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SCIENTOMETRIC PORTRAIT OF C.R. BHATIA, A GENETICIST AND PLANT BREEDER

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ABSTRACT

Reveals the following scientometric indicators of 129 publications by the scientist between 1961 and 1994: fifty percentile age (23), productivity coefficient (0.7), publication rate (3.8); papers - single authored (13), two authored (56), and three authored (35); collaboration coefficient above 0.7 having 60 collaborators with 346 total authorship; and in terms of position, credits as first and second author in 47 papers each, third author (21); publication scatter in 82 channels having publication density (1.6), publication concentration (24.4); bibliographic characteristics per paper- references (19), synchronous self citation rate (8.5), tables (3), visuals (2), which indicate his serious style of research communication. Domainwise the maximum publications are in the area of mutation research and mutation breeding (30), followed by seed proteins (25), biotechnology (21), biochemical genetics (20), plant breeding (10), bioenergetics (10) and general (13). His research group has been responsible for the development of 21 new crop cultivars that have been officially released and notified and are grown over a large area in several states of India

KEYWORDS: Scientometrics; C R Bhatia; Geneticist: Plant breeder.

DEFINITIONS

Authorship credit - The credit given to an author of a collaborative paper in terms of number. Normally each author figuring in a collaborative paper gets one credit.

Collaborative coefficient - The ratio of the number of collaborative papers to the total number of papers published.

Fifty percentile age - The number of years during which 50% of the papers were published starting from the year of publication of the first paper.

Productivity coefficient - The ratio of 50 percentile age to the total productivity age.

Publication concentration - The ratio in percentage of the number of channels accounting for half of the papers to the total number of channels used.

Publication density - Frequency of papers per channel

Total productive age - The number of years counted from the year of publication of the first paper to the year of publication of the last or latest paper. The term

term *paper* means a research paper, a short communication, or a review paper.

INTRODUCTION

A biography documents accomplishments of a person. Descriptive biographies of scientists have been written for almost as long as there have been scientists to write about. The cult of hero is as old as humankind. It sets examples which are lofty but not unattainable, and astonishing but not incredible.

An ever growing stress is being laid on scientometrists to publish data on individual scientists rather than gross statistical "macro" data (Schubert and Glanzel, 1992). Scientometric portraits of individual scientists such as Vinodini Reddy (Kalyane and Kalyane, 1993); M.S. Swaminathan (Kalyane and Kalyane 1994); U.R. Murty (Kalyane and Kademani, 1994); P.K. Iyengar (Kademani, et. al., 1994a); C.V. Raman (Kademani, et. al., 1994b); C.S. Venkata Ram (Kalyane and Devarai, 1994); K. Ramiah (Kalyane and Samanta, 1995);T.S. West (Kalyane and Munnolli, 1995); R.Chidambaram (Kalyane and Kademani, 1995; Kademani and Kalyane, 1996); P.M.Bhargava (Kalyane, 1995); K.S. Krishnan (Kademani, et. al., 1996a); S. Chandrasekhar (Kademani, et al, 1996b); P.G. de Gennes (Kalyane and Sen, 1996), Barbara McClintock (Kalyane and Kademani, 1997) have generated wide interest among historians of science, biographers of scientists, science policy makers, administrators of scientific establishments, R & D managers, scientometricians, educationists, young scientists, documentalists, information scientists and science journalists.

A scientometric portrait deals with quantitative and qualitative aspects of the communication of science by a well-known scientist with due credits to all collaborators and channels of communications used. The holistic approach emphasizes a win-win participative achievements of each collaborator. The objective is to inspire the younger generation and attract talent to be involved in scientific research and development by establishing co-authorship networks. Gaillard (1991) stated that most of the developing countries lack local "role models" to motivate other scientists; but this and other papers cited above attempt to document the fact that there are many role model scientists in developing countries itself who can inspire and motivate younger generation scientists.

BRIEF BIOGRAPHY

Chittranjan R. Bhatia was trained as a plant geneticist. He started his research career under the guidance of his mentor M.S. Swaminathan, F R S, at the Indian Agricultural Research Institute (IARI), New Delhi, where he obtained his Ph.D. (Genetics and Plant Breeding) in 1961. His doctoral work involved studies on manipulation of genetic material in wheat using different types of ionizing radiation and evaluation of the utility of induced mutants in national wheat improvement programme. Besides the basic information on the use of radiation for genetic manipulation in wheat, this work resulted in the release of a fully awned variety of wheat N.P. 836 from the IARI (Jagathesan, et. al., 1961). He collected natural genetic variability in maize, sorghum, and millets available in the remote areas of the country under the Indian Agricultural

Programme of the Rockefeller Foundation. He did his post-doctoral work at the Department of Genetics, Agricultural University, Wageningen, The Netherlands (1962-1964); and at the Brookhaven National Laboratory, Upton, New York, USA (1964-1966). His research also involved genetic manipulation of the quantitative traits and studies at the level of gene products - proteins and isozymes. He joined the then Biology Division of the Atomic Energy Establishment, now BARC (Bhabha Atomic Research Centre), Trombay, Bombay, and worked in diffe-rent capacities as Head of the Mutation Breeding Section (1971-85), Head of the Nuclear Agriculture Division (1985-90), Associate Director of the Biology Group (1988-90); and Director of the Bio-Medical Group (1990-93). He was appointed as the Secretary to the Department of Biotechnology under the Ministry of Science and Technology, Government of India, New Delhi (March 1, 1993 - December 31, 1995).

IMPACT

Major focus of C.R. Bhatia has been on the use of different tools and techniques for genetic manipulation for developing crop cultivars with higher productivity which has brought immense benefit to the farmers. Fifteen new crop cultivars of mungbean, blackgram, pigeonpea, groundnut, mustard, jute, and rice were released and notified from the BARC till 1993 and other promising materials were in the pipeline. The number of released cultivars has now gone up to 21. These cultivars are grown over a large area in the states of Maharashtra, Madhya Pradesh, Gujarat, Karnataka, Kerala, Bihar, and Assam. The scientometric domain of the present paper is not in a position to highlight the widespread socio-economic impact of this piece of applied research. Economic benefits accrued to farmers and consumers as a result of his research team need independent study.

Developing new crop cultivars is an entirely applied research activity involving basic understanding in different areas of plant sciences. C.R. Bhatia could combine development of new cultivars with generation of basic knowledge directly useful for application, and the use of molecular techniques in crop improvement programmes. Thus, strong knowledge base, appropriate strategies, and use of biotechnological tools for genetic manipulations played a significant role in applied work. Therefore, he is an excellent role model (scientific star) for young scientists who intend to embark upon plant genetics, plant breeding or biotechnology research.

RESULTS

Publication Productivity

The total productive age of C.R. Bhatia is 34 years (1961- 1994) during which time he produced 129 papers (Table 1). His first paper was published when he was 25. Fifty percentile age computes to 23 and falls on 1983, when he was heading the Mutation Breeding Section of BARC. It is a period of high visibility and recognition. Fifty percentile age is expected to accelerate the progress of a scientist. It is not surprising that he became the Head, Nuclear Agriculture Division, BARC in 1985.

Table 1: Yearwise Distribution of Papers of C.R. Bhatia in Various Channels of Communication

Year	J	P	B	T	PA	Age
1961	1	-	-	1	1	25
1962	2	-	-	2	2	26
1963	2	-	-	2	3	27
1964	-	-	-	-	4	28
1965	2	2	-	4	5	29
1966	1	-	-	1	6	30
1967	4	-	-	4	7	31
1968	1	1	-	2	8	32
1969	1	-	-	1	9	33
1970	2	-	-	2	10	34
1971	2	2	-	4	11	35
1972	2	-	-	2	12	36
1973	1	1	-	2	13	37
1974	1	-	-	1	14	38
1975	4	3	-	7	15	39
1976	2	3	-	5	16	40
1977	3	3	2	8	17	41
1978	1	-	-	1	18	42
1979	3	2	-	5	19	43
1980	1	-	-	1	20	44
1981	1	-	-	1	21	45
1982	3	3	-	6	22	46
1983	2	2	1	5	23	47
1984	-	4	-	4	24	48
1985	3	1	2	6	25	49
1986	8	2	1	11	26	50
1987	5	1	1	7	27	51
1988	2	1	1	4	28	52
1989	3	-	1	4	29	53
1990	3	3	1	7	30	54
1991	2	5	-	7	31	55
1992	-	-	1	1	32	56
1993	4	-	1	5	33	57
1994	5	-	1	6	34	58
Total	77	39	13	129		

J = Journal, P = Proceedings, B = Books, T = Total, PA = Productive age, and Age = Actual age of C.R. Bhatia (Date of birth: January 1, 1936)

It also needs mention that he was Co-Director of a FAO-IAEA Regional Training Course held at the National Atomic Energy Research Centre at Jakarta, Indonesia in 1979 and taught in a series of FAO-IAEA International Training Courses at the Institute of Genetics, Academy of Sciences, Bulgaria (1983); Zhejiang Agricultural University, Hangzou, China (1986); Atomic Energy Commission, Legon, Accra, Ghana (1990); Siebersdorf Laboratory of IAEA, Vienna, Austria (1990-1993). He thus attained international leadership in induced mutation breeding of plants. He was elected to the fellowships of the Indian Academy of Sciences, Bangalore in 1985; and Indian National Science Academy, New Delhi in 1988; and the Third World Academy of Science, Trieste, Italy in 1993. He is the founder member of the National Academy of Agricultural Sciences, New Delhi which was founded in 1990.

The productivity coefficient is found to be 0.68 and his publication rate averages 3.8 per year. His productivity can be categorised as moderate with his highest productive year is 1986 when he published 11 papers at the age of 50. The next highest productive year is 1977 when he published eight papers at the age of 41. He has published seven papers in as many as four different years, i.e. 1975, 1987, 1990, 1991 corresponding to his age 39, 51, 54, and 55. The early and mid-50s of his life is found to be most productive. The frequency distribution of papers is given in Table 2.

The quinquennial productivity trends are depicted in Fig. 1. He has mainly published in journals and proceedings in the first half of the productivity age while publications as contributions in books are found only during the second half of the productivity age.

Table 2. Frequency distribution of papers by C.R. Bhatia

	P	F	P.F
	1	8	8
	2	6	12
	4	6	24
	5	4	20
	6	3	18
	7	4	28
	8	1	8
	11	1	11
Total	33	129	

P = Number of paper(s), F = Frequency in number of year(s) corresponding to the paper(s), and P.F = Total number of papers.

Authorship Pattern

Authorship pattern in various channels of communications provided in Fig. 2, indicates that out of 13 single-authored papers, 5 papers were in journals and 5 in proceedings, and 3 papers were in books. Out of 56 two-authored papers, 36 papers appeared in journals, 13 in proceedings, and 7 in books. Out of 35 three-authored papers, 23 papers were published in journals, 9 in proceedings, and 3 papers in books. Out of 14 four-authored papers, 6 papers were in journals, and 8 in proceedings. Out of 8 five-authored papers, 5 were in journals, and 3 in proceedings. Two six-authored papers were published in journals. One eight-authored paper was published in the proceedings of a symposium.

Figure 1: Publication Productivity of C.R. Bhatia

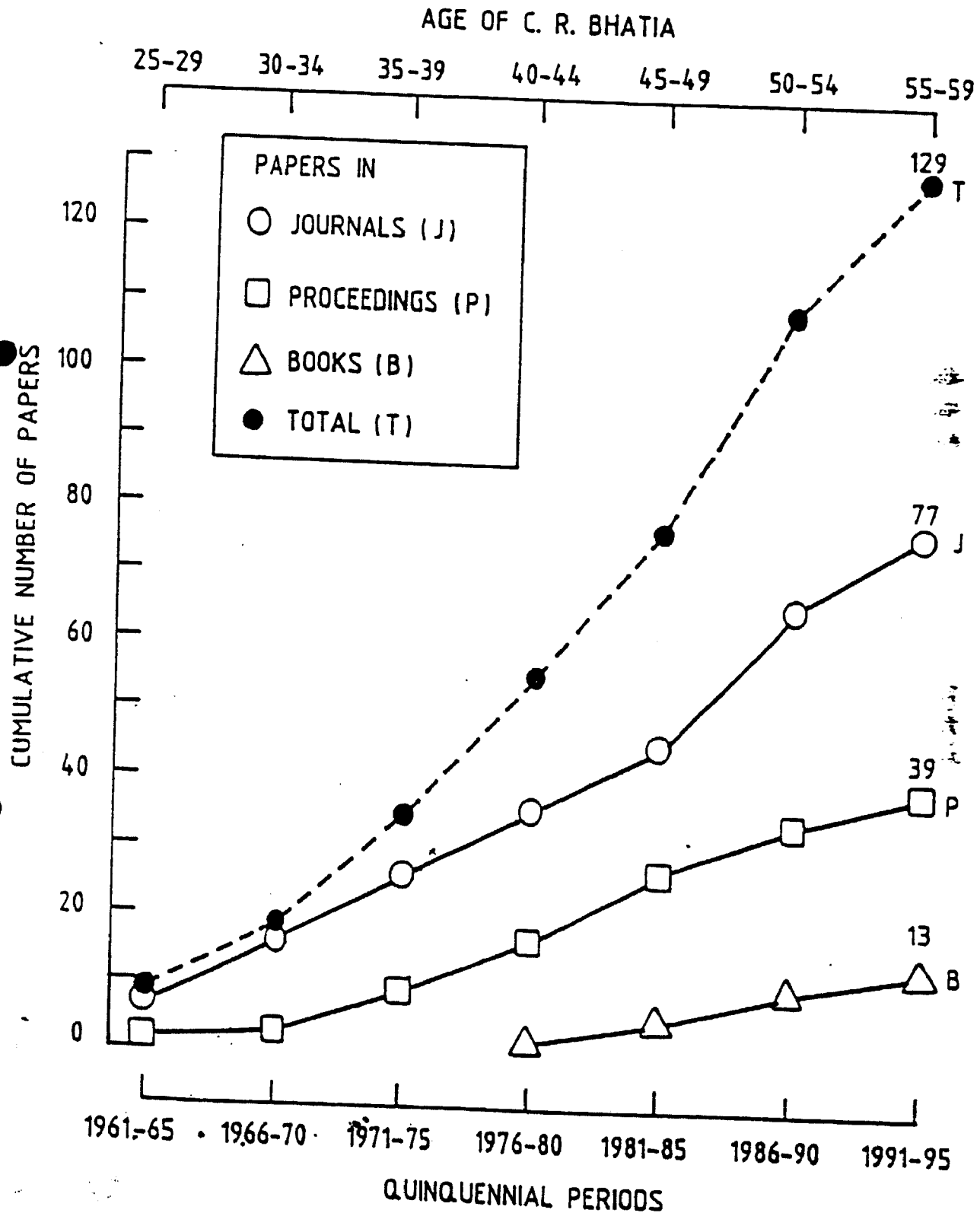


Table 3: Authorship Credits to Researchers Collaborating with C.R. Bhatia

No	Researchers	Authorship Credit(s)				Period
		J	P	B	TA	FPY-LPY
1	C.R.Bhatia	77	39	13	129	1961-1994
2	N.Gupta	1	-	-	1	1961-1961
3	M.S.Swaminathan	5	-	-	5	1961-1963
4	D.Jagathesan	1	-	-	1	1962-1962
5	J.A.M.Brown	-	1	-	1	1965-1965
6	K.R. Narayanan	3	-	-	3	1965-1990
7	J.Sybenga	1	-	-	1	1965-1965
8	J.H.van der Veen	-	1	-	1	1965-1965
9	H.H.Smith	3	1	-	4	1966-1967
10	M.Buiatti	1	-	-	1	1967-1967
11	G.E.Hart	1	-	-	1	1967-1967
12	J.P.Nilson	1	-	-	1	1969-1969
13	S.Bhattacharya	1	-	-	1	1970-1970
14	D.R.Jagannath	3	1	-	4	1970-1971
15	R.Mitra	15	13	5	33	1970-1993
16	A.R.Gopal-Ayengar	2	1	-	3	1971-1971
17	A.S.Khalatkar	4	1	-	5	1971-1977
18	B.N.Irani	1	-	-	1	1972-1972
19	R.M.Desai	2	2	-	4	1975-1979
20	A.Micke	-	1	-	1	1975-1975
21	P.Narahari	1	3	-	4	1975-1979
22	R.Rabson	3	2	1	6	1975-1987
23	T.G.Krishna	7	4	-	11	1976-1994
24	Helga Axman	2	-	-	2	1977-1979
25	A..Brunori	-	1	-	1	1977-1977
26	C.J.Driscoll	-	-	1	1	1977-1977
27	A.Hagberg	-	-	1	1	1977-1977
28	T.Hermelin	1	1	-	2	1977-1979
29	H.Pershke	2	-	-	2	1977-1979
30	K.N.Suseelan	6	1	1	8	1977-1989
31	S.G.Bhagwat	5	4	-	9	1979-1994
32	D.C.Joshua	3	5	1	9	1979-1991
33	S.E.Pawar	5	7	-	12	1979-1994
34	M.V.P.Rao	3	-	-	3	1979-1986
35	R.G.Thakare	-	6	-	6	1979-1991
36	Susan Eapen	2	-	-	2	1982-1986
37	I.N.Rao	1	-	-	1	1982-1982
38	V.Abraham	2	2	-	4	1983-1994
39	N.K.Notani	2	2	-	4	1984-1987
40	D.M.Kale	-	2	-	2	1985-1991
41	Helena Mathews	10	1	2	13	1985-1990
42	Chandra Mouli	-	1	-	1	1985-1985
43	G.S.S.Murty	2	3	-	5	1985-1990
44	P.S.Rao	6	-	-	6	1985-1990
45	Anjali Bhagwat	2	2	1	5	1986-1993

46	N.S.Rao	-	1		1	1986-1986
47	Patricia Viegas	2	1	-	3	1986-1987
48	K.P.Mishra	1	-	-	1	1987-1987
49	K.S.Reddy	3	1	-	4	1987-1994
50	Leela George	1	-	-	1	1988-1988
51	V.T.Srinivasan	1	-	-	1	1988-1988
52	G.J.Chintalwar	1	-	-	1	1989-1989
53	R.N.Pandey	1	-	-	1	1989-1989
54	N.Bharathan	2	-	-	2	1990-1990
55	J.D.Gadgil	-	2	-	2	1990-1991
56	R.E.Litz	2	-	-	2	1990-1990
57	R.Chandra	1	-	-	1	1993-1993
58	R.Rao	1	-	-	1	1993-1993
59	S.E.Saxena	1	-	-	1	1993-1993
60	P.Thomas	1	-	-	1	1993-1993
61	Sangeeta Godbole	2	-	-	2	1994-1994
Total		207	113	26	346	

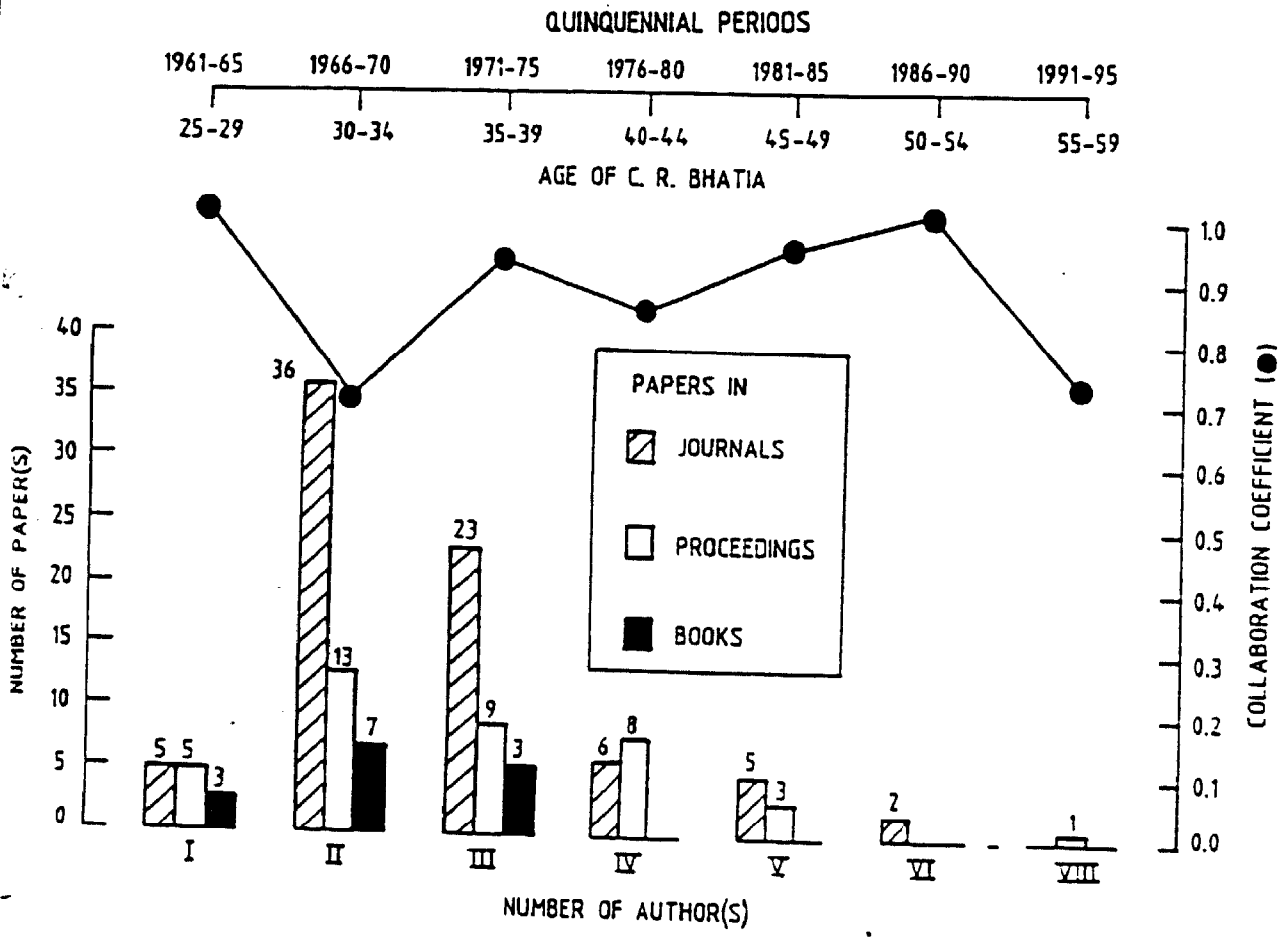
J = Journal, P = Proceedings, B = Books, TA = Total authorship,
FPY = First paper year, and LPY = Last paper year.

Table 4: Authorship Position of C.R.Bhatia

No. of Authors	No. of Papers	I	II	III	IV	V	VI
Journal Papers (77)							
One	(5)	5	-	-	-	-	-
Two	(36)	11	25	-	-	-	-
Three	(23)	5	3	15	-	-	-
Four	(6)	-	-	2	4	-	-
Five	(5)	1	2	-	-	2	-
Six	(2)	-	-	-	-	-	2
Proceedings of Symposia (39)							
One	(5)	5	-	-	-	-	-
Two	(13)	4	9	-	-	-	-
Three	(9)	3	2	4	-	-	-
Four	(8)	3	1	-	4	-	-
Five	(3)	1	-	-	-	2	-
Eight	(1)	-	1	-	-	-	-
Chapters in books (13)							
One	(3)	-	-	-	-	-	-
Two	(7)	4	3	-	-	-	-
Three	(3)	2	1	-	-	-	-
Total	(129)	47	47	21	8	4	2

I= First author, II= Second author, —and VI= Sixth

Figure 2: Authorship Pattern in Various Channels and Quinquennial Collaboration Coefficients in Publications of C.R. Bhatia



I = Single authored papers, II = Two-authored papers, ...VIII = Eight authored papers

Research Collaboration

Collaboration coefficient trend (Fig. 2) computed on five-year basis ranges between 0.7 and 1.0 which clearly indicates that consistently the scientist collaborated with others in his research activities which is considered a positive aspect of leadership in science. Decadewise collaboration coefficients are: 1961-70 (0.84), 1971-80 (0.88), and 1981-90 (0.98) which correspond to his age 25-34, 35-44, and 45-54. During 1991-94 collaboration coefficient declined to 0.73.

During the period under consideration he collaborated with 60 other scientists (Table 3). Authorship credits distribution as per channels of communication is found to be as follows: 207 credits goes to 50 authors publishing in journals, 113 credits to 31 authors publishing in proceedings; and 26 credits to nine authors contributing chapters in books. Authorship credits to all collaborators in chronological order of the first paper published corresponding with age of C.R. Bhatia are depicted in Fig. 3.

R. Mitra, Helena Mathews, S.E. Pawar, and T.G. Krishna were the main collaborators (Active researchers) with 33, 13, 12, and 11 joint publications respectively. S.G.Bhagwat, D.C. Joshua, and K.N. Suseelan each have 9, 9, and 8 papers respectively. He has been the mentor to his research group and played a pivotal role by nurturing and tapping best capabilities in every member of his team. Mutually beneficial relationships result in synergy.

Authorship Position in Collaborative Publications

The position of C.R. Bhatia as the first, second, third, fourth, fifth, and sixth author was in 47, 47, 21, 8, 4, and 2 papers respectively (Table 4). He was not the first author in 65 out of 116 collaborative publications. The names of the first authors in publications are summarized in Table 5. R. Mitra was the first author in 13 papers. Collaboration is a typical research style associated with professionalism.

International Collaborators

C.R. Bhatia collaborated with scientists from Austria (Axman and Perschke); Australia (Driscoll); Germany (Micke); Italy (Brunori and Buiatti); Japan (Sasaki and Yano); The Netherlands (van der Veen and Sybenga); Sweden (Hagberg and Hermelin); and USA (Hart, Nilson, Rabson, and Smith). Needless to say, International contacts are but a common factor in the domain of scientific research.

Indian Collaborators

Indian scientists who collaborated with C.R. Bhatia came from different states within the country e.g.: Andhra Pradesh (Murty, Narahari, N.S. Rao, R. Rao and Reddy); Delhi (Gupta and Mohan); Karnataka (Gopal-Ayengar, Krishna, P.S. Rao and M.V.P.Rao); Maharashtra (Anjali Bhagwat, Suresh Bhagwat, Desai, Gadgil, Godbole, Kale, Khalatkar, Pawar, Thakare, and Viegas); Tamil Nadu (Jagathesan, Jagannathan, Narayanan, and Swaminathan); and West Bengal (Bhattacharya and Mitra). This is an indicator of

Figure 3: Authorship Credits to Researchers in Chronological Order

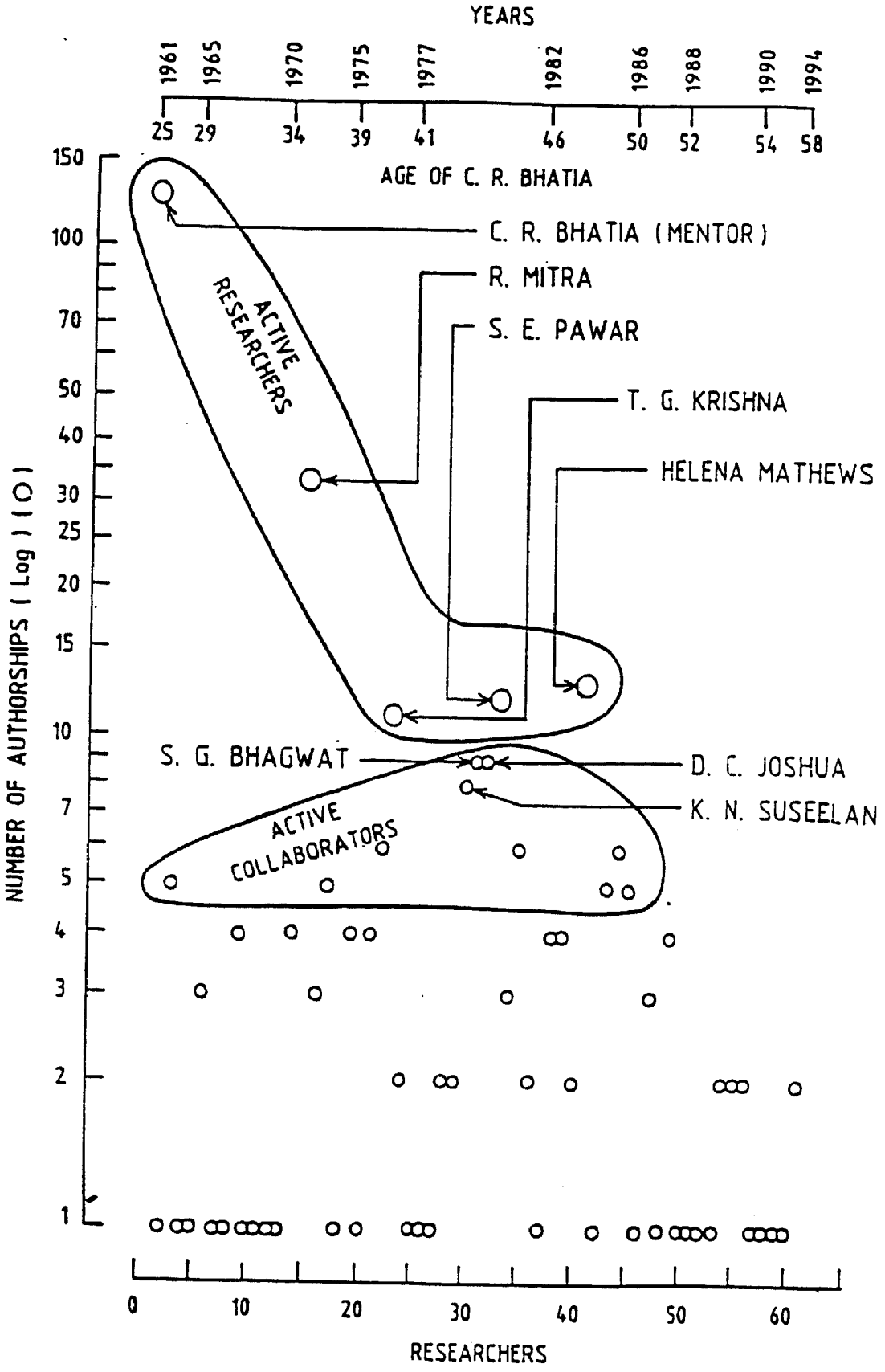


Table 5: First authors in collaborative papers with C.R. Bhatia

Name of the scientist (number of papers as first author)
Journal papers
With two authors (36): C.R. Bhatia (11); R. Mitra (6); S.G. Bhagwat(3); R.M. Desai, D.R. Jagannath, D.C. Joshua, A.S. Khalatkar, and T.G. Krishna (2 each); and V. Abraham, S. Bhattacharya, G.E. Hart, B.N. Irani, G.S.S. Murty, and S.E. Pawar (1 each)
With three authors (23): C.R. Bhatia (5); K.S.Reddy and K.N. Suseelan (3 each); A.S. Khalatkar, Helena Mathews, R. Mitra, and Sangeeta Godbole (2 each); S.G. Bhagwat, T.G. Krishna, K.P. Mishra, and D. Jagannathan (1 each)
With four authors (6): K.N. Suseelan (2); V. Abraham, R. Mitra, R.N. Pandey, and Patricia Viegas (1 each)
With five authors (5): C.R. Bhatia, Susan Eapen, Helena Mathews, M.V.P. Rao, and P. Thomas (1 each)
With six authors (2): Helena Mathews (2)
Proceedings of symposia papers
With two authors (13): C.R. Bhatia (4); R. Mitra (2); V. Abraham, S.G. Bhagwat, A.S. Khalatkar, A. Micke, P. Narahari, N.K. Notani, and R. Rabson (1 each)
With three authors (9): C.R. Bhatia (3), J.A.M. Brown, R. Brunori, G.S.S. Murty, R. Mitra, S.E. Pawar, and R. Rabson (1 each)
With four authors (8): C.R. Bhatia (3); D.C. Joshua, T.G. Krishna, G.S.S. Murty, P. Narahari, and S.E. Pawar (1 each)
With five authors (3): C.R. Bhatia; S.E. Pawar and R.G. Thakare (1 each)
With eight authors (1): S.G. Bhagwat (1)
Chapters in books
with two authors (7): C.R. Bhatia (3); R. Mitra (1); Anjali Bhagwat, and K.N. Suseelan (1 each).
with three authors (3): C.R. Bhatia (2), and A. Hagberg (1)

his pleasant personality to attract talents without any regional or language bias.

Collaboration with Women Scientists

Seven women scientists (Helga Axman, Anjali Bhagwat, Shakuntala Bhattacharya, Susan Eapen, Leela George, Sangeeta Godbole, Helena Mathews, and Patricia Viegas) collaborated with C.R. Bhatia which account for 14 percent of all the scientific collaborators. This is expected since not many women scientists opt for research career in plant breeding.

Publication Scattering

Channels of communication used by C.R. Bhatia to disseminate his research results are listed in Table 6. In all 82 titles of channels of communication has been used by the researcher for his 129 papers, of which 37 are journals accounting for 77 papers, and 33 are symposia proceedings publishing 39 papers. He has published 13 invited contributions as chapters in 12 books. Many of these books are published by well reputed publishers such as the American Society of Agronomy, CRC Press, Wiley-Eastern, Martinus Nijhoff, and Elsevier.

Publication density is found to be 1.57and publication concentration 24.4%. Among the journal papers seven were published in *Mutation Research*, six in *Theoretical and Applied Genetics*, five each in *Euphytica*, *Journal of Plant Breeding*, and *Proceedings of the Indian Academy of Science*. *Mutation Research*, *Theoretical and Applied Genetics*, and *Euphytica* are the core international journals in the area of mutation research and plant genetics and breeding. Journalwise scattering of publications, however, should be viewed considering the fact that the journals with page charges are not accessible to the Indian authors due to lack of funds.

Bibliographic Features

On an average 19 references were found per paper. Mean synchronous self-citation rate is 0.5 percent. Low self-citation rate indicates his research is in the mainstream. This also indicates that the researcher is productive, a key figure in his speciality and has kept himself abreast of publications by other scientists in his field.

The number of pages on an average for single-authored papers varied with the communication channels. Papers in journals averaged 4 pages, followed by proceedings 8 pages, and books 18 pages. The respective figures for multi-authored papers are ; 6, 9, and 17, which are quite similar to single-authored papers.

Key words used in the titles of the papers of C.R. Bhatia having high frequency are wheat (39); protein(s) (29); induced mutations (19); plant(s) (15), seeds (13); yield (12); bioenergetics (10); improvement (10); chromosome (9); genetics (9); variation (8); breeding (7); crops (7); ethyl methanesulfonate (7); and selection (7); gene(s), isoenzyme(s), legume(s) and mutagenic(ity) (six each) which reflect the main areas of his research interest.

Among the crops, the most frequent key words in titles are wheat (39), *Brassica juncea* or mustard (10), *Cajanus cajan* or pigeonpea (9), *Vigna radiata* or mung-

Table 6. Channels of communication used by C.R. Bhatia

No	Channel	No. of Papers	Cumulative Papers	Period FPY-LPY
1	Mutation Research	7	7	1965-1977
2	Theoretical and Applied Genetics	6	13	1972-1994
3	Euphytica	5	18	1961-1982
4	Plant Breeding (Z.Pflanzenzuchtung)	5	23	1962-1994
5	Proceedings Indian Academy of Sciences (Plant Sciences)	5	28	1986-1989
6	Cereal Research Communications	4	32	1977-1994
7	Journal of Genetics	3	35	1986-1991
8	Plant Science	3	38	1985-1990
9	Seed Protein Improvement by Nuclear Techniques (Proceedings)	3	41	1977-1977
10	Proceedings Plant Mutation Breeding for Crop Improvement	3	44	1991-1991
11	Biochemical Genetics	2	46	1969-1987
12	Current Science	2	48	1987-1989
13	Genetica	2	50	1963-1972
14	Heredity	2	52	1973-1982
15	Indian Journal of Genetics	2	54	1986-1993
16	Journal of Science Food and Agriculture	2	56	1994-1994
17	Nature	2	58	1961-1966
18	Phytochemistry	2	60	1970-1985
19	Proceedings Indian National Science Academy	2	62	1990-1993
20	Radiation Botany	2	64	1967-1975
21	Cereal Grain Protein Improvement (Proc)	2	66	1984-1984
22	Mutation Breeding of Oilseed Crops (Proc)	2	68	1990-1990
23	Manual of Utation Breeding (Chapter)	2	70	1977-1977
24-42	Papers in journals one each	19	89	1965-1993
43-71	Papers in proceedings one each	29	118	1965-1991
72-82	Chapters in book one each	11	129	1977-1994

FPY = First paper year, and LPY = Last paper year.

Table 7: Distribution of publications in various domains and channels

No	Domains	Journals	Proceeding	Books	Total
1	Induced mutations and mutation breeding	15	13	2	30
2	Seed proteins	8	13	4	25
3	Biotechnology	10	7	4	21
4	Biochemical genetics	18	1	1	20
5	General	12	-	1	13
6	Bioenergetics	7	2	1	10
7	Plant breeding	7	3	-	10

bean (6), barley (4), rice, sesame, and tobacco (3 each), *Crotalaria intermedia* (2), *Sesbania rostrata* (2), and among the non-crop plants was the model plant *Arabidopsis thaliana* (5).

Content Analysis

The main objective of the research was to bring practical benefits of the induced genetic variation to the farmers. The main domains (Table 7) of research communications indicate maximum publications in induced mutations and mutation breeding (30), followed by seed proteins (25), biotechnology (21), biochemical genetics (20), and plant breeding, and bioenergetics 10 each.

DISCUSSION

Studies on individual role model scientists in developing countries are not carried out because of unorganized efforts and lack of funds. However, role model scientists may not be totally lacking in the developing countries as is evident in the present case.

Most agricultural research organizations are hierarchical in nature, where superior scientists and team leaders have a crucial role to play in motivating their subordinates and junior scientists. The superiors' concern and leadership styles are important in managing motivation in such organizations (Mehta, 1997). Implications for supervisors of scientific staff include reducing the layers of hierarchy and empowering staff by giving them a voice in research goals and organizational operations. (Mulford, et. al., 1993). Promoting extrinsic and intrinsic motivations may result in harnessing of expertise and creativity at all hierarchical levels. Satisfaction of having achieved projected targets may sustain further creativity through optimum performance (Kalyane and Kalyane, 1996). Creativity is required at all stages in innovation chain leading to the development and introduction of new products, processes and services. Crea-

tivity represents the birth of ideas, and innovation is the process by which those ideas reach fruition (Bamfield, 1996).

C.R. Bhatia organized an excellent team which not only contributed to the development of new crop varieties but at the same time resulted in a large number of papers in joint authorship which were published in reputed international plant breeding, genetics, and plant science journals.

Though C.R. Bhatia worked mainly at BARC, a nuclear research centre, which does not have an extension wing like the other agricultural research centers. However, through their own efforts, the team could establish collaborative programmes with the Agricultural Universities, State Seed Corporations, and State Departments of Agriculture for seed production and distribution of the new varieties. The role of the Indian Council of Agricultural Research in testing of the new varieties in All India Coordinated Research Project trials also played a significant role. Thus, the balance of introvert and extrovert behaviours is most important in success of a scientific career.

Diffusion of the technology (seeds of new crop varieties) was brought about by participating in farmer fairs (*Kisan melas*), other exhibitions, and disseminating information through pamphlets in the local language. Thus, science was communicated at different levels and languages appropriate for the audience.

CONCLUSIONS

C. R. Bhatia has established himself as a leader in the induced mutation breeding programmes of locally important crop plants. He has gained the status of a mentor in this area by contributing to human resource development not only in India but also in other developing countries of Asia and Africa. His research has contributed to increased productivity of the crops to benefit the farmers. His success is attri-buted to well focused research programmes and team efforts aiming at the development of new crop cultivars and generating new basic knowledge and concepts.

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