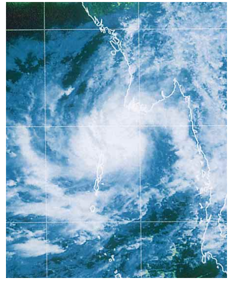


CHAPTER XXI

AGRICULTURE

India's Independence was won in the backdrop of the great Bengal famine of 1942-43. No wonder, our first Prime Minister, Jawaharlal Nehru said early in 1948, *everything else can wait but not agriculture*. Thanks to the packages of technology, services and public policies introduced since the beginning of the first Five Year Plan in 1950, the country has transformed itself from a 'begging bowl' image to one which occupies the first or second position in terms of production and area in several major crops.

We also occupy the first position in milk production globally. India ranks second in fish culture and third in capture fisheries. We have been able to build substantial buffer stocks of food grains, in spite of increasing demand due to rising population. The per capita food grain availability has also increased by one and a half times.

India's share in the world production and area for major crops (1995 – 97)

Crops	India's Share (%)		India's Rank	
	Production	Area	Production	Area
Wheat	11.4	11.2	2	2
Rice	21.4	28.5	2	1
Coarse Grains	3.4	9.0	5	3
Potatoes	6.2	6.0	5	5
Pulses	26.0	36.6	1	1
Groundnut	28.6	35.2	1	1
Sugarcane	22.6	20.0	2	2
Tea	28.3	18.5	1	2
Tobacco	8.3	8.7	3	2
Jute	52.5	51.5	1	1
Cotton (Lint)	14.0	20.7	3	1

Source: FAO, 1997

Growth in food grain production and population during the last 50 years

	1950	1960	1970	1980	1990	2000
Food grain production(mt)	50.8	82.0	108.4	129.6	176.4	201.6
Food grain import(mt)	4.8	10.4	7.5	0.8	0.3	-
Buffer stock(mt)	-	2.0	-	15.5	20.8	40.0
Population (million)	361	439	548	683	846	1000

CROP IMPROVEMENT AND PRODUCTION

Wheat: Wheat has been cultivated for several thousand years in India. Wheat grains have been found in the Mohenjadaro excavations. These have been identified as belonging to *Triticum aestivum* sub-species *sphaerococcum*, characterized by spherical shape and dwarf plant stature. From the days of Mohenjadaro up to the dawn of India's Independence in 1947, the country developed the capacity to produce about 6 million tonnes of wheat. It was not sufficient to meet the demand, leading to large-scale importation of food grains.

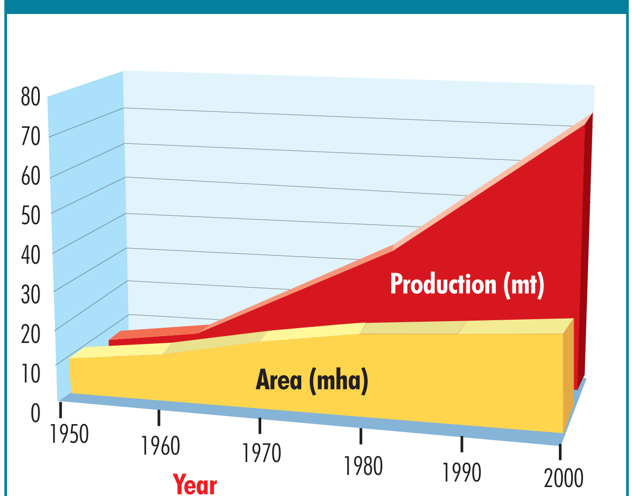
In addition to strengthening of research and organization of a national extension service, several measures to stimulate food production including land reforms, irrigation, fertilizer production were initiated in the fifties. Production of wheat and rice

Green Revolution: *Release of a postage stamp entitled 'Wheat Revolution' to commemorate quantum jump in wheat production by Indira Gandhi in July 1968 at the Indian Agricultural Research Institute, New Delhi.*

went up but productivity per unit area of land remained practically stagnant. Enhanced production came from an increase in both total cropped area and irrigated area. Wheat production went up to 12 million tonnes in 1964, which from the point of view of monsoon behaviour, was a good agricultural year. In order to enhance productivity in irrigated areas, the Government of India initiated the Intensive Agricultural District Programme (IADP) in 1961. The aim was to introduce good seeds and a package of agronomic practices which can help optimize the benefit from irrigation water. Unfortunately, the early IADP experience was not encouraging. It was found that the package of practices promoted had one important missing ingredient, namely varieties which can respond well to good irrigation and soil fertility management. It is this missing ingredient that was provided in 1966 through the High Yielding Varieties Programme (HYVP) in wheat, rice, maize, sorghum (jowar) and pearl millet (bajra). Wheat production rose to nearly 17 million tonnes in 1968. After several thousand years, the stagnation in yield was broken in wheat. Since similar productivity improvement was also visible in rice, the phenomenon has been described as "Green Revolution".

Wheat crop has exhibited a robust growth trend since the onset of the Green Revolution in 1968. In 2001 our farmers harvested nearly 74 million tonnes of wheat, while the wheat harvest at the time of our Independence was only 6 million tonnes. Much of the increase in wheat production has come from productivity improvement. Had this not occurred, we would have required nearly 74 million ha of area in contrast to the current actual area of about 26.7 million ha. It is rightly described as "land saving agriculture", since the pathway of production improvement is higher productivity. "Forest-saving agriculture" may be even more appropriate term,

GROWTH IN WHEAT PRODUCTION & AREA

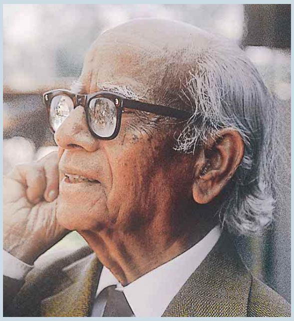


since agricultural expansion is often at the expense of forest area. Such phenomenal progress has been possible because of the introduction of mutually reinforcing packages of technology, services and public policies through the High Yielding Varieties Programme introduced by the Government of India in 1966. Yield improvement in wheat is one of the most exciting adventures in the field of agricultural science not only in our country but in the entire world.

B.P. Pal initiated the wheat improvement programme at the Indian Agricultural Research Institute (IARI), New Delhi. The emphasis of the programme of IARI was directed to achieve both disease resistance and yield. This ultimately resulted in varieties like NP 809 possessing a broad spectrum of resistance to stem, stripe and leaf rusts, and NP 824 possessing ability to respond to about 50 kg of nitrogen. In 1954, a research programme was started for developing non-lodging and fertilizer responsive varieties of wheat. With the earlier tall varieties it was difficult to get economic response to the application of mineral fertilizers and adequate irrigation water. Average wheat yields stagnated at less than 1 tonne per ha. This is why the breeding of non-lodging varieties was accorded a high priority during the fifties, when the country had taken to the path of expanding the area under irrigation and manufacturing of mineral fertilizers. Unfortunately, short and stiff straw was always associated with short panicles and fewer grains.

The breakthrough came in March, 1961, when a few dwarf spring wheat strains possessing the Norin-10 dwarfing genes, developed by Norman E. Borlaug in Mexico, were grown in the fields of IARI. Their phenotype was most impressive. They had reduced height and long panicles, unlike the earlier hybrids between *T. aestivum* and *T. compactum* and *T. sphaeroccum* and the induced erectoides mutants in which short height was coupled with small panicles. In 1964, a National Demonstration Programme was started in farmers' fields both to verify the results obtained in research plots and to introduce farmers to the new opportunities opened up by semi-dwarf

B.P. PAL



Benjamin Peary Pal (1906-1989) was born in a Hindu family at Mukandpur in Punjab on May 26, 1906. After early education in Yangon, Myanmar, Pal moved to Cambridge and received his doctorate degree in 1933. After returning to India, he joined the Imperial Agricultural Research Institute at Pusa, Bihar (now IARI, Delhi) as Second Economic Botanist and rose to become the Institute's Director. He was the first Director-General of ICAR. Pal is known for his work on breeding wheat variety (New Pusa 809) resistant to all the three types of rust disease. He also introduced a high degree of resistance to the smut disease. He is responsible for starting the All India Coordinated Research Projects for important Indian crops. It is through his initiative that the National Bureau of Plant Genetic Resources came into existence. Pal was an institution builder, able administrator and a policy maker. He groomed a large number of scientists, who later became leaders in agricultural research in India and abroad. He had a passion for ornamental plants and wrote authoritative books on roses. Many of the rose varieties bred by him are well-known.

B.P. Pal was a painter of landscapes and encouraged the arts. He was elected to the Fellowship of INSA in 1946 and to Presidentship 1975. He was a foreign member of the All Union Lenin Academy of Sciences and a Fellow of the Royal Society, London. He was a humourous person and effused warmth.

varieties for improving very considerably the productivity of wheat. When small farmers, with the help of scientists, harvested over 5 tonnes of wheat per hectare, its impact on the minds of other farmers was electric. The clamour for seeds began and the area under high yielding varieties of wheat rose from 4 ha in 1963-64 to over 4 million ha in 1971-72. This was because of the bold decision taken in 1966 at the instance of C. Subramaniam, the then Minister for Food and Agriculture, to import 18,000 tonnes of seed of the Mexican semi-dwarf varieties, Lerma Rojo 64A and Sonora 64.

The introduction of Lerma Rojo 64A and Sonora 64 was followed by the release of Kalyan Sona and Sonalika, selected from the advanced generation material received from Mexico. Further, hybridization between Mexican strains and Indian varieties resulted in many high yielding and rust resistant strains in different parts of the country. Mutation breeding for changing the red grain colour of Lerma Rojo 64A and Sonora 64 led to the production of Pusa Lerma and Sharbati Sonora. Crossing the semi-dwarf *T. aestivum* material with *T. durum* varieties produced semi-dwarf *T. durum* varieties like Malavika. In all cases, attention was paid to disease resistance and *chapati* making quality of the grain. Above all, the dwarf wheats would never have expressed their yield potential, without appropriate agronomic practices such as shallow seeding and giving the first irrigation at the crown root initiation stage.

Anticipatory research to avoid potential environmental problems was strengthened and a wide variety of high yielding strains possessing resistance or tolerance to the principal disease-causing organisms were developed. This underlines the fact that agricultural scientists were fully alive to the need for conducting an action-reaction analysis while introducing new technologies. Such awareness led to intensified efforts in varietal diversification and to the pyramiding of genes for tolerance to biotic and abiotic stresses. This is why wheat production had continued to show an upward trend during the last 35 years. The Indian wheat varieties Sonalika, WL 711, HD 2009 and HD 2172 are also popular in other countries like Bangladesh, Pakistan, Nepal, Bhutan, Afghanistan, Sudan and Syria. In Sudan, wheat var. HD 2172, grown in 90% of the wheat area, has paved the way for self-sufficiency in food grains.

The remarkable speed with which the high yielding varieties were identified from the initial Mexican material and later developed within the country was the result of the multi-location testing and inter-disciplinary research organized under the All India Coordinated Wheat Research Project of the Indian Council of Agricultural Research (ICAR). The coordinated wheat project is an outstanding exercise in meaningful, international and interdisciplinary cooperation. We salute B.P. Pal, who initiated both organized wheat breeding and coordinated varietal testing programmes in the country. Breeding efforts alone would not have borne fruit but for the outstanding support given by plant pathologists, agronomists, soil chemists and specialists in other disciplines. In short, the participants in the wheat research programme functioned like members of a symphony orchestra. Such harmony and cooperation led to historically path breaking results. Advances in wheat production also serve as an illustration of the value of fusion between political will and scientific skill. But for the political action taken by C. Subramaniam, scientific results might have just remained in the laboratory.

Rice: Systematic breeding of crop varieties which can respond to higher levels of plant nutrition started in India in 1952 when at the instance of Dr. K. Ramiah, a programme for incorporating genes for fertilizer response from temperate japonica rice varieties from Japan into indica strains was initiated at the Central Rice Research Institute (CRRI), Cuttack. Major aim was to select from segregating populations of *indica x japonica* crosses, lines which showed the ability to utilize effectively about 100 kg of N per hectare. With the advent in the early sixties of the semi-dwarf, non-lodging, relatively photo-insensitive indica varieties based on the 'Dee-Gee-Woo-Gen' dwarfing gene identified in China, interest in transferring genes for fertilizer response from *japonica* varieties waned. Semi-dwarf *indica* rices like Taichung Native 1, IR8 and Jaya provided the initial material for the High Yielding Varieties Programme. In later breeding experiments, tropical japonicas from Taiwan also proved useful as parents.

Introduction of 'Dee-Gee-Woo-Gen' dwarfing gene from semi-dwarf, short duration, day neutral, fertilizer responsive var. *Taichung Native* 1 in our tropical rice resulted in crossing the yield barrier as the yield jumped from 3 tonnes/ha to 7 tonnes/ha. Now the country has a large number of high-yielding rice varieties suitable for cultivation under irrigated and rainfed conditions. India is the second country in the world to commercialize hybrid rice technology. Hybrid rice provides further yield advantage of 1.0-1.5 tonnes/ha. Wide cultivation of high yielding varieties and hybrids have helped in increasing rice production from about 40 million tonnes to over 80 million tonnes during the last three decades.

Maize and Millets: Spectacular successes have also been achieved in improving the yields and production of maize, sorghum, pearlmillet and ecofriendly small millets – finger millet, foxtail millet, kodo millet, little millet, prosomillet and barnyard millet. India is the first country to develop hybrids in pearlmillet (bajra) which resulted in an increase in production from 2.84 million tonnes in 1950 to nearly 8.72 million tonnes in 1995. The newly developed hybrids are predominantly suitable for drought prone areas of Rajasthan. The crop, however, suffers from a serious downy mildew disease. Good progress has been made in developing extra early

Seed production in hybrid rice.

heterotic mildew resistant hybrids and composites to mitigate the losses caused by this disease.

Sugarcane: India is the leader in sugarcane research. Remarkable improvement in yield, quality and ecological adaptation has been achieved by crossing the cultivated species with wild relatives and making intergeneric crosses with bamboo, sorghum and maize. This pioneering work was initiated by Sir T.S. Venkataraman in the 1940's at the Sugarcane Breeding Institute, Coimbatore which was initially established as Sugarcane Breeding Station in 1912. The new sugarcane varieties improved the productivity from 34 tonnes/ha to 63-100 tonnes/ha making India the largest producer of sugar in the world. Our current production of sugar is more than 13.4 million tonnes. To overcome the problem of 'seed' quality micropropagation technology has been developed to produce nearly 78000 plantlets (in vitro) from a single explant in less than six months. Our sugarcane varieties like CO 419, CO 527 and CO 6806 are also very popular in African and South-East Asian countries.

Grain legumes constitute a major source of food in India.

Oilseeds and Grain Legumes: Groundnut, rapeseed-mustard, sesame, linseed and castor are our main oilseed crops. In 1951 India was producing 5.16 million tonnes of oilseeds, but the present yields have risen to 20 million tonnes. This achievement, a result of research oriented 'Technology Mission on Oilseeds' launched by the country in the mid eighties, has made the country self sufficient in oilseeds. A similar technology mission has been launched for improving the production of grain legumes (pulses) to meet the dietary requirement of the largely vegetarian population of the country. Our production of grain legumes has improved only marginally during the last fifty years.

Cotton and Jute: India has the distinction of being the first country to have developed and grown hybrid cotton commercially. These hybrids give the finest-quality of cotton with spinning performance of 120s counts, comparable with the best in the world. Supported by the high yielding varieties and hybrids and IPM practices the production of cotton in the country has grown from 2.75 million bales in the fifties to 12.18 million bales last year, from about 7.5 million ha cotton area. The country has also developed eco-friendly coloured cottons through hybridization and mutation breeding. The coloured cottons will reduce the hazards of using azo-dyes. In addition, India produces 8.6 million bales of jute fibre, a substantial increase from 1.6 million bales about 50 years ago. Introduction of high yielding varieties and hybrids and improved agronomic practices are mainly responsible for the increased production. A major emphasis is on developing value added products from jute fibre like fine yarn, blended yarn and speciality fabrics.

Horticulture

India enjoys an enviable position in the horticultural map of the world as almost all types of fruits, vegetables, spices and condiments can be grown. India is the second largest producer of fruits (40 million tonnes) and also second largest producer of vegetables (72 million tonnes). India has also made a remarkable progress in flower production and is heading towards *Hi-Tech* practices. Although, horticulture has been practiced in India since Vedic times, organized research on horticulture started about 40 years ago with the establishment of a separate Division of Horticulture at the IARI, New Delhi and of the Indian Institute of Horticultural Research (IIHR), Bangalore. Now the country has 19 independent research institutions and 17 coordinated programmes for research on horticultural crops. Development of high yielding varieties and hybrid fruits and vegetables has contributed to a phenomenal growth of 11.2% and 5.6% respectively during 1991-96 period. India is the largest producer of mango, banana, sapota and acid lime. In grapes India has recorded the highest productivity per unit area in the world. Among the vegetables India occupies the first position in cauliflower and second position in onion and third in cabbage.

Left: India is a major centre of diversity in banana, over 70 cultivars are grown here.
Right: Regular bearing mango hybrid Arka Neelkaran.

Mango: Mango, the king of fruits, is the most important fruit crop of India. It is also a major centre of diversity in mango which is believed to have originated in the Indo-Burma region. The first large orchard, known as *Lakhi Bagh*, as it had one lakh (0.1 million) plants, was planted by Akbar the Great in the 16th Century. Since that time mango is widely cultivated. Nearly 1200 varieties of mango have been identified which are being maintained and evaluated in field gene banks at different locations. These collections have provided important gene pools for regular bearing, crop duration, extended shelf-life and a wide range of pulp quality and flavours. Alternate bearing and mango malformation are two major problems in this crop. A singular achievement has been the development of dwarf and regular bearing hybrids through extensive breeding work carried out at IARI, New Delhi and IIHR, Bangalore. These hybrids can be planted in close spacing in high density orchards, accommodating 1600 plants/ha, which yield more than ten times per unit area than the conventional varieties.

Citrus: Citrus is the third largest group of fruit crops of India with a production of 2.98 million tonnes from 0.37 million ha. The major citrus fruits in India are mandarin orange, sweet orange and acid lime. More than 500 accessions of citrus are being maintained in field gene banks at different locations. Evaluation of the available gene pool has helped in identifying promising root stocks, sources of resistance to pests and pathogens and tolerance to salt and drought. Salt tolerant species have been shown to exclude chloride uptake. Hybrid from Rangpur lime x trifoliate orange is a promising rootstock for mandarin and sweet orange imparting resistance to *Phytophthora* and nematodes.

Banana: India is the major centre of diversity in banana, the fourth important source of food after rice, wheat and milk. Banana has been grown in India for over 4000 years. The country produces 10.4 million tonnes of fruit from 0.39 million ha. Over 70 cultivars of banana are grown in the country depending on regional preferences. Some of these are low yielders but fetch high prices on account of their quality. Efforts are being made to improve their yield as well as quality. Highly promising hybrids have been developed with improved bunch weight (14-16 kg) and high degree of resistance to *Fusarium* wilt.

Micropropagation of banana *in vitro* has helped in establishing high density plantations supported by drip irrigation giving higher economic returns. Viral diseases, particularly banana bunchy top virus are serious problems. Sensitive diagnostic techniques based on monoclonal antibodies and c-DNA probes have been developed to index and provide healthy planting material of uniform quality.

Potato: Potato was introduced to India about 400 years ago. During the last fifty years, area under potato has grown from 0.2 million ha to nearly 1.0 million ha but production has shown a dramatic increase from one million tonnes to 22 million tonnes. This has been made possible through the introduction of innovative 'seed-plot' technique for producing disease-free seed, development of high yielding varieties for cultivation under different agro-ecologies and improved agronomic practices. Instead of the conventional tuber, potato seed referred to as true potato seed (TPS) has been used in Tripura. In some parts of the country, notably Gujarat, potato yields are about 65 tonnes/ha, which is 50 per cent more than those obtained in the Netherlands.

Other Tuber Crops: Tuber crops are the most efficient producers of carbohydrates per unit area and time. Cultivation of high yielding varieties and improved management practices have increased cassava (tapioca) productivity from 10 tonnes/ha to more than 30 tonnes/ha in early seventies in Tamil Nadu, leading to improved turnover of cassava based cottage-scale starch and sago industry.

Plant Genetic Resources

The Indian sub-continent is an important centre of origin and diversity of agri-horticultural crop species and their wild relatives. Nearly 160 domesticated species, 350 species of their wild relatives and over 800 species of ethnobotanical interest are native of this region. The significance of diversity can be judged from the fact that out of the 80,000 rice varieties 50 per cent are found in India. Collection, conservation and utilization of plant genetic resources were initiated at the IARI, New Delhi in 1945 by the visionary plant scientist Harbhajan Singh. Realizing the importance of this initiative, the country established a National Bureau of Plant Genetic Resources (NBPGR) in 1976. To conserve and utilize the valuable germplasm, a gene bank has been developed at NBPGR for long term storage of more than one million accessions. At present the facility holds about 145,000 accessions in seed repository, 800 accessions in tissue culture repository and 1000 samples cryopreserved in liquid nitrogen. The NBPGR is also responsible for the long-term conservation of global base collections of several crops.

Natural Resources and Agroforestry

Soil and water are the vital natural resources for optimizing agricultural production. The country is, however, facing serious concerns of reduction in arable land due to urbanization, annual loss of nearly 5,334 million tonnes of soil due to erosion, and depleting water resources. For research on cropping systems, nutrient management, water management, soil management and agroforestry, the country has established 13 national research institutions and 15 coordinated programmes. These efforts have helped in delineating 20 agro-ecological regions (AERs) and 60 sub-regions based on physiography, soil and period of crop growth. Cropping systems research has identified sustainable multiple cropping systems capable of producing up to 10-12 tonnes/ha/year from irrigated areas.

Water is a key input. Technologies have been developed for water harvesting recycling and economic usage. Integrated watershed management models for different agro-ecological regions and agronomic practices have been developed to conserve soil and water. Scientific approaches have been developed to stabilize sand-dunes by introducing tree species like *Acacia tortilis* (from Israel) which establish successfully in sand-dune affected areas.

Agroforestry provides an ideal approach for the optimum utilization of natural resources like water, soil and sunlight. Agroforestry has been in practice for a long time in India. Growing of tea, coffee, ginger, turmeric and cardamom in the shade trees and intercropping with trees like coconut are common in the tropical regions. Through research efforts indigenous and exotic species of plants have been identified for agri-horti-silvi-pastoral, silvipastoral, agri-silvi-pastoral and agri-horticulture in different agroecological regions. Agri-silvi combination of *Acacia nilotica* and wheat or chickpea has been found suitable for improving the productivity of marginal and dry areas. Various multipurpose tree species of *Acacia, Albizia, Azadirachta, Butea, Casuarina, Dalbergia, Hardwickia* and *Tecomella* have been recommended for agroforesstry in different agro-climatic regions of the country and for achieving sustainable productivity from wastelands.

Top: Variability in maize in North-East India. Above: Water harvesting in the Thar desert of Rajasthan.

Plant Protection

Biotic stresses are a major constraint in achieving full yield potential of crop plants. The losses due to weeds, diseases and pests have been estimated to be around 40% in the tropics and semitropics. If the post-harvest losses (15-20%) are also added, the situation becomes even more alarming. For sustainable agriculture, in an environment-conscious world, the growth-reducing factors like pests, pathogens and weeds have to be managed through eco-friendly measures, supported by judicious use of chemicals to maintain high economic returns without disturbing the ecological balance. Therefore, integrated pest management (IPM) has been identified as one of the key technologies to increase crop productivity, as it is economical, ecofriendly and suitable for Indian farming systems where agricultural holdings are relatively small and the practice of intercropping of diverse crops is common. IPM practices involve need based application of chemical pesticides, use of botanical pesticides like neem products, use of resistant varieties and release of biocontrol agents. These have been developed for ecofriendly management of pest and diseases of rice, cotton, sugarcane, maize, oilseeds, pulses, citrus, grapes and vegetables.

Use of resistant varieties has been very successful in managing plant diseases. In the 1950's and early 1960's rust diseases of wheat used to result in 10% loss in yield. But now these diseases cause negligible damage due to deployment of resistance genes for wheat rust management. This has been achieved through extensive collaborative research efforts for identifying genes imparting resistance to different races of the rust pathogens and their deployment in different wheat-growing areas depending on the virulence of the prevalent races of the pathogens. If the losses due to rust pathogens were to continue, we would have been losing nearly seven million tonnes of wheat annually. It is a continuing effort. Researches are in progress for pyramiding genes like Lr 24, Lr 28 and Lr 19 for leaf rust resistance in wheat through molecular marker assisted selection as these genes are phenotypically indistinguishable. Resistance genes have also been identified in other crops for resistance to fungal, bacterial and viral pathogens.

***Cryptolaemus montrouzieri* predates on mealybugs which are a menace to fruit crops.**

Recent biotechnological developments provide powerful and novel mechanisms for the management of biotic stresses. The introduction of crystal protein gene (cry gene) of *Bacillus thuringiensis* (Bt) into crop plants for developing pest resistant varieties is a major breakthrough. At the IARI, New Delhi a mutated gene encoding *Bt-cry* 1Ac d-endotoxin has been found to be highly effective against cotton bollworm and rice yellow stem borer. Transgenic tobacco and other crop plants expressing trypsin inhibitor gene from cowpea have been shown to have resistance to coleopteran, lepidopteran and orthopteran pests. Over expression of chitinase or glucanase, the fungal cell wall hydrolyzing enzymes, in transgenic *Brassica juncea* has shown promise of developing resistance against *Alternaria* which is a limiting factor in the production of this crop.

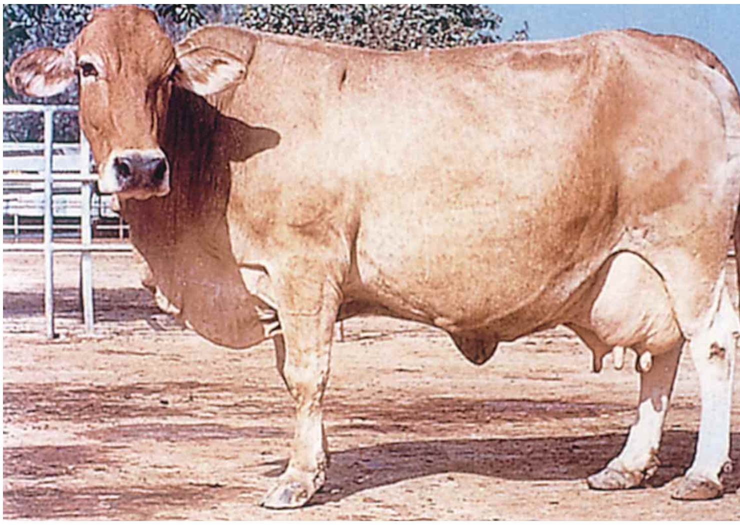
Biotechnological approaches are most useful for the management of viral diseases of plants, as transformation of plants with genes of viral origin imparts resistance to infection by viruses. Coat-protein (CP) gene of plant viruses has been found to be best for developing resistance against homologous viruses. Genomes of a large number of viruses, particularly those belonging to Gemini- and potyvirus groups, have been cloned to identify specific genes for use as transgene in developing resistant plants. Tobacco plants transformed with the CP gene of potato virus Y (PVY), which causes severe diseases in a variety of crops including tobacco, developed varying degree of resistance to infection by PVY.

Veterinary Sciences

India is very rich in livestock diversity. In terms of numbers we have over 200 million cattle, 76 million buffaloes, 46 million sheep, 110 million goats, 11 million pigs, 1.9 millions equines, 1 million camel and 310 million poultry. Animal wealth has also been an important component of Indian agriculture from times immemorial as important sources of nutrition, draught power and organic recycling. There has been a quantum jump in milk production from 17 million tonnes in 1950 to nearly 75 million tonnes in 1999, making India the top milk producer in the world. Similar increase in the production of eggs and broilers has been achieved.

Improvement of animals has been practiced in India from the days of *Matsya Purana* which deals with the selection of efficient bulls. Since then, breeding and selection of animals for different agro-ecologies has resulted in vast diversity in our livestock and poultry. However, organized animal research started with the establishment of Imperial Bacteriological Laboratory at Pune in 1889 which shifted in 1893 to Mukteshwar in the Kumaon Himalayas and later became the Indian Veterinary Research Institute (1947). We now have a network of 18 national research institutions and 16 coordinated programmes for conducting extensive research on different species of domestic animals, animal products and animal health.

India has worlds' best breeds of dairy buffaloes, draught cattle, carpet wool sheep and goats. We also have rare species of yak, mithun, pigmy hog and wild buffaloes. The country has established a National Bureau of Animal Genetic Resources with headquarters at Lucknow to work in collaboration with other institutions for evaluation, characterization, conservation, management and improvement of our rich animal genetic resources. The Bureau is developing cytogenetic profiles of livestock and databases for breed conservation and utilization. Chromosome profile has been determined for cattle (*Bos indicus*), buffalo (*Bubalus bubalis*), goat (*Capra hircus*), sheep (*Ovis aries*), horse (*Equus domesticus*), donkey (*Equus asinus*), single humped camel (*Camelus dromedarius*), pig (*Sus scrofa*), yak (*Bos grunniens*) and mithun (*Bos frontalis*).



Top: Karan Swiss cow, a cross between Brown Swiss and Red Sindhi/Sahiwal.
Above: The world's first in vitro fertilized buffalo calf.

Crossbreeding with exotic breeds has produced new improved genotypes. In cattle new genotypes Karan Swiss (Brown Swiss x Red Sindhi or Sahiwal) and Karan Fries (Friesian X Tharparkar) are giving an annual lactation of 3,385 and 3,820 litres respectively. Frieswal (Holstein X Sahiwal) yield even

An elite Karan Fries cow with its ten calves produced by super ovulation and embryo transplant technology.

better (4000 litres) at mature lactation. This programme has helped in improving milk production in the country. Similarly, improved genotypes have been developed for sheep, goats, rabbit and poultry. The Indian livestock germplasm resources have also been used for developing new breeds in Australia, Europe, South-East Asia and South America.

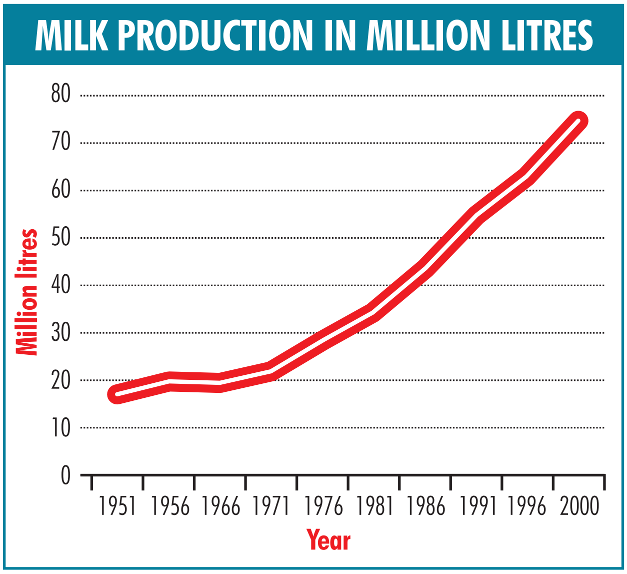
Significant advances have been made in cryopreservation of buffalo semen, *in vitro* maturation and *in vitro* fertilization of buffalo oocyte and embryo transfer technology (ETT). Through ETT, a superior bovine female can be made to produce 5 to 10 calves a year and up to 50 calves or more in its life time. ETT is also successful in buffalo, sheep and goat.

Disease diagnosis, disease monitoring and surveillance procedures, supported by improved vaccination programme have helped in increasing animal production. The country has produced vaccines to guard against the diseases like: anthrax, haemorrhagic septicaemia, blackquarter, fowl cholera, Ranikhet disease, swine fever, rabies, foot and mouth disease, sheep pox, goat pox, fowl pox, clostridial diseases in sheep, theileriosis, canine distemper and equine influenza. The laboratories in Bhopal and Bangalore have appropriate microbial containment facility for producing diagnostic reagents and vaccines against contagious diseases like foot and mouth disease. The laboratory in Bangalore also serves as referral laboratory and conducts epidemiological studies on rinderpest and rinder-pest like diseases, with the help of a network of 32 laboratories established to monitor these diseases.

Rinderpest was the most serious disease of ruminant animals in the country up to 1950 when an eradication programme was started entirely by indigenous efforts using vaccines developed by the Indian Veterinary Research Institute (IVRI). By 1960, mortality rate was reduced by 80-90%, which greatly helped in providing the additional draught power required during the 'green revolution' years. By 1995 the entire country was free of this dreadful disease and the fresh vaccinations were stopped in 1997. The vaccines developed in India have also been used in other countries in rinderpest eradication programme.

Fisheries

Fish is a dynamic self-renewable natural resource. It is the most economical source of animal protein and an important health food. Fisheries constitute a unique sector offering animal protein to a wide cross-section of society from a price ranging from Rs. 10/kg to as high as Rs.700/kg. High fecundity (up to 1 million eggs) and fast growth rate (growth coefficient often >1.0) have no parallels in other animal protein sources like the livestock, including poultry. These advantageous biological characteristics of fishes offer considerable scope for increasing production and achieving nutritional security to a large extent. With the availability of 2.4% of global land area, India has to nourish and sustain 16% of the world population; hence its dependence

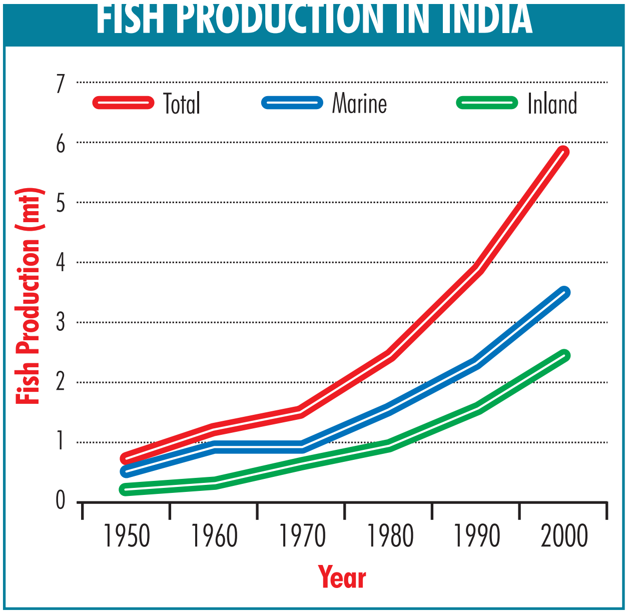


on aquatic food production is obvious.

From the vast and diverse aquatic resources of India 0.8 million tonne fish were captured during 1950s; even then, we exported about 20,000 tonnes of fish, mostly in dried form, and earned Rs. 25 million. The country has established 8 national fisheries research institutions, each with specific mandates to cater to all areas of fisheries research. Thanks to these institutions and their research contributions, we produce 5.8 million tonnes of fish and export about 0.4 million tonnes of shrimps, mostly frozen and canned, and earn a net foreign exchange of Rs. 55 billion. Briefly, fish production in our country has grown more than five times, fisheries contribution to the GDP of India also increased 3 times, a growth arguably one of the highest among the food production sectors.

The following land-mark scientific contributions have helped in achieving this remarkable enhancement in fish productivity. (i) The then Central Inland Fisheries Research Institute, Barrackpore published the first paper on the success in induced breeding of carp in 1957. Subsequently, technologies on induced breeding and larval rearing were developed for a number of species of carps. These research developments paved the way for the current annual freshwater carp production of >1 million tonnes. (ii) The Central Marine Fisheries Research Institute (CMFRI) developed the hatchery technology of penaeid shrimps during 1973-78 and commercial scale production started in the late eighties. In 1999-2000, the country has exported farmed shrimps worth $ >1 billion. CMFRI has also developed models for (a) stock assessment and population dynamics of multispecies, multigear fish resources in tropical waters, (b) fishery forecasting, and (c) in 1980 the Central Institute of Fisheries Technology (CIFT) and the Bay of Bengal Programme (FAO), Chennai, designed a high opening trawlnet with the help of gear experts in India. The design revolutionized the capture fisheries sector. In two decades, all the trawlnets (1,50,000 in number in 1998) in the country are of high opening type. They are responsible for an annual fish harvest of >1.2 million tonnes. CIFT has also developed technologies for the production of chitin and chitosan from prawn shell waste for wide ranging applications in pharmaceuticals, textile, cosmetic and paint industry. Absorbent surgical sutures have been developed from gut collagen of fish by cross and polymer coating for use in microsurgery. These developments have paved the way for, what is hailed as Blue revolution or

Bull's Eye fish, a deep water resource with a vast potential.



Aquaplosion in India. India has an enormous diversity of fish with 2,200 indigenous species. A National Bureau of Fish Genetic Resources has been established to develop a database on fish resources, preserve and maintain pure line fish stocks and breed fast growing hardy and high yielding fish varieties. These efforts will help in sustaining the blue revolution.

The Central Institute for Freshwater Aquaculture has cultured pearls in freshwater mussel and CMFRI has standardized pearl culture in *Pinctada fucata*, the most abundant pearl oyster in India. Technology has been developed to culture pearls in desired images and shapes.

Despite these the achievements in improving fishery production, the per capita fish availability is less (8 kg) than the world average (12 kg) and the quantity (11 kg) recommended by WHO. During late 1980s, aquafarming was undertaken by progressive fish-farmers in the east coast. By 1993, this kind of aquaculture activity led to farming of shrimp to the extent of 0.14 million ha and production of 0.83 million tonnes.

We have thus used less than 10% of available area that can be brought under aquaculture. Of the 297 species known to be suitable for aquaculture, Indian farmers have mastered the technology for mass production of only 15 species so far. For another 20 and odd species, mass culture techniques are being developed by the country's research institutions.

Challenges Ahead

The transition from a "ship to mouth" existence to one of food self-sufficiency at the prevailing level of purchasing power achieved during the last 50 years is perhaps one of the greatest human accomplishments since the dawn of agriculture 10,000 years ago. Such a transition was achieved through pioneering agricultural research and a multipronged strategy consisting of (a) increased food production, (b) building grain reserves, (c) operating an extensive public distribution system, (d) protective social security measures like food for work, nutritious noon meal and employment guarantee, and (e) land reforms and asset creation measures. However, we continue to force the challenge of endemic hunger as over 200 million children, women and men are under nour-

Open water fishery resources in India and their modes of fishery management

Resource	Resource size	Management mode
Marine jurisdiction (mKm^2)	2	-
Coastline (km)	8,219	-
Brackishwater (m ha)	2	Aquaculture
Rivers (km)	29,000	Capture fisheries
Mangroves (ha)	356,000	Subsistence
Estuaries (ha)	300,000	Capture fisheries
Estuarine wetlands (bheries)(ha)	39,600	Aquaculture
Backwaters/lagoons (ha)	190,500	Capture fisheries
Large & medium reservoirs (ha)	1,667,809	Enhancement (stock & species)
Small reservoirs (ha)	1,485,557	Culture-based fisheries
Floodplain wetlands (ha)	202,213	Culture-based fisheries
Upland lakes (ha)	720,000	

ished largely due to inadequate purchasing power arising from inadequate opportunities for skilled employment. The time is now ripe to take the final steps essential for the total elimination of hunger. The opportunity for a productive and healthy life for every individual would depend on the success of our strategies for hunger elimination.

The population of India is growing at the rate of 1.8 percent per year. If this trend continues, our population will double itself in less than 40 years. Only Kerala, Tamil Nadu, Goa and Mizoram have so far achieved a demographic transition to low birth and death rates. Andhra Pradesh is now on the verge of achieving the goal of population stabilisation. Besides population increase, improved purchasing power among the poor will enhance the demand for food, since under-nutrition and poverty go together. There is still a widespread mismatch between production and post-harvest technologies. In perishable commodities such as fruits, vegetables, flowers, meat and other animal products, this mismatch is often severe, affecting the interests of both producers and consumers.

Out of every three ha of cultivated land in our country, two ha are under rainfed agriculture. Therefore, top priority should be given to improving the productivity and stability of rainfed agriculture.

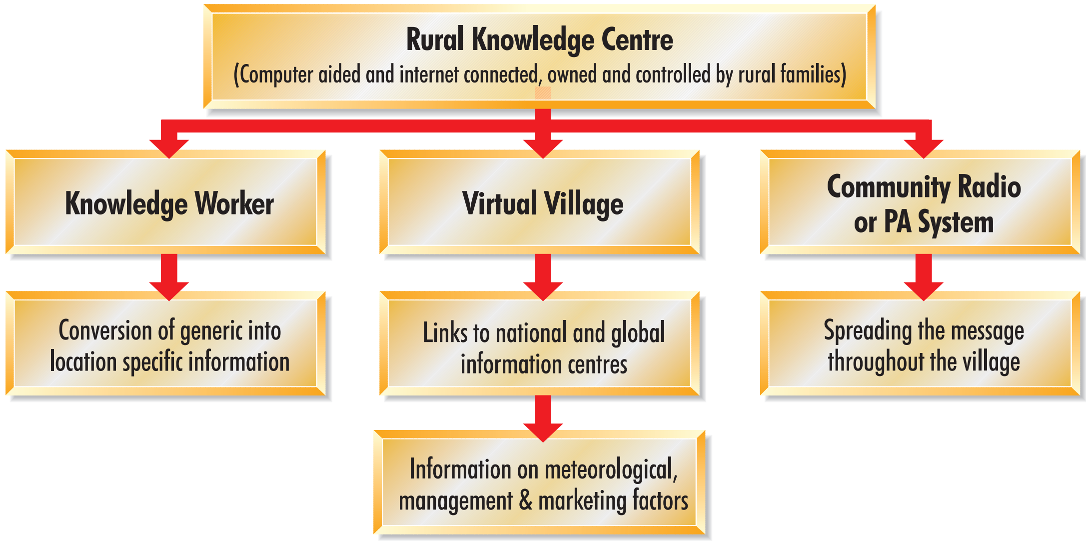
Looking Ahead

A major accomplishment of Independent India is the development of a dynamic national agricultural research, education and extension system. We have a well established network of State Agricultural and Animal Sciences Universities and national research institutions and All-India Coordinated Research Projects supported by the Indian Council of Agricultural Research. Therefore, we have opportunities to produce food and other agricultural commodities, particularly fruits and vegetables, not only for our country but also for international markets.

The gap between potential and actual yields is high in a majority of farming systems. In most of the crops, the present average yield is just one third of the achievable yield. Therefore, a massive effort is required to launch a new revolution in farming, through cost saving and efficient technologies both for production and post-harvest management. This would require adoption of the following strategies

- Defending the gains already made by adopting integrated natural resource management so that present production does not erode future prospects. This is particularly required for the traditional 'green revolution' areas.
- Extending the gains to areas which have been bypassed by the 'green revolution' technologies.
- Making new gains: The need for making new gains is urgent. This can be achieved by utilizing the available agro-climatic/soil maps, watershed/ wasteland atlasses, GIS mapping and remote sensing capabilities for developing improved and integrated crop-livestock-fish farming system, and developing infrastructure for value addition to farm products at the village level. These changes will provide opportunities for off-farm employment and income generation.
- Institutional and infrastructural support is essential for higher agricultural production. There is an urgent need for providing efficient irrigation, power supply, rural roads, cold storages, godowns and food processing units supported by assured and remunerative marketing as developed by the successful dairy and marketing cooperatives.
- Increasing rural income through (a) recognition and reward to the past and ongoing contributions of farm families in improving, selecting and conserving crop genetic resources as envisaged in the Protection of Plant Varieties and Farmers' Rights Bill, 2001, and (b) increased agricultural exports. To increase agricultural exports we will need greater investment in post harvest technology and infrastructure for meeting the requirements of sanitary and phytosanitary measures, ISO 9000, 14000 and Codex Alimentarius standards.

RESTRUCTURING AND RETOOLING OF EXTENSION SERVICES



For the success of the above strategies the country will require restructuring and retooling of extension services for an era of precision farming by establishing Rural Knowledge Centres and retraining of existing extension workers as Rural Knowledge Workers. The legacy of the past 50 years gives us confidence that our farm women and men will overcome difficulties and capitalize on opportunities and help the country to realise Gandhiji's vision of a hunger free India in the early part of this century.

The pictures, and the data for graphs and tables used in this chapter have been provided by ICAR.