HOF 01-070

本田財団レポートNo.70

「エコ・テクノロジーと飢餓の克服」

国際マングローブ生態系協会会長　M.S. スワミナタン

Dr. Monkombu S.Swaminathan

Dr. Swaminathan has made many excellent achievements in agricultural and plant genetic studies, in leading role in the combined efforts to resolve the global food crisis, and also has participated actively in the international works in the field of environmental protection.

Personal History

1925	Born in Tamil Nadu, India
1947	B. Sc. Agriculture from the Coimbatore Agricultural College, Madras University
1952	Ph. D. from the School of Agriculture, University of Cambridge, U. K.
1976～	Honorary Fellow of the National Academy of Science, India
1979～80	Secretary, Ministry of Agriculture and Irrigation
1982～88	Director General, The International Rice Research Institute (IRRI), Philippines
1988～	President, the International Union for the Conservation of Nature and Natural Resources
1990～	President, International Society for Mangrove Ecosystems

In addition, Dr. Swaminathan has received the Albert Einstein World Science Award in 1986, and the First World Food Prize, which is recognized as the equivalent of a Nobel Prize in the field of food and agriculture in 1987.
He also has published over 200 papers in international journals and several books.

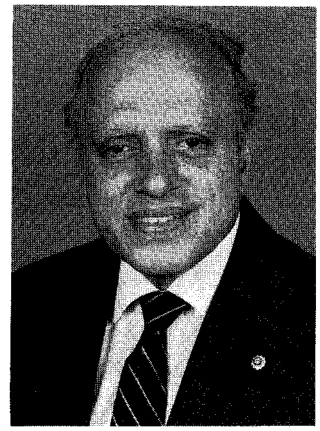
スワミナタン氏の受賞は、氏が農学および植物遺伝学に於いて数々の研究成果を上げるとともに、世界の食糧問題の解決のために指導的役割を果たし、また自然環境保護の立場からも国際的に活発な実践活動を展開されてきたことによるものです。

●略歴

1925	インド、タミール生まれ
1947	マドラス大学　農学部卒
1952	ケンブリッジ大学　農学部卒
1976～	インド国立科学アカデミー名誉会員
1979～80	インド農業灌漑省次官
1982～88	国際米穀研究所所長
1988～	国際自然保護連合会会長
1990～	国際マングローブ生態系協会会長

その他、1986年にアインシュタイン世界科学賞、1987年には農業のノーベル賞といわれる世界食糧賞を受賞。国際的学術誌にも多数の論文を発表。

ECO-TECHNOLOGY AND THE CONQUEST OF HUNGER



Dr. M.S. Swaminathan
President, International Society for Mangrove Ecosystems

Acceptance speech delivered at Tokyo, Japan on November 15, 1991, on the occasion of the award of the Honda Prize.

I. Introduction

In 1972, the United Nations convened a conference on "the Human Environment" in Stockholm, Sweden. In 1992, the UN is convening a conference on "Environment and Development" at Rio de Janeiro, Brazil. In the intervening 20 years, the world has witnessed enormous political, social, economic, demographic and technological changes. Many of these changes including the spread of democratic values and the containment of widespread famines have raised hopes for a better quality of life for all. On the other hand, the growing awareness that the pattern of economic development adopted until now has often been at the cost of environmental security and has also been widening the rich-poor divide, has led to the concept of "sustainable development", propounded with great clarity in the report of the World Commission on Environment and Development.

A document titled "Caring for the Earth" released by the World Conservation Union (IUCN), the World Wide fund for Nature (WWF) and the United Nations Environment Programme (UNEP) on October 21, 1991, defines sustainable development as "improving the quality of human life while living within the carrying capacity of supporting ecosystems". A sustainable economy protects the basic life support system of land, water, flora, fauna and the atmosphere. It is in this context that we salute today the vision and wisdom of the late Soichiro Honda, founder of Honda Motor Co., Ltd, whose mission in life was the promotion of sustainable human welfare and happiness, through achieving harmony between technology and nature. Under his inspiring leadership the Honda Foundation has fostered the eco-technology movement which alone can help us to bring about a sustainable end to hunger. I therefore dedicate this lecture to the memory of the late Soichiro Honda, affectionately called "Oyaji-San" by his friends and colleagues.

II. Changing nature of food security challenge

The famous French philosopher Sartre wrote "And when one day our humankind becomes full grown, it will not define itself as the sum total of the whole world's inhabitants, but as the infinite unity of their mutual needs". In 1972, there were 3.8 billion inhabitants on our planet. This number will be 5.4 billion in 1992. My country, India alone, has now a population of over 860 million. Considering the fact that it took over a million years for the human population to reach 1 billion by the year 1800 AD, the enormous progress made in recent decades to control infant mortality and promote longevity through preventive and curative health care measures is obvious. Thomas Malthus's prediction that the world's population would outstrip global food supply has also not come true so far, thanks to technological advances in improving biological productivity and pro-farmer public policies of governments.

The United Nations Fund for Population Activities (UNFPA) estimates that by the year 2000 the world population will reach 6.25 billion. Most of the additional population will be in developing countries. Over the next 20 years, of every 10000 births, only 50 will be in the rich countries. Economic disparities between and within nations may become wider. Even today, 77 percent of the world's people, mostly living in developing countries, earn only 15 percent of the total global income. The economist Jan Tinbergen in a report "Reshaping the International Order" has pointed out "A poverty curtain divides the world materially and philosophically. One world is literate, the other largely illiterate; one industrial and urban, the other predominantly agrarian and rural; one consumption oriented and the other struggling for survival. We have maldistribution of the world's resources on a scale where the industrialized countries are consuming about 20 times more of the resources per capita than the poor countries". Such a poverty curtain prevails not only among nations but also within nations, both rich and poor.

A large percentage of total income goes to the purchase of food in poor families. The food security challenge is thus becoming one of *economic access* to food, rather than one of mere *physical access*. Nutrition security, defined as "physical and economic access to balanced diets and safe drinking water" is still a dream for over 1 billion of world's population (Swaminathan, 1987). Compounding the problems created by inadequate diversification of employment opportunities, thereby resulting in an insufficient growth in household income, there is also the long term problem of *ecological access* to food, as a result of factors such as loss of biological potential of the soil, exhaustion and pollution of ground and surface water resources, the accumulation of green house gases in the atmosphere and the depletion of the ozone layer. How can we face the food security challenges of today and tomorrow under conditions of diminishing land and fresh water resources, expanding biotic and abiotic stresses, inadequate investment in rural techno-infrastructure and an inequitable trade environment?

III. Qualitative and quantitative dimensions of the challenges ahead

I would like to deal with the dimensions of the challenges ahead, taking my country India as an example. In 1963, the UN Food and Agriculture Organization (FAO) sent a team of experts to India to assess the country's food-grain production prospects for coming years. The FAO team concluded that a 10% increase in food grain production may be possible by 1970. If the actual achievement had been only of this order, there would have been widespread famines in the country. In fact such famines were forecast by Paul and William Paddock in their book "Famine-1975". Actually India's food grain production rose by 100% during the decade following the submission of the FAO report. Before I describe how the prophets of doom were falsified, I would like to refer to methods of combating the growing famine of jobs.

The Planning Commission of the Government of India estimates that despite significant progress in the 1970s and 1980s, nearly 30% of the population—more than 250 million people comprising 40 million families—still remain below the poverty line; and a growing share of this group are landless, wage dependent households in rural and urban areas.

There are presently 28 million unemployed and severely under-employed persons in the country. Between 1990 and 1995, India's labour force is projected to increase by 37 million persons. Therefore, 65 million new jobs will be needed to meet the employment needs of the country by 1995 and over 100 million by the year 2000. To achieve full employment level will require a growth in employment of 4% per annum, compared to the country's present rate of less than 2.0%. A doubling in the growth rate for new jobs will be the minimum requirement for eradicating unemployment during the present decade.

Agriculture is vital to overcoming poverty in the country, both as a provider of food and of jobs. It is the main source of employment for 70% of the population. Health as well as economics demands greater emphasis on agriculture. A 33% increase in per capita food consumption is needed to bring the diet of the present population up to international nutritional standards for caloric intake. In order to meet the food requirements of all its people at the turn of the century, India's total food production should reach at least 220 million tonnes by the year 2000.

At a meeting of the International Commission of Peace and Food held under my chairmanship at Madras from October 2-5, 1991, it was agreed that achieving the following targets will be essential for providing to the growing population of India physical and economic access to balanced diets.

a) *Foodgrains:* Raise foodgrain production from 177 million tons to 220 million tons (sufficient to meet projected domestic demand) by increasing per hectare yields of wheat from 2.3 tons to 3.1 tons and rice from 1.76 tons to 2.15 tons and bringing another 2 million hectares of irrigated land under high yielding varieties of wheat and rice. The shift of existing crops from ordinary to high yield varieties will increase employment per hectare by 50%.

b) *Cotton:* Triple the area under irrigated cotton with an addition of 4.8 million hectares to raise total production from 13.3 million bales to 26 million bales. Increase spinning capacity and expand weaving capacity in powerloom, mill and handloom sectors to meet the projected 50% increase in per capita cloth consumption, generate employment for 11 million persons and export Rs. 250,000 million in cotton textiles (currently Rs.25 is equal to one US dollar).

c) *Sugar:* Extend the area under sugarcane by an additional 1.6 million hectares and raise average yields from 60 to 80 tons per hectare to increase sugar production from 11 million tons to 26 million tons to meet rising demand (projected at 22—23 million tons within India by 2000) and increase exports to 3—4 million tons of sugar annually.

d) *Horticulture:* Raise fruit production by 50% and vegetable production by 100% to meet the full nutritional requirements of the population and generate 25% exportable surpluses through establishment of 2000 model horticultural estates covering 3 million hectares of irrigated land throughout the country, yielding an average of Rs. 18,000 per hectare profit for 3 million farmers, generating 3 million year-round jobs, and capable of raising a total of 6 million families above the poverty line.

e) *Aquaculture:* Raise inland fish production by 4.5 million tons (66% of projected domestic demand) through development of 50,000 hectares of intensive fish farms generating Rs. 1,250,000 per hectare profit for 250,000 families and full-time employment for one million women and men.

f) *Sericulture:* Double mulberry silk production by establishing 500 integrated sericulture estates each cultivating 175 hectares of mulberry, to generate an average net income of Rs. 30,000 per family for 250,000 families (80% landless) along with 750,000 additional full-time jobs. Develop advanced silk processing technologies in collaboration with Japan.

g) *Oilseeds:* Expand the area under irrigated oilseeds by 3 million hectares and improve yields to produce an additional 7.5 million tons of oilseeds to fully meet domestic demand. Groundnut, sunflower, rape and mustard and safflower provide considerable opportunities for higher production. At the same time the scope for increasing the production of rice bran oil and cotton seed oil is also great.

h) *Wasteland Reclamation for Forestry and Fodder:* An extent of 4.5 million hectares of wastelands should be reclaimed and utilized to meet the entire projected demand for industrial wood and provide sufficient animal feed for continued expansion of dairy development programmes.

i) *Dairy & Other sectors:* The programme areas listed above cover only about 50% of total output in agriculture, animal husbandry, fisheries and forestry. Important categories such as plantation crops, dairy, poultry, and marine fisheries have not been included. Programmes for the accelerated growth of these commodities should also be developed in order to double total food production within the decade. For the purpose of assessing the results of the strategy, it is assumed that output for these other sectors—with the exception of dairying will grow at an average, annual rate of 2.4%, the average for all of agriculture during the last decade.

Special reference needs to be made to the dairy industry, because of its large size and huge employment potential. According to projections by the National Dairy Development Board, total milk production will increase from the present 51.4 million tons (valued at Rs. 257,000 million) to 70 million tons (valued at Rs. 350,000 million) during the 1990s. An 18% increase in the number of milch animals in the country is expected to generate 11.6 million additional jobs.

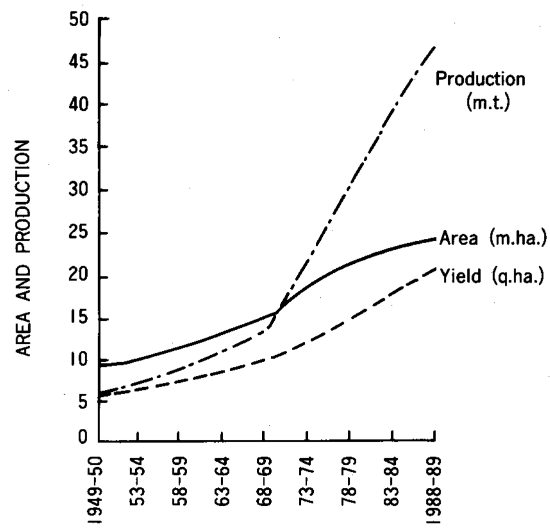
Achieving the above targets will obviously need considerable investments in rural techno-infrastructure development as well as great organizational and management skills and efforts. Technology alone, without the back-up of effective public policies and rural services, will not help to achieve the desired development goals.

IV. Technological basis of the "Green Revolution"

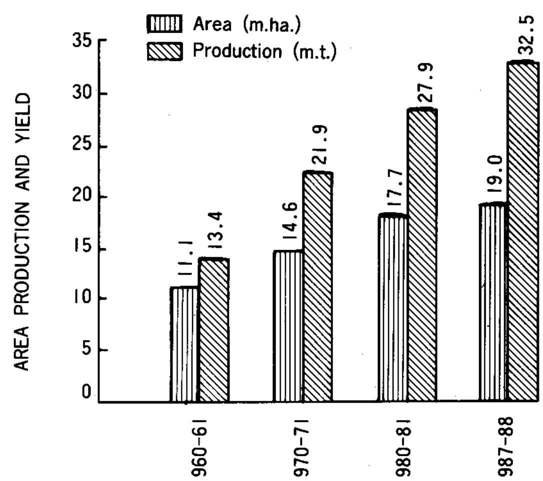
Just when predictions of widespread famines in India were being made, Indian farmers started increasing wheat and rice production at a fast pace. This phenomenon was described in 1968 by Dr. William Gadd of the U.S. Department of Agriculture as "the green revolution". The main characteristic of the green revolution is a substantial increase in wheat and rice production (Fig. 1 and 2) The scientific events which led to such a revolution in India were the following.

(a) After World War II, it was realised that the then cultivated varieties of wheat and rice could not respond positively to fertilizer doses exceeding 20 to 40 kg N per ha (Table 1). This was largely due to the tall nature of the stem, leading to lodging under conditions of good soil fertility. Since even at that time *japonica* varieties of rice grown in Japan showed a good response to fertilizer application, a *japonica* X *indica* hybridization programme sponsored by FAO was initiated in 1952 at the Central Rice Research Institute, Cuttack, India. This programme resulted in a few high yielding varieties like Mashuri in Malaysia and ADT-27 in India. The *Indica-Japonica* derivatives on the whole did not provide the desired yield breakthrough in rice at a national level.

Fig. 1



Average quinquennial increase in wheat area, production in yield



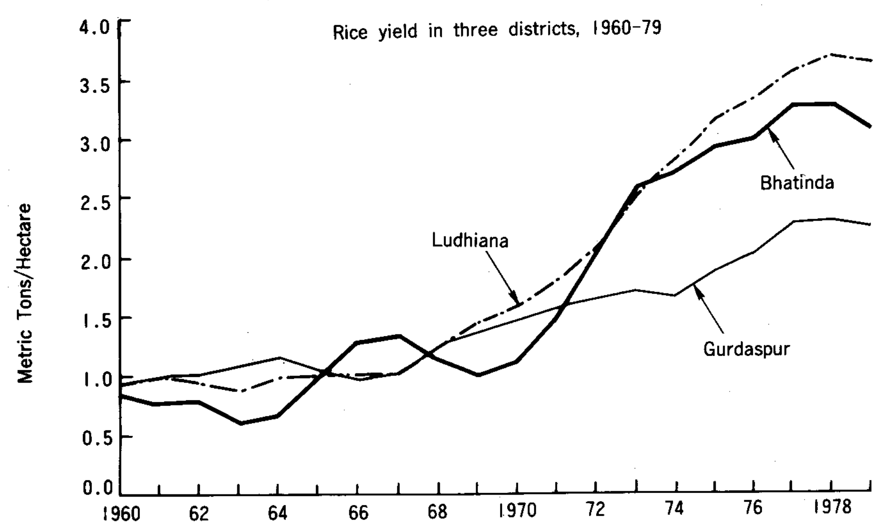
Percentage increase of wheat area and production as compared to toal food grain crops

Table 1

RESPONSE OF DIFFERENT CROPS TO NITROGEN AT DIFFERENT LEVELS

Crop	Av. yield of untreated ptots q./ha.	No of trials	Dose in kg./ha.	Response q./ha.	No of trials	Dose in kg./ha.	Response q./ha.
Rice	13.8	5,637	22.4	2.8	2,786	44.8	4.2
Wheat (Irrigated)	13.0	3,628	22.4	3.5	1,712	44.8	5.8
Wheat (Unirrigated)	8.7	1,045	22.4	2.4	503	44.8	3.7

Fig. 2



Source : Punjab, Statistical Abstracts of Punjab (Chandigarh: Economic and Statistical Organization, various Years).

Fig. 3

SUCCESSIVE PROGRESS IN INCREASING YIELD

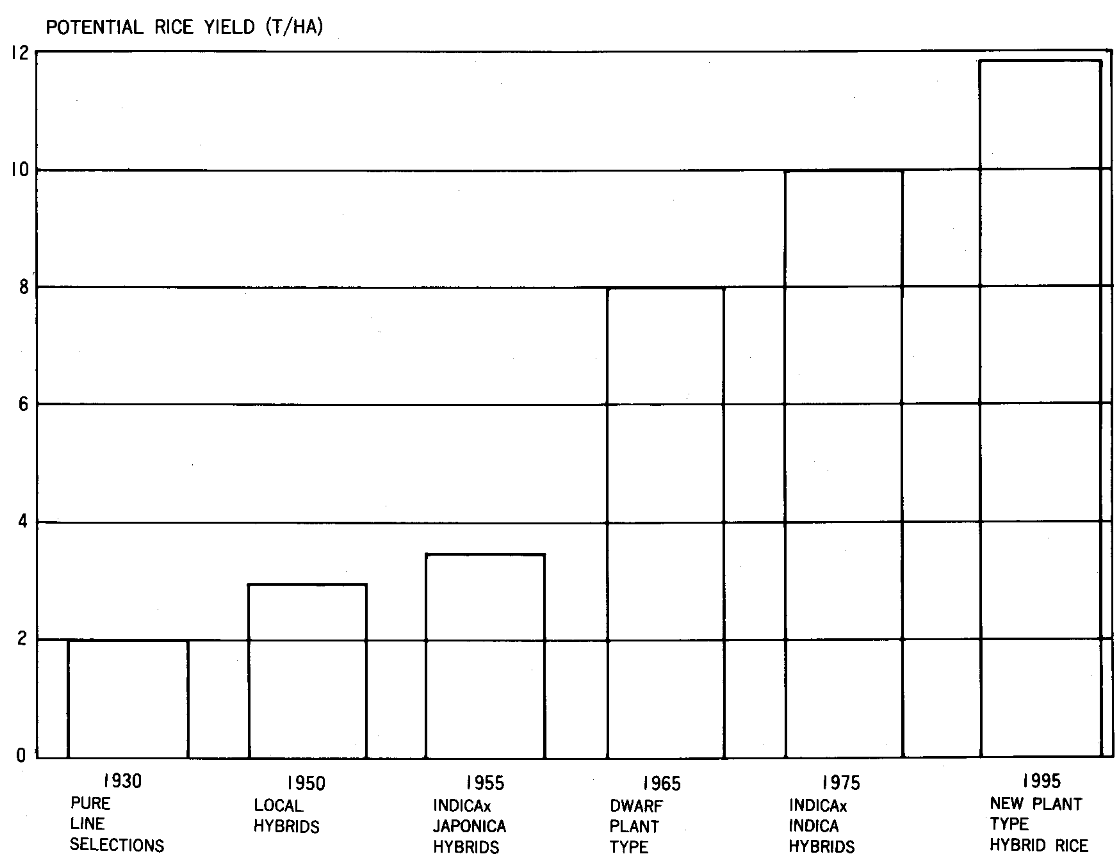


Fig. 4

NUTRIENT USE EFFICIENCY (% RECOVERY) IN WETLAND RICE IN THE LATERITE SOILS OF BHUBANESWAR IN A RICE- RICE SEQUENCE (AVERAGED OVER THE PERIOD 1971 TO 1985)

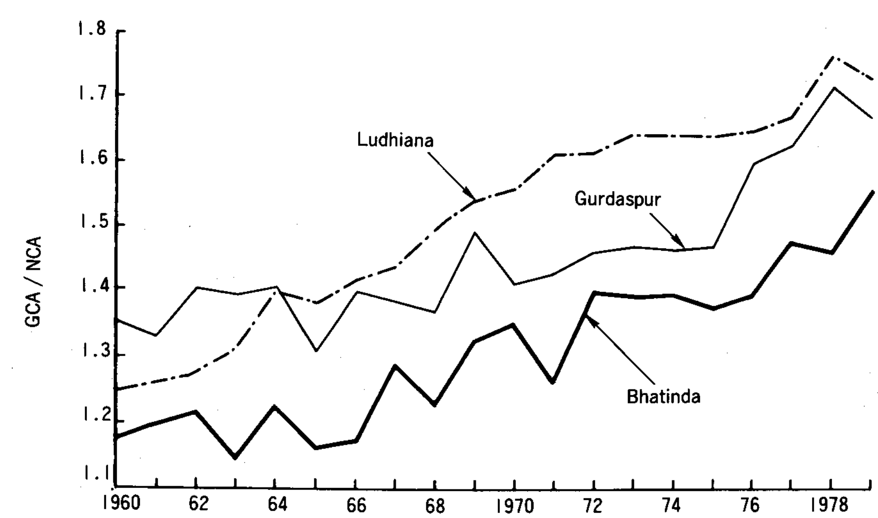
Fertilizer treatment	Percent recovery					
	N		P		K	
	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
N alone	27	30	–	–	–	–
NP	26	30	11	21	–	–
NPK	36	39	20	25	66	69
NPK+F.Y.M.	39	51	31	34	68	74

Source: Pande & Sahoo, 1989

(b) During the nineteen fifties, a semi-dwarf *indica* rice variety, Taichung Native-1, was developed in Taiwan using the dwarfing line "Dee-gee-woo-gen" identified in the Chinese mainland. Taichung native-1 (T.N.1) was introduced in India in 1964 through the International Rice Research Institute (IRRI) established at Los Banos in the Philippines in 1960 by the Ford and Rockefeller Foundations in collaboration with the government of the Philippines. In 1966, IRRI released IR-8, a high yielding strain developed by crossing the Indonesian rice variety Peta and Dee-Gee-Woo-Gen. IR-8 rice helped to raise the ceiling to yield further and triggered the rice revolution in India, Indonesia, Pakistan, Philippines and other *indica* growing countries in South and S.E. Asia.

(c) During the late seventies, Chinese Scientists led by Yuan Long-Pin, identified a source of cytoplasmic male sterility titled "WA cytoplasm" in a strain collected from Hainan Island. This discovery made the commercial exploitation of hybrid vigour possible. China has now nearly 10 million ha under hybrid rice, thanks to both the breeding of high yielding hybrids and the standardization of efficient seed production and agronomic technologies. Thus, an era of successive improvements in the yield of rice began (Fig. 3).

Fig. 5



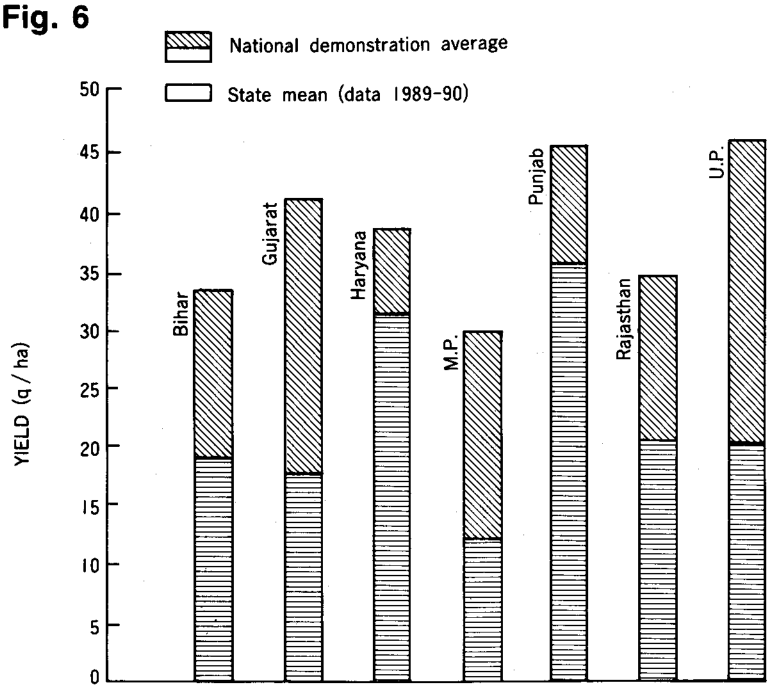
Source : Punjab, Statistical Abstracts of Punjab (Chandigarh: Economic and Statistical Organization, Various Years).

Cropping intensity in three districts, 1960-79

(d) In wheat, yield enhancing technologies became available after the introduction of Norin-10 dwarfing genes derived from material from Japan. Hybridization with Norin wheats led to the development of the winter wheat variety *Gaines* in Washington State, USA and to spring wheat varieties like Lerma Rojo 64-A, Sonora 64 and Mayo-64 in Mexico. Dr. Orville Vogel in USA and Dr. N.E.Borlaug in Mexico played key roles in the dwarf wheat breeding programme. In addition, through a shuttle breeding programme involving two diverse environments, Dr. Borlaug introduced the character of relative insensitivity to photoperiod in semi-dwarf spring wheats.

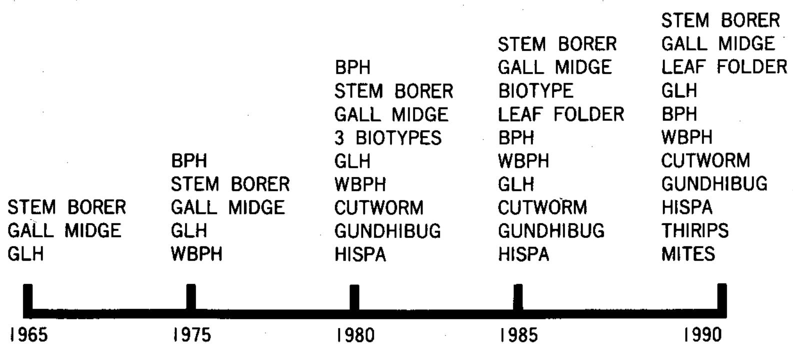
(e) Both in wheat and rice, the realization of the genetic potential for yield in the high yielding varieties became possible only because of associated advances in agronomic practices and pest management (Fig. 4). Cropping intensity could also go up in irrigated areas, since the semi-dwarf varieties of wheat and rice were not only high yielding but also relatively photo-insensitive (Fig. 5). In many parts of India, there is still a vast untapped yield reservoir in wheat and rice, although in States like the Punjab and Haryana, the difference between potential and actual yields at current levels of technology is low (Fig. 6)

Fig. 6



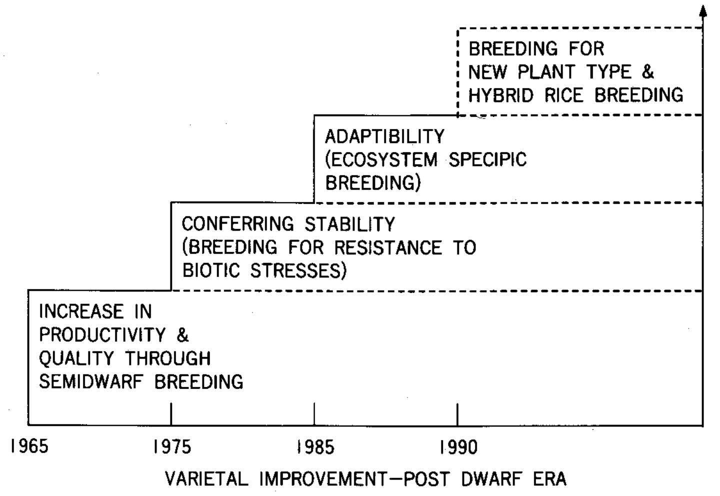
Yield averages of national demonstrations and of major states over the years 1982-83 to 1985-86

Fig. 7



CHANGING REST SCENARIO & EMERGENCE OF NEW PESTS & BIOTYPES

Fig. 8



(f) With a change in the crop micro-environment, the pest syndrome also started undergoing change (Fig. 7) Both biotic and abiotic stresses became important under conditions of intensive agriculture. A dynamic agricultural research system is thus a must for stimulating and sustaining a dynamic crop production system. For example, the breeding objectives in rice have changed considerably in India since 1965 (Fig. 8). We obviously need more powerful tools for achieving novel genetic combinations. Fortunately, molecular genetics is providing such tools.

(g) Based on the conclusion that a non-lodging character is essential for getting positive response from water and mineral fertilizer, I began in 1955 a multipronged approach to breeding fertilizer responsive wheat varieties at the Indian Agricultural Research Institute, New Delhi. The approaches included:

  (a) Induction of mutations for the *erectoides* i.e stiff straw character

  (b) Hybridization with *Triticum aestivum* sub. sp. *sphaerococcum* (known as the Indian dwarf wheat) and

  (c) Application of chemicals which can enhance stem stiffness.

None of the above 3 approaches gave the desired results. In early 1961, a few dwarf wheat lines were observed in the International Wheat Rust Nursery sent out by USDA which had short height but long panicles. On enquiry, I was informed by USDA that these lines came from Mexico. I then proposed inviting Dr. N.E. Borlaug to India and getting from him a wide range of dwarf wheat breeding material. Dr. Borlaug visited India in 1963 and sent a wide range of dwarf wheat material in September that year. Thus began the Indian dwarf wheat breeding programme involving the Norin dwarfing genes. This programme helped to increase wheat production in India from 12 million tonnes in 1964 to 55 million tonnes in 1990. Yield improvement played a prominent part in such an advance in production. Such progress became possible only because of the simultaneous introduction of mutually reinforcing packages of technology, services and public policies, particularly in input and output pricing and producer-oriented marketing.

V. Achieving continuous advances in productivity

Land is a shrinking resource for agriculture in developing countries. There is no option except to produce more from less land, water and energy in the coming years and decades. Hence, crop scientists are looking for opportunities for genetic and agronomic manipulation which can help to elevate yields.

At the International Crops Research Institute for the Semi-arid Tropics (ICRISAT), for example, hybrid vigour is being exploited for the first time in pigeon pea (*Cajanus Cajan*). ICPH-8, the world's first hybrid pigeon pea, was released in June, 91. Cotton breeders in India have exploited hybrid vigour during the last 20 years, using hand emasculation and pollination for producing F1 seeds.

Rice is the most important food crop of Asia and hence it may be useful to consider how far more we can improve yield in this crop. In 1990, approximately 520 million metric tonnes of rice were produced worldwide from 146 million hectares of rice land. It helped to feed 2.7 billion people. There will be 3.2 billion rice eaters by year 2000 and about 4.3 billion by year 2020. Rice production will have to be increased to 600 million tonnes by 2000 and to 800 million tonnes by 2020 to meet their needs. The area planted to rice has remained constant between 1980 and 1990 and there is little likelihood that it will increase any further. In fact good rice lands are being lost to urbanization and industrial development.

Thus, additional rice production must come from existing or diminishing land resources. The present average rice production of 3.5 tonnes from a hectare of land must be raised to 4.1 tonnes in 2000 and to 5.5 tonnes by 2020. If we are not able to increase the productivity of existing rice lands, rice cultivation will tend to get extended to marginal and fragile environments with adverse ecological consequences. For higher productivity, we need rice varieties with higher yield potential and greater yield stability as well as management systems which can help to achieve a reduction in the cost of production without reducing yield.

Modern high yielding varieties produce about 50% straw and 50% grains. Efforts are underway at the International Rice Research Institute, Philippines and at the Directorate of Rice Research, Hyderabad, India to breed varieties with a new plant type which will produce 40% straw and 60% grains. These should have 20 to 25% higher yield potential than the existing high yielding varieties and should help increase the per hectare productivity. For changing the grain/straw ratio, varieties are being bred with large panicles but with lower number of tillers. Modern high yielding varieties have 20—25 tillers but only about 15—16 of them produce panicles, each with 100—120 grains.

The new plant types currently under development have lower number of tillers but large panicles, each with 250—300 grains. The aim is the development of varieties with no unproductive tillers, with thick and sturdy stems to support large panicles and provide lodging resistance. For broadcast sowing, 5—6 tillers per plant may be ideal as plant density can be manipulated through seed rates. For transplanting, varieties with 10—12 productive tillers are being bred (Khush, G.S. 1991 — personal communication)

Donors of genes for various traits have been identified, hybridizations are underway and early generation populations are being evaluated. It is hoped that rice varieties with the new plant type may be available before the end of this decade.

For yield stability, the new varieties must have multiple resistance to diseases and insects. Genes for resistance from the primary gene pool of cultivated rice are being incorporated into the new plant type materials. Alien genes for resistance from the wild species have been transferred to cultivated rice through embryo rescue techniques. For example, genes for resistance to brown planthopper and bacterial blight have been transferred from *Oryza officinalis* and *O. australiensis.* Genes for resistance to blast have been transferred from *O. minuta.* Through genetic engineering methods, novel genes for resistance are being incorporated into the rice germplasm. Dr. Ko Shimamoto of Plantech Research Institute, Japan, has cloned the Bt gene from *Bacillus thuringiensis* and introduced it into Japonica rice through transformation. The transformed rice is resistant to stemborers. Dr. Roger Hull of John Innes Institute, England and Dr. Roger Beachy of Washington University, USA have cloned the coat protein genes of tungro viruses. These genes are being introduced into rice through transformation techniques. Transformed plants are likely to be resistant to tungro.

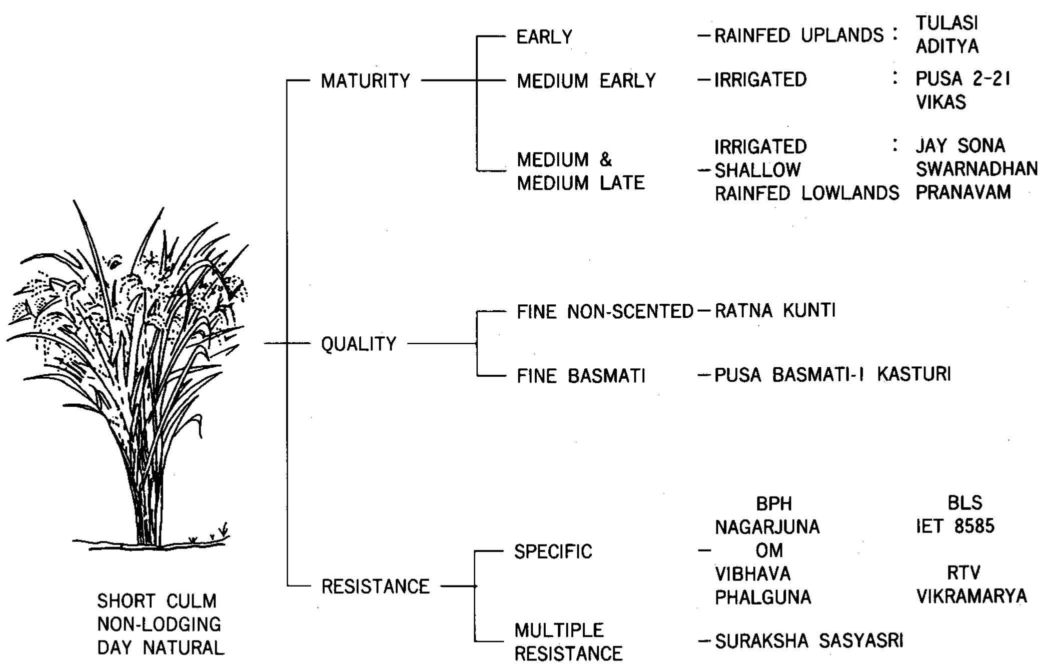
Upto now, most of the transformation work was carried out with *Japonica* rice because it was difficult to regenerate plants from protoplasts of *Indica* rice. However, Dr.

F.J.Zapata of IRRI has established protocols for regeneration of plants from IR58, a popular *Indica* variety. This opens up the possibilities for introducing novel genes into *Indica* rices which are grown on 90% of the rice lands.

The kinds of changes being brought about in morphological and physiological characters in rice are shown in Fig. 9.

The extent of progress made in India in recent decades in yield improvement in rice is indicated in Fig. 3. Such scientific progress in raising the ceiling to yield is helping to keep food production above population growth rates. The challenge lies in bringing about such improvements in yield in an ecologically sustainable manner, with biological inputs replacing chemical inputs to the extent possible.

Fig. 9



GENETIC TRANSFORMATION SINCE INTRODUCTION OF T (N) I

VI. Greening the Green Revolution

Extending the green revolution, by increasing production through the productivity pathway, to more crops and farming systems is both an ecological and economic imperative in population rich but land short countries like China and India. However, it is obvious that the following principles ought to be kept in view in order to ensure that productivity improvement is not only economically viable but is also ecologically sustainable (Swaminathan, 1991).

1. Land:
Based on both biological potential and biological diversity, land can be classified into conservation, restoration and sustainable intensification areas. Diversion of land suitable for sustainable intensification for non-farm uses should be prevented by legislation. Such land should be subjected to continuous soil health monitoring. Soils with diminished biological potential, also referred to often as waste or degraded lands, should be improved through the application of the principles of restoration ecology. Conservation areas rich in biological diversity must be protected in their pristine purity.

2. Water:
Effectiveness in water saving, equity in water sharing and efficiency in water delivery and use are important for the sustainable management of available surface and ground water resources. There should be an integrated policy for the conjunctive and appropriate use of river, rain, ground and sea water and for the

recycling of sewage water and industrial effluents.

3. Energy:
Integrated systems of energy management involving the use of renewable and non-renewable resources of energy in appropriate blends are essential for achieving the desired yield levels.

4. Nutrient supply:
Soils in India are often not only "thirsty" but also "hungry". Inputs are needed for output. Therefore, what we need is a reduction in the use of market purchased chemical inputs and not of inputs per se. It is in this context that integrated systems of nutrient supply assume importance. The components of the integrated nutrient supply system suitable for easy adoption include crop rotations, green manures and biofertilizers. Biodynamic systems that make significant use of compost and humus will help to improve soil structure and fertility.

5. Genetic diversity:
Genetic diversity and location-specific varieties are essential for achieving sustainable advances in productivity. Traditional systems of farming depended heavily on in situ conservation of genetic variability in the form of numerous land races, mostly by women. Genetic homogeneity characteristic of modern agricultural systems only leads to greater genetic vulnerability to biotic stresses. Participatory plant breeding efforts jointly with rural families will help to achieve a desirable blend of traditional and frontier technologies. Diversity of crops and varieties will be the result of such a joint endeavour, thus enhancing stability of yield.

6. Pest Management:
The control of weeds, insect pests and pathogens is one of the most challenging jobs in tropical and subtropical agriculture. Here again, a location specific integrated pest management system needs development and adoption. The conservation of natural enemies of pests is important for minimising the use of chemical pesticides and for avoiding the multiplication of insecticide-resistant pests. Botanical pesticides like those derived from neem need popularization. The conservation and wise use of genetic diversity are essential for breeding strains possessing multiple resistance to biotic and abiotic stresses. Selective microbial pesticides offer particular promise, of which strains of *Bacilus thuringiensis (Bt)* serve as an example. Transgenic techniques have made the transfer and expression of the Bt toxin possible in several crops. The applications of genetic engineering as applied to pest control are growing rapidly. It is however necessary to ensure that the "natural pesticides" synthesised by plants for their protection do not pose health hazards. Tests for wholesomeness should keep this aspect in view.

7. Post-harvest systems:
Whole plant utilisation methods and the preparation of value added products from the available agricultural biomass are important both for enhancing income and for ensuring good nutritional and consumer acceptance properties. Both producers and consumers will not derive benefit from production advances if there is a mismatch between production and post-harvest technologies. Drying, storage and marketing techniques should be such that they not only do not make much demand on non-renewable sources of energy but also prevent quantitative and qualitative damage to foodgrains or other agricultural commodities. Mycotoxins and bacterial food infections often become a serious problem and hence greater attention to the qualitative aspects of food storage and distribution is urgently needed. Nucleic acid probes and monoclonal antibodies can help in rapid diagnosis, and hence more investment in research and training in this field will be worthwhile.

8. Systems approach:
Ecological and economic sustainability is enhanced when the available land, water, energy and credit resources are utilised in a mutually reinforcing manner. A systems approach involving integrated attention to crop and livestock farming and to agroforestry and aquaculture will be helpful in generating more jobs and income and at the same time protect soil health.

9. Location specific research and development:
A fundamental requirement for sustainability is participatory research and training. This will call for new patterns of organisation of research, with scientists and farm families becoming partners in the development and dissemination of new technologies. Only then can we promote and protect national and global

Table 2

EXTENT OF LOSS CAUSED BY MAJOR INSECT PESTS OF RICE IN ENDEMIC AREAS

	INCIDENCE UNPROTECTED		AV. YIELD KG/HA		LOSS IN YIELD (%)
			PROT.	UNPROT.	
	D.H.%	W.E.%			
STEM BORER (WARANGAL)	39.3	26.3	3609	652	81.9
	Silver shoots %				
GALL MIDGE (SAMBALPUR)	83.2		3005	163	94.6
BROWN PLANT-HOPPER (MARUTERU)	Hooper burn		4504	623	86.2

D.H. : Dead Hearts; W.E. : White Ears

food security within the limits of the carrying capacity of the supporting ecosystems. "Think nationally but plan and act locally" is the only relevant method of promoting sustainability in farming.

Under conditions of small and fragmented holdings, the adoption of the above principles of sustainability will be possible only if all farming families in a village or a watershed or the command area of an irrigation project cooperate. For example, although IPM techniques have been available in the case of rice and cotton pests for some years now, their field adoption has been slow due to inadequate attention to the promotion of group cooperation among small farm families. Social organisation is as important as technological innovation for achieving continuous improvements in biological productivity on an ecologically sustainable basis.

The damage to crops caused by pests in tropical countries is serious and without plant protection crop losses will be high (Table 2). This is why more research is needed on methods of transferring genes for resistance to pests from wild species to cultivated varieties through recombinant DNA procedures. We should establish specialized gene pools for fostering ecologically sustainable agriculture.

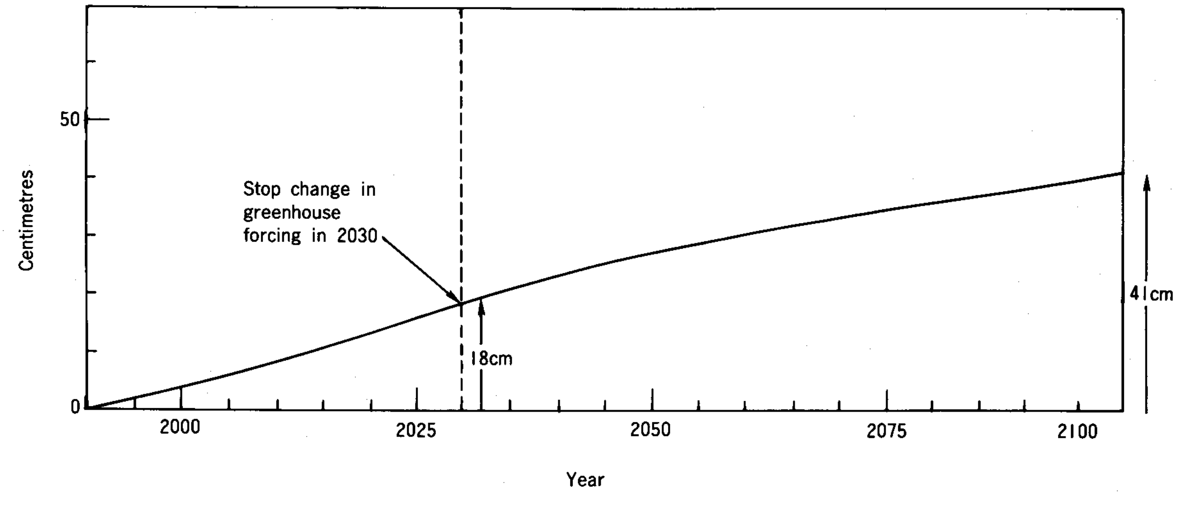
Taking nutrients, for example, it has been estimated that about 23 million tonnes of N, P and K nutrients are currently being removed by crops in a year in India. About 12.5 million tonnes are being returned in the form of mineral fertilizers. The replenishment of the rest of the nutrients will have to be in the form of organic manures and biological nitrogen fixation. Efficient stem nodulating species of green manure crops, such as *Sesbania rostrata* are now available, which can fix about 60 kg of N per hectare in about 45 days. If such green manure crops can be made photo-insensitive, they can be fitted into crop rotations in a manner that the sowing of the main crop is not delayed.

Soil health monitoring is a must for sustainable agriculture. In the Punjab State of India, for example, there was no response to P application in the late sixties. After the new varieties of wheat became popular and yields went up, P became essential. Later, Zinc deficiency started appearing over large areas. This was followed by Mn and S deficiencies in wheat. Thus, we are confronted with a dynamic situation. Farmers need location specific advice. The packaging of meteorological, management and marketing information in the form of a computer-aided extension system will be helpful to farmers operating small holdings. Genetic gardens for sustainable agriculture could help in assembling gene pools which can be used in research designed to promote the substitution of farm-grown biological inputs for market purchased chemical inputs. We are establishing such a specialized genetic garden at Madras, India, under the N. I.Vavilov Research and Training Centre for Biological Diversity of the M.S. Swaminathan Research Foundation.

What we need urgently is greater effort in the blending of traditional and frontier technologies. The frontier technologies of particular interest in agriculture are biotechnology, space and information technologies and management technology. In addition, a pro-poor bias should be built into the process of technology development and dissemination. The "bio-village" project started by us in the Pondicherry Territory of Inida is designed to serve this purpose (Swaminathan, 1991).

In addition to strategic research in well equipped genetic enhancement centres, there is need for anticipatory research to adapt to new consumer needs, processing methods and likely changes in temperature, precipitation, ultraviolet-B radiation and sea levels. Taking sea level rise as an example, it is clear that a certain amount of rise is bound to take place (Fig. 10). Over 60 percent of the human population live within 60 kms from the sea shore. Unfortunately, natural defence mechanisms against coastal storms and sea erosion provided by mangrove ecosystems, comprising mangrove forests, coral reefs, sea grasses and associated flora and fauna, are being damaged. Mangrove ecosystems serve as bridges between land and sea and can provide valuable genes for transfer to other species through genetic engineering. Thanks to generous help from the Government of Japan, through the International Tropical Timber Organization, action has been initiated for establishing a global grid of genetic conservation centres for Mangrove species. A Genetic Resources Centre for adaptation to sea level rise has already been established in the Tamil Nadu State of India with financial assistance from the Department of Biotechnology of the Government of India. Also the vision of Japanese scientists has led to the establishment of an International Society for Mangrove Ecosystems (ISME), with headquarters at Okinawa. These steps will help in a small way to halt genetic erosion in coastal biological wealth.

Fig. 10



COMMITMENT TO SEA LEVEL RISE IN THE YEAR 2030. THE CURVE SHOWS THE SEA LEVEL RISE DUE TO BUSINESS-AS-USUAL EMISSIONS TO 2030, WITH THE ADDITIONAL RISE THAT WOULD OCCUR IN THE REMAINDER OF THE CENTURY EVEN IF CLIMATE FORCING WAS STABILISED IN 2030.

VII. Achieving harmony between technology and nature

Achieving harmony between technology and nature is possible in agriculture, provided there is a clear understanding of the need for a systems approach in the development and dissemination of technology. At the same time appropriate public policies are equally vital for ensuring that natural resources are utilized in a sustainable manner. Such multi-dimensional planning and action are usually wanting both in research and development departments.

There is hence an urgent need in every country for a *Consortium of scientific and technological institutions for Sustainable Advances in Biological Productivity,* comprising research institutions and universities, government agencies and private and public sector industry, all functioning like members of a symphony orchestra.

Such a consortium will have to standardize indicators of sustainability and unsustainability and help to determine trade offs between short term goals and long term effects. Not all damage is irreversible but some, like the loss of species and ecosystems, are irreversible. This message was conveyed over 4000 years ago by the following verse in chapter 12 of *Atharva Veda.*

"What, O Earth, I dig out of thee quickly shall that grow again. May I not, O pure one, pierce thy vital spot or thy heart".

It should be the responsibility of the science and technology consortium to ensure that the vital parts of nature are not damaged. The carrying capacity of an ecosystem is a dynamic concept. A few centuries ago when population pressure on land was low, shifting cultivation was a perfectly sustainable land management system but today it is not. A major role of the S&T Consortium for Sustainable Advances in Biological Productivity should be the promotion of participatory research with rural families leading to the blending of the best in traditional wisdom and technologies with the most relevant frontier technologies.

In January 1968, when I saw India on the threshold of great changes in agriculture, I made the following statement in my Presidential address to the Agricultural Sciences Section of the Indian Science Congress.

"The initiation of exploitative agriculture without a proper understanding of the various consequences of every one of the changes introduced into traditional agriculture and without first building up a proper scientific and training base to sustain it, may only lead us into an era of agricultural disaster in the long run, rather than to an era of agricultural prosperity"

This is also the message which the Honda Foundation and its visionary founder have tried to spread. Let us heed to it before it is too late. Blending traditional and frontier technologies based on principles of ecology, equity and economics, provides new opportunities for improving simultaneously the livelihood security of farm families and the ecological security of farms. Such an approach alone can help us to achieve a sustainable end to hunger. Taking advantage of this opportunity will be the greatest tribute we can pay to the memory of Soichiro Honda. It is to this cause that my wife and I have decided to utilise the funds associated with the Honda Prize.

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