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Impact of Agricultural Research in India: Is it Decelerating?

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The public agricultural research system in India comprising institutes of the Indian Council of Agricultural Research (ICAR) and the state agricultural universities (SAUs) has been subject to several evaluations and reviews. This coupled with slowdown in the rate of agricultural growth after mid-1990s have created an impression of slowing down of research impacts. It is apprehended that the research system is not able to maintain uptrend in the scientific productivity, and newly emerging stresses are threatening sustainability of our agricultural systems. How far this fear is true? We have examined this question using some empirical evidence.

Research Investment

Before we analyse the impacts of agricultural research, it will be useful to examine the trends in the public research investment which is an important factor affecting them. India has consistently committed substantial government funds for research in all fields of science including agriculture. Total government funding for agricultural research and education increased in real terms (1999 prices) from Rs 2.5 billion in 1961 to Rs 7.9 billion in 1980. This further rose to Rs 25 billion in 2000—a ten-fold increase over the past four decades (Fig. 1). An increasing trend is observed for both central and state funding. The government funding grew at the rate of 3.2% per annum in 1970s, 7% in 1980s, but slowed down to 4.6% in 1990s. Nearly three-fourths of the total resources were spent on research and the rest on education (mostly in SAUs) and on-farm testing, refinement and demonstration of new technologies.

Another way to assess the funding is to compute an intensity ratio such as expenditure as percentage of agricultural gross domestic product (AgGDP). This ratio increased significantly during 1960s and 1980s, but remained around 0.4% during 1990s. This slowdown in research intensity is worrying given that the average intensity for all developing countries is 0.6 percent and 1% globally. China, a country of comparable size and stage of development, spends 0.43% of her AgGDP on research as against 0.29% in India (excluding education). The intensity ratios for Latin America and Africa are more than double of India. Thus, there is a clear case of under investment in agricultural research in India. Nevertheless, the actual government investment and size of agricultural research system have reached a level that requires a close social audit. It is reasonable to expect that uptrends in the research investment should not be accompanied by declining scientific productivity and payoffs.

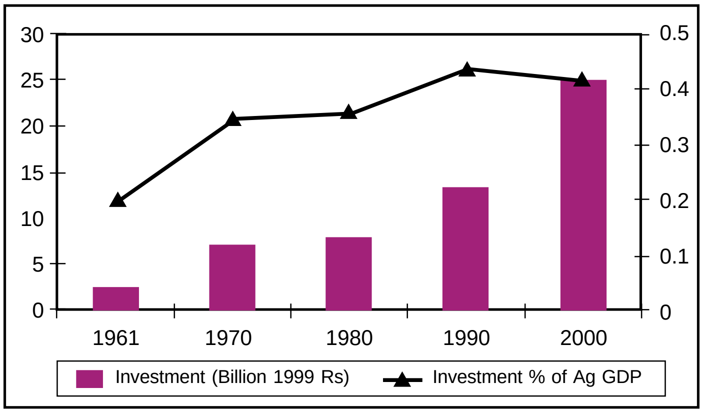

Fig. 1 Trends in government funding to agricultural research and education in India

Trends in Scientific Productivity

Scientific publications and technologies are the two main outputs of agricultural research which is applied in nature. These research outputs also adequately capture other research contributions like development of research methodologies and intermediate products, which either get published in scientific journals, or facilitate technology development.[1] This section examines the trends in these main outputs of the ICAR-SAU system.

Research publications

Research publications include journal articles, books and book chapters, monographs, research and teaching manuals, extension materials, etc. Since consistent time-series data are not available for all of these indicators, we have focused on research articles indexed by three abstracting sources for agricultural and allied sciences. These are the *Science Citation Index* (SCI), the *CAB Abstracts* (CABA), and the *Indian Science Abstracts* (ISA). We have taken total number of research publications authored by

[1] Patent is another indicator of research product, but this was not considered due to lack of information and emphasis in the system.

[2] The SCI, an internationally reputed source, is consistent in the coverage and quality criteria for indexing of scientific journals globally. The CABA and ISA index research publications appearing in almost all Indian journals. Data were obtained by electronic search of SCI and CABA databases (CD-ROM), and manual search of ISA database.CABA data for 1990 and 1998 are from Arunachalam and Umarani (2001).

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Table 1. Trends in annual research publications of ICAR-SAU system

	ICAR institutes		SAUs		Total (ICAR & SAUs)	Articles per FTE[b] scientist
	Top five[a]	All institutes	Top five[a]	All SAUs		
Number of articles indexed in SCI						
1980	446	696	496	758	1,454	0.14
1990	123	205	205	292	497	0.04
2002	143	299	154	231	530	0.05
Number of articles indexed in CABA						
1980	690	1,090	951	1,924	3,014	0.29
1990	902	1,645	1,664	4,413	6,058	0.48
1998	934	2,027	1,672	4,637	6,664	0.51
Number of articles indexed in ISA						
1990	651	1,170	1,547	4,308	5,478	0.43
2002	432	1,250	1,145	4,786	6,036	0.53

[a] SCI data are triennium averages; [b] Full-time equivalent (e.g., a scientist spending 50% of his time on research was considered as 0.5 FTE).

the scientists working in ICAR institutes and SAUs from these three sources.[2] As seen from Table 1, there is a drastic decline in the number of the SCI-indexed publications in 1990 over that in 1980. This decline is deeper for SAUs and it continued even in 2002. ICAR institutes however showed a moderate recovery in 2002. What is more worrisome is that even the institutes and universities with the best publication record could not achieve the 1980 level in 2002. This clearly shows depletion of upstream or strategic research[3] in the ICAR and SAU system.

A sharp decline in the SCI-indexed articles authored by the agricultural scientists echoes the broad trend observed for the Indian science. The total number of SCI-indexed research articles authored by Indian scientists in all fields of science decreased from 14,983 in 1980 to 10,103 in 1990, but rose back to 14,028 in 2002. However, part of the slow recovery of the articles of agricultural sciences during 1990s could be attributed to a shift towards publication in Indian journals which increased in number over time. Some of these journals were also rated high by the national professional academies and assessment boards.

Trends in the total number of publications of agricultural science are quite encouraging. The number of CABA-indexed publications increased from 3014 in 1980 to 6,058 in 1990, which further rose to 6,664 in 1998. A similar trend was also observed for the ISA-indexed publications. This increase in the number of publications during 1990s is important because it is believed that the number of agricultural scientists might have gone down during this period. The number of publications per scientist per year also increased from 0.48 in 1990 to 0.51 in 1998, registering an increase of about 6 percent (Table 1).[4] This clearly shows an upward trend in scientific productivity of the ICAR-SAU system. However, there are some noteworthy patterns. Nearly 80 percent of the papers were published in the non-SCI journals with zero impact factor[5] and only a small proportion of the papers were published in the journals with an impact factor greater than zero but less than two (Arunachalam and Umarani, 2001). About half of the SCI-indexed and more than 70 percent of the total publications were authored by the scientists working in SAUs, which is expected because of their scientific strength and dominance of student research. However, the tendency to publish in the low rating journals is a matter of concern. The average impact factor even for ICAR articles was 1.1 and 1.6 for CSIR in 2002, underscoring the need for improving the quality of publications in the country.

The current productivity level (0.5 paper) of agricultural research is too low in India. The question now arises how can it be increased? Scientific productivity is directly related with the availability of research resources. It is found that an institute with higher budget per scientist is likely to be more productive than a poorly funded institute. At the same time, it is also important how the available resources are used. The institutes with higher proportion of operational expenses in the total expenditure and greater scientific interactions and institutional linkages are likely to have better publication record. In addition, age of an institute capturing institutional factors like history and culture of an organization has a positive impact on the publication efficiency (Jha et al, 2004). This is because of the fact that the accumulating stock of tacit knowledge and tradition of "good practices" help in efficient use of research resources and attracting best brains. On the other hand, a high proportion of top cadre scientists is associated with lower scientific productivity, which is consistent with the "life-cycle theory" maintaining that (direct) productivity of an individual decreases after a certain age. These results have strong implications for the ICAR-SAU system which is dominated by the top cadre scientists. Also, the share of operational expenses in some of the institutions was less than 20%. Thus, balancing the cadre strength and factor-shares in research expenditure are essential for increasing scientific productivity of the system.

Technology development

The number of usable technologies developed is another indicator of scientific productivity, but it is very difficult to compile time-series data on them. We have therefore considered the trends in rice varieties developed to indicate the broad pattern of technological contributions. This is because rice is one of the important crops receiving greater attention of the research system, and most other crop management technologies evolve

[3] Assuming this research is published in SCI-indexed journals.
[4] Increase in the ISA-indexed articles is sharper due to widening of its coverage of publication sources.
[5] The impact factor is the frequency with which an average article from a journal is cited in a particular year.

Table 2. Trends in rice variety development, 1971-2000

	1971-1980	1981-1990	1991-2000
Total number of varieties developed	127	223	257
Percentage of varieties with fine grain quality[a]	29.1	34.9	36.5
Percentage of varieties tolerant to diseases	50.4	67.2	51.0
Percentage of varieties tolerant to insect pests	10.2	25.1	20.2
Percentage of varieties developed for marginal areas[b]	41.7	50.6	46.0
Percentage of short to medium duration varieties[c]	74.8	53.8	52.5

[a] Long slender grain type, [b] Rainfed upland and lowland, deepwater, saline and alkaline ecosystems

[c] 50% flowering in less than 100 days, Source: Based on DRR (Hyderabad) data

around improved varieties. As seen from Table 2, there is an upward trend in the number of varieties developed by Indian rice breeders. During the 1970s, 127 rice varieties were released, which rose to 223 in the 1980s—almost doubling the breeding productivity. The number of officially released varieties increased to 257 during the 1990s. Besides increase in the number of varieties bred, rice breeding also witnessed some qualitative changes over time. The proportion of varieties with fine quality (long slender) grain increased from 29% in 1970s to 36% in 1990s. Also, there is significant increase in the number of varieties developed for marginal production environments, as well as those tolerant to biotic stresses. This development has contributed to a substantial reduction in yield variability even in the rainfed areas of eastern India (Pal et al., 2000). Development of hybrid rice in partnership with the International Rice Research Institute and private seed companies has established yield advantage of 15-20%. Thus, maintaining high and stable yields with improved grain quality is a major contribution of Indian plant breeding programmes. Also, there was focus on breeding short duration rice varieties, which constituted about half of the total varieties released during 1980s and 1990s, down from three-quarters during the 1970s, owing to trade-off between yield enhancing and crop maturity reducing traits.

Similar trends were also observed in breeding programmes for other crops. For example, in maize, the number of varieties (50) developed during 1980-1993 was higher than those (45) developed during 1960-1980. Also, there was a shift in breeding focus from varieties to hybrids during the 1980s (Morris et al., 1998). Recently, high protein maize hybrids are developed to meet the rising demand for food and feed. In the case of wheat, so far more than 200 varieties have been released for cultivation in India, and yield potential has been increasing by one percent per year due to the persistence improvement in plant type. After the mid-nineties, an additional yield potential of above 0.7 tonne/ha has been established on farmers' fields, which is likely to be enhanced further through exploitation of hybrid vigour in wheat breeding (Nagarajan, 2004). The success of crop breeding programmes, coupled with the policy of open access to public material, contributed to the growth of private seed industry in the country.

In horticulture, forestry and medicinal and aromatic plants, rapid multiplication of disease-free planting material by tissue culture is contributing to rapid adoption of improved varieties and higher crop yields. The resource-conservation technologies are reducing groundwater use by 5 to 30 percent in the rice-wheat system. The packages for integrated management of pests and plant nutrients, along with pest tolerant varieties are expected to reduce the use of pesticides to the extent of 50 percent. Cross breeding and nutrition and disease management research in livestock have increased milk and meat yields and reduced mortality rates. But, the success was confined to dairy, commercial poultry and fish sector only, and subsistence livestock sector suffered because of limited commercialization of technologies which are often capital intensive, causing a scale bias.

Socio-economic Impact

Economic payoffs. Agricultural R & D has been assessed quantitatively by a number of studies done by the national and international organizations. It is shown that investment in agricultural R&D is a 'win-win' option as it is the largest contributor to agricultural total factor productivity (TFP), which in turn reduces rural poverty significantly (Fan et al., 1999). Although there are considerable variations, the average rate of return to investment in agricultural research was about 70 percent with a median value more than 50 percent. These rates are very much comparable to those obtained internationally, covering both developed and developing countries (Table 3). Furthermore, the marginal internal rate of return to research investment in India ranged from 57 to 59 percent since the green revolution era. This is against 35 percent rate of return realized for private agricultural R&D, and 45 percent for public agricultural extension (Evenson et al., 1999).[6] The growth in agricultural TFP is estimated to be 1.4 percent during 1980-2000, which is equal to that observed for the crop sector during initial phase of the green revolution (Coelli and Rao, 2005 and Evenson et al., 1999). However, deceleration in the TFP growth for crops is observed in the Indo-Gangetic Plains during the

Table 3. Internal rates of return (%) to agricultural research investment in India

	India			Global estimates
	Sector-level analysis	Crop-level analysis	All studies	
Mean	75.4	69.9	71.8	79.6
Mode	50+	About 60	50+	26.0
Median	58.5	53.0	57.5	49.0
Minimum	46.0	6.0	6.0	-7.4
Maximum	218.2	174.0	218.2	910

Source: Alston et al. (2000) and review of Indian studies

[6] The marginal internal rate of return to investment in irrigation ranged from 4 to 6 percent during the corresponding period.

mid-1990s (Kumar et al., 2004). This is certainly an undesirable trend, but it would be premature to entertain the deceleration hypothesis based on the data for few years. Moreover, there is no clear indication whether this deceleration is because of slow improvement in the technical efficiency—an important factor for growth in TFP, or technological regression. Thus, there is no clear evidence of decline in socio-economic impact of public agricultural research in the country. In fact, deceleration in the agricultural growth since the mid-nineties underscores the need for acceleration of technology flow to farmers, requiring higher investment in R & D.

Benefits to smallholders. Has agricultural research in India also benefitted small holders and dryland areas? Since the green revolution technologies were neutral to scale, the growth benefits were also shared by small producers, and urban poor benefited through reduction in food prices. The high-yielding varieties also spread rapidly to dry semi-arid regions of the central and peninsular India and covered more than 74 percent of area under sorghum and pearlmillet, which is higher than of paddy. Of late, there is rapid spread of modern varieties in the eastern India, contributing to most of the increase in the national foodgrain production during the 1990s. Jha (2001) has shown that technological change has been pervasive even in the rainfed areas, and crops like coarse grains, pulses, oilseeds, fibres, and vegetables have registered a positive growth in the total factor productivity. However, the impact has been rather limited in a few states, viz. Bihar, Madhya Pradesh, and Karnataka, partly because of incremental nature of technological advancements (unlike one-shot jump in irrigated areas), which are often eroded by erratic weather conditions. Barring these few limitations, the research system has been able to address the objective of sustainable agricultural development with social justice, and economic policy environment has helped in achieving this objective. Of course, international research community, mainly the CGIAR system, has been a useful ally in this endeavour. But, technology spillovers from the CGIAR system would not have been realized in the absence of the strong national system.

Conclusion

This paper has highlighted the fact that there is no deceleration in the productivity and payoffs of agricultural research in India, though there is some erosion of basic and strategic research. In order to sustain the current productivity trends, research investment should be enhanced to bridge the gaps in resource allocations across commodities and regions, strengthen strategic research in frontier areas like biotechnology, modernize research infrastructure, and human resource development. The second important challenge is to make the research reforms a reality. Correcting factor shares by reducing overheads, balancing cadre strength and encouraging "good practices" deserve immediate attention. The third challenge is arising from globalization of agricultural research under the strengthened intellectual property rights regime. The public research system should assert more in terms of protection and use of its intellectual property for maintaining a balance between resource generation, accessing proprietary technologies and developing a competitive technology delivery system, e.g. seed markets, with the overall objective of sustainable and equitable agricultural development.

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