

Innovations that Shaped Indian Agriculture-then and now

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Abstract

There are myriad innovations that have been part of agricultural transformation in India. This paper discusses various innovations and technological breakthroughs that took place in Indian agriculture during the British period and afterwards. Some of the innovations occurred inadvertently that are believed to have had higher impact on food production and livelihood security. Food security being India's major concern under changing climatic scenario, the reasons for slow down in food grain production in recent past have been looked into with a major emphasis on rice and wheat crops and the possible solutions for overcoming this slow down have been discussed.

Keywords: Agriculture, Food Production, Innovations, Institutional Dynamics, Policies, Sustainability

1. Introduction

After the disintegration of Mughal Empire, the economy of India depended mostly on Maratha Empire and after the third battle of Panipat there was turmoil in Indian economy. By the end of the 18th century the trade in Indian sub-continent gained momentum through East-India company¹⁶. Permanent settlement (Zamindari system) was introduced in Bengal (1793) and a Botanic garden was established in Calcutta in the year 1786. Further, the formation of the Agricultural and Horticultural Society of India (AHSI,) in Calcutta during 1820 also was a good initiation³. During the 1840s, the AHSI had eleven standing committees concerned with the different areas of its activity. These included committees for sugar, cotton, silk, hemp and flax, coffee and tobacco, oil-seeds and grain¹. Although potato was grown earlier to this period, it became a significant crop at the very end of the eighteenth century due to the growth of the British military presence in India and the profitable market for potatoes

in the cantonments that encouraged peasants to take up the crop. This development was not initiated by the AHSI, but it encouraged its further cultivation especially in Deccan and Tripura regions. The Ganges canal and other irrigation canals of British time had good impact on the rural livelihood. The British had three types of land revenue system viz., zamindari, raiyatwari and villagewari in different provinces⁵. Collection of taxes was more in individual peasant systems and hence public spending on infrastructure like canals and roads was more in these places⁴.

During the 18th and the 19th centuries agriculture was a vital industry in India with which all other local industries and other development of the country were related and depended¹⁴. Since the 14th century, the gearing wheel was being used for sugar extraction which was introduced by invaders from the Central Asia¹⁰. The British introduced wooden roller mills in place of mortar and pestle mills. Finally the wooden rollers were replaced by iron-roller mills in the last quarter of the 19th century. Thereby

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the cost of whole sugar extraction device was significantly reduced in 1830s. The British introduced mechanization in India, until this period the implements used in India were all of traditional ones.

The East India Company introduced improved ploughs which were very heavy and not suitable for heavy soil conditions. The significant improvement brought out by the British was the use of iron in place of wood in agricultural implements, use of iron-share in the native ploughs in place of wooden share and the replacement of mortar and pestle mill for sugarcane crushing instead of wooden or stone roller mills. The British also introduced water power for various purposes which were an important technological innovation in India. Before 1820, the use of water power was not observed in India. One water mill at Almorah to grind rice was found in 1820s and with the opening of Delhi canal during this period was an invaluable source of power for flour mills of Delhi and Karnal¹⁵. The Rotherham plow was the first one put to use in Netherlands, England and Scotland during the first half of 18th century and the first factory for its manufacture was established in 1783 in England⁸. The German-Dutch chemist Johann Glauber (c.1604–1670) developed the first mineral fertilizer with lime, phosphoric acid, nitrogen, potash and salt peter¹¹. The “Father of Fertilizer Industry” Justus Von Liebig (1803-1873) discovered that plants need mineral elements such as nitrogen and phosphorus for optimal growth.

Mendel discovered laws of inheritance and published in 1866 and Charles Darwin published the results of cross and self fertilization in plants in 1876¹¹. Only few Indian commercial crops such as Cotton, indigo, opium, and rice made it to the global market under the British reign in India¹³. During the period 1751–1801, the per capita Bengali incomes grew which can partially be attributed to the reduction in population due to catastrophic famine in 1769-70 and it had led to increased real wages⁶. The Indian economy grew at about 1% per year from 1880 to 1920, and the population also grew at 1%. Bengal had below-average growth rates in both food and non-food crop output, as the jute and wheat prices lowered substantially during 1930s⁹. However, due to the expansion of irrigation by canal networks, Punjab, Narmada Valley, and Andhra Pradesh became the centers of agrarian reforms and it provided impetus to grow cash crops for export and for raw materials for Indian industry, especially jute, cotton, sugarcane, coffee and tea¹⁶. For the development of Indian livestock, Indian Veterinary

Hospital Research Institute was started in Mukteswar in 1885. Imperial Council of Agricultural Research was established in 1929 at Pusa, Bihar on the recommendations of Royal Commission on Agriculture and later it was shifted to New Delhi.

2. Indian Agricultural Developments

2.1 During 1943–1964

Famines were more frequent during the colonial era in India. From various reports we could see that there were terrible famines between 1760 and 1943. Since 1850, several famines (nearly 20) killed at least 20 million people in India. The nation had to face acute food shortage during this period as the British were interested in growing only the cash crops like cotton, indigo, jute etc in order to supply the raw material for their factories back in England^{15,7}. The world's worst food disaster happened during 1942–1943 in British-ruled India known as the Bengal Famine. During this time Burma was caught by Japan and the rice imports from Burma were hoarded by the British resulting in exorbitant price rise. People could not afford to buy rice as the price of rice increased 3 to 4 fold¹⁷. Further, rice crop was badly affected by *Helminthosporium oryzae*¹² and the productivity was suppressed considerably. About 2 million people were died due to famine induced hunger in 1943 in the eastern India that included present day Bangladesh (<http://www.annualreviews.org/doi/pdf/10.1146/annurev.py.11.090173.000303> Retrieved on 5.3.13).

It was therefore obvious that food security was a dominant item of independent India's agenda as it has undergone unforgettable agony due to severe famines. In the first five year plan, emphasis was given on the agricultural development as there was acute food shortage, along with irrigation, fisheries, animal husbandry and marketing. Food production increased substantially from 54 MT (1950–51) to 65.8 MT by the end of first five year plan. In the third five year plan emphasis was laid on agriculture to make the country self sufficient in food grain production. Many fertilizer plants were established during this plan period. In the fourth five year plan, despite a worst drought, India could achieve self sufficiency in food grain production due to Green Revolution¹⁵. Further, agricultural research and education were given considerable attention.

Before independence, the main source of revenue was from the tax on land. But after independence, land taxes have steadily declined as a share of revenues and completely replaced by sales taxes². During this period, some special programs were implemented by the Government viz., The Grow More Food Campaign (1940s) and the Integrated Production Program (31950s) to focus on supply of food and cash crops respectively. The Bhakra-Nangal multipurpose dam was among the earliest river valley development schemes undertaken by independent India. All Five-year plans were oriented towards agricultural development especially on land reclamation and development, farm mechanization, electrification etc. Various institutions for agricultural research were founded under the Indian Council of Agricultural Research, New Delhi.

2.2 During 1964–1990

Due to widespread drought during 1965–66, India imported food grains from the US under PL-480 scheme. Unexpectedly, the United States has decided not to export wheat to India due to some internal problems. This decision at a critical time opened the ways for green revolution in India. Under the critical situation of lower level of agricultural production combined with increased population, the country was in dire need to increase its food production remarkably. This was the time when semi-dwarf varieties were developed in wheat in Mexico and rice in China. The introduction of these high yielding semi dwarf varieties of rice and wheat revolutionized the Indian agriculture scenario which was combined with right policies of government to provide essential inputs and market facilities, credit etc. The first high yielding variety in rice was released in 1968 as Jaya. In wheat, Lerma Rojo 64A and Sonora 64 were introduced directly from Mexico, later two varieties namely Kalyansona and Sonalika were released for cultivation. Because of these innovative ideas and policies the food grain production in the country increased to 108.46 MT in 1970–71, to 129.6 MT in 1982–81, to 176.4 MT in 1990–91. Therefore, the Green Revolution has changed the face of Indian agriculture and the country became self sufficient in its food grain production.

2.3 During 1990–2012

During the last two decades, a fatigue of the Green Revolution is set in both due to economic and ecological reasons. The regions where the benefits of Green

Revolution (North Western India) were harnessed in abundance are now facing the challenges of land degradation, yield plateauing and there by deceleration in compound growth rate. In 1991, economic reforms were introduced to liberalize the nation's economy. This has got a tremendous impact on Indian agriculture especially on food grain production. Slow down in growth began since 1995–96 for livestock, 1996–97 for crop sector, 1998–99 for fruits and horticulture, 1996–97 for crops other than fruits and vegetables. If we divide this period as post reform period (1990–91 to 1995–96) and post liberalization period (1996–97 to till date), the deceleration is more spectacular during post liberalization period. Farm growth has stagnated at an annual average of 2.3 % for the last ten years. After mid 1990's even food grain production is not catering to the increase in population. Considering the period 1980–1990, the yield of food grains was increasing at 3.2% per year later in the next decade i.e. 1990–2000, the growth has slowed down to 2.9%. During the last 10 years between 2000 and 2010, the food grain production has increased only by 1.2%. Critical analysis of observed yield data of past years showed that the reduced productivity in rice-wheat hot spot in India is nor far below the yield productivity of other countries like the US, Australia, China, Argentina, Egypt etc. Country like China grows wheat under marginal soils but with intensive management system. Climatic constraints (rainfall and day length) contribute significant yield loss in India particularly in nontraditional rain fed areas. The yield levels can be enhanced provided irrigation during critical stages. Even now agriculture sector remains the principal source of livelihood for more than 52% of the population, although, its contribution to the national GDP has declined to 13.9% due to high growth experienced in industries and service sectors. Many reasons are attributed for the deceleration in agricultural growth. Declining investment in agriculture by public sector, insufficient agriculture research and development and inefficiency of institutions providing inputs are some of the factors. Other factors such as land fragmentation, out-dated tenancy laws, lack of modern market and rural infrastructure, inappropriate input pricing policies, etc. were also said to be responsible for agrarian crisis in the country.

The most serious challenge for Indian agriculture is to define and pursue strategies that contribute to the reversal of processes which have caused widespread degradation of natural and environmental resources. On positive side, in independent India famines have not been

allowed to devastate, although our population has grown from 350 million in 1947 to 1.22 billion today. As of now India stands third in total cereals production, second in wheat, rice, fruits and vegetables production in the world. The country is first in milk production and has highest number of livestock in the world. It is the second largest producer of groundnut, wheat, vegetables, sugar and fish in the world. India stands fourth in coarse grains, fifth in eggs and seventh in meat production in the world. Indian agriculture contributes 8% to global agricultural gross domestic product to support 18% of world population on only 9% of world's arable land and 2.3% of geographical area. All above when compared with other countries, India faces a greater challenge, because it has only 2.3% share of world's land area, and it has to ensure food security for about 17.5% of its share in the global population. This leads to excessive pressure on land and fragmentation of land holdings against the backdrop of many other challenges, including growing population demands for more food grains, degrading natural resource base, emerging concerns of insect pests and diseases, climate change etc.

3. Future Innovations Required in Research, Policy and Institutional Dynamics for Agriculture in India

Once again, if we have to see a significant growth in agriculture, we need to put together the united efforts of all the stakeholders with innovations in research, policy and institutional dynamics. Scientists and agriculturalists strongly believe that with the right technology, public policy and institutional initiatives, India has the potential to be the leading producer and exporter of food produces in the world rather than struggling to feed its own population. The experience from the Green Revolution has also shown that besides technological advancements, supporting institutions like credit, land reforms etc., as well as incentives like prices, are of great importance for technology led growth in agriculture. Now, the agriculture sector calls for major reforms, from marketing to investment, institutional change, especially new technologies in water management, land markets and creation of efficient value chains. For achieving sustainable security in food production we need to give more emphasis on two major cereals, rice and wheat. In addition to this, we also need to make use of the frontier technologies viz., biotechnology,

nanotechnology, remote sensing, GIS, genome sequencing, marker assisted technology, weather modeling etc to come out with solutions for ever increasing demands in food production. The food production and security can be achieved through:

3.1 Research

In case of rice the research can be directed towards: 1) development of C4 rice, use of MAGIC (multiparent advanced generation intercross) - a process to breed multiple-stress-resistant/tolerant rice varieties, development of super hybrids and green super hybrids similar to China, 2) development of P efficient and aerobic rice varieties that can enhance the rice production in the country by breaking the yield barriers. In wheat - utilization of heterosis for developing hybrids, broadening the genetic base and enhancing productivity of low productive nontraditional areas viz., parts of Uttar Pradesh, Rajasthan, Madhya Pradesh, Orissa, Chhattisgarh and Bihar can be the options for enhancing wheat production in India. Diversification in rice-wheat system, residue management, improved water use efficiency and mechanization can contribute to improvement in the yields of rice and wheat.

Rain fed agriculture being practiced nearly 60% of cultivated land, supporting 40% of the country's human population and 60% of the livestock, and producing 40% of food is having significantly low productivity as compared to assured irrigated farming. Rain fed regions is complex, diverse, and risky compared to irrigated command areas. Innovative safety nets against risks would be required to convince the farmers for adopting improved rain fed technologies and intensive inputs. Water stress during the crop critical period is the most threatening cause for the lower productivity which is very difficult to address by any mean. Country like India should take meticulous care for environment development so that the farmers can go for harvest even during low rainfall drought like years otherwise crop failures could be more frequent in the years or decades to come.

3.2 Policy

3.2.1 Enhancing Public Sector Investment in Agricultural Research and Efforts for Effective Transfer of Technology

At present 0.6% of Agriculture GDP is being spent on Agricultural Research and Development, which needs

to be enhanced to at least 2 or 3 times from the present. India invested \$ 0.40 for every \$ 100 of agricultural GDP in 2008. This is far less than the amount invested by China (\$0.50), Brazil (1.8) and Japan (4.25), for every \$100 of their agricultural GDP in 2008 and it is also less than the average of \$ 0.56 for developing countries in 2000 (Beintema and Stads, 2010). Hence, an aggressive R & D investment strategy is absolutely essential for meeting the demands of present competitive world to have a reasonably good growth in agriculture as well as food security situation. An adequate and continuous investment in agricultural R & D is essential for sustained agricultural growth in the country.

3.2.2 Private Sector Investment

The leaders of China since the middle of 1990s have encouraged and supported private R&D investment by implementing important policies. The first, they provided incentives to public research institutes to boost basic research and privatized some public research institutes that conduct research on applied aspect. The shift in public research focused towards basic research and aimed at stimulating private-sector innovations. The second was that they liberalized input markets and enacted specific laws allowing the private sector to conduct research. The third was strengthening IPRs (Intellectual Property Rights) and provided specific subsidies and tax incentives for private companies conducting R&D in the field of agriculture and allied sectors. It is therefore learned that we need to change our research priorities and by making certain policy changes given under:

1. Public R & D should be geared up towards basic research and the institutes that are engaged in applied research can be privatized. This will help reducing the number of research institutes under public domain and thereby ensures higher level of fund availability for each institute.
2. Agricultural input industry should be totally privatized so that the private organizations would come forward to invest in innovative R & D for product development and popularization.
3. Tax exemption for the income generated on technology generated / transferred to farmers should be considered.

3.2.3 Water Management Policy and Input Subsidies

Developing minor irrigation wherever possible, giving less emphasis on free or subsidized electricity as it is mining the water from deeper aquifers, adopting water saving technologies in high water consuming crops like rice, sugarcane and banana to give room for growing other short duration irrigated crops need to be considered under input management strategies. During Green Revolution period, the subsidies on inputs were needed to encourage their use for enhancing the food grain production. But, this caused a great burden on fiscal budget along with deterioration of soil and water environment in intensively cultivated areas. For minimizing over exploitation of ground water, there should be legally bound water management regulations, which can further enhance the area under irrigation. Subsidies on fertilizers need to be gradually phased out by emphasizing the adoption of eco-friendly nutrient management practices.

3.2.4 Marketing Infrastructure

Post harvest losses account nearly 30% of the production which can be brought down as minimum as possible in the country. Encouraging value addition, establishment of collection centers and construction of warehouses can reduce the post harvest losses in many of the crops. As of now this facility even in developed states like Punjab and Haryana is definitely inadequate. The excess production of food produces in some states can be diverted to production deficient states by an agreement between states. For instance, tomato and maize produced in Karnataka and Tamil Nadu can be diverted to Kerala. Creating better market facilities and providing market intelligence to farmers also can help reducing the post harvest losses and enhance farmers' net income.

3.3 Institutional dynamics

3.3.1 Public-private Partnership

By encouraging public-private partnership in research and infrastructure development it is possible to enhance the agricultural production in the country. This is possible by undertaking case by case and developing models and tools to encourage Public-Private partnership in agricultural research, infrastructure development such as roads, marketing facilities, storage facilities etc. The role

of private sector in hybrid seed production of vegetables and maize is commendable and hope now they are venturing into hybrid seed production in rice too which is to appreciated.

3.3.2 Corporatization of Agriculture

By corporatization of agriculture, farmers can be made as share holders and such institution can use spot exchange platform to sell farm produces of their own to fellow farmer members to all domestic buyers and consumers through spot exchange network. Gradually, these companies can develop their own brand to market their produces directly in oversea markets too. Hence, the cost of intermediation will go down and farmers will be able to fetch the maximum price out of price paid by the consumer or by the oversea buyers. This is the ideal model to protect and promote the interests of Indian farmers.

3.3.3 Integrated Market for Food Grains

Marketing is one of the critical issues in agricultural production. Although government has been trying to safeguard the interests of the farmers through Minimum Support Price (MSP), the benefits are not percolating to grass root farmers. Hence, government needs to liberalize the domestic and international trade by developing an integrated market through out the country by which inequalities in farm income can be minimized or averted.

3.4 Miscellaneous

3.4.1 Integrated Farming Systems and Diversification

Practicing only crop farming is highly risk prone and hence it needs to be diversified with the inclusion of other enterprises like forestry, dairying, sheep and goat rearing etc., which can help not only in enhancing net returns but also maintaining soil health and quality for future generations. Crop diversification is also an important consideration as we are experiencing problems of soil deterioration in intensively cultivated areas of North Western States (Punjab, Haryana and Western UP) which are considered as green revolution states, where rice-wheat is the predominant cropping system. This needs to be modified by including other suitable crops depending on the availability of environmental resources and socio-ecological conditions.

3.4.2 Labor Problems

In India more than 2 lakh farmers have committed suicide during the last fifteen years due to economic and financial crisis which has clear connection and evidence with the continuous crop failures and unsustainable farming in resource poor farming situation. An exodus of labor is noticed from rural to semi-urban sites in search of work that fetch higher than agricultural wage. Small and marginal farmers are really in a fix to continue farming due to unavailability of labor for farming operations as they can not afford to pay the exorbitant rates with their small returns. Labor problem can be managed to some extent by developing farm friendly mechanization for land preparation, seeding, intercultural and harvesting. Custom hiring of these machineries for small and marginal farmers benefit, use of recommended herbicides for weed control and mutual sharing of labor are some of the options. Non availability of labors during peak harvest period is really worrisome in majority of the wheat growing tracts in Punjab and Haryana at times the harvest ready crop might be destroyed completely by unusual rainfall events. This mean it is unbearable for most farmers. Another extreme case in cardamom (Idukki dist, Kerala), which is a high value crop, needs to be harvested without delay. In this case, labors are brought from neighboring district Theni in Tamil Nadu regularly by transport vehicles; at least one thousand jeeps are plying between the districts every day. Otherwise the crop cannot be harvested in time. Alternate solution for this kind of labor issue is not yet identified. The cost of labors in these two scenarios is very high still labor availability is critical. In Dharmasthala, Karnataka, the self help groups (SHGs) are being trained in a unique manner to prepare their innovative farm plan by including diversified crops, mechanization, home management, children's education, irrigation etc. Apart from this, compulsory sharing of labor between the farming families is another unique feature of this model. This has solved the labor problem to a very great extent in the small and marginal farmers' fields of this area and this can be tried in other parts of the country.

3.4.3 Measures to Retain Youth in Farming

For retaining the youth in farming, the government should provide some alternate means of livelihood, as dependence on farming alone is highly risk prone. This is possible by establishing some agro processing industries in the villages and allowing the farmers to work in

rotation according to their convenience without clashing with their farming operations. Farmers can be made as share holders in this type of enterprises and the profit can be distributed among the shareholders as per their contribution. This is expected by forming some farmers' associations in the similar lines to that of Maharashtra where they have crop associations and they are running even agribusiness centers. This needs initiatives from farmers themselves and the local government should also help them to forge ahead by providing some initial help. In all above, gender mainstreaming and development, and use of modern ICTs (Information and Communication Technologies) for effective transfer of technology also contribute to enhance the food production and thereby food security of the country.

4. Summary

Agriculture is the back bone of Indian economy as it supplies raw material for many of the industries and it is the source of livelihood for majority of the rural population in India. There had been innumerable transformations in cultivation practices of crops to suit the demands of the populace. Parallel to that number of innovations were also part of these modifications which were successful in changing the face of Indian agriculture from mere 'Sip to Mouth' position to the present proud position of 'self sufficiency' and earning a sizeable amount of foreign exchange from agricultural exports. However, we cannot be complacent with these achievements as the demand for food is ever mounting due to persistent increase in human and animal population in the country. Hence, it is very much essential to take the stock of the situation and search for new innovations which can enhance the productivity without causing much damage to the environment. Greater scope for further improvement in yields of food grains in India is the strength for Indian agricultural science. Future research needs to concentrate more on climate resilient agriculture safeguarding the natural resource base in order to make our future generations thrive on this living planet.

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