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FOOD AND AGRICULTURAL RESEARCH – ITS PAST AND FUTURE CONTRIBUTION TO AGRICULTURAL, SOCIAL AND ECONOMIC DEVELOPMENT

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FOOD AND AGRICULTURAL RESEARCH - ITS PAST AND FUTURE CONTRIBUTION TO AGRICULTURAL, SOCIAL AND ECONOMIC DEVELOPMENT

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In his "Essay on the Principle of Population" (1790) Thomas Malthus wrote that "Population, when unchecked, increases in a geometrical ratio. Subsistence only increases in an arithmetical ratio", to which, in the light of recent experience, Porgy and Bess would probably respond: "It ain't necessarily so".

Food and Population

Population records indicate that in 1970 the developing countries were inhabited by 1.7 billion people. Throughout the decade of the 1970s LDC population grew at a rough average of 3 percent per year, from which trend, one can extrapolate that there will be roughly 2.2 billion people in the LDCs by the mid-1980s, an increase of about 500 million during one decade. From 1980 to 1990 it is anticipated that there will be an additional 30 percent growth, from 2.2 billion to nearly 2.8 billion. These are crude averages and the rate of population increase will continue to be highly variable among different countries. For example, a number of countries in Western Europe have reached zero or negative population growth. In

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The views expressed are those of the authors and do not necessarily represent the views of the International Development Research Centre.

the developing world however there are more than 30 countries whose population growth rates exceed 3 percent per year; ten are found in Latin America, ten in the Middle East, ten in Africa and a smaller number in Southeast Asia. One can but hope that many of the developing countries will look to the example of the People's Republic of China where between 1970 and 1975 the crude birth rate is estimated to have dropped from 32 to 19 per 1,000.

Based on overall statistics, food production in the LDCs kept slightly ahead of population growth throughout the 1970s. The average for all developing countries suggests that over the past 25 years food production per capita has been increasing at about 0.5 percent per year. Such averages are inherently misleading and conceal wide variations among developing countries. Whereas in many developing countries total staple food production is lagging behind or barely keeping pace with population increase, India in recent times has been able to set aside more than 20 million tons of cereal grains as a strategic store, most of which consists of wheat derived from the high yielding semi-dwarf cultivars.

Wheat, maize and rice provide interesting examples of how significant increases in yield (weight of grain per unit area of land) may be achieved as a direct result of perceptive, thoughtful, and imaginative research. During the past decade while population increased by 30 percent in developing countries, their total production of wheat increased by 50 percent, maize by close to 40 percent while rice production increased at roughly the same rate as population. Later it will be shown that while rice is produced in one of the most highly intensively cropped areas of the world, multiple cropping with rice as the main crop is increasing total food crop production in the rice lands of Asia. At the present time, high yielding wheat cultivars are grown on roughly 48 percent of the total land given to wheat in developing countries. If these same countries had imported the extra 24 million metric tons they have produced from high yielding wheat cultivars, it would have cost them roughly 3 billion U.S. dollars in foreign exchange.

High yielding wheat and rice types were introduced in the mid-1960s. Table 1 shows the proportions of the wheat and rice growing areas now sown to high yielding cultivars. At present more than a third of the wheat and rice producing areas of the developing countries, representing 55 million hectares, are under high yielding varieties. Seventy-five percent of the wheat areas of India, Pakistan, Bangladesh and Nepal are under high yielding wheat and more than 70 percent of the rice areas of the Philippines, and more than 30 percent of the rice areas of India, Indonesia, Malaysia, Pakistan and Korea are given to the high yielding genotypes. Rice and wheat production in developing countries have grown respectively by 2.4 and 4 percent annually since the widespread introduction of the high yielding crops.

One of the most critical factors relevant to the population and food equation in developing countries is the number of persons that must be fed from each unit area of farm land. Based upon data from FAO and other sources, during 1975 an average of three persons in the developing countries were supplied from each hectare of crop land. Extrapolating from an estimated increase of 30 percent in population per decade, by 1985 each average hectare in the developing countries must provide food adequate for four persons and by the end of the century for five persons.

But these averages do not reveal the dramatic differences among developing countries. Table 2 illustrates in sharp contrast our justification for cautious optimism on the one hand and near despair on the other when we compare the state of different countries. In 1975 in Mexico 60 million people were sustained by 28 million hectares of arable land, equivalent to about two persons per hectare. During the same year in Egypt 37 million people were fed from 3 million hectares, equivalent to 13 per hectare. Extrapolating present data, by 1985 Mexico will need to support three and Egypt sixteen persons per arable hectare. By 2000 A.D. Mexico will have increased to five and Egypt to twenty-two persons per hectare.

It is evident that unless a dramatic and unexpected brake is applied to population growth in developing countries, production levels of staple foods, which for most people means cereal grains, and to a lesser extent root crops, must be significantly expanded. If these increases are to be achieved simply by higher yields, that is greater weights of harvested grain per unit area of land, the average cereal grain yields in LDCs during 1975 of 1.3 metric tons per hectare must be increased by 1985 to 1.7 tons, and by 2000 A.D. to 2.2 tons per hectare. These represent crude linear extrapolations and take no account of wide variations in population increase nor in increased consumption demands by those segments of the LDCs' populations whose disposable income is rising above the national average.

Higher Crop Yields

There can be little doubt that higher yielding cultivars will continue to contribute in spectacular fashion to overall increases in productivity. For example, during the decade following the introduction of the higher yielding plant types of rice and wheat in the mid-1960s, average rice yields in LDCs increased by 17 percent and total production by 27 percent; wheat yields increased by 24 percent and annual production by 50 percent (see Table 3). Research on more neglected but none the less important cereal grains such as sorghum indicate that by careful genetic selection, combined with improved agronomic practices, yields may be increased by a factor of ten. Cassava, which provides the main source of carbohydrate calories for perhaps 300 million people in developing countries, gives normal average yields of five to ten tons of roots (roughly 1.5 to 3.0 tons of dry matter) per hectare. Through research directed to a better understanding of the factors that control photosynthesis in the leaves and the efficiency of translocation of photosynthates to the root, plant breeders and agronomists in Latin America can demonstrate yields of 30 to 50 tons of roots per hectare.

Because in so many developing regions the availability of arable land is a primary constraint, increased productivity must of necessity focus upon greater production of edible matter per unit area of land per unit of time. Understandably, therefore, greatest emphasis is given to seeking plant types with an inherent genetically controlled ability to produce higher yields, and to agronomic systems that exploit this high yielding capability to fullest advantage.

There are, however, complementary approaches that deserve attention and encouragement. Plant scientists now actively seek genotypes that mature more rapidly than their established relatives. The time to maturity of most traditional rice types is at least 120 days. Scientists at the International Rice Research Institute (IRRI) have identified cultivars that mature in less than 100 days, thus permitting two or even three crops of rice to be grown upon the same piece of land in the same year. Although these sequential multiple rice cropping systems present a whole new generation of economic and technological problems, they clearly offer a remarkable opportunity for increased annual production per unit area of land. Sorghum breeders in West Africa have selected lines that mature in less than 90 days and are therefore able to take full advantage of the very short rainy season.

Multiple Cropping Systems

One of the more recent and potentially dramatic research endeavours related to increasing land productivity, seeks to increase total edible matter production per year by greater cropping intensity through the use of multiple cropping, in which several food crops are grown either simultaneously in mutual symbiosis, successively when one crop is planted after the other is harvested, or sequentially in which one or more are planted while the other is still growing. Multiple cropping, the production of more than one harvest of the same or different crops from the same piece of land in one calendar year, is by no means a new agricultural phenomenon. Multiple cropping has been practised in China and many Asian countries for as long as historical records are available. According to Aristotle's pupil Theophrastus, in his "History of Plants", Babylonian farmers during the second millennium harvested two crops of wheat, followed by an abundant pasture for their domesticated animals, on land irrigated from the Euphrates. It seems not improbable that Egyptian farmers of the third and second millennia also practised multiple cropping, considering the remarkable permeation of irrigation canals and dykes fed from such reservoirs as Lake Moeris. If all the surface and underground water present were efficiently exploited and managed, the Indo-Gangetic Plain could become the most prolific food basket in history. Efficient irrigation water management appears as one of the dominant determinants to increased productivity through monocropping or multiple cropping systems. Another important contributor to modern multiple cropping systems is the development of rapidly maturing varieties previously referred to.

Farming Marginal Lands

The heavy and increasing demand upon available arable land calls for research to bring under food or fodder crops land previously considered unsuitable because of a hostile climate, soils of low fertility, inadequate rainfall or other unfavourable conditions. Many and varied efforts are being made simultaneously in order to extend the areas of food production.

One approach seeks plant types more tolerant of adverse conditions: rice cultivars that can be directly seeded under dry upland conditions where continuous irrigation is impossible or uneconomic; floating rice that grows fast enough to keep its head above water in areas where intermittent heavy rains cause flooding; rice that is tolerant of high salinity and other adverse soil conditions.

Increased research is being devoted to sorghum and several of the minor millets which display exceptional tolerance to continuous and intermittent drought; to comparatively neglected food crops such as quinoa, a staple food of the Amerindians, which in addition to being highly nutritious, display an adapted tolerance to the harsh conditions of the high Andes where many of the poorest people of Latin America survive.

There is now available an inter-generic cereal hybrid that is more tolerant of certain adverse conditions than any known cultivated naturally occuring cereal grain. Triticale* combines the high yield and desirable technological characters of its wheat parent combined with the ruggedness and superior amino acid composition of its other parent, rye. For more than a hundred years, wheat x rye hybrids were little more than botanical curiosities, until the combined efforts of scientists at the International Maize and Wheat Improvement Center (CIMMYT) and the University of Manitoba demonstrated that the inferior seed quality and mule-like infertility of wheat x rye hybrids could be ameliorated. From the massive population breeding and selection program there emerged a promiscuous outcross found

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* The name "Triticale" is derived by hybridizing the generic names for wheat, Triticum and rye Secale.

to exhibit an inheritable fertility. The number of fertile hybrids was subsequently increased by advanced techniques of embryo culture followed by colchicine treatment of the resultant seedlings. Most first generation triticale seedlings are infertile since they possess only a single set of wheat chromosomes and a single set of rye chromosomes. The two sets of chromosomes cannot pair for the purpose of sexual reproduction and therefore no offspring can result. When colchicine, an alkaloid derived from the autumn crocus, is applied to the seedlings, the chromosomes are frequently doubled and in consequence the two sets of chromosomes can pair enabling the hybrid to reproduce itself.

The superiority of triticale over wheat under adverse conditions is demonstrated in the Highlands of Ethiopia, in Northern India, where triticale is being successfully grown between 6,000 and 10,000 feet, in the Highlands of East Africa where it is more resistant to stripe and stem rust, and in Latin America where it is clearly more tolerant of light, sandy, acid and aluminum soils. Unfortunately, with the exception of Ethiopia and Mexico, food technologists have not kept pace with plant scientists, by demonstrating that triticale can be successfully used in traditional and other acceptable cereal foods.

A serious effort is now being made to bring into production more than 850 million hectares of forest and savanna land in tropical Latin America. The soils over most of this area consist of oxisols, ultisols and andosols which are generally acid (pH below 5.5) and low in available phosphorus. For the most part it is uneconomic to use imported chemically manufactured superphosphates, but at many locations in the region one finds naturally occurring rock phosphates such as the Huila and Pesca rocks of Colombia and Sechuna of Peru. Preliminary results indicate that by simple concentration of the phosphate present, followed by fine grinding with or without partial acidulation, the natural rock phosphates, when applied to the acid soils, significantly increase yields of food crops, forage grasses and pasture legumes.

Animal Production

There is a tendency among some commentators on world nutrition to ignore or even to decry the potential value of farm animals in food production systems. This opposition is based upon the simplistic calculation that roughly seven calories of input are required to produce one calorie of output when cereal grains are fed to livestock (see Table 4). What is overlooked is that carefully selected mixtures of forage grasses and pasture legumes will grow over many marginal land areas unconducive to production of cereal grains or other food crops. Furthermore, during seasons of low rainfall when the pastures are less abundant, the animals may be fed on hay or silage supplemented by a wide variety of agricultural and industrial wastes and by-products. The International Development Research Centre (IDRC) is supporting a growing network of research projects in Asia, the Near East, Africa, the Caribbean and Latin America, each of which seeks to raise animals on land unsuited to crop production and with agricultural by-products such as coffee pulp, cassava leaves and the waste from starch manufactures, which cannot be fed directly to human beings.

Mention has already been made of the critical value of efficient water management to intensive cropping. One of the most exciting opportunities for the more productive management of inland and coastal waters lies in aquaculture and mariculture: the farming of village ponds, natural and man-made lakes, rivers and irrigation canals; oysters, mussels, other shellfish and finfish in coastal waters.

Aquaculture and Mariculture

A major constraint to date, to increased fish production in Asia has been the shortage of fish seed owing to the fact that females of many fish species do not readily lay eggs in captivity. Ovi deposition can however be induced by injections of crude gonadotropin extracts from the pituitaries of other fish, including the Pacific salmon. The techniques of gonadotropin extraction and concentration have been refined at the Fisheries Research Board Laboratories in Canada.

Throughout the Philippines and some other countries of Southeast Asia, milkfish (*Chanos chanos*) provide as much as one half the supply of dietary protein. During 1977 at the Southeast Asian Fisheries Development Centre (SEAFDEC), for the first time on record, a female milkfish was induced to spawn by gonadotropin injection. This breakthrough promises enormous benefits to the Philippines, Indonesia and other Asian countries which now raise annually 250,000 tons of milkfish from naturally occurring fingerlings in natural and artificial ponds, in lagoons and in flooded paddy fields. Unfortunately the supply of natural fingerlings is but a fraction of the demand, hence the potential value of induced spawning.

In most countries, aquaculture means monoculture, the raising of a single species. Monoculture is constrained by the available food required by the species cultured. Recent research in India has developed polyculture systems that yield up to 10 times more fish than ponds stocked with a single species. Using a combination of as many as six non-competitive carp species, with fertilizers and supplementary feeds, research scientists in India have obtained up to 9000 kg of fish per hectare of pond surface per year. These systems of polyculture are now being established in village ponds in several Indian states.

In many developing countries, oysters and mussels provide a valuable dietary protein supplement for coastal communities. In their natural habitat, where they attach to mangrove roots and other submarine surfaces, the bivalves are overcrowded, their food supply is limited, and, consequently their growth is stunted. In Sabah and Sierra Leone, on ropes suspended from floating rafts in coastal waters, oysters of an average meat weight of 9 grams, are grown in 9 months. It takes 3 to 5 years to produce an oyster of equivalent size in temperate water. On average these oysters are 4 times the size and develop in one-fifth the growing period of the crowded wild mangrove oysters.

In Singapore in open coastal waters 225 kg of mussels are being produced below each square meter of raft every six months. This scale of production is approximately equivalent to 90 metric tons of protein per hectare of surface water. For comparison, a good crop of soybeans produces about 0.9 metric ton of protein per hectare per year.

Despite repeated attempts to develop capture fisheries, Singapore with a population of 2.2 million, today imports 75 percent of its annual fresh fish requirements of 65,000 metric tons. In an effort to decrease its current dependency on imports and to promote an effective fish production industry, biologists in Singapore have established an intensive sea cage culture system with the cooperation of fish farmers and coastal fishermen. The system, whereby fish are reared in floating cages, is suitable for the farming of many species of finfish. Preliminary studies on groupers gave production rates of 400 metric tons per hectare per year as opposed to 2 metric tons per hectare per annum with traditional pond culture practices.

Agroforestry

Agroforestry, the controlled management of combinations of trees with other crops and farm animals, offers opportunities for increased food supply for humans and animals, together with a more rational management and conservation of the natural environment. Roughly 36 million square kilometers of land are subjected to shifting cultivation in which the natural forest cover is destroyed by slashing and burning, following which crops are grown until the soil nutrients are virtually exhausted. Soil exhaustion takes no more than three years, when the shifting cultivators move on the repeat the process and expand depredation of the natural forest. A new international organization, the International Council for Research in Agroforestry (ICRAF), has been created specifically to explore how areas subjected to shifting cultivation may, in the future, be conserved and used efficiently by more scientific systems of land management and crop cultivation.

Trees in combination with crops offer many advantages. Deep tree roots act as nutrient pumps, the falling leaves restoring nitrogen and other essential elements to the top soil. Trees in the semi-arid tropics protect the crops from searing winds and blowing sand. IDRC has established a network of more than 20 projects in the semi-arid regions of Africa, each of which seeks to establish trees as a useful economic component of small farming systems. Trees, particularly but not solely the leguminous species, fix atmospheric nitrogen and provide feed, fodder and shade for farm animals, together with wood for fuel and building materials. A recent study in semi-arid West Africa revealed that women spend on average ten hours each day in three activities:(1) collecting fuel food, (2) collecting drinking water, (3) grinding grain. The shortage of cheap fuel is, in many developing countries, as acute as the shortage of edible food. Hence the greater production and efficient utilization of wood as a fuel deserves more intensive research.

Investment in Agricultural Research

Brief reference was made earlier to the actual and potential impact of the high yielding cultivars on rice and wheat production in developing countries. It has recently been estimated that high yielding rice types produce 40 percent more per hectare per year than traditional varieties and that annual incremental production of high yielding wheat and rice approaches 30 million tons, at an annual value between $3 and $4 billion, greater than the total cereal production of Africa south of the Sahara. Recent studies demonstrate a significant increase in farm income generated by these more productive technologies. They also indicate that the return on investment in research on high yielding varieties has indeed been very high. Other studies strongly suggest that, contrary to many public statements and widespread publications, in those areas for which the high yielding wheat and rice crops are ecologically suited they have been widely adopted by large scale farmers, small farmers, land owners and tenants. Though small farms tend to lag in their rate of adoption, following an initial lag or induction period, few differences are observed between large and small scale cultivators. For example, in the Pakistani Punjab high yielding crops were adopted by 73 percent of the smallest farms and 79 percent of the largest farms. Fertilizer application rates were similar across farms of different sizes.

The improved rice and wheat technologies resulted from the imaginative research undertaken at IRRI and CIMMYT, two of the family of International Agricultural Research Centers (IARCs) supported through a consortium of multilateral and bilateral donors that include UN agencies, international and regional development banks, various national governments and private foundations. The Consultative Group on International Agricultural Research (CGIAR) began in 1971 with a membership of 15 donors, a total contribution of barely $12 million which supported five IARCs. The CGIAR has now grown to almost 30 donor members, it supports 11 IARCs, two or three more coming into the wings, and in 1979 the total contribution to research will be in excess of $100 million. The list of IARCs supported by the CGIAR, together with a brief statement of the crops and systems for which they are responsible is to be found in Table 5.

The consensus of the literature is that the introduction of high yielding wheat and rice has not only increased food production but has had a significant and positive effect on income distribution, the primary beneficiaries being the lower income consumers who spend a high proportion of their total income on food. Since the demand for basic foodstuffs tends to be inelastic, increases in output tend to lower real food prices thus permitting low income consumers, who spend a high proportion of their total income on food, to increase their food intake and/or to improve its nutritional quality.

Since the CGIAR family of international centres concentrates exclusively on food crops and food production systems, it is believed that benefits similar to those derived from wheat and rice will be displayed as a result of the research of the other members of the CGIAR family of research centres. About 60 percent of the resources of the CGIAR are devoted to crops typically grown and consumed by low income groups, such as sorghum, maize, millet, cassava and food legumes, and to farming systems in semi-arid and arid conditions where some of the poorest small holder farmers of the world are to be found.

However, it must be remembered that research leading to improved technologies cannot resolve all economic and social ills. Nevertheless, in addition to increasing on-farm production and labour demand, more efficient technologies generate greater total national income which enlightened social policies can distribute more equitably.

Adoption of Research Results

One of the greatest problems facing the IARCs is how to accelerate the adoption of their improved technologies among a greater number of resource-poor farmers in developing countries. To hasten on-farm adoption of more productive technologies requires, concurrently, a variety of initiatives and changes in social and political attitudes. First, it requires the strengthening of national agricultural research and development programs and to this end the CGIAR is contemplating the creation of an international service for the strengthening of national agricultural research facilities in developing countries. But even if all the research facilities in developing countries were strengthened sufficiently to be able to absorb and adapt the improved technologies generated by the IARCs in many countries there is clearly an enormous intellectual and communications gap between research workers and the rural communities for whom the products of their research are supposedly intended.

Some scientists, not excluding those in developing countries, appear to overlook several important historical facts. First, food and agricultural technologies were in existence many thousands of years before systematic scientific research devoted to food and agriculture came onto the world scene. Half a million years ago Peking man (Sinanthorpus pekinensis) used fire to cook and therefore to preserve meat from a variety of ancestors of many contemporary animals. He probably extracted the juice from wild berries and either he, or one of his many generations of successors, discovered that the seeds of various natural grasses could be ground, mixed with water and cooked to provide appetizing foods. More than ten thousand years ago Egyptians used ridged and hollowed out stones to grind cereal grains, and at some point discovered by controlled grinding and winnowing of the ancestors of our modern wheats the means by which to separate all or part of the seed coats from the endosperm. It is interesting that flour milling as practised today is not different in fundamental principle from the system used by the ancient Egyptians, Greeks and Romans, and that only during the last 25 years, with the introduction of mechanical development to replace long fermentation, has any fundamental change taken place during 6,000 years in bread making technology. It seems probable that through the perception of the more curious and imaginative of many generations of farmers, agricultural systems have evolved in a manner that is rational and logical to their agroclimatic, social and economic environments. Consequently, it would seem sensible that food and agricultural scientists who seek to help and improve existing agricultural production and post-harvest systems, should first comprehend the systems that have been so painfully evolved over many centuries of trial, error and observation.

A fine example of this approach is to be found in the Cropping Systems Network sustained and coordinated by the International Rice Research Institute. This program started and has continued through a thorough study of existing rice farming practices in various parts of Asia, including a close examination and measurement of the technical and economic determinants by which the farmer's opportunity to expand his production is constrained. A detailed agroclimatic survey was made of the whole Asian region, then alternative multiple cropping systems were developed to suit different conditions of soil, topography and weather patterns. The University of the Philippines cooperated by screening a wide range of crops other than rice, including sorghum, sweet potatoes, food legumes and some horticultural crops, for characters that would best fit into the various alternative multiple cropping systems proposed. The alternative cropping systems were tested under a wide range of agro-climatic conditions, mostly in farmer's fields under farmer management. Children and high school students in these rural communities play their part by observing and recording the nature and level of farm inputs, such as labour for planting, weeding, harvesting and other activities, the cost of these inputs, and the value of the harvested crops. Agricultural economists have studied the effect of different cropping sequences on labour demand and have shown, contrary to many people's understanding, that labour in many intensive systems becomes a primary constraint.

The genius of Norman Borlaug recognized that the means to increased yields of wheat grain was a shorter stiffer straw, strong enough to support, without toppling, the larger heavier heads of grain.

Food Research and Technology

Food science and technology has contributed greatly to the high standard of living of inhabitants of the industrially developed nations of North America, Europe and Oceania. But in contrast with the success of the international agricultural research system, food science and technology programs for the benefit of the least possessed in developing countries have in general been less spectacular. While there have clearly been a number of food research, food technology and food industry development projects that have been productive and beneficial, many have fallen short of original expectations. It is the authors' belief that many of those that failed did so because they sought to begin their research in the laboratory rather than with the consumers, food processors and distributors whom their research should seek to serve.

The pattern by which such advanced technologies as nuclear energy, electronics and aero-space machines were developed, presents an intimidating and often misleading example to those who seek to apply science to long-established technologies. Nuclear energy is an unplanned, unforeseen derivative of remarkable research by scientists whose purpose was to gain a more profound and comprehensive understanding of the structure of matter. The sequence, basic research leading by chance to applied research that gives rise to an economically viable technology, is rarely an ideal and is often an inappropriate example for technologies that were devised and evolved by astute artisans and careful craftsmen.

An extensive, expensively equipped central food research institute, particularly if owned, controlled and operated by a national government, may prove less of an asset than hoped for to the improvement and expansion of existing agro-industries, and to the development of relevant, efficient and economic post-harvest systems among rural communities. Not only must technologies be appropriate to environments, research, in concept, scope and sequence of endeavour, must be appropriate to the existing and established technological capacity.

Among well intentioned donor agencies, multilateral and bilateral, one senses an unwarranted optimism in the transferrability of technology.

Scientific principles are universally applicable; many technologies are not. Biological technologies whether they relate to the cultivation of edible plants or to the transformation, preservation and distribution of plant products are greatly influenced by their surrounding environment. Consequently it is difficult if not impossible to transfer post-harvest technologies and food transformation systems from developed countries with temperate climates to the less developed countries of the semi-arid or humid tropics. Technologies, based on sound scientific principles need to be developed where they will be used, in close cooperation with those who will use them.

A number of reports by committees of the International Union of Food Science and Technology (IUFoST) have commented upon and recommended a new approach to technological improvement in developing countries. These reports review critically past experience in relations between donor agencies and developing countries; the difficulties of providing technological and economic benefit to small scale industries in rural areas from an urban, central government-owned food research institute; the suitability for developing countries of the generally accepted pattern of university courses for graduates in food science. Is the classical PhD the most apposite and applicable form of training for countries where the capacity to adapt and exploit original fundamental research is limited, indeed where the need is to guide an orderly and evolutionary process of technological improvement rather than to try to impose a revolutionary technological transformation? (It should be emphasized that the name "Green Revolution" was coined by journalists not by the scientists who worked for many years to develop and encourage adoption of the high yielding types of wheat and rice.)

These are questions with which IUFoST is wrestling. They are questions that deserve consideration by UNCSTD and the scientific community at large.

General Observations

There is much to be found in our recent technological history to refute Malthus' dreary prediction and to encourage cautious optimism in our ability to satisfy the basic nutritional needs of an expanding world population. It would however be idle and irresponsible to suggest any universally applicable panacea. The range of diversity and heterogeneity among developing nations far exceeds any differences between the so-called developed and less developed economies. Nevertheless, in the light of contemporary and past experience, there appear to be a number of courses of action worthy of serious consideration.

First, investment in the international agricultural research system deserves to be continued and expanded since the results so far indicate a substantial pay-off in terms of increased productivity, increased labour demand, increased farm income, and the lowering of food prices to consumers. Second, much greater investment is needed in research and development dedicated to a better understanding and improvement of post-harvest systems. Post-harvest losses continue to run at a high level, and as described in several of the publications listed in the bibliography, occur at all stages of the post-harvest sequence from the time of harvest to the time of consumption. Particular attention needs to be given to improved post-harvest systems for the principal cereal grains, oilseeds, food legumes and root crops.

A subject that has received less attention than it deserves concerns the technological and nutritional properties of agronomically superior food staples. Though higher yield potential must remain a high priority for plant breeders, high yield must be combined with other essential properties: grain types that can be satisfactorily processed industrially or domestically; that do not require excessively long cooking or which display other characters unacceptable to consumers. The future calls for a closer integration of interest and effort between agricultural scientists and food scientists and technologists.

A much greater research effort must also be dedicated to the preservation and distribution of fish in tropical countries where refrigeration is for the most part unavailable and uneconomic. The promise and potential of aquaculture and mariculture will not be realized until effective and economic methods of fish preservation are adopted. The applied research required must start where the fish are harvested with a thorough study of the climatological, social and economic conditions that prevail; the research at all stages must be pursued in close cooperation with the fishing community that will eventually make use of whatever technologies are elaborated.

There is an urgent need to strengthen food and agricultural research facilities in all developing countries. While external multilateral and bilateral donors may through financial and technical assistance contribute to this strengthening process, the greatest responsibility rests within the developing countries themselves, first with their governments who must assign a higher priority together with a higher level of dignity to those who engage in food and agricultural science and technology. As long as politicians, military men and white collar professionals are considered superior beings to those who devote their lives to the production, preservation and distribution of essential food, one cannot expect the concentration of intellect and endeavour that is necessary to be devoted to the food needs of the developing countries.

Furthermore, the food and agricultural scientists of the developing countries must be prepared to spend more time away from their laboratories and experimental farms gaining a better understanding of the social, economic and technical opportunities and constraints of small scale producers and processors. It is unfortunate that so many food research institutes in developing countries have been established in major cities thus ensuring that a great physical, intellectual and philosophical distance separates the scientist and technologist from the rural communities where the principal food and agricultural problems and opportunities are to be found. The serious levels of post-harvest spoilage of rice and fish will not be reduced by scientists manipulating a battery of spectrophotometers in laboratories several hundred kilometers from where the fish and rice are harvested.

Research Management

Perhaps the most urgent need in the whole world of food and agricultural science and research is for the training and development of managers of applied research, people who recognize that applied research is by definition research for human benefit and who must therefore acquire a capacity of broader and deeper comprehension and attitude than is provided by conventional BSc, MSc and PhD courses. Some scientists appear to believe that managers like marriages are created in heaven and that a competent scientist is automatically a competent research manager. It is the authors' belief, based on some years of experience, that research scientists who display a potential for management significantly improve their research management capability when given appropriate training.

The International Scientific Unions

Equally urgent to the ends we are discussing is a more extensive, comprehensive, organized and systematic involvement of the world's scientific community. The ability to contribute significantly to improved food and agricultural systems throughout the world, and in particular in developing countries, is by no means confined to those who regard themselves as food and agricultural scientists. One could cite many examples of chemists, physicists, mathematicians and engineers, to name but a few disciplines, who when presented with a scientific challenge of which they were previously unaware, responded quickly and fruitfully.

A few of those with whom IDRC has been associated include a group at Saskatchewan who are elucidating the hormonal mechanisms in sorghum by which drought tolerance appears to be influenced; engineers in Alberta and Saskatchewan who have developed improved milling and other post-harvest systems for cereals and legumes grown in the semi-arid and humid tropics; Professor Haslam at Sheffield who has recently isolated and identified the polyphenol which seriously reduces the nutritional quality of sorghum;

and Professor Johnson at Sussex whose group has synthesized analogues of the root exudates of food plants that stimulate the germination of several important pernicious parasitic weeds.

It is certain that a great many serious constraints to improved agricultural production and post-production systems could be eliminated if these were brought to the attention of a broader spectrum of scientific competence. It is sad but true that many decisions made by the administrators of multilateral and bilateral development agencies are guided more by political expediency than by scientific logic. There is therefore an urgent and pressing need for the world scientific community in both developed and developing countries to gain not only a more comprehensive understanding but also a greater degree of influence over those whose decisions determine food and agricultural research and development policies. This is not to denigrate or devalue the important role of many existing multilateral and bilateral development agencies, but it must be recognized that more than a few are guided by some measure of self interest or political pressure. The international scientific unions and their member organizations cut across all sorts and conditions of scientific men, women, academic institutions, international agencies, national governments, private, public and para-statal corporations. They therefore represent a formidable and as yet virtually untapped source of scientific wisdom and technological experience.

In the minds of many of our contemporaries science appears to be equated more with the evils of destruction and despoliation than with the virtues of creating a more just society and the satisfaction of human needs.

Is it not time for scientists of the world to unite in order to demonstrate that they wield and can exert an almost limitless power for human benefit? And should we not begin with an internationally organized scientific assault upon the most basic and universal of all human needs - the need for an adequate diet.

IDRC/OTTAWA
November 29, 1978
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Table 1

Proportions of Total Area of Wheat and
Rice Sown to High-Yielding Varieties: 1976-77

Region	Wheat	Rice	Total
		%	
Asia	72	30	41
Near East	17	4	17
Africa	23	3	7
Latin America	41	13	31
TOTAL	44	27	35

Source: Data provided by Dana G. Dalrymple, USAID

Table 2

Population Per Arable Hectare in Selected Countries, 1975, 1985 and 2000 A.D.
Assuming No Change in Population Growth Rate

	Arable hectares (millions)	Population 1975 (millions)	Population per arable hectare 1975 (persons)	Annual rate of natural increase 1965-75	Population 1985 (millions)	Population per arable hectare 1985 (persons)	Population 2000 AD (millions)	Population per arable hectare 2000 AD (persons)
Mexico	28	60	2	3.5%	85	3	136	5
Korea,Rep.	24	34	14	2.0%	41	17	54	22
India	167	608	4	2.0%	741	5	983	6
China P.R.	129	823	6	1.7%	974	7.5	1241	10
Kenya	1.8	13	7	3.3%	18	10	28	15
Tanzania	6.1	15	2.5	2.8%	20	3.5	30	5
Egypt	2.9	37	13	2.3%	46	16	63	22
All LDCs	670	1900	3	2.5%	2400	3.5	3343	5

Sources:

Arable hectares from FAO Production Yearbook. Arable hectares includes land used for both annual and permanent crops.

Population levels and rate of natural increase from "Population Growth 1965-75" published by Population Reference Bureau, Washington, D.C.

Ratio of man to land extrapolated.

Table 3

Performance of 6 Cereals in Developing Countries 1961-65 Compared with 1971-75

	Annual area			Annual Yield			Annual Production		
Cereal	1961-65 (million ha)	1971-75 (million ha)	Increase (percent)	1961-65 (kg/ha)	1971-75 (kg/ha)	Increase (percent)	1961-65 (million m.t.)	1971-75 (million m.t.)	Increase (percent)
Rice	85.8	93.0	8	1614	1884	17	138.5	175.4	27
Wheat	50.4	61.3	22	976	1211	24	49.2	74.3	50
Maize	44.8	53.4	19	1132	1313	16	50.7	70.1	38
All cereals*	270.7	299.9	11	1098	1296	18	297.3	388.9	31

Source: FAO Production Yearbooks

*Includes cereals not listed.

Table 4

Animal feed conversion (calories of input/calories of output)

Beef	16:1
Pork	6:1
Turkey	4:1
Eggs	3:1
Broiler	3:1
Average	7:1

Source: USDA, Economic Research Service

Table 5

The international agricultural research institute network

Center	Program
International Rice Research Institute	Rice, multiple cropping
International Maize and Wheat Improvement Center	Wheat, maize, barley, triticale
International Institute of Tropical Agriculture	Maize, rice, cowpeas, soybens, lima beans, cassava, yams, sweet potatoes, and farming systems
International Potato Center	Potatoes
International Crops Research Institute for the Semi-Arid Tropics	Sorghum, millets, peanuts, chickpeas, pigeon peas
International Laboratory for Research on Animal Diseases	Blood diseases of cattle
International Livestock Centre for Africa	Cattle production
International Center for Agricultural Research in Dry Areas	Wheat, barley, lentils, broad beans, oilseeds, cotton, and sheep farming
West African Rice Development Association	Rice
International Board for Plant Genetic Resources	Coordinate collection and exchange of plant genetic materials
International Center of Tropical Agriculture	Beans, cassava, beef and forages, maize, rice and swine

Annual Reports of all the IARCs may be obtained through the CGIAR Secretariat, c/o IBRD, 1818 H. Street, N.W., Washington, D.C. 20433, U.S.A.

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