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Fellow participants, permit me to take a few minutes from the crowded schedule of this conference to interject my perspective on the role that biotechnology will likely play, or not play, in the developing nations toward increasing animal and agricultural productivity and production in the next decade or two.

For the past two days, I have listened with fascination to the information being reported on investigations in biotechnology and genetic engineering that bears on the future improvement of animal and agricultural productivity. The discoveries in this new field of research are rapidly expanding the spectrum of applications to agricultural and biological sciences and will provide entrée to many new frontiers. The enthusiasm manifest by the participants verges on euphoria, it is infectious and inspiring.

I want to congratulate and thank US AID for having had the perspicacity for organizing this conference to further the interest in the new broad field of biotechnology. Moreover, I want to congratulate all of the participants whose informative and enthusiastic presentations will undoubtedly greatly accelerate research in this broad new field of biology.

Let us hope that in the not too distant future, the new basic knowledge now being reported will be linked to that of other

disciplines of agricultural sciences thereby resulting in an improved technology, which when applied will produce more food. Lest we forget, biotechnolgy will not function in a vacuum devoid of other scientific disciplines. Its success or failure will largely be determined by how it is linked to other scientific disciplines, especially to conventional plant breeding and genetics.

Simultaneously, with developing new research and technology capable of increasing crop yield and production, we must learn how to more equitably distribute the food produced; that should be the ultimate aim for all who work in agricultural sciences.

Before I proceed farther, I would point out I do not like the term biotechnology as it is currently commonly used in conferences and in the literature; it is too all inclusive, covering the broad sweep of biological investigation from tissue culture, cell culture, protoplast culture to manipulation at the molecular level. Because of this broad loose usage, it has contributed to confusion, not only for the general public, but for many scientists as well.

Before I proceed with my comments on the future potential role of biotechnology in food production in both the developing and developed nations, let me digress to comment on the excellent research proposal made by Dr. Richard Baldwin and the members of the IFAR Committee. Their proposal to form a "Manhattan Project" or "Moon Landing Project" -like inter-disciplinary teams of agricultural-biological excellence to attack some of the basic problems that will limit food production

in the long-term is an excellent idea. It would appear to me that the individual projects must be selected with care and limited in number to be economically viable. I like their choice of the project to attempt to supply with symbiotic nitrogen fixation most of the nitrogen requirements for wheat (or maize) by the year 2005. I am not, however, very enthusiastic about the proposal to produce hybrid soybean varieties, because of the limitations in amounts of pollen produced by soybean flowers. Nor am I very enthusiastic about cassava varieties with high levels of Vitamin A, because there are many other potential sources of Vitamin A in the tropics. On the other hand, a project to develop a high-yielding corn hybrid with greatly improved photosynthetic efficiency, or greater drought resistance, would have great significance. There are many other basic worthwhile deserving problems that might be solved by such a "team of excellence" approach.

Now permit me to return to the world food production and hunger problem that we must confront during the next one or two decades. As I look at the magnitude and complexities of the world food problems at present, I feel obligated to emphasize that we should never forget that research well done in one field or one discipline does not automatically produce more food, nor does adequate food production alone automatically eliminate world hunger and malnutrition. We only need to reflect on what has happened worldwide over the last 15 years to see how complex many of the interrelationships are in food and fiber production and distribution. We have had a serious cereal glut in food exporting countries since about 1983 or 1984 resulting in depressed agricultural prices. As a result, many farmers in the

developed food exporting nations who were deeply indebted have gone broke. We should also remember that at the same time there have been gluts in the food exporting countries of the developed nations, there was hunger and famine in Africa. This is a consequence of inadequate distribution of food, because of lack of foreign exchange (purchasing power) at the national level in many food deficit African countries and also because of lack of purchasing power, at the family level within these nations, caused by poverty resulting from unemployment or underemployment. India, for example, over the last 15 years, has produced more than an adequate supply of cereal grains. As a matter of fact, it has in recent years maintained in storage something on the order of 20 to 25 million tons of wheat and rice. But this does not mean that there is no hunger and malnutrition in India. Indeed there are many people who need more food, but again because of poverty and lack of purchasing power, it is not available to many low income people even though it is present in large quantities within the country. I do not wish to imply that there should not be stocks of food stored as a hedge against bad harvest, when rains fail or when disease epidemics or insect pests take a heavy toll on the crop. We must continue to maintain buffer stocks to utilize during such times of crisis.

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been the case previously. Let us examine what has happened in the short period of 15 or 16 years, from 1972 to 1988. In 1972 and '73, suddenly the large stocks of grains that had persisted in the USA during the late 1950s and throughout the 1960s, resulting in depressed prices for farmers in that country, as well as in many parts of the world, were depleted. This occurred rather rapidly and unexpectedly, because of severe droughts in two consecutive years in the Soviet Union and in China, which resulted in large imports of grain by those nations. When the reserve stocks were depleted precipitously, prices began to increase rapidly. There were outcries against soaring food prices by urban consumers in the United States, who had lost contact with the soil and had become accustomed to cheap food. They had forgotten about the problems and complexities of agricultural production. The result was that the general public, and especially many farmers, listened with too much credulity to the predictions of gloom and doom which were being presented at that time by several distinguished academicians armed with the best computers, which interpreted the shortages to indicate that the world had lost its ability to produce the food required to meet the demands of the four billion people that then existed.

What were the consequences of these predictions? It is my belief that many farmers and economic policymakers involved in agricultural decision making overreacted. They put back into production virtually all of the land that has been held out of production for a decade because of surpluses. The Secretary of Agriculture of the USA recommended that farmers plant from fence row

to fence row, implying that the international market would require all that could be produced. The situation was made worse about three years later, because of the easy credit at rural banks which was made available by the vast inpouring of petrodollars resulting from the huge jump in the international price of petroleum. These petrodollars were siphoned down to rural banks and resulted in easy credit. This influenced decision making and very often many of the best young farmers, tempted by too much easy credit, decided that if the predictions were true that the world had run out of its capacity to produce the food that was needed for our four billion people, then this was the time for them to buy the two small farms near their own holdings, (which were no longer economic units), and incorporate them into their own properties. In most cases, this was done by simply going to the bank where there was easy credit available and signing mortgages on the property that they held. These events soon led to speculation and soaring land prices. Price of Midwest farm land increased from $800 an acre in the early 1970s, to $3,500 during the early 1980s. In summary, vast investments were made to stimulate food production. Production increased spectacularly, resulting by 1983 in huge grain gluts. Then prices collapsed. Many farmers who had overzealously attempted to leverage easy credit and loans to rapidly expand their family farming operation, and by so doing were deeply indebted, went broke when the farm commodity price bubble broke. They had overreacted by listening to the doomsayers who had said the world could not feed the four billion people.

Unfortunately, at the same time that the surpluses were building in

the USA and in other exporting nations, there was widespread famine in Africa, in part because of the drought which hit vast areas. But looking beyond the immediate cause, it becomes apparent that for the last two and one-half decades, agricultural production has been increasing in the African countries south of the Sahara at about one and one-half percent per year, while population had been growing at about three percent a year. During the drought years of the middle 1980s, food demand outpaced production resulting in widespread food shortages. Nevertheless, I contend that even after the drought is broken, it is doubtful that, with the technology now being used, African countries south of the Sahara will be able to catch up with the food demands of their rapidly growing population.

I have been confining my remarks to agriculture and food production, but a similar situation occurred in the 1973-86 period on the energy front, which also affected agriculture. You may recall that in 1973 and '74, when the petroleum exporting countries (OPEC) arrived at an agreement whereby they could control production, the price of petroleum soared. The price increased from about two dollars a barrel first to 11.65 then to 18, then to 28, and finally to 32 dollars a barrel, within a period of three years. This huge increase in petroleum price also generated songs of gloom and doom by some experts and academicians who claimed that the world had lost its ability to exploit the petroleum as well as of other energy sources that were needed. A short time later, the same kinds of predictions were made that the world was running out of many of the basic mineral resources. The result in both energy and minerals was, again, that the world

overreacted. In the period from '74 to '86, there were huge investments made in petroleum exploration and in the development of new fields, in the re-exploiting of depleted fields, in the substitution of other energy sources, such as coal, gas and atomic energy and in energy conservation through more efficient transport systems. All of these changes led in late 1986 to a huge build-up in petroleum production and a collapse of the prices.

It should be pointed out that during the petroleum shortage and the sky-rocketing prices, the huge influx of petrodollars into American and Western European banks led to a dilemma for many of the bankers. International bankers went to Third World nations, and especially to those countries who had under-developed petroleum deposits and encouraged them to take out huge loans, leading them to believe that the petroleum prices which were then 28 to 32 dollars a barrel would soon increase to 60 dollars a barrel, since petroleum was becoming increasingly shorter in supply. Huge loans at high interest rates were taken out by a considerable number of Latin American and African countries. This resulted in economic crisis when the great glut on the world petroleum market developed in December of 1986, and prices plummeted from 32 to 11 dollars a barrel in a few months.

It should be pointed out that during the period of high prices of petroleum on the international market, there were many other developing countries very short of the foreign exchange, who had to import petroleum. Consequently, they were forced to take out large

loans to buy energy. The result of all of this is that the developing nations, in particular, are currently in dire economic straits. They are short of foreign exchange; they are deeply indebted; inflation is rampant and many are short of food. The sum total result is that the money available for agricultural research today, in real terms, is probably one-half, and in some cases only one-third, of what it was eight to ten years ago. Consequently, the Third World nations have retrogressed in their ability, in most cases, to improve and expand research to cope with the worsening food shortages.

Since the budgets for agricultural research in the developing nations are probably today only one-third of what they were in 1975 in real terms, how then should these countries allocate the available budgets? How much should be allocated to conventional agricultural research across the various disciplines? How much of the total budget should be allocated to research in biotechnology and in molecular genetics? It is obvious that applied research in those scientific disciplines that directly bear on food production, must be given major emphasis in the short term. Lest we forget, poverty, hunger, human misery and inflation in developing nations also exert tremendous effects on social and political stability. Unless much of the widespread hunger and human misery is ameliorated in the next two decades, there will be greater and greater instability in the world, and this will sooner or later also affect the developing nations as well. The attack on these ills must be aggressively launched with the conventional technology now available. It need not await for developments in biotechnology.

Now let me try to condense how I perceive what needs to be done to change production and to improve distribution of food in Third World food deficit nations in the next decade. Many of these nations for the last two decades, with the assistance of international centers, many bilateral foreign assistance programs and their own national programs, have developed important bits and pieces of the jigsaw puzzle of production in different disciplines that bear on improving agricultural productivity and food production. This has been done by conducting appropriate research in most of the disciplines that are keys to changing yield and production. What has not been done, in most cases, and which must be done if there is to be a change in production, is to assemble these bits and pieces of the jigsaw puzzle of production into an appropriate package of production technology and evaluate its benefits/risks on many farms. What is needed in order to achieve the potential benefits from research are a few courageous integrators across scientific disciplines, who are creative and can see the broad picture of food production technology and visualize its potential to reduce hunger by augmenting food supply when the package of technology is properly assembled, adequately evaluated, widely demonstrated on farms and finally broadly adopted by farmers. Unfortunately, in the research programs of most of the developing nations (and this is not restricted to developing nations but also occurs in developed affluent nations, where this luxury is more affordable), there is "chaos in the brickyard"--too many bricks in some disciplines and few or none in others. Hence, the research package is incomplete and it is difficult to build or assemble a good package of production technology (e.g., there are too many risks because of research gaps).

Once the package of technological bits and pieces of the jigsaw puzzle of production have been assembled, they must be tested first on dozens of farms and then over the next two years on hundreds and even thousands of farms. Adjusting the package will improve its efficiency as additional experience and data become available. When the package is properly assembled and widely demonstrated on many farms, the enthusiasm of the farmers (big and small) is fantastic -literally, "the grass roots are set on fire". Farmer enthusiasm is infectious and affects politicians, policy makers and even some of the immutable bureaucrats. In Africa at the present time, after only two years of work in three different countries, I sense, especially in Ghana, an enthusiasm that is fully the equivalent of what we saw in the middle 1960s in India and Pakistan, when the so-called Green Revolution, based on the high-yielding wheat and rice technology, was being transplanted into those countries.

Once the adequacy and the potential of the package of new technology have been broadly demonstrated to be capable of increasing yields spectacularly and by so doing one has established credibility by gaining the enthusiastic support of thousands of farmers, one is in a position to move on the economic policy front. It is then usually possible to convince policymakers and political leaders that unless policy errors of the past are rectified, there will be more rather than fewer social and political problems in the years ahead, since untold tens of thousands of farmers now know what is technically possible. The economic policymakers must be convinced that the

production inputs of the right kind must be made available at the village level on time, that there is credit for the small farmer to buy them at time of planting and pay for them at harvest and that there is an announcement made by government before planting that the farmer will receive a fair price for his grain at harvest. Moreover, the government must make provisions for procurement at time of harvest in surplus production areas in order not to permit local gluts which will depress the market price. Once widespread on-farm demonstrations have been done for three years with good success, one is in a position to launch a national production program. Before this is done, provisions must have been made for storage and improved transport to distribute food to areas where there is a shortage of production.

It is not enough to increase production to meet local needs. Action must also be taken to get the food into the stomachs of the poor, those who need more food and are badly nourished. Many devices must be examined and utilized to make this take place. There must be rural development projects to develop the infrastructure and provide work for many of the 75 to 85 percent of the population who are living at or near subsistence level in rural areas. There should be food-for-work projects to develop roads, build country schools, and all sorts of soil conservation, small scale irrigation and drainage projects and reforestation where possible.

Is there technology available that lies unused, which has the potential to change African food production over the next five to eight years? For the last two and one-half years, I have been

involved in developing small agricultural demonstration-production programs in three African countries, financed by Ryoichi Sasakawa, a Japanese philantropist. This program, known as the Sasakawa Global-2000 Programs, was launched after much pressuring, since I had twice retired and decided I had served my term on Third World food production fronts, and that I was never again going back to become embroiled on the front line in these kinds of programs. Under pressure, I agreed to do so once more. Surprisingly now after only two years, I am convinced there is an excellent chance for a breakthrough in both maize and sorghum production in Ghana within the next two years, within the next three or four years in Zambia, and also, perhaps, in Sudan, if that government pays more attention to improving the lot of their rural population and wastes less of its effort in civil war.

It is my firm belief that what is needed first of all to change food production in the near term in many African nations, is not a lot of new information and plant materials but rather a few integrators who have broad interests, experiences and skills across many scientific disciplines. They must have the skills to take the bits and pieces of research information and material that are available, lying unused on experiment stations and in laboratories, and assemble them into a sound production package. Second, they must test and demonstrate this package of improved practices on dozens, later hundreds and thousands of farms, modifying the package of technology to improve its efficiency as experience dictates. Moreover, they must have the courage to convince the economic policymakers to adopt new policies

which will stimulate the widespread adoption of the improved technology by farmers, which in turn will result in increased production. The integrator at the opportune time, must be able to communicate to the political leader at the top, that he now has available a technology which has the potential, in the right environment created by the right policy decisions, to dramatically increase the production of food, and by so doing improve the standard of living of the people. With the "grass roots afire", and heat and political pressure exerted from below, the political leaders will be more likely to move aggressively and make the right policy changes. It has been my experience when there is no "pressure from the grass roots", where the peasant farmers do not know what the potential of a new technology is, there will be no policy changes made by the political leaders. And so, what I am saying is that the situation on the food production front in Africa need not be as dismal as it appears to be at the present time, even with the limitations of the technology that is now available. This, of course, does not mean that there should not be more research to further improve the technology, to increase its potential productivity. Research must be a continuing process.

Looking at the broader world picture, I am convinced that the world now has the technology available to produce the food which would be adequate, if properly distributed, to provide adequate diet for our present population of 5.1 billion people. Perhaps the technology now available is, in addition, capable of producing the food required for 6 billion. Nevertheless, without a more effective system to achieve

a more equitable distribution of food to supplement the improved production technology, the social, economic and political problems will worsen.

I am pleased to see that vigorous research is going forward in the new field of biotechnology which, down the road, whether it is in 10 years or 30 years, can be used as needed to greatly expand the production potential of food and fiber.

It appears to me the greatest benefits from biotechnology and molecular genetics, in the near term, will be in medicine, animal sciences and microbiology. Improved vaccines, antibiotics and enzymes and hormones for the treatment of genetic defects are already beginning to appear on the market. It will likely take considerably longer to develop biotechnological research techniques that will dramatically improve the production of our major crop species.

In the final analysis, we should look at biotechnology as another new tool that will further help to protect mankind from diseases and pests and to help increase food and fiber production, rather than to believe it will be a panacea.

As I have said before, we cannot talk about food needs in isolation. It is curious that in two and one-half days, I have not heard one single comment made about the relentless advance of the population monster which threatens us on the 1) food front, 2) on the housing front, 3) on the health and medical care front, 4) on the employment

front, 5) on the energy front, 6) on the pollution front, 7) on the destruction of wildlife habitat front, 8) on the outdoor recreational front and 9) on the broader environmental front.

I would like to ask a question: why has the world neglected education on the environmental and population fronts? I hear the songs of gloom and doom which give me the impression that the human species is on the verge of being poisoned out of existence by agricultural chemicals, by the irresponsible and extensive use of fertilizers and pesticides, herbicides, and by a vast array of industrial chemical compounds. Despite the furor, the data show that the average life expectancy at birth in the USA increased from about 47 years at the beginning of the century, to 76 years in 1983; and it continues to increase. It appears to me that we have done a miserable job of educating the general public about the fact that in the human species, like in all other species, there is a biological clock built in. It varies considerably from individual to individual, depending upon the genetic hand of cards that one is dealt by one's father and mother, grandparents and great-grandparents, etc. Given one's hand of genetic cards, how one handles one's diet and one's lifestyle, have a lot to do with whether the potential hand of longevity that one is dealt, will actually become reality. The truth is that in the world at large, more and more people have a better life than in any previous generation. Unfortunately, in many of the Third World nations, and also among the low-income groups in many of the developed nations, there are large numbers of people who still do not have the basic necessities for a decent life. It is my belief that unless this is

rectified in the next couple of decades, there will be more and more social and political chaos in this world and sooner or later it will affect all nations.

Referring again to the fear of many of the environmentalists or neo-ecologists about the use of modern technology, I would like to remind us all that we should stand back and look at what the world situation would be like today, if we attempted to produce the food and fiber needed for the current 5.1 billion world population by employing 1930 technology, which was for the most part, pre-chemical. The technology of 1930, which was adequate to provide food and fiber for a world population of two billion, would be completely inadequate to provide the needs of the 5.1 billion people at the present standard of living and with the hopeful outlook for correcting the shortcomings of those who needed more food and fiber and other benefits for a decent life. So let us not be stampeded into listening to all of these songs of gloom and doom. Let us look at the world problems realistically. Let us continue to work diligently to improve the research and technology in our specialty-"looking enthusiastically through our individual knotholes"- while endeavoring to untangle more of the secrets of nature, which we will ultimately need to understand, in order to further improve the standard of living of more of the world's population.

While we do so, let us not be beguiled into believing we are going to solve indefinitely and permanently our population, pollution and environmental problems by exporting them to some virgin planet in

another solar system, as seems to be implied on the one hand by the world's failure to face up to the basic issues posed by the population monster and, on the other hand, by the extreme claims that are being made for the value of exploration of space. I am all for generating new knowledge on many fronts. Life would be dull without the challenges of an expanding universe and an expanding spectrum of knowledge. But let us not be misled into believing that the very large and increasingly more complex social, economic and political problems resulting from the explosion of population in recent decades, can be solved without bringing into better balance our ability to provide a decent standard of living for all who are born into this world. How many can be sustained on this planet and at what standard of living, is too broad an issue to discuss here. I doubt, however, that biotechnology will greatly increase the carrying capacity of the Planet Earth within the next several decades.

I am sorry that I have taken so much time, but I wanted us all to be realistic about what life is like in the Third World nations and what actions are necessary in order to provoke change and improvement. One can have the technology, but it has to be put to work. Someone has to assume the responsibility of making it work. There is no easy simple task.

Comments made by NEB during the AID Symposium "Strengthening Collaboration in Biotechnology: International Agricultural Research and the Private Sector" held on April 17-21, 1988 at Arlington, Virginia.