% of contributions are of collaborative nature. In general it can be seen that collaboration researches predominate in the Prof. GNR contribution. The authorship pattern of Prof. Rao. It is seen from the table that majority of his research publications are collaborative in nature. Thus, he alone contributed 13 articles which constituted to 2.61

percentages from his productivity. But triple and four authorship patterns are dominant in his publications, and both constituted to 62 percentage. And also five and more than five authors patterns are contributed to 21.83 percentage.

Table 3: Authorship position patterns of G.N.R Journal articles

S.No	Description	FPY	LPY	One	Two	Three	>Four	Total	Multiple author paper
1	Total Authorship	1942	1990	76	108	21	9	214	138
2	Percentage Authorship			35.51	50.46	9.81	4.22	100	
3	Number of Authors			76	20	37	24	141	91
4.	Authorship per paper			1	5.4	0.56	0.38	1.51	1.51

(First Productivity of the Year/Last Productivity of the Year)

The ratio of collaboration is 1:1.51.

4.1 Collaboration Coefficient

To analyse the pattern of co-authorship among authors of various countries the entire data was divided into single, two and more than two authors for each country and the results are shown in the Table 3. The patterns of Co-authorship among different countries have been examined by making use of Collaborative Coefficient (CC) suggested by Ajiferuke. The formula for calculating CC is as follows:

$$CC = 1 - [\sum(1/j)F_j/N]$$

Whereas

F_j = the number of authored papers

N = total number of research published; and

k = the greatest number of authors per paper

$$CC = 1 - [(76/389) + (138/389)/2 + (178/389)/3] = 0.477292$$

Accordingly the Collaborative Coefficient (CC) has been calculated for

The Collaboration Coefficient, as per the data given in Table by using the formula has also been calculated as follows:

Table 4. Total Number of Authors

1.2.1.1.1 S.No	1.2.1.1.2 Description	One	Two	More than two authors	Total authors
1	Total Authorship	76	138	175	389

The Collaboration Coefficient is 0.48, which is less than 0.50. The dearth of collaboration is comparative less since the coefficient is less than 0.5.

Table 5. Authorship position patterns of G.N.R Journal articles

S.No	Authorship position patterns	Number of contributions	percentage
1	Rao as first author	61	11.3
2.	Rao as second author	67	12.5
3.	Rao as third author	164	30.5
4	Rao as Fourth author	124	23.13
5	Rao as Fifth author	67	12.5
6	Rao as Sixth author	29	5.41
7	> Sixth position in the contributed articles	23	4.29
	Total	536	100

Prof. Rao has produced 536 journal articles along with many of his contemporary researchers as given in the table 5. It is seen from the table that he has produced as first author for 11.3 percentages of his entire article publications. Subsequently he contributed as second author for 67 articles that constituted to 12.5 percentages it is also to note that his position as third author is dominant in his production i.e.30.5 percentage followed by as fourth author of 23.13 percentages. The remaining percent of his article productions are confined to his authorship position as fifth, sixth and more than sixth position.

4.2 Collaboration co-efficient:

To analyze the pattern of co-authorship the contribution of C.N.R Rao, among Indian and foreign authors were divided in single, two and more than two authors. The pattern of co-authorship among Co authors have been examined using collaboration coefficient (CC) suggested by Ajiferuka. Accordingly the CC has been calculated as:

$$CC = 1 - [\sum(1/j)F_j/N]$$

Where

F_j = The number of authored papers

N = Total Number of research published

J = The greatest number of authors per paper

Table 6: Collaboration Ratio of C.N.R.Rao

S.No	Descriptions	FPY	LPY	Authored by Rao alone	With Two authors	With Three authors	With Four authors	Five and above	Total	Multiple
1	Total Authorship	1989	2010	13	74	163	169	117	536	522
2	Percentage Author			2.61	13.62	30.41	31.53	21.83	100	
3	Number of Authors			14	61	68	165	241		
4	Authorship per paper			1	1.19	2.39	1.02	0.48		

The CC for Prof. C.N.R.Rao which is less than 1.19 of two authors and 2.39 for three authors and 0.48 is five and above authors. This result shows that most of his research works are collaborative in nature and confirmed that as the data presented in the table 5 and 6.

Table 7. Year-wise Distribution

G.N.R				C.N.R.Rao		
S.No.	Year	No. of Articles	%	Year	No. of Articles	%
1	1942	1	0.5	1954	2	0.11
2	1943	6	2.8	1956	3	0.17
3	1944	6	2.8	1957	11	0.65
4	1945	3	1.4	1958	13	0.77
5	1946	6	2.8	1959	11	0.65
6	1947	9	4.2	1960	12	0.71
7	1948	2	0.9	1961	5	0.29
8	1949	3	1.4	1962	10	0.58
9	1950	3	1.4	1963	8	0.47
10	1951	10	4.7	1964	2	0.11
11	1952	7	3.3	1965	1	0.05
12	1953	2	0.9	1966	18	1.06
13	1954	4	1.9	1967	14	0.82
14	1955	7	3.3	1968	18	1.06
15	1956	4	1.9	1969	14	0.82

G.N.R				C.N.R.Rao		
S.No.	Year	No. of Articles	%	Year	No. of Articles	%
16	1957	5	2.3	1970	16	0.94
17	1958	1	0.5	1971	20	1.17
18	1959	2	0.9	1972	13	0.76
19	1960	7	3.3	1973	16	0.94
20	1961	6	2.8	1974	14	0.82
21	1962	8	3.7	1975	22	1.29
22	1963	13	6.1	1976	22	1.29
23	1964	2	0.9	1977	16	0.94
24	1965	12	5.6	1978	9	0.53
25	1966	12	5.6	1979	21	1.23
26	1967	7	3.3	1980	22	1.29
27	1968	10	4.7	1981	25	1.47
28	1969	4	1.9	1982	33	1.94
29	1970	10	4.7	1983	17	1.00
30	1971	8	3.7	1984	30	1.76
31	1972	5	2.3	1985	30	1.76
32	1973	7	3.3	1986	39	2.29
33	1974	2	0.9	1987	51	3.00
34	1975	4	1.9	1988	47	2.77
35	1976	3	1.4	1989	41	2.41
37	1978	2	0.9	1990	33	1.94
38	1979	1	0.5	1991	42	2.47
39	1980	2	0.9	1992	35	2.06
40	1981	2	0.9	1993	39	2.29
41	1982	2	0.9	1994	33	1.94
45	1986	2	0.9	1995	32	1.88
47	1988	1	0.5	1996	39	2.29
48	1989	0	0.0	1997	30	1.76
49	1990	1	0.5	1998	35	2.06
50				1999	43	2.53
51				2000	54	3.18
52				2001	49	2.88
53				2002	49	2.88
54				2003	47	2.77
55				2004	47	2.77
56				2005	40	2.35
57				2006	37	2.18
58				2007	44	2.59
59				2008	43	2.53
60				2009	46	2.71
61				2010	44	2.59
62				2011	49	2.88
63				2012	30	1.76
64				2013	28	1.65
65				2014	30	1.76
66				2015	27	1.59
67				2016	25	1.47
	TOTAL	214	100		1696	100

The year wise distribution of the Prof. GNR and prof C.N.R.Rao contribution is shown in table 7. From it can be seen that the contribution are even throughout his term of life. Of course, it can be seen that no article has been published in the year 1977, 1983-85, 1987 and 1989.

Table. 8 Productivity Life of G.N.R and C.N.R.Rao

Year	Total no.of Publications	Cumulative	Productivity Age	Age of Prof G.N.R	Year	Total no.of Publications	Cumulative	Productivity Age	Age of Prof C.N.R. Rao
1942	1	1	1	20	1954	2	2	1	20
1943	6	7	2	21	1956	3	5	2	22
1944	6	13	3	22	1957	11	16	3	23
1945	3	16	4	23	1958	13	29	4	24
1946	6	22	5	24	1959	11	40	5	25
1947	9	31	6	25	1960	12	52	6	26
1948	2	33	7	26	1961	5	57	7	27
1949	3	36	8	27	1962	10	67	8	28
1950	3	39	9	28	1963	8	75	9	29
1951	10	49	10	29	1964	2	77	10	30
1952	7	56	11	30	1965	1	78	11	31
1953	2	58	12	31	1966	18	96	12	32
1954	4	62	13	32	1967	14	110	13	33
1955	7	69	14	33	1968	18	128	14	34
1956	4	73	15	34	1969	14	142	15	35
1957	5	78	16	35	1970	16	158	16	36
1958	1	79	17	36	1971	20	178	17	37
1959	2	81	18	37	1972	13	191	18	38
1960	7	88	19	38	1973	16	207	19	39
1961	6	94	20	39	1974	14	221	20	40
1962	8	102	21	40	1975	22	243	21	41
1963	13	115	22	41	1976	22	265	22	42
1964	2	117	23	42	1977	16	281	23	43
1965	12	129	24	43	1978	9	290	24	44
1966	12	141	25	44	1979	21	311	25	45
1967	7	148	26	45	1980	22	333	26	46
1968	10	158	27	46	1981	25	358	27	47
1969	4	162	28	47	1982	33	391	28	48
1970	10	172	29	48	1983	17	408	29	49
1971	8	180	30	49	1984	30	438	30	50
1972	5	185	31	50	1985	30	468	31	51
1973	7	192	32	51	1986	39	507	32	52
1974	2	194	33	52	1987	51	558	33	53
1975	4	198	34	53	1988	47	605	34	54
1976	3	201	35	54	1989	41	646	35	55
1978	2	203	37	56	1990	33	679	37	56
1979	1	204	38	57	1991	42	721	38	57
1980	2	206	39	58	1992	35	756	39	58
1981	2	208	40	59	1993	39	795	40	59
1982	2	210	41	60	1994	33	828	41	60
1986	2	212	45	64	1995	32	860	45	61
1988	1	213	47	66	1996	39	899	47	62
1990	1	214	49	68	1997	30	929	48	63
					1998	35	964	49	64
					1999	43	1007	50	65
					2000	54	1061	51	66
					2001	49	1110	52	67
					2002	49	1159	53	68
					2003	47	1206	54	69
					2004	47	1253	55	70
					2005	40	1293	56	71
					2006	37	1330	57	72
					2007	44	1374	58	73

					2008	43	1417	59	74
					2009	46	1463	60	75
					2010	44	1507	61	76
					2011	49	1556	62	77
					2012	30	1586	63	78
					2013	28	1614	64	79
					2014	30	1644	65	80
					2015	27	1671	66	81
					2016	25	1696	67	82
Total	214					1696			

G.N.R productivity age begin in the year 1942 at the chronological age of 20 years. He has published highest number of 13-research paper during 1963 and 12 research papers each in the year 1965, 1966 at the productivity age of 22, 24 and 25 and chronological age of 41, 43 and 44. And chronological age is 40. It can be seen that his productive interest continued even after his superannuating too.

At the productivity age of 22 and chorological age of 41 he has attained fifty percentile age. The productivity co-efficient is calculated using the formula

$$P_c = \frac{\text{Chronological age of last publication}}{\text{Chronological age of fifty percentage}}$$

$$P_c = 68 / 41 = 1.7$$

The productivity co efficient is 1: 1.7

Year wise distribution of Prof. Rao is seen from the table that he started his carrier long back but his contribution or publication was first initiated in the year 1989 at his age of 55 and he produced his 536th article in the year 2010. The table presents the following results:

- The publication growth of Prof.C.N.R.Rao is strong linear in nature.
- Rich Number of (56) research papers were published during 2000 and 49 research Papers were published in 2001.
- On an average Prof. Rao contributed nearly 33 to 40 articles during 1989-2010.
- Peak productivity of Prof.C.N.R.Rao was starts from 2000-2001
- At the age of 67 and 68 of Prof.C.N.R.Rao, he published research articles of 56 and 49.

4.3 Average yearly contribution

During the productive age Prof C.N.R.Rao average yearly contribution has been calculated using the formula:

$$A/C = \frac{\text{Total Contribution}}{\text{Total Productivity age}} \quad \{536/77 = 6.96\}$$

A/C of Prof.C.N.R.Rao is 6.96. The result shows that in an average he contributed 6 to 7 papers for a year between 1989 and 2010. The year 1989 is the year for his first publication. Prof C.N.R.Rao published 536 research papers in the journals, 28 edited books and 14 original books. The productivity of age, chronological age and publication details are given in the table No.7. His productivity of age began at the his age of 56. it is interesting to note

that up to his age of sixty years, he published only four articles. After that his contributions geared up and reached the peak in the year 2000, in which he published 56 articles. There after there are fluctuations in his contributions and with in 22 years of his productive age he published 536 articles. It is also interesting to note that more than 62 percent of his productions are taken place between his age of 70 – 77.

Table 9 Decennial analysis of his productive age

G.N.R						C.N.R.Rao				
S.No	Productive age	Chronologic al age	year	no. of contri butio ns	%	Produc tive age	Chron ologic al age	year	no. of contr ibuti ons	Percen tage
1	1-10	20-29	1942-1951	39	18.22	-	-	-	-	-
2	11-20	30-39	1952-1961	55	25.71	-	-	-	-	-
3	21-30	40-49	1962-1971	86	40.18	-	-	-	-	-
4	31-40	50-59	1972-1981	28	13.08	-	-	-	-	-
5	41-48	60-68	1981-1990	6	2.81	-	-	-	-	-
Total				214	100	Total			-	-

It can be seen from the table and figure, the peak productivity age lies between 21-30 and 40-49 in chronological age of G.N.R

4.4 Average Yearly Contribution

During the Productive age, Prof. G.N.R’s average yearly contribution has been calculated using the formula

Avg. Yearly Contribution = Total Contribution/ Total Productive Age

$$A_{yc} = \frac{\text{Total Contribution}}{\text{Total Productivity Age}}$$

$$A_{yc} = 214/48 = 4.458$$

On an Average Prof. GNR Contributed 4 to 5 papers in a year during the period 1942 to 1990.

The table 9 presents of C.N.R.Rao, the decennial analysis of his productivity age. His contributions started at his age of 56 and ends at the age of 77. Hence, his productivity age is 22 years. These 22 years are divided decennially in to three quarters and accordingly distribution of his productions over a period of three quarters are calculated and resulting percentage of his production over this three quarters are given in the above table. From the table it can be interoperated that his maximum contributions i.e. 83.58 percentage taken place during his 11 to 20 productive age i.e. at his age of 66 – 75. His 22 years of productivity divided decennially into 3 quarters and maximum contributions i.e 83.58 percent took place during his productive age of 11-20 i.e at his age of 66-75.

4.5 Discussion

Prof. GNR Contributed 138 articles in collaboration with various scientists and the same are shown in the table 5.8. From the table it can be seen that he has collaborated with Prof. R.Srinivasan for 13 Papers. He collaborated with Chandrasekhar. R, Lakshmi Narayanan A.V. Sasisekaran V. for 11 papers each. He had also collaborated with foreign scientists namely Edsall, J.T, Flory,P.J., Kendrew, J.C., Liquori, A.M., Wooster,W.A., etc.,. On an Average Prof. GNR Contributed 4 to 5 papers in a year during the period 1942 to 1990. He find the triple helical structure and structure of protein every scholar have use the Ramachandran plot, based on this concept individual impact factor is high throughout the world.

Prof Rao contributes mostly journal articles rather than other forms of publications. Prof Rao publishes individually only 13 articles which consider 2.61 percent in his overall contribution. He contributed as first author for 11.3 percent of articles. Shanti Swarup Bhatnagar Prize for Science and Technology (1969) Hughes Medal (2000) his contributions to the field of materials chemistry, in particular, in relation to studies of the electronic and magnetic properties of transition metal oxides and high temperature superconductors. His work has been an inspiration to a generation of Indian scientists"ndia Science Award (2004)

His productivity of age began at his chronological age of 56 and up to his age of sixty, he published only four articles. After his combinations are quared up and reached the peak in the year 2000 in which he publish 56 articles. Most of his contributions are taken place between his age of 70-77. And on an average he contributed 7 articles per year.

- Collaborative research is dominated in the contributions of our protagonist.
- Authorship collaboration average he contributed 6 to 7 papers for a year between 1989 and 2010. The year 1989 is the year for his first publication.
- It indicates that collaboration is higher than the individual publications. It is observed from his web site that mostly he collaborated with the three authors viz., A.Govindaraj (Collaborated with 95 articles), S.Natarajan (55 articles) and G.U Kulkarni (46 articles) and most of his publications are collaborated with the Indian authors.

Conclusions

The present research on productivity of Prof.C.N.R.Rao offers guidance for further Research in the following areas: It will be interesting to examine the extent and pattern of collaborative research by other renowned scientists in other domains. It will be significant to study the citation pattern of Prof C.N.R.Rao's research contribution in a particular period. It will also be interesting to compare the findings of this study with experts of other branches of science and life sciences. The classical and new classical scientist was provided the outstanding contribution in the field of biological and chemical sciences. Bothe persons obtained the key post of inland as well as abroad. G.N.R win the evolved prize which is equal to the noble prize

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