CHAPTER-VI

FINDINGS AND CONCLUSION
6.1 INTRODUCTION

After the analysis and interpretation of data pertaining to Raja Ramanna’s publication productivity, citation analysis and synchronous references, an attempt has been made in this chapter to summarize the results, highlighting the major findings of the study.

6.2 MAJOR FINDINGS OF THE STUDY

The major findings of the study are:

6.2.1 Publication Productivity Analysis of Raja Ramanna

- Raja Ramanna’s scientific paper publishing career spanned over 54 years during (1949-2002) publishing 278 research publications.
- The Average number of publications published per year was 5.14.
- The first publication published was in 1949 in the journal *Nature* when Raja Ramanna was 25 years old.
- The highest number of publications i.e 18 were published in 1974 when Raja Ramanna attained 50 years of biological age.
- The Productivity Coefficient was 0.65 which is a clear indication that his publication productivity increased after his 50 percentile age in 1975.
- The most productive periods were 1961 when Raja Ramanna was 37 years of age, 1965 when he was 41 years of age, 1974-1977 when Raja Ramanna was 50-53 years of age and 1982-1985 when he was 58-62 years of age.
- Raja Ramanna had 208 (72.82%) single authored publications and 70 (25.18%) multi-authored publications.
• The highest number (18) of single authored publications were published in 1974 and the highest number of multi-authored (7) publications were published in 1958.

• The highest collaboration rate (1.00) was found in the years 1949, 1951, 1989, 1994 and 2002.

• Raja Ramanna was first author in 245 (88.13%) publications.

• Raja Ramanna had as many as 8 authored collaborative papers is indicative of multi-disciplinary nature of research activity.

• Raja Ramanna has contributed significantly to the domains of ‘Nuclear Physics’ 89 (32.01%) publications followed by 59 (22.22%) publications in ‘Nuclear Power and Peaceful uses of Nuclear Energy’, 20 (7.20%) publications in ‘Reactor Theory’, 7 (2.52%) publications in ‘Philosophy’ and 103 (37.05%) publications in ‘General’.

• The Activity Index (AI) of Raja Ramanna’s publications in various domains shows that the emphasis was given to Nuclear Physics during 1959-63, Nuclear Power and other Peaceful uses of Nuclear Energy during 1974-1978 and Reactor Theory during 1954-1958.

• Raja Ramanna had 62 collaborators during 1949-2002 whom he guided as mentor.

• Prominent collaborators of Raja Ramanna were S.S. Kapoor with 17 publications, P.N. Rama Rao with 13 publications, S.B.D. Iyengar with 8 publications, N. Umakanth, M.P. Navalakar and V.R. Nargundkar with 6 publications each, G.S. Mani, S.R.S. Murthy and D.M. Nadkarni with 5 publications each.

• The collaborator dynamics of Raja Ramanna showed an interesting trend that there were only two collaborators during 1949-1953 the formative period of research which increased to 17 collaborators during 1954-1958, 12 collaborators during 1959-1963, 15 collaborators during 1964-1968, 11
collaborators during 1969-1973, 5 collaborators during 1974-1978, 17 collaborators during 1979-1983, 7 collaborators during 1988, 2 collaborators during 1994-1998 and 3 collaborators during 1999-2002. This indicates that there were very a few collaborators in the beginning and increased thereafter and again a decline in the number of collaborators due to many reasons such as the mobility of the researchers in search of better avenues, and the involvement of the mentor more in administrative activities etc.

- The major channels of communications preferred by Raja Ramanna were Lectures (87), Journals (85), and Conferences (80).

- The Top Ranking journals preferred for communication were: Current Science (10), Electrical India and Pramana with four publications each, Industrial India, Journal of Scientific and Industrial Research, Nuclear Physics, Physical Review Letters and Transactions of the Bose Research Institute with three publications each.

- The Publication Density was 1.77 and Publication Concentration was 0.25.

- The scattering of journals of Raja Ramanna was found to be 2.16 based on the Bradford Multiplier.

- The highly frequent keywords which appeared in the titles of publications of Raja Ramanna were: Development (12), India (12), Fission of U-235 (10), Emission (9), Nuclear Fission (8), Nuclear Energy (7), Fission (7), Nuclear Power (7), Neutrons (7), Thermal Neutrons (7), Angular Distribution (6), Atomic Energy (6) and Physics (6).
6.2.2 Citation Analysis of Publications of Raja Ramanna

- The total number of citations received for the publications of Raja Ramanna during 1949-2005 were 282 as per Science Citation Index.
- Raja Ramanna became a citable author with his contribution in the field of Nuclear Physics in 1957.
- The highest numbers of citations (23) were received in 1985.
- The average number of citations received per year was 4.95.
- The average citation received per paper for scientific papers was 3.27.
- The total number of citations by others was found to be 245 (86.88%) and self citations were 37 (13.12%).
- The highest diachronous self-citation rate (100.00) was found in 2002 followed by 66.67 in 1996, 60.00 in 1997 and 50.00 in 1998.
- The average diachronous self-citation rate was 13.12.
- Out of 278 publications, 49 publications have received citations and 229 publications have not received any citations.
- Citation Time Lag for the publications of Raja Ramanna was in the range of 0-42 years.
- Four publications received citations in the same year of publication, 13 publications after one year of publication, 7 publications after two year of publication, 7 publications after three year of publication and four publications after four year of publication.
- Raja Ramanna’s publications in Nuclear Physics domain received 218 citations followed by 39 citations to Reactor Theory, 18 citations to Nuclear Power and other Peaceful uses of Nuclear Energy and 7 citations to General domains.
- Single authored publications have received 50 (17.73%) citations and multi-authored publications have received 232 (82.27%) citations.
• Maximum 81 (22.72) citations were received for three authored publications.
• There were 372 authors in the papers citing Raja Ramanna’s publications.
• The core citing authors were: Raja Ramanna with 37 citations, S.S. Kapoor with 24 citations, D.M. Nadkarni with 17 citations, R.K. Choudhary, V.S. Ramamurthy and M.V. Ramanaiah with 10 citations each.
• The publications from 26 countries have cited the publications of Raja Ramanna.
• The citing publications of Raja Ramanna from major countries were India with 129 citations, USA with 43 citations, USSR with 29 citations and UK with 11 citations which shows the impact of Raja Ramanna’s research on the research activity of other countries.
• The highly cited five publications of Raja Ramanna were identified based on citations received ≥ 13.
• The location of citations of Raja Ramanna’s publications were examined and found that 133 (47.16%) citations were in the ‘Introduction’ section, 94 (33.3%) citations were in ‘Results and Discussion’ section, 11 (3.9%) citations in ‘Experimental Method’ section, 8 (2.83%) citations in ‘Materials and Methods’ section, 7(2.48%) citations in ‘Experimental Data’ section and 6 (2.12%) citations in ‘Conclusion’ section.
• The reasons for citing Raja Ramanna’s publications were investigated and grouped into 34 categories.
• It was identified that 112 (39.71%) citations were used for ‘Review’ purpose, 86 (30.50%) citations for ‘Substantiating’ the results, 22 (7.80%) citations for ‘Experimental Data’, 9 (3.19%) citations for ‘Experimental Models’ and 7 (2.48%) citations for ‘Negating’ the research results.
• Majority of the citing documents were from: journal articles with 267 (94.68%) citations.
• The core citing journals were *Pramana* with 37 citations, *Nuclear Physics-A* with 22 citations, *Current Science* with 18 citations, *Journal of Nuclear Energy-A & B* and *Soviet Journal of Nuclear Science* with 16 citations each.

• Citation Density was 4.08 and Citation Concentration was 11.59.

• H-index of Raja Ramanna was 9.

• Among the top ranking journals citing raja Ramanna’s publications were from USA with 70 (24.82%) citations followed by India with 63 (22.34 %) citations, Netherlands with 56 (19.85%) citations and England with 39 (13.82%) citations which indicates the quality of Raja Ramanna’s publications.

• The most predominant language of citing journals was English with 270 (95.75%) journals followed by Russian with 11 (3.90%) journals and German with 1(0.35%) journal.

• Impact Factor-wise distribution of citing journals showed that more than 51% of the citations received were published from the journals with impact factors ranging from 0.001 to 30.927.

6.2.3 Pattern of Synchronous References Cited in the Publications of Raja Ramanna

• On analyzing the synchronous references cited in the publications of Raja Ramanna, it was found that out of 278 publications, 74 publications had synchronous references.

• A total of 924 synchronous references have been received to 74 publications.

• The oldest references cited belong to 1885, 1886 and 1893.

• The highest number of synchronous references 81 was in 1958.

• There were 11 synchronous references without year of publication.
• Synchronous references by others were 821 (88.85%) and 103 (11.15%) were self-references.
• The average synchronous self-reference rate was 11.15.
• ‘Nuclear Physics’ domain had 615 synchronous references belonging to the years 1885-2002 out of which 531 (86.34%) synchronous references were by others and 84 (13.66%) were self-references.
• ‘Nuclear Power and other Peaceful uses of Nuclear Energy’ domain had 122 synchronous references during 1961-1981, out of which 120 (98.36%) were references by others and 2 (1.64%) were self-references.
• ‘Reactor Theory’ domain had 106 synchronous references during 1936-1959, out of which 93 (87.74%) references were by others and 13 (12.26%) were self-references.
• The Time Lag between cited publications and publications by Raja Ramanna were in the range of 0-105 years.
• It was revealed that 96 synchronous references were cited in the same year of publication, 138 synchronous references were 1 year old.
• The synchronous references were categorized into four groups based on their age of publication. Out of the 913 synchronous references 234 (25.63%) belong to ‘Most Recent’ references category, 553 (58.37%) synchronous references belong to ‘Recent’ references category, 99 (10.85%) synchronous references belong to ‘Old’ references category, and 47 (5.15%) synchronous references belong to ‘Very Old’ references category.
• Single authored synchronous references were 475 (51.41%) where as 449 (48.59) synchronous references were multi-authored.
• In all, there were 371 authors who appeared in the papers cited by Raja Ramanna’s publications.
• The core cited authors were: Raja Ramanna with 102 references, S.S. Kapoor with 36 references, V.M. Strutunski with 25 references, V.S. Ramamurthy with 20 references, I. Halpern and J.C.D. Milton with 18 references each, R.B. Leachman and P.N. Ramarao with 16 references each and S.B.D. Iyengar, G.S. Mani, N.A.Perfilov and W.J. Swiateki with 14 references each.
• Five publications of Raja Ramanna having ≥ 38 synchronous references were identified.
• The types of synchronous references include Journal Articles with 575 (62.33%) followed by Reports with 118 (12.77%), Conference papers with 106 (11.47%), and Books with 102 (11.04%).
• A total of 575 journal articles cited in the publications of Raja Ramanna were spread over 97 journals.
• The core cited journals were: Physical Review with 172 references, Nuclear Physics with 60 references, JETP with 25 references, Physical Review Letters with 23 references and Physics Letters with 19 references.
• The Bradford Multiplier was 6.54, this indicates that most of the references cited by Raja Ramanna in his publications were concentrated in a small group of journals.
• The Publication Density was 5.92 and Publication Concentration was 4.12.
• The distributions of synchronous references do not follow Bradford distribution in case of individual scientist as the data set is very small.
• Among the top ranking journals cited in the publications of Raja Ramanna were: 35 (36.08%) journals from USA followed by England with 16 (16.49%) journals, Netherlands with 10 (10.30%) journals, USSR and India with 9 (9.25%) journals each.
• More than 30 percent of the journals cited were with Impact Factors ranging from 0.001 to 30.927.
• More than nine percent of journals had Impact Factors ranging from 1.001 to 2.00, rest of the journals cited did not have Impact Factors as they were very old and the concept of impact factor came into being very recently.

6.2.4 Correlation Between Citing Journals Vs Cited Journals

• There is a low correlation between the journals citing Raja Ramanna’s publications and the journals cited by Raja Ramanna in his publications. This indicates that it is not always necessary to have high correlation between what the author cites in his publications and what other authors cite as the motivation to cite one’s paper differs from scientist to scientist and fields to field.

6.3 FUTURE AREAS OF RESEARCH

The future areas of research to be carried out in the area of Scientometrics of individual scientists are:

- Studies on Social, political and cultural aspects of Raja Ramanna which may throw light on the multi-faceted personality of Raja Ramanna,
- Studies on social, political and cultural aspects of other prominent scientists which throw light on the multi-faceted personalities of scientists,
- Co-citation and Bibliographic coupling analysis of Raja Ramanna’s publications,
- Scientometric study can be extended to other eminent Indian scientists and Nobel laureates,
- Webometric studies on Scientists.
6.4. CONCLUSION

The publication productivity analysis, diachronous citation analysis and synchronous references analysis of Raja Ramanna's publications reveal in quantitative terms, impact of the contributions of Raja Ramanna to a variety of fields such as Nuclear Physics, Reactor Theory, Nuclear Power and other Peaceful uses of Nuclear Energy and other fields as well. The high rate of citations to Raja Ramanna's publications in journals of international scope and high impact factor is a clear indication of their high quality. Most of the citations received to his publications were for substantiating the results, methodology followed, Experimental models followed and to base the future research.

There were 372 authors, 103 institutions across 26 countries citing Raja Ramanna's publications indicating how well populated and highly integrated the research carried out by Raja Ramanna was at BARC, Mumbai and other reputed organizations with the main stream of research.

The analysis also confirms that it is not only the quantity of contributions, but the quality of contribution that matters to the scientific community. The contributions were recognized to consider him for several prestigious awards and positions. Therefore, conclusion can be drawn that there is a relationship in quantity, quality and recognition for original contributions of excellence which get diffused into common stock of knowledge, and there is a good relationship between such contributions and number of awards the contributor gets from the reward system of Science. There is a positive relationship in rewards, citedness and quality of contributions.
Raja Ramanna belongs to the rarest of a rare group of creative scientists who always kept himself active working on many fields simultaneously even till the age of 78 years. His interest in music and philosophy did not diminish till his death. It is clearly evident that there is a low relationship between the journals citing Raja Ramanna's publications and the journals cited in the publications of Raja Ramanna, which indicates that the world opinion always differs. In other words, as found in this study, the intellectual background upon which the scientists builds upon and investigates further and the intelligencia and scholarship that acknowledges this scientific pursuit may or may not correlate. Loose ends meet arbitrarily and coincide accidentally in science in the expanse of time to chance upon innovations, inventions and discoveries.

A scientist, as an individual can make great contributions to science, but when he creates and nurtures group of people, capable of carrying out high quality research work during the following generations is a still a greater achievement. Added to this development of indigenous resources, setting practically attainable guidelines, taking up projects and seeing through their logical conclusions leading to fruitful results are the hall-marks of a great scientist as well as a great scientific leader. All these aspects amply demonstrated in the case of illustrious research career of Raja Ramanna.

Considering all the above scientometric indicators, Raja Ramanna represented and demonstrated excellence in his performance and set up very high standards for his followers to surpass, he can be considered as performance ‘Role Model Scientist’ for the present and future generations to emulate. He undoubtedly remains in the science and technology map of the world both at national and international level for years and ages to follow.