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RESEARCH THRUSTS: AN INDUSTRY PERSPECTIVE

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The aim of agricultural research is to make American farming a more profitable, reliable and durable business, able to compete in both domestic and world markets. Unless that happens, the American farmer, the industries and institutions that serve American agriculture -- the USDA, the land-grant universities, the Monsantos, the Pioneer Hi-Breds and the Mycogens -- will not have markets for their goods and services.

I shall outline what I believe are major research thrusts that we need, to secure a more attractive agricultural future.

I recognize, as do all of you, that only some of the problems facing American agriculture will be solved by technological innovations like biotechnology or computers. Yet I hope to present evidence that technological innovations are crucial to enable the American farmer to compete in the world's agricultural market place for both U.S. and world wide markets, and are crucial to enable the nation to realize the economic potential of plants and livestock as annually renewable sources of wealth. The efficient and profitable production of agricultural goods must remain a durable core industry in America.

In this brief paper I will focus on some of the research thrusts presently underway in the industries that serve agriculture. But I hasten to add that while these technological innovations are crucial to enhance the efficiency of U. S. agricultural production, they will not revitalize America's agriculture unless farm business management, farm policy, USDA, land-grant universities, extension services and the many private-sector businesses that serve agriculture, are also innovative. We need innovative new partnerships between research universities, industry and government to ensure the rapid application of new science to agriculture. We need innovative teaching of 21st century precision agriculture by both the research universities and the extension service. We especially need an inno-

vative farm policy to enable American agriculture to adjust to the changes caused by national and international economic forces. And we need innovative institutions to help protect the income of farm people from the costs resulting from the integration of U.S. agriculture into world markets.

Let me begin with some of the key driving forces behind agricultural research and identify areas of research where companies like Monsanto are making major research investments for the future:

- Increased efficiency of production
- Environmentally-friendly crop chemicals
- Drive for crop quality

There are other driving forces such as efficiency of land use and replenishing ground water, but these three are a reasonable challenge for a brief paper.

Increased Efficiency of Production

To compete in world markets with developing countries with cheap labor and cheap land, and with developed countries that have sophisticated technology, American farmers will have to reduce the real costs of producing their crops. Our emphasis for several decades was in quantity of production -- yield -- with much less thought given to efficiency of production. Today we need technologies focused on efficiency, on reducing the cost per unit output produced, in contrast to the maximum production scenarios of the 1960's and 70's.

Since the early 1900's, U.S. farmers have relied on ever bigger machines and more chemicals to enlarge their crops -- and income. But the new trend is toward "precision agriculture". More and more successful farmers will aggressively adopt new technologies to reduce the real costs of production. The economic incentive to lower input costs will also lower the input of chemicals into agriculture as well as the amount of tillage.

We will certainly see technologies to reduce the need for fertilizers which are one of the highest input costs. Slow- and controlled-release fertilizers will be developed for major crops. We may also see the application of genetically-engineered root-colonizing and soil microbes to provide part of the fertilizer need.

We will see a variety of technologies to reduce field operations. Reduced till and no-till farming will grow with the development of more efficient herbicides, fungicides and insecti-

cides and more efficient formulations and delivery systems for crop chemicals and seeds.

We will see improved water management and innovative approaches to erosion.

Biotechnology

Biotechnology promises to have an enormous impact on crop production. Plant breeding has already provided plants with resistance to major diseases, to some insect pests, and with enhanced yields. But genetic engineers can rapidly accelerate plant breeding and offer new ways to protect crops and enhance yields, to make crops hardier and less dependent on the input of chemicals, fertilizer and the energy needed for tilling. Genetic engineers provide new tools with which the plant breeder can significantly enhance the efficiency of crop production, to make farming more reliable and more profitable.

Since 1983, when my colleagues at Monsanto originally developed the capability of plant transformation for petunia and tobacco, over a dozen vegetable and commercial crop plants have been transformed in various laboratories. In the next 5-7 years, genetic engineers will have conferred commercially desirable properties, such as resistance to pests, to pathogens, to stress and to herbicides, on many major crops including soybeans, rice, corn, wheat, canola, sorghum, cotton and alfalfa.

We have genetically engineered plants to resist insects, to resist viruses, and to resist Roundup® herbicide -- glyphosate.

In the case of insect resistance, we have made tomatoes and related crops resistant to caterpillar pests. There are promising ways to make them resistant to other insects as well. The potential advantages to the farmer are manifold. For example, when we have genetically engineered cotton to resist both caterpillars like the pink bollworm and beetles like the bollweevil, we will dramatically impact the growing of cotton. No longer will cotton farmers have to spray their fields six or more times each growing season with a conventional insecticide. The input cost savings should be large and the environmental consequences attractive.

The greatest potential of biotechnology for short-term productivity gains which will impact the American farmer's bottom line are herbicide-resistant crops. Seed companies have been breeding crops for herbicide resistance for several decades. Genetic engineering permits the rapid acceleration of such breeding programs. Within a decade crops resistant to more effective, less expensive and more environmentally-friendly herbicides will be widely used by farmers.

Researchers have already genetically engineered several crops to have resistance to Roundup® -- glyphosate -- which is an effective, broad spectrum, environmentally-friendly herbicide. There are numerous cases in which glyphosate-resistant crops can result in substantially lower weed control costs.

I suspect that in future we will see vastly increased development and use of environmentally-friendly broad spectrum herbicides like Roundup® with little built-in crop selectivity. Crop selectivity will be achieved by genetically engineering resistance into crops.

The process of genetically transforming plants has become much more rapid so that many major crop varieties can be effectively transformed for herbicide resistance. These herbicide-resistant crops will provide farmers not only increases in productivity but also provide important opportunities for new crops and new rotations where weed-control problems had previously prevented crop changes.

In addition to pest and herbicide resistance, within ten years I foresee the attractive prospect of developing crops that are more tolerant of heat, frost, and other stresses. Hardier crops with these performance features would certainly increase the reliability and efficiency of crop production. They will also extend the geographical range of crops and provide farmers with wider crop choices. I do not promise orange groves in Iowa, but some of the changes could be pretty dramatic!

Another attractive prospect of genetic engineering is to help halt the decline in the genetic diversity of crops which makes most modern agriculture vulnerable to attack by rapidly evolving plant disease and pest organisms. While traditional breeding often narrows the genetic variability of a crop species, genetic engineering has the potential to bring much greater diversity to crops. Virtually any desirable trait -- whether found in a bacterium, a weed or even an animal -- may now be used to improve plants. During the next two decades genetic engineering will provide the plant breeder with a precise and powerful tool to create new germ plasm, to quickly introduce important new diversity into key crops and ultimately to introduce new crops.

Biotechnology can be the instrument of another "green revolution". It has the potential to bring about major, previously unachievable advances in crop productivity and quality. It also promises to increase genetic diversity and make crops hardier, less subject to pests, disease, stress and bad weather,

Information Technology

Innovations in information technology will also have a major impact on the business of crop production. Farmers need infor-

mation tools to enhance productive efficiency and to be economically successful. Computer systems will become increasingly user-friendly. Information technology will become widespread in the office and in the field as farmers integrate computers into their overall operations. Agriculture will become high precision in field management, in marketing and in financial management. Initially I see a larger role for crop consultants, but I suspect more and more farmer/businessman will come to use artificial intelligence systems that mimic the logic of experts to provide expert advice and to hone their management skills.

Environmentally-friendly Products

Environmentally-friendly products will be a key thrust, especially when they can make a producer more efficient. We will see increased development and use of environmentally-friendly crop chemicals and related products. Breakthroughs in weed control, like glyphosate and herbicides like the sulfonylureas and imidazolinones which need to be applied in grams/acre instead of pounds/acre, will come into increased use. These products are safe for humans and wildlife because fish, insects and mammals (including humans) lack the biochemical pathways upon which the herbicides work.

I also expect increased development of new fast-acting post-emergence herbicides which are broken down rapidly in the soil.

We will see the introduction of new formulation systems which target a crop chemical to its target, require smaller amounts of chemical and protect non-target organisms. We will see more and more delivery systems changed to closed containers, avoiding all mixing operations that expose crop protection chemicals to humans. There will be no direct contact of the applicator or farm worker with the product.

The ultimate in environmental friendliness will be crops that have been genetically engineered with natural defenses against pests and diseases which I mentioned a moment ago, and new generations of microbial crop protection products and enhancers of productive efficiency like Bacillus thuringiensis protein or B.t. (Dipel®, Thuricide®).

My colleagues at Monsanto have been able to transfer a gene for a naturally-occurring insecticide, called Bacillus thuringiensis protein or B.t. from one soil microbe into another microbe which lives in natural association with the roots of plants. The object of the research is to provide a natural protection for the roots against certain insects which feed on them. A strategy such as this has tremendous potential . . . and minimal environmental impact.

Unhappily, Monsanto has not been given clearance to field test its new microbial crop protection system, although these genetically-engineered microbes, like the genetically-engineered crops, pose no unprecedented or unique environmental concerns.

I also believe that the uses of biotechnology in agriculture which I have described can play a vital role in restoring the durable productivity, the tilth, of our soils, and enhancing the quality of our ground water.

Drive for Quality

Another major trend of the modern precision farmer will be a drive for quality. In order to stay ahead of mass production in less developed countries, American and European farmers will seek to differentiate their products through superior quality:

- Higher protein producing plants.
- Oil crops that produce better-quality, less saturated edible oils, specialty oils in higher yields.
- Wheat crops with better baking qualities and barley crops with better brewing qualities.
- Feed crops with higher nutritional values and better digestive qualities.

Biotechnology -- the genetic engineering of crops -- can accelerate the development of value-added varieties and the drive for quality.

We will also see changes in consumer demands that will accelerate the drive for quality.

These several demands for quality create important market opportunities.

Strong arguments can be made for increased crop diversity. We need a prudent number of new crops to fuel American agriculture and forestry. Some efforts are beginning with crops like kenaf, an annual hibiscus and a cousin to cotton, which is a source of fiber for making paper and paper board. In the South particularly, the crop appears to be competitive with standard commercial crops and is capable of producing greater quantities of fiber per hectare than pulp wood at about half the cost. kenaf can yield from 25 to 45 metric tons dry weight of stems/hectare/year. In the October 24 issue of the Austin American-Statesman, the front page featured kenaf with comment from a research director of a large farm complex that "A farmer that knows how to grow cotton knows how to grow kenaf".

Another attractive new crop candidate for American farmers is oil seed rape or canola, which is already widely grown in Canada and elsewhere.

There are other crop possibilities but, in each case, a market has to be created for the product. It is a "chicken and egg" problem that requires partnership between the public and private sector and innovative planning. I suspect that thought should be given to diverting some of the resources that are now used to support research on commodity crops to develop new farm products. It is difficult to encourage crop shifting unless there are a reasonable number of new crops to shift to.

I should also like to suggest that the ability to genetically engineer plants promises to enlarge the mission of agriculture in other ways. Today agriculture focuses principally on food and fiber. But if we can genetically engineer plants to produce animal proteins, other prospects emerge. What if we were able to genetically engineer plants to produce human insulin or human blood factors for hemophilia or a vaccine for hepatitis or other diseases. This now appears to be possible. Perhaps some of the high-value-added crops of the 1990's will be plants that produce drugs for human diseases or other animal proteins. Perhaps we will be harvesting human insulin and other human drugs from the "north forty".

Biotechnology and Animal Agriculture

Let me make a brief comment here on the use of biotechnology to increase the productive efficiency of livestock production.

It has been known for years that bovine somatotropin, a natural protein produced by the cow's pituitary gland, stimulates milk production, but the traditional source for the substance, pituitaries from cow carcasses, was not a practical means of providing a commercial product.

Genetic engineering, however, has enabled us to transfer the cow gene for the protein into a bacterium which can produce bovine somatotropin in large enough quantities for testing and commercialization. Extensive tests on dairy cows have already shown that BST improves the productive efficiency and reduces the input costs of the dairy farmer. A dairy farmer with, say, 80 cows can produce as much milk as he previously could with 100 cows, use 15 percent less feed to produce that milk, and finally have a chance to be more profitable! Monsanto is continuing research on this product and intends to develop it and gain approval for a commercial product for the dairy farmer by 1989-1990.

A similar somatotropin could boost feed efficiencies in commercial hog operations by up to 20 percent while speeding the

the rate of weight gains and producing leaner animals. Pork chops of the future will be high in protein and very low in fat. I think nutritionists and consumers the world over will applaud and would pay a premium for that kind of improvement in meat quality.

Importance to Agriculture of Genetic Engineering Innovations

The commodity crop surpluses that exist today have prompted some critics to suggest a moratorium on agricultural research and technology development, particularly biotechnology. "Why invent something that will increase productivity" they ask, "when we have more than we can sell or produce today?

The answer is straightforward. If we do not continue to innovate, we will be forced out of business. We are not alone on this planet in producing commodity and other agricultural products. The capacity of American agriculture to retain its domestic markets and to expand its foreign markets depends on continued declines in the real costs of production and the development of differentiated quality-added and value-added products. American agriculture has achieved its preeminence in the world by innovating, by substituting knowledge for resources. This innovation must continue despite the problems that our agricultural economy faces today.

I believe that genetic engineering is the most important advance in agricultural science of this century and can enhance both the productive efficiency of agriculture and the quality of our environment. It has the potential to vastly increase the economic competitiveness of American agriculture. Yet, as you all know, there is an effort afoot to stop the application of genetic engineering to agriculture, and then to stop its application to other fields such as medicine. The public has been encouraged to be apprehensive about genetic engineering and biotechnology, and to adopt the view that genetic engineering is dangerous, unnatural and in some way infringes on "divine copyright". This concern promises to delay the application of biotechnology to agriculture in the United States, and has impeded the pursuit of this science in universities. Indeed, as of this day, the release of a genetically-engineered plant which is allowed to flower and go to seed has not occurred.

There is no reason to assume, guess or hypothesize that changing a single gene in a plant by genetic engineering and planting its seed in a field, would cause an environmental problem. It is absurd to pretend that we are living in a pristine forest, and to say that we shouldn't change anything. In the end, using biotechnology to control plant pests and to raise the agricultural productivity of areas we have decided to cultivate may be the best way to leave other parts of the world unaltered.

Let me remind you that honeybees, farmers and animal breeders have been recombining the genes of various organisms for millennia, and these organisms freely roam the planet. Thus genetic recombination is a key process in nature as well as in genetic engineering. Moreover, genetic engineering gives us an intimate view of how nature operates and allows us to work with nature. It has taught us to address nature in her own universal language, the genetic code, and nature has responded by producing proteins we have asked her to produce, like enzymes that dissolve blood clots or proteins that enable plants to resist insects and diseases, or proteins that improve the production efficiency of livestock operations. Genetic engineering is a marvelous Rosetta stone. Nature is finally scrutable and, at long last, human beings can work in harmony with nature. During the next decade humanity's knowledge of genetic engineering will increase far more rapidly than in the past, and we shall learn how to apply it more and more to unsolved but urgent problems. But we shall not be allowed to apply genetic engineering to agriculture without public support and without the support and interest of the nation's leaders. We need rational, science-based regulations which allow commercial development while meeting the goals of environmental protection and which permit the safe, purposeful release of modified genetic material.

I believe that the USDA should participate more actively in demystifying genetic engineering so that the public will accept this science as a natural, gentle science whose goal is to prevent pestilence and disease, to improve the productive efficiency and economic viability of American agriculture, and to enhance the quality of human lives. Unless you and your colleagues do that, along with our academic leaders and scientists, government regulators, Congress and the courts will slow down the development and application of genetic engineering to agriculture in this country and ensure that we lose a larger and larger share of both domestic and international markets for American agricultural products.

I am confident that the USDA, through its educational activities, can hasten the building of consensus upon which our democratic society depends, and I urge it and you to do so.

If we do not adopt new technologies like biotechnology which can significantly increase the efficiency of production and ensure product quality, it could cause a permanent crippling of U. S. agriculture. The day we limit the use of new technologies is the day we start to bring in massive quantities of Argentine wheat, Brazilian soybeans, and become a nation that imports larger and larger quantities of food.

It is also important to recognize that these new technologies will hasten the restructuring of U.S. agriculture whether or not they are adopted by U.S. farmers. For the technologies

will certainly be adopted in other agricultural countries and this will increase their productive efficiency, reduce their cost of goods, and make off-shore commodity products more attractive to users in the United States than high-priced local products.

A country or an industry can survive for a relatively short period of time by erecting barriers to competition and by not investing in innovation. But eventually that industry will have to adopt new technology to survive -- examples are the steel and auto industries which may have waited too long to adopt new technology.

If the application of biotechnology to agriculture is delayed for years before it is applied in the United States, the United States could wind up producing superb prototype technology for the rest of the world to apply.

For both the individual farmer and for the nation as a whole, the choice is clear: either be an innovative farmer or compete with one. Biotechnology can provide American agriculture with that innovative edge. Let's use it.

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