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# Green revolution: Experiences, challenges and opportunities in India

**Ashish Dwivedi[1] and** Vineet Kumar[2]
[1]Department of Agronomy, SardarVallabhbhai Patel University of Agriculture and Technology, Meerut (U.P.) India
[2]Department of Soil Science, SardarVallabhbhai Patel University of Agriculture and Technology, Meerut (U.P.) India
(Email:ashishdwivedi842@gmail.com)

A detailed retrospective of the Green Revolution, its achievement and limits in terms of agricultural productivity improvement, and its broader impact at social, environmental, and economic levels is provided. Lessons learned and the strategic insights are reviewed as the world is preparing a "redux" version of the Green Revolution with more integrative environmental and social impact combined with agricultural and economic development. Core policy directions for Green Revolution 2.0 that enhance the spread and sustainable adoption of productivity enhancing technologies are specified. The developing world witnessed an extraordinary period of food crop productivity growth over the past 50 y, despite increasing land scarcity and rising land values. Although populations had more than doubled, the production of cereal crops tripled during this period, with only a 30% increase in land area cultivated.

The GR strategy for food crop productivity growth was explicitly based on the premise that, given appropriate institutional mechanisms, technology spill-overs across political and agro-climatic boundaries could be captured. However, neither private firms nor national governments had sufficient incentive to invest in all of the research and development of such international public goods. Private firms operating through markets have limited interest in public goods, because they do not have the capacity to capture much of the benefit through proprietary claims; also, because of the global, non-rival nature of the research products, no single nation has the incentive to invest public resources in this type of research.


International public goods institutions were needed to fill this gap, and efforts to develop the necessary institutional capacity, particularly in plant breeding, were a central part of the GR strategy. Based on the early successes with wheat at the International Maize and Wheat Improvement Centre (CIMMYT) in Mexico and rice at the International Rice Research Institute (IRRI) in the Philippines, the Consultative Group on International Agricultural Research (CGIAR) was established specifically to generate technological spill overs for countries that underinvest in agricultural research, because they are unable to capture all of the benefits of those investments (Alston *et al.*, 1995). After CGIAR-generated knowledge, invention, and products (such as breeding lines) were made publicly available, national public and private sectors responded with investments for technology adaptation, dissemination, and delivery.

**Green revolution :** The Green revolution term was coined by Dr. William S. Gaud, Director of the US Agency for International Development (USAID) in 1968 to describe the breakthrough in food grain production and rapid diffusion of the dwarf wheat and rice varieties in India and other part of the developing world. The Green revolution, which came on the scene around the middle of the sixties, beginning with *Kharif* crop of 1966 in India refers to the quantum jump in food grain production following the use of high yielding varieties, pesticides, fertilizers coupled with improved irrigation facility and multiple cropping. It happened because of certain circumstances like drought conditions, which prevailed in 1965-66 and 1966-67. These were also the years when the seeds of high yielding variety come out in world.

**Positive effect of green revolution** : Green revolution led to enhance agricultural production providing food grain security. The problem of hunger and malnutrition prevailed

in our country before Green revolution and the demand of food was fulfilled through the imported food grains from other country. The Green revolution triggered with high yielding varieties brought a complete change in production technology, marketing, storage and extension. The production of food grains by 1977 grew so much that imports were stop, old debts were paid and the country became self-sufficient for producing food grain. The production of food grains rose from less than 61.0 million tonnes in 1949-50 to 131.0 million tonnes in 1978. The production of cereals (rice, wheat, maize and barley) rose from less than 51.0 million tonnes to about 120.0 million tonnes during the same period. By the end of 20th century the food grain production rose to 209.0 million tonnes with a buffer stock at around 60.0 million tonnes. In 2011 the food grain production in the country has reached to about 235.0 million tonnes.


**Development of new varieties of rice and wheat :** In India the dwarf varieties of rice and wheat were responsible for the Green revolution and the other developing nation of the globe.

**Development of wheat varieties :**

– The dwarf varieties of wheat were developed by an American born Mexican scientist Dr. Norman E. Borlaug at CIMMYT (Centro International de Mejoramiento de Maiz y Trigo) known as International Centre for Wheat and Maize Improvement, Mexico. These varieties of wheat repelled hunger and malnutrition not only from South America but also from several parts of the world. For these outstanding contributions Borlaug was awarded with Nobel Prize for peace in 1970. He is also known as "Father of Green Revolution."

– A Japanese variety of wheat *Norin-10* was the source of dwarfing genes for wheat improvement. Moreover, Sonora 64 and Lerma Rojo were the semi-dwarf wheat varieties developed by the incorporation of dwarfing genes all the way through plant breeding at CIMMYT, Mexico. The varieties were introduced to India in 1963. The Kalyan Sona and Sonalika varieties of wheat were modified form of the imported dwarf varieties which were integrated to Indian agriculture. It paved the way for Green revolution through the hard work of eminent agriculture scientist Dr. M.S. Swaminathan, who is known as the "Father of Green Revolution in India". For more than one decade these varieties were most popular in India. A great majority of wheat varieties now grown in the country are of semi-dwarf in nature. These wheat varieties are fertilizer responsive, high yielding and also resistant to lodging as well as diseases and pests.

**Development of rice varieties:** A dwarf and early maturing variety of *japonica* rice *De-geo-woo-gen* from Taiwan was the source of dwarfing gene for rice improvement. Taichung Native 1 (TN1) developed in Taiwan, and International Rice 8 (IR8) developed at IRRI (International Rice Research Institute), Philippines, were the varieties of rice developed by the introduction of dwarfing genes. These varieties were introduced to India in 1966. They were extensively grown for few years, but were later replaced by superior semi-dwarf varieties developed in India e.g. Ratna, Jaya, Basmati etc. The semi-dwarf varieties are lodging resistant, fertilizer responsive, photo-insensitive and high yielding.

**Table 1 : Comparison of yields in selected commodities (Metric tones/hectare)**

| Rice/paddy | | Wheat | | Maize | | Cotton | | Major oilseeds | |
|---|---|---|---|---|---|---|---|---|---|
| Egypt | 9.8 | UK | 7.7 | USA | 9.1 | China | 11.0 | Germany | 4.0 |
| USA | 7.8 | France | 7.5 | France | 7.5 | Brazil | 10.9 | USA | 2.6 |
| Korea | 6.7 | China | 4.2 | Germany | 6.6 | USA | 9.5 | Argentina | 2.5 |
| Japan | 6.4 | World | 2.8 | China | 4.9 | Uzbekistan | 7.9 | Brazil | 2.4 |
| World | 3.9 | India | 2.7 | World | 3.3 | Pakistan | 7.6 | China | 2.0 |
| India | 2.9 | Pakistan | 2.3 | Philippines | 2.1 | World | 7.3 | World | 1.8 |
| Thailand | 2.6 | Iran | 2.0 | India | 1.1 | India | 4.6 | India | 0.8 |
| Myanmar | 2.4 | Australia | 1.6 | | | Nigeria | 1.0 | | |

**Negative effect of green revolution :** Though, Green revolution has been successful eliminating hunger and malnutrition to a larger extent part of India, however it has to be several serious side effects are evident on environment and human health. The side effects of Green revolution on human health and environment are as follows:

**Health effect of green revolution :**

– Construction of canals for boost the agricultural production and increased area of rice cultivation under Green revolution package has led to outbreak and spread of mosquito borne diseases like *Malaria, Filaria* and *Japanese encephalitis*. Moreover, Due to improved irrigation facilities the plague of malaria has increased manifold. Malaria and filaria persists as serious health hazard in rice growing regions of the country. Japanese encephalitis which mostly afflicts children has emerged as a serious health menace in Uttar Pradesh, Jharkhand, Bihar and Assam. It is a viral disease spread by *Culex* species of mosquito. West Nile Feveris another mosquito borne disease gradually emerge as a health problem in the areas of Punjab. It is also a viral disease spread by *Culex vishnuii*and *Culex fatigans*species of mosquito.

– Excessive use of nitrogenous fertilizers like urea causes a decrease in the potassium content of the food grains. Potassium is important element, which checks the rise of blood pressure and also averts the chances of heart attack in human beings. Similarly excessive potash treatment decreases valuable nutrients in foods, such as carotene and ascorbic acid (Vitamin C). Though, Vitamin C is essential for the boosting of the defense system, while carotene is the precursor of vitamin A, which is important for vision. Moreover, Nitrate fertilizer has been reported to increase the crop yield (carbohydrate) but at the expense of proteins. Moreover, subtle balance of amino acids is disturbed within the protein molecule, thus lowering the protein quality. Thus the escalating problem of hypertension, cardiac disorders, night blindness, malnutrition, susceptibility to infectious diseases etc. among Indians is result of Green revolution.

– Endosulphan (Endosulfan) is a pesticide used for the control of pests in rice crop is highly hazardous causing serious eye, kidney and liver disorders. The harmful effects of endosulphan on human health have been reported from the state of Kerala. Pesticides like DDT are non-biodegradable and are fat-soluble, which enter the food chain and reach the human body where they are deposited in adipose tissue. When oxidation of the fat takes place in the body, the pesticides are released in the system causing harmful effect to human health. The concentration of pesticides increases with increasing food chain and the phenomenon is known as *Biomagnification*. India's daily diet is reported to contain 270 µg of DDT. The concentration of DDT in Indians has reached to alarming proportions ranging between 13 to 31 ppm (parts per million). Delhi's citizens have the highest level of pesticides in their body fat in the world. There have been reports of cases of cancer, deformities, hepatic diseases and neurological disorders due to pesticide poisoning in cotton growing belts of Maharashtra and Andhra Pradesh.

Pulses are the chief source of proteins in the diet of predominately vegetarian population of India. They form an important segment of the balanced diet. Apart from proteins pulses are the source of minerals and fibres. The Green revolution has helped in enhancing the per capita availability of cereals especially wheat and rice but similar impact is not reflected in availability of pulses per head. A significant decline in per capita availability of pulses had led to the problem of protein malnutrition. In rural areas Uttar Pradesh, Bihar, Madhya Pradesh and Chattisgarh, *Kwashiorkar* and *Marasmus* are the common diseases caused due to deficiency of proteins in children. Moreover, protein malnutrition in adults has made them susceptible to the infectious diseases like Pulmonary tuberculosis, which has emerged as a serious health problem among poor sections of the society of rural India.

**Environmental impacts of green revolution :**

– The worst effect of Green revolution has been witnessed on environment of the country. Green revolution has caused marked decline in the forest cover of India. Use of modern mechanical instruments had led to large scale deforestation for the agricultural practices. The per capita forest land in India is 0.1 hectare compared to the world average of 1.0 hectare. Indian forests comprise only 0.5 % of the world forest area. India is losing forest at a rate of 1.5 million hectares per year and consequently losing 6000 million tonnes of soil annually containing about 5.53 million tonnes of nitrogen, phosphorus and potash valued about Rs.700 crores. Deforestation has led to the problem of drought, siltation of rivers and dams, flood, loss of biodiversity and global warming. India is often blamed by International community for global warming due to large scale paddy cultivation (Green house gas methane is emitted from paddy field).

– Increased use of fertilizers and pesticides has caused the problem of air, water and soilpollution. Nitrous oxide produced by microbial action on inorganic fertilizers in soil causes depletion of stratospheric ozone layer, which serve as an shield against harmful UV-rays emanating

from the sun. Methane produced by methanogenic bacteria in waterlogged paddy field is a potent green house gas responsible for global warming.

– The chemical fertilizers and pesticides used in the agricultural field are drained by rain water to ponds, rivers and lakes causing water pollution. The phenomenon of nutrient enrichment of aquatic bodies is known as *Eutrophication* which deteriorates the water quality. Besides this, the seepage of fertilizers and pesticides also pollutes the ground water. There have been reports of ground water pollution from the state of Punjab.

**Conclusion :** Though the Green revolution has led to increased food grain production, however it several side effects are now being realized on environment and human health. The escalating problem of environmental pollution and the outbreak of mosquito borne diseases like malaria, filarial, Japanese encephalitis and West Nile fever are the unwanted gift of Green revolution in India. Thus the benefits of the Green revolution have been marginalized by the problems posed by it. Therefore, it is the need of the hour to gradually shift from the chemical fertilizers and pesticides based modern agriculture to natural and renewable resources based sustainable agriculture, which is cheap, environment friendly and sustainable in long run.

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