The Green Revolution in India: A Case Study of Technological Change

Govindan Parayil

Technology and Culture, Vol. 33, No. 4. (Oct., 1992), pp. 737-756.

Stable URL:
http://links.jstor.org/sici?sici=0040-165X%28199210%2933%3A4%3C737%3ATGRIIA%3E2.0.CO%3B2-C

Technology and Culture is currently published by The Johns Hopkins University Press.

The Green Revolution in India: A Case Study of Technological Change

GOVINDAN PARAYIL

The term "Green Revolution" is generally taken to mean the increase in cereal productivity experienced in some Third World countries as a result of the change in agricultural technology during the 1960s and 1970s.[1] In this article, my objective is to reconstruct the history of the Green Revolution in India, highlighting the processes of technology transfer and diffusion of knowledge and the institutionalization of a successful agricultural research system. It is an instance of a relatively successful technology transfer, notwithstanding some latent problems associated with it. Generally, the Green Revolution involved the use of seeds of high-yielding varieties (HYVs), primarily of wheat and rice, and the adoption of a package of improved agricultural practices involving fertilizers, pesticides, controlled water, credits, mechanical threshers, pumps, and so forth. These changes were instituted in place of the "traditional" agricultural practice involving the use of seeds whose genetic makeup goes back thousands of years. "Traditional" technologies also include wooden plows, waterwheels, and bullock carts, with the energy required for all agricultural activities provided by animals and humans. Finally, traditional agriculture is largely dependent on the vagaries of monsoon rains.

Subsistence farming is often characterized by an exclusion effect, which is a tendency on the part of peasant farmers to resist change. This tendency to maintain status quo prompted the government to

DR. PARAYIL teaches history of technology and science, technology, and society courses at Illinois Institute of Technology. He received his doctorate in science and technology studies from Virginia Polytechnic Institute and State University. He thanks Joseph Pitt, Dana Dalrymple, and Henry Bauer for helpful comments and criticisms of earlier drafts of the article.

[1]The term was first suggested by William Gaud in a speech entitled "The Green Revolution: Accomplishments and Apprehensions," given at a meeting of the Society for International Development in 1968. See D. G. Dalrymple, "The Adoption of High-yielding Varieties in Developing Countries," *Agricultural History* 53 (1979): 704–26. Also see V. W. Ruttan and H. P. Binswanger, "Induced Innovation and the Green Revolution," in *Induced Innovation: Technology, Institutions and Development*, ed. V. W. Ruttan and H. P. Binswanger (Baltimore, 1978), p. 359.

0040-165X/92/3304-0003$01.00

formulate and implement a new agricultural policy to break out of the stasis in agricultural productivity that culminated in a near-famine situation in the 1960s. As there was no more land to be brought under the plow, increasing the productivity of the land using modern technology became the most viable means of providing food for the near one-fourth of the world's population dependent on only one-sixteenth of its land area. The Green Revolution, which has made India self-sufficient in food grains even though it has spread only to a quarter of its arable land, may be characterized as the new technological paradigm that replaced the old one characterized by subsistence farming.

In areas where the Green Revolution was successful (such as in Punjab, Haryana, western Uttar Pradesh, and parts of Tamil Nadu and Kerala), the increased productivity of the land came with lasting and irreversible changes. Before the Green Revolution, almost all cultivators were peasants who mainly produced for subsistence. Markets were rudimentary or nonexistent. Peasants obtained what they could not produce but needed for subsistence from other peasants by exchanging grains and whatever other commodities they produced. Agricultural laborers and other rural skilled laborers like carpenters and blacksmiths were mostly paid in grain or other agricultural produce. Their technology was preindustrial, with energy supplied mainly by humans and animals.

In areas where it took root, the Green Revolution replaced one way of life with another within a short span of two decades. The peasant cultivators became farmers for whom agriculture was a calling beyond subsistence. They sold most of their produce in the markets. Agricultural laborers and other skilled workers whose help was needed in maintaining agricultural machinery were paid in cash. Along with an increase in agricultural productivity came a higher demand for farm labor, and with this came increased wages, which sometimes doubled in four to five years. Modern technology began to make a strong impact on agricultural practices in more favored areas. The social, political, economic, and cultural gap between rural and urban areas began to shrink. I will first address briefly the historical background to the agricultural situation in India before the onset of the Green Revolution.

Background

Growth in agricultural production in India up to the year 1965 was disappointingly low, with severe famines still possible.[2] Although the

[2]M. L. Dantwala, "From Stagnation to Growth: Relative Roles of Technology, Economic Policy and Agrarian Institutions," in *Technical Change in Asian Agriculture*, ed. R. T. Shand (Canberra, 1973), pp. 234–59.

failure of agriculture to meet the needs of India from the time of independence in 1947 until 1965 reflected a neglect in favor of the industrial sector, this failure should be contrasted to the deplorable agricultural situation in India during the British colonial regime.[3] It is only fair to say that the stagnation of agriculture during the colonial period left behind a worsening food situation in India.[4] Disastrous droughts combined with relatively little technological change and sluggish land reforms brought India to the brink of famine in the mid-1960s. Famine was averted only by massive shipments of subsidized food grains from the United States. This in turn set the stage for the development of new thinking on the part of policymakers and donor agencies about ways to increase cereal productivity by inducing changes in agricultural technology.[5]

Agricultural practices and technology in India, as in many other Third World countries, had not changed perceptibly for hundreds of years. The agricultural technology in India at the time of the British invasion in the mid-18th century was comparable or even superior to that in Europe.[6] But while European technology changed dramati-

[3]According to the estimates of S. R. Sen, *Growth and Instability in Indian Agriculture* (New Delhi, 1967), the average annual food grain increase in India from 1901 until 1947/48 was a meager 0.3 percent. In fact, during the 1930s the population growth rate outstripped the growth rate of food grain. See P. K. Mukherjee and B. Lockwood, "High Yielding Programme in India: An Assessment," in Shand, ed. According to the estimates of George Blyn, *Agricultural Trends in India, 1891–1947: Output, Availability and Productivity* (Philadelphia, 1966), the average growth in food grain production from 1891 to 1947 was 0.11 percent. Dantwala estimates that from 1937/38 until 1951/52 the food grain production in India declined at a rate of 0.68 percent per year. Whatever little increases there were in agricultural production from the time of independence until the early 1960s were attributable to increase in acreage. See B. Dasgupta, "India's Green Revolution," *Economic and Political Weekly* 12 (February 1977): 241–60. Famines were a frequent occurrence in British India. The most recent disastrous Bengal famine during 1942–43 left nearly 3.5 million people dead. See C. Bettelheim, *India Independent* (New York, 1968), p. 8.

[4]The stagnation in Indian agriculture during the colonial period was analyzed by Barrington Moore, *Social Origins of Dictatorship and Democracy* (Boston, 1967); and Blyn. However, Christopher Barker, "Frogs and Farmers: The Green Revolution in India, and Its Murky Past," in *Understanding Green Revolution*, ed. T. P. Bayliss-Smith and S. Wanmali (Cambridge, 1984), pp. 37–52, points out that there was a resurgence in productivity of export-oriented cash crops during the colonial period.

[5]See C. Subramaniam, *The New Strategy in Indian Agriculture* (New Delhi, 1979); and L. Brown, *Seeds of Change: The Green Revolution and Development in the 1970's* (New York, 1970).

[6]The condition of Indian agricultural technology was clearly stated in the writings of visiting English scientists and explorers. T. Halcott, "On the Drill Husbandry of Southern India," reprinted in *Indian Science and Technology in the Nineteenth Century: Some Contemporary European Accounts*, ed. Dharampal (New Delhi, 1971), p. 210, writes in 1796 that "until lately I imagined the drill plough to be a modern European invention,

cally during the ensuing two centuries, there was no such change in India. This statement must be qualified because the stasis affected only peasant agriculture, which used to be and continues to be the mainstay in the Indian subcontinent. Modern agricultural technology was introduced by the colonial administration mostly to boost the production of exportable cash crops such as cotton, tea, coffee, jute, rubber, and spices.[7] Although the imperial administration began research on wheat and rice in the early part of this century,[8] no perceptible change in productivity was experienced. Carl Pray observes that the British and American attempts to transfer wheat varieties to the tropics during the colonial period failed for lack of adaptive research. He argues, correctly, that adaptive research was essential for the successful execution of technology transfer programs to the colonies, which presented different economic, social, and physical contexts.[9]

Thus, at the time of independence in 1947, India was a vastly poor nation with almost 90 percent of its population living in nearly 600,000 villages dependent on agriculture.[10] Indian agriculture remained essentially the same as it had been hundreds of years earlier. No perceptible technological change was noticeable in agricultural practices.

The years after independence saw a steady decline in the production of cereals in India. Hence, the First Five-Year Plan (1951–56) was primarily devoted to agriculture and rural development. Small increases in production due to growth in the extent of irrigated land, new acreage, and favorable monsoons made the planners think the food problem had been solved. They decided to concentrate on

. . . but I find it in general use here." A. Walker, "Indian Agriculture," reprinted in Dharampal, ed., p. 179, in a report written in 1820 observes that "I am at a loss to know what essential present [in agriculture] we can make to India." He further adds that the "Hindoos" have been in possession of the drill plow (which he describes as one of the "most beautiful inventions in agriculture") since antiquity.

[7]See R. Mohan and R. Evenson, "The Indian Agricultural Research System," *Economic and Political Weekly* 8 (March 31, 1973): A21–A26; and Barker.

[8]The British Imperial Administration began research on wheat in 1905 and on rice early in the 20th century (the Indian Council of Agricultural Research sponsored rice-breeding projects starting in 1929). See D. G. Dalrymple, *Development and Spread of High-yielding Wheat Varieties in Developing Countries* (Washington, D.C., 1986), p. 34, and *Development and Spread of High-yielding Rice Varieties in Developing Countries* (Washington, D.C., 1986), p. 44.

[9]See C. E. Pray, "The Green Revolution as a Case Study in Transfer of Technology," *Annals of the American Academy of Political and Social Science* 458 (1981): 79.

[10]Mukherjee and Lockwood; E. C. Stakman et al., *Campaigns against Hunger* (Cambridge, Mass., 1967), pp. 236, 239; Bettelheim.

industrial development in the Second Five-Year Plan (1956–61).[11] The government unwisely changed the course of national economic development by fostering industries and assuming that the agricultural sector would take care of itself. The rude awakening came about as a result of the deteriorating food situation in the early to mid-1960s.[12] This was caused mainly by the neglect of the agricultural sector. It forced the policymakers to concentrate on improving agricultural production, with the aim of seeking self-sufficiency in cereals. The only way to attain this self-sufficiency was to introduce modern technology that would augment cereal production with land as the fixed variable.

The Agricultural Revolution: A Historical Perspective

The tendency to characterize the rate, degree, and nature of change in the history of agriculture as "revolutionary" is tempting. According to Earle Ross and Robert Tontz, "agricultural revolution" is a term widely used to describe historical events in agriculture in different parts of the world.[13] There is no consensus among historians as to when the agricultural revolution occurred in Europe. However, they concur that it started in England. The causal factors attributed by various analysts are the enclosure law, the use of factory-made implements, and the introduction of artificial fertilizers. David Grigg, however, argues that although these changes in agricultural technology increased the yields in European agriculture, it was only in the 1930s that a "revolutionary" change in productivity became noticeable, despite the use of the term by earlier analysts.[14] This change was attributable to the increased use of hybrid and high-yielding varieties of seeds.

[11]See Mukherjee and Lockwood, pp. 53–54. The planners had the idea that the rural sector would provide the cheap food for industrial expansion. The Arthur Lewis dual-economy model of industrial development and the modified Harrod-Domar growth models were popular at this time among Third World planners. The first prime minister of India, Jawaharlal Nehru, preferred investing in heavy industries. Nehru's plan was that the industrialization of the country would absorb the excess labor from the rural sector, and he believed that eventually the agricultural sector would take care of itself by feedback from the modern industrial sector.

[12]According to Dasgupta, the economic situation in India during the mid-1960s was the worst ever during the postindependence period. Per-capita income was at its lowest, unemployment was rising, and the country was heavily dependent on foreign food aid.

[13]E. D. Ross and R. L. Tontz, "The Term Agricultural Revolution as Used by Economic Historians," *Agricultural History* 22 (1942): 32–38.

[14]D. B. Grigg, "The Agricultural Revolution in Western Europe," in Bayliss-Smith and Wanmali, eds. (n. 4 above), pp. 13–14.

This view may be further corroborated by a look at the agricultural history of the United States. Although mechanization and the use of chemical fertilizers dramatically increased productivity, few modern agricultural historians refer to these changes as revolutionary.[15] The introduction of hybrid corn in the 1930s and 1940s set the stage for truly dramatic increases in cereal productivity.[16] High-yielding variety seeds began to be used on a commercial basis in the 1940s and 1950s, thus enabling an increase in productivity that may be identified as revolutionary.[17] Thus, the "revolution" in agriculture in the Western countries began after the 1930s as a result of the hybrid and HYV seeds.

Unfortunately, it took several more decades for this agricultural revolution to reach parts of the Third World, where the same phenomenon was dubbed the "Green Revolution." Before going into the details of the technological change in Indian agriculture, I will briefly address the history of the high-yielding varieties of seeds.

A Short History of the HYVs

High-yielding varieties of seeds have become synonymous with the Green Revolution. High-yielding varieties are defined as early maturing semidwarf types that, under intensive agricultural practices (chemical fertilizers, irrigation, pumps, threshers, etc.), provide a significantly higher yield compared to the traditional types. The widespread belief that the HYVs originated in the West is incorrect.[18] Semidwarf rice varieties originated in China around A.D. 1000.[19] These caught the attention of Japanese farmers in the 1800s because their productivity increased dramatically when chemical fertilizers

[15]Ross and Tontz point out that many analysts called changes that resulted from different innovations after the American Civil War "revolutionary" although they were mostly minor and continuing.

[16]For additional details, see Z. Griliches, "Hybrid Corn and the Economics of Innovation," in *The Economics of Technological Change*, ed. N. Rosenberg (Harmondsworth, 1971).

[17]See Y. Hayami and V. W. Ruttan, *Agricultural Development: An International Perspective* (Baltimore, 1985), for empirical details on productivity growth. Also see Grigg.

[18]Ruttan and Binswanger (n. 1 above), p. 360, complain that analysts of the Green Revolution who know better still claim that the HYVs originated in the West.

[19]D. G. Dalrymple, "The Development and Adoption of High-yielding Varieties of Wheat and Rice in Developing Countries," *American Journal of Agricultural Economics* 67, no. 5 (1985): 1067–73, *Rice Varieties* (n. 8 above), and "The Adoption of High-yielding Varieties" (n. 1 above); Y. Hayami, "Elements of Induced Innovation: A Historical Perspective for the Green Revolution," *Explorations in Economic History* 8 (1971): 445–72. The actual history of the HYV rice varieties is much more complex than presented here. For a detailed historical account, see Dalrymple, "Development and Adoption."

several American varieties. The most productive variety that arose from these experiments was known as Norin 10. Other important varieties developed from Daruma were Seu Seun 27 and Suweon 92. Norin 10 was introduced into the United States in 1946 and was crossed with several native varieties by Department of Agriculture scientists.[29] In 1948, scientists in Washington State crossed Norin 10 with Brevor, a native variety.[30] In 1954, the Norin-Brevor cross was taken to Mexico (to what is now the International Maize and Wheat Improvement Center, or CIMMYT), where Norman Borlaug and his colleagues developed several varieties of the HYVs that were transferred to India and other Third World countries in the mid-1960s.[31]

Technological Change in Indian Agriculture

The technological change in Indian agriculture may be characterized as the transformation of the newly derived knowledge in agricultural technology, both Indian and foreign, into food. A reconstruction of the history of the Green Revolution in India shows that four protagonists played crucial roles in its success: the government of India, multilateral and bilateral donor agencies, international agricultural research institutions, and the Indian farmers and peasants. The institutions under the government of India that planned and coordinated the transfer and diffusion of the new technology were the Ministry of Food and Agriculture and the Indian Council of Agricultural Research (ICAR),[32] along with the various agricultural research institutes and universities scattered all over the country.

The multilateral and bilateral donor agencies were the Ford Foundation, the Rockefeller Foundation, and the United States Agency for International Development (USAID). As a liaison and financial supporter to U.S. land-grant universities, USAID played a key role in helping to set up agricultural universities in India.[33] The international

above). Dalrymple provides a detailed historical account of the development of HYV wheat varieties.

[29]Dalrymple, "The Adoption of High-yielding Varieties," p. 706, *Wheat Varieties*, and "Changes in Wheat Varieties"; Chandler, pp. 26–27.

[30]Dalrymple, "Changes in Wheat Varieties," pp. 33–34.

[31]Dalrymple, "Development and Adoption" (n. 19 above); Ruttan and Binswanger (n. 1 above); Hayami (n. 19 above).

[32]The ICAR was established by the British in 1929 under the name Imperial Council of Agricultural Research to conduct research on commercial crops for export. See Mohan and Evenson (n. 7 above), p. A-21. After independence, the ICAR was renamed the Indian Council of Agricultural Research, ironically with the same acronym.

[33]H. Read, *Partners with India: Building Agricultural Universities* (Urbana, Ill., 1974).

agricultural research institutions were the IRRI and the CIMMYT.[34] In order to pool resources for maximum benefit and also to avoid duplication of research endeavors, a Consultative Group on International Agricultural Research (CGIAR) was organized in 1971.[35]

Finally, it was the farmers and peasants of India who, by adopting and adapting the new technology to their particular situation, made the Green Revolution a success. The development and spread of the Green Revolution involved different learning processes, which I will discuss later. Although the technological change in Indian agriculture during the period from 1965 to 1975 is generally referred to as the Green Revolution,[36] a reconstruction of the history of the technological change demands that we look at the developments in Indian agriculture beginning a decade or more earlier. Thus, we can observe three distinct stages in the process of the change.

The first stage (1952–65) was the development of a new and indigenous national agricultural research system. I chose 1952 as the beginning of the first stage because in that year the first USAID-university contract was signed. Later, in the mid-1950s, the Indian government sought the assistance of the Ford and Rockefeller foundations and the USAID to establish more agricultural universities and to develop a high-quality graduate school at the Indian Agricultural Research Institute in New Delhi.

The second stage (1962–67) was marked by the overhaul and reform of agricultural bureaucracy in India in order to facilitate the transfer and diffusion of the HYVs to the Indian situation. A thorough revamping of the agricultural institutions and commodity committees established by the colonial administration was an important facet of the newly developed research system. In 1962, Indian scientists successfully tested HYV Mexican wheat under Indian conditions. The HYV rice was tested in 1964. The HYVs were

[34]The IRRI, instituted in 1960, was the joint effort of the Ford Foundation and the Rockefeller Foundation. The land for the construction of the institute was provided by the Philippine government. The CIMMYT, instituted in 1967, was the joint effort of the Ford Foundation, the Rockefeller Foundation, and the Mexican government. Several other international agricultural research institutions were established after these. For further details, see Dalrymple, "Development and Adoption," p. 1067; and V. W. Ruttan, "The International Agricultural Research Institute as a Source of Agricultural Development," *Agricultural Administration* 5 (1978): 293–308.

[35]Under the umbrella of the CGIAR, there are ten international agricultural research institutes, a regional rice research and development organization (now being reorganized into a research institute), an organization to assist national research organizations, and a board on plant genetics resources. See Dalrymple, "Development and Adoption"; and Ruttan, p. 295.

[36]Ruttan and Binswanger, p. 358.

introduced nationally for the first time during the 1965–66 growing season.[37]

The third stage (1965–75) was marked by the change in agricultural practice as a result of the introduction of HYVs. Farmers began to adopt the new technology extensively beginning with the 1965–66 growing season. Agricultural productivity increased steadily until 1975. After 1975, the increase in productivity began to level off on an S-shaped productivity curve. By this time farmers in parts of India had realized a two- to threefold increase in their yield compared to the 1965 base. Agricultural productivity began to show considerable increase again in the mid-1980s, which some analysts identify as the second Green Revolution.[38] I will present the details of the technological change in relation to these three stages, highlighting the roles played by the protagonists mentioned earlier.

The First Stage: Development of a New Research System

In 1948, a year after independence, the Indian government set up the University Education Commission to revamp the country's educational system.[39] The commission recommended establishing "rural universities" similar to the land-grant universities of the United States. This recommendation stemmed from the "bookish" nature of then-existing agricultural education in India, which failed to address the immense agricultural problems adequately.[40] The high-powered committees consisting of Indian and American agricultural scientists and educators appointed by the Indian government in 1955, 1959, 1962,

[37]See U. Lele and A. A. Goldsmith, "The Development of National Research Capacity: India's Experience with the Rockefeller Foundation and Its Significance for Africa," *Economic Development and Cultural Change* 37 (1989): 305–44; Subramaniam (n. 5 above).

[38]See R. Chengappa, "Agriculture: A Golden Revival," *India Today*, April 15, 1989, pp. 78–83; S. Sud, "State of Agriculture: India Poised for Take-off," *Times of India*, January 19, 1989.

[39]See Read, p. 4. Agricultural colleges and research institutions were built by the British colonial administration beginning in the late 19th century, basically to cater to the interests of British plantation business. Various central research institutes and central commodity committees on sugarcane, tobacco, oilseeds, jute, coconut, lac, areca (betel) nut, etc., were set up under the imperial ministry of food and agriculture. See Mohan and Evenson. The Indian Agricultural Research Institute (IARI) was established in 1923, and an Imperial Council of Agricultural Research was formed in 1929 to coordinate the research activities. See C. Prasad, *Elements of the Structure and Terminology of Agricultural Education in India* (Paris, 1981). According to Lele and Goldsmith (p. 312), the Imperial Council of Agricultural Research (of 1929) "did not exercise leadership to focus research on pressing problems" in the food situation in India.

[40]Lele and Goldsmith.

and 1963 recommended the revamping of the Indian Council of Agricultural Research. Accordingly, all the central research institutes and commodity committees were brought under the ICAR. Moreover, the joint Indo-U.S. committees recommended strengthening indigenous research efforts and college-level training as well as establishing agricultural universities in all the states of the Indian Union.[41]

The establishment of agricultural universities patterned after American land-grant universities helped to transfer agricultural knowledge from the United States to India. Three U.S. institutions played key roles in the development of modern agricultural research capacity in India. The United States Agency for International Development helped with investments to start up the land-grant-type universities, the Rockefeller Foundation helped with the development of a national agricultural research system, and the Ford Foundation helped with farm-extension work.[42]

The first land-grant-type agricultural university was established in Pant Nagar, Uttar Pradesh; it is now known as Gobind Ballabh Pant University of Agriculture and Technology.[43] This school was modeled after the University of Illinois.[44] Other U.S. land-grant universities (Kansas, Ohio, Missouri, Pennsylvania, and Tennessee) entered into partnership arrangements with the government of India to establish several other agricultural universities.[45] The USAID provided the contract funds and represented the United States on behalf of the land-grant universities. According to Hadley Read, hundreds of researchers and agricultural professionals from these universities went to India to help with the establishment of the schools and their research facilities. Moreover, thousands of Indians trained in the

[41]A. H. Moseman, *Building Agricultural Research Systems in the Developing Nations* (New York, 1970), p. 110.

[42]Lele and Goldsmith, p. 313; Read, pp. 97–101.

[43]Prasad.

[44]For a detailed account of the institutional transfer process that culminated in the establishment of this land-grant university patterned after the University of Illinois, see P. R. Brass, "Institutional Transfer of Technology: The Land-Grant Model and the Agricultural University at Pantnagar"; and D. P. Singh, "Agricultural Universities and Transfer of Technology in India: The Importance of Management," both in *Science, Politics, and the Agricultural Revolution in Asia*, ed. R. S. Anderson et al. (Boulder, Colo., 1982).

[45]See Read (n. 33 above). These universities are Punjab Agricultural University (Ohio State University), Haryana Agricultural University (Ohio State), University of Udaipur (Ohio State), Madhya Pradesh Agricultural University (University of Illinois), Orissa University of Agriculture and Technology (University of Missouri), Maharashtra Agricultural University (Pennsylvania State University), Andhra Pradesh Agricultural University (Kansas State University), and Mysore University of Agricultural Sciences (University of Tennessee).

United States went back to India to teach and conduct research. The agricultural university cooperation between the United States and India was terminated at the end of 1972 at the request of the Indian government, but already a significant technological capability had been transferred.[46]

The Rockefeller Foundation played a key role in developing an agricultural research system that acted as the catalyst for the growth of a national research capability. The foundation, which had been running maize programs in Mexico and Colombia and had become the "leading repository of knowledge about maize in developing countries," was invited to help the Indians develop hybrid maize.[47] Simultaneously, the Indian government sought the foundation's help in establishing a high-quality graduate program at the Indian Agricultural Research Institute in New Delhi.[48]

The government's intention was to train a cadre of highly qualified agricultural scientists. Traditionally, these sciences did not attract bright students because of the low prestige ascribed to agriculture-related professions.[49] The Rockefeller Foundation gave high priority to the Indian government's request to set up a graduate school. Some of its best and most well-known scientists were assigned to India: Ralph Cummings, U. J. Grant, and Albert Moseman—individuals well respected in the agricultural research community in the United States.[50]

[46]According to Read (p. 105), the reason for the Indian government's decision to terminate the USAID-university technical assistance programs was based on "foreign policy differences" between the Indian and U.S. governments. President Nixon's unabashed support for Pakistan on the Bangladesh issue in the India-Pakistan War of 1970–71 was the major reason. Nixon and Henry Kissinger bitterly opposed India liberating Bangladesh from the Pakistani army.

[47]Lele and Goldsmith (n. 37 above), p. 314.

[48]The several Indo-U.S. committees recommended the revamping of the IARI because it was until then engaged in theoretical work that was not helpful in solving the crucial agricultural problems India was facing. Although the agricultural universities could step in to assume that role, their mandate was to serve the state governments and other regional entities. The central government wanted to train a highly visible group of agricultural scientists at the IARI to assume the leadership for organizing research at the national level as well as for coordinating research at the state and local levels. See Lele and Goldsmith for more.

[49]The reason attributed to this goes back to the caste system in India. Farm work was traditionally done by people from the lowest caste groups in the Hindu hierarchy, and, consequently, working with hands was considered menial. Somehow this prejudice toward farm work extended to agricultural sciences as well. For a comparative study of agricultural and nuclear sciences in India, see Stakman et al. (n. 10 above); and R. S. Anderson, "Cultivating Science as Cultural Policy: A Contrast of Agricultural and Nuclear Science in India," *Pacific Affairs* 56 (1983): 38–50.

[50]Lele and Goldsmith.

The graduate school at the Indian Agricultural Research Institute was inaugurated on October 6, 1958, and 150 students were admitted that year for M.S. and Ph.D. programs; Ralph Cummings became the first dean.[51] Today, the IARI is a well-known agricultural graduate school and research center, having graduated several thousand masters and doctoral students, not only from India but also from many other Third World countries in Asia and Africa.

In order to impart prestige to the agricultural sciences, top administrative positions were given to scientists instead of civil servants, a custom dating back to British rule.[52] In order to attract bright students to this field, an Indian Agricultural Research Service was developed, similar to the Indian Administrative Services, to give permanency and guaranteed career growth to the agricultural scientists.[53] In 1960, an Indian scientist, A. B. Joshi, took over the deanship of the IARI graduate school from Cummings.[54]

Unlike the Rockefeller Foundation, the Ford Foundation's role was confined to funding the development of agricultural universities, along with the USAID, and adaptive research on HYVs.[55] Since extension work was conducted mostly by state governments in concert with the agricultural universities, the Ford Foundation gave financial support to sustain this operation in the early stages. The foundation also supported the Integrated Agricultural Development District Programmes (IADP), intended to help farmers in selected districts of the country.[56] According to Read, "The Ford Foundation's India policy was to concentrate attention on those important agricultural areas not receiving support from USAID or other agencies."[57]

The Second Stage: Institutional/Bureaucratic Reform and Technology Transfer

Having a federal structure, the Indians wanted to adapt the American system of first developing a federal agricultural research

[51]Stakman et al.

[52]The British imperial government created a highly regarded Imperial Civil Service (ICS) to attract bright British and later Indian citizens to work in India for the imperial government. Traditionally, all top appointments went to the ICS officers, including those positions as heads of scientific and technological institutions. After independence, the Indian government continued the trend and even started an Indian Administrative Service similar to the erstwhile ICS. See Subramaniam (n. 5 above).

[53]Lele and Goldsmith, p. 323.

[54]Ibid., p. 321.

[55]Ibid.

[56]Read (n. 33 above), p. 98.

[57]Ibid.

capability and then supporting state-level research projects.[58] The last joint Indo-U.S. Agricultural Research Review Team recommended some sweeping changes in the largely civilian-dominated bureaucratic agricultural research system. Owing to pressure from the powerful civil service, however, the concerned ministers of agriculture were not able to implement the recommendations until C. Subramaniam took over as India's minister of agriculture in 1964. He single-handedly overhauled the agricultural bureaucracy, giving power and credibility to the agricultural scientists.[59]

Subramaniam took three critical steps. The first was to remove the permanent civil service officer, who was serving as the director-general of the ICAR, and to employ an eminent agricultural scientist, B. P. Pal, as the new director-general.[60] His second step was to appoint a committee of agricultural scientists to go over the latest joint Indo-U.S. expert committee reports to recommend to him the necessary measures to reorganize the scientific research infrastructure.[61] On the recommendations of the new team, Subramaniam brought all the independent research institutes and commodity committees under the ICAR. The third step was to establish an Agricultural Research Service, similar to those existing in the United Kingdom and the United States, to provide guaranteed career paths to agricultural scientists.[62]

Several senior scientists and influential members of the Planning Commission opposed the massive introduction of the new seeds, arguing that they were not suited to Indian conditions. The importation of the high-yielding wheat varieties was nearly prohibited by the government as a result of opposition from the Planning Commission and several other powerful quarters in the government.[63] Because of these pressures, Subramaniam's decision to introduce the

[58]The American system was largely based on Washington's support to subsidize research at state agricultural stations. See Lele and Goldsmith (n. 37 above), p. 313.

[59]Ibid., p. 322.

[60]Another eminent Indian agricultural scientist, M. S. Swaminathan, took over as head of the IARI from A. B. Joshi. Swaminathan, who obtained his doctorate from the University of Cambridge, later became the director-general of the ICAR.

[61]The Indo-U.S. committee, headed by Marion Parker from the United States, was appointed to examine the "reorganization of agricultural science in India." See Subramaniam, p. 15. The committee submitted its report in 1963. Also see Lele and Goldsmith, p. 340, n. 35.

[62]Subramaniam (n. 5 above), p. 21.

[63]W. D. Hopper, "Distortions of Agricultural Development Resulting from Government Prohibitions," in *Distortions of Agricultural Incentives*, ed. T. W. Schultz (Bloomington, Ind., 1978), pp. 69–78.

new seeds was postponed until the growing season of 1965–66 instead of the previously planned 1964–65 season.

Convinced of the high-yielding capability of the new seeds, Subramaniam, along with his trusted agricultural scientists, went ahead with the decision to import 18,000 tons of HYV wheat. They distributed the seeds to farmers at subsidized rates for sowing during the 1965–66 growing season.[64] Several analysts suggest that the importation of the Mexican wheat seeds to India in 1965–66 was the most important step in the history of the Green Revolution.[65] This may be an overstatement, however; the establishment of a national agricultural research system may actually have been the most important step. Without this system, the launching of the national demonstration program (see below), which created the demand for the importation of the new "miracle" seeds, would not have been possible.

The Third Stage: Diffusion and Adoption of the New Technology

Having reorganized the agricultural research system in India, Subramaniam next sought to demonstrate the effectiveness of the new HYV seeds to the farmers. Massive public information campaigns about the new technology were organized by the government in 1966 using radio, press, and cinema. It was not an easy task to convince the farmers to switch to the new technology. They did not want to bear the risk of a disastrous harvest again after several droughts, and they would take the risk only after becoming convinced that the new technology was more productive than their age-old methods.[66] Hence, in 1965 a thousand demonstration programs were launched all over the nation.[67]

According to this plan, a minimum area of 2 hectares of each selected field was devoted to the new technology. These parcels of land were entrusted to the extension officers and agricultural scientists, who were given the task of demonstrating the effectiveness of the new technology as a model farm to the community. In case the new technology did not provide a bumper crop, provision was made for compensating the farmers. The 250 tons of HYV seeds brought

[64]Subramaniam; Lele and Goldsmith; Chandler (n. 24 above).

[65]See Lele and Goldsmith; Brown (n. 5 above); and Hopper.

[66]This is consistent with the actions of the corn farmers of Iowa in the 1930s. B. Ryan and N. C. Gross, "The Diffusion of Hybrid Seed Corn in Two Iowa Communities," *Rural Sociology* 8 (1943): 15–24, contend that the farmers adopted the hybrid corn only after trying it on a trial basis on a small plot and after being fully convinced of the high productive potential of the HYV corn seeds.

[67]Subramaniam, p. 47.

earlier from Mexico were distributed for the demonstration programs.[68] These seeds yielded another 5,000 tons of seeds, which were immediately bought up by the farmers as a phenomenal demand developed for the new "miracle" seeds.[69]

Because of this demand, it was decided to import 18,000 more tons of HYV seeds from Mexico, and the Green Revolution took off.[70] Four years after the introduction of the HYVs on a massive scale, the yield of wheat had doubled.[71] Demonstration programs for the new rice varieties were also conducted on a national basis, though not as widespread as for the wheat varieties. According to Borlaug, India's decision to import and to implement the new HYV technology set off a chain reaction, not only in India, but in Pakistan and elsewhere.[72]

The seeds were subsequently changed to accommodate consumer preferences. The IR-8, the most popular rice variety, for example, was found to be chalky and not very much liked by consumers. Similarly, the Mexican wheat was reddish; Indians preferred the amber and white wheat varieties. Indian agricultural scientists were able to develop new seeds to satisfy the tastes and cultural preferences of the consumers, at the same time retaining the genetic quality that guaranteed high cereal productivity. Modifications were also required because of the varied soil and climatic conditions in India, which differed from conditions in Mexico for the wheat seeds and in the Philippines for the rice varieties. Indian scientists took feedback from the farmers and consumers seriously and were successful in quickly developing two Mexican wheat lines that "performed better in the field and the kitchen."[73] Similarly, adaptive research on the rice seeds obtained from the Philippines yielded 221 varieties by 1983.[74] In the 1983–84 growing season, 76.0 percent of the land under wheat and 54.1 percent of the land under rice were devoted to HYVs.[75] The remaining land was not brought under HYVs, not because the technology was inadequate, but because this land did not yet have

[68]Dalrymple, *Rice Varieties* (n. 8 above), p. 35.

[69]M. Mamdani, *The Myth of Population Control: Family, Caste, and Class in an Indian Village* (New York, 1972), p. 61, reports that the price for 1 kg of the "miracle" wheat was 1 rupee in the market in 1966. The popularity of the seed made the demand soar, and the market price surged phenomenally. He says that some farmers even bought the seeds at 100 rupees per kg during the 1967 growing season.

[70]Subramaniam, pp. 47–48.

[71]See Hopper, p. 69. Mamdani (p. 61), in his field research in a Punjabi village, found that wheat yields often trebled.

[72]N. E. Borlaug, *The Green Revolution: Peace and Humanity,* Nobel lecture (Oslo, 1970).

[73]Lele and Goldsmith (n. 37 above), p. 327.

[74]Ibid.

[75]See Dalrymple, *Wheat Varieties,* p. 37, and *Rice Varieties,* p. 46 (both in n. 8 above).

irrigated water and other inputs necessary to sustain the new technology.

Conclusion

In parts of India since the mid-1960s, there have been rapid increases in the formerly marginal productivity of the land and concomitant increases in cereal production as a result of the transfer and diffusion of a package of improved agricultural practices involving high-yielding varieties of seeds, fertilizers, pesticides, controlled water, credits, and some agricultural machinery. This is referred to as the Green Revolution. The demand for technological change in peasant agriculture was created by the failed development policies of the government. The model of economic development that Indian leaders pursued in the beginning was patently biased against agriculture. It was borrowed from the centrally planned economic model of the Soviet Union, which favored rapid industrialization at the expense of agriculture. Agriculture was neglected until the rude awakening of the 1960s when the country was threatened by famine. The technological change that ensued from the introduction of the new package of agricultural practices was a direct result of the interaction of the newly transferred technology and its recipients and their culture. The technology was welcomed by the peasant farmers only when it became compatible with the economic, social, and physical conditions in India.

Murray Leaf and Mahmood Mamdani's extensive field research in the Punjab, which was the most successful state in India in terms of exploiting the benefits of the technological change in agriculture, shows the changes in economic and social factors to be dramatic and irreversible.[76] In a brief but highly perceptive account of the technological change in agricultural practices in the Punjab, Pratap Aggarwal argues that the Green Revolution resulted in the "transformation of peasants into farmers."[77] Before the Green Revolution, the markets did not reach the rural areas. The need to gain credits to buy seeds and other inputs forced the peasants to enter the market. The need to sell their products in the market also strengthened the role of the markets in the life of the rural people. According to Leaf, one of the crucial decisions the farmers had to make was how much of each crop to grow. They had to consider the costs and benefits of each crop according to its market price before the growing seasons. The role of markets in farmers' decisions to take risks in adopting the new

[76]M. J. Leaf, *Song of Hope: Green Revolution in a Punjab Village* (New Brunswick, N.J., 1984); Mamdani.

[77]P. C. Aggarwal, "Green Revolution and Employment in Ludhiana, Punjab, India," in *Employment in Developing Countries*, ed. E. O. Edwards (New York, 1974), p. 381.

technology was illustrated by John Gartrell's field study in Andhra Pradesh in south-central India.[78]

The perception that all peasants are "irrational" and "fatalistic," and that they do not respond to new methods of agricultural practice, used to be rife among economists and agricultural planners. This was proved incorrect by the peasants in the Punjab and other parts of India. They accepted the new technology when they were convinced of its potential benefits. Leaf observed the same thing among the peasants and farmers he studied during his field research.

Most literature critical of the Green Revolution does not question the productive gain from the new technology.[79] Complaints pertain to equity issues in the distribution of income and the increases in cereal output to the poorest in the society. However, the inequalities in income distribution are decreasing in areas where the Green Revolution has been successful.[80] Agricultural laborers gained in terms of higher wages and more days of work due to the higher volume of crop productivity.[81] Smaller landholders were found to be more productive than larger ones. The militancy of agricultural workers in areas where the Green Revolution became successful (e.g., in Kerala and parts of Tamil Nadu) may be considered positive signs of social and political changes rather than regressive trends. The detractors of the Green Revolution are attacking the wrong enemy. The technology does not by itself dictate income distribution. These problems had to do with government subsidies, taxation, credit policies, and agricul-

[78]J. W. Gartrell, "Status, Inequality and Innovation: The Green Revolution in Andhra Pradesh," *American Sociological Review* 42 (1977): 318–37.

[79]Some of the works in this regard are K. Griffin, *The Political Economy of Agrarian Change: An Essay on the Green Revolution* (London, 1974); B. H. Farmer, ed., *Green Revolution: Technology and Change in Rice-growing Areas of Tamil Nadu and Sri Lanka* (Boulder, Colo., 1977); B. Glaeser, *The Green Revolution Revisited: Critiques and Alternatives* (London, 1987); K. Gough, "The Green Revolution in South India and North Vietnam," *Monthly Review* 29 (1978): 10–21; A. Rudra, "Technology Choice in Agriculture in India over the Past Three Decades," in *Macro-Policies for Appropriate Technologies for Developing Countries*, ed. F. Stewart (Boulder, Colo, 1987), pp. 22–73; and R. Frankel, *India's Green Revolution: Economic Gains and Political Costs* (Princeton, N.J., 1971).

[80]See Leaf; G. S. Bhalla, "Transfer of Technology and Agricultural Development in India," *Economic and Political Weekly* 14, nos. 51/52 (1979): A130–A142; S. S. Johl, "Gains of the Green Revolution: How They Have Been Shared in Punjab," *Journal of Development Studies* 11 (1975): 178–89. M. Lipton, *New Seeds and Poor People* (Baltimore, 1989), also claims that small farmers benefited from HYVs, even though public policy for making input factors available has often been biased in favor of large holders.

[81]G. Blyn, "The Green Revolution Revisited," *Economic Development and Cultural Change* 31 (1983): 705–25.

tural wage policies.[82] In fact, poverty has diminished in areas where the Green Revolution has spread, while it has become more acute in areas where there is no technological change in peasant agriculture.[83]

If the Green Revolution had been uniformly spread to all the states in India, then the grinding poverty that afflicts those who live in areas where agricultural modernization was least would have decreased considerably. The reasons that agricultural modernization has still not reached states like Bihar, Orissa, Rajasthan, and Madhya Pradesh include archaic and semifeudal land and social relations, lack of land reforms, and lack of investment in irrigation, education, transportation, and rural electrification. G. S. Bhalla contends that the "landlords might find it more profitable to continue exploiting the tenants through exorbitant interest charges on consumption loans rather than to make investments in new technology."[84] And most of these states are ruled by corrupt politicians, themselves large landholders who block land reforms and agricultural modernization programs. Clearly, proper institutional and bureaucratic reforms are essential for successful technology transfer.

The HYVs that made the Green Revolution possible were developed after extensive field research to fit the particular ecological and economic conditions and particular culinary preferences. The research system that enabled the assimilation of the new technology was largely transferred from the United States. The Indians were highly successful in adapting and transplanting the technology, including the institutions and knowledge embodied in it. The HYVs need constant renewal after a few years as their yield potential decreases. The Indians were successful in developing new seeds because they had already acquired the technological and institutional capability to develop them by plant breeding. The effort to solve a major problem in agricultural production in turn enabled the country to become

[82]The power of agricultural workers translated into the best and most far-reaching minimum wage legislation in Kerala. The Kerala Agricultural Workers Act of 1974 provides permanency for attached farm laborers, a provident old-age fund and pensions, permanent labor conciliatory services at the district level, greatly reduced hours of work (between six and eight hours), scheduled breaks, tea and lunch, and a minimum wage that is the highest in India. See R. J. Herring, "Dilemmas of Agrarian Communism: Peasant Differentiation, Sectoral and Village Politics," *Third World Quarterly* 11 (1989): 89–115.

[83]Extensive data on income and employment patterns in areas where the Green Revolution was successful convincingly refute the alleged view that the new technologies adversely affected these patterns. See, e.g., the studies conducted by Johl; Bhalla; and M. S. Randhawa, *Green Revolution* (New Delhi, 1974).

[84]Bhalla, p. A139.

self-sufficient in food and to develop a highly successful agricultural research capability of its own. The agricultural success story is thus "a prime example of mutually reinforcing foreign and local research efforts."[85]

The Green Revolution posits some compelling and crucial information about technological change in general and technology transfer in particular. It shows that technology is a form of knowledge created by humans and that technology can transcend cultural barriers provided pragmatic institutional changes are implemented. It shows that technological change is a problem-solving activity and essentially a form of knowledge.[86] The Green Revolution involved a change in the knowledge base of the peasant-farmers. It occurred as the outcome of a specific set of actions and learning experiences by a wide array of social and institutional actors. Notwithstanding some of the latent problems associated with the Green Revolution, such as the unregulated use of pesticides and agricultural machinery by some farmers, it represents a case of a successful technology transfer. Because of the Green Revolution, India became self-sufficient in food grain production.

[85]Lele and Goldsmith (n. 37 above), p. 328.

[86]For a detailed exposition of these concepts, see G. Parayil, "Technology as Knowledge: An Empirical Affirmation," *Knowledge* 13 (1991): 36–48, and "Technological Change as a Problem-solving Activity," *Technological Forecasting and Social Change* 40 (1991): 235–47.