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Impact of Agricultural Research : An Overview

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Agricultural research in India is largely in the public sector domain. Research in the private sector is limited, and mostly confined to research foundations and in-house R&D in a few input industries such as the seed sector. Research investment in Indian agriculture is channeled through ICAR, the apex organization, which allocates resources for agricultural research, education, and frontline extension through a vast network of research institutes and SAUs. As a result of ICAR's continuous support to agricultural research and extension, and sustained efforts of the scientific community, a large number of improved technologies have been developed, contributing significantly in achieving growth in production. Though the contribution of agricultural research has been immense, it has not been well documented in the past. The information available is scattered and based on anecdotal evidence. As a result, investment in agricultural research is often questioned.

In order to document and synthesize the impacts of past and ongoing research investment in agriculture, a workshop was organized jointly by the National Centre for Agricultural Economics and Policy Research and the International Crops Research Institute for the Semi-Arid Tropics on 10-11 February 2000. Fifty-one papers were contributed in multiple areas like genetic enhancement of crops, resource management, integrated pest management, animal sciences, agricultural

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Joshi, P.K., Pal, S., Birthal, P.S. and **M.C.S. Bantilan.** 2005**.** Impact of agricultural research: An overview. Pages 1-8 *in* Impact of Agricultural Research: Post-Green Revolution Evidence from India (Joshi, P.K., Pal, S., Birthal, P.S., and Bantilan, M.C.S., eds.). New Delhi, India: National Centre for Agricultural Economics and Policy Research and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

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implements, etc. A cross-section of research managers, policymakers, economists, agricultural scientists, and representatives from the seed industry attended the workshop. The papers documented the contribution of the past efforts of agricultural R&D in terms of several socioeconomic indicators, including efficiency gains, employment generation, and conservation of natural resources. Following is a synthesis of the workshop proceedings.

Investment in agricultural research and education (at 1980-81 prices) went up from Rs 733 million in 1965-66 to Rs 2994 million in 1998-99. The share of agricultural research and education in total government expenditure on agriculture was about 3.6% in the IX Plan. Agricultural research intensity is expected to reach 0.52% in the IX Plan, which is too low compared to that prevailing in the developed countries (2.5%).

Impact of Research in Genetic Enhancement

The genetic enhancement of a majority of agricultural crops received highest priority amongst different disciplines. The research efforts yielded positive dividends. Several improved varieties of almost all crops were developed and widely adopted by farmers. Their contribution to Indian agriculture is enormous. At the aggregate level, two important impact indicators were addressed: Total Factor Productivity (TFP) and poverty alleviation. The TFP index for crop-livestock reached 290% in 1991-92 from the base year (1964-65 = 100). Research contributed 48% to the TFP growth. The marginal Internal Rate of Return (IRR) on research investment was 53% during this period. Another indicator related to poverty alleviation and agricultural research. The poverty ratio declined from 55% in 1973-74 to 36% in 1993-94. A strong and positive association between research outputs and poverty alleviation was noted. Harsh and fragile environments (e.g., rainfed regions and hilly and mountainous terrains) yielded few acceptable research outputs. However, it was reported that the better-endowed (i.e., irrigated) regions produced a large number of successful technologies, which significantly contributed to enhancing the food security of those regions as well as that of the fragile environments.

Cereal production has increased substantially during the past three decades – from 70 million tons (Mt) in 1960-61 to 188 Mt in 1988-99. Most of the growth in production was driven by yield growth. Rice research in India has been highly rewarding, with IRR in the range of 30-50%. There has been a reduction in the unit cost of production and real price of rice. Similarly, technical change contributed to an increase in wheat productivity ranging between 34 and 51%. About 98% of the area under wheat in the Indo-Gangetic irrigated regions is now covered by varieties having the dwarf gene, yields from which increased annually by about 48 kg ha^{-1} between 1966-67 and 1998-99.

With yields stagnating in the Green Revolution belt, new research opportunities were explored. Among others, hybrid rice was found to break the yield barrier. Rigorous research efforts on hybrid rice over the last decade have led to the release of 12 rice hybrids by the public sector, and 7-8 hybrids were marketed by the private seed sector. The average yield gain of hybrids over that of popular inbred varieties was 16%. The major constraints to hybrid rice production are related to its relatively poor grain quality and high cost of seed production.

In the case of sorghum and pearl millet, adoption of improved varieties resulted in significant yield gains, reduction in unit cost of production, and yield stability. About 182 improved cultivars with multiple traits were developed from 1962 to 1998. Sorghum production fluctuated around 10 Mt but yield increased from 533 kg ha^{-1} in 1960-61 to 956 kg ha^{-1} in 1996-97. In the case of pearl millet, production rose to 8 Mt in 1997-98 from 3.3 Mt in 1960-61. Yields increased from less than 300 kg ha^{-1} in 1960-61 to 800 kg ha^{-1} in 1997-98. Farm-level evidence suggests that more than 90% adoption of improved pearl millet cultivars took place in Maharashtra and Gujarat. It is nearing 85% in Haryana, 80% in Tamil Nadu, and 30% in Rajasthan. It was noted that the average cost of pearl millet production per ton declined by 35% in Gujarat, 42% in Haryana, and 59% in Rajasthan in 1992-94 over 1972-74.

Maize production has been spectacular, surpassing 10 Mt in 1997-98. Much of the growth in maize production was due to the adoption of new seed-fertilizer-based technology. Hybrid maize is now moving to nontraditional areas because of its high-yield potential. Yields from hybrids were significantly higher than reported for OPVs. In the absence of hybrids, maize production in the major maize-producing states would have been about 1 Mt lower during 1994-95 than what was attained. Winter maize has shown considerable potential in flood-prone regions. Farm-level evidence has shown that due to the adoption of winter maize production technology, yield has increased three to four times more than in the case of rainy-season maize. The cost of production too has declined by

50%. The technology empowered women farmers as they got more fuel in the form of maize stalk stubble and maize stone on their farms. It also fulfilled the feed and fodder needs of farm animals, leading to higher livestock production, particularly of milk and poultry products.

The production of pulses too increased, though not as impressively as that of cereals. In the case of pulses, the increase was led by yield enhancement. However, a major concern was the decline in area being sown to pulses. Research in pulses contributed to improved varieties which were spreading in nontraditional areas. For instance, chickpea being sown in the hot and dry climates is now contributing more than 70% of the total chickpea production in the country. In Andhra Pradesh, chickpea area has increased rapidly since 1990-91. A large part of the area expansion was from areas released by either postrainy-season sorghum or postrainy-season fallow or both. This was possible due to higher output prices and the availability of improved, high-yielding, short-duration, and disease-resistant chickpea varieties in comparison to local varieties. In Gujarat, a majority of farmers still grows the local chickpea variety 'Dahod Yellow'. An improved chickpea variety (ICCC 4) is finding niches in Jamnagar district, where it was adopted in about 25% of the chickpea area. The benefits were in the form of higher yields, more income, decline in unit cost of production, and higher employment generation.

In the case of pigeonpea, improved varieties (Bahar, Narendra Arhar-1, Pusa-9, and Amar) covered about 40% of the area in few selected locations in the eastern part of Uttar Pradesh. The major constraints to adoption of improved technologies included lack of information about them, and nonavailability of quality seeds of improved varieties.

Moth bean and cluster bean are important crops in the arid regions. India, which ranked first in cluster bean export in the world market in the past, is now ranked second. The introduction of high-yielding varieties of cluster bean led to higher yields even when rainfall was low and erratic. The unit cost of production too declined substantially as a result of HYVs.

Oilseed production too has shown substantial increase after the government-sponsored Oilseeds and Pulses Mission was launched in 1987. Groundnut research has shown benefits in terms of a significant increase in yield and yield stability. Groundnut production in the country rose from 4.8 Mt in 1960-61 to 9.2 Mt in 1998-99. The adoption rate of improved varieties rose from 6% in 1989 to 84% in 1994 in Maharashtra and Gujarat.

This resulted in yield gains of 53% and a decline in the cost of production by 20%.

Sugarcane is an important cash crop. India is one of the largest producers of sugar in the world, with a global share of about 13%. Sugarcane production increased from 110 Mt in 1960-61 to 296 Mt in 1998-99.

Research programs on sugarcane began at the Sugarcane Breeding Institute, Coimbatore, in 1912. Since then, several varieties have been developed. As a result, average sugarcane productivity increased from 35 t ha^{-1} in the 1930s to 67 t ha^{-1} in the 1990s. Studies have revealed that 50 to 70% of the increase in productivity has been due to HYVs. The increase in sugarcane acreage and sugar factories clearly indicates the contribution of varieties and inputs. Research efforts addressed the issue of improving the efficiency of sugar production through early-maturing varieties. The improved varieties (Co 281) not only yielded considerable benefits in India, but also brought about major changes in the sugar industry in South Africa. Tropical India witnessed a 50% improvement in sugarcane yield. Sucrose production too improved (0.9%). Early-maturing varieties occupied only 14% of the total sugarcane area in the country. In Punjab (Co J 64), Gujarat, Tamil Nadu, and Andhra Pradesh (Co C 671), the benefits of early varieties were fully exploited.

Potato research is another success story. Potato production in the country went up from 3 Mt in 1960-61 to about 23 Mt in 1998-99. More than 35 HYVs and improved technologies for potato production were developed. Annual potato production increased by about 5.8% during 1949-50 and 1997-98. During this period, the area sown to potato increased by about 3.62% annually, and yields by 2.07%. The impact of research on potato and seed production systems has been obtained in terms of (i) self-sufficiency in potato, (ii) higher cropping intensity, and (iii) employment generation.

Impact of Natural Resource Management Research

The Indian research program also focussed its efforts on improving resource-use efficiency, conserving natural resources, particularly soil and water, and rehabilitating degraded soils. The management of degraded lands posed an important challenge. Land degradation in the form of soil erosion, salinity/alkalinity, and waterlogging are posing serious threats to sustainable agricultural development. Research efforts were made by ICAR and IARCs like ICRISAT to overcome these problems. In this context, research papers have shown the impact of various technologies (e.g., watershed research, reclamation of salt-affected soils, and vertisol technology). Research outputs of watershed programs were found appropriate in solving the problems of about 65% of the total cultivated area. Watershed programs have shown several benefits in various target domains, documented in the form of higher incomes, crop diversification, increase in irrigated area and fodder availability, and soil and water conservation. The problem of women migration was also addressed through it. The studies also reported that out-migration was checked to a large extent. Controlling soil erosion was found to benefit sustainable agricultural production in rainfed areas. Runoff declined from 42 to 15% and soil loss from 12 to 2 t $ha^{-1}year^{-1}$ in select locations.

Vertisol technology was developed to overcome the problem of about 12 million hectares of rainfed area. It increased agricultural production and prevented the degradation of soil and water resources. It was observed that there was maximum adoption of different technology components when rainfall was about 1000 mm. The benefits of adopting vertisol technology were documented as easy cultivation, effective pest management, higher production, less labor time and cost, higher income, increase in food and fodder security, lower cost of seed and nutrients, better soil and water conservation, prevention of soil erosion, and effective use of rain water.

Another problem which has emerged in surface-irrigated areas is related to soil salinity/alkalinity and waterlogging. Several technological and policy options were developed and widely adopted in the trans-Gangetic region. Chemical amelioration of alkaline soils has led to numerous benefits which include higher income, employment generation, stronger intersectoral linkages, reduced income disparities, more effective and efficient conservation of rain water, etc. Reclamation of alkaline soils has contributed significantly to increased foodgrain production. Making provisions for subsurface drainage has led to the perfect management of saline soils, and it has shown considerable potential. The large-scale adoption of the technology is constrained by its indivisible nature, which calls for collective action. Conflicting objectives among beneficiaries and the problem of free riders are the other constraints.

To increase the resource-use efficiency of perennial crops, research efforts developed several Perennial Crop Based Farming System Models (PCBFS models). It was observed that the PCBFS was more suited to medium and large farmers. Factors like high plant density and underplanting of the main crop, lack of irrigation facilities, the capital-intensive nature of the technology, lack of skilled labor, and the nonavailability of capital were the major constraints to its adoption.

Impact of Livestock and Farm Machinery Research

The livestock sector is complementary to agriculture. Its share in the agricultural gross domestic product was about 26% in 1996-97. Livestock output at the national level grew at an annual rate of 2.6% during 1950-51 and 1995-96. National-level evidence shows that output as well as TFP growth of the livestock sector picked up in the eighties when output growth touched nearly 4% per year and TFP growth jumped to nearly 1.8%, contributing about 45% to total output growth. One of the success areas was milk production, which increased from 20 Mt in 1960-61 to 70 Mt in 1997-98. Crossbreeding technology contributed to a 11% increase in milk production at the national level, and 57% in Kerala. Micro-level evidence revealed that the average milk yield of crossbred lactating cows and graded Murrah buffaloes was significantly higher than that of lactating non-descript cows and local buffaloes. Lack of awareness, poor accessibility to technologies, and lack of financial resources were the major constraints to adopting improved dairy technologies.

Small ruminants are important enterprises with resource-poor households in rural areas. Research efforts were made to raise their production and productivity. It was estimated that as a result of various diseases in goats, their mortality ranged from 5 to 25% in adults and 10 to 40% in kids. An *ex ante* assessment predicted that if the suggested health calendar for prophylactic measures in goats is adopted, the huge losses incurred by goat farmers would be reduced by about 70%. Another important small ruminant of poor farmers is the pig. It was reported that crossbred pigs showed higher litter productivity, growth rates, efficiency in feed utilization, and had thick lower back fat and higher lean cuts in their carcass than indigenous pigs.

The public sector too allocated research resources to develop simple and low-cost tools and implements, especially for resource-poor farmers. In the past, several implements have been designed and adopted by resource-poor farmers. A paper in these proceedings discusses three implements — the animal-drawn integral toolbar, pre-germinated paddy seeder, and khurpa-cum-sickle. It was observed that these performed better than traditional ones in terms of saving costs and improving labor efficiency.

Impact of Research on Integrated Pest Management

Pest management research has received high priority since the 1980s. Pests are heavily damaging various crops. After attaining self-sufficiency in food, the attention shifted to research on crop protection. With the passage of time, the indiscriminate use of chemicals in agriculture caused several undesirable externalities. Cotton, which covers only 5% of the total cropped area, receives as high as 55% of total pesticides. To overcome the problems of pesticide overuse, environmental degradation, and management of innocuous pests and diseases, Integrated Pest Management (IPM) was developed. As a result of IPM in cotton, mustard, and Basmati rice, pesticide use declined, yield increased, and natural fauna was protected. Similarly, the impact of controlling *Phytophthora* foot rot disease, caused by *Phytophthora capsici* in black pepper was quite rewarding. The adoption of cultural and chemical control measures was about 78 and 67%, respectively. The positive impact of the technology was reflected by decreased incidence levels, improvement in productivity, and a high cost-benefit ratio.

Conclusions

The workshop revealed the significant contribution that agricultural research has made in the agricultural and nonagricultural sectors. Yet, more systematic research is needed to empirically measure the research impact on social welfare and conservation of natural resources. It was realized that an appropriate policy environment, infrastructure, and institutions were preconditions for a greater impact of agricultural research. It was also stressed that appropriate policies were necessary for the distribution of research benefits to society.