Mapping agricultural research in India: A profile based on *CAB Abstracts* 1998*

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CAB Abstracts 1998 had indexed 11,855 publications from India, including 10,412 journal articles, from more than 1280 institutions in 531 locations. These were classified into 21 major research fields and 243 subfields. 'Plants of economic importance' (FF) is the leading area of research in India, followed by 'Animal science' (LL). The three subfields with the largest number of papers are: 'Pests, pathogens and biogenic diseases of plants', FF600 (1301 papers), 'Plant breeding and genetics', FF020 (1135 papers), and 'Plant production', FF100 (786 papers). In contrast, there were only 54 papers in 'Biotechnology' (WW). Academic institutions accounted for a little over 59% of the papers in 1998, as against 63.4% in the five years 1990–1994, and scientific agencies of the central government accounted for 22% of the papers. Agricultural universities had published 4039 papers and agricultural colleges 523 papers. Indian researchers had published over 78% of the 10,412 journal articles in 208 Indian journals, 587 papers in 180 UK journals, and 368 papers in 124 US journals. In no other field do Indian researchers publish such a large per cent of papers in Indian journals. Letters journals were used only infrequently: 317 papers in 40 letters journals. More than 8060 papers were published in non-SCI journals, and 1925 papers were published in journals of impact factor less than 1.0. Only 33 papers were published in journals of impact factor higher than 3.0. We have identified institutions publishing large number of papers in different subfields, in different journals, in journals of different impact factors, etc. This macroscopic analysis not only provides an inventory of India's publications, but also gives an idea of endogenous research capacity. If appropriately linked with public policy, it can help restructure the nation's research priorities.

ENSURING food and nutrition security of more than a billion people is a great challenge for India today. It requires increased production of grains, pulses, oilseeds, vegetables, fruits, milk, poultry, fish and meat, making the produce available to the people at affordable prices, and seeing that the food consumed is absorbed and assimilated by the population. The first step, of course, is to produce more food, despite dwindling resources. As India has gone global, there is also the threat to Indian farmers, especially after the removal on 1 April 2001 of most of the quantitative restrictions on imports on agricultural products and consumer goods, from large-scale imports of food grains and processed foods of all kinds, at prices they cannot match. Experts like M. S. Swaminathan argue in favour of ushering in what they call the 'evergreen revolution' to ensure food production at levels that can take care of the food and nutrition security of the growing population and adopting policies that are friendly to the local farming communities[1,2]. Undoubtedly, India needs to strengthen both research and public policy in order to improve the productivity, profitability, stability and sustainability of the major farming systems. Research needs to be strengthened, for example, to improve rice and wheat yields from just a third of international levels. Policy should address issues such as how to help small and marginal farmers to get better yields from increasingly fragmenting landholdings, often less than an acre per farming family, how to get the food to the ultra-poor, and how to use agricultural growth to eradicate poverty[3]. Look at the irony. The storehouses of the Food Corporation of India are overflowing with unsold grain, estimated between 45 and 60 million tonnes (in June 2001), a third of which is rotting in the open, and yet 250–300 million people do not have enough to eat[3]. This has led to the talk of grain mountains and hungry millions coexisting. Again, value added in the Indian food industry is 15–20%, compared with over 100% in some developed countries[3]. There is considerable scope for research in

*Dedicated to Prof. M. S. Swaminathan, scientist, scholar and humanist, on his 76th birthday.

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food preservation and processing. Three decades ago when India went through difficult times, the agricultural research establishment played the role of a savior and came up with some remarkable achievements. Will India's agricultural researchers be able to meet the new challenge? It is with a view to answering this question that we have attempted, not only to inventory agricultural research in India, but also to provide an appreciation of endogenous research capacity in this crucial field.

This paper maps agricultural research in India as seen from publications that came out in 1998 and indexed in *CAB Abstracts*. A few years ago, Arunachalam[4] had prepared a report entitled 'Agricultural research in India: A profile based on *CAB Abstracts* 1990–1994'. *CAB Abstracts* was preferred to the other secondary services such as *Current Contents–Agriculture, Biology and Environmental Science edition*, *AGRIS* and *AGRICOLA*, because it covered a much larger number of primary sources than the other three databases. The report had mapped agricultural research in India based on papers with an Indian address indexed in five years of *CAB Abstracts*. Arunachalam and his colleagues have also analysed India's contribution to other fields based on the literature indexed in major international databases such as *Medline*[5,6], *Biological Abstracts*[7], *Mathsci*[8], *Science Citation Index*[9], *Materials Science Citation Index*[10], and *Compumath Citation Index* (to be published). More recently, Arunachalam and Jayashree have mapped fish research in India and China, based on bibliographic data collected from six databases[11,12]. From our past experience with mapping Indian science, we know that agriculture research is performed in a larger number of institutions and locations and is published in a larger number of journals, than any other field of science.

Methodology

Bibliographic information on all papers having an address in India in the byline and published in the year 1998 was downloaded from *CAB Abstracts* on a CD. As papers published in 1998 will have been abstracted long after 1998, we scanned the CD-ROM discs of *CAB Abstracts* covering the whole of 1998, 1999 and the early months of 2000. The elements downloaded were: address, source (journal, volume, pages), publication year, publication type and classification codes. Unlike ISI's citation index databases, *CAB Abstracts* gives the address of only one author even if a paper has many authors, and therefore we have missed all jointly-authored papers where the Indian authors' addresses have not appeared. Another problem common to many non-ISI databases is that in many cases they do not provide the name of the country in the address field. To take care of this problem, we developed a search strategy where we had listed not only 'India' in the search based on address field, but also the names of Indian states and hundreds of Indian cities and towns where agriculture-related research could have been done. This led to capturing a few entries from outside India. For example, the search term 'Kochi' in the address field will not only capture papers from Kochi (Cochin) in Kerala but also papers from Kochi in Japan. Similarly, the search term 'Salem' will attract papers from Winston-Salem in USA. Such non-Indian entries were removed before the data were analysed. A third problem is the non-standard rendering of names of institutions. Often agricultural universities are named 'Krishi Vishwavidyalaya' or 'Krishi Vidyapeeth' (the Hindi equivalent). Names of institutions were standardized. Occasionally, papers from some cities (or towns) which are not part of India are erroneously assigned to India by the database. These were also removed by careful manual checking. We added the country of publication of each journal from sources such as *CAB International Serials Checklist* (1995 edn), *Serial Sources for the BIOSIS Previews Database* (1993 edn), and *Publist*, a web source of information on serials. For some journals, which were not found in these three sources, we gathered information from CABI's headquarters in the UK. We found the impact factors for journals in which Indian researchers have published their work, wherever available, from *Journal Citation Reports* (*JCR*) 1997. The data were analysed by document type, journals used, country of publication of journals, impact factor of journals, subfields at two different levels, institution, institution type, city/town and state. Wherever possible, we have compared our results for 1998 with the results for 1990–1994.

Analysis

Distribution by journal

There were 11,855 documents in all. These include 10,412 (about 88%) journal articles, published in 854 journals (Table 1), 838 conference papers and 132 books/book chapters. Seventeen journals have published 100 or more papers, 35 journals have published 50 or more papers but less than 100, 64 journals have published 25 or more papers but less than 50, and 96 journals have published 10 or more papers but less than 25. At the other extreme, 332 journals have published just one paper each and 117 journals two papers each. Figure 1 is a curve of the number of journals vs cumulative number of papers. In the top 116 journals in which Indians have published 25 or more papers, only seven are foreign journals: *International Rice Research Notes*, Philippines, 20th rank, 83 papers; *Biologia Plantarum*,

Table 1. Indian research papers classified by journal as seen from *CAB Abstracts* 1998

Journal title	Impact factor – *JCR* 1997	Journal country	No. of papers
Indian Veterinary Journal	0.000	India	355
Indian Journal of Agricultural Sciences	0.043	India	207
Environment and Ecology	0.000	India	195
Karnataka Journal of Agricultural Sciences	0.000	India	191
Indian Journal of Animal Sciences	0.080	India	179
Insect Environment	0.000	India	167
Journal of the Indian Society of Soil Science	0.000	India	167
Indian Journal of Agronomy	0.020	India	160
Crop Research Hisar	0.000	India	150
Current Science	0.376	India	147
Indian Journal of Experimental Biology	0.000	India	142
Indian Forester	0.000	India	141
Annals of Agricultural Research	0.000	India	134
Madras Agricultural Journal	0.000	India	122
Advances in Plant Sciences	0.000	India	118
Journal of Maharashtra Agricultural Universities	0.000	India	112
Indian Phytopathology	0.000	India	100
Agricultural Science Digest Karnal	0.000	India	88
Economic and Political Weekly	0.000	India	86
International Rice Research Notes	0.000	Philippines	83
Indian Journal of Dairy Science	0.000	India	80
Journal of Medicinal and Aromatic Plant Sciences	0.000	India	79
PKV Research Journal	0.000	India	78
Indian Journal of Genetics and Plant Breeding	0.000	India	77
Indian Journal of Forestry	0.000	India	75
Indian Journal of Plant Physiology	0.000	India	75
26 journals publishing 50–74 papers			1530
48 journals publishing 30–49 papers			1877
38 journals publishing 20–29 papers			912
74 journals publishing 10–19 papers			1038
193 journals publishing 3–9 papers			981
117 journals publishing 2 papers each			234
332 journals publishing 1 paper each			332
Total			10412

Czech Republic, 63rd rank, 46 papers; *Buffalo Journal*, Thailand, 84th rank, 35 papers; *Fitoterapia*, Italy, 85th rank, 33 papers, *Cruciferae – Newsletter*, UK, 26 papers; *Phytochemistry*, UK, 26 papers; and *Journal of Agronomy and Crop Science*, Germany, 25 papers. Of the 854 journals, 40 are letters journals and these have published 317 papers from India (3% of journal articles). Clearly, unlike in physics, in agricultural research in India (and probably elsewhere in the world), there is no sense of urgency in reporting one's findings. Of the 40 letters journals, six are published in India. There are a few newsletters: *Cruciferae Newsletter*, UK, in which Indian researchers have published 26 papers; *International Chickpea and Pigeonpea Newsletter*, India, 25 papers; *International Arachis Newsletter*, India, 18 papers; *International Sorghum and Millets Newsletter*, USA, 12 papers; *MFP News*, India, 9 papers; *National Bank News Review*, India, 9 papers; *Fertiliser Marketing News*, India, 7 papers; *Lens Newsletter*, Syria, 7 papers; *Mycorrhiza News*, India, 7 papers; *Wood News*, India, 5 papers; *Agro Chemicals News in Brief*, Thailand, 4 papers; *Camel Newsletter*, Syria, 3 papers; *Palawija News,* Indonesia, 2 papers; *ILEIA Newsletter*, the Netherlands, 1 paper; *International Rice Commission Newsletter*, Italy, 1 paper, etc.

Distribution by journal country

Unlike in physics, chemistry, new biology, medicine and mathematics, most papers from India in agricultural research are published in Indian journals (Table 2). In 1998, Indian researchers have published 8157 papers (> 78% of all journal articles, compared to 77% in 1990–1994) in 208 Indian journals (compared to 483 journals in the five years, 1990–1994). In life sciences, as seen from *Biological Abstracts* 1998, Indian researchers had published 55.4% of papers in Indian jour-

Table 2. Country of publication of the journals used by Indian researchers as seen from *CAB Abstracts* 1998 and 1990–1994

Country of publication	1998			1990–1994		
	No. of journals	No. of papers	Percentage of papers in world journals	No. of journals	No. of papers	Percentage of papers in world journals
India	208	8157	78.34	483	37178	76.96
UK	180	587	5.64	357	2742	5.68
USA	124	368	3.53	352	1888	3.91
The Netherlands	77	307	2.95	127	1245	2.58
Germany	67	191	1.83	124	1100	2.28
Italy	21	99	0.95	43	667	1.38
Philippines	4	98		12	468	
Czech Republic	5	74		5	123	
Thailand	9	61		15	172	
Australia	12	50		27	171	
Ireland	4	43		14	176	
Japan	18	42		36	427	
France	17	37		42	240	
Switzerland	13	32		27	150	
Korea	4	32		2	12	
31 other countries	90	232				
52 other countries				263	1474	
Unknown	1	2		24	68	
Total	854	10412		1953	48301	

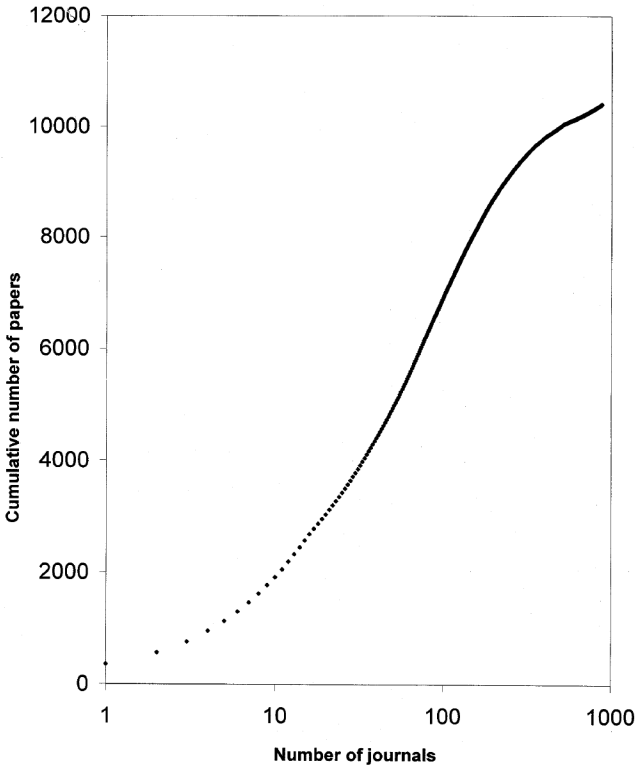

Figure 1. Number of journals vs cumulative number of Indian papers.

Table 3. Distribution of Indian papers by impact factor range of journals (based on impact factor data from *JCR* 1997)

Impact factor *JCR* 1997	No. of journals	No. of papers
0.000	441	8061
> 0.0 ≤ 0.5	105	1365
> 0.5 ≤ 1.0	131	560
> 1.0 ≤ 1.5	85	243
> 1.5 ≤ 2.0	44	83
> 2.0 ≤ 2.5	20	42
> 2.5 ≤ 3.0	10	25
> 3.0 ≤ 3.5	3	5
> 3.5 ≤ 4.0	5	11
> 4.0 ≤ 4.5	1	5
> 4.5 ≤ 5.0	3	4
> 5.0 ≤ 5.5	3	4
> 5.5 ≤ 6.0	1	1
> 6.0 ≤ 7.0	2	3
Total	854	10412

nals (Arunachalam, S., unpublished results). In medicine, as seen from *Medline* November 1987–1994 December, 33.5% of papers from India was published in Indian journals[5]. In mathematics, as seen from *Mathsci* 1988–1998, 38.5% of all Indian papers was published in Indian journals[8]. Also, 587 papers were published in

Table 4. Distribution of Indian research papers covered by *CAB Abstracts* 1998 and 1990–1994 by major area

Area code	Area	No. of papers	
		1998	1990–1994
FF	Plants of economic importance (general)	4855	25563
LL	Animal sciences	1808	7654
JJ	Soil science	910	2689
KK	Forestry, forest products and agroforestry	763	2323
HH	Pathogen, pest and parasite management (general)	757	2495
VV	Human health and hygiene (general)	500	2191
EE	Economics (general)	492	1718
QQ	Food science and food products	452	1921
PP	Natural resources (general)	372	1112
ZZ	Auxiliary disciplines	239	1052
UU	Sociology (general)	146	220
MM	Aquatic science	114	188
SS	Agricultural products (general)	86	470
NN	Engineering and safety	76	510
RR	Forage and feed products (non-human)	75	374
XX	Wastes (general)	58	445
WW	Biotechnology	54	231
CC	Profession, education, information and training (general)	49	79
AA	Agriculture (general)	19	109
DD	Administration of agencies and organizations	6	4
BB	History and biography	2	15
TT*	Medical and veterinary records	–	398
	Unknown	22	–
	Total	11855	51761

*Discontinued.

Table 5. Distribution of Indian research papers covered by *CAB Abstracts* 1998 and 1990–1994 by subfield

Subfield code	Subfield	No. of papers	
		1998	1990–1994
FF600	Pests, pathogens and biogenic diseases of plants	1301	8898
FF020	Plant breeding and genetics	1135	5675
FF100	Plant production	786	5231
HH400	Control by chemicals and drugs	594	1465
LL820	Parasites, vectors, pathogens and biogenic diseases of animals	485	2222
KK100	Forestry (general)	398	1102
JJ700	Fertilizers and other amendments	375	1086
FF060	Plant physiology and biochemistry	312	1335
VV200	Parasites, vectors, pathogens and biogenic diseases of humans	295	1302
LL210	Animal reproduction and development	236	578
FF040	Plant composition	225	987
QQ010	Milk and dairy produce	176	785
FF500	Weeds and noxious plants	163	469
KK110	Silviculture	152	464
JJ800	Soil water management	149	160
JJ200	Soil chemistry and mineralogy	143	289
QQ050	Crop produce	143	104
FF150	Plant cropping systems	141	279
LL600	Animal physiology and biochemistry (excluding nutrition)	136	297
LL860	Animal disorders (not caused by organisms)	133	365
	223 other subfields	4355	
	251 other subfields		18668
	Unknown	22	
	Total	11855	51761

Table 6. Indian institutions publishing papers as seen from *CAB Abstracts* 1998

Institution	City/town	No. of papers
Chaudhary Charan Singh Haryana Agricultural University	Hisar	473
Punjab Agricultural University	Ludhiana	390
Indian Agricultural Research Institute	New Delhi	378
Univesity of Agricultural Sciences	Bangalore	253
Tamil Nadu Agricultural University	Coimbatore	239
Assam Agricultural University	Jorhat	229
Indian Veterinary Research Institute	Izatnagar	221
University of Agricultural Sciences	Dharwad	213
G. B. Pant University of Agriculture and Technology	Pantnagar	212
Bidhan Chandra Krishi Viswavidyalaya	Mohanpur	153
National Dairy Research Institute	Karnal	152
Banaras Hindu University	Varanasi	150
Jawaharlal Nehru Krishi Vishwavidyalaya	Jabalpur	142
Dr Panjabrao Deshmukh Krishi Vidyapeeth	Akola	136
Himachal Pradesh Krishi Vishvavidyalaya	Palampur	127
Gujarat Agricultural University	Anand	119
Orissa University of Agriculture and Technology	Bhubaneswar	113
Indian Institute of Horticultural Research	Bangalore	104
Dr Y. S. Parmar University of Horticulture and Forestry	Solan	101
Rajendra Agricultural University	Pusa	100
Central Institute of Medicinal and Aromatic Plants	Lucknow	96
Mahatma Phule Krishi Vidyapeeth	Rahuri	92
Indira Gandhi Agricultural University	Raipur	90
International Crops Research Institute for the Semi Arid Tropics	Patancheru	89
University of Delhi	New Delhi	84
1256 other institutions		6668
Private		284
Unknown		447
Total		11855

180 British journals, 368 papers in 124 US journals and 307 papers in 77 journals in the Netherlands. In all, in 1998 Indian researchers have published in journals published in 46 countries.

Distribution by journal impact factor

More than 77.4% of the 10412 journal papers from India had appeared in 441 non-*SCI* journals, and 18.5% of papers was published in journals of impact factor (IF) less than 1.0. Only 33 papers (0.3%) have been published in journals of IF greater than 3.0 (Table 3). In contrast, about 55% of Indian papers in mathematics, as seen from *Mathsci* 1993–1998 (ref. 8), 47.8% of Indian papers in medicine, as seen from *Medline*[5], 42.7% of Indian papers in life sciences as seen from *Biological Abstracts* 1998 (Arunachalam, S., unpublished results) and 11.5% of papers in new biology, as seen from *SCI*, *Biochemistry and Biophysics Citation Index* and *Biotechnology Citation Index* (Arunachalam, S., unpublished results) were published in non-*SCI* journals. In the area of new biology, only 333 of the 2902 papers published by Indian researchers in 1995 were published in non-*SCI* journals, and 8.3% of papers was published in journals of IF greater than 3.0 (Arunachalam, S., unpublished results). This comparison should not be taken as a reflection on agricultural research in India. Agriculture, like mathematics and unlike new biology and to some extent physics, is a low-impact journal field. Besides, much of the research in agriculture is mainly of local relevance.

Distribution by subfield

The 11,855 Indian papers are classified under 21 major areas and 244 subspecialties (Tables 4 and 5). *CAB Abstracts* often classifies papers into more than one subspecialty. Here we have considered only the first mentioned subspecialty. Plant-related subspecialties such as 'Pests, pathogens and biogenic diseases of plants', FF600 (1301 papers), 'Plant breeding and genetics', FF020 (1135 papers), and 'Plant production', FF100 (786 papers) are popular with Indian researchers. The subfield FF (Plants of economic importance) has the most number of papers, 4855, followed by LL (Animal sciences), 1808 papers, and JJ (Soil science), 910 papers. Three other subfields have 500 or more papers: KK (Forestry, forest products and agroforestry), 763; HH (Pathogen, pest and parasite management, general), 757; and VV (Human health and hygiene, gen-

eral), 500. In 'Biotechnology' (WW), there were only 54 papers in 1998 and 231 papers in 1990–1994. Compared to 1990–1994, there have not been many changes. Subfield HH has moved down from rank 4 in the earlier period to rank 5 and KK has moved up from rank 5 to rank 4. There has been a considerable increase in the number of papers in the area 'profession, education, information and training' (CC) – from 79 papers in five years to 49 in one year. Two other areas which have recorded a substantial increase are 'Aquatic science' (MM) and 'Sociology, general', UU. The subfield 'Medical and veterinary records' (TT) is no longer in existence.

Distribution by institution

More than 1280 institutions are active in India and have published at least one paper in 1998 that was found worthy of being indexed in *CAB Abstracts* (Table 6). CCS Haryana Agricultural University, Hisar (473 papers), Punjab Agricultural University, Ludhiana (390 papers) and the Indian Agricultural Research Institute, New Delhi (378 papers) are the leading publishers of research papers in the country. These are followed by University of Agricultural Sciences, Bangalore (253 papers), Tamil Nadu Agricultural University, Coimbatore (239 papers), Assam Agricultural University, Jorhat (229 papers), and Indian Veterinary Research Institute, Izatnagar (221 papers). Twenty institutions have published 100 or more papers; 18 institutions have published 50–99 papers; 55 institutions have published 25–49 papers; and 113 institutions have published 10–24 papers. At the other extreme, 575 institutions have published just one paper, and 207 institutions have published two papers each. Individual units are listed separately in Table 6. For example, Agricultural College and Research Institute, Madurai (25 papers), is a constituent of Tamil Nadu Agricultural University, Coimbatore. There have been some minor changes from the previous period. For example, Punjab Agricultural University, the leading publisher of research papers in 1990–1994, slid to rank 2 and the University of Agricultural Sciences, Bangalore, moved up from rank 7 to rank 4. Figure 2 is a curve of the number of institutions vs the cumulative number of papers.

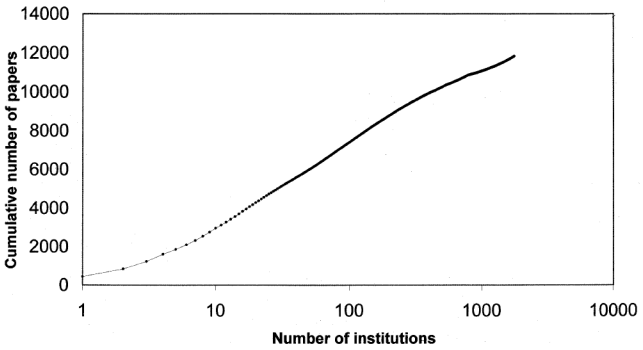

Figure 2. Number of institutions vs cumulative number of Indian papers.

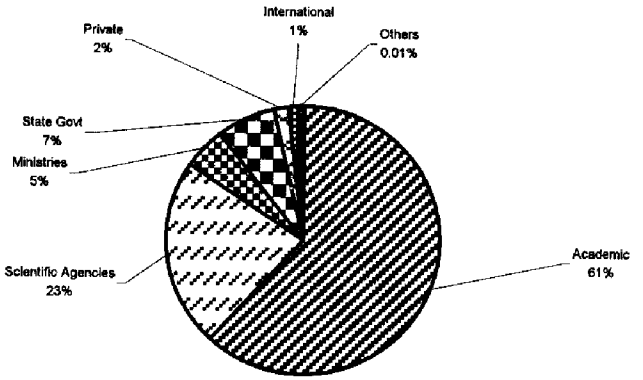

Figure 3. Contribution to agricultural research by different types of organizations.

Table 7. Indian states contributing to the world literature of agriculture as seen from *CAB Abstracts* 1998 and 1990–1994

State/union territory	No. of papers 1998	No. of papers 1990–1994
Uttar Pradesh	1661	8327
Karnataka	1117	3984
Tamil Nadu	1047	4072
Maharashtra	851	4084
Delhi	807	3666
Haryana	776	4017
Andhra Pradesh	687	3557
Madhya Pradesh	630	2091
West Bengal	572	2866
Punjab	483	2910
Kerala	454	1484
Himachal Pradesh	358	1799
Orissa	342	1158
Assam	336	737
Rajasthan	322	1798
Bihar	307	1303
Gujarat	293	1710
Jammu & Kashmir	93	675
Chandigarh (UT)	56	507
Meghalaya	52	376
Andaman & Nicobar Islands (UT)	41	157
Pondicherry (UT)	36	130
Manipur	35	111
Tripura	16	51
Sikkim	13	54
Goa	12	60
Arunachal Pradesh	9	14
Nagaland	1	38
Mizoram	1	5
Lakshadweep		1
Unknown	447	19
Total	11855	51761

Distribution by institution type

Academic institutions (including universities and colleges) have accounted for 7011 papers or 59.1% of the 11,855 papers (Figure 3). In the earlier period, academic institutions accounted for 63.4%. Central government research agencies (such as ICAR and CSIR) have raised their share from 21.2% in 1990–1994 to 22% in 1998. The share of ICAR institutes is a little over 17%, marginally higher than the 15.2% in the five years 1990–1994. We have included Indian Agricultural Research Institute under ICAR, although it also has the status of a university. As expected, agricultural universities (4039 papers) and colleges (523 papers) have published the largest number of papers. It is significant that general (arts and science) colleges have published 510 papers and general universities, 1744 papers. More than 190 papers have come from medical colleges and universities. This is not surprising, as *CAB Abstracts* does cover health-related research to some extent.

Distribution by state and city/town

Uttar Pradesh is the state accounting for the largest number of papers (1661), followed by Karnataka (1117), Tamil Nadu (1047), Maharashtra (851) and Delhi (807) (Table 7). Compared to 1990–1994, Karnataka has moved up from the fifth position to the second and Maharashtra has slid from the second to the fourth. Delhi has overtaken Haryana, and Madhya Pradesh and West Bengal have overtaken Punjab. Among cities, New Delhi leads with 800 papers, followed by Bangalore (590), Hisar (482), Ludhiana (394), Coimbatore (346) and Hyderabad (307). Thirty-one cities have published more than 100 papers and 18 cities have published 50–99 papers; at the other extreme, 196 cities have published just one paper each. There have been some minor changes in the ranks of cities/towns: Karnal has slipped from the eighth position in 1990–1994 to 13th in 1998, and Mohanpur from the ninth to the 18th.

Distribution of papers from different institutions by subfield, journal and journal impact factor

Table 8 gives the number of papers published by selected institutions in different subfields. Notice that there is hardly any paper in plant-related areas from the Indian Veterinary Research Institute (column G) and National Dairy Research Institute (column K). We have also constructed similar matrices on the use of Indian and foreign journals by selected institutions, and on the journals often used to publish papers in different major areas. University of Agricultural Sciences, Bangalore, and Dr Panjabrao Deshmukh Krishi Vidyapeeth publish many papers in local/in-house journals. Table 9 lists the number of papers published by selected institutions in journals of different impact factor ranges. Indian Institute of Science, Bangalore has published seven papers in journals of IF higher than 3.5; International Centre for Genetic Engineering and Biotechnology, New Delhi has four papers, Jawaharlal Nehru University, New Delhi, and National Institute of Immunology, New Delhi, three papers each and Delhi University, New Delhi two papers in journals of impact factor higher than 3.5. These papers in high impact journals are mostly in new biology and not agricultural research per se. Indian Agricultural Research Institute, Banaras Hindu University and Jawaharlal Nehru Krishi Vishwavidyalaya have published a few papers in medium impact journals.

Conclusion

Agriculture, encompassing crop and animal husbandry, horticulture, forestry and agro-forestry, inland and marine fisheries and agro-processing, is the major determinant of the livelihood destiny of nearly 700 million people of India, and the farm sector still employs 60% of the nation's workforce, despite a dip of 4% during 1993–1999 (ref. 3). Agricultural progress holds the key to the nation's economic and political future. Indian agriculture is now at the crossroads, says Swaminathan[2]. On the one hand, the nation's capability in frontier areas of science and technology, as for example in biotechnology, information, communication and space technologies, nuclear and renewable energy technologies and in management science, has opened up uncommon opportunities for achieving an evergreen revolution in most farming systems, based on knowledge and biological inputs rather than on chemical and capital-intensive production methods[2]. There are, on the other hand, both internal and external threats to our agricultural progress. The most important among the internal threats is the damage to the ecological foundations essential for sustained agricultural advance, such as land, water, forests and biodiversity. Prime farmland is all the time going out of agriculture and groundwater depletion is proceeding at an alarming rate. The other major internal weakness is the mismatch between production and post-harvest technologies and between production and market demand[13], and the consequent need for the Government of India to undertake 'trade relief' operations such as cyclone, flood and drought relief. The external threats include the unequal trade bargain inherent in the WTO agreement of 1994, and potential adverse changes in temperature, precipitation, sea level and ultraviolet B-radiation. Added to this is the American President Bush's reluctance, if not refusal, to honour the Kyoto protocol on climate change.

Table 8. India's contribution to the world literature of agriculture categorized by subfield and institution

→	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	Total
	47	51	82	29	48	47	0	48	17	26	0	15	15	16	23	16	18	37	24	559
	45	35	71	28	32	25	0	28	28	18	0	16	24	19	10	10	20	7	5	421
	27	32	18	28	26	20	0	31	17	14	0	5	12	24	11	12	16	8	7	308
	24	20	29	13	22	7	5	16	11	14	2	9	11	4	2	6	11	12	8	226
	33	31	1	7	1	17	71	1	8	0	1	1	1	2	9	2	0	0	0	186
	13	17	19	6	15	9	0	5	4	11	0	4	7	7	6	2	5	5	1	136
	10	20	27	5	9	1	0	8	5	1	0	11	6	0	1	0	4	3	1	112
	12	9	0	3	0	12	23	0	4	0	25	5	3	2	1	4	0	0	0	103
	5	3	0	5	0	0	1	0	3	2	42	1	0	1	0	16	0	0	1	80
	9	6	1	0	0	8	6	0	4	1	8	2	5	0	4	11	0	0	0	65
	14	5	15	1	6	6	0	1	2	3	0	3	1	2	0	0	1	1	0	61
	5	4	3	5	5	2	0	6	1	3	0	2	6	3	7	0	3	2	1	58
oil water management	9	9	2	5	5	2	0	0	3	3	0	0	2	4	2	7	1	1	1	56
	6	12	0	6	0	3	12	0	1	0	0	0	1	2	10	1	2	0	0	56
	2	1	5	2	3	2	0	3	5	8	0	2	5	3	1	3	3	1	0	49
	8	1	1	1	0	3	11	0	0	0	15	0	0	2	0	3	0	0	0	45
	10	2	4	1	4	2	0	2	1	2	0	8	2	3	2	0	1	0	1	45
	4	4	0	3	0	1	17	0	9	3	0	0	0	0	2	2	0	0	0	45
Symbiotic nitrogen fixation	10	1	5	2	2	1	0	2	3	4	0	3	4	0	0	1	5	0	1	44
	3	11	0	2	1	2	15	0	5	0	1	0	2	1	0	0	1	0	0	44
	9	3	0	0	0	2	7	0	4	0	10	0	1	1	1	0	0	0	0	38
	305	277	283	152	179	172	168	151	135	113	104	87	108	96	92	96	91	77	51	2737

– Chaudhary Charan Singh Haryana Agricultural University, Hisar
B – Punjab Agricultural University, Ludhiana
C – Indian Agricultural Research Institute, New Delhi
– University of Agricultural Sciences, Bangalore
E – Tamil Nadu Agricultural University, Coimbatore
F – Assam Agricultural University, Jorhat
– Indian Veterinary Research Institute, Izatnagar
H – University of Agricultural Sciences, Dharwad
I – G.B. Pant University of Agriculture and Technology, Pantnagar
– Bidan Chandra Krishi Viswavidyalaya, Mohanpur
N – National Dairy Research Institute, Karnal
L – Banaras Hindu University, Varanasi
– Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur
N – Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
O – Himachal Pradesh Krishi Vishvavidyalaya, Palampur
– Gujarat Agricultural University, Sardar Krushinagar
Q – Orissa University of Agriculture and Technology, Bhubaneswar
R – Indian Institute of Horticultural Research, Bangalore
– Dr Y. S. Parmar University of Horticulture and Forestry, Solan

Table 9. India's contribution to the world literature categorized by institution and journal impact factor* (Source: *CAB Abstracts* 1998)

Institution	Impact factor →	A	B	C	D	E	F	G	H	Total
CCS Haryana Agricultural University, Hisar		373	75	16	6	3	0	0	0	473
Punjab Agricultural University, Ludhiana		312	52	22	3	1	0	0	0	390
Indian Agricultural Research Institute, New Delhi		297	52	13	8	1	4	3	0	378
University of Agricultural Sciences, Bangalore		235	11	5	1	1	0	0	0	253
Tamil Nadu Agricultural University, Coimbatore		222	14	2	1	0	0	0	0	239
Assam Agricultural University, Jorhat		202	25	2	0	0	0	0	0	229
Indian Veterinary Research Institute, Izatnagar		176	34	8	2	1	0	0	0	221
University of Agricultural Sciences, Dharwad		206	5	1	1	0	0	0	0	213
G. B. Pant University of Agriculture and Technology, Pantnagar		176	31	4	1	0	0	0	0	212
Bidhan Chandra Krishi Viswavidyalaya, Mohanpur		141	10	2	0	0	0	0	0	153
National Dairy Research Institute, Karnal		128	11	5	5	2	1	0	0	152
Banaras Hindu University, Varanasi		92	27	12	8	4	3	4	0	150
Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur		99	30	3	4	4	1	0	1	142
Dr Panjabrao Deshmukh Krishi Vidyapeeth, Akola		135	1	0	0	0	0	0	0	136
Himachal Pradesh Krishi Vishvavidyalaya, Palampur		99	24	3	1	0	0	0	0	127
Gujarat Agricultural University, Anand		101	18	0	0	0	0	0	0	119
Orissa University of Agriculture and Technology, Bhubaneswar		96	16	0	1	0	0	0	0	113
Indian Institute of Horticultural Research, Bangalore		84	16	1	2	1	0	0	0	104
		3174	452	99	44	18	9	7	1	3804

*Only journals with impact factor (IF) up to 3.5 are included.
See the text for information on 27 papers published in journals with IF > 3.5.
A, 0.000; B, > 0.000 ≤ 0.500; C, > 0.500 ≤ 1.000; D, > 1.000 ≤ 1.500; E, > 1.500 ≤ 2.000; F, > 2.000 ≤ 2.500; G, > 2.500 ≤ 3.000; H, > 3.000 ≤ 3.500.

India can face the internal threats only through integrated attention to regulation, education and social mobilization through panchayati raj institutions. Also, there is need to restructure research strategies in a manner that strategic, anticipatory and participatory (i.e. with farm families) research, all received adequate attention. Participatory research is essential for developing location-specific technologies. Similarly, extension services should become farmer-owned and controlled and should become capable of converting generic into location-specific knowledge, essential for taking to precision farming methods. The rural knowledge centres should provide computer-aided and internet-connected information services, so that farm families have timely and relevant meteorological, management and marketing information[2]. Agriculture, which accounts for a quarter of India's economic output, not only remains tied to the whims of the monsoon rains, but also increasingly to the vagaries of the market.

The future of Indian agriculture depends on three factors, viz. research, public policy and the farming community's cooperative action. The greater the synergy among these three factors, the better it would be for India. This has been emphasized in the Chennai Declaration of the MSSRF-FAO Expert Consultation[14], which has three sections devoted to priority research areas, contributions of science, and the science – policy link. Research does not mean merely laboratory research; it includes research that would inform policy in all its aspects. Scientific organizations need to work with farmers and fishermen to move food security and nutrition higher up in the political agenda. Much of life sciences and agricultural research is coming under proprietary science and unless India gears up publicly-funded agricultural research, there is the imminent danger of long-term dependence on multinational corporations for knowledge, when agriculture is increasingly becoming knowledge-intensive. In the late sixties and seventies, Indian agriculture research was able to tide over a major crisis through the 'Green Revolution' that eventually transformed India from a basket case to a food surplus country. Will it be able to do yet another rescue act? Lester Brown of the World Resource Institute has warned that by 2030 both China and India may have to import quantities of food unheard of in history – 240 million tonnes for China and 40 million tonnes for India[15]. Can the Indian agricultural research establishment prove him wrong? Fortunately for India, there is great opportunity to raise productivity because of the gap between potential and actual yields. Unfortunately, India is investing less than 0.5% of agricultural GDP on research, says S. Balaravi, Assistant Director General of the Indian Council of Agricultural Research, New Delhi.

This macroscopic analysis of agricultural research and related publications does not cover public policy and the collective action of farming communities. It is restricted to analysing the research output over a one-

year period – in the form of published literature – of Indian agricultural researchers as a whole. This paper has identified the institutions that are active, the areas in which they are active and the journals in which they publish their work. While there has been much activity in the areas of plants of economic importance and animal sciences, there were only 54 papers in the area of biotechnology. There were only 231 papers in this area in the five years, 1990–1994 (ref. 4). Clearly, India appears to be slow in catching up in this rather important area, where companies like Aventis and Monsanto are doing pretty well. What is more, most of these papers in biotechnology have come from life sciences schools of higher educational institutions other than agricultural universities. We wish to reiterate that it would be beneficial if researchers from centres of agricultural research and centres of biotechnology and new biology research in the university and national laboratory sectors could come together and work on joint projects.

To be of greater value to policy-makers, we should refine this research programme to look at research at the level of individual crops. For example, what is being done to increase the production of under-utilized or minor crops and to use them in processed food? Other questions that would enhance the value of this research are: Is research being carried out to make agricultural production environment-safe, economically viable and socially sustainable? If so, with what success? Have there been efforts to integrate research, priority setting, public policy and the farming community's action? What is the status of research in the area of agricultural extension services? Are there efforts to use new information and communication technologies and locally generated databases and make the farm families the central focus of these services?

Or are men like Swaminathan merely crying in the wilderness?

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