83rd Annual Meeting
of The American Phytopathological Society
August 19, 1991, St. Louis, Missouri

New Challenges in Agriculture

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Wayne Gretzky is perhaps the greatest star in the history of ice hockey. He is the only professional hockey player to score more than 50 goals in 50 or fewer games in a single year. And he has done it year after year, as well as leading the league in scoring. When asked the secret to his success, Gretzky always answers, "I skate to where the puck is going to be, not where it has been." Clearly, he understands the importance of planning ahead and anticipating.

That is what we in agricultural research have to do. More and more agricultural producers understand that to protect their crops from diseases and pests, we need to use chemicals more judiciously and to look to other means of controlling crop losses. It is critical that we move rapidly to provide America's farmers with the information and technical expertise to adapt to new expectations and needs. Our efforts are spurred by the fact that one of the major influences on agriculture today is growing public (and congressional) concern over the environment.

Overall, agriculture is endeavoring to operate in an environmentally responsible fashion while continuing to produce both economically and profitably. This is generally called "sustainable agriculture"—and often regarded by critics as a return to the "low-tech" production methods of the 1930s. On the contrary, it is the use of the very best of technology in a balanced, well-managed, economically viable, and environmentally responsible system.

Farming is inherently a biological process, and farmers practicing sustainable agriculture are striving to use pest control and soil fertility practices that turn biological processes and interactions into assets rather than liabilities. Both the short- and long-term consequences of farm management decisions are taken into account, including financial and ecological implications. Not only our economic welfare, but the quality of our lives depends on our ability to develop agricultural systems that produce efficiently while sustaining our natural resources.

Not surprisingly, the level of funding provided for research in the agricultural sciences limits our ability to take advantage of the opportunities provided by the biological revolution to meet the challenges of feeding a growing population on a declining base of cultivated land in an environmentally sustainable manner. Over the past 20 years, the level of funding for agricultural research has remained static. In 1987, the National Research Council (NRC) published a report, Agricultural Biotechnology—Strategies for National Competitiveness, that recommended that for agricultural biotechnology to reach its full potential, a $500 million investment should be made in fundamental research in the agricultural biological sciences. Then, in 1989, the Board on Agriculture of the NRC published a report entitled Investing in Research—A Proposal to Strengthen the Agricultural Food and Environmental System. These two NRC reports formed the basis for the National Research Initiative on Agriculture, Food, and the Environment (NRI). This initiative was launched in President Bush's 1991 budget with a recommendation for funding in its first year at $100 million and a commitment to add $50 million in each of the out-years, provided that funds were appropriated on a nonearmarked basis. In the same year, Congress authorized funding of NRI at the recommended level of $500 million per year, reaching that amount by 1995.

Congress appropriated $73 million to start the initiative in 1991, and in the 1992 budget, President Bush recommended funding at $125 million, a 73% increase. In addition, there is a $25 million competitive facilities program that is an attempt to address the earmarking problem. This program provides funds for renovating or constructing new facilities for cutting-edge research and is funded at a level equivalent to 20% of the NRI. The administration has proposed that the program grow as the NRI grows, so if the NRI increases to the authorized level of $500 million, the facilities program could be funded at $100 million.

The NRI is a competitive grant program with six major research areas similar to the challenges just described: natural resources and the environment; food safety, diet, and health; new product development; international trade, markets, and policy; plant systems; and animal systems. The plant systems area contains funding for the mapping of genes that regulate agriculturally important traits such as disease and insect resistance and tolerance to environmental stress. With these research areas are four funding strategies: 40% of the funds will go to individual investigators; 30% to multidisciplinary research; 20% to mission-linked research; and 10% to strengthening grants for individuals or institutions.

In further funding efforts, the USDA is cooperating with the Environmental Protection Agency (EPA) on a joint budget initiative for 1993. This will focus on integrated management systems (IMS) and will include integrated pest management (IPM) and sustainable agriculture.

IMS encompasses the whole farm, relying on the expertise of farmers, interdisciplinary teams of scientists, and specialists from the public and private sectors. Results of the research and education program are presented in a practical, easily understood, comprehensive framework that enables the farmer to make informed choices among various societal and individual goals such as income, yields, environment, food safety, and risk aversion. Integration is based on the concept that while technologies for an individual crop enterprise can be essential components of sustainable agriculture, standing alone, the components do not provide sufficient answers.

IPM is a part of this integrated management system. We hope in 1992 to increase funding for an IPM special grants budget line that would support research in all priority components of IPM: biological control, host resistance, cultural control, resistance management, and application technology. The overall goal of the grants is to target identified knowledge gaps at the regional or national level; develop new information and approaches to address regional or national priorities; integrate the management of multiple pests in a production system; and interface with programs addressing water quality, low-input sustainable agriculture, and food safety.

The 1990 Farm Bill certainly reflected the increasing congressional concern for the environment. Subtitle B, focusing on sustainable agriculture, represents the intent of Congress to ensure that we move toward using the full range of alternative production systems. The goal is a more sustainable production system that is profitable, globally competitive, environmentally sound, and socially acceptable. To be specific, the purpose of this subtitle is to encourage research and education designed to maintain and enhance soil quality and productivity; conserve soil, water, energy, natural resources, and fish and wildlife habitats; maintain and enhance the quality of surface and ground water; protect the health and safety of people and food; promote the well-being of animals; and increase employment opportunities in agriculture.

The subtitle is divided into three major parts. Chapter 1, Best Utilization of Biological Applications (BUBA), stresses research and education projects that reduce the use of agrichemicals, improve low-input farm management, and promote crop, livestock, and enterprise diversification. Chapter 2, Integrated Management Systems (IMS), emphasizes developing decision-support systems and data bases, which are linked to education and technology transfer programs. IMS promotes a whole farm/ranch systems approach that can draw on research from BUBA, IPM, water quality, food safety, and other relevant areas. The IMS approach will be a key factor in the development of site-specific sustainable agricultural and natural resource systems. The third chapter, Sustainable Agriculture Technology Development and Transfer, features the development of a county agent training program (National Training Program), state-level education and outreach programs (Sustainable Agriculture Extension Program), and technical guides and handbooks.

Although Congress has specifically assigned different chapters to different USDA agencies, it is essential that our overall act be coordinated. For example, although the Cooperative State Research Service (CSRS) has the lead agency responsibility for Chapter 1, extension and ARS also are heavily involved. And while extension carries the lead for Chapters 2 and 3, their success clearly involves coordination with research. The USDA program of research and education on sustainable agriculture is forging a partnership between farmer/ranchers, scientists, educators, agribusiness, nonprofit organizations, and government—a partnership that will promote good stewardship of the natural resource base on which the agricultural economy depends.

Water is one of those critical resources. As science has enhanced our ability to track and detect smaller and smaller concentrations of chemical substances, environmental worries about current agricultural technology have focused on the impact of pesticides and fertilizers on surface and ground water. Agriculture has been cited by the EPA as the largest nonpoint source of surface water pollution. This fact encourages us even more to seek ways to reduce the use of chemicals and to increase their effectiveness in order to improve and maintain environmental and economic sustainability. Agriculture must be proactive in relation to reducing nonpoint source pollution. To do otherwise is to invite restrictive legislation.

In the 1992 budget currently under development in the Congress, USDA's portion of the Water Quality Initiative would be funded at $188.1 million. The federal and university research component includes an increase of $2.8 million over the 1991 budget of $77 million. This will allow agencies to continue to expand research in support of goals and objectives outlined in the USDA Research Plan for Water Quality.

Research projects will be continued in the Midwest corn belt and ongoing related programs continued and expanded to develop more effective biological controls and means to better target pesticide applications. There are $3.1 million for data collection and analysis and $75 million for technology transfer. The water-quality research and demonstration projects currently being conducted under the initiative have far-ranging objectives: 1) determining the extent and seriousness of agricultural chemicals' contribution to nonpoint source pollution, 2) developing improved farm and ranch production systems to maintain and improve water quality, 3) improving the understanding of fate and transport of agricultural chemicals in soil and water, 4) developing less costly water sampling techniques, and 5) determining the socioeconomic impacts of water pollution and its remediation.

IPM is a major approach to finding alternatives to pesticides. IPM includes biological control agents and is based on ecological principles that capitalize on natural pest mortality factors; pest/predator relationships; genetic resistance; and the timing and selection of cultural practices such as tillage, pruning, plant density, intercropping, and residue management. Part of the strategy is to wait to implement control programs until the pest population approaches a level at which control is necessary to prevent losses that exceed an economically acceptable level. Statistically designed field scouting to determine pest populations or disease infestation levels allows this more precise timing and application of pesticides. Management decisions must include better knowledge of the consequences of various levels of pest and predator populations, crop rotations, and precise timing of planting.

But adoption of IPM, and particularly biocontrol, has been slow. The farmer already has familiar chemicals that can essentially eradicate a wide range of pests in a manner that is both cost-effective and less vulnerable to the vagaries of weather. On the other hand, biocontrol agents never totally eliminate the pest, are often highly specific, and require careful management—making farmers less likely to adopt them as part of an IPM strategy. Part of the answer may lie in increased investment in biocontrol research. Meanwhile, public concerns over the environmental and possible health costs of the use of pesticides, and Congress's response to those concerns as seen in the 1985 and 1990 Farm Bills, has led to growing pressure to approach the issue more immediately through regulation.

The Congress has begun the reauthorization of the Clean Water Act. Agriculture is currently the only industry that contributes to surface and ground water pollution that is not regulated and not charged for pollution remediation. The prospect that this may change is providing incentives for the adoption of IPM technology and will lead to a greater investment in research in this area. American agriculture will be better off if it voluntarily adopts environmentally sensitive methods of food and fiber production, rather than waiting for a costly and difficult-to-enforce regulatory approach to be imposed. There are just too many variables in farming systems across the country—soil types, crops, rainfall variation, erosion potential, etc.—to establish a strategy that would be equitable across the board. A regulatory approach would reduce the range of management decisions under a farmer's control, eliminating the possibility of making allowances for personal experience with his/her farming system. It could result in a loss of production efficiency, thus leading to higher food and fiber costs for domestic consumers and decreased competitiveness in international markets.

Along with changing farming practices, research has long been directed to changing crops themselves. Traditional plant breeding and selection has been a primary means of developing genetic resistance to insects and disease. This reduces dependency on pesticides and increases efficiency of production because the costs of the chemicals have been eliminated, as well as the costs of applying them. Our search for ways of conserving fossil hydrocarbons is also strengthened, since many pesticides are made from petrochemicals, and the energy expended in application is eliminated. Further, worker safety is increased because of reduced exposure to potentially toxic chemicals.

This successful approach can now be greatly enhanced by molecular biology. A classic example is the contemporary research with *Bacillus thuringiensis* (*B.t.*). *B.t.* produces proteins that are toxic to many moth and butterfly larvae. Currently, a preparation of the *B.t.* proteins is sold in garden stores as Dipel to biologically control insects such as the tomato horn worm. Recently, the gene coding for this protein has been isolated and inserted into the genome of the tomato. By inserting a single gene into commercial varieties of the tomato, insect tolerance has been added, but other characteristics of the plant have not been altered. The gene from another strain of *B.t.* also has been isolated and inserted into commercial cotton to provide similar tolerance to the cotton budworms and bollworms.

In conventional plant breeding, hundreds of thousands of genes are exchanged in one cross, and the progeny may differ substantially from the parents, reducing its commercial desirability. Backcrossing for many generations is often necessary until the progeny have the desired combination of characteristics. The tools of molecular biology can be much more precise and obtain the desired results in a shorter period of time.

It also should be emphasized that molecular biology is a tool, and not an end in itself. If the full potential of the biotechnology revolution is to be realized, the knowledge of what traits are important for a crop's performance, or the biochemistry and physiology of host pathogen interactions, is essential. Furthermore, many of the agriculturally important traits of plants—such as resistance to environmental stress, nutritional characteristics, and many forms of insect and disease resistance—are regulated by multiple genes. The movement of multigenic characteristics is still in the province of the traditional plant breeder.

It is ironic that one of this century's best tools to help agriculture is being attacked under the banner of environmental, economic, ethical, and social concerns. Therefore, it is vital that we show the public that we are deeply committed to our responsibility to work within the parameters of a research and regulatory policy that limits potential risk. For the past year, we have been developing a definition of the scope of organisms that should receive regulatory oversight. The publication of guidelines for field testing of "organisms with deliberately modified hereditary traits" (genetically modified organisms) was an example of how this definition could be used.

The regulatory framework for biotechnology should be based on sound scientific principles, in which oversight is commensurate with the level of risk. We have three major goals: 1) to provide assurance to the public that there is adequate review before the release of modified organisms if we are unfamiliar with how they will affect the environment or health; 2) to avoid singling out recombinant-DNA technology as being any more risky than other procedures used to modify an organism; and 3) to refrain from unduly hindering research with burdensome and unnecessary overregulation.

Some people feel that we should not use the term "genetically modified organisms" because it indicates there is risk. But there is already a public perception of risk and, to much of the public, perception is reality. This issue must be resolved or the great potential of biotechnology will not be realized. Another mechanism for addressing public concerns is risk assessment research. For the first time, the Farm Bill explicitly directs USDA to support biotechnology risk assessment research. The bill directs the Secretary of Agriculture to establish a grant program to fund research on methods to confine introduced organisms, monitor their dispersal, study potential gene transfer, and investigate other areas in which biosafety information may be incomplete. To support this research, USDA will designate 1% of its biotechnology research funding exclusively for risk assessment work. Although the department is still looking at budget data and discussing the details of implementing this legislation, it is likely that the funding level for risk assessment research will be about $1 million a year.

Fifty years ago, 20% of the population was directly involved in food and fiber production; now only 2% is involved. While the total food and fiber system—production, processing, marketing—remains one of the nation's largest employers, the number of people directly involved in production on the farm is the lowest in our history and in any nation. Many consumers are not familiar with the challenges a farmer faces with the vagaries of weather, fluctuating prices, and increasing regulatory constraint. Yet, they feel perfectly free to second-guess the farmer's every decision. The farmer is not alone in coming under public criticism. Scientists are feeling it too. As the public's general knowledge of science grows less and less, it is a normal reaction that they should have diminished confidence in it. Decisions then tend to be made on the basis of perception and emotion rather than on fact and reason.

Citizen groups actively lobby for restrictions on research, or the technology that evolves from research, when they perceive that it may have negative impacts on their individual interests. In each case, the interest groups are proposing to regulate what research may or may not be done from the point of view of their own special concerns—be they environmentalists, labor groups, or rural sociologists. They often overlook the most important fact: the ultimate beneficiary of agricultural research is the consumer. As pointed out earlier, American consumers spend less for food than those of any other nation in the world. If we do not continue the research necessary to increase production efficiency and at the same time be environmentally sensitive, the cost of food will rise. The impact will be felt most profoundly by low-income families in urban areas who spend a larger proportion of their income for food. Also, as we look toward the twenty-first century, we must address the issue of increased population. The Economic Research Service projects that by 2010 world population will reach 7.5 billion. Simply to maintain current caloric intake on a world average, food production will have to increase by 40%.

There is no need for a priori restrictions on agricultural research. In the first place, in basic research it is almost impossible to anticipate how the new knowledge will eventually be used. Blocking research to satisfy a specific interest group's demands may jeopardize the total society or other groups, such as low-income families. It is part of our role as scientists and end users of technology to get across to the public the facts it needs to make informed policy decisions and to avoid ill-conceived and hasty restrictions on research and the use of its results.

The U.S. agricultural system is viewed by the world as one of the outstanding products of American ingenuity. In 1950, one American farmer produced food and fiber for 27 people; in 1990, the production was for 128 people. This increased efficiency has been passed on to the consumer in lower food costs. In 1950, the average consumer spent 21% of his/her disposable income on food. In 1990, the figure was one of the world's lowest (11.8%). In addition, agricultural efficiency has made the United States a strong competitor in international trade. Food and fiber production represents one of the few segments of our economy in which there is a favorable balance of payments.

This success was created by more than native ingenuity. In the period of U.S. history following World War II, the power of science was harnessed to give agriculture a dramatic boost in productivity. Through a combination of genetic improvement, the application of fertilizers, and the use of chemicals to control insects, diseases, and weeds, agriculture achieved striking increases in yields. But that was in simpler days when the goal was merely to produce enough food and fiber and to deliver it to the consumer. Today's agriculture is being required to fill many roles and meet many obligations. In the 1990s, agriculture is being asked to play a major role in preserving our environment. This may be the first time in agricultural research's recent history that a challenge (environmentally sensitive production), a new tool (molecular biology), and improved funding capability (the NRI) have come together at the same time. It is now up to us to take advantage of that convergence to bring the great potential of the biological and agricultural sciences into reality.