Keynote Address

The Approaching Crisis in Sustaining High-Yielding Agricultural Systems

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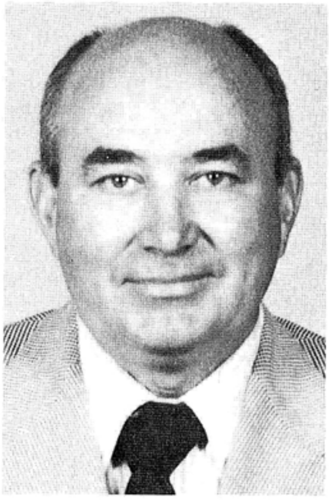

Agricultural technology during this century has greatly increased the yields of many of the world's major food crops, most notably rice, wheat, and corn. The Green Revolution has promised to feed the exploding world population, but one has only to review statistics on population and nutrition to realize the world food production system is not working adequately for either the rich or the poor countries of the world. Possibly as many as 450 million to 1 billion people are hungry and malnourished today, most of whom live in countries where populations are destined to grow well into the future (3).

Evidence of the severity of the problem is expressed in these quotes: "The world food problem is getting worse rather than better. There are more hungry people than ever before." (Presidential Commission on World Hunger 1975.)

In January 1980 the U.S. Comptroller General reported to Congress, "World hunger and malnutrition continue; slow progress has been made in carrying out the [1974] World Food Conference objectives."

The Global 2000 Report states, "For hundreds of millions of the desperately poor, the outlook [in 2000] for food and other necessities of life will be no better. Barring revolutionary advances in technology, life for most people on earth will be more precarious in 2000 than it is now . . . unless the nations of the world act decisively to alter current trends."

The situation does indeed appear grim. The problems of sustaining and increasing the agricultural productivity of the earth and providing its people with the possibility of a decent life are enormous. These problems face us now. Ways must be found to sustain and stabilize the world food supply. Also, something must be done to reduce poverty so that those countries with the worst need for food can purchase what they cannot produce.

The World Situation

The human time bomb. The world's human population is increasing at the rate of 100 persons per minute (during the course of this presentation more than 3,000 babies will be born). The population is expected to increase by 50% by the year 2000, to 6.5 billion people. In terms of sheer numbers, the population will grow faster in the next century than it is right now, with 100 million people being added each year compared with 75 million this year. Of this growth, 90% will occur in the poorest countries that already are having problems feeding their people (1).

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At projected growth rates, the world's population could reach 10 billion by 2030 and may approach 30 billion by the year 3000. These levels are near the maximum carrying capacity of the earth. Already in parts of Africa and Asia the carrying capacity of the land has been exceeded. Resulting poverty and ill health have complicated efforts to control birthrate. The experiences in these two areas have provided ample evidence that unless something can be done to reduce birthrate and decrease poverty, the human population will be decreased by starvation, disease, and strife (1).

If present population growth trends continue, the world in 2000 will be more crowded, more polluted, less stable ecologically, and more vulnerable to disruption than now. Serious stresses involving population, resources, and environment are clearly visible in the future. Despite our great material output, the people of the world in the next century will be poorer in many ways than they are now.

World food production. On the average, world food production is projected to increase more rapidly than the human population. However, most of this increase will be in the developed countries. In the LDCs where the population is increasing at the greatest rate, food production per capita is not expected to increase and may even decline. At the same time, food prices are expected to double. Thus, the already poor who can't afford to buy food at today's prices will be in even greater difficulty. Their lack of affluence will greatly compound the problem created by a soaring birthrate (2).

Expanding the amount of land planted to crops and increasing yields per hectare are the two ways for increasing food production. Increases in land planted to crops probably will not exceed an average of 1% per year during the remainder of the century and could be much less. In 1970, one hectare of land supported 2.6 persons, but in 2000 it will have to support four (5).

Increases in yield will need to average 2.5% per year. This will not be easy to achieve or sustain. Most of the increases in food production will occur in the developed countries. This will be accomplished through the greater use of fertilizer, pesticides, and irrigation, but in many cases with diminishing returns (5).

The solution to the food production problem will not come from placing new land under cultivation. Instead, it must come from the development and implementation of new technology that will increase the genetic potential for higher yielding varieties, reduce energy requirements for crop production, lessen the need for fertilizer and irrigation, and reduce preharvest and postharvest pest losses. If pest losses could be reduced by 80 or 90%, this alone would do much to alleviate the food shortage.

World fertilizer use. Much of the increased food production attributed to the Green Revolution has been accomplished by a great increase in the use of fertilizers. World fertilizer consumption is increasing exponentially with a doubling time of 10 years. Total use now is five times greater than in the 1940s (2).

There are serious problems ahead. Petroleum, phosphate, and potash are nonrenewable resources that are being depleted at a rapid rate. This has caused many farmers in the affluent countries such as the United States to reduce use. In many poorer countries, costs of fertilizers and pesticides have become more than subsistence farmers can pay. They can only use fertilizer when their government gives it to them or subsidizes its purchase. Some countries are having difficulty in obtaining the hard currency needed to purchase fertilizers and pesticides.

Moreover, heavy dependence on chemical fertilizers leads to the loss of organic matter in the soil and a reduction in water-holding capacity. Over the long term, farmers in all countries may have to follow the example of the Chinese who have maintained their soils in a highly productive state through the maximum use of manure, compost, and leguminous crops with the minimum use of chemical fertilizers.

Water. The high cost and scarcity of water for agriculture already is a problem in many areas of the world. It will continue to be an even greater problem with competing demands for water among people, industry, and agriculture. The consumption of water is expected to increase by 200 to 300% during the next 20 years. By far the largest part of this increase will be for irrigation. It is estimated that the amount of water needed for irrigation will double by 2000. Moreover, irrigation is a highly consumptive use because the water is evaporated, is transpired by plants, and becomes salinated or contaminated by pesticides (1). Population growth also will more than double the demand for water. Thus, water will become a critically short resource. Technology must be developed to conserve the use of water on and off the farm. On the farm this might be done by the design of more efficient irrigation systems, better conservation of rainfall, improved production systems, and the breeding of drought-resistant plants.

Energy. Most of the recent advances in increasing food production have come through the increased use of energy-intensive inputs such as mechanization, fertilizers, and pesticides. We are now facing a serious energy problem because the production of petroleum is not able to keep up with demand. Reserves are being rapidly depleted and new sources are not easy to find. As reserves are being depleted, the price of fuel and petrochemicals will increase because of the scarcity and unreliability of supply. Rapid escalation of fossil fuel prices or sudden interruptions in supply can severely affect world agriculture production, raising food prices and creating severe economic problems for farmers and countries. As agriculture becomes even more dependent on energy, the potential for disruption becomes even greater. It is obvious that over the long term we must develop new agricultural technologies for producing crops and increasing yields that are less, not more dependent, on fossil fuel energy.

The U.S. Situation

Mechanization. Plentiful and relatively inexpensive food has been available to Americans because of application of technology that has allowed our farmers to produce more food with less labor than any country in the world. A great part of the increased productivity of the American farmer may be attributed to the replacement of muscle power (man and animals) with machines and the increased use of chemical fertilizers and pesticides. Fossil fuel energy provides a major input into present agricultural productivity (3).

Over the past 50 years, 25 million horses and mules have been replaced with 5 million tractors, freeing large numbers of people for other pursuits and releasing 60 million acres of land for the production of human food rather than feed for draft animals (3).

The number of people supplied per U.S. farmer has increased from 14 to 40 during the period of 1950 to 1970. However, this number has been leveling off since 1970, with one farmer now supplying fewer than 50 people. In terms of our total population only about 4% are engaged in farming. Thus, it does not appear that we will be able to gain a great increase in productivity in future years through the use of increased mechanization (3).

Energy. Agricultural technology in the United States was developed under the stimulus of cheap and readily available energy. Machines and herbicides have replaced labor. Increased yields have come from crop varieties bred to respond to high inputs of fertilizers, pesticides, and irrigation. Our entire system of agricultural production, storage, and processing has been built on cheap and stable supplies of fuel, fertilizers, and pesticides. The economic well-being and the good life for farmers also have depended on cheap and stable supplies of fuel, electricity, and petrochemicals. The question now may be asked as to how long can we maintain this system of production and the economic well-being of our farmers in the face of increasing energy costs, shortages of supply, and stable (or declining) prices of farm products.

Over the short term, the rising cost of energy, combined with inflation and high interest rates, relative to prices received for their products is creating economic havoc for many American farmers. For example, the cost of producing a pound of cotton has increased from less than 50¢ a pound to almost $1.00 since 1975 but the price received per pound has increased from 58¢ to less than 80¢. You do not have to be a wizard in economics to see that many cotton farmers are going bankrupt and others are using up large amounts of collateral in land and machinery. The same situation is true for most of our major crops.

Keeping farmers in business is becoming a major problem in this country. This is occurring when the world demand for food is increasing. Unfortunately, much of the demand is from the poor countries who do not have the means to pay for what they need. Thus, we are caught in a vicious circle where high energy costs, poverty, and increased birthrates are interlinked. Over the short term, we can produce the food needed by the hungry of the world if they could develop a means for paying a fair price for it and if birthrates could be stabilized. The problem over the long term, however, is much more complex. Technologies must be developed that will allow us to sustain and increase yields with the use of less fossil fuel energy.

Crop yields. The crop yield index in the United States has risen over the years as fertilizer use per acre has increased. Fertilizer, especially nitrogen, was cheaper in relation to farm commodity prices until 1973 and farmers greatly increased the amounts used. Yields have increased but at a declining rate of increase per unit of fertilizer applied. In recent years, there has been a leveling off of yields in response to fertilizer (3).

There appears to be a limit to the yield response that may be achieved regardless of the price of fertilizer, and price is having an effect on the amount of fertilizer being used today. It appears that an increase in the use of fertilizer will not produce great increases in yield. New technology must be developed to increase yields without the need for more fertilizer. In fact, over the long term, ways must be found to sustain yields without completely depleting the earth's reserves of potash and phosphate.

Crop protection. Levels of crop loss without the use of pesticides are difficult to estimate. The USDA (8) reported in the early 1960s that insects alone did $3.8 billion worth of damage each year. The National Academy of Sciences (4) reports that in 1975, $3.4 billion worth of pesticides were sold in the United States, of which more than 50% were used in agriculture and forestry. By today's prices, the total combined cost of pest damage to crops and for the pesticides applied for their control probably exceeds $10–12 billion annually.

Crop pests clearly cause large annual decreases in yield. The annual loss to pest insects and diseases is estimated to be about 30% for cotton and soybeans. Losses to alfalfa and fruit probably range between 10 and 20%. In some areas, pests would destroy the entire crop if natural controls fail, or if applied controls become ineffective due to the appearance of a pesticide-resistant strain (ie, tobacco budworm on cotton), or if large-scale plantings of a susceptible variety are attacked by an epidemic disease (ie, leaf blight on corn).

Even greater preharvest and postharvest losses are being sustained in many developing countries where technologies are not on par with ours. Tremendous losses to pests are occurring (some estimate as much as 45% on a global basis [7]) even though vast amounts of toxic chemicals are being applied for their control. The nation (and the world) cannot continue indefinitely to sustain this amount of pest losses to major crops without serious consequences to our ability to produce adequate quantities of food.

If food production is to be increased, it is essential that harmful crop pests be controlled. Chemicals presently provide the most reliable and immediate means for suppressing outbreaks of insects and mites. Herbicides are being increasingly used to replace hand labor for controlling weeds. Chemicals will continue to be necessary to control certain pests. But over the long term, we need to develop and implement an integrative ecological approach to pest control that will provide better protection to crops, will be less costly, and will present less danger to human health and the environment than current methods that depend on the intensive use of chemicals.

Research Needs

We have an abundance of food in this country because we have the best system of agricultural research of any country in the world. In recent years, however, the support for agricultural research has declined. The number of agricultural scientists is fewer and their operating budgets have been reduced in terms of constant dollars. Funding must be restored to crop and problem-oriented research areas and greater attention must be paid to basic research in genetic engineering if we are to develop the new technologies needed to sustain and increase yields.

Energy conservation. More efficient breeds of animals and crops must be developed. The cultural practices used to grow them must require less energy. We will not achieve a major breakthrough in food production until we learn how to trap more of the sun's energy by the light-harvesting array of plants.

We must make more efficient use of solar energy, not only by breeding more efficient plants but also by learning how to use this source of energy for power for irrigation pumps, drying equipment, and electricity.

We also must develop and implement ways to conserve energy in the production, storage, processing, and transport of agricultural commodities.

We must learn economical methods for recycling crop residues and animal wastes.

Lastly, we must develop new energy sources, ones that are permanent and renewable, including the use of alcohol, vegetable oil, solar, hydrogen, and nuclear energy.

High-priority research areas. The National Research Council in their report on world food and nutrition listed the following areas as having a high probability for increasing crop yields: 1) biological nitrogen fixation by nonleguminous plants, 2) increased photosynthetic ability by plants, 3) increased resistance of plants to environmental stress, 4) improved methods of pest management, 5) weather and climate modification, 6) better management of tropical soils, 7) better management of irrigation and water, 8) expansion of fertilizer sources, 9) improvement of breeds and better management of ruminant livestock, 10) development of new technologies for aquaculture and mariculture, 11) development of better farming systems, 12) reduction of postharvest losses, and 13) better systems for the marketing and distribution of food crops (6).

Successful research in these areas could provide the means for feeding several hundred million additional people. However, if we are to accomplish this massive task we must be provided with the funds and support needed.

Conclusion

A broad spectrum of research and development activities, ranging from the implementation of existing technology to the search for new scientific frontiers, is required if we are to meet the demand that will be placed on the earth's food production systems by the end of this century. There is a particular need for biological innovations that will lead to greater crop and livestock yields and for research on farming systems that will put all the pieces together. But science and technology alone cannot solve the world's food problem. The various governments are going to have to establish better policies and organizations for administering science and technology and for extending new knowledge to producers, processors, and distributors of food. There also must be better incentives and opportunities for involving our most creative people in the agricultural sciences.

Over the short term, there is reason to be optimistic that we can produce all the food we need. But the resources of the earth are limited and in the long run nothing is more important for improving the world food problem than a reduction in the human birthrate and a decrease in poverty. Coupled with this must be the development of new and less fossil-fuel-dependent methods of sustaining and increasing crop and livestock yields. But if this is to be done, there must be sufficient funding for the science and technology and there must be the political will here and abroad to capitalize on it. The prospects for agricultural research and extension in the future are exciting, perhaps the most exciting of all time. I believe we will succeed.

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