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THE GREEN REVOLUTION: PAST SUCCESSES AND FUTURE CHALLENGES

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It is my great pleasure and personal satisfaction to attend the First International Wheat Symposium in Cd. Obregon, Sonora, Mexico. Here in Cd. Obregón, Sonora, 53 years ago, I began the wheat breeding research in association with my Mexican colleagues. The outcome and impact of this collaborative research has been documented widely, however, I shall try to give you an overview of my early work leading into Green Revolution and subsequently the establishment of International Agricultural Research Centers (IARC).

The term "Green Revolution" was coined in 1968 by Dr. William S. Gaud, Director of the US Agency for International Development (USAID), to describe the breakthrough in food production caused by the introduction and rapid diffusion of the new semidwarf wheat and rice varieties in India, Pakistan and other parts of the developing world.

The Green Revolution has had a far-reaching impact on the economic and social structures of many low-income, food-deficit nations. Many initial reporters chose to depict the Green Revolution as the wholesale transfer of technology from high yield agricultural system to peasant farmers in the Third World. To me, however, it signified a new era in agricultural research and development in the Third World, one in which modern principles of genetics and plant breeding, agronomy, plant pathology, entomology and economics were applied to develop technologies appropriate to the conditions of local farmers.

The impact on food production of the high-yielding wheat and rice technologies has been enormous (Table 1). In 1964-65 there were probably less than 5,000 hectares worldwide planted with the new high-yielding semidwarf wheat and rice varieties worldwide; by 1990, there were more than 130 million hectares growing these plant types.

Table 1. Estimated Changes in Wheat and Rice Production, Yield, Area, and Input Use in Developing Countries, 1965-94.

	1965	1975	1980	1985	1994	% Change 1965-94
Population, millions	2,210	2,950	3,280	3,650	4,350	97
Wheat & rice production, million ton	303	451	527	652	739	144
Yield, ton/ha	1.5	1.8	2.3	2.8	3.2	113
Area, million ha	190	228	234	234	230	21
fertilizer, million nutrient ton	4	20	38	46	65	1,525

Source: FAO Production and Fertilizer Yearbooks

The new wheat and rice varieties have been the catalyst for many other technological changes in agriculture in Asia. Fertilizer use has increased more than fifteen-fold, the irrigated wheat and rice area has expanded by 50%, and the amount of irrigation water available for wheat and rice cultivation more than doubled. The high-yielding wheat rice technologies also led to positive spillover effects on other crops, as farmers sought to improve productivity in other farm enterprises.

One of the greatest contributions of the Green Revolution in India has been the land saved, which would have been needed to feed the population. Let's examine the figures briefly. Had the same wheat and rice yields prevailed today that prevailed in 1961-65, India would have needed an additional 94 million hectares of similar quality to produce the 1995 wheat and rice harvests (Tables 2 and 3). Imagine the environmental consequences of trying to bring this additional land into cultivation! Indeed, it would have required the bringing into production lands not suited for intensive cultivation, including forest and grasslands, because of vulnerability to erosion.

Table 2. Profile of Wheat Production in India and Land Saved Through Productivity Gains

YEAR	AREA (1000 ha)	YIELD (kg/ha)	PRODUCTION (1000 ha)	LAND SAVED (1000 ha)
1961-66	13,191	830	10,950	--
1970	16,626	1,209	20,093	7,582
1975	18,111	1,338	24,235	11,087
1980	21,962	1,437	31,560	16,061
1985	23,100	1,909	44,100	30,032
1990	23,500	2,120	49,850	36,560
1995	25,490	2,560	65,240	53,112

Source: FAO Production Yearbooks

Table 3. Profile of Rice Production in India and Land Saved Through Productivity Gains

YEAR	AREA (1000 ha)	YIELD (kg/ha)	PRODUCTION (1000 ha)	LAND SAVED (1000 ha)
1966-70	36,360	981	35,770	--
1975	37,890	1,045	39,580	2,487
1980	38,970	1,082	42,180	4,027
1985	41,100	1,418	58,300	18,329
1990	42,170	1,756	74,053	33,827
1995	41,640	1,952	81,260	41,194

Source: FAO Production Yearbooks

Contrary to the prediction of some critics--that the new high yielding technologies were only suitable for richer farmers--it is now well-documented that India's resource-poor farmers, with only relatively brief lag times, adopted the new seed/fertilizer technologies about as frequently as the more resource privileged, large-scale farmers. Nor did prediction that Green Revolution technologies would accelerate labor displacement in rural areas prove true. While some categories of labor declined, e.g. threshing, many new job opportunities opened up in farm machinery operations, input supply, grain marketing and other agro-services; the net effect on rural employment has been positive.

The consumer, however, has been the main beneficiary of the Green Revolution. The really important attribute of the new technologies was that they simultaneously provided farmers with increased profits and consumers with more bountiful and reliable food supplies which, in turn, led to declining real food prices. It is calculated that in real terms the cost of wheat-rice has declined by over 70% in this time--a tremendous contribution to poor men, women and children. The larger wheat and rice harvests have enhanced food security in many developing countries. In India, for example, wheat stock reserves have been built up in good years to help compensate for the bad years when harvests are poor. Greater food security has been especially important to the poor consumer, who in the past suffered chronic and serious malnutrition in years when poor harvests sent food prices skyrocketing.

The Green Revolution also taught many political leaders in the Third World, that a dynamic agricultural sector can neither be initiated nor sustained without the support of dynamic research and technology delivery systems. Over the past 25 years, a large research infrastructure--scientists, experiment stations, laboratories, trained manpower--has been built up in the developing world, involving tens of thousands of researchers, mostly in publicly funded institutions. Considerable growth in the international agricultural research network has also occurred since the establishment of IRRI in 1960 and CIMMYT in 1966. Today 16 centers and 1,200 scientists are supported by the Consultative Group for International Agricultural Research (CGIAR).

Current Status of World Food Supply

In 1990 our world food supply totaled about 4.6 billion tons gross weight (2.4 billion tons edible dry matter), which was more than twice the tonnage produced in 1961-65 (Table 4). Approximately 98% of this food supply came from the land; less than 2% came from the oceans and inland waters. Some 30 plant species provided most of world's calories and protein. Eight species of cereal grains, collectively accounted for 70% of calories and 42% of the protein contained in the world food supply.

If the world's food supply were distributed evenly, the total food supply could have provided an adequate diet (2,350 calories, principally from grain) for 6.5 billion people--1 billion more than the current population. If, however, dietary standards in developing countries had been better, so that 15% of the calories came from animal products, less than 4 billion people could be fed. And if people in developing countries had attempted to obtain 30% of their calories from animal products, as in the USA or European Union countries, a world population of 2.7 billion people could be sustained-only half of those actually present on the planet Earth.

Table 4. World Food Production, 1990

Commodity	Gross Tonnage	Million metric tons Edible Dry Matter[1/]	Protein[1/]	Production Increase, % 1980-90[2/]
Cereals	1970	1640	165	20
Wheat	600	528	62	29
Maize	480	422	44	13
Rice	520	353	30	31
Barley	180	158	16	10
Sorghum/millet	85	76	7	-4
Roots & Tubers	575	154	10	5
Potato	270	59	6	0
Sweet potato	125	37	2	-7
Cassava	150	55	1	22
Legumes, oilseeds, nuts	300	204	68	29
Sugarcane & sugarbeet[3/]	125	125	0	20
Vegetables & melons	450	53	5	26
Fruits	345	47	2	17
Animal products	850	168	74	24
Milk, meat, eggs	750	141	56	18
Fish	100	26	18	33
All Food	4,615	2,390	397	20

[1/] At zero moisture content, excluding inedible hulls and shells
[2/] 1979-81 and 1989-91 averages used to calculate changes
[3/] Sugar content only
Source: 1990 FAO Production Yearbook

Feeding the Future: The Challenges Ahead

Future world food demand will be determined by two factors: population growth and per capita food consumption. The United Nations Population Agency's medium projection is for world population to reach 6 billion by the year 2,000 and about 8 billion by 2,025, before stabilizing about 10 billion toward the end of the 21st century. Over 90% of the worlds projected 3 billion additional people will reside in what are now low-income developing nations (Table 5).

Table 5. World Population Projections

	Population (millions)			% Increase
Region	1990	2000	2025	1990-2025
Low and Middle-Income Economies				
Sub-Saharan Africa	495	668	1,229	148
East Asia & Pacific	1,577	1,818	2,276	44
South Asia	1,148	1,377	1,896	65
Europe	200	217	252	26
Middle East & N. Africa	256	341	615	140
Latin America & Caribbean	433	515	699	61
Sub-total	4,146	4,981	7,032	70
Other Economies [1/]	321	345	355	11
High-Income Economies	816	859	915	12
World	5,284	6,185	8,303	57

[1/]This classification includes the former Soviet Union, Cuba, the Democratic People's Republic of Korea, for which inadequate and/or unreliable data is available.
Source: World Development Report 1992, World Bank

Even if the often inadequate per capita nutritional levels of 1990 were maintained, annual world food production in 2,025 must be 60% greater (7.4 billion tons gross weight) than it was in 1990 (4.6 billion tons gross weight). However, if there are dietary improvements among the poor in low-income, food-deficit countries, annual world food demands by 2,025 could be as great as 8.2 billion tons, gross weight, twice as much as the 1990 production level.

South Asia and Sub-Saharan Africa are the regions with the most poverty (Table 6). By year 2,000, South Asia will still have the largest absolute numbers of poor people although sub-Saharan Africa still will have the highest percentage--50% of the total population--in such dire straits.

Using the population growth rates shown above, and expected changes in per capita cereal demand, we have come up with the following projections for the cereal crops through the year 2,025 (Table 7). To meet the projected food demands, the average yield of all cereals must be increased by 80% between 1990 and the year 2,025. Fortunately, there are still many improved agricultural technologies--already available or well advanced in the research pipeline, and only partially being exploited--that can be employed in future years to raise crop yields. There are still unexploited "yield gaps" in virtually all low-income, food-deficit developing countries as well as in the former Soviet Union and Eastern Europe.

Table 6. Poverty [1/] in the Developing World, 1985-2000

	Percentage of population			Number of poor below the poverty line (millions)		
Region	1985	1990	2000	1985	1990	2000
South Asia	52	49	37	532	56	511
East Asia	13	11	4	182	169	73
Sub-Saharan Africa	48	48	50	184	216	304
Mideast & N. Africa	31	33	31	60	73	89
Eastern Europe [2/]	7	7	6	5	5	4
Lat. Amer. & Carib.	22	26	25	87	108	126
All Developing	31	30	24	1,051	1,113	1,107

[1/] US $370 annual income per capita in 1985 purchasing power parity is used as the poverty line; it is based on estimates from a number of sources. In 1990, the poverty line would be approximately US $420 annual income per capita.
[2/] Does not include the former USSR.
Source: World Development Report 1992 (table 1.1, p. 30)

Yields can still be increased by 50-100% in many areas of Asia, Latin America, the former USSR, and Eastern Europe, and by 100-200% in much of sub-Saharan Africa. Such productivity gains can be achieved by improving efficiency all along the crop production line, beginning with better land preparation to assure optimum crop stands, more timely planting of the very best available varieties, proper fertilization, and improved control over menacing weeds, diseases and insects. Conserving soil moisture under rainfed agriculture, and managing water more efficiently under irrigation will become ever more important as yields become higher, assuming proper nutrient balance in maintained.

Table 7. Current and Projected World Cereal Production and Demand (million tons) and Yield Requirements (kg/ha)

	Current	Projected		Yields, ton/ha		
	Production	Demand		Actual	Required	
Cereals	1990	2000	2025	1990	2000	2025
Wheat	600	740	1,200	2.4	2.8	4.4
Rice	520	640	1,030	2.4	3.1	5.3
Maize	480	620	1,070	3.7	4.1	5.8
Barley	180	220	350	2.3	2.7	4.1
Sorghum/millet	85	110	180	1.5	1.8	2.6
All cereals	1,970	2,450	3,970	2.5	2.9	4.5

Source: FAO Production Yearbook and my estimates

More recent estimates by IFPRI indicate that extra demand for wheat and maize will far outstrip that for rice.

The declining per capita availability of arable cropland in may of these countries means that future production gains must come, even more than in the recent past, from higher crop yields and more intensive land use practices. Furthermore, because 10 to 12 years usually elapse between the time research is funded to the point when the results show up in food production figures, the productivity gains for the remainder of the 20th century must come from research investments already made. Fortunately, there are many improved technologies already available or well advanced in the research pipeline, that can raise crop yields by 50-100% in most tropical and subtropical farming areas of Asia and Latin America, and by 100-200% in much of sub-Saharan Africa. To capitalize on this unexploited agricultural potential, however, far greater investments will be needed now and in future years in agricultural research, water resource development, input production and distribution and marketing systems, rural education, and public health.

The Importance of Agricultural Research

Continuing research and new technology generation are the key to meeting the world food demands of the 21st Century. Although the capacity to produce and distribute new agricultural technology in the Third World has increased immensely over the past 30 years, the rate of agricultural modernization during the 1980's has slowed. One of the problems, I believe, lies within the organization and management of agricultural research system itself—both at the national and international level. I am especially concerned about the very poor links between research, per se, and technology generation and delivery.

In looking back over my 53-year career in international agricultural research and development, I have found it often easier to develop an improved technology than to get it into the hands of farmers. In trying to transform a stagnant traditional low-yielding agriculture, we must be aware of the inertia and defeatism that exists at many levels in government organizations. The peasant farmer is often blamed for being unwilling to adopt new technologies; I strongly disagree with this thesis, having found the peasant farmer to be very receptive to adopting new technology if it offers a large increase in productivity within reasonable levels of risk.

Often the mayor stumbling block has been government civil servants, including many agricultural research leaders, who try to protect themselves by clinging to the *status quo*, and thereby often repress creative new research initiatives. For this group *status quo* of the known traditional methods are comfortable, whereas the fear of the risks of the new unknown technology is frightening. These are the negative forces against which agricultural researchers and extension workers must struggle if they are to succeed in serving their farming communities. Without venturesome scientists who are capable of cutting across disciplines and integrating research information into viable technologies, and who have the courage and ability to make their case with political leaders to bring research advances to fruition, the future diffusion of new agricultural innovations in the low-income, food-deficit nations is not at all assured.

From my perspective, agricultural research managers and decision makers need to spend more time on the ground, monitoring what is happening—or not happening. Further, IARC, researchers themselves must limit their pursuit of beautiful academic butterflies and must strengthen their interactions with national research and extension systems, and farmers. Too many have become detached from the realities in farmers' fields, preferring to measure their achievements by the information and products generated—and learned papers published—rather than by adoption of their technologies in the countryside. This should be changed.

Plant breeding is the greatest practical achievement of the biological sciences in the 20^{th} century. Compared to the traditional varieties, today's new cereal crop varieties are vastly more efficient in grain production and their genetic resistance to diseases and insects and tolerance of various agroclimatic stresses. The greatest successes in diffusing improved cereal varieties have been in wheat and rice, where about 70% of the area of these crops in the developing world is planted to high-yielding varieties. Growing success is now also being achieved in diffusing the improved varieties of maize, barley, sorghum, the pulses, and oilseeds developed by agricultural researchers.

Obsolete Bureaucratic Quarantine Regulations

Permit me to comment on obsolescent plant and animal quarantine regulations. Thirty years ago, the human disease quarantines were complicated and bureaucratic. To travel internationally one had a large number of vaccination certificates, for a large number of diseases. Some of these vaccinations, such as for cholera and typhoid, were very ineffective and not recognized as being useful by many MDs. As a result, a large, flourishing, sterile, arrogant, difficult bureaucracy was spawned. Following many years of struggle, quarantine regulations have been changed, with the result that today, to travel internationally, one needs only a vaccination certificate for yellow fever, for most countries. These regulation still prevail despite the appearance of HIV (AIDS) for which there currently is no control.

Even though two hundred million tons of grain per year and large tonnages of many other agricultural commodities are traded internationally, there is no fumigation or disinfection required, because of the way the standards are written. Yet there are many impurities that move with this grain, including weed seed, loose bits of straw, dirt, insects, and fungal spores of many different kinds. On the other hand, if one attempts under current regulation to ship 10 gram to 1 kilo samples of grain of improved crop varieties to collaborators in other countries, one is confronted with a whole complex of plant quarantine regulations and an extremely inflexible and arrogant bureaucracy.

Genetic Diversity

One of the great obstacles to further assist in the diversification of genetic material is the above mentioned difficulties with the plant quarantine system. They are obsolete, they need to be brought up to date and made realistic in terms of the level of risks involved as has been done in public health and the human medical quarantine regulation. Why don't agricultural scientists speak out against the ludicrous system of plant quarantine for experimental germplasm? Surely, no one would deny that the two hundred million tons of grain that are traded internationally pose far greater dangers than the shipment of small quantities of seed that have been inspected carefully, disinfected and/or fumigated with the best processes now available. Again, *status quo* is confortable while the fear of the unknown is frightening to bureaucrats. Unfortunately, many scientists, who have become infected with this timidity virus are reluctant to speak out against obsolete rules and regulations and consequently indirectly are increasing the dangers for failure of our crop production system.

At the present time, some scientists in a number of countries are outspokenly attacking geneticist and plant breeders for lack of genetic variation in the improved crop varieties they are developing and deploying. I do not accept this accusation. It is my belief, certainly in wheat, but I am confident that in rice, maize and most of the other basic crops, that there is more genetic variation present in the breeding programs and in the total cropping system today that has ever existed in the past. This tremendous genetic variation has been incorporated by conventional plant breeding and, in more recent years, further diversified by the use of biotechnology transformations and the incorporation of DNA from other species and genera. Of course, it is true that not all of that genetic variation is being planted at any one time (many lines and varieties with diverse resistance are held in reserve) and that some very popular and successful varieties or hybrids are grown on vast areas. However, if plant pathologists and entomologists are properly monitoring commercial crops to report changes in new races and if seed delivery systems are in place to rapidly multiply and move the seed of new varieties (held in reserve) to farmer's fields, and if active plant breeding programs are maintained to pyramid genes for resistance then our agriculture can be protected from serious damage. This is more true today that ever before. Moreover, if and when need demands, the use of multiline varieties can be resorted to (which I demonstrated in the 1950's to be a feasible method of introducing great diversity of genetic resistance to stem and leaf rust wheat varieties).

Getting Agriculture Moving

To achieve the agricultural productivity gains needed in low-income, food deficit countries to keep pace with rising consumer demand, a combination of factors constraining yield must be manipulated and overcome in an efficient and orchestrated manner. These include: 1) restoration and management of soil fertility, 2) development and use of improved crop varieties (and animal breeds) combining higher genetic yield potential with improved disease and insect resistance, and 3) the use of improved crop management practices including integrated pest management and integrated soil fertility management programs.

Given current scientific knowledge, it is my belief that agricultural chemicals—especially fertilizers—are absolutely essential to produce the food needed to feed today's population of 5.8 billion, which is increasing currently at the rate of nearly 100 million per year. The amount of organic fertilizers available and crop rotations employing legumes cannot alone—without the use of chemical fertilizers—restore and maintain soil fertility to a level adequate to meet the current and rapidly growing food production requirements. The population monster does not allow us to turn back the clock to the "good old days" of the early 1930's, when little chemical fertilizer was used. Lest I be misunderstood, I want to stress that fertilizers, and agricultural chemicals, like medicine, should be used with the proper caution. Clearly, the maintenance of soil fertility becomes more complicated as crop production is intensified. In the future, farmers will have to become more skilled in soil chemistry and agronomy if they are to deal with the growing secondary and micro-nutrient deficiencies which must be corrected to sustain high grain yields.

The technology that has greatly changed the world food production over the last 50 years, and enable food production to stay abreast and increase slightly faster than world population, involves the use of improved high yielding disease resistant crop varieties and proper seed rates and dates of planting, land leveling, fertilization to restore depleted nutrients, and control of disease, insects and weeds. The so-called broadly-adapted, high-yielding varieties of wheat and rice that were introduced into Asia during the 1960's, and which produced dramatic results, were not an elixir in themselves. They do not have the ability to produce high yields on worn out soils without restoration of the nutrient balance by the proper use of fertilizer to meet the nutrition needs of the plant.

Yet, despite the enormous benefits chemical fertilizers have brought to the world—which greatly outweigh any deleterious effects due to overuse (in a few areas of the developed nations)—the issue of chemical fertilizer use is still subject to heated, and generally uninformed, debate. The fertilizer use issue was a problem in the 1940's and 1950's in Latin America, especially in Mexico. It was one of the main issues that was passionately debated in India, Pakistan and China during the 1960's and early 1970's and currently, it is one of the issues that is most hotly debated in African countries south of the Sahara. In reality, the major culprits in overuse of fertilizer are the profligate agricultural systems used in many countries of the north especially in some areas where large amounts of animal manure are combined with the use of heavy applications of chemical fertilizers.

Over the past two decades, the environmental movement which has grown in popularity and power, has done much to further confuse the issues concerning restoration of soil fertility. For example, the "virgin" uncultivated oxisols of Brazil, Colombia, Venezuela, Peru and parts of Africa and Southeast Asia, because of heavy leaching over geologic periods of time, are depleted of several essential nutrients for vegetative growth. Moreover, because of the leaching of calcium and magnesium they are strongly acidic and high in soluble aluminum, which is toxic to the roots of most plant varieties. This is the work of Mother Nature, not agricultural man. Humankind certainly is also guilty of depleting plant nutrients. That is why slash and burn shifting cultivation has been so pervasive until relatively recent times. By opening new land, there was an abundance of nutrients for a few years, but as the nutrients were depleted, and plant competition was increased by aggressive weeds, crop yields dropped precipitously, to a point where it was easier and more economical to open new land and abandon the previous land to fallow for 10-15 years. Only during the past one hundred years and especially during the last fifty, has shifting cultivation given way to continuous cultivation based on the replenishment of soil nutrients increasingly with chemical fertilizers.

We should not forget that the forests of Western Europe were largely destroyed to provide the land for agriculture which fed those nations as they were being urbanized and industrialized. The same is true of the United States. The Ohio River Valley, for example, which is today one of the most important parts of the USA grain belt, was once covered with forests, but was deforested and converted into some of the best agricultural land in the world. Consequently, when we see what is going on in the rain forest and some of the other forests in areas of Latin America and Africa today, Europeans and Americans should not forget their own histories. While I do not condone what is going on there, we need to remember that the problem of soil infertility has been haunting humankind from the beginning of agriculture. As numbers accelerate, the significance of restoring and maintaining soil fertility becomes increasingly crucial, not only for food security, but indeed to preserve civilization.

Let me use an outstanding example, the case of one of the first American civilizations, namely the civilization of Teotihuacan which was established apparently about 300 BC and flourished, began to deteriorate in the early part of the eighth century AD, and had collapsed by the end of the century. The civilization of Teotihuacan was built on agriculture. At its peak, the city was estimated to have had a population somewhere between 150,000 and 200,000 people. It was even larger than the city of Rome in the time of Caesar. Why did it collapse? There are many different theories. Some scientists believe that the springs and water table dropped below the levels necessary to support the potable water needs of the city; others blame cataclysmic earthquakes; others blame epidemics of pandemic disease; others the shortage of wood for housing, roofing and for cooking and heating fuel, and others attribute the collapse to conquest by a stronger tribe.

It is my contention that Teotihuacan collapsed primarily because of the depletion of plant nutrients. We must remember that this huge city was built without either the benefits of the wheel or an animal beast of burden. If one assumes a population of 150,000 with a diet of 2,350 calories per day, largely from maize and beans, one begins to see the problem of supplying that city with its daily food needs. The requirements for maize alone would have been about 88 tons per day. Expressed in terms of 40 kg sacks that would have to be carried on human backs, some 2,200 sacks per day would be required, or approximately 800,000 sacks per year. At that time, there was no information available to the population about how to restore the fertility to the land and the result was the collapse of Teotihuacan. As the soil fertility was depleted, more and more of the food had to be brought from greater distances, until finally the system collapsed.

Currently, extremists in the environmentalist movement, who have strong influence over international financial institutions by way of lobbying, have convinced the authorities that there is no need for chemical fertilizer, and that organic fertilizers can meet crop needs for a stable food supply. How far from the truth! We cannot produce the food that the world needs with the use of organic fertilizers alone, especially for African countries south of the Sahara, where there is very little organic matter available. To preach this recommendation is to condemn these African countries to continuing hunger and misery. It is time that the world wakes up to this threat!

A major factor responsible for the high payoffs from past agricultural research investments in the developed market economies, has been the success of their technology delivery systems since the end of world war II, in which private sector organizations have played a mayor role in supplying information, inputs and agricultural services to the farmer. In most developing nations, the situation is currently exactly the opposite. Private sector organizations still play only a minimal role in the delivery of improved technology. Inefficient bureaucratic paraestatal organizations who are responsible for handling input supply, credit and marketing have not been successful in serving the farmer, especially the small-scale producer. Government planners and policy makers must come to grips with the problems of poorly functioning technology delivery systems. What is the value of research materials, information and data that are not used?

In 1986, I helped initiate several agricultural development projects in a handful of sub-Saharan African countries, in collaboration with the late Japanese philanthropist, Ryoichi Sasakawa (and now enthusiastically supported by his son, Yohei), and former US President Jimmy Carter. These agricultural assistance programs, called Sasakawa-Global 2000 projects, have met with tremendous success in demonstrating basic improvements in maize, sorghum, and/or wheat production. Most of the components of these technologies had been available for a decade, but were around, largely unused, on agricultural experiment stations.

Over the past 10 years, we have worked with 5,000 extension agents in Ghana, Tanzania, Benin, Togo, northern Nigeria, Ethiopia, and Mozambique and more than 250,000 small-scale farmers. We provide each farmer with the technical backstopping and the needed inputs (on credit) to grow a test plot (0.25 to 0.5 ha in size) employing a simple package of improved technology: the best high-yielding variety available, moderate applications of fertilizer, and improved cultural practices. With yields two to three times greater than those previously obtained with traditional technology, the receptivity and enthusiasm of these small-scale farmers is every bit as great as it was in India and Pakistan, when the Green Revolution was taking off 30 years ago. We are now working closely with national policy makers and international development agencies officials to develop policies to strengthen technology delivery systems to expand and sustain these productivity gains.

Closing Comments

Twenty-seven years ago, in my acceptance speech for the 1970 Nobel Peace Price, I said that the Green Revolution has won a temporary success in man's war against hunger, which if fully