SIXTY-THIRD ANNUAL SESSION OF THE INDIAN SCIENCE CONGRESS WALTAIR, 1976

General Presidential Address

by

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SCIENCE AND INTEGRATED RURAL DEVELOPMENT

This is the second time during the last five years that Members of the Science Congress Association have chosen an agricultural scientist as their General President. I regard this as an index of the importance attached to agricultural sciences by our scientific community. On behalf of scientists in agriculture I would like to assure the Members of our Association that we shall strive to prove worthy of this trust and honour.

Since our last meeting at Delhi in January 1975, we have lost one of our most distinguished Past Presidents, Prof. T. R. Seshadri. Prof. Seshadri worked in his laboratory till the last day and was the embodiment of all that is best in science. It was in Andhra University that his scientific genius flowered. We deeply mourn his demise and pay homage to his memory.

I personally feel highly privileged to be the President of this Session for several reasons. First, the Andhra University, which has completed nearly 50 years of distinguished service to education and science, is hosting a Science Congress session for the first time. As an honorary alumnus of this University, I share the joy and pride of this occasion. Secondly, the State of Andhra Pradesh has been known for long for the skills of its farming community. Whether it be the cultivation of rice, sugarcane, tobacco, chilli, mango or grapes or animal husbandry, the Andhra peasant has proved to be an expert.

Thirdly, this is the first session of the Science Congress when, in addition to discipline-centred papers and symposia, there will be a cross-disciplinary examination of a topic of national relevance. The aim is to utilise the vast inter-disciplinary expertise present at the Congress for a deeper understanding of a specific national problem. "Science and integrated rural development" was chosen at our last session held at Delhi as the focal theme for this session. Scientists, both from our country and abroad, and our Sectional Presidents have taken much trouble to articulate their thoughts on what scientists can and should do to promote rural development and agrarian prosperity, and I am confident that we will have a useful discussion on the various facets of this theme. The exhibition has also been suitably restructured. For the first time

we will have a Forum on Home Science and Nutrition and will give special attention to Fisheries. The major suggestions arising from our discussions will be summarised on the last day when the Deputy Chairman of the Planning Commission, who is also the Chairman of the National Committee on Science and Technology, has kindly agreed to receive them personally.

Finally, we have the privilege once again of having our Prime Minister Shrimati Indira Gandhi with us at this opening session. By holding charge of the portfolios of the Departments of Science and Technology, Atomic Energy, Space Research and Electronics, in addition to serving as the President of the Council of Scientific & Industrial Research, you, Madam Prime Minister, have shown your firm commitment to the harnessing of science for national development. To the concept of economic growth with social justice, you have also added the dimension of growth with ecological balance so as to harmonise the short and long term goals of development. On behalf of the scientific community, I thank you for your presence and for your clear policy direction for the promotion of a symbiotic interaction between science and society.

The various initiatives taken by our Central and State Governments since 1947 have now placed our country in the third position in the world in scientific and technical manpower. On the other hand, we were included at the World Food Congress held in Rome in 1974 among the "most seriously affected" (MSA) countries with regard to food, which is the first requisite in the hierarchical needs of man. Why do we find this mismatch between our position in the world of science and the quality of the lives of a majority of our people ?

It seems to me that a basic deficiency of our developmental system is our inability to emulate our genes, in each one doing his or her specific task properly and well and everyone working together in a coordinated manner. Let me elaborate this further. I wonder how many of us realise that the total weight of the chemical substance of heredity, de-oxyribose nucleic acid (DNA), for our entire population is only about 4.2 mgs, if we add up the weights of DNA present in the single cell embryo of each individual from which we grow. By the same method of calculation the present population of *Homo sapiens* would have a DNA content of about 28 mgs. In these 28 mgs of DNA, the specifications for the heritable characteristics of our entire species are inscribed. How has the genetic system combined economy with such remarkable efficiency and precision ?

Genes have three essential properties. Each gene has a specific function; each is capable of replication or making exact copies of itself; and each is capable of mutation or heritable change. The function of a gene is regulated both in terms of its particular location on a chromosome and also in terms of a particular time sequence in development. During the reproductive phase, genes are able to combine in different ways and this process of recombi-

nation followed by segregation generates wide variability. Thus, in practice, except for identical twins, no two individuals are exactly similar. Mutation, or heritable change, adds to the capacity to respond to changing selection pressures.

Another remarkable property of genes is the system of vertical and horizontal coordination to which they subject themselves. Thus, each gene performs its specific function and is able to replicate itself, to change and to work cooperatively and sometimes competitively with other genes. Integration of vertical and horizontal coordination has invested the heredity system with precision and power. If only everyone of us was aware of the way in which our own bodies function and applied the lessons learnt from it in our daily life, we might be more successful in achieving what individually and collectively we wish to accomplish.

What is it that we want to accomplish ? In my view, the most important task is to draw the greatest benefit from our existing human resource and to limit its further unplanned growth. Past experience suggests that human resource cannot be effectively used by traditional approaches to "creating jobs", which often tend to degenerate into doles. What is needed is the growth of employment policies from an overall strategy of resource utilization designed to convert sunlight, soil, water, mineral, plant, animal and other resources into wealth meaningful to people. Instead of devoting undue attention to brains drained to other countries, we should pay serious attention to the utilization of brains within the country. The starting point is obviously the village, which is where both untapped assets and native brains exist. This is why the Science Congress has chosen integrated rural development as its first focal theme.

Eighty per cent of our population now live in rural areas. Some experts have calculated that this percentage will be 71 in 2000 A.D. Even if the percentage goes down, the rural population is expected to grow in number from 441 million in 1971 to 662 million by 2000 A.D. Of the existing rural population, nearly 50 per cent is believed to suffer from poverty. Rapid rural development based on the scientific utilization of all our resources, both natural and human, is therefore a must.

It is worth noting that countries which have gone too far on the road of urbanisation are now repenting this choice. Rapid urbanisation has generated a steep rise in the consumption of non-renewable forms of energy. For example, the transport needs of large cities have grown so vast that the number of motor vehicles in the world increased by 120 million during the 1960s, generating problems of atmospheric pollution and human temper. There is today a marked movement back to the countryside, but with the integration of some of the basic benefits of urban life with rural living. A planned reclustering of jobs, services and amenities more widely throughout the country in accordance with the agro-ecological potential and socio-economic needs of each area will facilitate this movement.

Rural-Urban Relationships

Gandhiji stressed that only a marriage between intellect and labour could lead to rural regeneration. Education, in the past, particularly at the university level, unfortunately tended to promote the concept that rural jobs, which were mostly by related to agriculture, required only brawn and not brain. The exodus of the educated caused neglect of the hinterland. Yet we now know that unless life in a rural community is made tolerable for all, the problem of poverty can not only not be solved but will get worse. Therefore, a national policy of scientific rural-urban development as an integrated package is essential.

So far we have generally tended to pay only lip service to the cause of rural development. People living in cities talk about the freshness and beauty of nature but would not like to go and enjoy them even after retirement. Similarly, public policies have tended to promote an interest in urban living. For example, today if a scientist or a public servant moves from a Class "A" City to a smaller place, he loses in his total emoluments. It is only in the case of the Defence Services that the principle of serving all parts of the country has been developed with appropriate provisions for non-family postings. Recently, the Indian Council of Agricultural Research has introduced the concept of compulsory service for a specific period in a tribal or neglected area by all members of the Agricultural Research Service. Compulsion alone cannot yield the desired results. What is important is to incorporate, in personnel policies, appropriate provisions for the education of children and for medical facilities to enable qualified scientists and technologists to work in areas where these facilities do not yet exist.

Rural Assets and Liabilities

An important task for this year's Science Congress is to review our rural assets and liabilities and the present state of the art of harnessing science to improve rural economy and living. On the basis of such a review, certain broad guidelines are to be developed for using the tools of science to enhance the assets of rural life.

Though our assets are well known, it is worth repeating them because they are so impressive. First, we have the second largest human population in the world, most of whom are young. Although a considerable proportion of the adult population is classified as illiterate in the formal sense, they have shown a great capacity to absorb, adapt and benefit from modern technology. There are abundant recent examples to justify this statement. The doubling of wheat production within a span of five years, the progress made in improving rice and wheat production in areas where they were unimportant before, the spread of maize, formerly regarded as a *kharif* crop, in the *rabi* season along the Indo-Gangetic Plains, the spurt in long staple cotton production, the availability of apples everywhere in the country, the progress in the production of potato, tapioca and other tubers, the development of low-cost

ground water exploitation technology like bamboo tubewells, the spread of *Gobar* gas plants and the growing diversification of export products from the rural sector are all indices of rural capability. Striking changes are visible in several parts of our country in farming systems, and animal husbandry is beginning to get more efficient. Our farmers have thus shown their readiness to adopt new technology provided it is economically viable and low risk in character and if appropriate packages of services and public policies help to ensure a reasonable return for their labour and investment.

Our animal wealth is also vast. We have over 16 per cent of the world's cattle populalion, 45 per cent of the buffalo population, over 69 million goats representing the largest population in the world, over 43 million sheep occupying the sixth position in the world, and rich populations of poultry and inland and coastal fisheries. We are also endowed with excellent wild life resources. Our soils are by and large robust and productive, although in some areas lack of care has led to considerable erosion and the development of salinity, alkalinity and other problems. Shifting cultivation is still the major source of living for nearly two million people in the north-eastern Himalayan region. This method of handling the soil was developed hundreds of years ago as the only then available answer to the law of the diminishing return from the soil. There is however no place for it now.

Our water resources are vast and varied, and the National Commission on Agriculture has calculated that the area under irrigation can almost be doubled during the next 25 years from the present 42 million hectares. In the gross sown area of about 164 million hectares, regions with high (1150 mm and above), medium (750 to 1150 mm) and low (less than 750 mm) rainfall occur in almost equal proportion. Thus, over 45 per cent of the net sown area in the country has a reasonably assured water supply. Even in the arid zone of Rajasthan there is fortunately a good underground water reserve. The water quality is by and large good, although there are areas where the groundwater is saline. An integrated strategy for the utilization of ground and surface water and for harvesting all rain water in each ecological and topographic area will help to transform our agriculture and rural economy.

The high priority accorded to irrigation, command area development and groundwater exploitation in the Fifth Plan and in the 20-point economic programme should help to make our agriculture self-reliant and provide considerable resilience in crop planning. If we consider only light duration (energy), water availability and temperature, which are three of the major factors regulating crop production potential, the period of maximum insolation in the tropics and sub-tropics unfortunately coincides with low availability of water and high temperature. The latter would lead to high evapo-traspiration and consequently greater demand for water. In the absence of irrigation, water becomes the chief limiting factor in crop productivity. Thus, the period of potential maximum yield unfortunately becomes in reality a period of

minimum productivity. In contrast, in the temperate zone the period of maximum day length fortunately coincides with periods of precipitation and temperatures conducive to growth (see table). The high and stable yields obtained with irrigation during *boro* and summer seasons in our country with several crops have fortunately focussed attention on this problem.

Estimated yield potential and per cent achieved in four rice-growing countries*

Country	Approximate duration of effective grain-filling period (days)	Average sunlight (Cal. $cm^{-2}day^{-1}$)	Estimated yield potential (t/ha)	Average yield** (t/ha)
Spain	35	500	17.9	6.27
Australia	35	600	21.1	6.25
Japan	35	350	12.1	6.02
India (*Kharif*)	25	300	7.3	1.85
(Andhra Pradesh) (*Rabi*)	25	500	13.4	2.20

*Efficiency for solar energy utilization is assumed to be 2.5%.
**FAO Production Yearbook 1973.

Our plant resources are vast and we have nearly 20,000 plant species, a greater number than in countries with a much larger geographical area. This is yet another index of the varied agro-climatic conditions prevalent in our country which offer scope for a wide range of plant species to thrive.

Thus, if one draws an agricultural balance-sheet purely in quantitative terms, our assets are great. It is an irony therefore that we should still find it difficult to provide for the basic minimal needs of our population and that we should face problems of unemployment and under-employment both in rural and in urban areas. Since I consider the population-food supply equation and the population-employment equation equally important and interdependent, I would like to dwell briefly on certain scientific aspects of these two equations.

Food Requirements

According to the estimates of the National Commission on Agriculture, our population by 1981 may be about 668 million. The total food needs for the present population and estimated population of 945 million by 2000 A.D. are about 122 and 220 million tonnes respectively. The major nutrition problem of our country is inadequacy of calories in the diet of the economically handicapped. Under-nutrition, in turn, has been attributed in many instances not so much to lack of food in the market as to lack of purchasing power in the hands of the urban and rural poor. Therefore, the food problem in many areas needs to be stated not just in terms of a certain quantity of foodgrains alone but also in terms of certain person-years of jobs which would provide the wherewithal to buy food.

If we separate the problem of increasing food production from the ability of the market to absorb it at remunerative prices we will find that there should be no difficulty in producing the food we need. In several countries of Asia, an increase or decrease in food production by a margin of about 5% may make all the difference between an uncomfortable glut and acute scarcity. Consequently, price fluctuations tend to be high, thus making it difficult for poor farmers to decide how much to invest in inputs. Some form of crop insurance will help, but this presents many operational difficulties. Ideally, there should be a global solution to this problem. The World Food Congress had recommended the establishment of an International Food Security system through a nationally or regionally held but internationally financed grain reserve of about 80 million tonnes. If implemented, this will provide a mechanism for channelling adequate external resources for the purchase of home-grown food. Both an uneconomic depression in prices and considerable loss of surplus produce in poor home storage structures can be prevented in this way.

Improvement in Productivity

Ultimately, the only real mechanism for achieving improved standards of living is increased productivity both in farms and factories. In the area of crop productivity, we occupy an unenviable position in the world.

The National Commission on Agriculture has calculated that even by 1985 the above average yield of rice and wheat in our country would be only of the order of 1.6 and 2.1 tonnes per hectare respectively. The position with regard to *jowar*, pulses and oilseeds is even worse. For these crops, the National Commission feels that the average yields in 1985 will range only between 8 and 9 quintals per hectare. We have only to compare this with the average yields of rice of 5 to 6 tonnes per hectare prevalent even now in countries with small holdings like Japan and Taiwan to see the large gap between what seems to be possible and what we are able to accomplish. Unless we take speedy action to indentify the major constraints to productivity in each cropping pattern and remove them, ours will be a very inefficient farming system. Further, there is a positive correlation between productivity and stability of yield—the higher the average yield, the greater is the stability.

In my view, the keys to achieving a comfortable position on the food front in our country in the near future are rice and *jowar* (sorghum), which occupy over 50 million hectares. I would hence like to refer briefly to some institutional arrangements which will have to be made to achieve a higher growth rate in productivity in these crops.

The following are some of the serious problems affecting rice production during the south-west monsoon period.

(a) Inability of farmers to raise nurseries and transplant at the optimum time.

(b) Lack of availability or application of improved technology for direct-seeded and upland rice.

(c) Difficulties in efficient water management, resulting either in too much or too little water.
(d) Inability to control pests effectively and in time.
(e) Poor fertilizer use efficiency.
(f) Poor post-harvest technology.

How Can We Tackle Such Problems ?

In several of our rice-growing areas and more particularly in the tribal areas, a farmer spends over two months in preparing rice seedlings for transplanting. He collects cowdung and other organic refuse and often burns this material in the place intended for raising seedlings. He uses a thick seed rate and thereby gets thin seedlings. As a result, he plants a bunch of weak seedlings together and places them rather deep in the puddle. Such practices need to be almost reversed if the yield potential of the new strains is to be realised. Community nurseries provide an institutional solution to this problem. The timely supply of healthy seedlings to farmers enables not only transplanting at the optimum time but also correct varietal choice, according to the particular situation of the farm in the village and the supply of nutrients like phosphorus and zinc at the seedling stage.

Scientific water and pest management would also need community endeavour. The new plant varieties form a dense crop canopy. This kind of crop canopy also promotes the greater incidence of some pests which were not important before, such as the brown plant hopper, which has played havoc with rice production in Indonesia and also in some parts of our country like Kerala. It would be difficult for each small holder to undertake the necessary tasks himself, even if he has the requisite will. According to the National Sample Survey, farm holdings below one hectare increased from 19.9 million in 1961 to 26.1 million in 1971. In fact, the Agricultural Census of 1971 estimates that holdings below one hectare are 35.7 million. Whatever be the correct figure, the trend is towards an increase of small holdings, which is in accord with the national policy. It would be necessary to match the national policy on size of holdings with appropriate institutional arrangements for helping small farmers not only to overcome their economic handicaps but also the biological handicaps beyond the control of an individual farmer. Devices like farmers' service societies, small and marginal farmers' agencies and more recently rural banks have been set up to tackle the economic and input supply aspects of this problem. However, in my view, unless we approach the problem in its totality, it will be difficult to achieve substantial jumps in productivity which are otherwise well within our reach purely on scientific and ecological considerations. This is particularly urgent since the technology of the future will be increasingly based on recycling principles and integrated approaches which will demand collective action by farmers in a village or watershed for efficient adoption.

As in rice, there is immense scope in *jowar*, a major food crop of unirrigated areas, for improving yield and production. Our average yield today is only about 500 kgs per hectare, while in many countries where *jowar* is grown for feeding cattle and pigs, the average yield is about ten times higher.

A breakthrough in rainfed agriculture can be expected only by planning for large quantum jumps rather than for slow and graded annual targets which are within striking distance of environmental fluctuations. The predominantly black soil belt of *jowar*, as in Madhya Pradesh, Maharashtra and parts of Karnataka and Andhra Pradesh, usually grows tall varieties of 5 to 6 months' duration. By substituting such varieties with a 3-month hybrid or variety, assured yields can be expected even during years with sub-normal rains. However, if the rains are plentiful as happened during 1975, a ratoon crop of *jowar* can be taken up or alternatively a second crop like safflower, sunflower or chickpea can be grown. It has been estimated that nearly 4 million hectares out of about 18 million hectares under *jowar* would provide opportunities for taking a double crop in years of normal rainfall, provided short-duration varieties and hybrids are grown. The establishment of single maturity *jowar* zones with regard to varietal distribution would help to minimise pests like midge.

Scientists should make, block by block, a detailed analysis of the factors impeding biological and industrial productivity. Even in a crop like sugarcane, which is one of our great botanical assets, we find that our yields are low for a variety of reasons. The National Commission on Agriculture has calculated that even by 1985 the *gur* yield will only be 6 tonnes per hectare as against about 5 tonnes per hectare now. Sugarcane is the most efficient natural quantum converter that we know today as a collector and storer of solar energy in a useful form. The efficiency of quantum conversion to sugar is about 0.25 per cent, which is very good for a field crop. Countries like Brazil where land is not a limiting factor are trying to exploit the botanical efficiency of sugarcane, even to produce ethanol and thereby cut down the import of petroleum products. For example, it has been calculated that in the San Francisco River region of Brazil, where yields are high, only 1,50,000 hectares of sugarcane will be needed to meet 10% of the annual gasolene requirements of Brazil. Why are we lagging behind in exploiting the yield potential of this wonderful crop ?

Some answers to this question have been provided by the district of Visakhapatnam, where our Congress is being held. The yields in this district were formerly poor. But by a correct varietal choice such as the variety Co. 997, and by extending the needed help to growers through cooperative societies which run all the sugarcane factories in the district, there has been a steady increase in sugar production. Similar cooperative endeavour in the supply of disease-free planting material, scientific nursery and planting practices and pest management will have an immediate beneficial effect on sugarcane yield in States like Uttar Pradesh and Bihar.

Scientific Discovery, Production Advance and Prosperity Improvement

In my view, a few basic steps are needed if we want to convert the scientific breakthrough now taking place in most crops, farm animals and in inland and coastal aquaculture into a production advance, and a production

advance into improved prosperity for all sections of the rural community. First, all groups must accept the concept of productivity. For this purpose, minimum productivity targets will have to be fixed and a farmer who does not achieve the target continuously for a few years without valid reasons should stand every chance of losing his land. Minimum targets such as 3 tonnes per hectare per year from two crops on irrigated land and 1 tonne per hectare per year in areas with over 1000 mm rainfall are neither ambitious nor unrealistic if proper institutional arrangements are made for supporting farmers. Appropriate Agricultural Productivity Acts by our State Governments could provide the social compulsion for cooperative efforts in areas like soil and moisture conservation and pest control. As an ingredient of such legislation, consideration deserves to be given to minimum limits to operational land holdings, below which the holding should not be fragmented as a unit of management, whatever be the ownership pattern.

The second need is to match the obligations of farmers under Agricultural Productivity Regulations with corresponding obligations on the part of State Governments. For this purpose, the Gram Sabhas or Panchayats may have to be restructured in such a manner that every member of the Panchayat assumes specific responsibility to organise the social support necessary for the effective adoption of a technological innovation. Unless there is a link between those who move society and those who move science and technology, it will be difficult to achieve the ends we desire. Every prospering experiment in our country in rural transformation owes its impact to a combination of these two factors.

Unlike in industry, no depreciation can be allowed on the basic assets of agriculture. The land-man ratio has already reached critical limits in several parts of our country. The history of agricultural advance of the past century has shown that in many countries productivity has continuously risen through scientific farming without any harm to the long-term production potential of the soil. As productivity increases, the area under a specific crop can go down and more land could become available for energy plantations and silvi-pastoral systems, which are essential for meeting rural fuel and feed needs. In a few States like Karnataka, there is evidence that total production is going up in a few major crops side by side with a reduction in area. This trend should become national.

Need for Accelerated Research

I have talked so far of the institutional and policy packages needed for increasing the feasibility and efficiency of adoption of new technology in our villages. Emphasis on this does not mean that all that needs to be done on the scientific front has been accomplished. On the contrary, every change produces several reactions, some favourable and some adverse. Scientific vigilance and vision will be needed to maximise the beneficial effects and minimise the negative consequences of new technology. I have already referred to the undesirable association between a "high-yield environment"

for plants and a corresponding favourable atmosphere for pests. Unscientific multiple cropping and monoculture of the same genetic strain of a crop over large and contiguous areas compound the problems of pests, which are even otherwise serious in the tropics and sub-tropics. Not only annual crops but perennial crops like citrus, mango, coconut and sandal, are affected by serious disease problems which are still evading solution. Besides pest management, I shall refer to a few more obvious areas where research work needs to be stepped up speedily.

Of the highest priority is more intensive work on the preparation of an integrated inventory of land, water, mineral and other natural resources, area by area, and the development of scientific land and water use plans. Such an inventory should indicate the steps needed to reclaim large areas now stricken by salinity, alkalinity and acidity, as well as to conserve water, soil fertility and germ plasm of plants and animals. A second area is more careful examination of weather in relation to crop and animal productivity. Fortunately, a close coordination has of late been developed between meteorologists and agricultural research and extension workers. Day-to-day decisions by farmers require the correct interpretation of short-range weather outlook. We have a good mass-media network and we can easily develop the capability to convey accurate and timely advice to farmers. Meanwhile, research on soil-crop-weather correlations, weather modification, hail dispersal and efficient forms of utilising dew should go on. A third area relates to the efficiency of conversion of cultural energy (i.e. all forms of energy introduced by man after he domesticated plants and animals) into digestible energy. The most important components of cultural energy are implements and farm power, water and nutrients, particularly fertilizer. In the technology developed so far in the affluent countries, the ratio of conversion of cultural energy into digestible energy became less coincident with an increase in productivity. For exmample, David Pimental and co-workers in a recent article in "SCIENCE" (Vol. 190, 754-761) point out that by the use of U.S. agricuitural technology to feed a world population of 4 billion a high-protein calorie diet for one year would require the equivalent of 5000 billion litres of fuel. If petroleum were the only source of energy for food production and if we used all petroleum resources solely to produce food, the estimated reserve of 66053 billion litres would last a mere 13 years. The challenge therefore lies in developing techniques which will help to improve productivity continuously without a concurrent loss in the efficiency of conversion of cultural energy. This will need a stepping up of research on tillage, water use, integrated nutrient supply and recycling of recoverable sources of energy. Also, this area needs support from well-defined public policies. For example, the conservation and use of all organic wastes would need the introduction of a rural fuel supply policy based on a combination of steps such as raising energy plantations, organisation of community bio-gas plants, supply of coal or lignite at subsidised prices and supply of electricity and other forms of energy at reasonable rates.

Fourthly, as mentioned already, research relating to the control of the menace posed to crops through the triple alliance of pests, diseases and weeds must be stepped up. It is obvious that for the foreseeable future chemical pesticides will continue to be used. For applying them with due care and caution, surveillance and early warning systems need to be developed more extensively which will facilitate the timely application of the minimum quantity of pesticide needed. Simultaneously, work on genetic resistance through screening at "hot-spot" locations and through collaboration with International Agricultural Research Centres needs to be stepped up. Diverse genes for resistance will have to be indentified since biotypes occur in many serious pathogens and insect pests, leading to the breakdown of host resistance.

Fifthly, all aspects of production physiology aiming at the improved utilization of solar energy and reduction of photo-respiratory losses by genetic or chemical means will have to receive greater attention. Sixthly, the whole area of biological nitrogen fixation both by symbiotic and non-symbiotic mechanisms requires more attention. Nitrogen Fixation Research and Development Centres might well be established at State level jointly by Agricultural Universities and State Departments of Agriculture. Here, collections of nitrogen-fixing micro-organisms, both symbiotic and free-living, could be maintained. Such Centres could distribute pure cultures of recommended strains for further multiplication and also administer quality control programmes. Since considerable basic work involving sophisticated instruments is also needed, the establishment of a National Nitrogen Fixation Research Centre supported by all the major scientific agencies might be desirable. Seventhly, we need more work on fertilizer technology in order to prevent the loss of fertilizer taking place during the *kharif* season through leaching. Some work has been done on reducing losses through blending nitrogenous fertilizers like urea with neem and other cakes and by using shellac-coated urea and sulphur-coated urea. What we need is a low-cost method involving locally available material which could simultaneously help us to reduce leaching losses and provide the needed micro-nutrients. Fertilizer technologists should concentrate on local problems and local solutions. Fertilizer is the most effective as well as most expensive input, and our requirement will grow not only for crop production, but also for animal and fish production. A national grid of small, medium and large fertilizer plants and compost units and an expanded soil testing service will hence be needed for sustaining agricultural advance. Since data on the fertilizer needed for specific yield targets are becoming available for major crops, fertilizer could be used as an effective trigger in any national policy of stabilising food production.

Eighthly, all aspects of forestry research, including the development of quick-yielding fuel and pulp trees such as annual strains of bamboo, need more intensive attention.

Finally, increasing the production of domestic animals, poultry and fish by breeding, reduction of infertility, better nutrition and health care requires much closer study. The exploitation of hybrid vigour in cattle and fish deserves

more attention. Disease problems of new genetic strains of cattle and sheep, and the harnessing of non-conventional sources of feed, particularly call for more scientific work. Recent research on fish culture in both inland and coastal waters has opened up new vistas of production. This will have to be supported by vastly expanded research on fish diseases and nutrition.

As for the future, genetic engineering involving the transfer of genes from one species to another is being increasingly regarded as a potential tool for achieving re-combination of favourable genes. Basic research in this area requires expensive facilities. A recent symposium on basic research as relevant to agriculture, organised by the Indian National Science Academy, has stressed the advisability of creating such facilities.

A serious lacuna in our present research and developmental efforts is the inadequate attention to problems of post-harvest technology. An uneven match between production and post-harvest technology has resulted from our relative neglect of the latter. Even in areas where rice is cultivated with improved varieties and fertilizer, the harvested crop has to be dried most times by small farmers on paved roads. The high moisture content of grains at the time of harvest and inadequate drying prior to storage, particularly during the *kharif* season, are resulting in increasing problems of food toxins. Studies by scientists of the Central Food Technological Research Institute at the Gurupur village in coastal Karnataka revealed a heavy fungal growth and high levels of aflatoxin in rice consumed by the population. Hepatitis outbreaks due to toxins in food have been reported by scientists of the National Institute of Nutrition (Proceedings of the Nutrition Society of India, No. 12, 1975). Thus, appropriate post-harvest technology is essential both for the farmer to get the maximum return for his labour and investment and the consumer to get food of good quality.

Population Growth and Opportunities for Gainful Employment

The next area to which I wish to refer is the population-employment equation, which, in my view, will assume even greater importance in the coming years than the population-food supply equation. The obvious first step is a vast intensification of our research and developmental efforts in the area of population stabilisation. Recently opened areas of research, such as vaccination against fertility, male contraceptives and immunisation with specific placental proteins, need to be extended full support. The cultivation of improved strains of plants containing certain steroids is now part of our strategy for reducing the cost of oral contraceptives.

The Bhagwati Committee had estimated that total employment opportunities of the order of 22.52 million man-years would have to be created in rural areas in 1969, if full-time employment was to be provided to all the available labour force. Other calculations have shown that at least 10 million man-years of employment need to be provided immediately in the rural areas. If we

measure unemployment by the criterion of productivity per person-day, the figure becomes very high, as several economists have pointed out. Ultimately, it is only productivity per person-day that can provide the basis for true prosperity. Thus, rural employment, productivity and prosperity are all interdependent. Nutrition, in turn, is related to this triangle.

The National Commission on Agriculture has calculated that to generate full employment, at least 30 per cent of the rural labour force may have to be employed in the non-agricultural rural sector, including processing, textiles and other village industries. The Commission has hence suggested both agricultural and non-agricultural programmes for generating the needed number of jobs. Rapid generation of non-agricultural, though agro-based, sources of employment is also essential if a minimum limit to operational holdings is to be introduced.

Among non-agricultural occupations in the rural sector, the development of infrastructure such as roads, housing, irrigation works, electrification and agro-service centres, has been important in the past. As agriculture advances, marketing, trade, processing, storage, distribution and transportation will demand more labour as has already been observed in north-west India, where the rice-wheat rotation and mixed farming practices are making substantial progress. There has been much talk of the growth of village and small-scale industries and the planned allocation of labour-intensive industries to rural areas, but in practice it has been difficult to make such projects viable. The non-availability of improved management and marketing techniques has rendered sustained advance difficult. Thus, wherever sericulture or honey production or any other such occupation makes progress in a village, marketing problems soon become overwhelming and farmers are unable to sustain their interest in the new vocation. There are, of course, outstanding exceptions to this trend and these are usually associated with either well-organised cooperatives or exceptional selfless individuals who command the respect of the rural society and are able to organise the entire production system efficiently. Considering the fact that about 75 million people may have to be employed in the non-agricultural sector during the next two decades, we need to pay urgent attention to the development of self-replicating models of rural growth. All the calculations mentioned by me take it for granted that children need not look for jobs and that they can be spared for schooling. Today, child and woman labour, much of it unpaid, constitutes a dominant component of the rural work force. While steps have been taken to ensure that women and men get equal wages, only economic progress can result in the child being freed for school.

Steps have been taken recently through the establishment of rural banks to channel more credit to rural areas. Similarly, rural agro-industrial complexes are being developed. In addition to the various pilot employment

schemes of the Central Government, different State Governments have initiated programmes to meet the objective of full employment. Thus, Maharashtra is operating an Employment Guarantee Scheme and Gujarat a "Right to Work" project. Other projects include the Labour-cum-Development Banks of Kerala, organisation of a Land Army in Karnataka and Mobilization of Labourers in the Rajasthan Canal Project area. The Small Farmers, Marginal Farmers and Agricultural Labourers Development Agencies aim to generate more opportunities for self-employment through a diversified farming structure. A weakness of some of these programmes is the lack of detailed scientific attention to resource use. Little benefit has generally been derived from the data available from different surveys including the recent rural engineering surveys. Scientists, technologists, educationists and rural communities have not been involved in an organised manner in such exercises. In the Maharashtra Employment Guarantee Scheme, a nutritional dimension has been incorporated and this process of integrating scientific approaches with human resource use needs to be fostered.

Education for Rural Development

The ultimate success in achieving balanced rural-urban growth will depend much upon the nature of our educational system and its integration with other developmental inputs. Different countries have approached this problem in different ways and case studies from 17 countries compiled recently for the World Bank by Manzoor Ahmed and P.H.Coombs indicate that the greatest success by any criteria has been achieved where there is a clear and overpowering national ideology and strong leadership committed to this ideology. Also, success has been assured where education, formal or non-formal, has been developed as an ingredient in a package where economic initiatives are central. Two other points emerge :

(a) Women as a group have been almost universally neglected, and so too the landless, since most of the agriculture-based education programmes benefit only those with ability to farm land.

(b) The danger of internal stratification developing between formal and non-formal education is very great. This could further strengthen undesirable urban-rural, elite-masses and educated-illiterate dichotomies.

Our country has been a leader in many areas of educational thought and endeavour. What are our assets ? We have (a) a huge and by and large well-organised infrastructure of formal education which can be re-oriented to new needs and objectives; (b) a large reserve of educated manpower, especially at the high levels, though insufficient at the middle levels; and (c) well-developed mass media which can be geared to educational purposes. Our major liability is that the imperial legacy has tended to withstand too well the encroachments of innovation.

When we became independent in 1947, it was generally assumed that quantitative expansion of the formal system of education at all levels, with suitable diversification, and qualitative improvement would be sufficient to take care of the needs of both economic development and social transformation. A radical change of consciousness is today evident for it is now recognised that the vast mass of human beings outside the formal system of education constitutes and will continue to constitute the majority of our citizens for a considerable time to come. As a result, non-formal education is now seen as the major task for the future. The new role for formal education in this larger context will be to underpin, support and contribute to the development of non-formal education in a variety of ways. The blend of both approaches will depend upon local needs.

Our attempts to equalise educational opportunities for children of all strata of society have also not been fully successful. While incentives like mid-day meals have been of some help, the main tool for equalisation has been the scholarship schemes. A drawback of these schemes is that the child who has dropped out is not considered, while selection by tests tend to leave out the very persons whom it should help. Unfortunately, culture-free tests to evaluate natural abilities by unconventional approaches in villages and urban slums are yet to be devised. We could enrich science with unusual talent and skills with effective talent-scouting.

Vocationalisation as a Response to Unemployment

The assumption behind vocational education has been that it will equip a person with certain technical knowledge and skills to enable him to make a livelihood through a vocation. The absence of a close linkage between the available avenues of employment on the one hand and the training on the other has invalidated this approach. For example, though agriculture, forestry and fisheries account for the employment of over 80% of the labour force, the fewest number of vocational courses are available in these areas. There is a shortage of teachers who can effectively teach these subjects even if courses were offered, and there has been no serious effort to train teachers on a large scale in these skills. Agro-industries too have been neglected.

Another lacuna is training for self-employment. Very few courses are offered in the skills needed for self-employment on a small or medium scale at the middle levels of education. Only recently, the Indian Council of Agricultural Research has started establishing *Krishi Vigyan Kendras* which will cater to the needs of practising farmers and fishermen. Nearly all non-formal educational programmes for women undertaken by welfare agencies in the last twenty-five years have concentrated on teaching skills like sewing, embroidery and tailoring. Women tailors however are notoriously few. More recently, non-formal education programmes for women have emphasised home-based skills related to health, nutrition, child care and kitchen gardening. Schemes for training women in skills related to agriculture, forestry and fisheries are

still few, despite the fact that 50% of the agricultural labour force are women, and 80% of all women in employment are engaged in the production and post-harvest aspects of agriculture.

Expansion of Higher and Professional Education

The pattern of higher education and professional training in the past has evolved from colonial models on the assumption that quantitative expansion and high 'quality' ('quality' being measured according to hypothetical 'world' standards rather than in relation to national needs or objectives) would automatically take care of our scientific manpower needs. It is now recognized that the 'brain drain' is in part an outcome of a mismatch between the type of specialised education offered and the types of employment available. In retrospect, it appears as though unconsciously we have trained our scientific manpower to meet the requirements of Western industry, science, technology and society. That 'content' is an important ingredient in 'quality' is now being realized. The recent committee on the restructuring of medical education has made a breakthrough in the subject by beginning from the needs and goals of the country for medical care and analysing the ingredients of a medical education suited to meet them. Similar exercises are needed in other areas. Agricultural education has generally tended to remain close to the field. Such nearness to field problems has a pay-off in research, as is evident from the fact that we are the first nation to cultivate hybrid cotton on a commercial scale, using labour-intensive technologies. Agricultural Universities which have not yet done so should develop experimental and demonstration farms which will inspire farmers and serve as windows into our agricultural future.

Social Responsibility of Science

Though lip service is often paid to the ideals of social commitment, our system of selection, training and evaluation of scientific personnel at all levels, or of the teaching profession, does not provide for it. For instance, selection and later promotion are mainly based on academic records and attainments and publication of papers. Job requirements rarely include such elements as participation in developmental activities. These could take a variety of forms, ranging from the writing of textbooks and preparation of kits, toys, games and educational materials to participation in mass media programmes, demonstration and extension campaigns for the popularisation of science, and work in teacher training and lower-level education and training programmes. Such elements could be built into the system if the relevant activities with 'social' value that a scientist could legitimately engage in were spelt out.

Some Significant Innovations in Education

Lest the foregoing should give the impression that we are not trying to change, I would like to cite a few significant recent innovative approaches.

(i) The recent introduction of compulsory work experience in schools, which has its roots in earlier aspirations expressed in Basic

Education, has a great potential for making education more meaningful and relevant to life. For its proper handling, however, the active assistance of all scientific agencies in the country will be essential.

(ii) The introduction of 10+2+3 pattern has as its major objective the task of making secondary education terminal and reducing the rate of expansion of higher education. Earlier attempts in this direction have not met with success chiefly because of a lack of a positive correlation between educational content and employment possibilities. Detailed planning will have to be done on this, if this scheme is also not to fail for the same reason. Until this gap is bridged, there may be some merit in linking education and employment in the same Ministry of Government.

(iii) The Farmers' Functional Literacy Project and similar schemes in adult education and their success in the last decade have indicated the tremendous potential for need-based and functional adult education.

(iv) The National Social Service for youth and the experimental mass programmes for youth, such as Youth Against Famine and Youth Against Dirt and Disease, are others with potential for increasing the contact of students with the realities of our rural life.

Some smaller programmes which are still in an experimental or pilot stage but which need to be watched carefully for their possible use as prototypes for change are :

(i) The establishment of Nehru Yuvak Kendras in 100 districts to channelise the energies of rural youth.

(ii) The Bhumiadhar experiment in non-formal education carried out by the National Council of Educational Research and Training.

(iii) The Science Education Centre of the Bombay Municipal Corporation launched and supported by the Tata Institute of Fundamental Research and the Community Science Centre, Ahmedabad.

(iv) The programme for improvement of primary science education, primary curriculum development and community participation in education being developed in certain areas with UNICEF/ UNESCO support.

(v) The establishment of Krishi Vigyan Kendras by the ICAR for imparting the latest technical skills to practising farmers, fishermen, rural youth and women.

In the non-official or voluntary sector, some significant experiments have been made. They have many lessons to teach in regard to planning, supervision, methods and objectives, and a careful evaluation of such programmes would be rewarding. Often, such programmes tend to be linked inevitably with certain dedicated individuals and their fate also becomes linked with the fate of those individuals. We should hence evolve an organised way of institutionalising such innovative procedures.

Criteria for a Suitable Infrastructure to Relate Science and Education to Rural Development

Taking the existing institutional and educational patterns as given, I shall try to indicate the directions in which they need to move to become a force for the regeneration of our rural economy and life. A satisfactory system should—

(a) Enable the formal education system and all scientific laboratories to become instruments which can further the non-formal education of the masses. Ways can be found, but the first essential is that institutions accept the servicing of the non-formal sectors as one of their basie objectives.

(b) Encouraging group effort and group development in contrast to the attempt to lift individuals from one level to another. Acharya Vinoba Bhave's concept of simultaneously fostering a spirit of cooperation and competition among students by making a "group of students compete with their own past" has to be translated into curricular and extra-curricular procedures.

(c) Relate vocational education and training to the job requirements of the present and the future through intensive local studies.

(d) Spell out the goals of professional education at all levels—from paraprofessional through middle level to high level specialists—in terms of the objectives and needs of our country.

(e) Spell out the social responsibilities of scientists (in both research and education) and of academics in all disciplines in concrete terms of job requirements. People should be enabled to understand and fulfil their responsibilities to development through professional contributions and not merely by being associated in their leisure time with political, social welfare or educational organisations.

With these as guiding principles, let me now indicate briefly the necessary mechanism to get the system moving.

(i) Every institution of higher education (including university departments, colleges, research and training institutions, junior colleges

and schools) should incorporate some form of development activity into their regular teaching-learning programme. This could take the form of placements of students in projects as part of their field practical work, or as apprentices; involvement of the staff or the institution itself in "action or operational research" and other possible studies. Such participation should be a condition for the receipt of financial assistance from Government. I would like to stress that this involvement be not thought of merely in terms of "adopting a village", holiday work camps and other sporadic activities, or different forms of "Sunday social work" but be a part and parcel of the regular programme of work and be regularly budgeted for. As an example of what can be done, the ICAR had submitted to Vice-Chancellors of our Universities a programme for student and faculty involvement in rodent and pest management, control of noxious weeds like "carrot grass", and tree planting. The response has so far not been encouraging, except from a few Agricultural Universities.

(ii) Projects taken up will have to be extremely localised in character so that in each case it would be possible to have some kind of coordination between the various agencies concerned.

(iii) Grant-giving agencies and Government departments funding scholarship schemes should introduce more group awards as recognition of contributions of inter-disciplinary groups to society in any walk of life, and group scholarships to enable institutions to strengthen themselves and provide better education and services to a whole community.

(iv) Academies and research organisations should start honouring those who have done good work under difficult circumstances, for example in tribal and neglected areas.

(v) Curriculum planning at +2 level should incorporate a period of field work placement as an integral part of the course for both academic and non-academic streams. Several ways are possible, including :

(a) Employment for specific period in an appropriate development project in the area.

(b) Survey or field study.

(c) Apprenticeship in a working agency.

These may sound fairly small steps to be taken now. However, the task is enormous and requires intensive work in localised studies, planning,

working out of details, field surveys, coordination of a number of agencies, and learning new ways of working together. The involvement of students in the planning exercise is vital, as unless they are convinced of the utility of such an approach for their future, the attempts are unlikely to prove successful. Few of the steps that I am advocating, for instance, are new. They have been advocated many times before, separately and by many persons, including myself. Yet, movements in this direction seem pitifully small in comparison to the magnitude of the effort needed.

Let us not multiply differences but seek common denominators for action. Formal and non-formal education are both essential and mesh with each other in real life. While writing this lecture, I asked myself how I learnt the principles I value most. The answer was clear—through informal education in childhood. My late father inspired by Gandhiji was then (in the early nineteen thirties) engaged in a battle against untouchability, which took different forms, including an agitation for opening the gates of Hindu temples to Harijans. He was also involved in collecting and burning foreign clothes since he was convinced that a swadeshi movement was essential for our economic well-being. Finally, he succeeded, through a combination of scientific technique and social action, in eradicating filariasis in a short time from a town which was then notorious for mosquitoes. These examples fostered in me an awareness of the injustice of irrational prejudices, the need for self-reliance and the pivotal role of community action in accomplishing great tasks in a way which no formal teaching could have done. The experience of everyone here with regard to "education" must be similar.

Spreading the Innovative Procedures

All over our country, there are hundreds of little programmes pursuing innovative approaches. We are not short of ideas or the men to carry them out. But to transform these myriad efforts into part of an organized plan and to involve the entire academic community in this effort is the task I see before us now. It is a task of an order of magnitude which is probably unprecedented in the history of our education or scientific endeavour. Time is short. We may have forestalled the prophets of doom who predicted a future of starvation for our country, but shall we be content to drag the spectacle of our misery into the next generation ? How much longer shall we drift, making valiant uncoordinated individual efforts here and there to hold back disaster but seemingly unable to gear up the total organism to the challenge ? This is the question to which the scientific community gathered here must address itself.

We need to fully exploit our human ability to create rational patterns of collective activity. Such patterns will continue to be coloured by personalities, but the basic structure should lend itself to replication, like the DNA molecule. It is easy to state this principle but the pathways of achieving it

are by no means within easy reach, since they encompass our entire working culture. Nevertheless, we should begin by applying ourselves to the question of the basic common requirements that would enable us to move in the right direction and evolving the appropriate legislation that would serve as a framework for action. Legislative measures for integrated rural and urban development designed to promote the symbiotic growth of the village and the city can take into consideration the following needs :

(i) the setting up of scientific and administrative consortia for each block and town which can help to develop and implement ecologically sound rural works and urban growth programmes (in the scientific consortium, all scientific and technical institutions in the area as well as colleges and schools should be involved, and in the administrative consortium appropriate representatives of all rural community, industry and input supply agencies will have to be members);

(ii) minimum limits for land productivity and operational holdings for irrigated and unirrigated land in each area to provide the social compulsion for cooperative endeavour and proper use of land;

(iii) reservation of specific industries, credit and energy for the rural sector;

(iv) an employment guarantee scheme as an integral part of an overall resource utilisation strategy;

(v) reservation of unproductive land for non-agricultural uses like brick-making, construction of buildings, etc. and banning the use of good soil for such purposes;

(vi) a rural drinking water and fuel supply policy;

(vii) a scientific plant-animal-man food-chain policy for each agro-ecological area based on long-term considerations of the fertilizer, feed, water and land requirements of each production system;

(viii) soil and water conservation and tree plantation; and

(ix) an integrated formal and non-formal educational system involving participation by students and teachers in appropriate rural/urban development programmes.

A beginning towards providing ecological guidelines for development has been made through the Water (Prevention and Control of Pollution) Act of 1974. Comprehensive legislation for integrated rural-urban development will be a continuation of this process. However, we should also guard against the tendency to feel that once a law has been enacted all that is necessary has been done. Good administration and implementation of policies alone can make the legislation worthwhile.

Knowledge and Humility—Basic Equipments for Rural Service

Before the era of science and technology and of population explosion, life was probably simpler, although often precarious. The following verse* for example, illustrates how farmers once felt totally independent of government:—

From sunrise I work,
Till sunset when I retire;
I drink the water from the well
That I have dug;
I eat the food from the field
That I have tilled.
Kings and emperors,
What have they to do with me?

When the pressure of population on finite resources was not heavy, such individual autonomy was well within the realms of possibility. Nevertheless, under such a situation life was not free of trouble. For example, in the last two decades of the last century alone, the then British Government had to set up several Famine Commissions to go into serious problems of hunger and unemployment, although population pressure was not high at that time.

You, Madam Prime Minister, expressed this in a different way when a few years ago you said in reply to a critic who attributed recent agricultural progress solely to good monsoons, and I quote: "For a long time, God was working alone in our fields. Later, God and man combined together and did their best, but today God, man and science have joined, and the results are there to see".

There are at present many areas in human life and endeavour which are beyond our comprehension and control. Darkness and light, unrelated to science, alternate in our lives. This, in my view, is a desirable state of affairs since it instils in us that humility which leads to understanding and enquiry and thereby to progress. Gandhiji described humility as a basic equipment for those who wished to serve the villages. Let us discuss various aspects of "science and integrated rural development" with humility but with the awareness that humility must be followed by both enquiry and action. Our collective future depends upon how fast we act to bridge the gap between exception and the rule in all areas of development.

*Quoted from Chi-wen Chang's "A Strategy for Agricultural and Rural Development in Asian Countries" — 1974.