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Scientometric profile of Indian scientific output in life sciences with a focus on the contributions of women scientists

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Abstracts An analysis of 9,957 papers published by Indian scientists and indexed by WoS in 12 sub-disciplines of life sciences during 2008–2009 indicates that academic institutions produced the highest number of papers. Of these, 340 (3.4 %) were contributed by female scientists exclusively and 4,671 (47 %) were written jointly by male and female scientists. Women scientists produced about 0.36 papers per author, while their male counter parts produced 0.50 papers per author. Significant number of women scientists was first author and about 23 % were corresponding authors in papers written jointly by both sexes. Women scientists emphasized on the sub-discipline of cell biology and reproductive biology and male scientists emphasized on the sub-discipline of zoology. Women scientists work in small teams and have very less international collaborative papers. Women scientists publish in low impact factor and domestic journals and also are cited less as compared to their male counter parts.

Keywords Scientific productivity · Scientometrics · Gender studies · Women studies · India

Introduction

Female constitutes almost half (49 %) of India's total population. Since independence, the enrolment of women in science at graduation and post graduation levels has improved

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considerably and can be considered as an important indicator of social progress in India. Although, women have earned 37 % of all science PhDs awarded by Indian institutions, the ratio of women scientists entering the workforce is still very less and women constitute only 15 % of the total manpower engaged in R&D in science and technology (Department of Science and Technology, India). Women faculty is a miniscule 7 % at prestigious institutes like Indian Institute of Science and the Indian Institutes of Technology (Indian National Science Academy 2004). The proportion of women as fellows of Indian National Science Academy and winners of the prestigious Shanti Swarup Bhatnagar Prize awarded by the Council of Scientific and Industrial Research (CSIR) is a mere 3 % (Gupta and Sharma 2002; Telegraph India). However, the status of women in science and their contributions to science has received considerable attention recently. The Department of Science and Technology of the Government of India has started several programmes for the promotion of women in science.

Several studies dealing with bibliometric assessment of Indian science have been published in the last two decades (Garg and Dutt 1992; Arunachalam et al. 1998; Garg et al. 2006; Gupta and Dhawan 2009). Yet, to date, no study has examined the contributions of Indian female scientists that compare their productivity with their male counter parts at the national level. However Gupta et al. (1999), studied the productivity of male and female scientists of CSIR using Lotka's law and observed no significant difference between the productivity of male and female researchers. The methodology used by Gupta et al. (1999) was similar to one used by Lemoine (1992) on the productivity pattern of male and female scientists in Venezuela. Goel (2002) studied the publication productivity of Indian male and female researchers in psychology and found that the females were far behind than males in publishing research papers. Recently Bal (2005) examined 669 publications indexed by Pub Med during January 1994–April 2004 to study the scientific productivity of female biologists and found that women contributed 15 % of all publications. Also, a study by Hasan et al. (2012) found no significant difference in the contributions made by the male and female research scholars of CSIR.

Understanding the female contributions to scientific productivity at national or institutional level is an important issue for policy makers in science and higher education. For this, it is important to promote and monitor women's contribution in different fields of science and technology. The present study attempts to analyze the contributions of Indian women scientists to the Indian scholarly output and its impact using the publication and citation data in the 12 sub-disciplines of life sciences in journals indexed by *Web of Science (WoS)* database of Thomson Reuters for 2008–2009. The field of life sciences was chosen because several studies indicate that women have passed a threshold in the field of biology (Long 1993) and secondly, many more women are found in the field of biological sciences than in physics, chemistry or mathematics (Bal 2005; Webster 2001).

Methodology

The source of data for the present bibliometric study is Thomson Reuters WoS which annually indexes articles available in more than 8,000 science and technology journals published from different parts of the world. The most difficult task of any bibliometric study on gender productivity is the identification of the gender/sex of the authors of the papers, since publications and bibliographic databases do not provide information on the gender of authors and only include the initials of the author names and not their full names. However, WoS started giving full names of the authors in 2007, before which it was providing only initials and surnames of the authors. Authors downloaded all articles published by Indian authors from the WoS for the years 2008–2009 in the last week of December 2011. From these downloaded records, authors culled out 9,957 items that belonged to 12 sub-disciplines of life sciences. The data so downloaded was converted into Fox-Pro database for ease of analysis. Each downloaded record was scanned to identify the name of female scientists and was the most time consuming exercise. Similar methodology has also been used by Naldi et al. (2004) to identify names of authors and inventors to sort the data by gender.

The downloaded data included name of all authors with their affiliations, name of the journal with its place of publication, sub-discipline of the paper, and type of publications. The data was later enriched with the impact factor of the journals, performing sector to which the institution belonged (academic, research agency, or private) and the type of collaboration i.e. domestic and international. Authors have used the method of complete counting in which each author was given a unit weight for their contributions. After sorting the data by gender, authors identified papers exclusively authored by female scientists, male scientists, and joint contribution of both sexes.

Review of literature

During the last two decades, several researchers from different countries have studied the performance of female researchers in relation to their male counterparts in different fields of science and technology. For instance (Lewison 2001), using ISI data showed that there has been a rise in female output from 8 to 30 % from 1980 to 2000 in Iceland and there is little difference in the citations to male-authored versus female-authored papers. The scientific impact of research using impact factor of journals for three groups of Spanish researchers was estimated by Bordons et al. (2003). She found similar impacts between men’s and women’s work in two of the three disciplines examined. The Brazilian female contributions in scientific production in the three fields of immunology, oceanology, and astronomy in terms of quality and quantity using WoS 1997–2001 was examined by Leta (2003). She found that men and women published similar number of papers and they were also of similar potential impact. Mauleón and Bordons (2006) made a comparative assessment of scientific performance of male and female scientists in the area of material science at the Spanish Council of Scientific Research (CSIC) and found that women are less productive than men. Moya-Anegón et al. (2007) examined volume of production, visibility, patterns of collaboration and networks of co-authorship in different fields in Spain using WoS 2004 and found that women scientists publish more in national journals. Muñoz-Muñoz (2005) studied the scholarly output produced by female lecturers at the University of Granada (Spain) from 1975 to 1990 and found that a third of the journal articles were produced by women teachers at the university. Mozaffarian and Jamali (2008) explored the gender distribution of Iranian authors in ISI indexed journals in different subject areas and found that women’s contribution was much less than men. Abramo et al. (2009) compared the sex differences in research efficiency of star scientists with rest of the academic population in Italy which support the theme that women are less productive than men. Arruda et al. (2009) compared proportion of published articles from Brazilian female researchers in relation to male researchers in the field of computer science and found that women concentrate less on hardware and network research. How female patenting activities differ from men’s in the US biotechnology industry was studied by (Mc Millan 2009). He found that men dominate the patenting activity with only 4 % of the patents being filed by women alone. Borrego et al. (2010) examined scientific output and impact of 731 male and female PhD holders who were awarded their doctorate at Spanish universities between 1990 and 2002 and found no significant differences in the amount of scientific output between males and females and also articles by female PhD holders were cited significantly more often, even when self citations were excluded. Lariviere et al. (2011) analyzed the correlations between sex and research funding, publication rate, as well as scientific impact at the University of Quebec (Canada) and found that women are less productive than men and also get slightly less citations than men. Pudovkin et al. (2012) in an exercise performed on 313 papers published by DRFZ (Germany) also found that male scientists are more prolific and cited more often than female scientists. Vela et al. (2012) undertook a study of female participation in 12 leading software journals as authors, editorial board members, associate editors, and editors-in-chief over a period of 2 years and found that women are not under represented as editorial board members and editors-in-chief, although their representation as editors-in-chief is low. Sotudeh and Khoshian (2013) studied performance of male and female scientists in terms of their output and impact in the discipline of nano science and technology and found that women perform equally well as their men counter parts in terms of output and impact.

Based on the above review of literature, the studies on gender and productivity can be classified into two categories. One that support the theme that male researchers publish more than women and obtain fewer citations than those of their male counter parts (Prpic 2002; Mauleón and Bordons 2006; Penas and Willett 2006; Mozaffarian and Jamali 2008; Abramo et al. 2009; Lariviere et al. 2011; Pudovkin et al. 2012). However, some researchers (Lewison 2001; Leta 2003; Ledin et al. 2007) differ with this view point and argue that there exist no significant difference in impact between men and women. On the other hand some researchers are of the view that females produce higher quality research compared to their male counterparts (Symonds et al. 2006). Various studies have attempted to probe the reasons for this differential (Hunter and Leahey 2010; Fox 2005).

Objectives

The focus of the present study is on the following aspects:

- Relative productivity of female and male scientists, to identify the relative position of women scientists in the sequence of authors in papers written jointly by female and male scientists and also to determine how often female scientists sign first and act as corresponding author when they work in a team;
- To identify different scientific fields in life sciences where female scientists concentrate;
- To study co-authorship and collaboration pattern in publications to understand how the team size varies for different genders;
- Impact of the scientific output as judged by publishing country of journals, their impact factor, and the pattern of citations obtained by the research output.

Results and discussion

During 2008–2009 WoS indexed 86,266 articles published from India. Of these, 9,957 (11.5 %) were in 12 sub-disciplines of life sciences. These articles were authored by

21,581 authors, of which 5,545 (25.7 %) were female scientists and the rest 74.3 % were male scientists. Female scientists exclusively authored 340 (3.4 %) articles while male scientists authored 4,946 (49.6 %) articles and the number of papers authored by both sexes was 4,671 (47 %). An analysis of data by type of documents indicates that out of 9,957 articles ~94 % were published as journal articles and reviews.

Since independence India has developed a vast infrastructure for science and technology. Several agencies are involved in scientific research in India. These are universities and institutes of higher learning like Indian Institutes of Technology (IITs), and medical colleges and hospital. Besides these, government funded laboratories under the aegis of different performing sectors like the Council of Scientific and Industrial Research (CSIR), Department of Atomic Energy (DAE), Department of Science and Technology (DST), Department of Biotechnology (DBT), Defense Research and Development Organization (DRDO), Indian Council of Agriculture Research (ICAR), and Indian Council of Medical Research (ICMR) etc. Data on the distribution of scientific output according to different performing sectors indicates that academic institutions (universities and colleges) are the highest contributors (~46 %) to the total output in life sciences followed by medical colleges/hospitals (15.6 %) and the CSIR (14.6 %). These three together contributed about three-forth of the total scientific output in life sciences and the remaining one-fourth of the output came from other scientific agencies named above. The total output came from 1,872 institutions located in different parts of the country. Of these 30 institutions contributed 4,368 (44 %) of the total output in life sciences. These prolific institutions belonged to academic institutions (10), CSIR (7), medical colleges/hospitals (4), DAE, ICAR, ITTs (2 each) and ICMR and DST (1 each). One was an international institution which was located in India.

Relative productivity and relative position of women scientists

In order to gain an accurate estimate of females' contribution, authors calculated the sum of the females' fractional contribution in the total Indian output. To do this, authors multiplied each female fraction by the number of articles in that category. For example, there are 737 articles in the category of 1/3 female fraction (Table 1), which means that there are three authors per article and only one of them is a female. Based on this, women's fractional contribution is 245.7 articles out of 737 ($1/3 \times 737 = 245.7$). Based on this calculation, the sum of the fractional contributions for women is 1,974 articles, which is about 20 % of total Indian output in life sciences including articles exclusively written by women scientists. The remaining 80 % of the contributions were made by men. Article per author share as a measure of productivity at the individual level for women scientists is $1{,}974/5{,}547 = 0.36$ and for men it is $7{,}983/16{,}036 = 0.50$ (approximately). This indicates that the productivity of female scientists at the individual level was slightly less than that of their male counter parts. The finding is similar to Abramo et al. (2009) for their study on the sex differences in research efficiency of star scientists with rest of the academic population in Italy, (Lariviere et al. 2011) for the University of Quebec (Canada), (Mozaffarian and Jamali 2008) for the productivity of women scientists in Iran, (Mauleón and Bordons 2006) for scientific performance of male and female scientists in the discipline of material science at CSIC, Spain and (Pudovkin et al. 2012) for their study on the productivity of scientists at DRFZ (Germany).

The order of appearance of author names on a document is considered useful for determining their importance, as not all positions of author names have the same value. Data was analyzed to identify the position of women scientists in papers jointly authored

Table 1 Ratio of female authors to the total number of authors in total output

(1) Female ratio	(2) No. of papers	(3) 1*2	(4) Female ratio	(5) No. of papers	(6) 4*5	(7) Female ratio	(8) No. of papers	(9) 7*8
1/1	42	42.0	3/3	63	63.0	5/5	12	12.0
1/2	677	338.5	3/4	98	73.5	5/6	6	5.0
1/3	737	245.7	3/5	104	62.4	5/7	4	2.7
1/4	607	151.8	3/6	64	32.0	5/8	5	3.1
1/5	359	71.8	3/7	40	17.1	5/9	5	2.8
1/6	211	35.2	3/8	36	13.5	5/10	8	4.0
1/7	146	20.9	3/9	27	9.0	6/6	1	1.0
1/8	77	9.6	3/10	43	12.9	6/7	3	2.6
1/9	46	5.1	4/4	14	14.0	6/8	5	3.8
1/10	89	8.9	4/5	26	20.8	6/9	2	1.3
2/2	206	206.0	4/6	28	18.7	6/10	6	3.6
2/3	288	192.0	4/7	20	11.4	7/7	2	2.0
2/4	288	144.0	4/8	17	8.5	7/10	1	0.7
2/5	204	81.6	4/9	8	3.6	8/10	1	0.8
2/6	145	48.3	4/10	30	12.0	9/10	1	0.9
2/7	95	27.1	Total of column 3, 6 and 9 = 1,974					
2/8	47	11.8	Article per author by women = 1,974/5,547 = 0.36					
2/9	22	4.9						
2/10	52	10.40						

by both sexes. It Indicate that of all the joint authored papers, women scientists were first author in 85 % papers and in 23 % papers women scientists acted as corresponding author. This implies that women occupy important position in a significant number of papers.

Activity profile by gender

Based on the journal classification used by WoS the publication output was classified into 12 sub-fields of life sciences. Using activity index (AI) (Schubert and Braun 1986) authors identified the fields of relative research effort, a particular gender devotes to a given sub-field. Here AI has been applied in a modified way and is explained below.

$$\text{Mathematically, AI} = \left\{\left(N_{ij}/N_{io}\right)/\left(N_{oj}/N_{oo}\right)\right\} \times 100,$$

where

N_{ij} total number of publications of a particular gender i in discipline j;
N_{io} total number of publications of gender i in all the disciplines;
N_{oj} total number of publications of all genders in discipline j;
N_{oo} total number of publications of all genders in all disciplines

The data on absolute output and AI by gender is presented in Table 2. It indicates that different genders emphasized on different sub-fields. For instance, women scientists were most active in the sub-field of reproductive biology followed by cell biology. Female scientists had very low activity in the subfield of virology, biochemical research methods and evolutionary biology. The activity index of male scientists was highest in the sub-field of zoology and evolutionary biology. Male/female scientist's activity was highest in the sub-field of cell & tissue engineering as well as virology and lowest in the sub-field of zoology.

Pattern of co-authorship among different genders

Co-authorship and collaboration pattern has been calculated to understand how the team size varies for different genders. For this purpose, data has been divided into four categories. These are single authored papers, two authored papers, multi-authored papers (papers with three and four authors) and mega authored papers (papers with more than four authors). Table 3 presents the distribution of output by single, two, multi and mega-authored papers besides the value of the collaborative coefficient (CC) (Ajiferuke et al. 1988) for different type of genders. The average value of CC for India during the period of study is 0.69. The value of CC is lowest for papers written exclusively by female authors and highest for papers jointly authored by both sexes. It implies that women scientists work in small teams which imply that women scientists have a lesser tendency towards co-authorship. This is also indicated by small number of papers for multi and mega authored paper exclusively written by women scientists. Moya-Anegón et al. (2007) in their study on scientific output of Spain also found that women have a lesser tendency towards co-authorship. However, one important point that needs to be mentioned here is that women are co-authors with their male colleagues in 47 % of the papers which have been published jointly by both sexes. In few of the papers, the number of female authors is more than male authors (Table 1).

Pattern of domestic and international collaboration among different genders

Of the total 9,957 papers published by different genders, 9,697 (97 %) were published in domestic and international collaboration. Of these, 7,844 (80 %) were produced in

Table 2 Publication output (activity index) by gender

No.	Subject	Publication output (activity index)			Total
		Female	Male	Male/female	
1	Biochemistry & Molecular Biology	86 (97)	1,399 (98)	1,424 (103)	2,909
2	Biotechnology & Applied microbiology	92 (113)	1,328 (101)	1,241 (98)	2,661
3	Immunology	41 (103)	625 (101)	613 (99)	1,306
4	Cell Biology	35 (164)	281 (81)	385 (115)	701
5	Biochemical Research Methods	11 (47)	447 (118)	310 (85)	768
6	Genetics & Heredity	18 (74)	358 (91)	418 (111)	794
7	Virology	3 (36)	109 (80)	163 (124)	275
8	Zoology	5 (68)	174 (147)	61 (53)	240
9	Reproductive Biology	11 (182)	101 (103)	86 (91)	198
10	Developmental Biology	2 (84)	42 (109)	34 (91)	78
11	Evolutionary Biology	1 (50)	44 (135)	21 (67)	66
12	Cell & Tissue Engineering	1 (106)	9 (59)	21 (142)	31
	Total	340	4,946	4,671	9,957

Table 3 Pattern of co-authorship by gender

Type of authorship	Female output	Male output	Male/female output	Total
Single authored papers	42	219	0	261
Two authored papers	206	1,162	673	2,041
Multi-authored papers	77	1,981	2,018	4,076
Mega authored papers	15	1,584	1,980	3,579
Total	340	4,946	4,671	9,957
CC	0.49	0.67	0.73	0.69

domestic collaboration and the rest 17 % in international collaboration. The distribution of papers according to type of collaboration for different type of genders is given in Table 4. The number of papers written in domestic collaboration is more than four times of the number of papers written in international collaboration. One of the possible reasons for high domestic collaboration may be well established facilities available at the premier Indian scientific institutions. Further analysis of the data indicates that the share of internationally co-authored papers written exclusively by female authors is lowest as compared to papers written by male and papers jointly authored by male/female scientists. This indicates that female scientists have very low international linkages as compared to their male counter parts. Several reasons for low international collaboration by women scientists can be seen in Smykla and Zippel (2010).

Impact of research output

In order to determine the scientific impact of articles, authors have used three different indicators. These are the publishing country of journals where the research results were published, impact factor (IF) of these journals, and the number of citations obtained by the published articles. The IF is an indicator of the reputation of the journal. Papers published in journals with higher IF by and large indicate more credit than papers published in journals with low IF. Citation analysis measures the impact of each article by counting the number of times they were cited by other articles. High levels of citations to a scientific publication have been interpreted as signs of scientific influence, impact, and visibility. An author's visibility can be measured through a determination of how often their publications have been cited in other authors' publications.

Table 4 Pattern of collaboration by gender

Type of collaboration	Female output	Male output	Male/female output	Total
Domestic	294	3,607	3,943	7,844
International	7	1,118	728	1,853
Total	301	4,725	4,671	9,697

Distribution of output by publishing country of journals

Indian scientists prefer to publish in international journals published from the advanced countries of the West, as these are of better quality and have a wider readership as compared to domestic journals. Thus, this helps scientists to reach a wider audience. Quite a few prefer to publish in Indian journals, because they feel that international journals are rated too high and it would be difficult for them to reach that level. Also, the prevalent value system in India promotes scientists preference to publish in journals published from abroad. Distribution of output according to publishing country and the gender is given in Table 5. It indicates that Indian scientists published their papers in journals published from 44 different developed and developing countries including India. It also indicates that in all the genders Indian scientists preferred to publish in journals published from the US and about one-third of the total papers were published in journals originated from the US. However, the share of published papers in Indian journals by women scientists was considerably high (26 %) as compared to their male counter parts (16.7 %) as well as joint male/female (14.8 %) papers. Women scientists publish more in national journals have also been observed by Moya-Anegón et al. (2007) in a study of different fields in Spain. Table 8 in Appendix 1 lists journals most commonly used by Indian scientists for publishing their research results.

Distribution of output by range of impact factor and gender

The distribution of output by range of IF and gender is given in Table 6. The analysis indicates that the average impact factor of journals where the Indian scientists published papers is 2.22. Distribution of papers by range of IF indicates that about one-fourth of the total papers appeared in journals whose IF varied between 0 and 1. One of the possible reasons for high number of papers in low IF journals is that a large number of papers have been published in Indian journals as well as in journals published from other developing countries. These journals have a low IF as compared to journals published from the advanced countries of the West. According to gender, the highest proportion (38 %) of papers in this category belonged to female scientists. Also, according to different gender types, the lowest average IF (1.78) was for papers written exclusively by female scientists and highest (2.35) for papers written jointly by male/female scientists. Also, papers published in the highest range of IF (>5), it was lowest for female scientists (2 %) and highest

Table 5 Distribution of papers by publishing country of journals and gender

Journal publishing country	Papers by female (%)	Papers by male (%)	Papers by male/female (%)	Total
USA	97 (28.5)	1,442 (29.0)	1,619 (34.7)	3,158 (31.7)
UK	60 (17.6)	1,190 (24.0)	1,118 (23.9)	2,368 (23.8)
India	88 (25.9)	827 (16.7)	690 (14.8)	1,605 (16.1)
Netherlands	36 (10.6)	501 (10.0)	509 (10.9)	1,046 (10.5)
Germany	13 (3.8)	256 (5.2)	181 (3.8)	450 (4.5)
Ireland	6 (1.7)	59 (1.2)	67 (1.4)	132 (1.4)
Switzerland	6 (1.7)	68 (1.4)	55 (1.2)	129 (1.3)
Other 37 countries	34 (10.0)	603 (12.2)	432 (9.2)	1,069 (10.7)
Total	340 (100)	4,946 (100)	4,671 (100)	9,957 (100)

(6.2 %) for papers jointly authored by male/female scientists. This implies that women scientists published in low IF journals as compared to their male counter parts and papers written jointly by both sexes. This is supported by Lariviere et al. (2011) who in a study for the University of Quebec (Canada) found that men tend to publish in more prestigious journals as compared to their women counter parts.

Distribution of citations by gender

Table 7 presents data on the distribution of papers according to the citations received by the papers under different gender categories. Of the total 9,957 published papers about 33 % papers did not get any citations and the remaining 67 % papers were cited one or more times. Pattern of citations according to gender indicates that of all the papers published exclusively by women scientists about 43 % papers did not get any citation, while for the male and papers jointly authored by male/female, the proportion of papers not being cited was 33 and 31 % respectively. Proportion of papers getting more than 10 but less than 50 citations in different gender categories indicates that it was lowest (2.6 %) for women scientists which are about half of the proportion of male (5.2 %) and joint authored (5.0 %) papers. However, the proportion of papers getting more than 50 citations is slightly higher for women scientists as compared to their male counter parts and joint authored papers. The observation that women get lesser citations than their male counter parts is supported by Penas and Willett (2006). The value of citation per paper (CPP) is also less for papers exclusively written by female scientists.

Findings

In the past only a few studies (Gupta et al. 1999; Bal 2005; Hasan et al. 2012) from India has been published in literature that dealt with the productivity of women scientists. The results of these studies are based on a small data. The present study is based on a large data and is the first study on national level that compares the productivity and impact of women scientists with their male counter parts in the field of life sciences. Following are the salient findings of the study.

- Like any other country, highest number of papers was published as journal articles. Three-forth of the output was concentrated among academic institutions, CSIR and medical colleges/hospitals. The total output came from 1,872 institutions scatted all

Table 6 Distribution of output by range of impact factor and gender

Range of IF	Female No. papers (%)	Male No. papers (%)	Male/female No. papers (%)	Total papers
0–1	129 (38.0)	1,395 (28.2)	1,085 (23.2)	2,609 (26.2)
>1 ≤ 2	77 (22.6)	1,340 (27.1)	1,153 (24.7)	2,570 (25.8)
>2 ≤ 3	71 (21.0)	1,065 (21.5)	1,122 (24.0)	2,258 (22.7)
>3 ≤ 4	30 (8.8)	528 (10.7)	642 (13.7)	1,200 (12.1)
>4 ≤ 5	26 (7.6)	373 (7.5)	378 (8.2)	777 (7.8)
>5	7 (2.0)	245 (5.0)	291 (6.2)	543 (5.4)
Total	340 (100)	4,946 (100)	4,671 (100)	9,957 (100)
Average IF	1.78	2.12	2.35	2.22

Table 7 Pattern of citation of different genders

No. of citations	Female No. of papers (%)	Male No. of papers (%)	Male/female No. of papers (%)	Total papers (%)
0	146 (42.9)	1,651 (33.4)	1,446 (31.0)	3,243 (32.6)
1	61 (17.9)	975 (19.7)	909 (19.5)	1,945 (19.5)
2	53 (15.6)	616 (12.5)	641 (13.7)	1,310 (13.2)
3	22 (6.5)	423 (8.5)	434 (9.3)	879 (8.8)
4	12 (3.5)	274 (5.5)	315 (6.7)	601 (6.1)
5	12 (3.5)	247 (5.0)	232 (4.9)	491(4.9)
6–10	24 (7.1)	495 (10.0)	456 (9.8)	975 (9.8)
11–50	9 (2.6)	254 (5.2)	233 (5.0)	496 (5.0)
>50	1 (0.3)	11 (0.2)	5 (0.1)	17 (0.2)
Total	340	4,946	4,671	9,957
CPP	2.2	2.9	2.9	2.9

over India. However, the output was concentrated among 30 institutions, which produced about 44 % of the total output. Of the total authors who contributed these articles a significant number (25 %) were women scientists.

- Of the total scientific articles published by Indian scientists in the discipline of life sciences, about 20 % were authored by female scientists including about 3.4 % exclusively authored by female scientists. The study indicates that women scientists published about 0.36 articles per author and male scientists published 0.50 articles per author. Thus, the study supports the theme that women scientists are less productive than male scientists.
- With regard to distribution of output by sub-disciplines, it is observed that women scientists concentrate in the sub-disciplines of reproductive biology and cell biology. The sub-disciplines where women scientists concentrate less are virology, biochemical research methods and evolutionary biology.
- Out of all the co-authored papers, the ones authored solely by women are about 3.4 %, a very low figure in comparison with the 47 % represented by only male co-authorship. However, 47 % of the total output has at least one or more female author(s).
- In the papers jointly authored by male/female scientists, women scientists were first author in 85 % papers and in 23 % women scientists acted as corresponding authors.
- Women scientists work in small teams as compared to their male counter parts.
- Of the total papers published by Indian scientists 17 % were written in international collaboration and the rest in domestic collaboration. For women scientists the share of internationally co-authored papers is very small.
- The impact of research as seen by pattern of publishing country of the journals indicates that women scientists preferred to publish more in domestic journals as compared to their male counter parts.
- The women scientists publish in low impact factor journals and also get fewer citations than those of their male counter parts. CPP is also low for papers exclusively written by women scientists.

Appendix 1

See Table 8

Table 8 Journals most commonly used by Indian scientists

No.	Commonly used journal (more than 100 papers)	Publishing country	No. of papers	Impact factor
1.	Indian Journal of Medical Research	India	320	1.516
2.	Bio Resource Technology	UK	283	4.253
3.	Indian Journal of Experimental Biology	India	211	0.550
4.	African Journal of Biotechnology	Nigeria	185	0.565
5.	Indian Journal of Medical Microbiology	India	184	0.370
6.	World Journal of Microbiology & Biotechnology	USA	153	1.082
7.	Indian Journal of Biotechnology	India	139	0.550
8.	Research Journal of Biotechnology	India	137	0.174
9.	Chromatographia	Germany	136	1.098
10.	PLoS One	USA	126	4.351
11.	Indian Journal of Genetics and Plant Breeding	India	123	0.000

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