Agricultural Technologies: Social Contributions

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....agricultural science in India has not only made significant economic and social contributions in the past, it was reorienting the programs to sustain these benefits in future also

Millions of people derive their livelihood security from agriculture in India, and it directly provides employment to nearly 52 per cent of total workforce. However, agriculture contributes only 14 per cent to India's gross domestic product (GDP). Despite falling share of agriculture in the national GDP, this sector remains important as it ensures food security for over one billion population of the country and provides raw materials to agro-based industries. Agricultural growth has also direct and decisive impact on reduction of rural poverty in the country.

The concerted efforts of farmers, scientists, and policy makers have made Indian agriculture a pride. Agricultural production has considerably increased during past 50 years (1965-2015) after the introduction of new agricultural technology in the mid-sixties. During 2014-15, India produced 252 million tonnes of foodgrains, 26 Mt of oilseeds, 17Mt of pulses, 257 Mt of fruits and vegetables, and 146 Mt of milk. The role of the National Agricultural Research System (NARS) has been pivotal to this immense growth in agricultural production. But now, Indian agriculture faces new challenges of sustainability in terms of sustaining factor productivity, increasing profitability, and building resilience to climate change, besides attaining significant increase in the production of pulses and oilseeds for self-sufficiency.

Sustaining growth in total factor productivity requires efforts to maintain flow of technology to farmers. The production loss in perishable products indicates weak linkages (both forward and backward), and emerging climate change points towards the proper management of resources like land and water to meet the food-security goals. Addressing these problems and emerging challenges and providing durable solutions is a technology and policy challenge. This is also essential to sustain benefits of agricultural technology in terms of economic and social welfare.

Research System and Intensity of Investment

Agricultural research system in India is being managed under a three tier system, viz. (i) Indian Council of Agricultural Research (ICAR) at apex level, (ii) State Agricultural Universities at state level, and (iii) private sector at

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both at sector and commodity level. Apart from these, there are some institutions in central Departments of Agriculture, Council of Scientific and Industrial Research (CSIR), Ministry of Science and Technology, Ministry of Commerce and Industry, etc. ICAR has a network of more than one hundred institutes spread across the country. These institutes are organized on commodity or resources pattern and few have multi-commodity and resource structure. SAUs are expanding presently more than seventy in number. One of the major institutional links between ICAR institutes and SAUs is the All-India Coordinated Research Project (AICRP). These coordinated projects working on the principle of inter-are disciplinary and inter- institutional collaborations. The first AICRP on maize was started in 1957, and the ICAR had 79 AICRPs during 2015-16, involving several disciplines and commodities, viz. soils, water, crops, horticulture, livestock, fisheries, agricultural engineering, home science, education, etc. The AICRPs on crops have defined operational area based on ecological conditions. This set up enables AICRPs to effectively utilize natural resources and man and material to solve problems at various levels in a coordinated manner according to predetermined priorities and strategies.

Research Investment

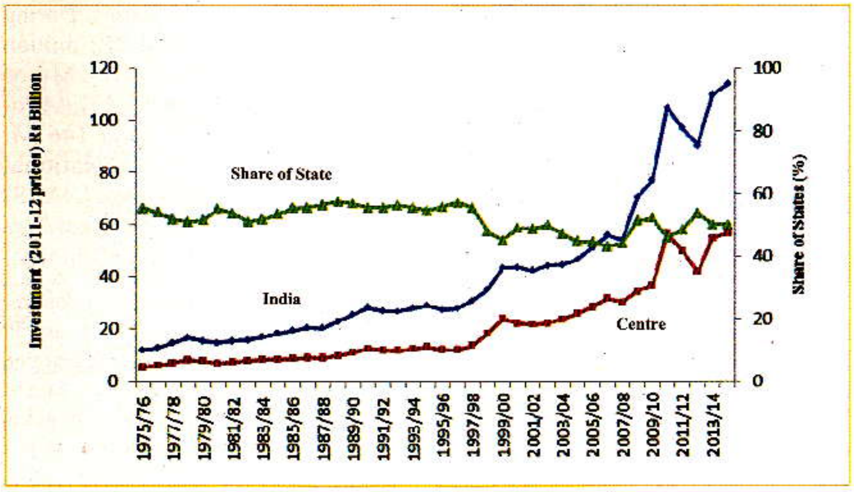
In India, agricultural research system is mainly under the public domain and the government has played a major role in developing agricultural R&D system. The Government has consistently provided funds for research in all fields of science including agriculture. The total government expenditure for agricultural research and education (R&E) increased in real terms (2011-12 prices) from Rs 11.9 billion in 1975/76 to Rs 113.8 billion in 2014-15 —a ten-fold increase in past forty years (Figure 1). There is an increasing trend in spending on agricultural R&E by both Centre and States. Analysis has shown that the share of states in total R&E has fallen from 58 per cent in 1988-89 to 43 per cent in 2006-07, and in 2014-15 the share is about 50 per cent. However, a large proportion of central funds are transferred to SAUs through development grants and other activities like frontline extension. Local R&D institutions have failed to emerge as major players and supporters of agricultural R&D in India. The central sector has always been pressing for obtaining incremental resources. State systems either do not bother or lack of capacity in arguing their case for additional funding. This issue of under funding needs immediate attention of policy makers.

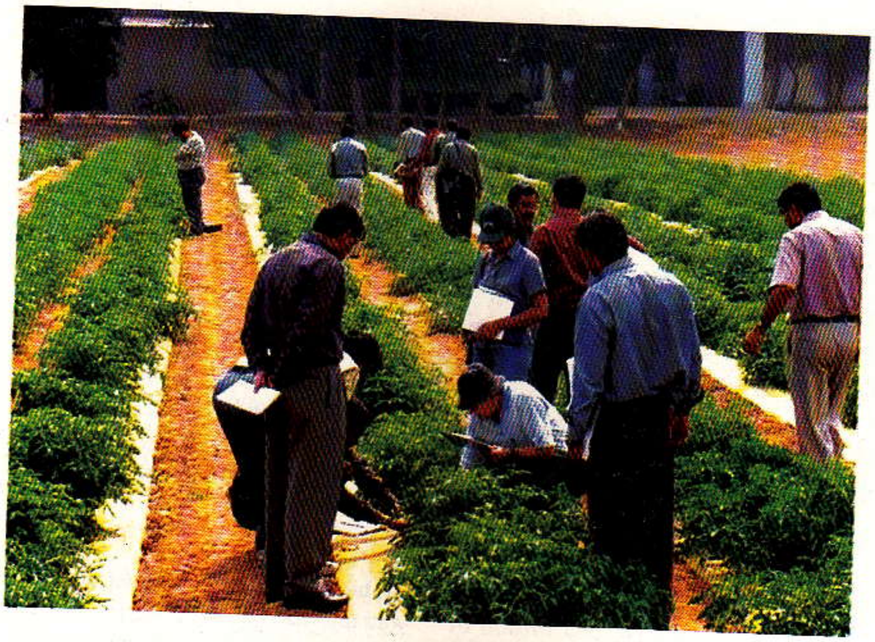
Another way to look at level of public spending for agricultural R&E is to compute research investment intensity which is the ratio of research expenditure to agricultural gross domestic product (AgGDP). This ratio was 0.57 during the TE 2008-09, against the level of 0.40 during 1990s. This level of research investment intensity is comparable with 0.6 percent overall average for the developing world (Beintema and Stads, 2010). However, the agricultural R&D intensity is generally recommended as 1.0 percent for developing countries. Thus, there is a clear case of under investment in agricultural R&E in India. However, with the size of agricultural research system and actual expenditure along with emerging complex challenges and opportunities, reasonable increase in public spending will be in offing.

Contributions of Agricultural R&D

Agricultural research and development (R&D) has potential to offer long-term solutions to the problems of agriculture sector. The scientific progress in agriculture have helped in development of new technologies having added potential and provided options to derive the same or even higher benefits at lower cost per unit of output. These contributions have been most impressive in India and the historical rate of returns to the public investment has been in excess of 50 percent. Most of these benefits have accrued through improvement in crop and animal productivity. Developments in pre-and post-harvest management technologies have facilitated reduction in losses and helped in increasing the availability and value addition (Alam *et al.*, 2002). Reduction of production losses and adding value to the produce is a direct contribution towards increasing total availability, lowering cost of production, and contributing to the national economy. Although the technology alone is not capable to provide complete

Figure 1: Public expenditure on agricultural research and education in India





solution for managing the problems of agriculture, but it is capable of offering better durable solutions. Hence, the role of agricultural research and development (R&D) is critical in managing problems and challenges facing agriculture, particularly in India.

In order to illustrate the contributions of agricultural R&D, the case of varietal development in rice is discussed here. This is because rice is a major crop of India and most of technological developments evolve around plant varieties. Moreover crop variety is one of the usable technologies and better indicator to assess the contributions of R&D. Rice crop is studied as this is one of the major crops covering large cultivated area, and receiving greater attention of the research system facing numerous constraints. The data presented in Table 1 show upward trend in number of varieties developed by the Indian rice breeders. During the 1970s, 127 varieties were released, which reached to 223 in the 1980s--almost doubling the breeding productivity. The number of released varieties increased 257 in 1990s, and further rose to 301 during 2001-2012.

Besides increase in the number of varieties bred, rice breeding programme also witnessed some qualitative changes over time. The share of varieties with fine quality (long slender) grain increased from 29 per cent in 1970s to 36 per cent in 1990s, and the share has however declined to 28 per cent during 2001-2012 but with notable contribution in terms of basmati varieties like Pusa 1121 and Pusa 1509, there is a significant increase in number of varieties developed for marginal production environments, as well as those tolerant to biotic stresses. These varietal developments contributed to marked reduction in yield variability even in rainfed areas of eastern India. Hybrid rice varieties have also been bred and have evinced yield advantage of 15-20 per cent. Thus, maintaining high and stable yields with fine grain quality is a major gift of rice breeding programme. The focus has also been on breeding short to medium duration varieties, which constituted about half of the total varieties released during 1980s and 1990s, have reached close to 80 per cent during 2001-2012, owing to high variability in monsoon rainfall, increased cost of irrigation water, and awareness to take one more catch or cash crop to earn extra profit from per unit of land.

Similar developments of breeding programmes have also been observed in other crops, for example, maize, and wheat. In maize, besides increase in yield, efforts have been made to develop high protein maize hybrids to meet the rising demand for feed and fodder. In case of wheat, during more than 100 years period, a total number of 381 varieties were developed

Table 3: Trends in Rice Variety Development

Rice Variety Features	1971-1980	1981-1990	1991-2000	2001-2012
Total number of varieties developed	127	223	257	301
Percentage of varieties with fine grain quality [a]	29.1	34.9	36.5	28.1
Percentage of varieties tolerant to diseases	50.4	67.2	51.0	52.3
Percentage of varieties tolerant to insect-pests	10.2	25.1	20.2	33.1
Percentage of varieties developed for marginal areas [b]	41.7	50.6	46.0	33.5
Percentage of short to medium duration varieties [c]	74.8	53.8	52.5	79.2

Note: data from Pal *et al.* (2005) and http://drdpat.bih.nic.in/ Downloads/ Rice-Varieties-1996-2012.pdf

[a] Long slender grain type, [b] Rainfed upland and low land, deep water, saline and alkaline ecosystems

[c] 50 per cent flowering in less than 100 days

Table 2: Contribution of Agricultural Research to major crops in India

Particulars	Paddy	Wheat	Gram	R&M	Cotton
Share of TFP in output growth (per cent)	24.5	58.9	26.1	10.1	31.6
Share of research in TFP growth (per cent)	55.7	40.1	42.2	88.6	83.6
Research contribution in production growth (percentage points)	0.32	0.83	0.07	0.40	0.82
Production in 2005-06 (Mt)	133.47	71.27	5.8	7.72	19.19
Research contribution in production (lakh tonne)	4.23	5.90	0.039	0.31	1.58
Price: 2005-06 (Rs/q)	570	1080	1435	1715	3570
Research contribution to selected crops (in crore Rs)	241.0	636.8	5.6	53.2	562.4

Source: Chand *et al.* (2011)

(1905-2010). Of these, 136 varieties are having rust resistance traits. Besides, more than 215 varieties of wheat have been developed keeping quality traits like grain nutrition, glutenin content, and pasta quality. In recent years, bio-fortified wheat varieties rich in micro-nutrients have been released and will benefit to large poor masses to live healthy life.

Besides, research in horticultural crops making available disease-free planting materials by tissue culture and other modern technology and contributing to rapid adoption of thus improved varieties and higher crop yields. The resource conservation technologies are reducing water use by 5 to 30 per cent in the rice-wheat system. The development of livestock technologies have increased milk and meat yields and reduced mortality rates in animals.

Economic benefits

Adoption of improved technology on farmers' field leads to higher crop yields which in turn lead to higher production. The analysis has shown added production of 4.23 lakh tonnes of paddy, and 5.90 lakh tonnes of wheat (Table 2) was achieved due to adoption of improved technology alone during 1975-2005. In value terms, this additional production is estimated to be 241 crores and 636.8 crores, respectively. The additional output not only increased total crop production, but this helped in ensuring food security of over one billion of population of India, and achieving cent-percent self-sufficiency in crops like rice, maize, wheat. However, self-sufficiency for oilseeds and pulses is still lagging behind and need more efforts and urgent attention.

Reduced cost of production

The concept of total factor productivity (TFP) in economics literature is commonly used to signify role of research. The estimates of TFP refer increase in output due to technological and knowledge-based factors other than physical inputs used in production process. Figures in Table 2 show that research and knowledge inputs have contributed to increased output growth in majority of crops during 1975-2005. Wheat crop has been most benefited followed by cotton, gram and paddy. Data further reveal that research and technology led growth has helped decline in real cost of production (at 2005-06 prices) in the range of 1.0-2.3 per cent per annum in the case of cereals, gram, cotton and rapeseed and mustard. This has helped in keeping the prices of cereals low for consumers and benefiting the producers also through a decline in real cost of production. Thus, the estimated actual economic benefits from research far exceed the investment and therefore justify higher investments by the Government.

Table 3. Estimated marginal product and internal rate of return to research investment in India

Crop	Marginal product value, Rs	Internal rate of return, per cent
Rice	2.02	29
Wheat	4.03	38
Maize	1.85	28
Jowar	4.28	39
Bajra	2.29	31
Gram	2.84	34
Pigeon pea	12.82	57
Groundnut	0.71	18
Rapeseed & mustard	0.89	20
Cotton	4.15	39

Source: Chand *et al.* (2011)

Returns to Research Investment

Research investment in agricultural research has been a 'win-win' option as it is the largest contributor to total factor productivity (TFP) in agriculture, which in turn reduces rural poverty significantly (Chand *et al.*, 2011, Fan *et al.*, 1999). Analysis revealed that additional investment of rupee one in research generated more than Re one on an average in all the crops, except groundnut and rapeseed & mustard during the period 1975-2005 (Table 3). Highest marginal value product of research investment was obtained in pigeon pea where additional investment of one rupee generated additional output worth Rs 12.82. For most of other crops, the additional benefits range from two to four rupees with increase of investment by one rupee.

Another way to look at the potentiality of investment is the internal rate of return (IRR) which provides the idea of potential profitability and quick recovery of investment. Data in Table 3 revealed that the overall IRR to public investment in agriculture turned out to be 29 per cent for rice, 38 per cent for wheat, 28 per cent for maize, 57 per cent for pigeon pea, and 39 per cent for cotton during the period 1975-2005. These returns have been consistent with those estimated by other studies for a shorter period after the green revolution. The results suggest that further investments on research in agriculture will generate significant returns and lead to development of agriculture in the country.

Sustaining the Research Benefits

Indian agriculture has stood the test of time, despite facing constraints on resources to the competing goals and programmes. This was possible through development and dissemination of technology. The economic benefits realised in the past are comparable to country and other benefits in terms of reduction in rural poverty and promoting environmental sustainability. Efforts are also made to make the system more responsive and effective in meeting specified goals and objectives. This entails scrutiny of limited resources on regular basis and their allocation to potential areas/activities to yield better results. Prioritization, monitoring and evaluation (PME) is a useful tool to take stock of research activities/ processes in the regime of declining funding for agricultural research and the need for stronger accountability. This new management tool was applied in the system for better targetting of research, and rational allocation of available research resources. This was considered more important in the situation of large system and complexity of research objectives. Now PME is regular feature in the research system to better understand the research complexities and establish the links between agricultural technology, rural livelihoods and national development priorities. Biophysical and social scientists and research managers work together to build the system more responsive within existing conditions. Another major thrust has been on research partnership between various institutions, which often involves working with private agencies and farmers. Such partnerships help optimize resource use, develop synergies and pursue a demand-driven technology agenda. In areas of mutual interest, public institutes work with private companies for commercialization of technology and benefits are shared in the framework developed for management of intellectual property rights. Thus, agricultural science in India has not only made significant economic and social contributions in the past, it was reorienting the programs to sustain these benefits in future also. This however will need allocating more resources for research and also fostering linkages between other stakeholders and development agencies to accelerate dissemination of technology.

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