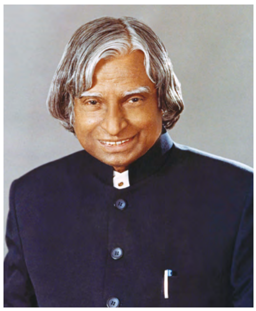
Oration 9:
2005 K.R. Narayanan Oration

Message from the President of the Republic of India



I am happy to know that the Australia South Asia Research Centre of The Australian National University is hosting the 2005 Narayanan Oration on the theme 'Science and Shaping our Agricultural Future' on 27 September 2005.

I visualise Village Knowledge Centres (VKCs) in *panchayats*, which would empower our rural communities. The VKCs would have computers and connectivity and would be windows to the world of knowledge that would reap the benefits of e-governance, tele-education, tele-medicine, e-commerce and e-judiciary initiatives. VKCs ultimately would be used to access village specific information to shape a prosperous future for these communities. An organisation of farmers by the farmers for agricultural farming and marketing is the need of the hour.

On this occasion, I extend my greetings and felicitations to all those associated with the Australia South Asia Research Centre and wish the oration all success.

A.P.J. Abdul Kalam
New Delhi
2005

Science and Shaping our Agricultural Future

M.S. Swaminathan

It is a privilege to deliver a lecture in honour of Dr K.R. Narayanan, immediate Past President of India. Dr Narayanan represents all that is best in Indian culture and democratic system of governance. He rose from the lowest to the highest position in Indian Society by virtue of his innate human and professional qualities. Dr Narayanan knows the pangs of hunger and has therefore been on the forefront of the hunger-free India movement. He encouraged scientists to work on problems relevant to the alleviation of poverty and eradication of hunger. I have therefore chosen the topic, 'Science and Shaping our Agricultural Destiny' for this lecture.

Introduction

From the beginning of time, technology has been a key element in the growth and development of societies. The spread of technologies has however been uneven throughout history. In food production, we have now reached the age of biotechnology and precision farming. Many of the technologies like improved seeds are scale neutral with reference to their relevance to farms of varying sizes but are not resource neutral. Inputs are needed for output and hence those who do not have access to inputs tend to get bypassed by technological transformation. Synergy between technology and public policy has therefore remained a pre-condition for technologies to confer benefit to all sections of the farming community, irrespective of the size of their holdings and their innate capacity to mobilise capital and take risks. Among factors of production, access to irrigation water has been a major determinant of technological change, since without assured irrigation, it is difficult to apply nutrients in quantities essential for high yields, even if genetic strains capable of high productivity are available.

Today, global agriculture is witnessing two opposite trends. In many South Asian countries, farm size is becoming smaller and smaller and farmers suffer serious handicaps with reference to the cost-risk-return structure of agriculture. Farm size in most industrialised countries is becoming larger and larger and farmers are supported by heavy inputs of technology, capital and subsidy. The recent breakdown of the Cancun negotiations of the World Trade Agreement in the field of agriculture reflects the polarisation which has taken place in the basic agrarian structure of industrialised and developing countries.

In India, average yields of major food crops remained well below 1 metric ton per hectare for centuries, until the introduction of high yielding varieties in the 1960s. To produce one metric ton of rice the rice plant needs at least 20 kg of nitrogen and appropriate quantities of phosphorus, potash and micronutrients. The native soil fertility was often below this level and hence yields tended to remain below a ton.

The steps taken after independence to improve the productivity of food crops fall under the following major categories:

- package of technology
- package of services in areas such as input supply and extension
- package of public policies in areas such as land reforms, rural infrastructure development, investment in irrigation, input and output pricing policies and assured and remunerative marketing.

Improvement of agricultural production through the productivity pathway is essential for both resource poor farmers and consumers. Casual agricultural labourers are the largest in number among the chronically poor and cultivators the second largest group. Most of the chronically poor were either landless or near-landless. The smaller the farm, the greater is the need for increasing productivity, so that the farm family has a higher marketable surplus. Productivity improvement also tends to reduce the cost of the commodity, thereby benefiting resource poor consumers. Above all productivity improvement is essential for safeguarding the remaining forests, since otherwise forest land will get converted to produce food. Thus, the productivity pathway of agricultural advance helps in strengthening ecological, livelihood and food security.

What we need is an evergreen revolution, which can help to increase productivity in perpetuity without associated ecological harm (Swaminathan 1996). Exploitative agriculture offers great dangers if carried out with only an immediate profit or production motive. 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, in the long run, into an era of agricultural disaster rather than one of agricultural prosperity (Swaminathan 1968). We need ecotechnologies rooted in the principles of ecology, economics, gender and social equity and employment generation. The vulnerable sections need job-led economic growth and not jobless growth.

In spite of striking agricultural progress and democratic decentralisation, chronic and transient poverty and poverty induced malnutrition are widespread. International and national media refer to this as the co-existence of 'grain mountains and hungry millions' (Swaminathan 2005). Section 2 outlines the issues in the context of food security and access, Sections 3 and 4 the transition from the green to gene to evergreen revolution in rice and wheat, Section 5 provides case studies that show how we can bridge the technological divide and Section 6 concludes.

Food Availability, Access, Absorption and Threats to Food Security

Food security was formerly considered essentially in terms of production. It was assumed that adequate food production would ensure adequate availability of food in the market as well as in the household. In the '70s, it became clear that availability alone does not lead to food security. It is becoming evident that even if availability and access are satisfactory, the biological absorption of food in the body is related to the consumption of clean drinking water as well as to environmental hygiene. Finally, even if physical and economic access to food is assured, ecological factors will determine the long-term sustainability of food security systems. We have to define food as physical, economic, social and ecological access to balanced diet and clean drinking water, so as to enable every child, woman and man to lead a healthy and productive life. The needs of each age group must be addressed (see cycle approach described by MSSRF 2001). Such an approach will involve the following steps (Swaminathan 2002a, 2002b).

Food Availability

This is a function of both home production and imports. There is no time to relax on the food production front. The present global surplus of food grains is the result of inadequate consumption on the part of the poor, and should not be mistaken as a sign of over-production.

Food Access

Lack of purchasing power deprives a person from access to food even though food is available. Inadequate livelihood opportunities in rural areas are responsible for household nutrition insecurity. For example, India today has over 30 million tonnes of wheat and rice in government godowns; yet poverty induced hunger affects over 200 million persons. It is endemic in south Asia and sub-Saharan Africa (Ramalingaswami et al. 1997; WFP 2001). Macroeconomic policies, at the national and global level, should be conducive to fostering job-led economic growth based on micro-enterprises supported by micro-credit. Where poverty is pervasive, suitable measures to provide the needed entitlement to food, should be introduced. The State of Maharashtra introduced, nearly 25 years ago, an Employment Guarantee Scheme to assist the poor to earn their daily bread during seasons when opportunities for wage employment are low.

Food Absorption

Lack of access to clean drinking water, poor environmental hygiene and poor health infrastructure, lead to poor assimilation of the food that is consumed. Nutrition security cannot be achieved without environmental hygiene, primary health care and clean drinking water security. Culinary habits also need careful evaluation as some methods of cooking may lead to the loss of vital nutrients.

Threats to Food Security

The most important among the internal threats to sustainable food security is the damage to the ecological foundations essential for sustained agricultural advance, like land, water, forests and biodiversity. Second, in the areas of farm economics, resource flow to the agriculture sector is declining and indebtedness of small and marginal farm families is rising. Input costs are increasing, while factor productivity is declining. Third, a *technology fatigue* has further aggravated farmers' problems, since the smaller the farm the greater is the need for sustained marketable surplus, in order to have cash income. Linkages between the laboratory and the field have weakened and extension services have often little to extend by way of location, time and farming system specific information and advice (chapter on 'Wake Up Call' in the NCF 2006).

The external threats include the unequal trade bargain inherent in the WTO agreement of 1994, the rapid expansion of proprietary science and potential adverse changes in temperature, precipitation, sea level and ultraviolet ß radiation. Though it is now over 10 years since the WTO regime started operating in agriculture, serious attempts are yet to be made to launch in rural areas movements for quality literacy (sanitary and phytosanitary measures and codex alimentarius standards of food safety), trade literacy (likely demand-supply and price situation), legal literacy (IPR, Farmers' Rights) and genetic literacy (genetically modified crops). No wonder the prevailing gap between potential and actual yields even with technologies currently on the shelf is very wide (Table 1).

Table 1: Comparative crop productivity (kg/ha)

Crop	USA	China	India
Maize	8,900	4,900	2,100
Paddy	7,500	6,000	3,000
Soybeans	2,250	1,740	1,050
Seed cotton	2,060	3,500	750
Tomato	6,250	2,400	1,430

Source: 'Wake Up Call' chapter in NCF (2006).

In the area of technology, there is also need to bridge the growing digital and genetic divides. Post-harvest technology is poor and there is little value addition particularly in the case of fruits, vegetables and spices including a wide range of tubers and medicinal and aromatic plants. Sustainable intensification, ecologically, economically and nutritionally desirable diversification and value addition to the entire biomass are important for raising small and marginal farm families above subsistence level. All this will call for initiating an era of knowledge intensive agriculture. Modern information communication technologies (ICT) afford an opportunity for launching a knowledge revolution in rural India.

Technological Transformation of Productivity, Profitability and Sustainability: Rice

Asia grows most of the world's rice output and 90 per cent of rice is produced by small farmers who depend on it for their livelihood and food security. The role of rice in national and global food security systems will increase, not only because of increases in population and purchasing power, but also because of likely changes in climate and sea level rise due to global warming. An immediate task is bridging the gap between potential and actual yields, widely prevalent in several rice growing countries and particularly in different parts of India. This is possible even at currently available levels of technology, through mutually reinforcing packages of technology, services and public policies. In the decades ahead, more rice will have to be produced under conditions of shrinking per capita arable land and irrigation water availability and expanding biotic and abiotic stresses. Due to breeding efforts based on an appropriate integration of Mendelian and molecular techniques, the ceiling to yield is being raised continuously (Figure 1).

Aided by biotechnology, the greatest potential for productivity gains in yield ceiling in the future lies in rainfed environments (Peacock and Chaudhury 2002). Integrating genetic efficiency with genetic diversity of diverse gene pool through pre-breeding and participatory breeding should be encouraged (Figure 2). Hybrid rice, 'super rice' and 'super hybrid rice' are likely to dominate the rice world in the future. What is however important is the initiation of research which can lead to the standardisation of methods of feeding the rice plant for higher yields in an ecologically sustainable manner. Research on breeding and feeding for higher yields should proceed concurrently.

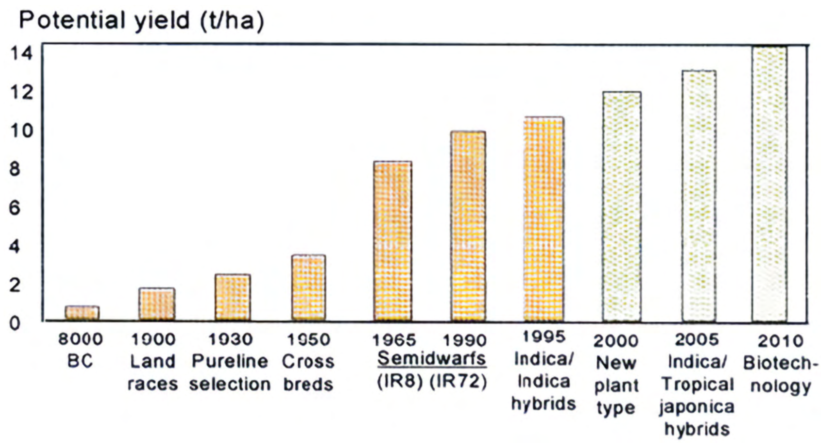


Figure 1: Progress in the yield potential of rice

Figure 2: Paradigm shift: Adding the dimension of environmental sustainability

We have several simple and elegant tools that enable us to manipulate the rice genome to elicit desirable responses — tolerance to pests and diseases, moisture stress, salinity-alkalinity, heat, increased photosynthetic efficiency, dry matter accumulation, and source sink partitioning. Rice gene sequence information is widely viewed as an invaluable asset for developing products and technologies. Because of advances in molecular mapping and breeding, there are new opportunities for improving the nutritive qualities of rice, with particular reference to iron, vitamin A and other micronutrients. Under an expanding intellectual property rights (IPR) regime, it is important that research for public good receives the needed support at the national and international levels so that the resource poor can gain from it. Farmers have to achieve revolutionary progress in productivity, quality and value addition. The emerging ecological, economic and social challenges have to be met through partnerships among rice researchers and developmental organisations, committed to the cause of improving the productivity, profitability, sustainability and stability of rice farming systems.

Pingali et al. (1997) have described in detail the steps needed to increase rice production in Asia to meet future needs. If global warming and the associated changes in temperature, precipitation and sea level rise do occur, the position of rice in national and global food security systems will increase, since rice has the ability to grow under very diverse environmental conditions. Rice is by far the best-adapted crop to lowland soils that are prone to flooding during wet season. They draw attention to the following challenges facing rice research and development agencies:

- Productivity gains from the exploitation of Green Revolution technologies are close to exhaustion.
- In the absence of further technical change, Asian farmers face increasing costs per tonne of rice produced.
- Adverse agricultural externalities are increasing due to lack of holistic perspective of the farm resource base management.
- Despite an anticipated decline in per capita rice consumption, aggregate Asian demand for rice is expected to increase by 50 to 60 per cent during the 1990–2025 period due to population increase and poverty reduction.
- Economic growth and the commercialisation of agricultural systems could reduce the competitiveness of rice relative to other crops and other farm enterprises.
- An upward shift in rice yield frontier is necessary to meet future rice requirements and to sustain farm-level profits.

Compounding these problems, there are potential dangers arising from the diminishing investment in research in institutions devoted entirely to national and international public good and the expanding intellectual property rights (IPR) regime. The question now is how much more improvement can we bring about in productivity without ecological harm? In other words, can we launch an evergreen revolution in rice in the new millennium, marked by sustained advances in productivity, profitability, stability and sustainability of rice farming systems (Swaminathan 1996, 2000, 2002a). How can we also increase the role of rice in the nutritional security of families dependent on it for their dietary energy supply? How can rice production be insulated from the adverse impact of potential changes in precipitation, temperature and rise in sea level? Above all, how can we maintain and strengthen international cooperation in rice improvement?

Increasing Production and Productivity

Bridging the Yield Gap

Due to imperfect adaptation to local environments, insufficient provision of nutrients and water, and incomplete control of pests, diseases and weeds the present average rice yield is just 40 per cent of what can be achieved even with technologies currently on the shelf. There is considerable scope for further investment in land improvement through drainage, terracing, control of acidification, etc. in areas where these have not already been introduced. While irrigated areas are making good progress, there is need for more attention on intensive research and development in rainfed, low land and upland areas. Ensuring that benefits from technology accrue to resource poor or marginal farmers will require special efforts as outlined in the case studies in Section 5.

An integrated approach is necessary to remove the technological, infrastructure and social and policy constraints responsible for the productivity gap and in some cases, productivity decline. Reducing the cost of production through eco-technologies and improving income through efficient production and post-harvest technologies will help to enhance opportunities for both skilled employment and farm income. Public policies should not only pay attention to agrarian reform and input and output pricing, but also to reaching the unreached in technology dissemination through training, techno-infrastructure and trade. A constraints analysis of the type shown in Figure 3 should be undertaken. Public policy on anticipating and avoiding production constrains research on facilitating adoption of new technology by small farmers should receive as much attention as agronomic research.

Future agricultural production programs will have to be based on a three-pronged strategy designed to foster an evergreen revolution, which leads to increased production without associated ecological and social harm. These strategies include defending the gains already achieved, extending the gains to rainfed areas and making new gains through farming systems diversification and value addition.

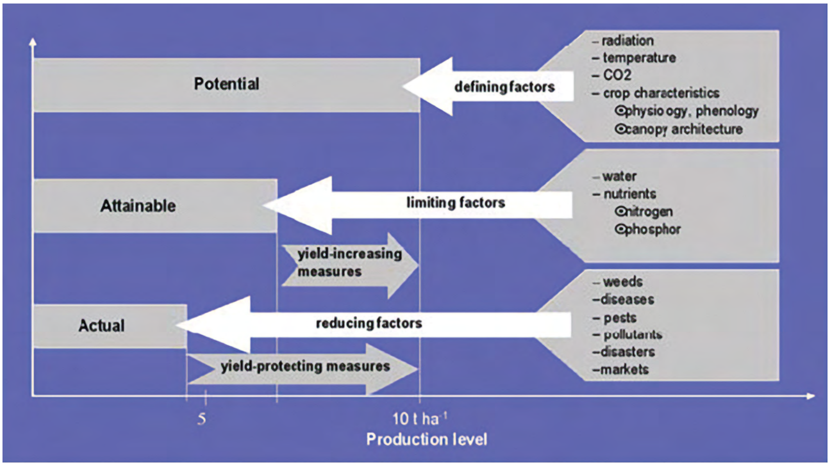


Figure 3: Yield gap — constraints analysis

Source: Modified from Rabbinge et al. (1994).

Defending the Gains Already Achieved

There is need for stepping up maintenance research for ensuring that new strains of pests and pathogens do not cause crop losses and prevent the introduction of invasive alien species. Water harvesting, watershed development and economic and efficient water use can help to enhance productivity and income considerably. Where water is scarce, high value but low water requiring crops should be promoted. As pulses and oilseeds are important income earning and soil enriching crops, they should be included in rice farming systems.

Extending the Gains

There is need to develop and disseminate eco-technologies for rainfed and semi-arid, hill and island areas, which have so far been bypassed by modern yield enhancement technologies. Regional imbalances in agricultural development are growing based largely on the availability of assured irrigation on the one hand and assured and remunerative marketing opportunities on the other. The introduction of eco-regional technology missions that look at all the links in the chain and work towards the stipulated goal, aimed at providing appropriate packages of technology, the specific farm infrastructure services required by the technology (techno-infrastructure), and input and output pricing and marketing policies, will help to include the excluded in agricultural progress. Technologies for elevating and stabilising yields are available for semi-arid and dry farming areas (Ryan and Spencer 2001). Therefore the emphasis should be on farming systems that can optimise the benefits of natural resources in a sustainable manner and not merely on cropping systems. Dry farming areas are also ideal for the cultivation of low water requiring but high value pulses and oilseeds.

Making New Gains

Farming systems intensification, diversification and value-addition should be promoted. Watershed and wasteland atlases should be used for developing improved farming systems, and designing what crops to grow based on soil structure so as to provide more income and jobs. Value addition to primary products should be done at the village itself. This will call for appropriate institutional structures which can help provide key centralised services to small and marginal farm families and provide them with the power of scale in eco-farming involving techniques like integrated pest management, integrated nutrient supply, scientific water management, precision farming, etc., as well as in marketing. A quantum leap in sophistication of management of all production factors will be required to sustain yield gains from the present levels to the commercially feasible threshold of about 80 per cent yield potential (Swaminathan 2001).

Small Farm Management

Institutional structures, which will confer upon farm families with small holdings, the advantages of scale at both the production and post-harvest phases of agriculture, are urgently needed. For example, thanks to the cooperative method of organisation of milk processing and marketing, India now occupies the first position in the world in milk production. Strategic partnerships with the private sector will help farmers' organisations to have access to assured and remunerative marketing opportunities.

Vital Areas for Sustainable Advances in Rice Productivity

There are great opportunities for achieving higher yields per unit of land; provision of water at the right time to rice farmers enabled them to shift to precision farming methods. The five vital areas of research, development and extension, which need attention from the point of view of achieving environmentally sustainable advances in rice productivity, are soil health and fertility management; water management; integrated plant health management; energy management; and post-harvest management (for more details see Swaminathan 2004).

Evergreen Revolution

As earlier mentioned, this implies improvement of productivity in perpetuity without associated ecological harm. Rice scientists should foster an evergreen revolution in rice through partnerships for the development and dissemination of precision farming technologies. The major goals that were proposed for the FAO sponsored International Network for an Evergreen Revolution in Rice by Swaminathan (2002b) are as follows:

- Initiate an Integrated Gene Management program.
- Improve productivity per unit of input, particularly of nutrients and water and thereby reduce the cost of production.
- Substitute to the extent possible knowledge and farm produced inputs for capital and market-purchased chemicals.
- Enhance the ecological and social sustainability of high-yield technologies.
- Increase farmers' income and opportunities for skilled employment.
- Establish an information grid and farmer-participatory knowledge system for empowering women and men engaged in rice farming with new knowledge and skills, thereby conferring on rice farmers the strengths of Knowledge Societies.

Research Strategies and Priorities

These strategies include Integrated Gene Management (IGM), integrated efforts in feeding and breeding rice for high productivity, information empowerment, overcoming hidden hunger caused by micronutrient deficiencies and promoting rice as a substrate for oral vaccines.

The IGM program in rice should be based on conservation, sustainable use and equity in sharing benefits. The over 100,000 strains available today in rice is the result of the conservation ethics of farm and tribal families. Most of them are from Asian countries. India is the largest contributor to this collection followed by Laos (Appa Rao et al. 2002).

Overcoming Hidden Hunger Caused by Micronutrient Deficiencies

The challenge of micronutrient deficiencies in diet is becoming great especially for the chronically poor. Iodine, Vitamin A and iron deficiencies are serious in many parts of the developing world. Worldwide, iron deficiency affects over one billion children and adults. Recent analyses from the United States Institute of Medicine (Earl and Woteki 1998; Burkhardt et al. 1997; Swaminathan 2002a) highlight the effect of severe anaemia in accounting for up to one in five maternal deaths. Maternal anaemia is pandemic and is associated with high MMR; anaemia during infancy, compounded by maternal under-nutrition, leads to poor brain development. Iron deficiency is also a major cause of permanent brain damage and death in children and limits the work capacity of adults (Smith and Haddad 2000; Swaminathan 2002b). There is not enough appreciation of the serious adverse implications to future generations arising from the high incidence of low birth weight (LBW) among newborn babies. LBW is a major contributor to stunting and affects brain development in the child. The new millennium will be a knowledge century, with agriculture and industry becoming more knowledge intensive. Denial of opportunities for the full expression of the innate genetic potential for mental development even at birth is the cruellest form of inequity that can prevail in any society (Smith and Haddad 2000). We must take steps to eliminate as soon as possible such inequity at birth leading to a denial of opportunities to nearly one out of every three children born in South Asia, for performing their legitimate role in the emerging knowledge century.

Wherever rice is the staple, a multi-pronged strategy for the elimination of hidden hunger should be developed by rice scientists. IRRI has undertaken research on enriching rice genetically with iron and other micronutrients. Fortification, promotion of balanced diets, new semi-processed foods involving an appropriate blend of rice and micronutrient-rich millets as well as genetic improvement, could all form part of an integrated strategy to combat the following major nutritional problems in predominantly rice-eating families:

- protein-energy malnutrition
- nutritional anaemia (iron deficiency)
- vitamin A deficiency
- iodine deficiency

- dietary deficiencies of thiamin, riboflavin, fat, calcium, vitamin C and zinc.

Swaminathan (2002a) suggested that the International Rice Commission could include nutrition security aspect as an integral part of the International Network. We must fight the serious threat to the intellectual capital of developing countries caused by low birth weight children and hidden hunger (UN Commission on Nutrition). Some of the research areas worthy of attention in this context are described below.

Breeding for Nutritional Quality

Nutritive quality is as important as cooking quality for countries in tropical Asia, where rice is the principal source of dietary protein, vitamin (B_1) and minerals (Fe, Ca) (Juliano and Villareal 1993). Rice provides about 40 per cent of the protein in the Asian diet. Among the cereal proteins, rice protein is considered to be biologically the richest by virtue of its high digestibility (88 per cent), high lysine content (±4 per cent) and relatively better net protein utilisation. Yet, it is nutritionally handicapped on account of two factors *viz*: (i) its inherently low protein content (6–8 per cent); and (ii) inevitable milling loss of as much as 15–20 per cent. Unlike in other cereals, increased protein content in rice does not result in decreased protein quality as all of its fractions (glutelin 65 per cent, globulin and albumin 15 per cent and lysine-cysteine rich prolamin 14 per cent) are rich in lysine and other essential amino acids. Even a marginal increase of 2 percentage points of protein, therefore, would mean 10–15 per cent increase in the nutritionally rich protein intake in our diet.

Genetic Engineering Approaches for Correcting Micronutrient Deficiencies

Breeding for Nutritional Improvement was recommended at the 19th Session of the International Rice Commission, which called for an increase in focus on strategies to combat malnutrition (Philip et al. 2000; Gopalan 2001). There are four categories of direct interventions believed to be successful in reducing micronutrients malnutrition: supplementation, fortification, dietary diversification and genetic enhancement. Nutritional status of populations will focus on the potential for improving malnutrition, primarily micronutrient malnutrition through genetic improvement.

Golden Rice

About 250 million people worldwide are deficient in vitamin A. Over 5 million children in South and South-East Asia are reported to suffer from the serious eye disease 'xerophthalmia' every year, and about 500,000 of them eventually become partially or totally blind due to deficiency of vitamin A. Besides affecting vision, vitamin A deficiency predisposes children to varied respiratory and intestinal diseases resulting in high mortality. Researchers from Swiss Federal Institute of Technology inserted these genes from daffodil and a bacterium into temperate rice plants to produce a modified grain, which has sufficient b carotene (precursor of vitamin A) to meet total vitamin A requirements in a typical Asian diet (Ye et al. 2000). Golden rice technology was made available to developing nations for research. If this technology can be moved to the production stage, it could represent an important contribution to improved human nutrition. In particular, rice fortified genetically with vitamin A and iron will be very useful to improve the nutritional status of pregnant and nursing women.

Iron Deficiency

Iron deficiency anaemia (IDA) is the world's most common nutritional deficiency. It affects pregnant and nursing women and young children most commonly. IDA in mothers predisposes to still births, neonatal mortality, anaemia and low birth weight in infants, and increases the risk of maternal mortality (Swaminathan 2002a; Earl and Woteki 1994). Regular intake of iron or administration of iron prevents anaemia. Daily supplementation with iron-folic acid tablets is a low-cost and effective intervention.

Technological Transformation of Productivity, Profitability and Sustainability: Wheat

The rediscovery of Mendel's laws of genetics in 1900 opened up a new era in crop breeding in general, and wheat breeding in particular. Although the art of plant breeding is as old as the beginning of agriculture nearly 12,000 years ago, systematic research in the areas of genetics and cytogenetics, which commenced in the early part of the 20th century, created uncommon opportunities for improving the productivity, profitability, stability and sustainability of wheat production. Even before

Mendel (1822–1884), plant hybridisers like Kolreuter, Knight, Gartner and Burbank were able to produce improved varieties of crops through careful observation and selection. The concept of sustainability to which we now attach great importance was recognised long ago as essential for sustained agricultural progress.

During the past 100 years, Mendelian genetics has helped not only to exploit naturally occurring genetic variability but has also accelerated the process of generation, manipulation and combination of new variability. We are now in a state of transition from Mendelian to molecular breeding. Breeder's eye for selection and for spotting the winner will continue to play an important part in successful plant breeding.

It is projected that global demand for wheat will increase by 40 per cent by the year 2020. Also, 67 per cent of the world's wheat consumption will be in developing countries. Between 1961 and 1990, yield increases accounted for 92 per cent of the additional cereal production in developing countries. In the years ahead, there is no option except to produce more from less per capita land and water resources. Can we sustain the yield revolution in wheat? It will be useful to consider this issue in the context of the genetic pathways which led to the wheat revolution of the 20th century.

Progress in Yield Improvement

Wheat is a crop of great antiquity. We can identify at least four major phases in the evolution of wheat breeding during the 20th century.

Phase I (1900–30): Early Days of Mendelian Genetics

Soon after the re-discovery of Mendel's laws of genetics in 1900, systematic work on the genetics of resistance to stem, leaf and stripe rusts started. Selection from naturally occurring genetic variability also began.

During the early part of the 20th century, the major breeding challenges were in the area of resistance to rusts and grain quality improvement. A study of the yield improvement achieved between 1900 to 1930 in USA shows only limited progress. The emphasis was more on stability of production through disease resistance than on achieving quantum jumps in yield.

Phase II (1930–60): Enlarging the Base of Theory and Its Application

This period was marked by the introduction of cytogenetic knowledge and tools in wheat improvement. This phase of wheat improvement was characterised by widening the gene pool used by breeders, incorporation of genes for the semi-dwarf plant type, shuttle breeding and breeding to meet the challenge of physiologic specialisation in pathogens.

Phase III (1960–80): The Green Revolution Phase

This phase is also generally referred to as the Green Revolution era. It was characterised by revolutionary progress in improving wheat production and productivity in several developing countries like India and Pakistan. The introduction of the semi-dwarf plant type enabled the wheat plant to yield well under conditions of good soil fertility and irrigation water management. Farmers who were used to harvesting 1 to 2 tonnes of wheat per hectare started harvesting over 5 t/ha (Swaminathan 1993). In view of the widespread interest in this remarkable transformation in India's agricultural destiny, it will be useful to summarise some of the highlights.

During 1942–43, the Indian subcontinent witnessed a severe famine in Bengal resulting in the death of nearly 3 million children, women and men. This prompted Jawaharlal Nehru, the first Prime Minister of Independent India to remark in 1948, 'everything else can wait, but not agriculture'.

In 1964, a National Demonstration Program 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 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 hectares in 1963–64 to over 4 million hectares in 1971–72. A small government program became a mass movement (Swaminathan 1993). Wheat production in India rose from 10 million tonnes in 1964 to 17 million tonnes in 1968. In 1999, Indian farmers harvested about 72 million tonnes of wheat, taking India to the second position in the world in wheat production.

Greater interdisciplinary collaboration among breeders, plant pathologists, agronomists, physiologists, soil scientists, entomologists, nemotalogists, economists and other social scientists, climatologists and policymakers was the principal factor responsible for the success of the green revolution. The green revolution era can also be termed 'the golden age in interdisciplinary and international collaboration' in wheat improvement for sustainable food security. The concept of shuttle breeding transcended continental boundaries and a global college of wheat scientists emerged. Above all, the green revolution showed how to generate synergy between technology and public policy.

Phase IV (1980–2000): Transition from Mendelian to Molecular Breeding

The last 20 years have witnessed great progress in using sophisticated approaches to wheat breeding. Hybrid wheat is reaching the possibility of large-scale commercial cultivation. The use of genetic-cytoplasmic male sterility and of chemical hybridising agents (CBA) are responsible for progress in the commercial exploitation of hybrid wheat. Different management practices such as lower seed rate, raised bed planting, split nitrogen application and different row width are being tried to enhance the expression of hybrid superiority. The cultivation of hybrid wheat is slowly gaining in momentum in South Africa, Australia (New South Wales), China, Argentina and France. The use of wild relatives in genetic engineering is growing (Khush and Baenziger 1998). The global average yield of wheat is 2.5 t/ha; the low average yield of wheat is because of large areas of wheat being under rainfed conditions. Progress in improving yield is however steady. So far, advances in yield improvement have been associated with increases in harvest index (i.e. grain/straw ratio). Further advances will depend upon greater biomass production and not merely on partitioning the phytosynthates.

Challenges Ahead

At the dawn of the 21st century, we can look back with pride and satisfaction on the revolution, which farm men and women have brought about in our agricultural history during the 20th century. The Punjab farmer, hardworking, skilled and determined, has been the backbone of the revolution.

While we can and should rejoice about the past achievements of farmers, scientists, extension workers and policymakers, there is no room for complacency. We will face several new problems, of which the following are important.

- First, increasing population leads to increased demand for food and reduced per capita availability of arable land and irrigation water.
- Second, improved purchasing power and increased urbanisation lead to higher per capita food grain requirements due to an increased consumption of animal products.
- Third, marine fish production is tending to become stagnant and coastal aquaculture has resulted in ecological and social problems.
- Fourth, there is increasing damage to the ecological foundations of agriculture, such as land, water, forests, biodiversity and the atmosphere and there are distinct possibilities for adverse changes in climate and sea level.
- Fifth, while dramatic new technological developments are taking place, particularly in the field of biotechnology, their environmental, food safety and social implications are still being debated.
- Finally, gross capital formation in agriculture is tending to decline in both public and private sectors during the present decade. The rate of growth in rural non-farm employment has been poor.

Since land and water will be shrinking resources for agriculture, there is no option in the future except to produce more food and other agricultural commodities from less per capita arable land and irrigation water. In other words, the need for more food has to be met through higher yields per unit of land, water, energy and time. It would therefore be useful to examine how science can be mobilised for raising further the ceiling to biological productivity without associated ecological harm. It will be appropriate to refer to the emerging scientific progress on the farms as an evergreen revolution, to emphasise that the productivity advance is sustainable over time since it is rooted in the principles of ecology, economics, social and gender equity and employment generation.

The Green Revolution based on Mendelian genetics has so far helped to keep the rate of growth in food production above population growth rate. The green revolution was however, the result of public good research supported by public funds. The technologies of the emerging gene revolution based on molecular genetics in contrast, are spearheaded by proprietary science and can come under monopolistic control. How can we take the fruits of the gene revolution to the unreached? This is a challenge, which we need to address.

I would like to list five major challenges, which will confront the wheat scientists during this century.

Equity

The Convention on Biological Diversity (CBD) stipulates that plant exploration, collection and introduction should be based on the principles of prior informed consent and equity in benefit sharing. Therefore exchange of wheat genetic resources in the future will be possible only on the basis of Material and Knowledge Transfer Agreements.

Ecology

Ecological sustainability of high productivity will be an important determinant in relation to the choice of technologies. For example, if hybrid wheat can enable us to produce 8–10 t/ha, over 300 kg of nitrogen will be needed by the crop. It is obvious that if the nutrient needs of hybrid or other high-yielding wheat varieties are to be met entirely through mineral fertilisers, there will be serious environmental problems including nitrate pollution of ground water. Hence, success in achieving high productivity on a sustained basis will depend upon our ability to develop new methods of feeding the plant. Research on breeding and feeding should be carried out concurrently by a team of breeders, physiologists, agronomists and soil scientists.

Concerns Relating to Genetically Modified Organisms (GMOs)

There are growing public and political concerns relating to GMOs. The concerns relate to food and environmental safety and bioethics. It is essential that these concerns are carefully addressed through a mechanism for risk-benefit analysis, which inspires public confidence. An integrated disease management strategy should be developed to ensure that GMOs with novel genetic combinations for disease resistance do not break down due to the emergence of new physiological strains of pathogens. Also, regulatory procedures should be transparent and should inspire public confidence. There is also need for integrating molecular breeding with organic farming methods.

Expansion of Proprietary Science

The world is witnessing an expansion of proprietary science governed by Intellectual Property Rights (IPR). Public good research supported from public funds, in contrast, is shrinking. What will be the impact of such a situation on international varietal or other trials organised by CIMMYT? Is the golden age of cooperative research coming to an end? How can we find a balance between public good and private profit?

Climate Change and Safeguarding Genetic Diversity

Will molecular breeding resulting in 'super wheats' lead to a high degree of genetic homogeneity in farmers' fields? We know that genetic homogeneity will enhance genetic vulnerability to biotic and abiotic stresses. Hence, we should foster an integrated program of pre-breeding and participatory breeding. Pre-breeding will help to generate novel genetic combinations, while participatory breeding with farm families will help to combine genetic efficiency with genetic diversity. Numerous location specific varieties can be developed in this manner. This will be the most effective way of meeting challenges arising from potential changes in temperature, precipitation and sea level as a result of global warming arising from the growing imbalance between carbon emissions and absorption.

Sustaining and Strengthening Agricultural Progress

In a predominantly agricultural country like ours, agricultural progress serves as the most effective safety net against hunger and deprivation. There is need for intensifying our efforts to improve agricultural productivity, quality and income. An urgent need in this area is the strengthening of institutional structures, which can help to confer on small and marginal farmers, the ecological and economic benefits of scale at both the production and post-harvest phases of farming. The following are some of the institutional structures whose reach has to be extended.

Without socially relevant and beneficial institutional structures, the extrapolation domain of successful experiences and development efforts will remain limited.

Table 2

S. No	Sector	Institutional Mechanism
1.	Dairy	Cooperatives
2.	Poultry	Egg Coordination Council
3.	Integrated on-farm and off-farm employment	Biovillages
4.	Power of scale to small producers	Small Farmers' Agri-business Consortium
5.	Technological upgrading of production and post-harvest sectors	Agri-clinics Agri-business centres
6.	Group action for micro-enterprises supported by micro-credit	Market-driven self-help groups
7.	Timely and affordable credit	Kisan credit cards, integrated informal and formal banking systems
8.	Operation of minimum support price	Food Corporation of India and State Food Corporations, as well as assured buy-back arrangement and contract farming by the private sector

Dr K.R. Narayanan inaugurated the JRD Tata Ecotechnology Centre at the M.S. Swaminathan Research Foundation (MSSRF) in 1998. In the second part of my lecture, I shall briefly summarise the work done in MSSRF on issues relating to linking ecological security with food and livelihood security in a mutually reinforcing manner.

In 2005, MSSRF whose work has always received encouragement and support from Dr K.R. Narayanan will be completing 15 years of work in the areas of research, education, capacity building, mentoring, policy advocacy and networking. In retrospect, the decision made in 1990 to choose integrated coastal zone management for priority attention with a view to linking the ecological security of coastal areas and the livelihood security of coastal communities (both fisher and farming families) in a mutually reinforcing manner has proved to be a wise one. The Coastal System Research (CSR) program of MSSRF was designed to give concurrent scientific attention to sea and land surfaces along the shoreline. The CSR program was initiated in anticipation of potential adverse changes in sea level as a result of global warming. An early scientific step in this process was the conservation of mangrove genetic resources and the rehabilitation of degraded mangrove wetlands in Tamil Nadu, Andhra Pradesh, Orissa and West Bengal. Such mangrove forests served as 'bio-shields' during the Tsunami attack on 26 December 2004. They had also served a similar purpose during the super cyclone in Orissa in 1999. These observations have helped to generate at both the political and public levels interest in the development of bio-shields along the shoreline.

The following are among the major contributions of the CSR program during 1990–2005.

- Restoration of degraded mangrove wetlands along the east coast of India: the area restored by MSSRF scientists alone comes to 1475 ha of degraded area restored with the help of 5240 families organised in 33 village mangrove councils. Nearly 7 million saplings were planted.
- Conservation strategy for mangrove genetic resources in the Asia-Pacific region and the establishment of a Genetic Garden for meeting the challenge of sea level rise at Pichavaram, Tamil Nadu.
- Genome mapping of mangrove species (*Avecinnia marina*) and the identification and transfer of genes for sea water tolerance from *A.marina* to rice, mustard and pulses.
- Development of a trusteeship mode of management of the Gulf of Mannar Biosphere and helping to create the first Biosphere Trust in the world, with the support of the Global Environment Facility and the governments of Tamil Nadu and India.
- Development of integrated Bio-shield – Biovillage – Village Knowledge Centre Programmes in coastal areas.
- Development of a code for the participatory management of mangrove ecosystems, involving cooperative action among fisher and farm communities and Forest and Fisheries departments.
- Development of a comprehensive strategy for the rehabilitation of Tsunami ravaged coastal areas in Tamil Nadu, Pondicherry, Andhra Pradesh, Kerala and the Andaman and Nicobar Islands.
- Drawing national and international attention to the urgent need for conserving mangrove wetlands and promoting the adoption of a Charter for Mangroves.
- Organising national and international training programs for creating a cadre of well-trained mangrove forest managers.
- Preparation of comprehensive atlases of the mangrove forests of Tamil Nadu, Andhra Pradesh and Orissa.

- Standardisation and popularisation of mangrove propagation methods based on both vegetative and micro-propagation techniques; and helping local communities to undertake the raising and planting of mangrove forests.
- Preparation of a tool kit for raising bio-shields in coastal areas.
- Establishment of the first community developed and managed artificial reef in the Gulf of Mannar area based on the technology developed by the Central Marine Fisheries Research Institute.
- Developing eco-agriculture strategies for coastal drylands through participatory evaluation and propagation of varieties of pulses developed at the Bhabha Atomic Research Centre through mutation breeding, and the establishment of green belts and genetic garden of horticultural crops for sustainable food and livelihood security.
- Launching a Fish for All movement at Kolkata in December 2003 in association with the World Fish Centre (ICLARM) located in Penang, Malaysia, to promote sustainable capture and culture fisheries movements.
- Advocacy for the adoption of aquarian reform measures designed to promote harmony between artisenal and mechanised fisheries as well as aquaculture and agriculture.

The CSR approach helped MSSRF to propose a comprehensive and integrated strategy for launching a 'Beyond Tsunami' program based on concurrent attention to ecological, livelihood, agronomic, psychological and educational rehabilitation. The experience gained by MSSRF in developing integrated coastal zone management procedures helped a National Committee set up by the Ministry of Environment and Forests under my Chairmanship to review the Coastal Regulation Zone Notification of 1991, to propose 12 basic guiding principles for the sustainable and scientific management of the coastal zone. Some of these are:

- Ecological and cultural security, livelihood security and national security should be the cornerstones of an integrated coastal zone management policy.
- The coastal zone would include an area from territorial limits (12 nautical miles), including its sea-bed to the administrative boundaries or the biological boundaries demarcated on the landward side of the sea coast. The coastal zone management should also include

the inland tidal water bodies influenced by tidal action and the land area along such water bodies. This area should be taken up for an integrated, cohesive, multi-disciplinary and multi-sectoral coastal area management and regulatory system.

- Regulation, education and social mobilisation should be the three major components of a participatory and sustainable Coastal Zone Management strategy. Panchayati Raj institutions in coastal areas should be fully involved in the educational and social mobilisation programs.
- Coastal regulation needs to be based on sound scientific and ecological principles and should safeguard both natural and cultural heritage. Heritage sites need particular care and should be conserved in their pristine purity. These include areas of environmental significance, rich in biodiversity and scenic beauty. Bird sanctuaries, parks and breeding grounds of migratory birds should be protected.
- The precautionary approach should be used where there are potential threats of serious or irreversible damage to ecologically fragile critical coastal systems and to living aquatic resources. Scientific uncertainty should not be used as an excuse for the unsustainable exploitation of coastal resources — both living and non-living.
- Ecological economics should underpin economic activities, so that present day interests and future prospects are not antagonistic. Significant biological, cultural and natural assets should be considered incomparable, invaluable and irreplaceable and should receive overriding priority in the allocation of resources for coastal area protection and conservation.
- Coastal policy and regulations should be guided by the principles of gender and social equity as well as intra-generational and inter-generational equity, (i.e. the interests of future generations). They should be based on Mahatma Gandhi's dictum, 'Nature provides for everyone's needs, but not for anyone's greed'. All stakeholders should be involved in decision making. Precious biological wealth, coming under Marine Biosphere Reserves, should be managed in a trusteeship mode, with all the stakeholders protecting the unique natural wealth of biosphere reserves as trustees and not as owners. A case study should be made on how the Gulf of Mannar Biosphere Trust is functioning, so that the Trusteeship pattern of sustainable management by the principal stakeholders can be replicated.

- The regeneration of mangrove wetlands, coral reefs and sea grass beds as well as the promotion of coastal forestry and agro-forestry will confer both short- and long-term ecological and livelihood benefits. Carbon sequestration through coastal bio-shields will make an important contribution to promoting a balance between carbon emission and absorption, in addition to offering protection during coastal storms and calamities like tsunami. An important lesson taught by the tsunami disaster is that the rehabilitation of degraded mangrove forests and the raising of coastal plantations of salicornia*,* casuarinas, Vetiver and appropriate species of halophytes will represent a 'win–win' situation both for nature and coastal human habitations. No further time should be lost in initiating a national coastal bio-shield movement along the coasts of the mainland of India as well as islands. This can be a priority task under the National Rural Employment Guarantee and Food for Work Programmes.
- The severe loss of life and livelihoods as well as property caused by tsunami in Andaman and Nicobar Islands and in the coastal regions of Tamil Nadu, Kerala, Andhra Pradesh and Pondicherry teaches us that short-term commercial interests should not be allowed to undermine the ecological security of our coastal areas. Human memory tends to be short and neglecting the lessons of tsunami will be equivalent to writing off the future of coastal communities.

Based on the experience gained during the last 15 years, it is proposed to establish in Chidambaram a Resource Centre for Integrated Coastal Zone Management, for the purpose of imparting training in the erection of bio-shields, the development of biovillages and the establishment of Village Knowledge Centres. Tool kits for these purposes have already been prepared.

In addition to the above, steps have been taken in association with the Tata Relief Committee and the World Fish Centre (ICLARM) to establish a Fish for All Training and Resource Centre at Akkarapettai village near Nagapattinam for imparting training in all aspects of capture and culture fisheries through the principle of learning by doing. The centre will give attention to capacity building of fisher women and men in every step in the chain of capture/culture to consumption.

During 2004–05, MSSRF's strategic and participatory research to meet the challenges of climate change, which has been so far confined to the coastal zone, was extended to the arid and semi-arid areas of Andhra Pradesh and Rajasthan with financial and technical help of the Swiss Agency for Development Cooperation (SDC) and in partnership with Action for Food Production (AFPRO) and the National Institute of Agricultural Extension Management (MANAGE). This project will help to study vulnerability to adverse changes in temperature and precipitation and develop mitigation and adaptation strategies. Such proactive measures are essential to prevent human suffering resulting from agricultural collapse during drought and flood. The climate change program will take into account the impact of radiation, carbon dioxide concentration in the atmosphere, temperature and precipitation. It will also help to understand and chronicle traditional coping mechanisms, so that these can be conserved and strengthened. Computer simulation models on the impact of variations in temperature and precipitation will be developed and contingency plans to mitigate the adverse impact of climate change will be introduced.

Besides developing a methodology for conserving the Gulf of Mannar Biosphere Reserve for posterity through a multi-stakeholder trusteeship system of management, MSSRF has evolved during the last 15 years three other major institutional innovations in areas of significance to sustainable food and livelihood security and poverty eradication. These are described briefly below.

Community Nutrition and Water Security System

This system introduced in the Koraput district of Orissa consists of organising field gene banks (in situ on-farm conservation), seed banks, genetic enhancement through participatory breeding, water banks (i.e. water harvesting and saving in farm ponds), and grain banks.

This system helps to enlarge the food basket by facilitating the inclusion of millets and other under-utilised but nutritious crops in the Community Grain Bank. Such a decentralised community-managed nutrition security system helps to foster concurrent attention to conservation, cultivation, consumption and commerce. The tribal community of Koraput pioneering this system was given the Equator Initiative Award by UNDP at the World Summit on Sustainable Development held at Johannesburg in 2002.

Currently there are 2,34,676 village *panchayats* in 31 States and Union Territories. In addition, there are traditional councils in Meghalaya, Mizoram and Nagaland. Each of these *panchayats*/local bodies can spearhead the Community Food and Water Security movement. This will be the fastest and a sustainable method of making hunger history.

Fostering Job-Led Economic Growth

The most serious challenge facing India is overcoming the famine of jobs or sustainable livelihood opportunities in rural India. MSSRF, whose mandate is imparting a pro-poor, pro-nature and pro-woman orientation to technology development and dissemination, designed and developed the biovillage model of sustainable human well-being for this purpose in 1992. The biovillage concept involves the technological upgradation of agriculture and agro-based enterprises in villages through ecotechnologies developed by blending frontier technologies like information and biotechnologies as well as space, nuclear and renewable energy technologies with traditional ecological prudence. Thus, the biovillage based on the economics of human dignity, capitalises on the benefits conferred by ecotechnology to both the environment and the rural economy. By giving simultaneous attention to on-farm and non-farm employment, the biovillage promotes job-led economic growth and helps to transfer poor families from the primary to the secondary and tertiary sectors of economic activity. This model is now being adopted both in other parts of India and other countries like Bangladesh and Mozambique.

With the help of the Technology Information Forecasting and Assessment (TIFAC) program of the Government of India, a business plan was prepared for establishing Rice BioParks. A wide range of economically viable business activities were identified for producing value-added products from rice straw, husk, bran and grain. Business plans were prepared for nearly 28 different enterprises.

Thus, the biomass of cultivated plants can provide opportunities for new enterprises. Similarly, the production and marketing of the biological software essential for sustainable agriculture, such as biofertilisers, biopesticides, vermiculture, etc., could help self-help groups (SHG) of women and men to enhance their income. MSSRF organised a workshop for sharing experiences on SHGs. It became clear at the workshop that SHGs can become economically sustainable only if they have backward linkages to technology and credit, and forward linkages to markets and management. MSSRF has developed an accounting software for helping SHGs to maintain both accuracy and transparency in accounting.

With the help of the Central Food Technology Research Institute, Mysore, training in post-harvest processing was given to trainees from Ladakh to help them prepare value-added products from apricot and seabuckthorn. Similarly, technical advice was given to the Sher-E-Kashmir University of Agricultural Science and Technology of Kashmir in Srinagar for establishing a Womens' Biotechnology Park at Srinagar on the lines of the one functioning in Chennai.

Under the International Year of Rice Year Programme, consultations were held at Koraput in Orissa, Pattambi in Kerala and Shillong in Meghalaya for reviewing the current status of research on medicinal and aromatic rices. Detailed scientific strategies were developed for the improvement of the Navara rice of Kerala and Kalajeera rice of Koraput through participatory breeding and knowledge management. In all such programs the role of women in conservation and enhancement of genetic resources was given specific attention.

Centre

The third major institutional innovation developed by MSSRF for transforming the rural economy is the computer-aided and internet connected Village Knowledge Centre.

The work undertaken by MSSRF in setting up community-centred and managed Village Knowledge Centres (VKC) in Pondicherry villages since 1998 based on modern information and communication technologies (ICT) with financial support from IDRC of Canada has shown that ICT helps to improve the timeliness and efficiency of farm operations and enhances income through producer-oriented markets. Also, experience has shown that bridging the digital divide is a powerful method of bridging the gender divide. Knowledge connectivity therefore confers multiple economic and social benefits. The VKC operates on the principles of social inclusion and giving voice to the voiceless. The information provided, which includes location-specific data on entitlements to different government schemes, is demand-driven and is in the local language. For example, in Union Territory of Pondicherry there are over 150 schemes designed to help the poor; yet nearly 20 per cent of families are below the poverty line. After the onset of the digital age, knowledge on entitlements and how to access them has grown rapidly. The VKC will be a powerful instrument for operationalising the provisions of the *Right to Information Act* (2005).

Encouraged by the ability of rural women and men to take to ICT like fish to water, MSSRF initiated in 2003, two major steps to take ICT to every one of the over 600,000 villages in India by 15 August 2007, which marks the 60th anniversary of 'our tryst with destiny', to quote Jawaharlal Nehru. The first is the organisation of a National Alliance for Mission 2007: Every Village a Knowledge Centre which provides a platform for partnership to all committed to the cause of extending the power of ICT to rural India. The National Alliance has now over 150 members comprising Central and State government agencies, business and industry, academia and non-governmental and mass media organisations.

The second is the establishment of the Jamsetji Tata National Virtual Academy for Rural Prosperity with generous support from the Tata Education Trust. The Internet – community radio combination is a powerful method of reaching the unreached in terms of delivery of dynamic information. Public policy in promoting the use of community radio should be based on the following principle enunciated by the Supreme Court in its judgment delivered in December 1995, 'Air waves constitute public property and must be used for advancing public good'. This is the same principle enshrined in the Dandi March movement of Mahatma Gandhi in relation to sea water, which is the basis of MSSRF's program on sea water farming for coastal area prosperity.

At a recent meeting held at MSSRF, Panchayati Raj leaders have assured that they will provide space, electricity and telephone connection for establishing VKCs in the Panchayat premises. Thus, all the 234,676 village *panchayats* in 31 States and Union Territories as well as Traditional Councils in the North-East States can be brought together under the umbrella of the National Alliance. A hub-spokes model will help to reach all villages from Panchayat VKCs. Such Centres can be operated by ICT SHGs of rural women and men. MSSRF is assisting NABARD to organise about 10,000 ICT SHGs in 10 States of the country during 2005–06.

Besides connectivity and content, capacity building is essential for ensuring local ownership of VKCs. This is where the Jamsetji Tata National Virtual Academy (NVA) of MSSRF hopes to play a key role. The President of India, Dr A.P.J. Abdul Kalam inducted the first 137 Fellows of the NVA drawn from 15 States on 11 July 2005 at New Delhi. Microsoft is providing generous support for capacity building under its Unlimited Potential program.

The Fellows of NVA are rural women and men who have studied up to the 10th class or up to the first degree. They serve as Master Trainers and undertake the training of other rural women and men as well as children. These grassroots academicians will be the torchbearers of the rural knowledge revolution. Another significant development in taking the benefits of the space age to the rural poor was the inauguration by the Prime Minister of India, Dr Manmohan Singh on 18 October 2004 of an ISRO–MSSRF joint initiative in setting up Village Resource Centres (VRCs) which can link rural families to the best available sources of knowledge in medicine and health care, education, agriculture, markets and government programs. This program which initially linked MSSRF (Chennai) to VRCs in Thiruvayaru, Sempatti and Thangachimadam in Tamil Nadu is being extended to Chidambaram, Pudukottai, Pondicherry, Nagapattinam and Kanyakumari during this year. With the help of the Indian Space Research Organisation, additional centres are being opened in tsunami-affected areas and in farmers' 'distress hotspots' in Kerala, Andhra Pradesh, Maharashtra and Karnataka. These are areas where suicides by farmers occur. Those operating the computer aided knowledge system at such centres will be either wives or daughters or sons of those who were driven to take their lives. This will help to provide a sense of realism and urgency in achieving a match between content and the need to save livelihoods and lives. While VKC operates at the village level, the VRC is designed to cover a block and thereby serve as a resource centre for all the villages in the block.

The Prime Minister of India has announced a well-funded Bharat Nirman program to accelerate progress in providing urban amenities in rural areas and to bring an additional 10 million hectares under assured irrigation. Knowledge connectivity should be the backbone of the Bharat Nirman program, since it is fundamental to deriving maximum benefit, in terms of a better quality of life in villages, from the investment on roads, telephone connectivity and other forms of physical connectivity. The involvement of *panchayats* and *gram sabhas* in providing the needed logistic and policy support will ensure the efficient functioning of VKCs. To begin with VKC should be tools of information, knowledge and skill empowerment of rural families, particularly of the economically and socially under privileged sections of the society. This is a fundamental responsibility of government. Hence, the initial expenses should be met from the Bharat Nirman Programme and the Universal Service Obligation (USO) Fund. By the end of this decade (i.e. by 2010), the VKCs will become vibrant centres of economic activity and will provide opportunities for outsourcing of assignments from urban to rural areas. They will then become not only economically self-reliant but will help to create a wide range of skilled jobs for youth in villages. A VKC-centred Bharat Nirman will be the most effective method of fostering rural and agrarian prosperity and arresting the unplanned migration of the rural poor to urban areas resulting in the proliferation of urban slums. Therefore, knowledge connectivity through VKCs should be the corner stone of a New Deal for Rural India.

What motivates the scientists and scholars of MSSRF are the words of the Poet Rabindranath Tagore:

> With your mind intent, cross this sea of chaos
> And sail to that shore of new creation.

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