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The adoption of the products of biotechnology has proceeded at a much faster rate than almost anyone anticipated. The potential of these products to deliver significant value and change agriculture has driven enormous research funding over the last 15 years. In the case of Pioneer Hi-Bred, we increased our research spending from three percent of sales to more than eight percent of sales at the same time that the total sales were increasing rapidly. The need for research funding to develop and apply the new technologies has driven considerable change in agrobusiness and the farm sector. In particular, it has sparked a wave of consolidation of agricultural chemical companies and seed companies. Along with the enormous promise of the technology, there are concerns related to the wide-scale use of this technology. This meeting deals with one of those concerns: the development of pests that are resistant to the genetically altered host. I have been asked to share my thoughts on the management of the new technology so as to minimize the risks as we explore practices that might mitigate the risks of development of pest resistance. Our workshop is to explore these issues from the perspective of industrial and economic concerns.

Resistance to synthetic agrochemicals or to gene products produced in crops can develop in insect, pathogen, or weed populations. The general mechanisms and basis of the development of resistance is well understood since it is a case of natural selection. However, the specific controlling factors and their management are much less clearly understood. Current models for minimizing selection pressure and maximizing efficacy of the transgenes is much more limited. Although there are only a few transgenic crops introduced into the market at this time, many more are at various stages of development. A few transgenes like Bt (*Bacillus thuringiensis* endotoxin) and various types of herbicide tolerance are finding broad acceptance and are being introduced

across crop species. Transgenic crops with insect resistance and herbicide tolerance have significant value to farmers by replacing synthetic agrochemicals for insect control and expanding the ability to use broad spectrum and relatively environmentally safe herbicides in production systems. The farmers' desire to solve these problems using genetic solutions has resulted in rapid acceptance of the new technology. Meanwhile, our understanding of resistance management has been useful but has not been adequate to result in widely accepted management programs. Nor has the efficacy of implemented management plans been established. The need for resistance-management programs to function across geographical areas, crops, state and national borders, and different company products makes the development and implementation of compliance with management plans particularly challenging.

It is worthwhile to explore the nature of the participants in the industrial and economic arena, and consider the strengths and weaknesses they bring to resistance management. This exercise might suggest approaches that maximize the strengths of the participants and minimize the weaknesses.

Technology Providers

University programs, small companies, or the technology development efforts of large companies discover genes providing crop protection traits. The strength of the technology providers is that they are extremely aggressive in applying both basic and applied science to important problems. Their activities drive changes in competitive positions as new products with improved characteristics displace or reduce the use of existing products. An example is the transition from synthetic chemical control of pest insects to genetic control. These technology generators tend to move very rapidly and to focus narrowly on the technology. They are more likely to concentrate on their business and their technology, and not have the resources or time to devote to addressing larger societal issues. Some projects are done because they are possible technically, while a discussion of the broader social, economic, and environmental issues may lag the technology.

Crop Input Companies

Over the last 15 years there has been significant consolidation of the companies involved in providing crop production inputs. Recently there have been significant moves to consolidate crop-input companies and chemical/agrochemical/pharmaceutical companies. Many of the remaining players in this area are large "life sciences" companies that have activities in agricultural chemicals, seeds and other traditional inputs, as well as pharmaceutical, nutritional, and processing activities. These companies bring significant, positive capabilities. They are willing to spend large sums of money on research and to move new products quickly into the hands of farmers and consumers. They concentrate on selling products not traits, and have the resources and

scope to address regulatory requirements and to move technologies around the globe. These companies, because of anti-trust concerns, are limited in their ability to cooperate with one another once they begin to compete in the marketplace. In the case of herbicide-tolerant soybeans, a number of companies are selling varieties across the entire soybean growing area and they are limited in their ability to plan among the companies for restrictions on acreage or usage of the products. Additionally, these companies are gaining benefit from moving quickly and being the first to introduce products, and would like to avoid multiple-year discussions of societal impacts. Their businesses may involve one or two crops, but not all the crops containing a trait like Bt for insect resistance. This means that resistance-management planning that goes across regions and crops may not be addressed by the same companies. Pioneer, for instance, sells Bt corn, but is not in the cotton business. In spite of this, a resistance-management plan in the southern United States must consider both crops.

FARMERS

American farmers are the most efficient producers of grain in the world. They do this at a low cost, and have provided a reliable, inexpensive source of food for the US, and increasingly the world. They are in competition with farmers in other countries and tend to adopt technology quickly to optimize their own position. In dealing with questions of transgenic insect resistance, they recognize that in a low-margin commodity business there are significant benefits of new technology that accrue to the early adopters. Consequently their interests are not always in concert with those of their neighbors or those of the companies selling the products. This divergence tends to make coordinated planning for minimizing the development of pest resistance difficult.

SUMMARY

The opportunity for an extended theoretical discussion of the issues surrounding the development of insect resistance to transgenes is well past. There are a number of new technologies and genes currently being developed that extend well beyond the Bt insect resistance or herbicide tolerance traits that are in the marketplace. These traits represent both alternate genes for insect resistance as well as other traits that have yet to be commercialized. The discussion of resistance management shouldn't be seen as being for or against a single technology. In the case of insect resistance, the replacement of chemical technologies by genetic technologies offers an additional approach. This transition offers many benefits to the environment and farm safety, but also raises questions. It is unlikely that the groups listed above will reach durable approaches to minimizing insect resistance without a dialog that ensures a representation of them all and that recognizes and minimizes their specific weakness.

It is in all our interests to manage the genes for insect resistance in a way that prolongs their useful lifetime. Increased understanding of the nature and efficiency of resistance management programs has significant value.