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An unexplored story of successful green revolution of India and steps towards ever green revolution

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Abstract
Pre green revolution period, India had suffered with great famine, malnutrition, under-nourishment and poverty. So, India forcibly introduced green revolution programme comprised of high yielding variety of seeds and increased use of fertilizer and irrigation methods to achieve higher food production. Due to this, India has achieved self sufficiency in food grain production. India has jumped food grain production with able to produce 131 mt in 1978-79 and 281 mt in 2017-18 from 50 mt in 1950's. However, recent facts screening many problems are arising due to continuous use of HYV and chemical fertilizers with the impact of green revolution. Genetic erosion of our traditional cultivars (in wheat, rice, sorghum, minor millets), loss of soil fertility, erosion of soil, soil toxicity, diminishing water resources, pollution of underground water & salinity of underground water are some of the negative impacts over green revolution. Hence, another holistic revolutionary in agriculture needs to be introduced as second green revolution with inclusion of food nutritional security programme, nature loving farming practices, diversified cropping systems, mixed farming systems with high remuneration, water saving cultivars in dry land, resistant crops against various biotic and abiotic stresses and bio-fortified crops.

Keywords: Challenges, green revolution, M.S. Swaminathan, food grains, India, HYV

Introduction

Pre green revolution period

One of the chronic problems India faced following independence was insufficiency of food. The country's nastiest recorded food crisis occurred in 1943 in British-ruled India. Known as the Bengal Famine, an estimated 4 million people died of hunger that year in eastern India. Initially, this disaster was attributed to an acute shortfall in food production in the area. It was being continued, albeit British ruler had left out from India. With the separation from Burma (now Myanmar) in 1937, India became deficient in food. Food problem became even more acute after the partition of the sub-continent into India and Pakistan in 1947, presenting a series challenges to India's agricultural sector (Khush 1997) [4]. Although there was a sharp rise in grain production after independence, it was not sufficient enough to meet the food requirements of a growing population. To meet the food shortage and to stabilize the prices, India was forced to import increasing amounts of food and it was described as "Ships to Lips". Due to this, the controversial agreements made by India to import food from the US under the PL-480 scheme started in the year 1956. Under that scheme, nearly 3 million tonnes of food grains were imported in the very first year and the volume of imports kept rising reaching about 4.5 and 10 million tonnes in the year 1963 and 1966, respectively (Brar, 1996) [2]. However, the quality of imported food grains was not good because it was adulterated with admixture of several weed seeds. For instances, mustard seeds was admixed with *Argemone mexicana* seeds and Wheat with *Phalaris minor* and *Parthenium hystereous* weeds seeds. When the import of food grains was going on, the political scenario changed with Indo-China war in 1962 and Indo-Pak war in 1965. To further complicate the situation there were two successive droughts in the year 1965 and 1966, leading to fall in agricultural output by 17 percent.

During green revolution period

So, these above situations have necessitated the "Green Revolution", which occurred primarily as a result of technological breakthroughs, high yielding varieties, improved water supplies and better agricultural practices. In addition, increased mechanization of agricultural operations and the use of plant protection measures also contributed to the emergence of the "Green Revolution" in India.

Before the green revolution, economic self-reliance and particularly self-sufficiency in food grains became the top priority objective of India's economic policy and also for that matter India's foreign policy. The new Agricultural Strategy was drawn up. The then Prime Minister, Lal Bahadur Shastri, Agriculture and Food Minister, C. Subramaniam and Indira Gandhi, who followed Shastri in 1966, all gave full support for developing Indian agriculture on new lines.

Within India, the main supporter of the Green Revolution strategy was C. Subramaniam, who became Agriculture minister in 1964 and M.S. Swaminathan, who became the Director of Indian Agricultural Research Institute (IARI) in 1965 and had been trained by Norman Borlaug. About ten years ago, Dr. M.S. Swaminathan met Dr. Norman Ernest Borlaug in an international conference was held at American Institute of Biological Sciences in 1953. During that period, Dr. N.E. Borlaug has worked on the rusts diseases in wheat *i.e.*, leaf rust, brown rust & stem rust; then he developed a varieties which are identical in phenotype and distinct in genotype by altering the genetic make-up. Initially, Dr. Swaminathan has worked first in rice crop and then in wheat crop. Our traditional varieties of wheat, rice and other crops were not pleasingly responded to applied fertilizers and irrigations caused lodging and more yield loss, although gave in right quantity and at right time in 1960s. This was led to introduction of semi dwarfing wheat cultivar with new gene called 'norin'. Also, Dr. Swaminathan has requested Dr. Borlaug to send breeder seeds of newly developed semi-dwarfing wheat cultivars as well as he has been invited to visit India. In March 1962, a few of the Borlaug's dwarf spring wheat strains were grown in the fields of the Indian Agricultural Research Institute (IARI) in Pusa, New Delhi. In March 1963, the Rockefeller Foundation and the Mexican Government sent Borlaug and Dr. Robert Glenn Anderson to India to continue his work after request of Dr. M.S. Swaminathan. While, Dr. N.E. Borlaug ultimately arrived in Delhi on 25th March 1963, he had been surprised by arranged his birthday celebration at the lawn of Genetics division of Pusa institute by Mrs. Mina Swaminathan (wife of Dr. Swaminathan) whereby served with Mexican food and Mexican music. After a trip to India in 1963, Dr. Borlaug dispatched 400 kg of semi-dwarf varieties to be tested in India. In 1964, rice seeds were brought in from IRRI in the Philippines.

The advent of the new high yielding dwarf varieties of Mexican wheat in 1966-67 marked the beginning of an agricultural development in India that opened unprecedented opportunities for increasing net returns to farm management. The HYV seed was so much more productive that it considerably reduced the risk of change. For instance, per hectare production of wheat increased about 2 1/2 times. They identified four Mexican HYV's i.e. Lerma rojo-64, Sonora-63, 64 & Mayo-64. These varieties were grown in multi location trials in Kanpur, Pusa, Pantnagar and Ludhiana. These varieties had proved about three times higher yield than traditional varieties.

In October 1965 with these results, the new policy was put into practice when 114 districts (out of 325) were selected for an Intensive Agricultural Areas Program (I.A.A.P.). In November 1965, the Food Ministry was ready with a full blown version of the "New Strategy": in essence it called for the implementation of a High Yielding Varieties Program in districts that had already been selected for intensive development under the I.A.D.P. and I.A.A.P. schemes.

However, in 1968, biologist Paul R. Ehrlich presented a new theory which stated that, "the battle to feed all of humanity is over. In the 1970's and 1980's hundreds of millions of people will starve to death, despite of any crash programs embarked upon now". Ehrlich further stated that, "I have yet to meet anyone familiar with the situation who thinks India will be self-sufficient in food by 1971 and India couldn't possibly feed two hundred million more people by 1980". In 1968, when Ehrlich's book was released, William Gaud of the United States Agency for International Development (USAID) was calling Borlaug's work as "Green Revolution".

By 1968, nearly half of the wheat planted came from Borlaug's dwarf varieties. The gospel spread so fast that by 1972-73, 16.8 million hectares were planted with dwarf wheat and 15.7 million hectares were planted with dwarf rice across the Third world. 94 percent of the hybrid rice area was in Asia of which nearly half was in India. High yields led to a shortage of various utilities, labour to harvest the crops, bullock carts to haul it to the threshing floor, jute bags, trucks, rail cars, and grain storage facilities. Some local governments were forced to close school buildings, temporarily to use them for grain storage.

In India, with the rapid introduction of high yielding wheat varieties, production reached a record high of 16.6 million tons in 1967-68, one third more than the previous peak output of 12.3 million tons achieved in the last good weather year of 1964-65. Moreover, despite a recurrence of drought and other unfavourable seasonal conditions, wheat production in 1968-69 exceeded the new level, giving substance to the slogan of a "green revolution" in the wheat areas. Indeed, in 1969-70, national wheat output rose to another record high of approximately 20 million tons (Sidhu and Dhillion, 1997) [8].

Regionally, in India, the greatest effect of the Green Revolution has occurred in the wheat growing areas of Punjab, Haryana and Western U.P. In South India, the effects of Green Revolution have been concentrated in the States of Andhra, Tamil Nadu and Kerala.

Post green revolution period

It remains true that the Green Revolution's most spectacular effect have occurred with wheat production. The average yield of rice went up by 60.1 percent in the period from 1969-70 to 1988-89, whereas it went up by 97.1 percent for wheat. To honour this moment, government of India released special stamp called Wheat Revolution to mark a Quantum jump in terms of improvement and production.

In short, Norman Borlaug is called "the father of the Green Revolution", "agriculture's greatest spokesperson" and "The Man Who Saved A Billion Lives". For the recognition of his services to humanity, he was awarded the Nobel Peace Prize (1970) and also the Padma Vibushan, India's second highest civilian honour. According to the Nobel Prize Committee, "the kinds of grain which are the result of Dr. Borlaug's work speed economic growth in general in the developing countries". In India, Dr. M.S. Swaminathan and C. Subramaniam are well acknowledged as "father of green revolution of India".

Achievements of green revolution

The production of rice has increased from 35 million tonnes in 1960-61 to 54 million tonnes in 1980-81 and then to 112.9 million tonnes in 2017-18, showing a major breakthrough in its production. The yield per hectare has also improved from 1013 kgs in 1960 to 2578 kg in 2017-2018.

Again the production of wheat has also increased significantly from 11 million tonnes in 1950-51 to 36 million tonnes in 1980-81 and then to 99.7 million tonnes in 2017-2018. During this period, the yield per hectare also increased from 850 kgs to 3371 kgs per hectare. All these improvements resulted from the adoption of new agricultural strategy in the production of wheat and rice.

Problems of Green Revolution

With the introduction of Green Revolution in India, the focus has been mainly on the production of wheat and rice that involves extensive use of soil and water resources and external inputs. Green Revolution steered the country to advance agricultural production and related economic gains, however this occurred at the cost of pollution and depletion of soil and water resources, decline in wild and crop plant diversity, loss of general well-being and decline in public health and loss of cultural values.

Ecological Concerns: The main ecological impacts of the current agriculture systems and related practices are:

- Loss of soil productivity and pollution of soil resources
- Pollution and depletion of water resources
- Loss of crop and wild plant diversity
- Increased vulnerability to the impacts of climate change and poor adaptive capacity of farmers

Loss of Soil Productivity and Pollution of Soil Resources: Continuous cultivation of wheat and rice over a large land area has resulted in nutrient run down in soils. Aulakh *et al.* (2007) have reported nitrate and phosphorus leaching and subsequent contamination of groundwater throughout the nation. Most importantly, natural resources, i.e. soil and water, were taken as guaranteed and subsequently manipulated and used excessively to enhance agricultural production (Jalota *et al*., 2005) [3] to such an extent that recovery of these resources does not seem feasible in the near future.

Pollution and Depletion of Water Resources: Pollution of water resources mainly due to excessive use of fertilizers and pesticides and decline in availability of water for human use due to increase in cultivation area under irrigation. Aulakh *et al.* (2009) [1] conducted a wide survey on water quality and highlighted the existence of dangerous levels of arsenic, selenium, lead and other minerals in soils and water that are hazardous to human health. Singh and Sidhu (2006) [9] suggested that the fall in water table has flow-on effects in terms of:

- The cost of pumping out water has increased, while the quality of water is getting poorer
- Submersible pumps are replacing the centrifugal pumps, hence increasing the power use
- Increase in the number of tube wells resulting in increased use of electricity.

IFPRI (2007) further reported that most districts in central Punjab exhibited severe overexploitation of water resources leading to risk of salinity. Salinity could be a serious problem for food production/ security all over India if it does occur in the current agricultural systems.

Loss of Crop and Wild Plant Diversity: As more and more area has been brought under wheat and rice cultivation, the diversity of wild plants and other cultivated crops such as pulses and other cereals has decreased. Singh and Sidhu (2006) [9] reported that a number of crops like sunnhemp, cluster beans and sorghum had almost disappeared and there is reduced varietal diversification in rice and wheat. Due to loss of plant diversity and forest cover, loss of fauna such as honey bees that play important role in agricultural systems and loss of common birds such as sparrows and peacocks has occurred at a fast speed (SEP, 2005; 2007). The situation is so worse that there are rare sightings of a famous bird, peacock (a national bird of India), of sparrows, crows and honey bees which used to be seen common about 20-30 years ago.

Challenges and Need for Second Green Revolution

- There is large challenge to feed the peoples as estimated about 1.70 billion peoples in 2050 as now have 1.30 billion peoples with limited cultivated area.
- While the first GR was to ensure food security, as there was severe scarcity of food in the country, the second GR should aim at creating sustainable livelihood security for the poor and eradication of poverty by generating gainful self-employment.
- The second GR should focus on generation of employment for the small and marginal farmers and the landless, while enhancing agricultural production.
- Mechanization imparts capacity to the farmers to carry out farm operations, with ease and freedom from drudgery, making the farming agreeable vocation for educated youth as well. Therefore, development of need-based tools and implements need to be given priority to achieve timeliness and improves productivity and input-use efficiency.
- Since quality seed material, particularly in case of pulses and oilseeds, is one of the major constraints to improve the productivity in rice-fallow area, there is need to develop a seed chain of newly developed varieties in each state.
- There is large gap between between farmers and non farmers. An average income of Indian farmer is four times lesser than income of non-farmer. Hence, government should support the farmer's livelihood through farmers' welfare policy.
- Although India exporting rice worth about six billion USD including basmati rice, still 22-25 per cent of children are suffered by hunger, malnutrition and under-nutrition. Hence, research towards on biofortification of foods has to be focused to eliminate the food nutrition crisis. Government should be ensured that all the peoples are accessing the nutritional foods.
- Diverse cropping systems including oilseeds, pulses and millets and alternate farming systems for different agro-ecological regions need to be introduced.
- Design and development of different crops varieties to successful orient the different situations like waterlogging, salinity, drought and other natural vagaries.
- Conservation agriculture practices like direct sowing, laser leveling, retention of residues and minimum tillage hold promise in conserving moisture, nutrients and energy and thereby reducing the cost of cultivation apart from maintaining and improving carbon stock in the soil (Laik *et al*., 2014) [5]. Suitable varieties of different crops for conservation agriculture also need to be evolved.
- Tree farming particularly horticultural interventions can also provide year-round employment to the stakeholders of the region. A majority of the small farmers in India

depend on livestock for supplementary income. Livestock is, by and large, well distributed among various sections of the communities unlike land holdings. Therefore, promotion of mixed farming with livestock can also generate employment for small and marginal farmers.

- Ground-water problems (presence of arsenic, fluorides, and iron etc.) be tackled before there appear as major issues.

Conclusion

From the above, it could be concluded that green revolution have saved millions of peoples worldwide from famine and hunger. Now this nation is able to provide food security to all the peoples due to intensive adoption of green revolution programme. However, India possesses worst in world hunger index. Exploiting the finest of scientific knowledge and technological infiltrate is vital for next green revolution as we endeavor to reinstate agricultural innovation and production systems to meet today's intricate challenges. These second green revolution should meet the sustainable development in agriculture, ecologically balance, technically sound, nutritionally secure and economically affordable for inputs.

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