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Plant genetics and breeding research: Scientometric profile of selected countries with special reference to India

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Analysis of 32,574 papers published by USA, UK, China, India and Brazil in the field of 'plant genetics and breeding' research during 2005-2009 indicates that USA produced the highest number of publications followed by China. The impact of research output as seen by the values of different impact indicators is highest for UK. The sub-domains of emphasis of research shifted in 2009 as compared to 2005 for all countries. India contributed about 9 percent to the world publication output. Indian output formed a part of the mainstream science as seen by the pattern of publication and citation of the research output. The total Indian output originated from 1,806 institutions located in different parts of the country. About 41 percent of the total Indian output was concentrated among 23 institutions. Among the institutions, international institutes located in India had the highest impact. The proportion of single authored papers has decreased considerably and the share of internationally co-authored papers has remained almost steady during the period of study.

Introduction

Agriculture is central to the economies of most developing countries, as it represents the means of livelihood of a substantial proportion of their population. In India alone, nearly 650 million people are dependent on agriculture or related activities representing about two-third of India's population. Agriculture and allied sectors contribute nearly 25 per cent of Gross Domestic Production (GDP). According to a policy brief by Beintema and others[1], "India invested considerably in its public agricultural research system during the past two decades and ranked fourth in terms of total investments in public agricultural R&D in the world, following United States, Japan and China. Public spending in agricultural R&D in India, in inflation adjusted terms, grew substantially during 1991–2003 at an average rate of 6.4 percent per year".

Plant genetics and breeding is one of the major research areas in the field of agricultural sciences in India. It utilizes vast array of techniques and methodologies related to breeding, cytogenetics, genomics, molecular biology, transgenics, tissue culture etc. This involves genetics and breeding research on several commodities like cereals (rice, wheat, maize etc.), pulses (chickpea, pigeon pea, mungbean, lentil etc.), oilseeds (rapeseed, , sunflower etc.), fruit crops, vegetables, spices, flowers and many industrial crops. The main purpose is to evolve or develop suitable varieties or ideal genotypes which can out yield the existing varieties and is resistant/tolerant to biotic and abiotic stresses using natural or created variability through conventional or marker assisted selection or transgenic approach. The research in this field of knowledge will help to feed well the burgeoning Indian population as well as gain stand in export market for India.

The current study presents a scientometric profile of 'plant genetics and breeding' research in India. It compares the relative position of India vis-à-vis other developing and developed countries during 2005 – 2009 based on data obtained from Web of Science. USA and UK have been taken as representatives of developed nations, while India, China and Brazil as representatives of growing economies.

Objectives of the study

- To identify the pattern of research output for USA, UK, China, India and Brazil during 2005-2009;
- To find out the impact of the research output of the above mentioned countries using different bibliometric indicators; and
- To present the shift in emphasis of the sub-domains of research for each country in 2009 as compared to 2005 using an analysis of the keywords.

Methodology

The study is based on publication and citation data downloaded from Thomson Reuters' Web of Science (WoS) database for the period 2005-2009. The records were extracted using appropriate keywords in the "Topic" search field of the WoS database. The keywords were selected from the content and index pages of the book '*Principles of Plant genetics and Breeding*'[2]. Appendix 1 lists these 126 keywords. The downloaded data contained information about the author(s), title of the paper, affiliation of the author(s), name of the journal where the research results were published, citations received by the paper and the keywords. The downloaded data was converted into a FoxPro database using a simple FoxPro program. It was required as the downloaded data needed standardization on different variables, like name of the institution and journal name. Manipulation of data using 'analyse' command provided in WoS is not sufficient and authentic. Downloaded records were filtered for USA, UK, China, India and Brazil. The downloaded data was enriched with impact factor of the journal and its country of publication. The author keywords from these records numbered 4884. A frequency table for these keywords was generated. The analysis was carried out on 198 keywords having frequency more than 15. These keywords were later classified into 15 broad non-overlapping sub-domains of 'plant genetics and breeding' which were used for calculating the activity index of five different countries for 2005 and 2009 respectively.

Bibliometric indicators used

A wide range of indicators are available in literature to assess the impact of the research output and we have used the following indicators:

Number of publications (P); number of citations (C); mean number of citations per publication (CPP); percentage of publications not cited (PNC); impact factor of the journal (IF); and Relative Citation Impact (RCI). Besides these impact indicators, Activity Index (AI) was used to examine the shift in emphasis by different countries in different sub-domains, as well as the change in the co-authorship pattern for India.

The numbers of publications (P) and the citations (C) have been directly obtained from the downloaded data. CPP is the ratio of C/P and has been widely used in scientometric analysis to normalize the large disparity in volumes of literature published by different countries. The values of impact factor for different journals were obtained from the annual compilation of Journal Citation Report (JCR) 2008. RCI[3] is a measure of both the influence and visibility of a nation's research in global perspective. It is defined as the ratio of a country's share of world citations to the country's share of world publications (C % / P %). RCI =1 indicates that country's citation rate is equal to world citation rate; RCI >1 indicates that country's citation rate is higher than world's citation rate and RCI < 1 indicates that country's citation rate is less than world's citation rate.

Analysis

The results of the study have been divided in two parts. Part one of the results deals with the pattern of output for the above mentioned five countries besides examining the change in emphasis during 2009 as compared to 2005. Second part of the results presents a scientometric profile of 'plant genetics and breeding' research in India.

Research trends and shift in emphasis

Pattern of research output of different countries during 2005-2009

During the period of study, USA, UK, China, India and Brazil published 32,574 papers. USA published the highest number of papers followed by China.

Brazil had the lowest output (Table 1). Figure 1 shows the pattern of output of five different countries during 2005-2009. It indicates USA and Brazil followed almost similar pattern of growth except that there is a steep decline in the research output of the USA in 2009, while for Brazil, a marginal decline in the research output has been observed in the year 2009. For UK, a slight decline has also been observed during 2008, while Indian output is consistently increasing and has stabilized during 2008-2009. China is the only country which showed a steady and steep rise in the output during the period covered in the study.

Impact of output of different countries during 2005-2009

Publication output and the citations received by the papers published by each country during 2005-2009 are given in Table 1. It indicates that among the five countries USA produced the highest number of papers, followed by China. However, among all the countries, the value of CPP and RCI is highest for UK followed by USA. For China, India and Brazil, the value of CPP as well as RCI is less than their corresponding world averages, which indicates that the papers published by these countries are poorly cited in the international literature. However, China had slightly better impact of research output than India and Brazil as reflected by the values of CPP and RCI. Similar trend is also reflected by the percentage of papers not cited in the international literature. Percentage of papers not cited was highest for Brazil followed by India and lowest for UK.

Activity profile of selected countries in different sub-domains during 2005 and 2009

As the absolute output of publications is confounded by the size of the country as well as the size of the speciality, Activity Index (AI) first suggested by Frame[4], and elaborated by Schubert and Braun[5] have been used. AI characterizes the relative research effort a country devotes to a given field and takes into consideration the effect of the size of the country as well as the size of the field. AI is the ratio of the country's share in the world's publication output in the given field to the country's share in world's publication output in all fields. Usually, AI is calculated by using the total absolute publication output. However, in the present study the values of AI have been calculated by using the

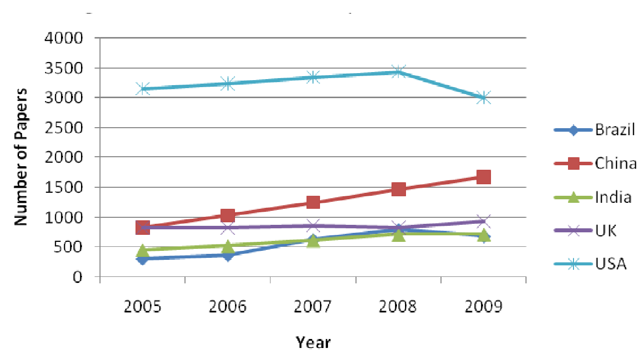

Fig. 1-Impact of output of different countries during 2005-2009

Table 1—Publication output and impact of different countries during 2005-2009

Country	Papers(P) (P)	P (%)	Citations(C) (C)	C (%)	CPP	RCI	Percentage of papers not cited
USA	16190	49.7	155236	62.1	9.6	1.2	20
UK	4307	13.3	50227	20.1	11.6	1.5	18
China	6253	19.2	27256	10.9	4.4	0.6	35
India	3042	9.3	10145	4.1	3.3	0.4	44
Brazil	2780	8.5	7161	2.8	2.6	0.3	53
Total	32574	100	250037	100	7.7	1.0	

total publication output resulted from the use of different keywords for 2005 and 2009.

Mathematically:

$AI = \{(N_{ij} / N_{io}) / (N_{oj} / N_{oo})\} \times 100$

N_{ij}: Number of publications of country i in a sub-speciality j;

N_{io}: Number of publications of country i in all the sub-specialities;

N_{oj}: Number of publications of all five countries in a sub-speciality j;

N_{oo}: Number of publications of all five countries in all the sub-specialities.

Here 'all' implies the five countries considered.

AI = 100 indicates that a country's research effort in the given field corresponds precisely to the world average, AI > 100 reflects higher than average activity, and AI < 100 indicates lower than average effort by the country.

The values of activity index have been calculated for two different periods i.e., 2005 and 2009 respectively to examine the shift in emphasis during 2009 as compared to 2005. The results of the activity index are given in Table 2. From the values of AI given in Table 2, it is observed that the distribution of AI is highly skewed. There are some countries that concentrate their research effort only in one sub-domain, while other countries distribute their research efforts in more than one sub-domain. For instance, in 2005 USA had the highest activity in the sub-domain of quantitative genetics/biometrics which shifted to pollination/mating system in 2009. However, quantitative genetics/biometrics also remained a high priority area in 2009 as well. In case of UK, the highest activity in 2005 was in cytology/cytogenetics which changed to pre-breeding/germplasm and quantitative genetics/biometrics in 2009. For China, the research activity diverted from hybridisation and transgenenics /tissue culture to abiotic stress and gene expression. However, marker–assisted selection remained the area of priority in both the periods. For Brazil, the activity shifted from varietal improvement/conventional breeding, abiotic stress and marker–assisted selection in 2005 to hybridisation, pre-breeding/germplasm and pollination/mating system in 2009.

In case of India, the major research areas were varietal improvement/conventional breeding to abiotic stress and marker assisted selection. In recent years climate change is the hot area of research. The breeders are focussing towards development of varieties suitable for moisture stress condition and high temperature tolerance particularly for winter crops such as wheat and *rabi* pulse. With the advent of molecular marker technology, Indian scientists have initiated molecular markers–related works in the last decade and achieved great success in the crops like rice, wheat, maize and chickpea etc. Indian researchers have initiated marker assisted selection and varieties have been developed in rice (Improved Pusa Basmati 1; Improved Sambha Mahsuri), maize (Vivek QPM 9) and pearl millet (HHB67-2)[6]. However, transgenics/tissue culture remained an area of research priority during 2005 as well as in 2009.

The above analysis indicates that the priority kept shifting from one sub-domain in 2005 to the other in 2009 for all the countries.

Scientometric profile of 'plant genetics and breeding' research in India

Type of documents published

During 2005-2009, a total of 3,131 research items were published by Indian scientists. Of these, 2764 (88.3%) were research articles, 278 (8.9%) were review papers and the remaining 2.8 percent were conference proceeding, meeting abstracts, editorials, letters and corrections. Only 3042 records published as research articles and review papers have been subjected to a detailed scientometric analysis. Raw analysis of data indicates that the number of publications grew significantly during 2008 and 2009 as about half of the total papers were published during these two years.

Mainstream connectivity of Indian research output

This aspect was examined by using characteristics of the journals used for publication, namely the publication in domestic versus international journals, the impact factor of the journals used for communicating research results and the pattern of citation of the research output.

Table 2—Change in activity profile of different countries in different sub-domains

Sub-domain	AI USA 05	AI US A 09	AI UK 05	AI UK 09	AI China 05	AI China 09	AI India 05	AI India 09	AI Brazil 05	AI Brazil 09
SD1: Abiotic stress	51	90	21	76	70	268	78	291	0	0
SD2: Hybridisation	108	83	90	85	144	107	77	56	72	126
SD3: Pre-breeding/ germ plasm	104	115	97	158	64	78	79	113	47	211
SD4: Genetic evolution/mutation	113	111	113	120	84	77	70	55	87	69
SD5: Gene expression	103	92	92	90	119	128	97	74	31	42
SD6: Cytogenetics / cytology	101	87	134	106	88	93	96	87	104	66
SD7: Bio informatics	82	99	57	113	56	115	16	58	78	93
SD8: Pollination/mating system	100	127	82	85	119	94	47	95	88	144
SD9: Quantitative genetics / biometrics	134	118	90	130	80	49	110	26	69	93
SD10: Genetics / inheritance	106	105	59	70	56	97	53	57	110	50
SD11:Varietal improvement & conventional breeding	103	110	81	60	110	72	121	105	165	119
SD12: Molecular biology & genomics	100	94	112	86	106	102	106	100	75	78
SD13: Biotic stress	114	102	105	92	112	88	84	116	120	75
SD14 : Transgenics / tissue culture	101	75	117	66	139	121	217	181	93	67
SD15: Marker Assisted Selection	78	86	76	75	149	105	98	188	121	139
Sub-domains of highest priority	SD9	SD8 SD9	SD6	SD3 SD9	SD2 SD14 SD15	SD1 SD5 SD14	SD11 SD14	SD1 SD14 SD15	SD11 SD13 SD15	SD2 SD3 SD8
Sub-domains of highest activity during 2005-2009		SD9	SD3,SD4 and SD6		SD1,SD5, SD15		SD1, SD11, SD14,SD15		SD11and SD15	

Domestic vs. international journals

Publications from India in the field of 'plant genetics and breeding' have appeared in 652 journal titles originated in India and abroad. Of these, 611 journal titles originated from abroad and 41 from India. Highest number of journal titles where Indian scientists published was from USA. Analysis of the data for the distribution of scientific output in domestic and international journals presented in Table 3 indicates that Indian scientists published about 20 percent of the research papers in domestic (Indian) journals and the remaining 80 percent papers in journals published from abroad, unlike agriculture sciences, where a large proportion of papers were published in Indian journals[7]. Plausible reason for publishing less number of papers in Indian journals might be non-availability of well established Indian journals in the field of 'plant genetics and breeding'. Among the journals published abroad, maximum papers were published in journals originated from USA, followed by those published from the Netherlands and England. About 58 percent of the papers published by Indian scientists appeared in journals originated from these three countries. It suggests that the research conducted by India in the field of 'plant genetics and breeding' is published in journals originating from the advanced countries of the West and as such well connected to the mainstream science. Appendix 2 lists 24 most preferred journals where Indian scientists have published 1 percent or more papers. About 39 percent of the total papers were published in these 24 journals. Of the 24 most preferred journals, 9 were domestic journals and the rest were published from abroad.

Distribution of papers according to Impact Factor

Journal Impact Factor (JIF) is undoubtedly, one of the most established indicator used to evaluate the relative influence, importance or prestige of scholarly journals. It is the ratio of the number of citations in the current year to the citable items published in the previous 2 years. Papers appearing in journals with high impact factor indicate mainstream readership and mainstream connectivity. During the past decades, several studies had been published that applied journal impact factors and related citation measures to analyse the research performance of individual scientists, institutions and nations[8].

The impact factor where the Indian researchers published their research papers was divided into four quartiles. The distribution of papers in each quartile is shown in Table 4. Distribution of output according to the JIF provided in Table 4 indicates that about 35 percent of the Indian research output appeared in low IF journals and the rest 65 percent in medium, high and very high impact factor journals. This also suggests that the Indian research output in the field of 'plant genetics and breeding' is internationally visible and well connected to the mainstream science.

Table 3—Output of Indian scientists in domestic and foreign journals

Journal Publishing Country	No. of journals	No. of papers	% of papers
USA	179	625	20.5
India	41	622	20.4
Netherlands	83	607	20.0
England	165	536	17.6
Germany	36	155	5.1
Ireland	7	71	2.3
France	8	38	1.2
Nigeria	5	34	1.1
Australia	9	33	1.1
Japan	14	29	1.0
Others (37 countries)	105	292	9.6
Total	652	3042	100.0

Table 4—Distribution of papers according to impact factor

Quartile (Category and value of Impact Factor)	No. of papers	% of papers
Q1 (low, 0.87)	1007	35.1
Q 2 (Medium, 1.7)	736	25.6
Q 3 (High, 2.8)	598	20.8
Q 4 (Very high >2.8)	442	15.5
Total	2783*	100.0

*Number of papers was less than 3042 as many papers were published in journals whose IF was not available

Citation pattern of the research output

Impact factor analysis is indicative of the impact of the research output, but may not be conclusive due to inherent limitations. To corroborate its results, citation analysis was undertaken as an added dimension to reflect on the impact of the output on the international community as citation of a publication in the scientific literature marks both quality and visibility. Quality papers are frequently cited which in turn helps them to acquire greater visibility and publicity in academic circles[9].

Citations were examined for each paper for the period 2005 to 2009**.** The results of the citation analysis indicate that 3,042 papers received 10,145 citations in all during 2005-2009 (Table 5). Citation rate per paper for the Indian research output is 3.3. Further analysis indicates that 44 percent papers remained uncited. Proportion of papers cited between 1-5 times was 40 percent and the remaining 16 percent were cited more than five times. Of these, 7.5 percent papers were cited more than 10 times and only 2 percent papers were cited more than 20 times. Appendix 3 lists papers which received 50 or more citations. From this, it can be inferred that the papers published by Indian scientists in the domain of 'plant genetics and breeding' research could not attract high citations from the international community. Determining probable reasons for this need further deeper exploration. However, of the 44 percent uncited papers, 83 percent were published during 2009 and 48 percent in 2008 which have a fair chance to be cited in coming years, and may yield better citation results.

Publication output and impact of different performing sectors

India is a country with a vast S&T infrastructure. It comprises of more than 400 national laboratories under different scientific organizations like Department of Science and Technology (DST), Department of Biotechnology (DBT), Council of Scientific and Industrial Research (CSIR), Indian Council of Medical research (ICMR), Department of Atomic energy (DAE), and, Indian Council of Agriculture Research (ICAR). Scientific research in India is also performed in the academic institutions (universities, deemed universities and colleges) whose number exceeds 350 as well as in 1300 recognized in-house industrial units, several government departments and private institutions and foundations. Table 6 shows the distribution of output according to different performing sectors those produced 1 percent or more of the scientific output along with their total citations, RCI and CPP.

Data presented in Table 6 shows that academic institutions are the largest producers of scientific output in the field of 'plant genetics and breeding' like the total Indian scientific output[10] and research output in other fields[11]. The publication output of academic institutions was followed by Indian Council of Agriculture Research (ICAR) and State Agriculture Universities & colleges. These two together produced 28 percent of the total scientific

Table 5—Frequency of citations of Indian research output during 2005-2009

No. of citations	No. of papers	% of papers	Total citations
0	1335	43.9	0
1	468	15.4	468
2	296	9.7	592
3	178	5.9	534
4	143	4.7	572
5	127	4.2	635
6 -10	269	8.9	2062
11-15	107	3.5	1341
16-20	57	1.9	993
>20	62	2.0	2948
Total	3042	100.0	10145

Table 6—Publication output and impact of different performing sectors

Organizations	Total papers (%)	Total citations (%)	RCI	CPP
Academic Institutions	1173 (38.6)	3446 (34.0)	0.9	2.9
Indian Council of Agriculture Research (ICAR)	488 (16.0)	1808 (17.82)	1.1	3.7
State Agriculture Universities & colleges (SAUs)	376 (12.4)	733 (7.2)	0.6	1.9
Council of Scientific and Industrial Research (CSIR)	365 (12.0)	1405 (13.8)	1.2	3.8
International R&D institutions	130 (4.3)	883 (8.7)	2.0	6.8
Indian Institutes of Technology (IITs) and engineering colleges	76 (2.5)	326 (3.2)	1.3	4.3
Department of Atomic Energy (DAE)	73 (2.4)	298 (2.9)	1.2	4.1
Department of Biotechnology (DBT)	64 (2.1)	233 (2.3)	1.1	3.6
Department of Science and Technology (DST)	59 (1.9)	205 (2.0)	1.1	3.5
Ministry of Environment and Forests (MoEF)	48 (1.6)	98 (0.96)	0.6	2.0
Private R&D institutions	42 (1.4)	187 (1.8)	1.3	4.5
State Government R&D institutions	40 (1.3)	103 (1.0)	0.8	2.6
Others	108 (3.6)	420 (4.1)	1.1	3.9
Total	3042 (100)	10145 (100)	1.0	3.3

output. ICAR with its 97 research institutes and 45 State Agricultural Universities is the nodal agency for carrying out research in the field of agriculture in general and 'plant genetics and breeding' research in particular and have played a major role in promoting 'plant genetics and breeding' research in India. The Council of Scientific and Industrial Research also contributed about 12 percent of the publication output. These four sectors together produced 79 percent of the total output. This indicates that the publication output is concentrated among few performing sectors. The remaining 21 percent output came from other sectors listed in Table 6.

The standing of different performing sectors judged from the values of RCI indicates that international R&D institutions located in India had the highest (2.0) value of RCI like the 'genetics and heredity' research in India[12]. This was followed by private R&D institutions and Indian Institutes of Technology each having a RCI value of 1.3. Academic institutions, State Agriculture Universities and colleges, Ministry of Forests and Environment and the R&D institutions under the State government had RCI < 1. This indicates that papers published by these four sectors were cited less than the average Indian papers. Less than half of the papers published by Indian scientists had higher value of RCI than the Indian average.

The value of CPP for India is 3.3. Like the value of RCI, the value of CPP is also highest (6.8) for international R&D institutions. Other sectors having higher values of CPP than average were ICAR, CSIR, IITs, DAE, DBT, DST and private R&D institutions. For rest of the performing sectors listed in Table 6, the value of CPP is less than Indian average.

Publication output and impact of prolific institutions

The total output of 3,042 publications came from 1806 institutions scattered in different parts of the country. However, among these 23 institutions published 1 percent or more of the papers. These 23 institutions contributed about 41 percent of the total Indian output published by India during 2005-2009 and the remaining 59 percent publications were contributed by 1783 institutions. Table 7 lists 23 most prolific institutions that contributed 30 or more papers along with their publication and citation indicators. Of the 23 prolific institutions, 12 were academic institutions and the rest belonged to CSIR (4), ICAR (3), DAE and DST each one and two were international institutes located in India. Among the institutions listed in Table 7, the highest contribution came from Indian Agricultural Research Institute, New Delhi followed by University Of Delhi and National Botanical Research Institute, Lucknow.

Impact of the research output of these institutions has been examined by using the same indicators as has been used for measuring the performance of five different countries and performing sectors above. Of the 23 prolific institutions listed in Table

Table 7—Indian Institutions publishing 30 or more papers during 2005-2009

Institute	Papers(P)	P (%)	Citations (C)	C (%)	CPP	RCI
Indian Agriculture Research Institute	167	5.5	1195	11.8	7.2*	2.1*
Delhi University	136	4.5	611	6.0	4.5*	1.4*
National Botanical Research Institute	91	3.0	349	3.4	3.8	1.2
Tamilnadu Agriculture University	83	2.7	279	2.8	3.4	1.0
Intern. Crops Research Institute of Semi Arid Tropics	80	2.6	364	3.6	4.6	1.4
Bhabha Atomic Research Centre	55	1.8	215	2.1	3.9	1.2
Punjab Agriculture University	53	1.7	85	0.8	1.6	0.5
Banaras Hindu University	49	1.6	157	1.6	3.2	1.0
Bose Institute	49	1.6	182	1.8	3.7	1.1
Aligarh Muslim University	43	1.4	168	1.7	3.9	1.2
Mysore University	42	1.4	104	1.0	2.5	0.7
CCS Haryana Agriculture University	41	1.3	64	0.6	1.6	0.5
Intern. Centre for Genetic Engg. & Biotechnology	38	1.2	488	4.8	12.8	4.0
Central Institute of Medicinal & Aromatic Plants	37	1.2	55	0.5	1.5	0.4
University of Agriculture Sciences (Bangalore)	37	1.2	136	1.3	3.7	1.1
Central Food Technology Research Institute	35	1.2	143	1.4	4.1	1.2
Hyderabad University	34	1.1	131	1.3	3.9	1.2
National Chemical Laboratory	34	1.1	125	1.2	3.7	1.1
Indian Institute of Science	32	1.1	196	1.9	6.1	1.7
Bharathidasan University	31	1.0	53	0.5	1.7	0.5
Calcutta University	31	1.0	101	1.0	3.3	1.0
Institute of Himalayan Bioresource Technology	31	1.0	77	0.8	2.5	0.8
National Bureau of Plant Genetic Resources	30	1.0	66	0.7	2.2	0.7
Others	1783	58.6	4801	47.3	2.7	0.8
Total	3042	100.0	10145	100.0	3.3	1.0

*Indian Agriculture Research Institute, New Delhi and University of Delhi, Delhi has higher values of RCI and CPP, because these two institutions had a collaborative paper which was cited more than 700 times.

7, RCI was higher than 1 for 12 institutions and was highest (4.0) for International Centre for Genetic Engineering and Biotechnology, New Delhi, followed by Indian Institute of Science (1.7), International Crop Research Institute for Semi Arid and Tropics, and University of Delhi each 1.4. This implies that papers published by these institutions were cited more than the average Indian papers. Average value of CPP like the RCI, was higher than average for 13 institutions. Like the value of RCI, International Centre for Genetic Engineering and Biotechnology, New Delhi also had the highest CPP (12.8). The value of RCI is less than 1 for most of the State Agriculture Universities including Central Institute of Medicinal and Aromatic Plants. The value of CPP is also less than Indian average for these institutions. A raw analysis of data indicates that these institutions published their research results in low impact factor journals and hence were less cited, which resulted in low values of CPP and RCI.

Collaboration pattern of Indian scientists

Science is no longer a pursuit of an individual. Governments in different countries have taken initiatives to enhance contacts among scientists in science through collaborative research programmes, both at the national and international levels. Such initiatives have resulted in increased collaboration at national and international levels. Various reasons for collaboration have been listed by Beaver[13]. In the present study, the trend of collaboration has been examined into two different ways i.e., change in the pattern of co-authorship during 2005-2009 and the pattern of international collaboration during 2005-2009.

Change in pattern of co-authorship during 2005-2009

To measure how the pattern of co-authorship have changed during 2005-09, authors made use of Co-authorship Index (CAI) suggested by Garg and Padhi[14] and used by Guan and Ma[15] in their study on computer science. CAI is calculated in a way similar to AI. For this purpose papers were divided into four categories. These were single authored papers, two authored papers, multi-authored papers having 3 or 4 authors and mega authored papers having more than 4 authors. The results of CAI given in Table 8 indicate that the value of CAI for single authored papers has gone down considerably from 129 in 2005 to 57 in 2009. The value of CAI for two authored and multi-authored papers have increased marginally in the later period, which indicates an increasing trend towards multi-authored papers.

Pattern of international collaboration during 2005-2009

Indian scientists published 574 papers in international collaboration with 70 different countries. Of these, highest number of collaborated papers was with USA (153) followed by Germany (71) and South Korea (54). Other collaborating countries having more than 20 papers in collaboration were Australia (43), UK (41), France (34), China and Japan 33 each, Philippines (25), and Mexico and Israel 21 each. Remaining 59 countries had 45 collaborated papers. Table 9 presents the distribution of domestically and internationally co-authored papers during 2005-2009. From the data presented in Table 9, it is observed that the proportion of internationally co-authored papers hovered around 18 percent during the entire period of study except in 2006, when the proportion of internationally co-authored papers rose to ~ 22 percent.

Conclusion

Scientometrics as a technology forecasting tool identifies emerging scientific areas and helps in monitoring early signals of new technological developments by searching literature. The study examined the pattern of output, impact and shift in emphasis of research in respect of USA, the UK, China, and Brazil with special emphasis on India. In case of India, the study identified different agencies involved in research in this area, the communication and citation pattern of the research output, highly productive institutions and the impact of their research output.

Table 8—Pattern of co-authorship Index during 2005-2009

	Single authored papers (CAI)	Two authored papers (CAI)	Multi authored papers (CAI)	Mega authored papers (CAI)	Total
2005	22 (129)	85 (92)	201 (97)	154 (74)	462
2006	23 (119)	98 (93)	227 (96)	179 (76)	527
2007	31 (136)	132 (107)	276 (100)	179 (65)	618
2008	21 (80)	152 (106)	332 (104)	210 (66)	715
2009	15 (57)	142 (99)	328 (102)	235 (73)	720
Total	112	609	1364	957	3042

Table 9—Distribution of domestic and international co-authored papers

Year	Domestically co-authored papers	Internationally co-authored papers (%)	Total papers
2005	371	91 (19.7)	462
2006	413	114 (21.6)	527
2007	507	111 (17.9)	618
2008	583	132 (18.5)	715
2009	594	126 (17.5)	720
Total	2468	574 (18.7)	3042

The study indicates a steady and steep rise in the publication output for China during 2005-2009 and stabilized research output for India during 2008-2009. Although, USA had the highest publication output but UK had the highest impact. China had a better impact of research output than India. All countries shifted their emphasis to newer sub-domains in 2009. The papers published by Indian scientists appear to be well connected to the main stream science. The academic institutions, the Indian Council of Agriculture Research and the Council of Scientific and Industrial Research are the major contributors to the research output. International R&D institutions located in India had better impact of research than their Indian counterparts. The nature of research work has shifted from individual research to team work and internationally co-authored papers have remained almost steady during the period under study.

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Appendix I

Key words used for downloading data

Abiotic resistance, Abiotic stress in plants, Additive gene action, Additive variance, Advance backcross breeding, Adventitious shoot production, Agamospermy, Alleles, Allogamous, Alloploid, Alternative splicing, Amphiploid, Amplified fragment length polymorphisms, Androccium, Androgenesis, Aneuploidy, Angiosperms, Anther culture, Apomictic cultivator

Apomixis, Apospory, Artificial hybrid, Autogamous, Autoploidy, Backcross breeding, Better parent heterosis, Biopharming, Biparental inheritance, Breeders equation, Breeders eye, Breeding seed, Callus, Chemical mutagen, Clonally propagate plant, Clonally propagated species breeding, Clones, Cloning genes, Composite cultivator, Compositional traits, Cryopreservation, Cytoplasmic inheritance, Disease resistance, Disease resistance in plants

DNA, Dominance gene action, Dominant mutation, Double fertilization, Double haploids, Emasculation, Fertilization, Gametic incompatability, Gametogenesis, Gene action, Gene erosion, Gene mutation, Gene pyramiding, Gene transfer, Generic vulnerability, Genetic basis heterosis, Genetic determination, Genetic gain, Genetic linkage, Genetic marker, Genetic resistance, Genetic resource, Genetic transformation, Genetic use restriction system

Genetic variation, Genetic vulnerability, Genetically modified genome, Genomic mutation, Genomics, Genotype, Germplasm, Haploids, Hybrid breeding, Hybrid cultivar, Hybrid cultivator, Hybrid seed production, Hybridization ideotype, Insect pest resistance, Insect resistance engineering, Isozymes, Marker assisted selection, Mating design, Molecular breeding, Molecular marker, Monoecious gene, Monoecious plants, Monocistronic gene, Monoploid, Morphological markers, Morphological traits in plant, Mutagenesis, Mutagenesis in plant, Mutation breeding, Organic plant breeding, Physiological traits in plants, Physiology

Plant breed, Plant cellular organi, Plant genetic diversity, Plant genetic resource, Plant genetic structure, Plant germplasm, Plant reproductive system, Plant tissue culture, Plants genome, Ploidy modification, Pollination, Polygenic resistance, Polyploidy, Polyploidy in plant, Protein markers, QTL mapping, Seed germination, Sexual hybridization,Sexual hybridization in plants, Somatic embryogenesis, Somatic hybridization, Tanonical correlation, Taxonomy,

Transgenic plant, Variety protection, Wide crosses in plants

Appendix II

Most preferred journals used by Indian Scientists for publishing research results

#	Title of the journal	Publishing country	Papers
1	*Current Science*	India	148
2	*Euphytica*	The Netherlands	78
3	*Biologia Plantarum*	The Netherlands	76
4	*In Vitro Cellular and Developmental Biology-Plant*	England	75
5	*Plant Cell Reports*	USA	70
6	*Indian Journal of Agricultural Sciences*	India	69
7	*Plant Cell Tissue and Organ Culture*	The Netherlands	69
8	*Scientia Horticulturae*	The Netherlands	54
9	*Journal of Plant Biochemistry and Biotechnology*	India	51
10	*Plant Science*	Ireland	50
11	*African Journal of Biotechnology*	Kenya	48
12	*Acta Physiologiae Plantarum*	Poland	42
13	*Plant Archives*	India	41
14	*Genetic Resources and Crop Evolution*	The Netherlands	37
15	*Indian Journal of Biotechnology*	India	32
16	*Research on Crops*	India	31
17	*Indian Journal of Horticulture*	India	30
18	*Journal of Environmental Biology*	India	28
19	*Theoretical and Applied Genetics*	USA	26
20	*Plant Biotechnology Reports*	USA	25
21	*Indian Journal of Genetics and Plant Breeding*	India	25
22	*Plant Physiology and Biochemistry*	France	23
23	*Plant Breeding*	England	23
24	*Plant Growth Regulation*	The Netherlands	20
	Sub total		1171
	Other 618 journals		1871
	Total		3042

Appendix III

Highly Cited authors

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