Golden Jubilee of Green Revolution
2015

Golden Jubilee of Green Revolution

Reminiscences

IARI 1905

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NAAS

The first lesson we must learn is of self-help and self-reliance. If we assimilate this lesson, we shall at once free ourselves from disastrous dependence upon foreign countries and ultimate bankruptcy. ... We are not a small place, dependent for this food supply upon outside help. We are a subcontinent , a nation of 400 million. We are a country of mighty rivers and a rich variety of agricultural land, with inexhaustible cattle-wealth. That our cattle give much less milk than we need, is entirely our fault. Our country... should not today only be providing herself with sufficient food but also be playing a useful role in supplying the outside world with much needed foodstuff...

– Mahatma Gandhi

Golden Jubilee of Green Revolution
2015

Golden Jubilee of Green Revolution

Reminiscences

भारतीय कृषि अनुसंधान संस्थान

भाकृअनुप
ICAR

NAAS

The wheat mountains of the Punjab

"...The arrival of large quantities of wheat in the grain markets of the Punjab-Haryana region is a heart-warming sight..."

It was in April-May 1968, that the country witnessed the wonderful spectacle of large arrivals of wheat grain in the mandis of Punjab like Moga and Khanna. Wheat production in the country rose to nearly 17 million tonnes that year, from the previous best harvest of 12 million tonnes. Indira Gandhi released a special stamp titled "Wheat Revolution" in July 1968, to mark this new phase in our agricultural evolution. The nation rejoiced at our coming out of a "ship to mouth" existence. Later in 1968, Dr William Gaud of the U.S. referred to the quantum jumps in production brought about by semi-dwarf varieties of wheat and rice as a "green revolution." This term has since come to symbolise a steep rise in productivity and, thereby, of production of major crops.

– M S Swaminathan

राधा मोहन सिंह
Radha Mohan Singh

कृषि एवं किसान कल्याण मंत्री
भारत सरकार
Minister of Agriculture and
Farmers Welfare
Government of India

सत्यमेव जयते

संदेश

मुझे यह जानकर प्रसन्नता हुई है कि राष्ट्रीय कृषि विज्ञान अकादमी द्वारा भाकृअनुप–भारतीय कृषि अनुसंधान संस्थान, नई दिल्ली से **''भारत में हरित क्रांति की स्वर्ण जयंती''** के अवसर पर दिनांक 27 नवम्बर, 2015 को एक समारोह आयोजित किया जा रहा है। इस ऐतिहासिक अवसर पर मैं सभी कृषि वैज्ञानिकों को और विशेषकर 1960 व 70 के दशक में भारत में हरित क्रांति लाने में संलग्न रहे कृषि वैज्ञानिकों को बधाई देता हूँ।

भारत में हरित क्रांति की सफलता, स्वतंत्रता प्राप्ति के उपरान्त हासिल की गई प्रमुख सफलताओं में से एक है। हरित क्रांति की सफलता ने जहां एक ओर खाद्यान्न के मामले में राष्ट्र को आत्मनिर्भर बनाया वहीं दूसरी ओर कृषि प्रगति के नए मार्ग प्रशस्त किए। हरित क्रांति निःसंदेह राष्ट्रीय स्तर पर किए गए सामूहिक एवं सहयोगी प्रयासों का ही प्रतिफल था, लेकिन इसमें वैज्ञानिकों द्वारा समुचित प्रौद्योगिकियों के विकास कार्य निश्चित रूप से सराहनीय हैं। हमारे अनुसंधान संस्थान में विकसित नई प्रौद्योगिकियों द्वारा बागवानी, पशुधन एवं मात्स्यिकी क्षेत्र में सतत प्रगति के साथ देश की कृषि को एक एवरग्रीन क्रांति की दिशा में आगे ले जाया जा रहा है।

मैं, इस सुअवसर पर राष्ट्र के कृषि वैज्ञानिकों को पुनः बधाई देता हूँ।

दिनांकः 23 नवम्बर, 2015

(राधा मोहन सिंह)

डॉ० संजीव कुमार बालियान
Dr. Sanjeev Kumar Balyan

सत्यमेव जयते

कृषि एवं किसान कल्याण राज्य मंत्री
भारत सरकार
Minister of State for Agriculture
and Farmers Welfare
Government of India

संदेश

मुझे यह जानकर प्रसन्नता हुई है कि राष्ट्रीय कृषि विज्ञान अकादमी द्वारा भाकृअनुप–भारतीय कृषि अनुसंधान संस्थान, नई दिल्ली के सहयोग से **''भारत में हरित क्रांति की स्वर्ण जयंती''** के अवसर पर दिनांक 27 नवम्बर, 2015 को एक समारोह आयोजित किया जा रहा है।

भारत में हरित क्रांति के माध्यम से कृषि क्षेत्र के रूपांतरण से न केवल करोड़ों लोगों के जीवन में आमूल–चूल बदलाव आया वरन इससे भूख के चंगुल से निकल कर विश्व स्तर पर राष्ट्र की प्रतिष्ठा पुनः स्थापित हुई। यह देखकर खुशी होती है कि देश के कृषि वैज्ञानिक अपने कार्यों से आत्मसंतुष्ट हुए बिना निरन्तर नई प्रौद्यौगिकियों का सृजन कर कृषि विकास के मार्ग पर अग्रसर रहे। इसी का सुफल परिणाम है कि आज हमारा देश न केवल खाद्यान्न की दृष्टि से आत्मनिर्भर है वरन वह निर्यातक राष्ट्रों की अग्रिम पंक्ति में भी शामिल है।

मैं, इस अवसर पर राष्ट्र विकास में अपना योगदान करने वाले सभी कृषि वैज्ञानिकों एवं किसान भाइयों को बधाई देता हूँ और उन्हें भावी प्रयासों के लिए अपनी शुभकामना देता हूँ।

संजीव बालियान

दिनांकः 23 नवम्बर, 2015

(डॉ. संजीव कुमार बालियान)

मोहनभाई कुंडारीया
Mohanbhai Kundariya

सत्यमेव जयते

कृषि एवं किसान कल्याण राज्य मंत्री
भारत सरकार
Minister of State for Agriculture and Farmers Welfare
Government of India

संदेश

देश के कृषि विकास में मील का पत्थर साबित हुई हरित क्रांति के बीजारोपण एवं सफलता के साथ-साथ हमारे कृषि वैज्ञानिकों के सतत शोध प्रयासों और किसान भाईयों की कड़ी मेहनत के फलस्वरूप आज हमारा राष्ट्र खाद्यान्न आयातक की श्रेणी से निकलकर खाद्यान्न निर्यातक की श्रेणी में आ पहुंचा है। अभी भी विश्व में अनेक राष्ट्र हैं जहां हरित क्रांति जैसी सफलताएं प्रतीक्षारत हैं। इस दिशा में विशेषकर दक्षिण एशियाई देशों में भारत अपनी नेतृत्व क्षमता से सफलता के नए मार्ग प्रशस्त कर सकता है।

मुझे खुशी है कि **''हरित क्रांति की स्वर्ण जयंती''** के अवसर पर राष्ट्रीय कृषि विज्ञान अकादमी द्वारा भाकृअनुप-भारतीय कृषि अनुसंधान संस्थान, नई दिल्ली के सहयोग से दिनांक 27 नवम्बर, 2015 को एक समारोह का आयोजन किया जा रहा है।

देश में हरित क्रांति के सफलतापूर्वक 50 वर्ष पूरा होने पर मैं कृषि वैज्ञानिकों को बधाई देता हूँ और राष्ट्र की कृषि प्रगति की शुभकामना करता हूँ।

दिनांक: 24 नवम्बर, 2015

(मोहनभाई कुंडारीया)

Foreword

HARVEST OF HOPE

TODAY is a solemn occasion when we are commemorating the Golden Jubilee of the Green Revolution in India, a moment for celebrating Indian agriculture. This is also an occasion to salute the Farm-Technology-Policy unison of Green revolution, Scientist-Farmer combine and Vision-Action synergy, and further, plan a strategy for the Food-Nutrition Secure India. It was a turning point in the history of the country fifty years back, when the seeds of food self-sufficiency were sown. This presents a unique opportunity for us to offer tributes to the Nobel Laureate, Late Dr. Norman E. Borlaug, and hear from legends like Prof. M.S. Swaminathan, who were the key players of the event. I deem it an honour to record our deep sense of debt and gratitude to the Institutions and Individuals who enabled green revolution, on behalf of the entire agricultural fraternity.

Looking forward, challenges of climate variability, declining and degrading state of natural resources, input use efficiencies including water and energy, emergence of biotic and abiotic stresses, harvest and post-harvest losses, and access to markets need to be addressed. In order to meet the ever increasing demand for food-feed-fuel and make farming attractive and remunerative, greater emphasis would be required with regard to efficient farming, integrated farming, speciality agriculture and secondary agriculture. Innovations and Investments need to be stepped up for realizing the paradigm of Agriculture-Food-Nutrition-Health-Environment-Employment.

Climate-resilient agriculture, One Health vision, Agriculture as a sought after profession and a Healthy India are the ingredients of a comprehensive agriculture strategy. A journey of the path traversed and a look at the way ahead give us the confidence to take on challenges, and redeem the pledge to fulfill the food requirement of our countrymen in all its dimensions. Together, We Can.

New Delhi
27 November 2015

(S. Ayyappan)
Director General, ICAR
President, NAAS

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From Green Revolution to an Ever-green Revolution

M. S. Swaminathan

The great Bengal famine of 1942-43 provided the backdrop to our Independence. Gandhiji mentioned at Naokhali that “to the hungry, God is bread and that this God should prevail in every home and hut in our country”. I joined as a Graduate student at the Indian Agriculture Research Institute, New Delhi during 1947-49. During that period, Jawaharlal Nehru came and addressed the Director and Senior Scientists of IARI, when he mentioned, “everything else can wait but not agriculture”. I remember the grim situation then prevailing on the food front. Government had to depend on imported PL-480 wheat to feed the public distribution system. Shri K M Munshi as Food and Agriculture Minister appealed for the enlargement of the food basket so as to include millets and tubers in the diet. His wife, Smt Leelawati Munshi started a series of Annapurna Restaurants where wheat and rice were substituted with ragi and various millets. This was for the purpose of overcoming the shortage of wheat and rice.

Jawaharlal Nehru decided to improve the infrastructure for scientific agriculture and started a chain of fertilizer plants and irrigation projects. Once water and fertilizer became available, the government initiated an Intensive Agriculture District programme (IADP) designed to optimise the benefits from good soil fertility and moisture availability.

- IADP was launched in 1960-61 for maximising the benefits of irrigation water and mineral fertilizer and by 1963-64, IADP covered 15 districts.
- Unfortunately the impact on yield improvement was not up to the expectation, since the package of practices missed one important ingredient, namely, a genetic strain which can respond to the rest of the package.

Reminiscences

I joined the Central Rice Research Institute, Cuttack in 1954 and was engaged in the Indica-Japonica hybridization programme designed by Dr K Ramaiah. The idea behind this programme was to transfer from Japonica to Indica varieties the ability to respond to fertilizer application. Some good varieties like ADT 27 and Mashuri came out of this programme. However there were problems of semi-sterility which impeded the yield potential of such hybrids. Fortunately, soon the Dee Gee Woo Gen dwarfing gene became available from the International Rice Research Institute, Philippines as well as Taiwan.

*In late 1954, I joined the staff of the Botany Division of IARI (a Division which I renamed in 1966 as Genetics Division). I mentioned to Dr B P Pal who was then the Director of IARI, and who was also an eminent Wheat Breeder, my desire to work on semi-dwarf and fertilizer responsive varieties of wheat, using multiple research strategies, including radiation induced erectoides mutants, on the lines of the work done by Prof A Gustafson in Sweden. He warmly supported my proposal and mentioned that breeding wheat varieties which can respond to fertilizer application was the need of the hour. Unfortunately, all the semi-dwarf strains my students and I produced by different approaches had also reduced panicle size and hence a lower yield potential. In 1955, I learnt from Dr H Kihara, the famous Japanese wheat scientist that Dr Gonziro Inazuka of the Norin Experiment Station has semi-dwarf varieties with long panicles (ie, without any pleiotropic effect) and that these were being used by Dr Orville Vogel in Pullman, Washington State, in his winter wheat breeding programme. I wrote to Dr Vogel and he was kind enough to send seeds of the semi-dwarf variety Gaines. He however also wrote that being a winter wheat, Gaines may not flower in Delhi. He therefore suggested that I approach Dr Norman Borlaug in Mexico who had incorporated the same dwarfing genes in a spring wheat background. I had met Dr Borlaug in 1953 at the University of Wisconsin, USA when he delivered an interesting lecture on “Multi-line Breeding in Wheat” for imparting enduring resistance to stem, leaf and stripe rusts. He had also entered some of his semi-dwarf material in the International Wheat Rust Nursery trials organised by

Farmer showing the grain of
Jamuna at Auchandi village, Delhi, 1970

** This narration is based on my paper “Genesis and Growth of the Yield Revolution in Wheat in India: Lessons for Shaping our Agricultural Destiny”. Agric Res, Springer, NAAS Journal, (September 2013) 2(3):183–188*

USDA. Dr M V Rao and I studied this material in 1961 and were very impressed with the new plant type. I therefore wrote to Dr Borlaug requesting him to send a wide range of breeding material containing the Norin dwarfing genes. He promptly replied offering to send the seeds, but he expressed a desire to visit India to study the growing conditions before making a set for being sent to me. Unfortunately, it took more than a year for the visit to materialise because of the procedures involved. Finally, he came to Delhi in March, 1963, when he and I travelled all over the wheat belt in North India. Several of my colleagues like Drs S P Kohli, M V Rao and V S Mathur also accompanied him during some of the trips. At the end of the field trips in late March, 1963, Borlaug and I decided on the following road map.

Dr Borlaug will go from Delhi to Lahore, Pakistan, where he had sent his material a couple of years earlier, so that he could select those which were doing well under the growing conditions prevailing in the Pakistan part of Punjab. He would send me by September, 1963 about 100 kg seed of each of four Mexican semi-dwarf strains, namely Sonora 63, Sonora 64, Mayo 64 and Lerma Rojo 64A. I also suggested to him that he should send a wide range of segregating material (F2 to F7) so that we could make selections possessing resistance to the prevailing races of wheat rusts (stem, leaf and stripe rusts) as well as desirable culinary properties. **We gave high priority to the genetic checkmating of wheat rust races.** I explained to him that selection from crosses made in Mexico will help us to purchase time, since the quantity of wheat imports under the US PL-480 programme was increasing each year (it reached a level of 10 million tonnes in 1966).

Eternal vigilance is the price of stable agriculture and this will call for concerted and continuous attention to soil and plant health and to the scientific checkmating of the adverse impact of climate change. At the public policy level, assured and remunerative marketing opportunities hold the key to stimulating and sustaining farmers' interest in achieving higher productivity and production.

The seeds from Mexico arrived in early October, 1963, and I immediately divided them into 6 lots and sent them to Ludhiana, Kanpur, Pant Nagar, Pusa (Bihar) and Indore, in addition to keeping seeds for sowing at IARI, Delhi. Thus, a multi-location trial was organised in the very first year of this programme. Agronomic research was also started immediately under the overall guidance of Dr O P Gautam, since it was clear that changes in several agronomic practices like depth of sowing, time of first irrigation etc., would be needed in case of semi-dwarf strains. The agronomic practices needed in the case of the new plant type were standardised by the

Agronomy Division of IARI within a short time. Similarly, plant pathologists led by Dr R Prasada and Dr L M Joshi identified rust-resistant strains and Dr A Austin assessed the chapatti making quality of the new varieties. Dr Borlaug was full of praise for this inter-disciplinary team work, particularly for the speed with which we developed new varieties from the segregating populations sent by him. **The segregating material helped us to breed outstanding semi-dwarf varieties like Kalyan Sona and Sonalika, possessing amber grains and good yield potential.** In contrast, the Mexican dwarf wheats had red grains. Kalyan Sona and Sonalika proved to be very popular with farmers. Consumers liked their chapatti making quality. Incidentally, the name Kalyan Sona was a combination of the names Kalyan and Sona given for the same material by scientists in Punjab Agricultural University (led by Dr D S Athwal and later, Dr K S Gill) and IARI. Also, amber grain mutants were isolated in irradiated Lerma Rojo and Sonora 64. I summarised all the available results in my lecture at the All-India Wheat Workshop held at New Delhi in July, 1964 (Swaminathan M S, 1965). Since then, hundreds of high yielding varieties of *Triticum aestivum, T. durum,* and *T. dicoccum* have been released by wheat scientists all over India.

Based on my analysis of the results of the multi-location trials conducted during 1963-64, I concluded that launching a yield revolution in wheat based on semi-dwarf, fertilizer and irrigation water responsive varieties, is an idea whose time has come. I therefore proposed in June 1964 the organization of 1,000 National Demonstrations in the fields of farmers with small holdings for introducing the new plant type to them. In my proposal to Government, **I emphasized that the demonstrations should be in the fields of resource poor farmers, since the success of demonstrations in rich farmers' fields will be attributed to affluence and not to technology**. The Ministry of Agriculture had some reservations about this approach, but the then Minister for Food and Agriculture, Mr C Subramaniam over-ruled the objections and approved the programme in August 1964. In the National Demonstration plots, laid out during 1964-65, small farmers harvested 4 to 5 tonnes/ha in contrast to less than 1 tonnes/ha before. **The success of the National Demonstrations unleashed the enthusiasm of farmers and a small government programme became a mass movement.**

Dr K. Ramaiah, the first Director of the Central Rice Research Institute (CRRI), Cuttack, proposed that one should transfer genes for fertilizer response from japonica to indica rice varieties. This was the beginning of the breeding of high-yielding varieties, which subsequently led to 'the Green Revolution'.

In 1964, a National Tonnage Club of Farmers was organized, whose membership was confined to farmers producing about 2 tonnes/ha of wheat or other crops. Thus, the seeds of the yield revolution were sown in the minds and outlook of small farmers.

In 1964-65, I devised a two pronged strategy for purchasing time in terms of seed multiplication. Because of the success of the National Demonstrations, the clamour for new seeds grew rapidly. The two pronged strategy consisted of first, organizing **the Jounti Village of Delhi State** as a Seed Village. Dr Amir Singh, who knew the villagers, played an important role in convincing them that they should take to the production of the seeds of new varieties. In 1967, Smt Indira Gandhi visited the Jounti Seed Village and inaugurated the Jawahar-Jounti Seed Cooperative. The details are described in my article in **Indian Farming** (Swaminathan M S, 1968). The second aspect of the strategy was to get bulk quantities of seeds from Mexico. Shri C Subramaniam and Prime Ministers Lal Bahadur Shastri and Indira Gandhi accepted our recommendation for the import of 200 tonnes and 18,000 tonnes of seeds of Lerma Rojo and Sonora 64 in 1965 and 1966, respectively. These imports were done as part of our "Purchase time" strategy.

…there is no miracle in agricultural progress – it involves hard and integrated work with concurrent attention to all links in the production, marketing and consumption chain….

In 1968, about four million tonnes of additional wheat became available due to the high yielding varieties programme. Most of this belonged to the red grain Mexican variety Lerma Rojo. The Agricultural Prices Commission recommended a difference of ₹ 5 per quintal between red and amber grain varieties. It was clear that such a difference would dissuade farmers from growing the Mexican varieties during the following year. I mentioned to Mr Dias, who was the then Food Secretary, that we should announce a uniform support price for amber and red grain varieties. He was kind enough to take me to the then Agriculture Minister, Shri Jagjivan Ram in his Chamber in Parliament to explain the reasons why we should have a uniform price. After hearing me, Shri Jagjivan Ram announced in Parliament, a uniform minimum support price of ₹ 65 per quintal for all wheat varieties. **This one decision of Shri Jagjivan Ram played a catalytic role in spreading the new high yielding varieties on a large scale during *rabi* 1968-69 and in subsequent years**. Meanwhile, we had intensified our work in developing new varieties with the desired culinary quality characters. Shri V S Mathur played a key role in the development of a range of very high yielding and high quality varieties.

Synergy between Science and Public Policy

An important factor in stimulating accelerated growth in wheat productivity and production was the unhesitating support given by political leaders to scientific ideas. Bharat Ratna C Subramaniam was a pillar of strength throughout the three years he served as Food and Agriculture Minister (1964-67). Lal Bahadur Shastri, through his slogan "Jai Jawan Jai Kisan", highlighted the critical role of farmers in not only feeding the nation but also in safeguarding its sovereignty. It was however Indira Gandhi who clearly saw the link between food self sufficiency and our ability to adopt an independent foreign policy. No wonder, when Dr Vikram Sarabhai (who succeeded Dr Homi Bhabha as Chairman of the Atomic Energy Commission) and I met her at her residence in late 1966 (the year she had taken over as Prime Minister) for discussing the opportunities opened up by remote sensing in natural resources mapping and management, the first question she asked me was, "How soon can we build a food grain buffer stock of 10 million tonnes?". I was a bit taken up by this question, but on reflection, I realised that we had imported 10 million tonnes of wheat in 1966 at the cost of heavy political humiliation. I replied, "We should be able to build a grain serve of 10 million tonnes by early 1970s, if farmers can be assured a remunerative price." I further added that we should start building grain storage facilities in the areas of production like Punjab, Haryana and Western Uttar Pradesh. At that time, most of the grain storage facilities were located near ports. She mentioned this to Shri Morarji Desai, who was then Deputy Prime Minister and Finance Minister.

To the credit of Shri Morarji Desai, he soon took a meeting in the vicinity of the godowns of the Food Corporation of India located near the Indian Agricultural Research Institute and advised FCI to come up with a plan for building grain storage structures in the production areas, using *Usar* land (ie. Salt affected land with low agricultural production potential). Unfortunately, till today, lack of adequate facilities for the safe storage of food grains is our greatest weakness.

I captured the keenness of farmers in the following words: Brimming with enthusiasm, hardworking, skilled and determined, the Punjab farmer has been the backbone of the revolution. Revolutions are usually associated with the young, but in this revolution, age has been no obstacle to participation. Farmers, young and old, educated and uneducated, have easily taken to the new agronomy. It has been heart-warming to see young college graduates, retired officials, ex-armymen, illiterate peasants and small farmers queuing up to get the new seeds. At least in Punjab, the divorce between intellect and labour, which has been the bane of our agriculture, is vanishing.

Another decision of Indira Gandhi may be worthy of record. One evening in January 1967, Dr Vikram Sarbhai and I were returning after visiting several villages in Delhi State where semi-dwarf varieties of wheat were being cultivated. Vikram was impressed with the enthusiastic response of farmers to the new plant type. He told me that we should accelerate progress in bridging the gap between scientific know-how and farmers' do-how by the effective use of the radio and television. Vikram felt that we should communicate this immediately to Indira Gandhi. We went straight to her house from the village trip and fortunately she was free and gave a patient hearing. She then rang up the Minister for Information and Broadcasting and asked him to start a **"Krishi Darshan"** programme immediately. Within 3 weeks, the Krishi Darshan Programme was launched.

I would also like to make a brief reference to the transition from green to ever-green revolution in agriculture. On January 4, 1968, I made the following statement in my Presidential address to the Agricultural Sciences Section of the Indian Science Congress held at Varanasi (Swaminathan M S, 1968).

"Intensive cultivation of land without conservation of soil fertility and soil structure would lead ultimately to the springing up of deserts. Irrigation without arrangements for drainage would result in soils getting alkaline or saline. Indiscriminate use of pesticides, fungicides and herbicides could cause adverse changes in biological balance as well as lead to an increase in the incidence of cancer and other diseases, through the toxic residues present in the grains or other edible parts. Unscientific tapping of underground water would lead to the rapid exhaustion of this wonderful capital resource left to us through ages of natural farming. The rapid replacement of numerous locally adapted varieties with one or two high yielding strains in large contiguous areas would result in the spread of serious diseases capable of wiping out entire crops, as happened during the Irish Potato Famine of 1845. Therefore, the initiation of exploitative agriculture without a proper understanding of the various consequences of every one of the changes introduced into traditional agriculture and without first building up a proper scientific and

training base to sustain it, may only lead us into an era of agricultural disaster in the long run, rather than to an era of agricultural prosperity."

This statement was made early in 1968 before Dr William Gaud coined the term "green revolution". To achieve an ever-green revolution, we need technologies which can help farmers to improve productivity in perpetuity without associated ecological harm. By mainstreaming ecological principles in technology development and dissemination, we can achieve sustained and sustainable advances in productivity (Swaminathan M S, 2010).

Looking back one of the important factors which lead to the radical change in our agricultural scenario was the appointment of Bharat Ratna C Subramaniam as the Minister for Food and Agriculture in 1964. Soon after he joined as Minister, he set up a panel of scientists to advise him on the way forward. I was the Secretary of this Panel and I prepared a paper on the opportunities available for making a major breakthrough in the production of five crops – wheat, rice, maize, jowar (sorghum) and bajra (pearl millet). This High Yielding Varieties Programme was the turning point in our agricultural history. The defect which I had noticed in the IADP programme namely, the lack of a genetic strain which can respond to good soil fertility and irrigation water availability was overcome by the new plant type. Thus, scientific skill, political will and farmers' toil all came together at the same time leading to the green revolution. As already mentioned, the negative environmental features associated with the excessive use of mineral fertilizer and chemical pesticides and unsustainable exploitation of groundwater led me to develop the evergreen revolution pathway of sustainable production. The famous scientist Dr E O Wilson made the following point about the significance of the evergreen revolution

"The problem before us is how to feed billions of new mouths over the next several decades and save the rest of life at the same time without being trapped in a Faustian bargain that threatens freedom from security. The benefits must come from an evergreen revolution (as proposed by Swaminathan). The aim of this new thrust is to lift production well above the levels attained by the Green Revolution of the 1960s,

using technology and regulatory policy more advanced and even safer than now in existence."

Therefore, it will be better to avoid terms like second green revolution. We need productivity in perpetuity without associated ecological harm. This is also the aim of goal 2 of the Sustainable Development Goals recently adopted by the Member Nations of the United Nations. As a Member of Rajya Sabha, I am happy to have witnessed the transition from a ship to mouth existence to right to food enshrined in the National Food Security Act 2013. If our farmers are properly supported on the lines recommended by the National Commission on Farmers which I chaired, they will produce enough food for the country. We should remember that "the future belongs to nations with grains and not guns". There can be no more PL-480 era, since the US does not have so much surplus grain. We have to depend upon ourselves to feed our growing population. This is why an evergreen revolution in agriculture is important for the country. At the same time, we must leverage agriculture for overcoming the malnutrition problems in the country. For this purpose, I designed a Farming System for Nutrition programme (FSN). While the evergreen revolution pathway will provide adequate food for the future, FSN will provide a food based approach to ending malnutrition.

Green Revolution

Gurdev S. Khush

According to Ralph Cicerone, President of the US National Academy of Sciences, four most important scientific discoveries of the 20th century are: Green Revolution, elimination of Small Pox and Polio from our Planet, placing man on the moon and deciphering the DNA code. Green revolution resulted in unprecedented increases in food production and saved billions of lives. The 1960s was a decade of despair with regard to the world's ability to cope with the food-population balance, particularly in densely populated countries of tropics and subtropics. In these countries, cultivated land frontier was closing while population growth rates were accelerating, owing to the rapidly declining mortality rates due to advancements in modern medicine and health care.

International organizations and concerned professionals were trying to raise awareness regarding the ensuing food crisis and to mobilize global resources to tackle the problem on an emergency basis. In a famous book entitled, "*Time of Famines*" published in 1967, Paul and William Paddock predicted, "Ten years from now, parts of the underdeveloped world will be suffering from famine. In 15 years, the famine will be catastrophic and the revolution and social turmoil and economic upheavals will sweep areas of Asia, Latin America and Africa."

Thanks to the wide scale adoption of "green revolution" technology, the predicted large-scale famines and social and economic upheavals did not happen. Between 1966 and 2000, the populations of densely populated low-income countries doubled but food grain production increased three-fold. In 2000, the average per capita food grain availability was 22% higher than in 1966. The technological advance that led to the dramatic achievements in the world food production during the last forty years was the development of high-yielding varieties of cereals, in particular those of wheat and rice first developed at the International Wheat and Maize Improvement Center

(CIMMYT) and the International Rice Research Institute (IRRI) respectively in the 1960s. Since then many national programs have developed numerous improved varieties of these cereals that have been widely grown.

Several traits are associated with increase in genetic yield potential of green revolution varieties. For rice and wheat, the yield improvement resulted from a reduction in plant height through incorporation of genes for short stature. This led to improvements in harvest index (grain-straw ratio) as well as to increases in biomass production. The varieties of rice and wheat grown prior to green revolution were tall and leafy with weak stems with a harvest index of 0.3, that is they produced 30% grain and 70% straw. They could produce a total biomass of 10-12 tonnes /ha. Thus, their maximum yield potential was 4 tonnes /ha. When nitrogenous fertilizer was applied at rates exceeding 40 kg /ha, these varieties tillered profusely, grew excessively tall, lodged early, and yielded less than they would with lower fertilizer inputs. The improved varieties on the other hand, have a harvest index of 0.5. Because of their short stature, they are lodging resistant and responsive to fertilizer inputs. Their biomass can be increased to 20 tonnes /ha through fertilizer inputs. Thus, their yield potential is 10 tonnes /ha. This improvement in the harvest index was the single most important architectural change in the rice and wheat varieties that more than doubled their yield potential.

Several other traits were modified that were equally important in increasing the adaptability and yield stability of new varieties. For example, most of the traditional varieties of rice grown in the tropics were photoperiod sensitive and took 150-180 days to mature. They were suitable for growing single crop of rice in monsoonal Asia. New varieties on the other hand, are photoperiod insensitive and can be planted any time of the year. Moreover, the growth duration has been reduced to 110 days. The availability of these short duration varieties has led to increased cropping intensity. Farmers now grow two crops of rice where only one was grown before or even two crops of rice and another upland crop. Similarly, improved wheat varieties were developed by Dr Borlaug for wide adaptability and insensitivity to photoperiod by growing segregating populations over 100 latitude and from sea level to an elevation of 8,500 feet. Through this shuttle breeding approach time taken to develop a new variety was reduced by half. The yield stability was increased through the incorporation of genes for disease and insect resistance. For example, genes for resistance to several races of stem rust, leaf rust and stripe rust have been incorporated into high yielding varieties of wheat. New rice varieties are resistant to as many as four diseases and three insects. Tolerance to some abiotic stresses, such as saline, alkaline and iron toxic soils, and flood tolerance as well as drought has been incorporated into improved rice varieties. Through collaboration between CIMMYT and the Brazilian national program, wheat varieties have been developed that are tolerant to aluminium toxicity. These varieties have helped reclaim aluminium toxic soils for wheat cultivation. They also have higher yield, yield stability and adaptability. Special attention has been paid to selecting for appropriate cooking quality and taste preferences and milling recovery in rice and baking and milling characteristics in wheat.

Collaboration with National Programs

For dissemination of technologies for increasing food grain production, IRRI and CIMMYT, developed strong collaboration with national programs. This included:

- Sharing of germplasm
- Training of national program scientists
- Organizing conferences and symposia
- Publication on various aspects of rice and wheat science
- Joint workshops with national program scientists.

Collaboration started with testing of improved breeding materials in the national programs. For example, IRRI distributed first set of rice breeding lines to rice growing countries in Asia and Latin America in 1963-64. These included experimental line IR8-288-3 that was named IR8 based on its superior performance at IRRI and in yield trials in national programs. Similarly, Dr Borlaug distributed improved wheat lines in 1962-63 and out of these materials, high yielding lines such as Kalyansona were selected in India and Maxipak in Pakistan. Exchange of germplasm is the most important continuous activity. Both IRRI and CIMMYT have been distributing the breeding lines

...For example, more than 700 IRRI breeding lines have been released as varieties in Asia, Africa and Latin America.... .

and named varieties through international nurseries. These materials are evaluated by national program scientists. Some are released as varieties and others are used as parents in local breeding programs. For example, more than 700 IRRI breeding lines have been released as varieties in Asia, Africa and Latin America. Forty IRRI lines have been released as varieties in India. Of these IR 36 and IR 64 are still widely grown. More than 1,000 improved rice varieties have been developed by Indian scientists and vast majority of them have IRRI germplasm in their ancestry. The national program scientists who have participated in various degree training programs at IRRI now number over 20,000. They have contributed much to the success of green revolution.

Impact of Green Revolution

The green revolution has had impact not only on increase in food production but also on many socio-economic and environmental issues.

Impact on food production

The gradual replacement of traditional varieties of wheat and rice by improved ones, together with improvement in associated farm management practices has had a dramatic effect on the growth of rice and wheat output, particularly in Asia. Farmers harvest 5-7 tonnes of unmilled rice per hectare with high yielding varieties compared to 1-3 tonnes with conventional varieties. Farmers have raised average yields of wheat and rice by substituting high-yielding varieties for traditional varieties. Since 1966 when first high yielding variety of rice was released, the world rice area harvested has increased only marginally, from 126 to 152 million hectares (18%), while the average rice yield has increased from 2.1 to 4.3 tonnes /ha (115%). The total rice production has increased from 257 million tonnes in 1966 to 710 million tonnes in 2013-14, or almost three times. In India, rice production increased from 34.6 million tonnes in 1960 to 154 million tonnes in 2013-14 or 4.5 times. Similarly, world wheat production increased from 230 million tonnes in 1966 to 695 million tonnes in 2013-14. In India, wheat production increased from 10.3 million tonnes in 1960 to 97 million tonnes in 2013-14 or more than 9 times.

Impact on food security

In many Asian countries, the growth in rice and wheat production has outstripped the increase in population leading to a substantial increase in cereal consumption. According to various estimates, caloric intake in Asia is 22% higher now as compared to 1960s. The increase in per capita availability of rice and wheat and decline in the cost of production per tonne of output contributed to a decline in the real price of rice and wheat, both in international and domestic markets. The unit cost of production is 20-30% lower for high yielding varieties than for traditional varieties and price of rice and wheat adjusted for inflation is about 30% lower now than in mid 1960s.

The decline in food prices has benefitted the urban poor and rural landless, who are not directly involved in food production but who spend more than one-half of their income on food. As net consumers of grain, the small and marginal farmers, who are dominant rice and wheat producers in most Asian countries, have also benefitted from downward trend in real prices of rice and wheat.

Impact on landless workers

The diffusion of high yielding varieties has also contributed to a growth in the income of rural landless workers. High yielding varieties require more labor per unit of land, because of increased intensive care in agricultural operations and harvesting of a larger output. The labor requirements have also increased, because of the higher intensity of cropping, which has been made possible by the reduction in crop growth duration. As farm income increases, better off farm households substitute leisure for family labor and hire more landless workers to do the job. The marketing of a larger volume of produce and an increased demand for non-farm goods and services resulting from larger farm incomes has generated additional employment in rural trade, transport and construction activities. The economic miracle in many Asian countries was triggered by the growth in agricultural income and its equitable distribution that helped expand the domestic market for nonfarm goods and services.

Impact on environmental sustainability

In sharp contrast to rich countries where more of the environmental problems have been urban and industrial, the critical environmental problems in most of the low-income developing countries are still rural, agricultural and poverty based. More than half of the world's very poor live on lands that are environmentally fragile and rely on the natural resources over which they have little control. Land-hungry farmers resort to cultivating unsuitable areas such as erosion-prone hillsides, semi-arid areas where soil degradation is rapid and tropical forests, where crop yields on cleared fields drop sharply after just a few years.

The widespread adoption of high-yielding varieties has helped most Asian countries meet their growing food needs from productive lands and thereby has reduced the pressure to open up more fragile lands. Had 1961 yields still prevailed today, three times more land in China and two times more land in India would have been required to equal the present level of cereal production. If Asian countries attempted to produce present level of harvest at the yield levels of 1960s, most of the forests, woodlands, pastures and rangelands would have disappeared and mountainsides eroded with disastrous consequences for the upper watershed and productive low lands, besides extinction of wildlife habitats and destruction of biodiversity. The availability of cereal varieties with multiple resistance to diseases and insects, reduced the need for application of agrochemicals and facilitated the adoption of integrated pest management practices. Reduced insecticide use helps: (i) enhance environmental quality, (ii) improve the human health in farming communities, (iii) make more safer food available for consumers, and (iv) help protect useful fauna and flora.

Impact on poverty alleviation

Poverty is the main cause of hunger. Poor people lack access to nutritious food due to lack of purchasing power. Thus, combatting extreme poverty requires an expanded commitment to raising agricultural productivity and lowering food prices.

Reminiscences

Numerous studies have shown that the impact of economic growth on reducing poverty depends on the nature of growth in agriculture. A World Bank study found that growth in agriculture sector had a much greater impact on reducing poverty than did the urban and industrial growth in India. In longer-term perspective, progress in global poverty reduction has been remarkable. In 1969-71, 41% of the global population was poor and hungry; today the share is 16%. China reduced poverty from 46 to 12% of its population. In India, share of poor and hungry people has been reduced from 39 to 20 %. However, in spite of this progress, more than 500 million of the world's hungry live in Asia corresponding to almost two-thirds of the total of developing countries.

Improvement in children's education

A recent study has shown that the green revolution vigorously enhanced investment in children's education that was often considered a luxury, which many poor could not afford. Agricultural development catalyzed by the green revolution led to growth in farm incomes that accelerated parents' investment in schooling of their children. This also resulted in further income growth and poverty reduction via educated children's participation in the relatively lucrative nonfarm sector in developing countries.

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Epilogue

There is no denying the fact that green revolution has had a tremendous impact on human welfare by reducing hunger and poverty, resulting in political stability and development in Asia. The battle against hunger has not been completely won as yet, as 800 people in the world go to bed hungry every night and somehow survive on an income of $ 1.25 a day. Governments in developing countries must continue to invest liberally in agriculture accompanied by farmer friendly public policies. Governments of rich countries must continue to support agricultural development in Africa. Agricultural scientists must continue to utilize latest breakthroughs in the science of genetics and molecular biology to develop highly productive, pest resistant and nutritious crop varieties. Public should have faith in the opinions of scientists and science academies about the safety of food produced through recombinant DNA technology.

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2015

Strong Political Will Made The Difference

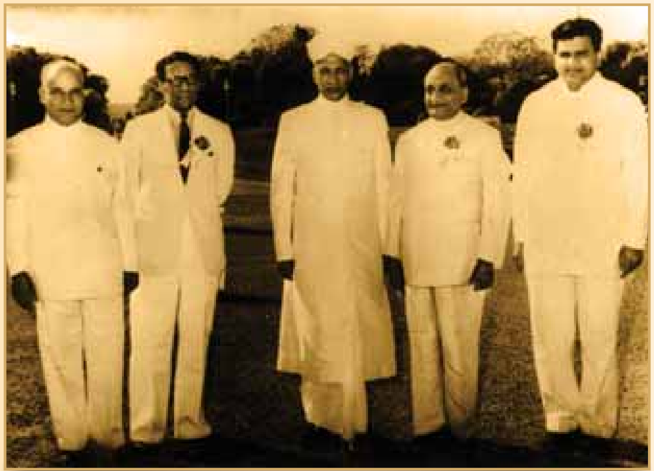
Most things, except agriculture, can wait

– Pt J L Nehru

Agriculture not only gives riches to a nation, but the only riches she can call her own

– Pt J L Nehru

Reminiscences



Even as he checked drought by inventing the irrigation systems, controlled floods by dams, studied scientifically soil deficiencies, insect infestations, plant diseases, to overcome them and increased agricultural production, he can yet reach new heights of creative achievement. In this exciting enterprise your Institute will have a great part to play.
– Dr S Radhakrishnan, IARI, April 1955

Recognizing that the crisis in agriculture was related to a breakdown of nature's processes, India's first Agriculture Minister, had worked out a detailed strategy on rebuilding and regenerating the ecological base of productivity in agriculture based on a bottom-up decentralized and participatory methodology.

K M Munshi told the State Directors of Agricultural extension-

' Study the life's cycle in the village under your charge in both its aspects—hydrological and nutritional…Work out the village in four of its aspects: (1) existing conditions, (2) steps necessary for completing the hydrological cycle, (3) steps necessary to complete the nutritional cycle, and the complete picture of the village when the cycle is restored, and (4) have faith in yourself and the programme.

Our sweat is the answer to all our problems, and that the tiller, the artisan and the teacher are the three agents who feed the body, mind and soul.

– Dr Zakir Hussain

Lal bahadur Shastri's unifying call of "Jai Jawan Jai Kisan" was greatly helpful in unifying the nation behind the true saviors of the nation, the farmers and the soldiers and rallied all the citizens of India to support them.

Reminiscences

Shastriji took personal interest in the Indian Council of Agricultural Research re-organization process. He had a vision for steering India out of defeat into a united nation. He laid out exceptional policies for defense, exports and agriculture. In all his efforts, the respect and pride of the nation were not compromised at any cost.

Agriculture constitutes the very foundation of the economy. We cannot falter or fail here.

– Smt Indira Gandhi

It hardly requires any elaboration that agriculture in India is the backbone of the whole national economic structure... In my view we can realise significant results only by understanding the problems facing agriculture and remedying them without further delay.

– V V Giri

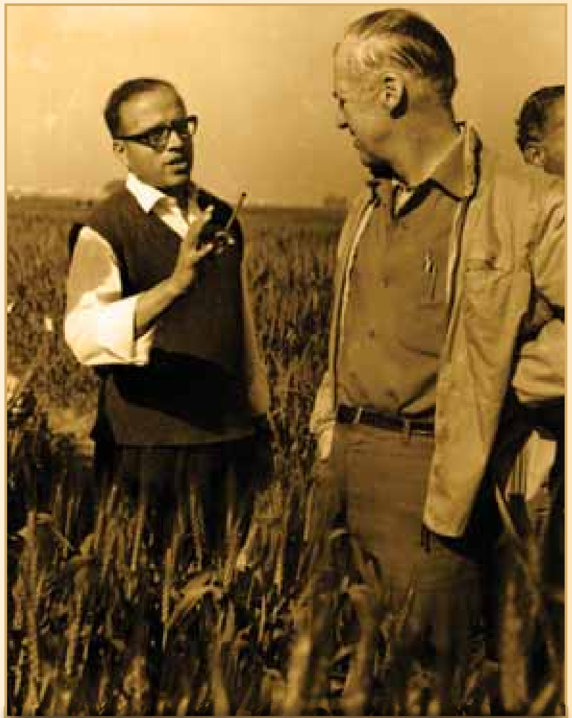
Ms Indira Gandhi's decision to build up substantial grain reserves, often against the advice of the Planning Commission, helped India take an independent view on important issues, including the decision to carry out nuclear implosion tests at Pokhran in 1974 and 1998.

Reminiscences

Dr Fakhruddin Ali Ahmed believed that state agricultural universities and agricultural research institutions needed aggressive leadership and sufficient decision making authority so as to forge functional links with similar state and central organisations.

Mr C. Subramaniam was a pillar of strength throughout the three years he served as Food and Agriculture Minister (1964–67); Smt Indira Gandhi clearly saw the link between food self-sufficiency and India's ability to adopt an independent foreign policy.

Shri Jagjivan Ram announced in Parliament a uniform minimum support price of ₹ 65 per quintal for all wheat varieties. This decision played a catalytic role in spreading the new high-yielding varieties on a large scale during the *rabi* season of 1968–69 and in subsequent years. Meanwhile, I and others had intensified our work in developing new varieties with the desired culinary quality characters.
– M S Swaminathan



Public policy with reference to input and output pricing, and assured and remunerative marketing was absolutely essential to get the economics right and thereby sustain farmers' interest in producing more. This also became clear from the somewhat disappointing results of Dr Borlaug's efforts in Africa, where there was no arrangement for procuring the surplus grains from farmers at an assured minimum support price, thus underscoring the fact that high-yielding varieties alone would not help accelerate production, unless coupled with other essential inputs, particularly remunerative prices for the produce and assured marketing opportunities.

Reminiscences

On the occasion of his receiving the Nobel Peace Prize in 1970, Dr Borlaug was gracious enough to write: The Green Revolution has been a team effort and much of the credit for its spectacular development must go to Indian officials, organisations, scientists and farmers.

Wheat production reached a level of 17 million tonnes in 1968, in contrast to 12 million tonnes four years earlier. Smt Indira Gandhi and the then Agriculture Minister Shri Jagjivan Ram released a special stamp titled 'Wheat Revolution' in July 1968. The stamp had a picture of the IARI library building, to symbolize the role of science in the transformation of yield potential in wheat.

Did I Have Green Fingers?

Yoginder K. Alagh

It is indeed a great honour to be invited to write on the ushering in of the Green Revolution in India. Having been born and brought up in the land of Gandhi and Nehru, at the outset it is important to state that India and what it does is much bigger than any one of us and therefore what an individual can only do is to give her or his perspective as the Caravan went by as the Shair said. The only role it may have is to recount some footnotes of history as some facts may disappear as a generation calls it a day.

December 1975

It was a cold day on December 5, 1972 when I joined the Planning Commission as its Chief Advisor as it was called. In those days, the Perspective Planning Division of the Planning Commission was a very powerful group and my predecessor Pitamber Pant had direct access to the Prime Minister, Indira Gandhi. The files I inherited had a record of notings from 'Pitamber' to 'Indu'. The mandate from the Prime Minister was clear. Perspective Planning in India had laid the foundations of an industrial economy, steel plants and so on. But the country had the humiliation of begging for grain. To use a metaphor our nose was rubbed in the ground. Indira Gandhi was clear. Self Reliance must be first in food grains.

I was thirty-six-year-old and my peers were all Additional Secretaries or Secretaries to the Government. I was to be given the same rank, which I did not care for, in order to protect my salary as a highly paid academic on loan to the Government. I tried to find how agricultural planning was done in India. We used I discovered certain 'Norms'; one hectare of irrigation gives x tonnes of grain, a tonne of fertilizer y tonnes and so on. If demand was projected higher and there was no money, some more 'yield' came from 'better management'. It was a completely fictitious exercise. I discovered that the incremental irrigation and fertilizer application in the past did not explain the actual or weather corrected additional yield of grain either for the country or for any state. In other words, it was a bogus planning tool.

The Background

The term Green Revolution in India leads to two images. In the popular mind, it is associated with a period in which India crossed the hump in terms of shortage of, and external dependence for, its grain and food requirements. The second more technical perception of the green revolution considers it as the productivity breakthrough emerging from the high yielding variety of seeds in food grains, particularly wheat and then rice. Agricultural growth discussions in India are set in the framework of the phenomenon loosely called the Green Revolution (for short description see Y.K. Alagh's entry on the Green Revolution in the *Oxford Economic Atlas for India*, 2nd edn., 2012). These seeds initially imported from Mexico for wheat were adapted, replicated and developed by Indian scientists. On account of their photo insensitivity properties, they were shorter duration crops as compared to the earlier varieties and this property by itself led to more intensive use of land, in addition to water and nutrients. Technology and productivity improvement became the driving force in the green revolution areas.

In the *Millennium Studies on Indian Agriculture* sponsored by the ICAR, my introductory volume shows the Green Revolution in India as spanning four time epochs. The first phase of the introduction of the high yielding technology is attributed to the initiative of the political leader C. Subramaniam and the civil servant B. Sivaraman. In the second half of the mid-sixties, a "ship to mouth" phase of grain shortage and large grain imports as PL-480 aid from the USA, they took the risk of importing the dwarf varieties of wheat from the IWRI in Mexico and were assisted by Dr M.S. Swaminathan and ICAR teams in replicating the seeds. The second was a phase in which the technology was internalized in what is called the favored region, favored crop period in the decade of the seventies. However, in the early seventies, there was still considerable pessimism on the growth potential of Indian agriculture. Paddock and Paddock, in *Famine 1975* (as quoted in Y.K.Alagh's

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The Future of Indian Agriculture), argued

Today, India absorbs like a blotter 25 per cent of the entire American wheat crop. No matter how one may adjust present statistics and allow for future increase in the American wheat crop .... It will be beyond the US to keep famine out of India during 1970. The reason? Of all the national leadership the Indian comes close to being the most childish and inefficient, perversely determined to cut the country's economic throat (Paddock and Paddock 1968: 217).

Uncertainty in 1975

The Draft Fifth Plan had mistakenly taken 116 million tonnes as the base production taking into account the bumper crop of 1970 as base and projected 140 million tonnes as the target by 1978/79. Meanwhile as actual production ranged around a 100 million tonnes, the country was in considerable grief with food inflation hitting it in addition to the first energy price hike in 1972. Dr Manmohan Singh was Chief Economic Advisor in the Finance Ministry and his estimates consistent with the then World Bank orthodoxy ranged between 118 to 120 million tonnes. In fact, after I produced a working plan which said that foodgrain production in 1978/79 would meet demand at 125 million tonnes, I was the only planner with the distinction that the Economic Survey of the Finance ministry contradicted the Planning Commission and said that production in 1978/79 would be only 122 million tonnes.

Operationalising the Green Revolution in the Turn Around Plan

It was at that time that policy making in India focussed on resource allocation and policy support to agriculture with priorities set at the level of the then Prime Minister Indira Gandhi who saw food security as the central issue. The final version of the Fifth Plan saw a conscientious attempt at sectoral planning strategies elaborated in considerable detail which became a part of the planning method. This methodology for the energy sector was derived from the *Fuel Policy Report* of 1972 (Government of India, Planning Commission, 1974). The agricultural sub-model was simultaneously developed from detailed studies (*see*, Government of India, 1978, 1979 and Y.K.Alagh, 1992 for elaboration of the methodology of sub-modelling) and these were operational decision making tools which worked.

Reminiscences

The first thing we were after was what has the farmer actually achieved in the field, not fictitious yield targets. Fortunately crop cutting experiments were available by number of waterings and type of seeds used. I used those after re-tabulating them to set input requirements for irrigation by the Irrigation establishment and extension for seeds by the ICAR. In May 1975, we said that if irrigated area went up by 8 million hectares and extension was available, India's food output would be 125 million tonnes in 1975 and that would meet demand although the nutrition problem would remain. But this would mean more money — ₹ 400 crore to complete ten irrigation projects languishing over a decade and a half and another equal sum for loans for tubewells. The Finance Ministry said no. There is inflation. The Budget is over. The Prime Minister asked us to brief her office and the money was sanctioned. There was no looking back. India's food production in 1978/79 was 127 million tonnes. In 1975/76, when we had formulated a plan for food self reliance, irrigated area went up by 5 million hectares and irrigation intensity from 108.77 to 110.25.

In Washington for an academic meeting, I had gone back to my academic liar in Thaltej, a senior World Bank official asked me "Yoginder, your production exceeded your target, was it over done." I replied "David, I come from Gujarat. I provided the slack for this is the Razors edge for my country."

"There was no looking back. India's food production in 1978/79 was 127 million tonnes. In 1975/76, when we had formulated a plan for food self reliance, irrigated area went up by 5 million hectares and irrigation intensity from 108.77 to 110.25."

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Blooms and Blushes of Green Revolution

S. S. Johl

In mid-sixties, India became heavily dependent on PL 480 food grain supplies from USA. The country was considered as a virtual basket case living from ship-to-mouth. At this crucial juncture, dwarf varieties of wheat became available from ICRISAT in México. India took daring policy decision to import the seeds in bulk and distributed it in the wheat growing areas of the country for direct cultivation as well as among agricultural universities and research institutes for developing agronomic practices and further improvements in the seeds. The dwarf varieties immediately clicked with the farmers' perceptions. In areas like Punjab, Haryana, western Uttar Pradesh and Siri Ganganagar of Rajasthan, where canal water was available in abundance, very soon large areas were covered under these varieties. Punjab and parts of Haryana specially adopted these varieties fast because of tube-well irrigation facilities. Land holdings in these areas were consolidated and every holding had independent approach road, which allowed the individual farmer to take independent decision.

Agricultural universities and research institutes immediately engaged themselves in improving the seeds further. Punjab, Haryana and Pantnagar (Western Uttar Pradesh) agricultural universities as well as Indian Agricultural Research Institute, New Delhi had by then developed their research infrastructure strong enough to absorb and develop further the technologies available from elsewhere. They proceeded fast to further develop the seeds and released amber colored higher yielding varieties of wheat, like Kalyan-Sona. Farmers adopted these improved varieties one after the other and made the country self sufficient by the end of sixties. In 1972, India held more than 20 million tonnes of food grains as buffer stock.

Reminiscences

Another push to the process of Green Revolution came by the end of sixties and early seventies with the dwarf rice varieties developed and provided by the International Rice Research Institute (IRRI) from the Philippines. Indian researchers further improved these varieties through selection process suitable to the agro-climatic conditions of specific areas and states. Coordinated Research Projects for wheat and rice initiated by the Indian Council of Agricultural Research created appropriate environment to test the crop cultivars developed by various research centers on a national scale for area specific suitability. Thus, the farm sector was fully geared towards making India self sufficient in food grains and became capable of generating surpluses in term of supply exceeding demand in the country. In fact in a cyclic way it became difficult to efficiently handle the grains resulting in extensive spoilage through rains, insect infestations as well as leakages and thefts that continue till today.

Any farm production can sustain itself on ruminative prices and efficient market clearance. In order to support the efforts on research and production front, Government of India through the Act of Parliament created a grain handling organization, Food Corporation of India (FCI) and Agricultural Prices Commission, later to be named as Commission for Agricultural Costs and Prices (CACP). The FCI was made responsible to purchase food grains from the markets of the country, store as well as issue the grains for distribution to the consumers, particularly in the deficit areas through the Public Distribution System (PDS). Since, then the FCI is procuring the wheat and paddy (unhusked rice) from the surplus producing areas directly as well as through the state government agencies acting as their agents at Minimum Support Prices (MSPs) and Procurement Prices recommended by the CACP. The MSPs were statutory prices at which the government obligated itself to stand as the buyer of last resort in the market and buy all the quantities offered at this price. Anyone, however, could buy the produce at prices higher than the MSPs. MSPs were required to be announced before the planting seasons twice in a year for *rabi* and *kharif* crops so that farmers could plan their cropping patterns keeping these assured prices in mind. Because of the fact that procurement prices always exceeded the MSPs, the Commission for Agricultural Cost and Prices (CACP) abolished the system of announcing procurement prices in 1988 and MSPs were made the effective

"Because of the fact that procurement prices always exceeded the MSPs, the Commission for Agricultural Cost and Prices (CACP) abolished the system of announcing procurement prices in 1988 and MSPs were made the effective procurement prices."

procurement prices. The system worked quite efficiently for initial years but then started getting weighed down under pressure of hugeness of the volumes of grains to be handled in the absence of matching infrastructure for proper storage of the food grains. The grains started rotting in the surplus producing areas as these were stored in the open on plinths and even without plinths in some places. The FCI started suffering huge losses. On several occasions for years together stocks exceeded two to three times the buffer stock and pipeline supply requirements of the country. India had to operate as substantive exporter in the international market. Often the quality being of low standard, quite a few consignments were rejected by the importing countries. On several occasions the country had to export the grains at prices even lower than the below poverty line (BPL) prices. All this reflected upon the weakness and inefficiencies of the system of Food Corporation in the context of procurement and Public Distribution. Unfortunately, till today the country has not been able to create matching infrastructure for storage and efficient leak proof system of public distribution. Emphasis has been all through on increasing production at any cost and not caring much on proper handling and storing the grains which has been rather a more pressing need.

"Food is the moral right of all who are born into this world."

– Dr Norman Borlaug

The mandate for the APC/CACP was to (i) provide for well thought out Minimum Support Prices (MSPs) for the agricultural products to end uncertainties of market through the government standing in the market as buyer of last resort, not at the same time controlling the market; it is a different matter that in the process, out of need for maximizing the procurement of grains for public distribution, government scuttled the capacity of other operators in the market through measures like restrictions on inter-state and inter-district movements of grain, denying credit to the private buyers on stored grains, discrimination, rather denying the private traders railway wagons etc; (ii) vouchsafe the interests of the consumers, and (iii) to make suggestions for adjustment of production patterns to the changing consumption patterns in the society. The commission in their biennial reports has been making recommendations of MSPs and also non- price suggestion consistent with its mandate. There is a peculiar phenomenon that relates to the MSPs. Prices move only upwards and every year bonuses also add to the base line. Yet, on farm front, any facility to the sector including higher prices, get translated into the higher rents and tenant cultivators suffer on this account. Also, at least two-thirds of the small and marginal farmers do not have much to sell. They mostly resort to distress sales of small quantities and many of them have to buy the same produce at higher prices in the lean periods. Pegging the prices higher and higher helped more those farmers who had substantive marketable surpluses to sell.

The policies of Green Revolution period have now come to roost. Excessive use of chemical fertilizers and pesticides has poisoned the soils and underground water which has become unfit for drinking purposes. Water-table is receding in the main Green Revolution areas, and due to inadequate recharge the water balance is deteriorating to the disadvantage of the farmers also, because they have to resort to installing the submersible pumps at huge costs. Facilities like free or highly subsidized power and water to boost production is further leading to over use and misuse of water, having cascading adverse effect on other sectors of the economy. Small and marginal farms are again at the receiving end due to such policies. While associating myself with other scientist from the beginning of green revolution, all these developments on policy front I have been continuously bringing to the notice of the authorities that be, but unfortunately vote bank politics has been and even today is overshadowing all the rationalities to the disadvantage of the farmers and the society at large. This unholy political barrier to the rational policy stance has to be demolished for putting the sustainable agricultural production on higher growth path.

> *"Agriculture is a harvest of sunshine, a resource which we have in plenty"*
>
> *– Smt Indira Gandhi*

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The Indian Green Revolution: My Reflections

R. S. Paroda

My association with the Indian initiative for food security started when the seeds of Green Revolution were being sown. I had then joined the Indian Agricultural Research Institute as a post graduate student in 1964 for Ph.D. in Genetics. Coincidentally, it so happened that my research problem was on genetic improvement in wheat. It was a turning point in my research career as I got a unique opportunity to work in close association/guidance with eminent wheat researchers of India like Dr B.P. Pal, Director, Dr A.B. Joshi, Dean, Post Graduate School, Dr M.S. Swaminathan, Head, Division of Genetics, Dr S.P. Kohli, Coordinator, All India Wheat Improvement Project, Dr M.V. Rao and Dr V.S. Mathur, Wheat Breeders and above all the Nobel Laureate Dr Norman E. Borlaug, Director, Global Wheat Program at CIMMYT, Mexico. Also, I happened to come in close contact with Dr Amir Singh, Head, Division of Seed Science and Technology, who was very actively involved in faster seed multiplication of Mexican dwarf wheat varieties in and around Delhi, especially with the farmers of Jyonti village and those in the adjoining state of Haryana.

I had known the importance of food security from my childhood as my mother often used to remind me that I was born in the year of Bengal Famine. She would also emphasise on the importance of household food security and state that farmer's primary responsibility is to produce enough food not only for self only but for others as well. According to her, the worst thing in life would be to beg for food from others, especially your neighbours. As a student of agriculture, I did realise that India was not able to produce enough food to meet its growing demand. By mid-sixties, we were importing food grains to an extent of around 10 million tonnes, especially when we had no money to buy. As a result, India imported wheat from the USA under PL-480 loan, which we continued paying back till late nineties. Also our food security in those days was considered being 'Ship to Mouth' i.e., which ship would land on which port and where the food will get distributed.

Reminiscences

Thanks to 'Green Revolution' that we have left an 'Era of Famines' behind. Instead, we have entered an ' Era of Self-sufficiency' with more than 50 million tonnes of foodgrains in our buffer stocks and an all time high annual export touching around 20 million tonnes.

I was indeed fortunate to witness the 50th anniversary of Indian independence celebrations in the central hall of Parliament. In his address, our Hon'ble President Dr K.R. Narayanan proudly emphasised on two major achievements of science since independence, one in agricultural field and the other in medical science which led to food self sufficiency and doubling the life expectancy (from 32 to 64 years), respectively. Being an agricultural scientist, having remained associated with Green Revolution period and later being responsible for sustaining the agricultural production growth, I indeed held my head high with great pride. As head of the Crop Science Division (1987-1992) in ICAR and later as Director General (1994-2001), my sincere efforts were towards attaining a higher growth pattern so as to continue producing more than 5 million tonnes of food grains annually, needed specially to meet the demand for an ever growing population (almost 16 million-equivalent to one Australia every year).

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In retrospect, I must thank Mr Rick Thomas - a gardener, who used to water my plants in the Green House at the Welsh Plant Breeding Station, Aberystwyth, UK to have sarcastically commented as to whether I would stay behind to accept a lucrative job offer that I had at that time or return to India to help my fellow countrymen who were dying of hunger and poverty. It was like a bolt on my head and came as a 'wake up call' to return and serve my country. Looking back, I have no regrets for taking that decision even when there was no job offer for me in India. Luckily, I found myself placed temporarily as a CSIR Pool Officer to work in the Division of Genetics. Both Dr. H.K. Jain, the Head of the Division and Dr. M.S. Swaminathan, the Director, IARI not only accepted my placement but encouraged as well as praised the publications that were brought out as Commonwealth Post-doctoral Fellow in the United Kingdom.

The Green Revolution period also brought me in close contact with, besides doyen of Indian agriculture Dr M.S. Swaminathan, great Dr Norman E. Borlaug in various responsibilities during my career, first as a student and wheat researcher, then Director, National Bureau of Plant Genetic Resources (NBPGR), Deputy Director General (Crop Sciences) and later as Director General, ICAR. Dr Borlaug was a great crusader, with passion to work for the developing countries, especially India. He felt immensely for the small holder farmers.

Both he and Dr Swaminathan, supported well by able researchers, administrators and policy makers, led the efforts to accomplish Green Revolution in India. Rightly so, they are credited as fathers of Green Revolution. According to Dr Borlaug, the three cradles of our Green Revolution were: (i) political will, (ii) good institutions and human resource, including progressive farmers, and (iii) partnership between national (ICAR) and global institutions (CIMMYT). Fir him, the real impact of Green Revolution, besides increased productivity, was: (i) reduced visible poverty and (ii) increased income, especially of our small holder farmers.

During my spell at ICAR, the major challenge was to address the second generation problems of Green Revolution such as: factor productivity decline, over-exploitation of natural resources resulting in poor soil health and water quality, erosion of genetic diversity, environmental pollution, increased cost of inputs, adverse impact of climate change, increasing population etc. Thus, sustaining the gains of Green Revolution and achieving higher growth in other crops, specially maize, oilseeds and pulses, and sectors of agriculture like horticulture, livestock, fishery were major challenges that we had to face boldly with initiatives like creation of 30 new institutions, modernisation of infrastructure and facilities to improve both efficiency and effectiveness, reorientation of research agenda to address Vision 2020 of all national institutions/state agricultural universities and various new initiatives like New Seed Policy, Special Food grains Production Programme, Special Hybrid Production Programme, National Agricultural Technology Project (NATP), Missions on Oilseeds, Seed Technology, Horticulture etc. In all of these, greater emphasis was laid on the capacity development of young scientists and technical staff for out scaling innovations for greater impact on the livelihood of our small holder farmers.

It is a matter of great pride that in the process, Indian NARS could not only achieve Green, White, Yellow, Blue and Rainbow Revolutions but could also sustain the momentum over the last five decades reflecting an all round growth and development in agriculture. To be associated with these achievements, in a small way, was the most satisfying journey beginning with the Green Revolution in India. In retrospect, I consider myself fortunate to have started my career with the beginning of Green Revolution. I am really proud to see India emerging as a key player in achieving global food security. Indeed it has been a journey worth taking, every step of the way!

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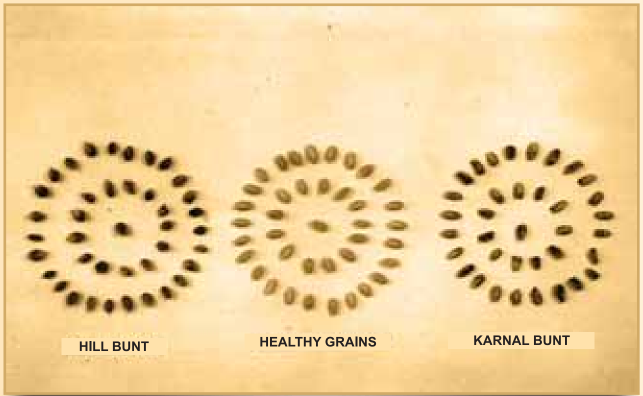
Journey of Wheat



Sample of wheat grains Pusa 1959

Wheat crop at substation IARI, Simla, 1956

Agriculture Minister and MPs looking the wheat field, Pusa, 1963

Reminiscences

MPs examining the wheat field, Pusa, 1963

Dr Swaminathan with others at Pusa, Delhi, 1968

"Science and technology, if they are to play their proper role in the progress of our country, must be intimately linked to the life and work of the common man in the country. Science... should be carried to... the fields and to the farms and to the remote villages."

– Shri Lal Bahadur Shastri

India lives in farmers' huts

– Mahatma Gandhi

Reminiscences

Threshing wheat, Punjab

Sonalika, Pusa, 1978

Woman farmer, Madhya Pardesh;
a bumper crop brought smiles on faces.

GBPUAT, Pantnagar, the first University to undertake an ambitious programme of quality seed production

Greening the Green Revolution

R. B. Singh

Green Revolution: The Greenest Face of Science

The introduction, development and widespread adoption of semi-dwarf, photo-insensitive, input-responsive and high yielding varieties of wheat and rice in the mid-1960s brought unprecedented transformation in the national agricultural economy and food security. Only in four years, 1966 to 1970, India's wheat production doubled, from 11 million tonnes to over 21 million tonnes, the feat not ever achieved in the preceding four thousand years. This phenomenon was named "Green Revolution" by William Gaud of the USAID in 1968, and the same year, the Government of India commemorated it by issuing a postal stamp.

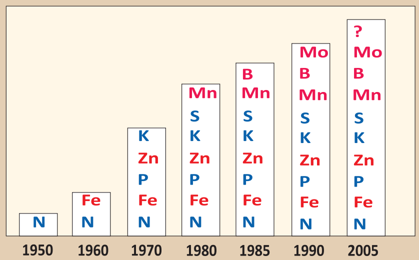
With the launch of the Green Revolution, between 1966 and 2014, wheat production swelled almost ninefold, from about 11 million tonnes to 95 million tonnes, and rice production increased five-fold, from 21 million tonnes to 104 million tonnes, attaining an all-time high foodgrain production of over 265 million tonnes in 2013-14. About 80 percent of the production gains were attributed to yield enhancements, underpinning the driving role of technology. This transformed the nation from the state of ship-to-mouth in the 1960s to the state of Right to Food based on home-grown food now. The mid-1960s dooms day predictions of Paddock Brothers and others were thus belied.

The Green Revolution was followed by or accompanied with White, Yellow and Blue Revolutions, respectively, leading to current record productions of nearly 140 million tonnes of milk (highest in the world), 270 million tonnes of fruits and vegetables, and over 10 million tonnes of fish. These revolutions, collectively called as Rainbow Revolution, had halved the incidences of poverty and hunger in the country and rendered India one of the top three food producers in the world. Importantly, the revolutions were largely due to the synergy of technologies, policies, services, farmers' enthusiasm and strong political will.

The unintended liabilities of the Green Revolution

Poor adoption of the Green Revolution technologies had caused serious agro-ecological, environmental and economic disruptions: erosion of fertility, destruction of soil texture, low carbon content, intensifying micronutrient deficiencies, declining land/water use efficiency, lessening net return to farmers on their investment and plateauing yield.

Progressive expansion in the occurrence of nutrient deficiencies



Unmindful mining of groundwater, particularly under the rice-wheat system, has adversely affected both quantity and quality of water (arsenic and nitrate contents) and the per caput water availability has already reached "stress" level. With business as usual, by 2050, the availability will drop to "scarcity" level.

Notwithstanding the loss of biodiversity due to the widespread adoption of selected uniform one or a few varieties, genes for biotic and abiotic stress tolerances have eroded in the process of developing HYVs and selecting primarily for high yield under intensive management situations.

The Green Revolution had generally by-passed the vast rainfed areas, particularly the drylands, thus widening the inequities. Further, the rice and wheat HYVs had pushed pulses and oilseeds to still marginal areas, adversely impacting productivity and production of these protein-rich commodities, especially pulses. Per caput consumption of pulses had declined from 22 kg/year in 1951 to 15 kg/year in 2014, hence exacerbating the widespread protein undernutrition. Moreover, the country is constrained to import huge quantities of pulses and edible oils to meet the domestic demand.

Declining resilience of the green revolution

As given below, global studies have projected that India will face the largest decline in its agricultural productivity from climate change at 2050.

Projected changes in agricultural productivity from climate change at 2050

Country	%change
Australia	-17
Canada	-1
United States of America	-4
China	-4
India	-25
Brazil	-10
European Union	-4
Least developed countries	-18

Crop models in India indicate that average yields in 2050 may decline by about 50 % for wheat, 17 % for rice, and about 6 % for maize from their 2000 levels. The Indo-Gangetic plain, which produces one-fifth of the world's wheat, is likely to be especially adversely impacted. This alone could threaten the food security of 200 million people and the number of under nourished children may further increase. Overall, the poorest will be hit the hardest by the climate change.

The Indian enigma

Despite the striking transformation brought about by the Green Revolution process, often due to reasons beyond the national level production, unethically, India is the home to almost one-fourth of the world's hungry and poor. In 2012-14, India had 191 million hungry people against 805 million in the world. Surveys revealed that 40% of children in India lack healthy body mass index (BMI). It is estimated that the high undernutrition in the country annually costs about 3% of the national GDP, let alone the entrenched human deprivation.

Prevalence of Undernourishment			
Regions/ Countries	Number (Million)		
	1990-92	2012-14	Charge % 1992-2014
World	1015	805	-20.6
Developing regions	994	791	-20.5
India	221	191	-9.5
China	289	151	-48
Brazil	22.5	n.s.	<-50

The Indian enigma of the coexistence of high overall economic growth rate and the entrenched high prevalence of hunger and poverty and veritable asymmetries can be attributed substantially to the neglect of agriculture and of the farmer in an agriculturally important country where agriculture accounts for about 13% of the national GDP and nearly 50% of the employment. This trend must be unacceptable in our country where agriculture is the base of the livelihood security of the masses and is the best bet for achieving freedom from hunger and poverty. The "Stunted" structural change in Indian economy has also added to the asymmetries, highlighting the importance of production plus approach.

Greening the grey

The Green Revolution launched in the 1960s has waned. As we celebrate the Golden Jubilee of the Green Revolution, given the centrality of a vibrant food and agricultural system for a prosperous India, the revolution must be reinvigorated and rendered greener. The way forward is to consolidate the gains made in the past and to address the persisting livelihood insecurities and liabilities. Among several important issues, two priority areas, namely, enhancing total factor productivity (TFP) growth and promoting climate smart agriculture (CSA), deserve special mention.

Regarding TFP, despite doubling and trebling the average yield of rice and wheat during the Green Revolution era and beyond, average yields of most cereals, pulses and oilseeds are low, and there are serious gaps in actual, realizable and potential yields. Moreover, given that there is no scope for horizontal expansion of cultivated land, the needed doubling of the food production by the year 2050 must be realized through doubling the yield/ha.

The TFP growth has been sluggish. A Global Agricultural Productivity Growth study has shown that towards 2030, with the business as usual, only 59 % of total India's demand of food and agriculture production will be met. Compared to China, especially recognizing that average yields of most major commodities in India are about 40 to 50% of those in China, there is ample scope for improving India's TFP through increasing inputs use efficiency and productivity. Needless to assert, TFP is now the primary source of global agricultural growth. It increases when outputs rise and inputs remain constant or even decrease. It is this fact which will green the Green Revolution.

As regards climate smart agriculture, with its triple wins of enhanced productivity, resilience and mitigation, the approach is a must for greening the Green Revolution. Pursuing "save and grow", CSA movement should be rooted in climate smart villages. Such villages could be created only by ensuring them to be congruently water smart, energy smart, carbon smart, nitrogen smart, weather smart and knowledge smart. Under the Saansad Model Village initiative of the Government, each Member of Parliament may develop at least one climate smart village.

As we move forward, adaptation and mitigation must be seen as two mutually reinforcing pillars of climate smart agriculture, and adaptation-led mitigation should be the way ahead. As climate is ever-changing, one-time adaptation response is not enough, and the adaptive capacity should continually be improved. Genetic restructuring, altered agronomic practices, diversification, integrated cropping and farming systems, and efficient use of biodiversity and other natural resources should meet the differentiated micro (farm level) as well as macro level situations.

Integrated genomics, GMOs, gene editing and other cutting-edge technologies should increasingly be mustered to develop desired genotypes. It is gratifying that rice, wheat, pigeonpea, tomato and mango genomes have already been mapped, mostly by our own scientists, and offer unique opportunities for designing our crops

...Increased investment, efficiency and systems support, rational subsidy, and timely flow of cost-effective quality inputs and credit, insurance and other institutional support systems are essential policy actions....

as per our needs of green agriculture. Our policies and actions must promote judicious application of new technologies.

Summing up, towards greening the Green Revolution, the challenge for agricultural researchers is to develop innovations that offer: (i) sustainable intensification of production, (ii) profitability and social attractiveness, and (iii) ecosystem services to improve water quality, soil health and biodiversity conservation. We should get technology moving and ensure access of farmers to the technology by re-establishing a trained, retooled and dedicated cadre of extension workers, and strengthen agricultural research and technology development and transfer systems. We must also enhance production and productivity of small and marginal farmers, halt the on-going miniaturization of farm sizes, and promote off- and non-farm rural employment, land reforms and leasing.

Increased investment, efficiency and systems support, rational subsidy, and timely flow of cost-effective quality inputs and credit, insurance and other institutional support systems are essential policy actions. The physical and economic connectivity of farm to market, post-harvest operations including the role of food processing industries, and cautious diversification should be augmented for enhancing farmers' income and rural employment security. Finally, congruence and synergy of ecological, environmental, economic and equity principles should sustain and further humanize the Green Revolution.

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Reminiscences

"I am but one member of a vast team made up of many organizations, officials, thousands of scientists, and millions of farmers - mostly small and humble - who for many years have been fighting a quiet, oftentimes losing war on the food production front"

– Dr Norman E. Borlaug

Golden Jubilee of Green Revolution
2015

India's Journey Towards Green Revolution and Beyond: The Role of Rice

E.A. Siddiq

It was early 1960s, when India came to know of the yield-breaching potential of the short statured wheat from CIMMYT, Mexico and rice from Taiwan/IRRI, the Philippines. Extensive adoption of them since mid 1960s enabled the country experience accelerated pace of production growth culminating in self-sufficiency by early 1980s. It was a coincidence that my research career as rice breeder at the Indian Agricultural Research Institute (IARI), Delhi started with the beginning of this eventful period defined as the era of "India's Green Revolution". Large part of my career as a researcher and reasonably long stint as a research manager, I learnt to identify and prioritise the researchable issues of national/regional relevance as well as to decide on strategies appropriate to address them. Also, the experience, I gained while implementing research projects, taught me that efforts lacking focus, determination and spirit to face disappointments and would not help achieve the goal. Whatever little I could achieve as narrated below would not have been possible but for the lessons I have learnt and applied.

Until the advent of the high yield technology, rice was not a major staple crop in north and northwest India. Rice planted over a few hundred thousand hectares was confined to the highly preferred and prized but very low yielding basmati rices. In keeping with the nation's goal of achieving self-sufficiency in food grains official stress and support for high yielding varieties was inevitable. Impressed with the yield advantage and hence handsome net return as compared to low yielding basmati rices despite premium price, farmers in the region switched over to varieties like IR8 and Jaya. Realizing that unless traditional basmati rices are as well made high yielding, there will be no way to conserve this unique germplasm and take advantage of their export prospects, IARI initiated an exclusive breeding programme to combine the basmati quality in the high yielding dwarf plant type background. We did not realize then that the task would be so challenging, given the genetically very complex nature of the key traits that make 'basmati quality'. Moving step by step adopting the strategy of 'convergent breeding' we succeeded in our research goal-the high yielding dwarf basmati variety named Pusa Basmati-1 after 24 years. In the long course of its development, disappointment after disappointment at every stage and discouraging comments from higher ups never dampened our spirit and determination to achieve the goal. The moment we achieved what we had been chasing for so long we forgot all the hassles we passed through. Enabling many folds increase in the volume of basmati export Pusa Basmati-1 together with other derivatives of it earns around ₹ 30,000 crore annually.

The second major contribution of ours, relevant again to the northwest India, is in the sustenance of the rice-wheat system. Despite being the most productive and profitable system, very short period available after rice harvest for timely planting of wheat, unabled farmers to harvest the full potential of the system. Understanding that the prolonged and slow pace of rice harvest leaving no adequate time for preparation of field for wheat planting, due to dependence on manual labour, farmers started practicing mechanized harvest of rice as in wheat. Unlike in wheat the strategy, however, did not work, as no rice variety including Jaya and IR8 remains non-lodging at the time of harvest under high fertility conditions of the region. This lacuna in the system prompted IARI to initiate an exclusive breeding scheme for evolving very sturdy non-lodging rice varieties suiting the need of the region so that they would be amenable to combine harvest. Plant-wise screening of advanced segregating populations mechanically for their degree of proneness to lodging at two critical stages of plant growth helped to stumble upon a few that we were looking for. One of them named Pusa 44-33 was released for general cultivation. The variety is the only one that makes combine harvest practicable and has sustained thereby the rice-wheat system of over 25 years.

Towards second yield breakthrough

Ever since the first yield breakthrough had been possible by using the dwarf plant type varieties, rice researchers have started thinking on the need and prospects of a second breakthrough. Physiologists were skeptical about such a possibility believing that the dwarf plant type variety had already reached optimum in sink-source equilibrium. Belying this notion, Chinese breeders surprised the rice world with development of commercially viable hybrid rice technology with higher yield threshold by late 1970s. Initial attempts to replicate this technology in other major rice growing countries including India failed largely on account of the use of China-bred parental lines. It was however, more knowledge on the success story of hybrid rice there that prompted us to have a relook at it and revive when I joined the Directorate of Rice Research at Hyderabad. With initial support from the ICAR and Barwale Research Foundation, hybrid breeding research gained strength following the UNDP support for 10 years. The mega project fashioned in a network mode involving 10 major rice research centres/institutes and coordinated by the Directorate, started delivering five first-generation hybrids in next five years followed by many subsequently. This was possible because of the availability of progressively improved parental lines and the knowledge and experience shared by China and IRRI. Sadly, however, the pace of adoption of the technology still leave much to be desired. Even 20 years after its introduction the country could not cross 2 million hectare mark as against 15 million hectares China could plant over a comparable period. Had we timely addressed the causes of reservation against the technology–less acceptable cooking quality, lack of medium-medium late hybrids ideally suited to long *kharif* season, inconsistent yield advantage and vulnerability to all major pests–the country could have gained substantially by now. It is a good sign that the new generation hybrids evolved using selectively improved parental lines are gaining popularity and it is hoped that at the current pace of adoption area under hybrid rice would soon cross over 5 million ha in the irrigated ecology itself.

Rice samples (paddy, milled rice and cooked rice) of Pusa Basmati-1 in comparison with Basmati-370, the traditionally Basmati rice.

Two other areas of research launched in network mode during my stint at the Directorate of Rice Research were 'Development and use of molecular technology in rice improvement' and 'Accelerated breeding to cater to the varietal need of rainfed lowland rice ecologies'. Twenty-five years back, when the Rockefeller Foundation came with a proposal to help India to acquire and use molecular tools in directed improvement of rice, we thankfully accepted the proposal and launched the 'India Rice Biotechnology Network (IRBN)'. The novelty about the project was its strategy to bring together National Laboratories engaged in basic research and the applied research oriented agricultural research institutes/universities. Among the provisions in the project, it was the human resource development by training young Indian scientists in advanced biotechnology laboratories abroad, that helped the country lay a strong foundation for crop biotechnology research. Emphasis given to development and application of molecular marker technology in training has helped India develop a series of rice varieties of broad spectrum resistance to biotic stresses (PB1, Sambha Mahsuri etc.) and submergence tolerant varieties (Swarna Sub1, Samba Mahsuri Sub1 etc.) for rainfed lowland ecologies and developed through marker assisted breeding. Replacement of old varieties with so value-added ones is helping sustain the production growth.

Pusa RH10-First fine grain aromatic rice hybrid

The criticism that handicapped rice ecologies had been by-passed by the 'Green Revolution' technologies is not without reason. Over 55% of the rice area is rainfed with stagnating yields at very low levels. Of various reasons attributable to, want of still higher yielding varieties adapted to major constraints of the two rainfed ecologies is the major one. Feeling that the effort so far made was inadequate, a regional consortium in network mode was conceived for rainfed lowland ecologies placing emphasis on accelerated breeding for relatively favourable shallow lowland ecology. The effort led to increased flow of medium late maturing semitall nominations and identification and release of fairly wide choice varieties for this ecology.

Recognizing that lack of awareness of such developments among farmers as well as village level extension workers, on the occasion of the Silver Jubilee of the All India Coordinated Rice Project, the Frontline Demonstration (FLD) was conceived and launched to bring to farmers the knowledge of new varieties along with the relevant production technologies. The demonstration on a contiguous compact block of 5-10 acres in large numbers keeping the surrounding farmers' fields as control all over the eastern states made the expected impact – increased percentage adoption of the demonstrated package and gradual rise in yield level. Finding the extension approach rewarding, ICAR has extended the FLD across field crops. In place of National Demonstration, which no more exists, FLD's could be effective means to assess the gap between achievable and farmer achieved yields across crops and ecologies and to

Among the problems and issues that still remain either partially addressed or as yet unattended to, raising progressively the ceiling to genetic yield, enhanced use efficiency of water and fertilizer nutrients, adaptation to climate change and nutritional enrichment are important.

plan measures to narrow down the gap. Narrowing yield gap in irrigated rice, which receives priority among the short term strategies along with accelerated adoption of hybrid technology would help the country achieve the rice production projected for 2025.

Vision for Second Green Revolution and beyond

If technology driven production advance enough to feed the growing population is taken as the 'Green Revolution' we have already witnessed Green Revolution-I and have been experiencing its socio-economic impact since then. If the same definition is extended to the Second Green Revolution, realization of it would not be easy, given as yet no readily exploitable varietal technology with higher ceiling to genetic yield in sight. Challenges are not met without means to meet them.

Among the problems and issues that still remain either partially addressed or as yet unattended to, raising progressively the ceiling to genetic yield, enhanced use efficiency of water and fertilizer nutrients, adaptation to climate change and nutritional enrichment are important.

Raising the genetic yield level being the only means to achieve the future production targets priority research attention to the issue is inevitable. Strategies contemplated and research underway in different parts of the world including India are broadly (a) development of morpho-physiologically more efficient new plant type varieties, (b) inter-subspecific hybrid technology in the new plant type background, (c) discovery and exploitation of yield QTL/genes still remaining hidden in the wild/weedy relatives, and (d) designing of new plant architecture.

Conceptually new plant type is the marriage between genotype and crop geometry and it is designed for high density planting. Characterised by less profuse tillering, long and upright top leaves of high radiation use efficiency, heavy panicles and robust and active root system, the IRRI developed NPT lines have been reported to yield around 11 tonnes/ha as against 13-14 tonnes/ha achieved by Chinese breeders in indica/tropical japonica hybrids in the background more improved new plant type background. Given the progress already made it is hoped that NPT varieties, indica/japonica hybrids in NPT background would be available in the near future for commercial planting. The fact that all the allelic variability for yield and yield components available in the progenitor wild/weedy species could not be captured in the modern cultivars during the course of evolution of rice and if they could be identified by QTL approach and stacked harmonious ones by marker assisted breeding genetic yield level could be raised significantly. Such possibilities have now been demonstrated by Cornell University (USA) and Indian Institute of Rice Research.

As for other researchable issues, rice transgenics with high water and N use efficiency are in the advanced stages of deregulation in India and progress made in the enrichment of rice with high protein, minerals and vitamins is encouraging. In the era of genomics designing rice more and more productive, increasingly input use efficient and climate smart is a distinct possibility, no matter how long it would take.

"An illiterate farmer can represent the difficulties of the agricultural classes much better than an Indian learned but without experience in that particular field. I wish; therefore, to see an ever-increasing number of delegates from among farmers, weavers, carpenters, blacksmiths, shoe-makers and other such groups. I, for one, think that no substantial progress in the country is possible so long as patriotic farmers do not attend our political and social conferences in numbers proportionate to their numerical strength."

– Mahatma Gandhi

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Golden Jubilee of Green Revolution
2015

Inside Story of Development and Dissemination of Hybrid Rice in India

Sant S. Virmani and Ish Kumar

After the development of high-yielding semi-dwarf rice varieties which heralded Green Revolution in rice growing countries during late 1960s and 1970s, rice scientists were curious to explore if rice yields could be increased further. Exploitation of heterosis in rice was considered an option to achieve this objective. However, several constraints, viz. lack of information on extent of heterosis in rice, lack of appropriate male sterility system for hybrid rice breeding, extent of outcrossing in rice for hybrid seed production etc. were responsible for lack of interest in pursuing this research. Although IRRI initiated hybrid rice research in 1970 and developed a cytoplamic male sterility system in *indica* rice yet this work was discontinued in 1973 in favor of other rice research priorities to stabilize yields of high yielding rice varieties rather than exploring further enhancement of yield. Interestingly, China developed hybrid rice technology under the leadership of Prof. Yuan Long Ping without any publicity until 1977 when a team of Chinese hybrid rice scientists including Prof. Yuan visited IRRI and announced its successful commercialization in a few million hectares. Following this announcement, IRRI decided to revive development of this technology in tropical countries in 1979 under my leadership.

Development and dissemination of hybrid rice technology in India was started in 1980 when first set of rice breeders were trained in China by IRRI along with several other rice breeders from South Asian countries led by me under IRRI-China collaboration. Additional Indian rice breeders were trained in China in 1981 and in subsequent years at IRRI to build up a professional team of Indian hybrid rice breeders who would conduct this research in the country on sustainable basis. Concurrently, IRRI also took initiatives in subsequent years to train Indian rice breeders and seed production managers to develop this technology locally. Simultaneously, Indian rice research managers and policy makers were also sensitized to invest in hybrid rice research so that the rice scientists trained in China and IRRI could be provided the required financial and human resource support to develop the technology for adoption by Indian rice farmers. Besides, IRRI also continued to provide its new hybrid rice breeding materials adapted to tropical conditions on continuous basis to Indian hybrid rice breeders to help them in the development of hybrid rice technology expeditiously. I visited India from IRRI twice a year during the two rice crop seasons to interact with Indian hybrid rice breeders and provided them necessary guidance to develop the technology by utilizing local and IRRI bred parental lines. Based on the experience in other hybrid crops, it was also recognized in the beginning that private sector will have to play active role in the dissemination of hybrid rice technology. Therefore, steps were taken to involve private seed companies in seed production and adaptive research on hybrid rice. Whenever appropriate, the Indian rice scientists, private seed company personnel, public research managers and policy makers were invited to IRRI and or China to encourage them for the expeditious development and dissemination of this technology.

In 1987-88, the Food and Agriculture Organisation (FAO) of the United Nations got interested in providing financial support to the Indian Council of Agricultural Research (ICAR) for organizing a comprehensive national hybrid rice research and development program in India. On behalf of IRRI, I was assigned by FAO as a consultant to help in designing this program in cooperation with Indian rice scientists and research managers. A leading private seed company in India and its Foundation (MAHYCO Research Foundation) which had also gathered information on hybrid rice research and development in China and IRRI, got motivated to invest in hybrid rice research and development in India and offered a grant of ₹ 30 million to ICAR to strengthen hybrid rice research and development in the country. Since this was an unusual offer in the history of agricultural research in India, it took some time for the ICAR to accept it as it had to go through several bureaucratic hurdles. A comprehensive research and development program on hybrid rice was undertaken in 1989 using the funds provided by FAO and MAHYCO Research Foundation and technical backstopping by IRRI. Thus, it took ICAR almost nine years to establish a comprehensive hybrid rice research and development program in the country. Encouraged by these developments, some private seed companies also initiated research and development programs on hybrid rice in India with technical backstopping of IRRI. Since private sector had to play an important role in the

Between 1989 and 2014, a total of 72 rice hybrids have been released in India. Out of these, 32 hybrids have been developed by the public sector and 40 have been released by private sector.

development and dissemination of hybrid rice technology, IRRI strongly advocated a strong public-private sector partnership for the purpose. In 2003, an international workshop was organized by IRRI in Pune, Maharashtra in which several public and private sector officials, involved in hybrid rice research and development in India and other countries participated to discuss how a locally acceptable model of partnership, could be developed between public and private sectors, utilizing strengths of each sector, to establish an effective hybrid rice research and development program in a country.

Over the years, several rice hybrids have been developed in India using IRRI-bred cytoplasmic male sterile lines (viz. IR58025A) and locally identified restorer lines. These were shared with rice farmers utilizing the channels of both public and private sectors and commercialization of hybrid rice began by early 1990s. Simultaneously, Indian scientists put in their efforts to develop locally-bred CMS lines. Currently, commercial rice hybrids in India are bred by utilizing IRRI-bred and locally-bred CMS lines, viz. APMS 6A, Pusa 6A, CRMS 31A, CRMS 32A, COMS 1A, COMS 2A. CMS line APMS 6A has favored short slender grains and has been used to develop short/ medium slender grain- hybrids, viz. DRRH3. Similarly, in private sector, new female lines with small slender grains have also been developed and used to breed rice hybrids, viz. 27P64, JK 3333 and 25P52. Although these hybrids have been claimed to be similar to the popular mega variety BPT 5204, however, millers do not rank them to be equal to BPT for their grain shape and cooking quality features. New CMS lines, being developed by public and private sector, are in the pipeline to overcome this hurdle.

CMS line Pusa 6A carries a special significance as it has very long slender & aromatic grains with excellent cooking and eating qualities. This line has been used as parental line of Basmati type hybrids, viz. PRH10.

Most of the CMS lines, bred in India have lacked high out-crossing potential and need further improvement to become commercially popular.

Between 1989 and 2014, a total of 72 rice hybrids have been released in India. Out of these, 32 hybrids have been developed by the public sector and 40 have been released by private sector. Based on their adaptability, 27 hybrids have been notified for a limited area i.e for 1 state but 43 hybrids have been notified for multi-locations (more than 2 states). In order to cater the need of the farmers, more than 50 local seed companies and MNCs are engaged in research, development, production and marketing of hybrid rice seeds. The private sector companies represent >95% of hybrid rice seed sales in the country, while the remainder <5% is thinly spread among public sector organizations.

Out of the commercial hybrids released so far, 6444 is the prominent hybrid and covers about 40-50 % of the total hybrid rice area in the country. It has shown very high adaptability and yield in the farmer's field especially in eastern and central India. In 2013, the record high yield (23 tonnes /ha fresh weight) was reported in Bihar. The other popular hybrids from private sector, viz. PHB71, 27P31, US 312, Tej, PA6129, Dhanya 748, PAC 832, VNR2355 and INDAM 001, also occupy sizable area. Among public sector hybrids, KRH2, Sahyadri 1 and 3 etc. also occupied limited area in southern India. Some public sector hybrids, viz. PRH 10, DRRH2, DRRH3, Ajay and Rajalakshmi were commercialized by many private companies under public private partnership, whereas hybrids, viz. PSD 1 and 3; CORH-3, KRH-2, Sahyadri 1; JRH 4 and 5 were taken up by a company each. Hybrid PRH 10 with Basmati grain type, developed in public sector, is known for its extra long slender aromatic grains, excellent cooking (high kernel elongation upon cooking) and eating quality parameters. However, on account of issues viz. inadequate purity of seed, this hybrid suffered a setback in the market over seasons.

Bacterial leaf blight (BLB) is a serious disease of rice in India especially in eastern states where it has serious incidence every 3-4 years. IR 58025A, the female parent of most of the commercial rice hybrids, is susceptible to BLB, so most of the derived hybrids are also susceptible. New parental lines and hybrids with resistance to BLB have been bred both in public and private sector. The prominent hybrids from private sector are 6444 Gold, L Dhani, VNR2355+. These hybrids have been commercialized in different parts of India, especially in wet season, when incidence of BLB is higher. A BLB resistant IR58025B line, carrying resistance genes (xa5+xa13+Xa 21) has also been bred in Directorate of Rice Research (DRR), Hyderabad and efforts are underway in breeding the BLB resistant A line from it which would carry the 3 BLB

Hybrid rice technology in India has made a slow but steady progress over the years and its future appears bright provided both public and private sectors work in a strong partnership

resistance genes. New BLB resistant R lines are also now available with many private companies. Recently varieties like Pusa 1460, RP BIO 226 have been developed by pyramiding (BLB) resistance genes (xa13 & Xa21).

Hybrid rice seeds are also exported by India to neighboring countries like the Philippines, Vietnam, Bangladesh. In 2014, an estimated hybrid rice seed sale of 32,000-35,000 tonnes was done by all private seed companies to cover both domestic and export market.

All existing commercial rice hybrids in India, are derived from WA CMS system and mostly involve inter-varietal crosses. Research on identifying and or utilizing new sources of CMS is in progress. Although 2- line rice hybrids, utilizing photo-thermo-sensitive genetic male sterility (PTGMS), are being developed in public sector for several years, yet no commercial success has been achieved so far in the country.

In India, hybrid rice has been reported to be cultivated on ~2.5 million hectares during 2013. This resulted into additional 3.4 million tonnes of rice production at the rate of about 1.4 tonnes extra yield per ha to the rice farmers cultivating hybrid rice. This provides them about $ 150 extra income per ha. Also hybrid rice seed production agencies generate 60-80 person days/ha additional employment opportunity in rural areas. The country plans to increase the acreage under hybrid rice to 5 million hectares during the next few years.

Progress in hybrid rice seed production has occurred in the past one decade because of heavy involvement of private sector. Many private sector companies get an average seed yield of 1.5- 2.5 tonnes/ha, though the higher yields in the range of 3.5- 6.5 tonnes/ha have also been obtained experimentally. Many private sector seed companies have the capacity to process and package more than 200 tonnes of hybrid seeds per day.

Hybrid rice technology in India has made a slow but steady progress over the years and its future appears bright provided both public and private sectors work in a strong partnership by utilizing each other's strengths and national and state governments provide the required policy support for the development and dissemination of this technology.

Reminiscences

Journey of Rice

The end-product of education should be a free creative man, who can battle against historical circumstances and adversities of nature

– Dr S. Radhakrishnan

Puddling, an ancient practice, is tilling of flooded rice fields. Farmers of a village worked together to complete this hard work

Each carrying a bunch of seedlings reached the field for transplanting

A line is made for transplanting in a row; everyone planted a seedling in one row then stepped back to plant in next row

Reminiscences

Paddy nursery for transplanting

A bumper crop of paddy in Kerala, 1959

Harvesting of rice in Kashmir

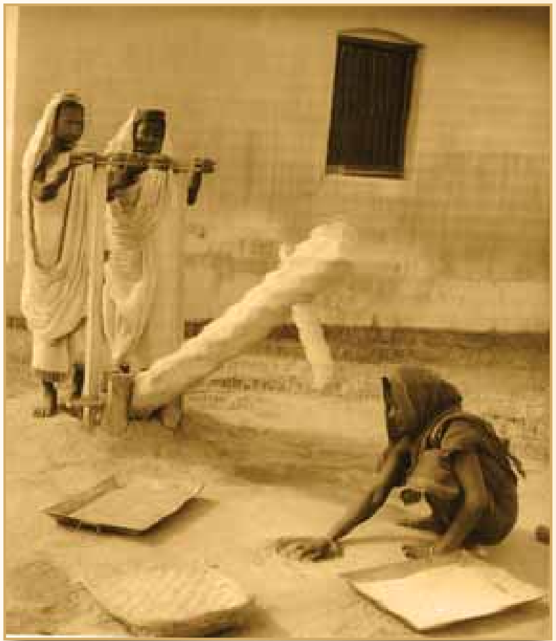
A beaming farmer with good harvest

Bullock operated two-cylinder reciprocating pump, PAU 1975

Reminiscences

Threshing of paddy, Kerala 1958

Threshing of paddy, Orissa



Husking of paddy with *dhenki*, a tough job

A rice winnower, West Bengal, 1960

IR-8 rice variety, Pusa, Delhi 1970

Some Recollections

Dr P. L. Gautam

I had the honour to earn Master's and Doctorate degrees from the prestigious Pusa Institute. This was the time of post green revolution. We were privileged of having stalwart teachers and researchers. Pusa Institute was one of the leading institutions of the county to provide leadership in nurturing Green Revolution.

Immediately after completing Ph.D. in Genetics, I appeared in an interview for the post of Assistant Professor at Pantnagar. After the interview, Dr R L Paliwal, Dean Agriculture took me to meet the then Vice Chancellor, Dr Dhyan Pal Singh. After brief interaction, the VC informed that "you are selected and you can join tomorrow." Such was the fast decision making in the interest of attracting talents from different parts of the country. I enjoyed teaching and research work in wheat and contributed to the release of dozen of wheat varieties including UP262, UP115 and UP2003, thanks to the multidisciplinary team work, dignity of labour, congenial working atmosphere, simplified administrative procedures and the missionary zeal from top to bottom. It was experience of its own kind as during the crop season sometimes the work started with sunrise and terminated till we could record data and observe the plants in the field. But nobody counted the hours. It was so thrilling and exciting to attend the visitors including large groups of farmers, students and scientists during crop season. Interestingly, the teams coming from CIMMYT and PC/PD wheat did not have ceremonial visits but worked with us in selection of plants, recording data and sharing new developments. It was great learning. One can hardly imagine that veterans like Drs Borlaug, Anderson, Saari, Rajram, Walter, M V Rao, Dubin, Curtis and several others could devote so much time working in our fields.

Dr Borlaug and Dr Swaminathan along with Pantnagar wheat scientists visiting progressive farmers of *Terai*

The institutions also pass through testing times and Pantnagar was no exception in this regard. The University faced with one of the worst labour turmoils during 1978-79. Unfortunately, breeding research in wheat and other *rabi* crops suffered enormously and invaluable breeding material was lost. It was very unfortunate but Pantnagar wheat breeding team converted it into opportunity and revived the

> *I remember Pandit Dhaniram Vasudeva, senior wheat breeder HAU Hisar, who refused to speak in favour of his variety in one of the workshops, stating, "I will not speak, my variety will speak." This reflects the dedication and confidence of the veterans in their products and research.*

Pt. J L Nehru discusses with Major Sandhu plans for establishing Pantnagar University

program through hard work and accessing germplasm and breeding material from India and abroad. After turmoil and chaos, I was also given additional responsibility of heading crop research centre (CRC) and Hill Campus of the University. I succeeded in rehabilitating the CRC and the Hill Campus witnessed qualitative expansion of its activities in the region.

My experience at Pantnagar was unique as it taught dignity of labour, hard work, discipline and working closely with the farmers. The Pantnagar culture was unique and that's why the University is still one of the leading organizations of the country. It was wonderful to serve this university as Vice Chancellor for two successive terms and I can say with all humility and humbleness that after creation of the Uttarakhand state, the University was reoriented to the changed mandate with great success. I also shouldered the responsibility of leading the bifurcated seed corporation and provided the leadership to serve the farming community.

The annual wheat workshops were full of heats and commotion and the scientists were so much emotionally involved in decision making and formulating widely accepted recommendations. People were aware of conflict of interest at that time. I remember Pandit Dhaniram Vasudeva, senior wheat breeder HAU Hisar, who refused to speak in favour of his variety in one of the workshops, stating, "I will not speak, my variety will speak." This reflects the dedication and confidence of the veterans in their products and research.

Reminiscences

During interactions with the scientists, Dr Borlaug used to say that plants speak (whisper not shout) and you must have time and patience to hear them. A lesson to the new generation of active scientists that in agriculture while chasing new technologies is important, we must toil hard in the labs and fields to feed the burgeoning human population.

Dr Borlaug and Dr Swaminathan in discussion with wheat researchers of Pantnagar

From Green Revolution to Rolling Revolution in Agriculture

Dr P. K. Joshi

I stepped-in agriculture profession when the green revolution was just at its incipient stage. In 1969, I was admitted to the G B Pant University of Agriculture and Technology (GBPUAT), which played the most important role in conducting research and scaling-out of dwarf and high-yielding varieties of rice and wheat. I got an opportunity to have outstanding teachers and researchers in various disciplines of agriculture. I was so lucky to have Dr Noman E Borlaug as the chief guest in the convocation of my batch. At that young age, I was fascinated to observe the significance of science in agriculture. During the course of my studies, I realized that agriculture is the most important profession for bringing happiness among poor people. I recognized that agriculture is the strength of any nation. I also realized that scientists do not have any political and administrative boundaries. They contribute for the mankind in the world. Therefore, I decided to stick to the agriculture research for my profession, disregarding enormous and lucrative job opportunities in banking sector emerging due to nationalization of banks during that period. When I look back, I feel proud that the decision was right. I am sharing some of the memories of my journey in agriculture profession from green revolution to rolling revolution in agriculture.

...scientists do not have any political and administrative boundaries. They contribute for the mankind in the world ....

Rice in non-traditional areas

Since my student days to my joining the Indian Agricultural Research Institute (IARI) in 1976, the agriculture sector witnessed a significant transformation. The green revolution was at its peak. I started working on agricultural productivity changes in Indian agriculture. Wheat production steeply increased after introduction of dwarf and high-yielding varieties. Wheat production went up to 29 million tonnes in 1978-79 from 12 million tonnes in 1964-65. During the same period, area expansion was to 20.92 million ha from 13.42 million ha. We were working on policy and institutional constraints in fully utilizing the potential of high yielding varieties. Most important constraint was credit requirements for adoption of high yielding varieties. During the same period, high-yielding and dwarf rice varieties were finding new niches in Punjab, Haryana and Western Uttar Pradesh, where their area increased remarkably. Traditionally, these areas were non-tradition areas, and growing pearl millet during rainy season. Rice production in the country rose by 14.46 million tonnes in fourteen years from 39.31 million tonnes in 1964-65 to 53.77 million tonnes in 1978-79. Rice area expanded by 4.67 million ha from 35.81 million ha in 1964-65 to 40.48 million ha in 1978-79. Our studies highlighted irrigation, market and credit constraints in further increasing rice area and production.

Management of degraded soils

I was fortunate for getting an opportunity to work with outstanding scientists at the Central Soil Salinity Research Institute (CSSRI). The institute was engaged in developing technologies to reclaim alkali soils. The institute developed a package of technology for reclaiming alkali soils for Indo-Gangetic plain. The economics studies were very well blended with technologies and got government support for 75 % subsidy in gypsum and incentives for irrigation. The studies demonstrated the economic and equity benefits of subsidies in gypsum and reclaiming alkali soils. The reclamation of alkali soils has triggered area expansion of rice and wheat in Punjab and Haryana, when the impact of green revolution in the normal soils has been fading away. There has been a widespread concern how to increase production of rice and wheat in the food basket of India. The reclamation technology significantly contributed in area expansion of rice and wheat that has led to increase in agricultural production. The lessons learnt from the success of Punjab and Haryana,

...There has been a widespread concern how to increase production of rice and wheat in the food basket of India. The reclamation technology significantly contributed in area expansion of rice and wheat that has led to increase in agricultural production ....

a scheme was prepared for piloting in Uttar Pradesh in view of small holdings and poor farmers. The piloting of the scheme was successful which attracted support from the Ministry of Agriculture and the Planning Commission from the central government. The scheme latter got funding support from the World Bank for UP Sodic Land Reclamation Project (Phase I) launched in 1993 and still continuing as phase III. The project benefitted a large number of poor farmers in coming out of poverty and improved their livelihood security besides increasing agricultural production.

I also got an opportunity to work with an excellent multi-disciplinary team in managing saline soils. It was a wonderful experience of closely working with the biological scientists and engineers. The recommendations based on socio-economic studies on sub-surface drainage contributed in saving 2/3 cost of installing sub-surface drainage. The studies also found collective action by the farmers as pre-condition for managing saline soils. This led to development of a pilot project first financed by the Dutch Government and latter operational project by the Government of Haryana for managing saline soils. This contribution led to improve soil health, increase production and enhance farm incomes.

Sustainability of rice-wheat system

Success of the green revolution started fading in early 1990s and raising concerns on the sustainability of rice-wheat system in the Indo-Gangetic plain. Over-exploitation of groundwater, imbalance use of nutrients and injudicious use of pesticides for rice and wheat production was threatening the sustainability of the most productive system in the world. I got the opportunity to work at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the National Center for Agricultural Economics and Policy Research (NCAP). It was great opportunity to work and collaborate with brilliant international and national partners to understand the rice-wheat system and provide appropriate solutions for improving the sustainability of the system. The studies clearly revealed that the threat of falling water table and deteriorating soil health was due to inappropriate policies related to subsidies in water, fertilizer, and also government's bias in favor of rice and wheat at the cost of natural resources. The studies clearly delineated the emerging unsustainable districts in the Indo-Gangetic plains and their negative implications on production of rice and wheat. It was also observed that the policies did not respond to changing agricultural scenario. Based on the techno-economic studies we proposed for promoting water-conservation technologies, rationalizing fertilizer subsidies, and introducing legumes in the system. The studies sensitized the policy makers and attracted considerable debate in the Indian parliament.

Impact assessment

With the weathering green revolution, new problems emerged in the green revolution belt. It was just a chance that investment in agricultural research started falling during the same time. Also the stakeholders started questioning the contribution of agricultural research. It was a mere coincidence that I got an excellent opportunity to work on research priority setting and impact assessment of agricultural research. I undertook numerous impact assessment studies with several economists and biological scientists which attracted stakeholders' and donors' attention. The studies also identified constraints in larger adoption of improved technologies. I remember one study on impact of ICP 8863, a wilt resistance pigeon pea variety, which was largely adopted in wilt affected areas of Karnataka and little in its neighboring districts of Maharashtra. Maharashtra is the largest wilt affected area but the variety was not adopted as it was not released in the state. We interacted with the Maharashtra State Seeds Corporation Ltd (MAHABEEJ), and demonstrated the benefits in Karnataka due to adoption and losses in Maharashtra due to non-adoption. Realizing the importance, the corporation immediately decided to produce the seed and sell as truthfully leveled seed till the variety is released by the state. The important lesson was that sharing evidence-based empirical research outputs to right stakeholder makes high impact. Several impact assessment studies during NATP (National Agricultural Technology Project) period were undertaken to justify the overwhelming contribution of agricultural research. Same time, I was also involved in research priority setting. The economics team was evolving mechanisms to institutionalize priority setting, monitoring and impact assessment in the national research program. It was aggressively done during the National Agricultural Technology Project (NATP) but did not succeed.

...sharing evidence-based empirical research outputs to right stakeholder makes high impact ....

Agricultural diversification and markets

With passage of time and serious efforts India became food secure. During early years of the 21st century huge food stock was available with India. Same time, per capita demand for cereals was declining and demand for high-value commodities was rising. The structural transformation in dietary pattern was emerging due to rising income, growing urbanization and unfolding globalization. This led to promotion of agricultural diversification in favor of high-value commodities, such as vegetables, fruits, milk, meat, poultry and fish. Studies conducted by me at the International Food Policy Research Institute (IFPRI) with the partners, clearly showed that market reform is pre-requisite for promoting agricultural diversification. Linking smallholder with the remunerative markets is essential for increasing production of high-value commodities. It was found that contract farming, cooperatives, self-help groups, farmer producer organization, etc., can play important role in linking smallholders with the markets. A number of studies was done by me and my colleagues on constraints in up-scaling these innovative institutional arrangements. The studies also found that the organized private sector is increasingly taking ahead technology-based innovations, research and marketing in the agriculture sector. But such interventions are very few and need their out-scaling in areas where poverty and undernourishment is of high order. The precondition to attract private sector for large investment is to create enabling business environment through appropriate policies and quality infrastructure, especially markets, roads, etc. The studies sensitized the policy makers in strengthening the role of institutions to link smallholders with the markets for high incomes.

Climate smart agriculture

All government efforts in increasing agricultural production in ensuring food security are marred by increasing incidence of climate change. It is witnessed that during the two last decades the intensity and extent of drought, floods, sudden rise/fall of temperature and unseasonal rainfall and hailstorms are rising. These uncertain eventualities are adversely affecting agricultural production, income and food security at household, regional and national level. I got opportunity to work with Climate Change, Agriculture and Food Security (CCAFS) to up-scale the concept of climate smart agriculture. The climate smart agriculture contributes in (i) increasing crop yields and farm incomes, (ii) reducing climatic risks, and (iii) enhancing carbon sequestration and minimizing greenhouse gas emissions. Our research contributed in prioritizing investment opportunities for climate smart agriculture and developed schemes by conversing various government programs and making them climate smart agriculture. The outputs of the studies are contributing in up-scaling and out-scaling climate smart agriculture in adapting and mitigating impact of climate change.

Way forward

My professional journey coincided with changing complexities in agricultural sector. I witnessed unfolding of green revolution. It contributed in solving the problem of food self-sufficiency. However, India also witnessed considerable increase in productivity and production of majority of crops but the contribution of technology was not duly recognized. Looking to the statistics, these were no less than any green revolution in any part of the world. For example, food grain production reached to a peak of 264.77 million tonnes in 2013-14. Production of maize increased from 5.70 million tonnes in 1968-69 to 24.35 million tonnes in 2013-14. Similarly production of potato went up from 4.73 million tonnes in 1968-69 to 44.31 million tonnes in 2013-14. These are the few illustrations on the role of agricultural research system, and contribution of agricultural scientists. Such a silent and rolling revolution in agriculture sector was not recognized. Unfortunately, except during green revolution period, science and polices were not synchronized to take advantage of the improved technologies. It is essential that policies facilitate adoption of improved technologies for a rolling revolution in agricultural sector.

...It is essential that policies facilitate adoption of improved technologies for a rolling revolution in agricultural sector....

I see a bright future for Indian agricultural research system. At National Academy of Agricultural Research Management (NAARM), I have seen energetic, enthusiastic and young researchers, eager to solve emerging problems. I am confident that they will take up the batten of agricultural research forward for bringing happiness among poor. However, the pre-requisite is to allocate sufficient resources in agricultural research and tune policies to harness the potential of agricultural research.

Golden Jubilee of Green Revolution in India: A Panorama

An exemplary model for inter-disciplinary research and international cooperation

T. M. Manjunath

Golden Jubilee of Green Revolution
2015

Throughout the journey of 'Green Revolution,' the entire team, comprising scientists and political leaders from Mexico, the Philippines, the USA and India, worked together in unanimity with all the efforts focused at revolutionizing agriculture for the welfare of humanity, thus serving as an exemplary model for inter-disciplinary research, international cooperation, enthusiastic participation by farmers and public acceptance, signifying that science has no boundaries and is truly universal. All technologies are important and each has its own place and, therefore, technological prejudice or intolerance should be avoided and attempts made to integrate them.

Preamble

Right from the early days until now, situational compulsions have been responsible for improved agricultural practices and developing new technologies to enhance the production and protection of food. Every technology was relevant to that particular period – be it from hand to tractor ploughing, from manual to mechanized harvesting, from traditional seeds to hybrid seeds, from organic to chemical fertilizers and pesticides, from canal irrigation to sprinkler irrigation, traditional breeding to genetically modified crops, from single crop to high-density multi-species cropping, etc. If we are to realize the importance of such evolution, we have to travel back in time to understand the challenges and limitations that had prevailed at that time. It is very easy, but unfair to criticize or denounce a technology by hindsight without offering any tangible alternatives. Let us try to understand the relevance of certain developments in agriculture in the backdrop of the Green Revolution as we celebrate its Golden Jubilee.

Reminiscences

When India became independent in August 1947, there was severe shortage of food to feed its population of about 33 crore or 330 millions. The agricultural productivity in general was low, being less than 1 tonne/ha in wheat and rice. The country was poor and it did not have enough foreign exchange to import the required quantities of food. At such a critical juncture, the US of America came to our rescue. Under a special scheme called the Public Law 480 (PL-480), they supplied to us wheat and rice at a highly concessional rate against rupee payment. Between 1956 and 1960, just in four years, the USA supplied 15 million tonnes of wheat and 220,000 tonnes of rice. The PL-480 made the difference between food riots and relief from hunger for millions. Hence, during those days, our condition used to be referred to as "Ship to mouth."

A wake-up call

Amidst all these, the Indian Government was striving to bring about overall developments, both industrial and agricultural, through its centralized and integrated national economic programs called the Five-Year Plans, starting from 1951. However, while the development was in progress, the country faced several serious crises in the 1960s. Two wars, Indo-China (1962) and Indo-Pakistan (1965), created serious political and economic crises. It was aggravated by two successive droughts (1965-66) which shattered its agricultural economy. The agricultural sector recorded substantial negative growth and the country faced a serious food problem. Although India did not have enough foreign exchange, it was forced to import about 10 million tonnes of food grains, mainly wheat, at international market rates for two consecutive years. This posed a huge challenge to India and also taught a lesson that over-dependence on food imports was a folly and that we should strengthen our own agricultural sector. In fact, these crises served as a wake-up call for the government to restructure its developmental policies including agricultural policies. This opened the door for Green Revolution.

This posed a huge challenge to India and also taught a lesson that over-dependence on food imports was a folly and that we should strengthen our own agricultural sector.

Green Revolution

It is a well-known fact that the Green Revolution, spreading over the period from the mid-1960 to mid-1970, changed India's status from a food-deficient country to self-sufficient in food, from 'begging bowl' to 'bread basket.' Several factors were responsible for the success of Green Revolution: (a) imported and improved semi-dwarf high-yielding varieties (HYVs) of wheat and rice; (b) improved irrigation; (c) use of chemical fertilizers and pesticides; (d) emphasis on intensive agriculture over extensive agriculture (double-cropping in the existing farmland); (e) loans from banks and credit cooperatives; (f) support pricing policy; (g) Food Corporation of India; (h) establishment of farm extension services and Agricultural Universities, etc. Due to combined effects of all these, the agricultural productivity, which used to be a dismal 522 kg/ha around the period 1947 - 1964 increased to 944 kg/ha during 1965 to 1975, thus fulfilling our food requirements. This golden period is called 'Green Revolution' which established India as one of the world's biggest agricultural producers.

Exemplary team work

The success of Green Revolution brought out the importance of international collaboration, policy support from the central and state governments, interdisciplinary research, need for scientific outreach, adoption of new technologies and participation by farmers, etc., which are worth recognizing and emulating. Some of these are highlighted below:

- The first step in Green Revolution in India started with the importation of the Mexican semi-dwarf varieties of wheat. These varieties containing '*Norin*' dwarfing genes were developed in Mexico by Dr Norman Borlaug. These were found to be highly responsive to fertilizers and irrigation, yielding several times higher than the traditional varieties. It revolutionised wheat production in Mexico and later also in other areas of Latin America and beyond, thus heralding the first-ever Green Revolution. Dr. Borlaug, though worked in Mexico, was an American Agronomist. Hailed globally as the 'Father of the

Green Revolution,' Dr Borlaug was awarded the Nobel Prize in 1970 in recognition of his humanitarian contribution to save at least a billion people from hunger in the developing world.

- The 'Father of the Green evolution in India,' Professor M.S. Swaminathan, is a distinguished plant breeder.Being aware of the limitation of our local varieties, he was the first to visualize the potential of Mexican dwarf varieties to enhance our production. He interacted with Dr Borlaug and obtained the new seeds from him in October 1963. This set the stage for wheat revolution in India. Dr Borlaug gave full credit to Dr Swaminathan for his thoughtful and purposeful ideas and stimulating team work.
- The original breeding stocks of the Mexican wheat were utilized by a team of Indian scientists that comprised breeders (led by Dr Swaminathan and Dr M. V. Rao), agronomists (led by Dr O. P. Gautam), plant pathologists (led by Dr K. Prasada and Dr L. M. Joshi), biochemists (led by Dr A. Asutin), *et al.* to develop local strains that were suitable for Indian conditions, including resistance to wheat-rusts and the preferred culinary properties (suitable for making *chapathis* with amber grains as against the red grains of the original Mexican variety), as mentioned by Professor Swaminathan in one of his papers on wheat revolution. Throughout this process, Dr Borlaug, who visited India regularly, was constantly in touch with Dr Swaminathan and his team.
- Multi-location field trials were organized in several wheat-growing states in north India, involving a large number of technical personnel and farmers who realized the importance of the technology during the process. The new varieties were readily accepted and widely cultivated by the farmers in Punjab, Haryana and Western Uttar Pradesh which resulted in quantum jump in wheat production from about 12 million tonnes in 1964 to 17 million tonnes in 1968 without any significant increase in cultivated area. This was the first step in the success of Green Revolution.

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- The introduction of Mexican semi-dwarf wheat was followed by the importation of a semi-dwarf high yielding variety of rice, IR 8, which was developed at the International Rice Research Institute (IRRI), the Philippines. It responded well to fertilizers and irrigation with potential to yield 5 to 10 times more than the traditional rice. Hence, IR8 was called the 'Miracle Rice.' As with wheat, a team of Indian scientists worked on it to develop several local strains including the semi-dwarf hybrid IR36. These varieties became popular throughout the rice growing regions of India, more particularly in south India, and boosted the production. This added further strength to Green Revolution.
- During the entire process of importation and the research and field trials with wheat and rice, the then Prime Ministers, Shri Lal Bahadur Shastri and his successor Smt Indira Gandhi, and the then Union Minister for Food and Agriculture, Shri C. Subramaniam, and later Shri Jagjivan Ram, gave exemplary policy support and encouragement to the efforts being made as has been gracefully acknowledged by Professor Swaminathan in his lectures and publications. Based on recommendations of the scientists, the government took several progressive steps to improve agriculture, which included:
    - The government investment in agriculture sector almost doubled.
    - Gross irrigated area also increased by 2 to 3 times.
    - Chemical fertilizers, pesticides, agriculture machinery (tractors, pump sets, etc.), soil testing facilities, agriculture related educational programmes, appropriate credit facilities, etc. received due importance.
    - An Agriculture Price Commission was set up to ensure that farmers were assured of a sustained remunerative price.

The net result of these initiatives led to the overwhelming success of the Green Revolution. Scientists and administrators from Mexico, the Philippines, the USA and India have contributed significantly to its success. There was exchange of knowledge and research materials, and of equal significance was the enthusiastic participation by farmers. This process has continued and during the 1980s, several high yielding varieties of maize, *jowar, bajra*, millets and other crops were developed. All these contributed to significant increases in production. Since then, India is on a progressive path.

Way forward

As successful as the Green Revolution was, the wholesale transfer of technology to the developing world had its critics. They blame that Green Revolution has been responsible for increased use of chemical fertilizers and pesticides, resulting in environmental pollution and soil degradation. It is may be true that some farmers, in their anxiety to obtain higher production, over-used these chemicals, in the sense that they used dosages of these chemicals which far exceeded the recommended dosages. We have to appreciate the fact that modern technologies have saved millions of people from hunger. We have also to realize that during the 60 years period from 1950-51 to 2010-11, the food production went up by 375% (from 51 to 242 million tonnes) and productivity 268% (from 522 to 1921 kg/ hectare) with only 30% (from 97 to 126 million hectares) increase in the cultivated area (it remained around 120 m ha for 40 years). This achievement was due to emulating Green Revolution. However, we need to evolve more effective new technologies to face the emerging challenges such as scarcity of water, global warming, etc. and to substantially increase the food production to match the ever-growing population, which is projected to increase from the present 1.28 billion to 1.70 billion by 2050. Research is always dynamic in nature because the characters of problems change with time. So there would always be a need for conducting new research to answer the demands of the time. It is indeed possible that there are individual scientist or group of scientists or research organizations that believe in traditional ways of cultivation and are averse to modern technologies. However, it is noteworthy that while the approach may vary the nobel objective of all technologies, be it traditional or modern, is the same which is to achieve adequate production to feed teeming millions. One has to realize that every single technology is important in enhancing crop production and protection. There is thus a need to harness all the technologies. This is possible if all the scientists with divergent views talk to each other, listen to each other and understand each other in the best interest of agriculture and feeding the society at large. Technological prejudice or intolerance must be avoided. Rather, a judicious integration of available technologies, depending upon their suitability to a particular situation, should be explored which augurs well for future.

Throughout the process of the Green Revolution, the entire team, comprising national and international scientists and political leaders, worked together without bothering ***WHO*** or ***WHAT*** came from ***WHERE***, with the single objective of revolutionizing agriculture for the welfare of humanity. This example is worth emulating even today as food is a global necessity, and science and technology has the potential to offer solutions to many problems that may crop up from time to time. Science has no boundaries. It is truly universal.

■

Global View

World's Food Demand May Overtake The Supply

MELBOURNE, Friday.—Grave concern was expressed at the British Commonwealth Scientific Conference, just concluded in Melbourne, over the possibility of the world's population eventually overtaking its food supply.

This was said yesterday by the chairman of the Commonwealth Scientific and Industrial Research Organisation (Dr. Clunies Ross) in a review of the work accomplished by the conference.

Dr. Ross said that various speakers had emphasised that as fast as increased scientific knowledge had improved the world supply of food, improved medical and hygiene services produced a greater number of mouths to feed.

Scientists had expressed the view that eventually the food supply might not be able to meet the demand.

No time had been fixed when this might happen. It had been seen by the conference "as a cloud on the horizon."

The Canberra Times (ACT : 1926 - 1995), Friday 4 November 1966, page 2

The Canberra Times

Friday, November 4, 1966

THE SICK MAN OF ASIA

"UNLESS we increase agricultural production and control our population and thus achieve self-sufficiency in the next few years, we will have forfeited our right to call ourselves a free country, let alone a great country. We must become self-reliant. The aid and help should be a temporary phase". The country is India and the speaker the Prime Minister, Mrs Gandhi. It was last April, a time of severe food shortages, and the occasion a meeting of State Chief Ministers and Ministers of Agriculture in New Delhi. Seven months later, having scrambled through somehow, India is in trouble again. The south-west monsoon has failed, and two States, Bihar and Uttar Pradesh, face a grim time. Presumably continuing American food shipments will pull them through short of disaster, if the food can be distributed with reasonable efficiency.

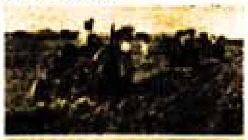
The Canberra Times (ACT : 1926 - 1995), Thursday 15 December 1966, page 39

India tackles famine problems realistically

By PETER LONG

As an indication of the enthusiasm for these new seeds and the significance attached to them, he instanced the importing of 18,000 tons of a Mexican variety of wheat to be used as seed after only a relatively short period of tests.

There was "some measure of a gamble" in their action, he said, but added, "it has paid off".



Modern methods help overcome India's agriculture problems.

The Canberra Times (ACT : 1926 - 1995), Monday 9 January 1967, page 2

INDIAN AGRICULTURE IN PERSPECTIVE

By N. L. NAGRATH

THE immediate reasons for the present food crisis in India are more natural calamity than human failure.

AFTER the near static conditions for the better part of this century, the production of food grains rose from 51 million tons in 1950-51 to 88 million tons in 1964-65. This is an increase of more than 60 per cent. (Production in the drought year of 1965-66 was only 72 million tons.)

An additional 14 million acres were brought under major and medium irrigation with 32 million acres under minor irrigation. Nearly eight

ing sufficient foodgrains for its requirements. With proper management it should have been possible to build up buffer stocks to tide over what can now paradoxically be called a rainy day.

The production of food grains before the onset of the drought last year show a reasonable growth since the inception of overall agricultural planning in 1951. During the same period the imports of food grains fluctuated around four million tons a year, roughly five per cent of domestic production. (See production figures in relation to population figures in accompanying table.)

A move in time not space

The system

It took centuries for Europe to emerge from its feudal system, which is only less complicated and not essentially different from the Indian caste system. It took centuries to complete the process by which the younger sons migrated from a village.

The process of enlightenment, the dawning conception of science and, in short, the notion that man might control his own destiny, which is the essence of progress, took hundreds of years in Europe; in India, as in Russia, it is hoped to achieve it in a few decades.

Golden Jubilee of Green Revolution
2015

The Canberra Times (ACT : 1926 - 1995), Thursday 11 September 1969, page 22

FARMERS IN INDIA ACCEPT NEW METHODS

Rapid progress which India had made in the past two years toward self-sufficiency in wheat production proved it was "simply not true" that Indian farmers were unwilling to accept new techniques, an ANU economist said yesterday.

India's current five-year plan aimed at providing for the country's wheat needs by 1971, Dr Brian Lockwood said, and there were strong indications that it might succeed.

"If they do reach self-sufficiency soon, that will give them about 30 years' grace until the population catches up with them again, unless something is done about the birthrate in the meantime", he added.

and Mexican wheat, the output from Indian farms had soared.

Imported high - yielding varieties of wheat were now grown on 95 per cent of India's wheat country.

The research for new and better-adaptive varieties that was going on at the same time was quite impressive.

Wheat grown under irrigation responded to heavy applications of fertilisers, but other food grains, such as millets and sorghum, could be produced efficiently in dry country. The emphasis of the 1969-1974 plan would be on producing crops from dry areas as well.

"With the support prices being paid by the Government for their crops, Indian wheat farmers are getting more per bushel than Australians or Americans", he said.

The Canberra Times (ACT : 1926 - 1995), Thursday 25 January 1968, page 2

India can beat its problems

SIR JOHN CRAWFORD, in his presidential address to the 40th Congress of the Australian and New Zealand Association for the Advancement of Science yesterday, countered the gloomy view of Thomas Malthus with an optimistic appraisal of India, which celebrates tomorrow its 18th anniversary as a republic.

THE distinguished Australian economist Sir John Crawford believes India can, and probably will, confound the prophets of doom

the prophets of doom and solve its food and population problems. But it will need help from other countries.

"It is now clear", he said yesterday, "that given the resources, population growth can and will be checked and that agriculture can be ex-

"YET agriculture, as we have seen, is merely part, a vital part, it is true, of economic development. Just as a stagnant agriculture leads to a collapse of economic development, so failure to industrialise at all will not be in the interests of agriculture.

can and will be checked and that agriculture can be ex-panded to give a good deal better than bare subsistence to a land which, with Pakistan, contains almost one-fifth of the world's population now and will exceed this ratio before this century's end".

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“Today, India absorbs like a blotter 25 per cent of the entire American wheat crop. No matter how one may adjust present statistics and allow for future increase in the American wheat crop... It will be beyond the US to keep famine out of India during 1970. The reason? Of all the national leadership the Indian comes close to being the most childish and inefficient, perversely determined to cut the country’s economic throat” (Paddock and Paddock 1968: 217).

But, ironically, in 1975, India not only met the domestic requirement of food but also became an exporter of foodgrains. This was the success of the technological change of the mid-sixties, which was commonly known as ‘Green Revolution’, which should be equally credited to the process of participation of the farmer in readily accepting the technological innovations along with the availability of new inputs. The role of farmer in the process of the spread of technological change is of prime importance but acknowledged or highlighted rarely. The half-clad, ill-fed, and under-nourished farmer with strong resource constraints was fully charged to provide food security to the country and to prove wrong the predictions of a widespread famine by the western economists.”

"To the hungry man, god comes in the form of bread"

"Of course the farmer is the father of the world. But it is his greatness that he is not aware of the fact....They are not conscious that they deserve any credit. They do not care to be honoured."

"India lives in farmers' huts. The weavers' skill is a reminder of India's glory"

– Mahatma Gandhi

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