SCIENTOMETRIC PORTRAIT OF R. CHIDAMBARAM, THE INDIAN NUCLEAR PHYSICIST
BASED ON CITATION ANALYSIS

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Abstract

The paper analyses the citations to the publications of Dr R Chidambaram, using *Science Citation Index 1958-92* as the source for data. The extent of citations received, in terms of the number of citations per paper and the categories of citing documents and the distribution of citations among them are determined. Analysing the year-wise break up of citations the peak periods are identified. Citation pattern in relation to the status of authorship is examined and subject areas of domain of the contributions and the extent of citation to the papers in each domain are ascertained. The citing journals are identified and a ranked list of them is compiled. Characteristics such as subject specialization and geographical area of purview of the citing journals are analysed. By studying the distribution of citations among journals, the Bradford Multiplier is calculated and Bradford-Zipf citograph is plotted. The time lag between publication of a paper and it receiving its first citation is estimated.

1 Introduction

Dr R Chidambaram, the Chairman of Atomic Energy Commission, Government of India since 1993 is a well known nuclear physicist and a successful model scientist. His contributions in the fields of Nuclear Magnetic Resonance, Neutron Diffraction and Hydrogen Bonding, High Pressure and Shock Wave Physics and Quasi-crystals are well accepted by the scientists both at national and international levels (Kalyane and Kademani, 1995). This is evident from the citations that his publications have received in Indian and foreign learned journals. Citation analysis is now-a-days considered as a very effective technique to measure the scientific activity, utility, and impact of scientific output of individual scientists, institutions and nations. The present study attempts to highlight the scientific contributions of R Chidambaram by way of citation analysis.

2 Objectives

The objectives of the study are:

- to identify the extent of citation received to the publications of Dr Chidambaram and the categories of documents citing them,
- to find out the year-wise break up of citations,
- to examine the citation pattern in relation to the status of authorship of the cited articles,
- to identify the domains of specialization of Dr Chidambaram and to find out the extent of citations to the contributions in each domain,
- to ascertain the characteristics of citing documents and to compile a ranked list of citing journals,
- to examine the scattering of citations among journals and to estimate the Bradford Multiplier,
- to draw Bradford-Zipf citograph, and
- to calculate time lag between publication of a paper and it getting its first citation.

3 Methodology

The technique adopted for the present study is citation analysis. Citation brings out the connection between two documents; the one which cites and the other which is cited. The act of citing is in general, an expression of the importance of the material cited, as authors often refer to previous materials to support, illustrate or elaborate on a particular point (Garfield, 1978; Garfield, 1994a). A highly cited work, naturally, is the one that has been found to be useful by a relatively large number of authors, or in a relatively large number of experiments. Citation count is therefore, a measure of scientific activity, utility and impact of scientific work. However, citation counts do not say anything about the nature, utility or impact of the work (Garfield, 1979).

Citation analysis constitutes an important tool in quantitative studies of science and technology. To assess the quality of a given publication, the number of times it has been cited in the literature can be counted. Similarly, the number of times a person has been cited in the literature can be taken as a measure of the quality of that person's work (Garfield, 1979a; 1994; Lawani, 1977; Mahapatra, 1992; Moravcsik et al, 1976; Narin et al, 1983; Smith, 1981; Wallmark and Sedig, 1986).

Citation analysis is a more complex task than is often recognized in the sense that it requires careful identification of exactly what is being analysed. Every citation represents a decision of the author to draw attention to the work of another as being relevant to his theme at a particular point in the document he is writing (Sandison, 1989). Citation counts not only help a research administrator to assess the quality of each individual scientist but also that of his organization as a whole. A few studies of this sort have been conducted on scientists like Kovacs, LePichons, Einstein, Sinha, Chandrasekhar, Ray, Dirac, Moracsik, Ramachandran, Chidambaram and, INSA fellows (Garg and Karki, 1992; Gawkell, Guay, 1986; 1980; Gupta, 1978; Gupta, 1983; Gupta, 1983a; Gupta and Gupta, 1983; Krach, 1990; Ruff, 1979; Sinha and Bhatnagar, 1980; Sinha and Ullah, 1993; Todorov and Winterhager, 1991).

The unit of study in citation analysis can be any form of written communication or an author, an organization or a nation (Small and Greenlee, 1979). However, citation counts cannot be taken as the sole measure of quality, because numerous other factors affect scientists' work and the impact of their publications is only a measure of their overall influence. For instance, a scientist who spends most of his time on teaching may contribute in an indirect way to the future achievements of his institution. Sometimes a scientist may require years of background work to prepare a paper and that single paper itself would be a vital contribution having more value than that of the publications of other prolific authors. Nevertheless, policy makers and scientists themselves are almost invariably keen to see this kind of information (Brown, 1993; Cronin, 1984; MacRoberts and MacRoberts, 1989, Mahajan, 1993, Martyn, 1975). One should be very careful while collecting and analysing citation data as it is likely to contain discrepancies (Garfield, 1977; Moed and Vriens, 1989).

For the present study, a bibliography of the publications of R Chidambaram was compiled and each item was subjected to manual scores for citations received as per ***Science Citation Index (1958-1992)*** published by the Institute for Scientific Information, Philadelphia. Bibliographical data of both cited and citing papers were collected on formats designed for the purpose. The data obtained were then analysed and the results are summarized in the subsequent sections.

4 Results and Discussion

R Chidambaram became a citable author with his original contributions in the field of Nuclear Magnetic Resonance in 1961. His subsequent contributions on 'Neutron diffraction and hydrogen bonding' in 1963, 'High pressure and Shock wave physics' in 1975, and 'Quasi-crystals' in 1988 have enabled to enhance his popularity among scientists at the international level. An analysis of the publication productivity of Chidambaram has been published separately (Kalyane and Kademani, 1995). Appendix 1 gives a resume of his achievements.

4.1 Extent of citations and categories of citing documents

The total number of citations received for the publications of R Chidambaram till 1992 was 1302. Average number of citations per year comes to 37.2 and average number of citations per paper, including general papers is 8.24. For scientific papers alone the average number of citations is 9.71. Scientific progress, calculated as percentage of the cited publications to the total number of publications, comes to 65.82.

Among the citations to the contributions of Chidambaram, 1090 (83.71%) are in journal articles (fig 1). 104 citations (7.99%) have appeared in reviews. Citations in books constitute only 0.7%.

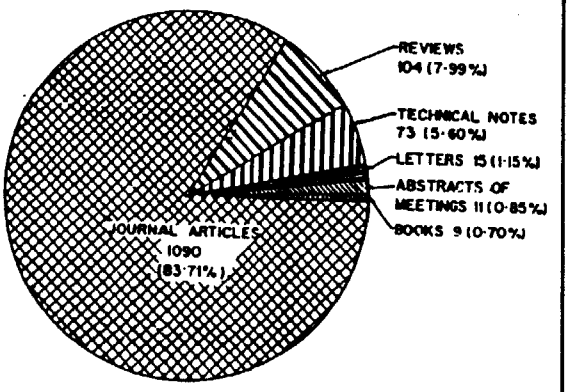

Figure 1

Distribution of citations among the various types of documents

In the entire history of Council of Scientific and Industrial Research (CSIR) of India, for example, only three out of over 20,000 papers published by its scientists have been cited more than 100 times, whereas the corresponding figure at the international level is one out of every 250; and only one scientist, author of one of the three papers, in the CSIR has received more than 1000 citations, excluding self-citations; one has to judge if this can be truly called creditable in the light of stringent international standards, for work done in the CSIR (Bhargava, 1993).

4.2 Year-wise break up of citations

Year-wise citations to publications of R Chidambaram are given in figure 2. The highest number of citations, ie 88 was received in 1972, and 77 citations each were received in 1986 and 1991. It was during the period 1986-89 that the maximum number of citations (265) were received. Total team self-citations were 212 (16.28%) and the highest total team self-citations (30) were found in 1991.

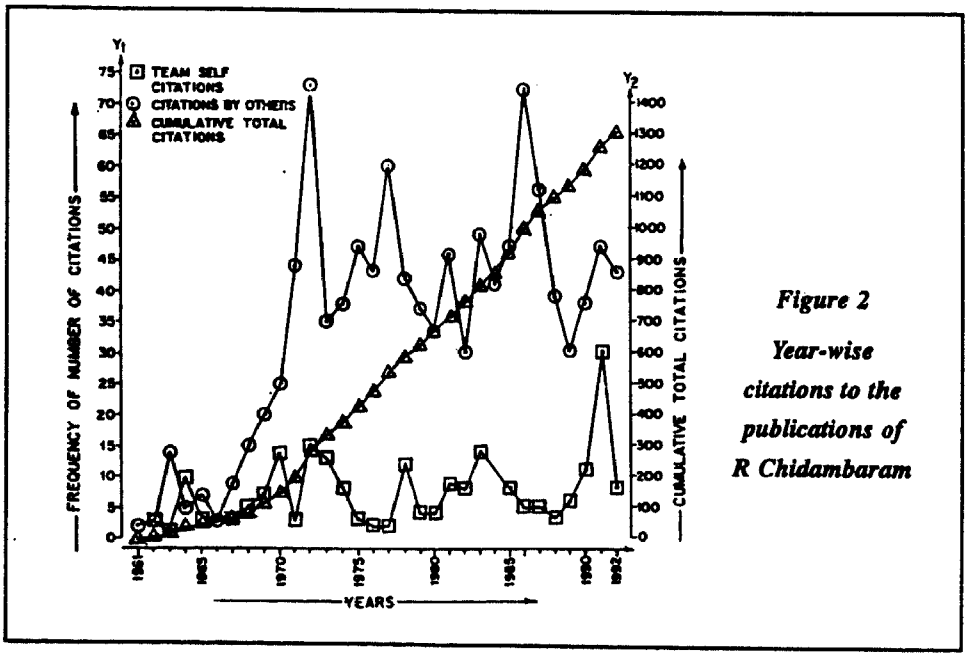

Figure 2

Year-wise citations to the publications of R Chidambaram

'Team self-citation' is defined as the citations to the publications of an author by any member of his research team or by himself. The practice of citing oneself is both common and reasonable. Studies show that at least 10% of all citations are self-citations, in which he or she is the principal author. The percentage would be much higher if authorship other than as principal author in the cited documents is also taken into consideration. Since scientists tend to build on their own work, and the works of their collaborators, a high self-citation count more often than not, indicates nothing more ominous than a narrow speciality (Garfield, 1979).

Total citations other than team self-citations, in the case of R Chidambaram, were found to be 1090 (83.72%). Three peaks of high citations by others were found in 1972, 1977, and 1986 having number of citations 73,76 and 72 respectively.

4.3 Citation pattern vs Status of authorship

The number of citations received to the publications of Chidambaram in relation to his position in authorship is shown in figure 3. His single authored papers have received 132 (10.13%) citations during 1961-1992. The papers having himself as the first author have received 328 (25.20%) citations. Other papers in which Chidambaram is only a co-author other than first author have received the maximum 842 (64.67%) citations. This clearly indicates that multiauthorship papers are highly cited.

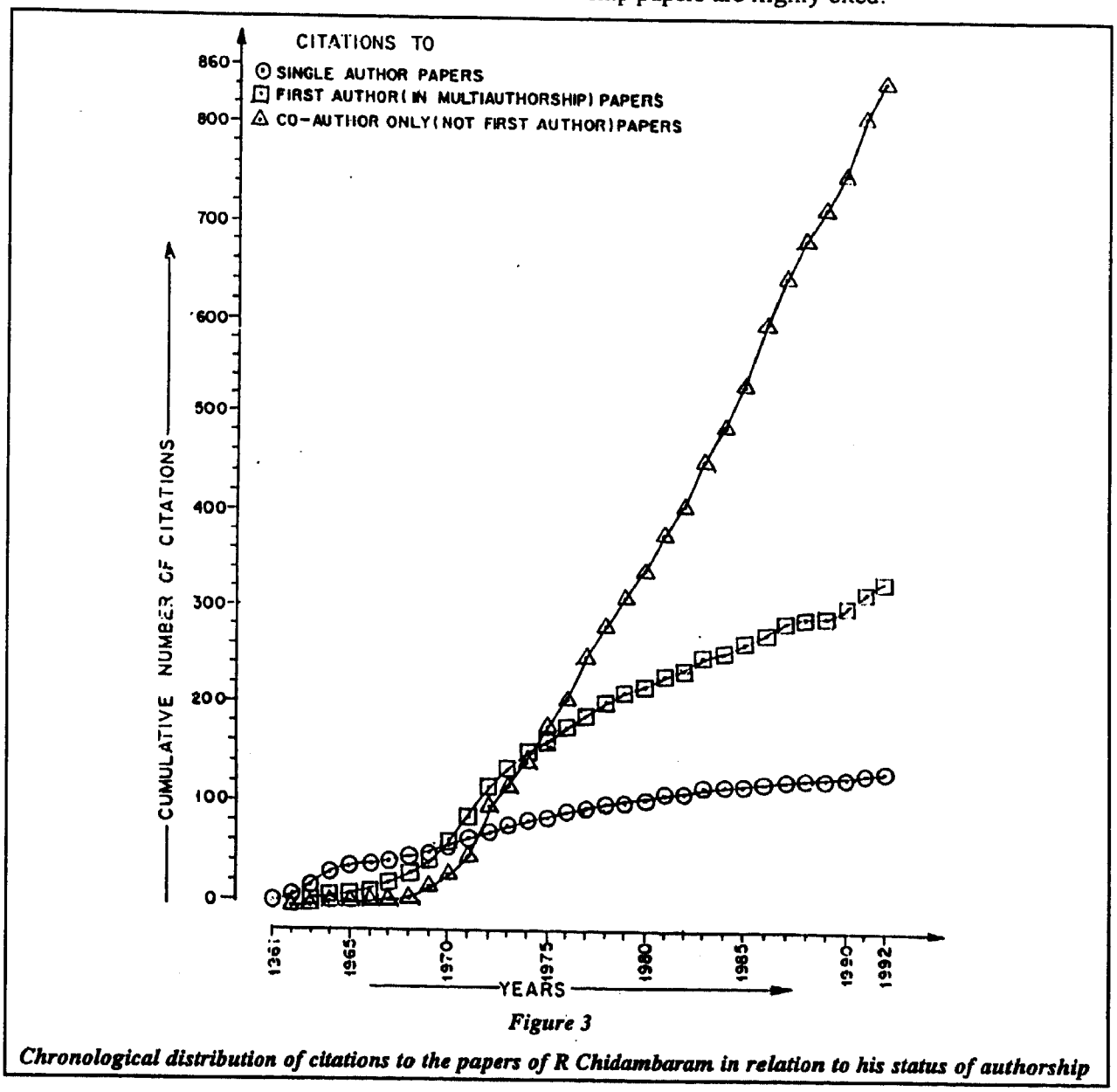

Figure 3

Chronological distribution of citations to the papers of R Chidambaram in relation to his status of authorship

The reasons for high percentage of citations to multiauthored papers are many. One is the enhanced quality and deeper specialization resulting from collaboration of researchers. Researchers do not work alone but they prefer to share with their likes than with those who differ greatly in the training acquired as well as in the profession (Kalyane and Kalyane, 1991). The general trend all over is towards multiauthorship papers (Kalyane and Vidyasagar, 1991). Quality gain, calculated as the ratio of the number of citations to multiauthored papers to the number of citations to single authored papers is 8.86.

An important requisite for a successful research system, according to M S Swaminathan (1979) is the development of a pattern of interdisciplinary co-ordination within the scientific team, so that it performs like a symphony orchestra. Multiauthorship results in a synergistic output. Upward moves in laboratories' formal or informal position heirarchy were associated with a change of scientists' research involvement from goal executing to goal setting functions as well as with an increasing access to scientific manpower and project money (Knorr and Mittermeir, 1980).

Jointly authored papers tend to be cited more than others. In fact, the more authors a paper has, the more likely it is to be cited. For the field of cancer research, Lawani (1980) has shown clearly that citation rate and quality of paper, as judged by a form of peer review, both correlate positively with the number of authors per paper.

The acceptance rate of articles which are collaboratively authored tends to be higher than for single authored papers, thereby suggesting a generally positive relationship between collaboration and quality. The analysis of ten-year citation rates of 270 randomly selected articles in three applied fields likewise shows a similar relationship, with somewhat higher citation frequencies for multiauthored papers than for single authored papers (Smart and Bayer, 1986).

4.4 Domains of specialization

R Chidambaram has contributed significantly to four major domains namely, 'Nuclear Magnetic Resonance', 'Neutron Diffraction and Hydrogen Bonding', 'High Pressure and Shock Wave Physics', and 'Quasi-crystals' during the period under study. The citation rates may be influenced by domain, channels of communications used, number of researchers collaborating with him, and duration of research.

Table 1

Distribution of the articles on 'Nuclear Magnetic Resonance' on the basis of number of citations to each paper

No. of times cited	No. of Articles	Total citations received	Cumulative no. of citations
0	8	0	0
1	2	2	2
2	1	2	4
3	1	3	7
4	1	4	11
7	1	7	18
12	1	12	30
37	1	37	67
59	1	59	126

The distribution of articles on the basis of citedness in 'Nuclear Magnetic Resonance' is shown in table 1. The total number of papers in this domain is 17 and the number of citations to these papers is 126. Similarly, 64 papers have been contributed on 'Neutron Diffraction and Hydrogen Bonding' and they have received altogether 1014 citations (table 2). 'High Pressure and Shock Wave Physics' (table 3), and 'Quasi-crystals' (table 4) had total 135 and 16 citations respectively; the total number of papers in these domains being 46 and 10. Only 11 citations were found to his other articles which are general in nature. A detailed study on the highly cited and most significant papers of R Chidambaram

were reported separately (Kademani and Kalyane, 1996). A list of papers cited more than ten times is given in appendix 2.

Table 2

Distribution of articles on 'Neutron Diffraction & Hydrogen Bonding' on the basis of citations received

Citedness of articles (no.of times)	No.of articles	Total no. citations received	Cumulative no. of citations
0	24	0	0
1	6	6	6
2	3	6	12
3	3	9	21
5	2	10	31
6	1	6	37
8	1	8	45
10	1	10	55
11	2	22	77
12	2	24	101
14	1	14	115
15	1	15	130
18	1	18	148
22	1	22	170
25	1	25	195
26	2	52	247
28	1	28	275
31	1	31	306
33	1	33	339
36	1	36	375
42	1	42	417
50	1	50	467
51	1	51	518
55	1	55	573
64	1	64	637
112	1	112	862
113	1	113	862
152	1	152	1014

Table 3

Distribution of Articles on 'High Pressure & Shock Wave Physics' on the basis of citations received

Citedness of articles (No.of times)	No. of. articles	Total no. citations received	Cumulative number of citations
0	19	0	0
1	5	5	5
2	12	24	29
3	1	3	32
4	3	12	44
10	3	30	74
13	1	13	87
21	1	21	108
27	1	27	135

Table 4

Distribution of Articles on 'Quasi-crystals' on the basis of citations received

Citedness articles No.of times	No. of articles	Total no.of citations received	Cumulative no. of citations
0	3	0	0
1	3	3	3
2	1	2	5
3	1	3	8
4	2	8	16

Communication patterns tend to be quite different in different fields. Some fields have many practitioners, some have a few. In some areas 'invisible colleges' are very well developed and

active, whereas in other areas they are not so active. Some fields are characterized by careful and substantial publications, others have a hectic assortment of feuilleton type articles. In some fields the ratio of activity to productivity, and productivity to progress, appears rather large, while in others small. Direct comparison of two faculty members at a University, one working in a small and careful field and the other in a large and hectic one, by simply counting up their publications or citations is clearly unfair, and in some cases it can even be grossly so. Similarly different countries might have substantially different mixes of various scientific areas and hence their publications or citation ratings are really incomparable. Finally, at different times scientists work on different types of problems which possibly have different publications and citation patterns (Moravcsik, 1973; Geller et al, 1978).

4.5 Characteristics of citing documents

During the period covered in the study, Chidambaram has authored 164 papers, of which 77 were published in Indian channels of communications and 87 in international channels (table 5). The former papers have received 119 citations while the latter have got 1183 citations. The number of citations received per paper was found to be 1.54 for the publications in national channels and 13.59 for the publications in international channels. Maximum citations 547 were for three-authored papers published in journals of international scope. Among the papers published in Indian journals, the maximum number of citations (69) was scored by three-authored papers.

Table 5

Authorshp-wise distribution of papers and citations of R. Chidambaram in national and international publications

Authorship	No. of papers published		No. of citations received		Citations per paper	
	National	International	National	International	National	International
Single	38	12	24	111	0.63	9.25
Two	19	11	18	378	0.94	21.00
Three	11	38	69	547	6.27	14.39
Four	7	18	5	100	0.71	5.55
Five	–	6	–	39	–	6.50
Six	1	–	2	–	2.00	–
Eight	1	2	1	8	1.00	4.00
Total	77	87	119	1183	1.54	13.59

Total 231 journals have cited the publications of R Chidambaram. Citation density and citation concentration are found to be 5.6 and 8.23 respectively. Among the citing journals, ***Nature*** has the highest impact factor (22.139) and it has five citations (table 6). Other high impact factor journals citing him five times were ***Angewandte Chemie*** (5.974) and ***Biochemistry*** (5.196). He has received 10 citations in the journal ***Co-ordination Chemistry Reviews*** having impact factor 3.763, 20 citations in ***Journal of Physical Chemistry*** having 3.452 impact factor, 77 citations in ***Journal of Chemical Physics*** having impact factor 3.533 and 32 citations each in ***International Journal of Peptide and Protein Research*** (1.894), ***Journal of American Chemical Society*** (3.593) and ***Physical Review-B*** (3.259).

Table 6

Ranked list of Journals citing R Chidambaram

Sl. No.	Title of Journal	No.of Citations	Percentage	Cumulative Percentage	Impact Factor	Immediacy Index	Coverage in A & I Jls.	Country of Publication
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1.	Acta Crystallogr.B.	163	12.61	12.61	1.802	0.132	16	Denmark
2.	J.Chem.Phys.	77	5.96	18.57	3.433	0.778	28	US
3.	Int.J.Pept.Protein Res.	32	2.47	21.04	1.894	0.259	19	Denmark
4.	J.Am.Chem.Soc.	32	2.47	23.51	3.593	0.649	–	US
5.	Phys.Rev.B.	32	2.47	25.98	3.259	0.577	19	US
6.	Acta Crystallogr.C.	31	2.40	28.38	0.479	0.200	7	Denmark
7.	J.Mol.Structure	31	2.40	30.78	0.943	0.132	13	Netherlands
8.	Inorganic Chem.	30	2.32	33.10	2.721	0.466	18	US
9.	Bull.Chem.Soc.Jpn.	27	2.09	35.19	0.876	0.207	–	Japan
10.	Current Science	27	2.09	37.28	0.253	0.075	46	India
11.	Acta Crystallogr.A	25	1.93	39.21	2.409	0.235	17	Denmark
12.	Z.Kristallogr.	24	1.86	41.07	0.401	0.116	24	Germany
13.	J.Phys.Condens.Matter	23	1.78	42.85	1.627	0.296	17	UK
14.	J.Phys.Chem.	20	1.55	44.4	3.452	0.646	30	US
15.	Solid State Commun.	20	1.55	45.95	1.369	0.301	12	US
16.	J.Magn.Resonance	18	1.39	47.34	2.886	0.476	12	US
17.	Pramana	17	1.31	48.65	0.390	0.064	10	India
18.	J.Solid State Chem.	16	1.24	49.89	1.575	0.326	–	US
19.	Acta Crystal	15	1.16	51.05	–	–	–	Denmark
20.	Bio-Polymers	14	1.08	52.13	2.221	0.432	18	US
21.	Kristallografiya	14	1.08	53.21	0.259	0.095	12	Russia
22.	J.C.S. Dalton Trans	13	1.01	54.22	1.834	0.479	–	UK
23.	Chem.Phys.Lett.	13	1.01	55.23	2.686	0.560	15	Netherlands
24.	Phys-B	13	1.01	56.24	0.393	0.258	1	Netherlands
25.	Biochim.Biophys.Acta	12	0.93	57.17	2.610	0.316	25	Netherlands

Contd....

Table 6 contd

(1) (2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
26. Ind.J.Pure Appl.Phys.	11	0.85	58.02	0.132	0.008	19	India
27. Spectrochim. Acta-A	11	0.85	58.87	0.806	0.144	11	US
28. Z:Naturforsch.A	11	0.85	59.72	0.783	0.180	11	Germany
29. Act.Chem.Scand.	10	0.77	60.49	0.716	–	27	Denmark
30. Co-ord. Chem. Rev.	10	0.77	61.26	3.763	0.274	6	Netherlands
31. J.Sci.Ind.Res.	10	0.77	62.03	0.062	0.033	37	India
32. Proc.Indian Acad Sci.Chem.Sci.	10	0.77	62.80	0.300	0.022	–	India
33. Can.J.Chem.	9	0.69	63.49	0.461	0.099	34	Canada
34. J.Phys.C.	9	0.69	64.18	1.976	0.575	–	UK
35. Phys.B&C	9	0.69	64.87	0.186	0.050	–	Netherlands
36. Rev.Chim.Miner	9	0.69	65.56	0.646	–	–	France
37. Indian J.Bio chem.Bio Phys	8	0.62	66.18	0.328	0.031	25	India
38. J.Phys.Chem.Solids	8	0.62	66.80	1.255	0.215	15	UK
39. Ferroelectrics	7	0.54	67.34	0.773	0.100	13	US
40. Z.Neorg.K.	7	0.54	67.88	0.241	0.086	–	Russia
41. J.Struct.Chem.	6	0.46	68.34	0.239	0.112	6	US
42. J.Theor.Biol.	6	0.46	68.80	0.643	0.105	30	UK
43. Mol.Phys.	6	0.46	69.26	1.741	0.419	9	UK
44. Phys.Lett.A	6	0.46	69.29	1.135	0.291	12	Netherlands
45. Phys.Status Solidii.A	6	0.46	70.18	0.492	0.108	12	Germany
46. Am.Mineral	5	0.39	70.57	1.693	0.413	20	US
47. Angew.Chem.	5	0.39	70.96	5.974	1.252	24	Germany
48. Bio-Chemistry	5	0.39	71.35	5.196	0.874	40	US
49. Chem.Listy. Czechoslovakia	5	0.39	71.74	0.321	0.028	17	
50. Dokl.Akad.Nauk. SSSR Seriya Khimya	5	0.39	72.13	0.235	0.061	6	Russia
51. Inorg.Chim.Acta-A	5	0.39	72.52	1.372	0.173	14	Switzerland
52. J.Phys.F.	5	0.39	72.91	2.273	0.412	17	UK
53. J.Phys.Soc.Jpn.	5	0.39	73.30	1.818	0.463	–	Japan
54. Koord.Khim.	5	0.39	73.69	0.325	0.098	–	Russia
55. Nature	5	0.39	74.08	22.139	5.224	93	UK

Contd....

Table 6 contd....

(1) (2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
56. Phase Trans.	5	0.39	74.47	0.564	0.180	8	US
57. Phys.Rev.A	5	0.39	74.86	2.157	0.463	15	US
58. Z.Anorg.Allg.Chem.	5	0.39	75.25	0.950	0.334	9	Germany
59-81	(23 x 4)	92	7.12	82.37			
82-102	(21 x 3)	63	4.87	87.24			
103-138	(36 x 2)	72	5.57	92.81			
139-231	(93 x 1)	93	7.19	100.00			
Total	1293						

Impact factor and Immediacy Index are as per 1992 SCI Journal Citation Reports except for jnls with Sl.nos 32,34,35,36 and 52, (which are as per SCI, JCR 1988)

Subject-wise distribution of citing journals and citations is provided in table 7. The impact of his research is evident from the applications of his research in the wide ranging domains of chemistry, physics, biology, engineering, earth science, metallurgy, pharmacology, astronomy, mathematics, crop protection and food industries.

Table 7

Subject-wise distribution of citing journals and citations

Sl. No.	Subject	Citing Jnls.	No.of Ctns.
1.	CHEMISTRY		
	Chemistry (General)	54	259
	Analytical Chemistry	2	14
	Crystallography	16	291
	Electrochemistry	1	1
	Inorganic Chemistry	10	65
	Organic Chemistry	10	32
	Physical Chemistry	15	69
	Sterio Chemistry	1	1
	Water Chemistry	1	1
2.	PHYSICS		
	Physics (General)	53	347
	Nuclear Physics	4	8
	Optics	3	8
	Superconductivity	1	1
3.	BIOLOGY		
	Biology (General)	5	15
	Biochemistry	12	63
	Biophysics	1	3
	Botany	1	1
	Cytology & Histology	1	1
	Physiology	1	1
4.	SCIENCE (General)	9	62
5.	ENGINEERING		
	Engg. Mech. & Materials	3	5
	Electrical & Electronics Engg.	1	1
	Electronics	1	1
	Chemical Engineering	1	1
	Instrumentation	1	1
	Mines & Mining Engg	3	12
6.	EARTH SCIENCES		
	Earth Sciences (General)	2	2
	Geology	1	1
	Geophysics	4	7
7.	METALLURGY	6	9
8.	PHARMACOLOGY	2	3
9.	ASTRONOMY	2	2
10.	MATHEMATICS	1	2
11.	CROP PRODUCTION	1	1
12.	FOOD & FOOD INDUSTRIES	1	1
	Total	231	1293

Table 8 gives the country-wise distribution of citing journals and the number of citations in them. Among the top ranking journals citing R. Chidambaram, 71 are from United States with 399 citations, nine from Denmark with 281 citations, 23 from Netherlands having 129 citations, 39 from United Kingdom having 122 citations, and 13 from India having 97 citations.

4.6 Scattering of citations and Bradford's Law

The 231 journals which have cited the papers of Chidambaram, grouped into four zones having almost equal number of citations would be as shown in table 9. Applying the Bradford's Law, the value of Bradford multiplier was calculated and the average is found to be 3.28. The five

Table 8

Country-wise Distribution of Citing Journals & Citations

Sl. No	Country	Number of Citing Journals	No.of Citations	Percentage	Cumulative Percentage
1.	United States	71	399	30.86	30.86
2.	Denmark	9	281	21.73	52.59
3.	Netherlands	23	129	9.98	62.57
4.	United Kingdom	39	122	9.44	72.01
5.	India	13	97	7.50	79.51
6.	Germany	20	78	6.03	85.54
7.	Russia	16	53	4.10	89.64
8.	Japan	5	39	3.02	92.66
9.	France	5	19	1.47	94.13
10.	Canada	3	14	1.08	95.21
11.	Czechoslovakia	4	11	0.85	96.06
12.	Italy	5	9	0.70	96.76
13.	Switzerland	4	9	0.70	97.46
14.	Austria	2	7	0.54	98.00
15.	Belgium	2	5	0.39	98.39
16.	Hungary	2	5	0.39	98.78
17.	Poland	1	4	0.31	99.09
18.	Yugoslavia	1	3	0.23	99.32
19.	Argentina	1	2	0.15	99.47
20.	Australia	1	2	0.15	99.62
21.	China	2	2	0.15	99.77
22.	Sweden	1	2	0.15	99.92
23.	Ukraine	1	1	0.08	100.00

Table 9

Bradford's distribution of citations

Zone	No.of Journals	No.of Citations	Bradford Multiplier
First	5	336	–
Second	14	324	2.80
Third	42	325	3.00
Fourth	170	308	4.05

Average Bradford Multiplier (b) = 3.28

journals in the first zone are ***Acta Crystallographica B, Journal of Chemical Physics, International Journal of Peptides and Protein Research, Journal of American Chemical Society, and Physical Review - B.***

4.7 Bradford-Zipf Citograph

Bradford-Zipf citograph was obtained by plotting the citation frequency and cumulative citations against the number of journals on semi-log scale. The graph is shown in figure 4. Similar results were obtained for LePichon's publications also (Gupta and Gupta, 1983).

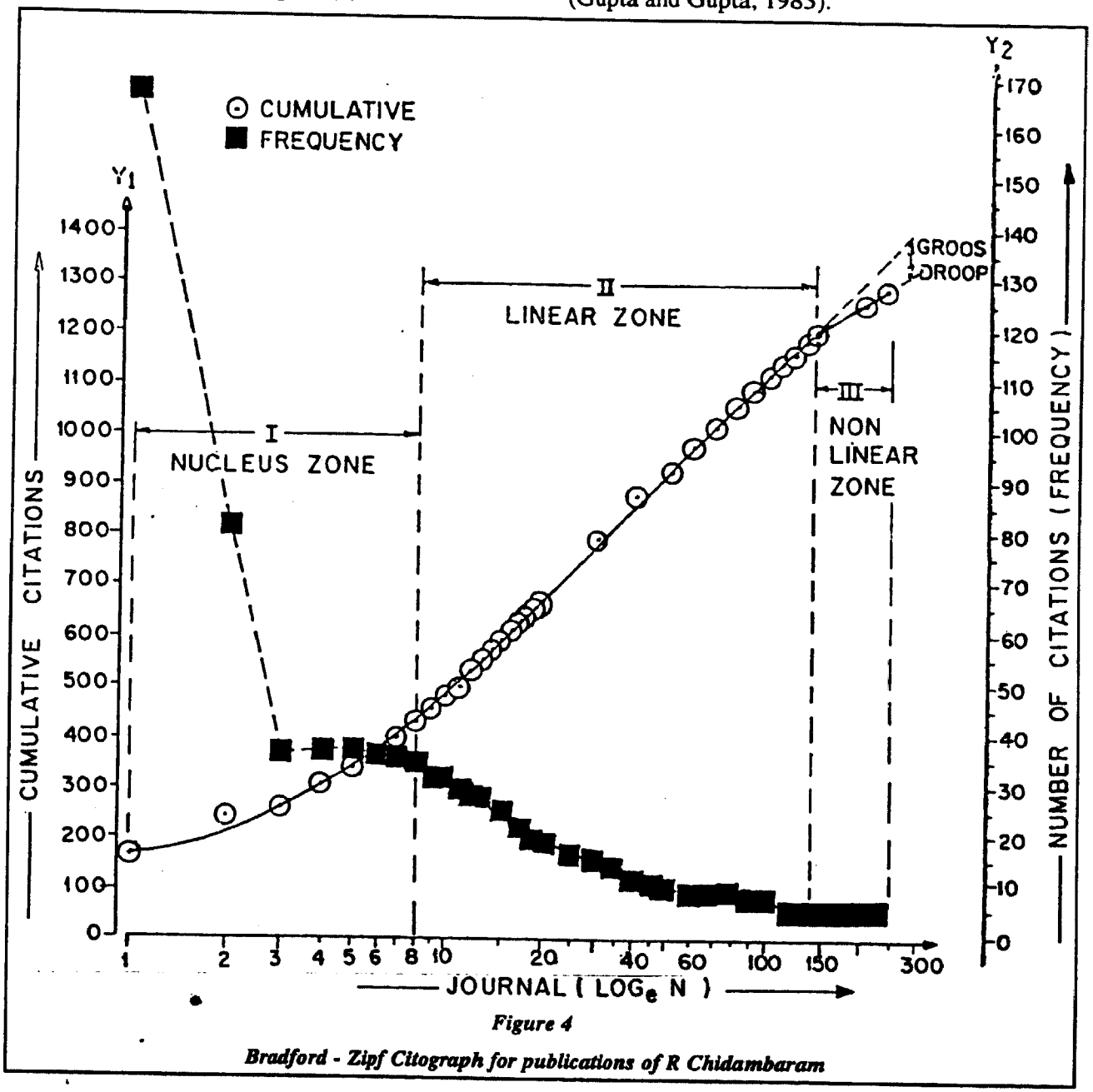

Figure 4

Bradford - Zipf Citograph for publications of R Chidambaram

4.8 Citation time lag

Usually, scientific papers get cited in another paper after the publication of the former, may be in the same year. That is, time-lag is positive or zero, time-lag being the differnce between the year of citing and the year of cited paper. The average value of time-lag within a particular citing paper or a series of papers reflects how modern the paper is or how integrated it is in an evolving research front. In rapidly evolving 'hot' areas, time-lag will be small and in many cases zero. If time-lag is large, say ten years, it usually indicates that the paper or series of papers belongs to a stagnating research area or is otherwise out of contact with main stream research.

Time-lag between publication of an article and it receiving its first citation, in the case of publications of R Chidambaram is in the range of 0 to 24 years. It was revealed that 27 papers were cited in the same year of their publication, but one paper got its first citation only after 24 years of its publication. The mean value of time lag is found to be 14 months, with a variance of 13 months and standard deviation of 43 and standard error of 4.5 months.

5 Conclusion

The present citation analysis clearly reveals, in quantitative terms, the impact of the contributions of Dr Chidambaram in a variety of fields such as physical sciences, biological sciences, engineering, earth science and metallurgy. The high rate of citations to his papers in journals of international scope and in journals of high impact factor is a clear indication of their high quality. In general, the findings of this study give the portrait of Dr R Chidambaram as a model scientist.

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Appendix 1

Rajagopala Chidambaram : a resume of his achievements

Born : On 12th November 1936, at Madras, Tamil Nadu, India

Education : B.Sc. (1956), M.Sc. (1958) from Madras University, Ph.D. (1962) from Indian Institute of Science, Bangalore

Ph.D. thesis was awarded the Martin Foster Medal for the best thesis during 1961-1962. D.Sc. (1991) Indian Institute of Science, Bangalore.

Positions held : Head (1962) Neutron Physics Section, BARC; Head (1981) Neutron Physics Division, BARC; Director (1984) PhysicGroup, BARC; Director (1990) BARC; and Chairman (1993) Atomic Energy Commission.

Awards / Achievements / Honours:

- Chairman of the Session on 'Hydorogen Bonding in Hydrates' at the International Union of Crystallography Congress in Stony Brook, USA in 1961.
- Visiting Expert of the IAEA on Neutron Difraction to the Philippine Atomic Energy Commission (1967-68)
- Consultant and member on the Technical Committee on Peaceful Nuclear Explosion of IAEA (1970-77)
- Padmashri Award in 1975 for his key role in the 'Peaceful Nuclear Experiment' at Pokhran on May 18, 1974.
- Honorary Professor at the Jawaharlal Nehru Centre for Advanced Scientific Research at Bangalore since 1990.
- Distinguished Alumni Award by the Council of the Indian Institue of Science Alumni Association in 1991.
- President, Physics Section of the Indian Space Congress for 1991-92
- Second Jawaharlal Nehru Birth Centenary International Visiting Fellowship by the Indian Science Academy in 1992 to visit Germany and Japan.
- Chairman, Board of Govemors of the International Atomic Energy Agency (1994-95).
- The R.D. Birla Award of the Indian Physics Association for the year 1995.
- Vice President, International Union of Crystallography Congress for 1996-99
- Lifetime Acievement Awaard by the Indian Analytical Instruments Association, December 11, 1997.
- One of the Architects of Pokhran II / Shakti '98.
- 11 May 1998: Three successful nuclear tests carried out at Pokhran. The tests were conducted with a fission device, a low-yield device and a thermo nuclear device.
- 13 May 1998 : Two nuclear tests of low-yield variety meant for weapon calibration. using the least amount of fissile material to gain maximum sub-kiloton nuclear device.
- Lifetime Achievement Award by the South Indian Education Society, 27th June 1998.

Appendix 2

The Most Cited Papers of R.Chidambaram

(The number at the end of each entry indicates the number of citations the paper has received)

1. Neutron Diffraction Study of the Structure of Potassium Oxalate Monohydrate: Lone-Pair Coordination of the Hydrogen-Bonded Water Molecule in Crystals. / R.Chidambaram, A.Sequeira and S.K.Sikka *Jour.Chem.Phys.*41, 3616-22 (1964) 152
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3. The Structure of Copper Ammonium Sulfate Hexa-hydrate from Neutron Diffraction Data. / G.M.Brown and R.Chidambaram *Acta Cryst.*, B 25, 676-687 (1969) 112
4. A Neutron Diffraction Study of L-Glutamic Acid.HCL. / A.Sequeira, H.Rajagopal and R.Chidambaram *Acta Cryst.* (1972), B 28, 2514 64
5. Structure of the Hydrogen-Bonded Water Molecule in Crystals / R.Chidambaram *Jour.Chem.Phys.* (1962), 36, 2361 59
6. Neutron Diffraction Refinement of the Structure of Potassium Oxalate Monohydrate. / A.Sequeira, S.Srikanta and R.Chidambaram. *Acta Cryst.* B26, 77-80 (1970) 55
7. Neutron Diffraction Study of the Crystal Structure of Barium Chlorate Monohydrate. / S.K.Sikka, S.N. Momin, H.Rajagopal and R.Chidambaram. J. *Chem. Phys.* 48, 1883 (1968) 51
8. Neutron Diffraction Determination of the Structure of Berryllium Sulphate Tetrahydrate, BeSO4 4H20. / S.K.Sikka, R.Chidambaram *Acta Cryst.*B 25, 310 (1969) 50
9. Potential Functions for Hydrogen Bond Interactions 1. A Modified Lippincott-Schroeder Potential Function for N-H—O Interaction between Peptide Groups. / R.Chidambaram, R.Balasubramanian and G.N.Ramachandran. *Biochim.et Biophys.* Acta 221, 182-195 (1970) 42
10. A Bent Hydrogen Bond Model for the Structure of Ice-I. / R.Chidambaram *Acta Cryst.* 14, 467 (1961) 37
11. Bent O-H—O Hydrogen Bonds in Crystals. / R.Chidambaram and S.K.Sikka *Chem.Phys.Letters* 2, 162 (1968) 36
12. Potential Functions for Hydrogen Bond Interactions II. Formation of an Empirical Potential Function. / R.Balasubramanian, R.Chidambaram and G.N.Ramachandran. *Biochim. et Biophys. Acta* 221, 196-206 (1970) 33
13. Structure of L-Asparagine Monohydrate by Neutron Diffraction. / M.Ramanadham, S.K.Sikka, R.Chidambaram *Acta Cryst.* B 28, 3000 (1972) 31
14. Neutron Diffraction Refinement of the Crystal Structure of Potassium Copper Chloride Dihydrate, K2Cuc14.2H20. / R.Chidambaram, Q.0. Navarro, A.Garcia, K.Linggoatmodjo & Lin Shi-Chien *Acta Cryst.* B26, 827-830 (1970) 28
15. Equation of State Theories of Condensed Matter upto about 10 TPa. / B.K.Godwal, S.K.Sikka, and R.Chidambaram. *Physics Report*, 102, 121-197 (1983) 27

Contd...

Appendix 2 Contd...

16. Structure of Lithium Potassium Sulphate LIKS04: A Neutron Diffraction Study. / Sandhya Bhakay-Tamhane, A.Sequeira, and R.Chidambaram *Acta Cryst.* c40, 1648 (1984) 26

17. Low-Temperature Phase Transitions in L1kS04: A Neutron Study. / Sandhya Bhakay-Tamhane, A. Sequeira and R.Chidambaram. *Solid State Communications*, 53, 197-200, (1985) 26

18. Potential Functions for Hydrogen Bond Interactions 111. Empirical Potential Function for the Peptide N-H—O-C Hydrogen Bond. / G.N.Ramachandran, R.Chandrasekharan and R.Chidambaram. *Proc. Ind. Acad. Sci.* 74A, 270 (1971) 25

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