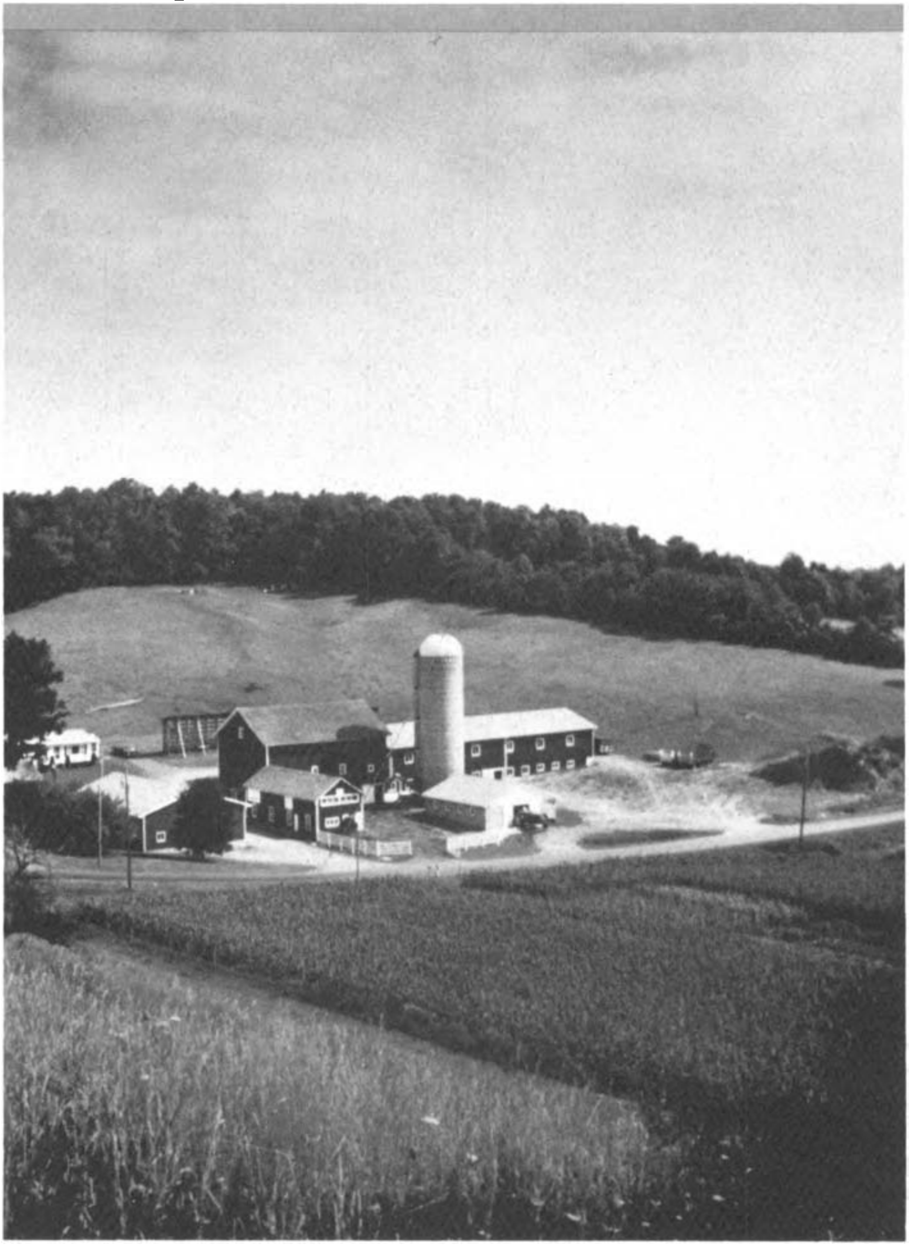
NABC Report 1



Biotechnology and Sustainable Agriculture: Policy Alternatives

NABC Report 1
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Edited by June Fessenden MacDonald

1989

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PREFACE

The National Agricultural Biotechnology Council, established in 1988 with funding from The Joyce Foundation, is a consortium of five major agricultural research institutions:

Boyce Thomspon Institute for Plant Research
Cornell University
Iowa State University
The Texas A&M University System
University of California, Davis

The Council, through sponsorship of meetings and workshops, and NABC Reports, strives to facilitate the development of policy recommendations for the safe and efficacious development and use of agricultural biotechnology products and process for the benefit of society; to involve all interested and affected groups in a holisitic, rather than discipline-or constituency-oriented evaluation of the potential impact of biotechnology on agriculture and development of policy alternatives; and to promote increased understanding of agriculture and biotechnology.

Many agricultural biotechnology topics were considered for this first NABC meeting. These topics included field introductions of genetically modified crops; research support for agricultural biotechnology; proprietariness of genetically modified microbes, plants and animals; food and feed safety, and quality; communication of agricultural biotechnology to society; international competitiveness; global environment; sustainable agriculture; relationships of not-for-profit and for-profit organizations; and many others.

At the suggestion of Iowa State University, Biotechnology and Sustainable Agriculture: Policy Alternatives, was selected as the topic of the First Annual NABC meeting, held at Iowa State University, Ames, Iowa, on May 22-24,1989. The conference was organized to include anyone interested in exploring the role biotechnology can play in achieving the goals of sustainable agriculture.

Attendees represented government, agribusiness, biotechnology, economics, philosophy, sociology, ecology, sustainable agriculture, animal welfare, media, farmers, environmentalists, lawyers, and consumer interest groups. There was an effort to insure representation across all sectors and interest areas.

The meeting was constructed as a series of lectures to provide a common informative base for four subject area workshops— Biopesticides, Herbicide Tolerance in Plants, Disease Control in Animals, and Animal Growth Promotants. The workshops with participants representative of many differing viewpoints were charged with the task of identifying key issues and areas where additional research was needed as well as setting forth recommendations for the formulation of policy recommendations.

This volume is not a proceedings of the First Annual NABC Meeting, but rather a report meant to communicate the results of the workshops and conclusions of the meetings to those outside the immediate biotechnology and sustainable agriculture areas. Hopefully sections one and two will convey a flavor of the meetings and provide a synopsis of the issues identified in each subject area and recommendations for research and policy generated in each workshop.

The overview was written by Ralph W. F. Hardy, NABC Council Member, who attended the 1989 meeting, and June Fessenden MacDonald, Deputy Directorof NABC who joined the publication effort in November, 1989. The workshop reports were prepared by the rapporteurs and co-chairs with comments by workshop participants. In one case, the workshop of Herbicide Tolerance in Plants, the rapporteur was taken ill and Dewayne C. Torgeson of BTI and Johan Swinnen, NABC Joyce Graduate Fellow at Cornell University, stepped in to compile the report.

For those who desire more specific information, the keynote addresses and topical lectures are presented in Sections three and four, respectively. Most are edited transciptions of the actual presentations, although in a few instances the presenters preferred to provide text prepared for the meeting.

NABC hopes that this report, representing in a single volume the range of perspectives on biotechnology and sustainable agriculture, will contribute to increased understanding of different viewpoints and provide a foundation for addressing some of the concerns facing society today in the agriculture area.

ACKNOWLEDGEMENTS

Many people contributed to the success of the First Annual NABC Meeting and the production of this report.

First and foremost, NABC gratefully acknowledges funding for the meeting from The Joyce Foundation and the U.S. Department of Agriculture.

Special recognition goes to the Planning Committee at Iowa State University, chaired by Walter Fehr, Director of Biotechnology,with Jack Dekker, Fred Evans, Steve Gendel, Marvin Hayenga, Dennis Keeney, David Kline, Brian Reichel, Mack Shelley, Tony Smith, Allen Trenkle, Kathleen Waggoner, Make Warren, Bill Woodman, Harold McNabb, James Roth, Laura Sweets, and Gordon Bultena and NABC member Ralph W.F. Hardy, President of the Boyce Thompson Institute for Plant Research, organized the workshops. The success of the First Annual NABC Meeting was due to their careful planning.

The NABC gratefully acknowledges the efficient conference organizational service provided by Marilyn Petersen, Glenda Webber and Priscilla Matt of the Biotechnology Program at Iowa State University. Critical to the production of this report was the transcription of the conference tapes by Edith Landin in Iowa and the editorial work by Lisa McGowan in Ithaca, New York.

The cooperation we have received in the production of this report from all of the conference organizers, presenters, workshop chairs, and rapporteurs has been phenomenal, and is sincerely appreciated.

Very special thanks goes to Hana Barker, who, although new to her position, provided the administrative, editorial and design skills necessary for the production of this report.

June Fessenden MacDonald
Deputy Director, NABC

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1 Overview

Overview

Major fundamental advances in molecular and cellular understanding of biology, particularly since the 1960s, have generated a new technology referred to as biotechnology. However, biotechnology—the use of an organism or its product(s) as a product or a process—is a centuries' old technology. Humans have selected, improved, and used organisms and their products for decades: yeasts for bread, wine and cheese making, domesticated animals and crops for agriculture and food, antibiotics, insulin and other natural therapeutics for health care; and microorganisms for waste treatment and mining. The above examples may be referred to as the old, established or traditional biotechnology in which we have a great deal of familiarity and much favorable experience. In these traditional examples, genetic selection or modification was performed, for the most part, at the organismal level, e.g., plant and animal breeding.

In contrast, the "new" biotechnology of the 1960s and later provides the tools for the use of molecular and cellular, in addition to organismal approaches. Commercial examples from this expanded biotechnology are most developed in the human health care where molecular modification of microorganisms is used to produce useful quantities of natural therapeutics, e.g., human insulin for diabetes, human growth hormone for genetic dwarfs, erythropoietin for kidney dialysis patients, and "pure" vaccines to eliminate the dangerous side effects of impurities in traditional vaccines. Also, specific and highly sensitive diagnostics for disease organisms or conditions have been developed.

THE NEW AGRICULTURAL BIOTECHNOLOGY

Several potential products of this molecular and cellular biotechnology for agriculture, food, and feed uses are at the research and development stage with commercialization expected in the early 1990s. Examples are microbially produced animal growth promotants for increased efficiency of meat and milk production and for improved quality of meat, genetically modified microorganisms for use as biopesticides and growth promotants, and genetically modified crops that are self-protected against insect pests and diseases tolerant to synthetic chemicals such as herbicides or improved in nutritional value.

This report and the NABC will focus on new biotechnology as an extension of established biotechnology. New biotechnology is expected to have a major impact on many human activities, including agriculture and food. Most developed countries perceive the new biotechnology as providing the next basis for international commercial competitiveness. This perception is strongly held in the United States, in the European Economic Community, and in Japan; and actions are being taken to strengthen national and regional competitive positions. Developing countries are also anxious to access biotechnology produced for their own needs, while at the same time there is concern that food products and substitutes will be using biotechnology to replace agricultural export products, often their main source of cash income, grown in the Third World.

This new biotechnology is perceived differently by various groups and differently by individuals within a group. Some see it as a major new opportunity, others as a threat, and others are merely confused. These divergent views were noted by President Gordon P. Eaton of Iowa State University in his welcoming comments at the First Annual NABC Meeting.

> "Those of you who are biotechnologists are dedicated to pushing back the frontiers of your science. You are motivated and driven by your quest for understanding the fundamental processes that control living organisms. You are seeking ways to use that knowledge to modify living organisms in ways that have never before been possible. The potential of your success is viewed by some in our society as enormously exciting and holding ultimately great benefit for society.

At the same time, it is viewed by others as not only threatening, but even frightening. As your knowledge of the living organism expands, our traditional approaches to agriculture are being dramatically changed. I think, at this point, we frankly aren't sure, sometimes, how we are going to deal with your success, and I suggest that that may be true for a very long time to come."

Bovine somatotropin (BST), one of the first commerical agricultural products, is an example of technical success we do not know how to deal with. Its use in the dairy area has received unprecedented visibility and debate. The use of BST will improve efficiency of milk production—the major emphasis of dairy research for the past several decades. More milk from fewer cows may have a modest positive environmental impact in terms of reduced production of methane (a greenhouse gas pollutant) and nitrate (a water pollutant) from manure. However, some farmers and others are concerned about a treatment that will increase milk production substantially when the milk market already has excess production capability with the resultant inability of some dairy farmers to stay in business. Some consumer groups are concerned about the safety and wholesomeness of this milk and suggest that it be labeled as milk produced by cows supplemented with injected BST.

In other food areas, there is consumer desire for foods produced with decreased or no synthetic chemical pesticides, concomittantly there is increased emphasis on biological control of pests. Animal rights activists voice comcern about animal treatment, representing another concern for the agricultural producer. These and other agricultural concerns, especially the economic disaster in crop agriculture in the early 1980s and its destructive impact on rural midwestern communities, has prompted increased interest in agricultural ethics, rural communities and structure and is bringing new voices to the dialogue on agricultural biotechnology. These interest groups now include agribusiness, farm producers, technologists, lawyers, ecologists, economists, environmentalists, molecular biologists, human health professionals, social scientists, philosophers, public interest groups, consumers, and politicians.

THE NABC RESPONDS TO A NEED

In response to the need for a neutral forum for dialogue among these diverse interest groups on agricultural biotechnology and its use, Robert B. Nicholas of McDermott, Will & Emery and Ralph W.F. Hardy of Boyce Thompson Institute for Plant Research conceived the National Agricultural Biotechnology Council (NABC) in February 1987. A university/institute council was formed, representing leading national, not-for-profit research and educational institutions with a national geographic distribution. The National Agricultural Biotechnology Council members and their institutions now include Vice Chancellor Charles J. Arntzen, The Texas A&M University System; Senior Provost Robert Barker, Cornell University; President Gordon P. Eaton, Iowa State University; President Ralph W.F. Hardy, Boyce Thompson Institute for Plant Research; Chancellor Theodore L. Hullar, University of California at Davis; and Robert B. Nicholas, Partner, McDermott, Will & Emery a Washington, DC law Firm. The Council members provide guidance to the NABC including identification of the focus of the annual meeting. Initial funds to support the NABC were obtained from The Joyce Foundation and the U.S. Department of Agriculture.

An earlier council for agricultural technology, the Council for Agricultural Sciences and Technology (CAST), was formed in the 1950s. It combined agricultural, commercial, and professional society interests to address issues of agricultural science and technology. Many useful reports have been produced, and CAST, headquartered at Iowa State University, has had a significant beneficial impact on agricultural issues. We hope that the NABC will prove to be as useful for agricultural biotechnology as CAST was for agricultural technology. In contrast to CAST, NABC has expanded the participants in its dialogues to include many additional groups beyond agribusiness and professional societies that must be involved in any dialogue on agricultural biotechnology issues. We hope that this expanded constituency will give a 1990s creditability and relativity to the NABC.

The general objective of the NABC is to bring together economic, environmental, health, social and ethical viewpoints on an agricultural biotechnology topic of current importance. Through presentations, workshops, and workshop reports, we hope to increase communication and understanding and generate policy options as appropriate for the safe and efficacious development of biotechnology for benefit to the farmer/producer, agribusiness, food processor and distributor, consumer, society, and our nation.

THE FIRST NABC MEETING

Iowa State University proposed that the 1989 meeting focus on biotechnology and sustainable agriculture, an area of major interest to both the university and the state. This proposal was accepted. The Council recognized that there had been many meetings on sustainable agriculture or variants thereof, but there were no meetings discussing the relationship of biotechnology to sustainable agriculture. Under the local leadership of Dr. Walter R. Fehr, Biotechnology Coordinator at Iowa State, and with the involvement of the Bioethics Committee and Leopold Center for Sustainable Agriculture, the meeting was planned.

Four timely subject areas of agricultural biotechnology that were relevant to sustainble agriculture were selected: biopesticides, herbicide-tolerance in plants, disease control in animals, and animal growth promotants. Biopesticides include natural or genetically modified pest predators, parasites, and pathogens or their products, as well as plants modified to resist pests or disease. The most advanced biotechnological biopesticides include the Bacillus thuringiensis toxins for insect pest control and the coat proteins of viruses to protect plants against viral diseases. Herbicide tolerance refers to crop plants that have been selected or genetically modified for increased tolerance to selective as well as non-selective herbicides. Herbicidal resistance, which had earlier included the concept of tolerance is now used to refer to weeds that have developed resistance to herbicides. This distinction of tolerance and resistance was not always made clear in the presentations or discussions on this topic. Biotechnological products for problems and control of animal disease are less developed but could include diagnostics, vaccines, and therapeutics, resulting in a focus on the general area of animal welfare, not on specific products. Animal growth promotants include BST and porcine somatotropin (PST) with BST the most debated of any agricultural biotechnology product. Animal growth promotants and herbicide-tolerance have entered the political arena where at least one state's 1990 governorship election now has agricultural biotechnology as a key issue.

SUSTAINABLE AGRICULTURE

Sustainable agriculture is difficult to define because there is no established definition. The vision of sustainable agriculture varies from a major emphasis on the non use of synthetic chemicals as fertilizers and pesticides to a major emphasis on maintenance of family farms to the attendant agricultural practices that provide regeneration or no long-term loss to natural resources. Most agree that sustainable agriculture involves environmental equilibrium with a longer-term view than has been characteristic of traditional agriculture with its dominant emphasis on short-term economics. This longer-term view must balance the real needs of farmers, consumers, society, the environment, the nation, and even the world. It must be sensitive to the preservation of resources such as germ plasma, soil, water, fossil fuels, and even technologies and social structures. Sustainable agriculture must seek to make agriculture more environmentally and farmer friendly. Sustainable agriculture must also include the dominant role of the consumer who is the ultimate purchaser of agricultural products. President Eaton made some perceptive comments on sustainable agriculture:

> "Sustainable agriculture also has a unique culture. Persons involved with this activity are seeking ways to reduce the inputs, particularly the chemical inputs, to agricultural production. As these inputs are reduced, as surely they must be, there will be a greater reliance on labor and perhaps even a loss in total productivity, although not necessarily, and hopefully not, a reduction in profitability Although few would question the appropriateness of reducing inputs agricultural production in order to preserve the quality of our environment, there is concern as to whether or not the traditional family farmer will be willing or able to adapt to a system that may reduce productivity and will require additional labor. There is also, I think, in some quarters concern about the possibility of the United States continuing to serve as a major world supplier of food if productivity of its agricultural systems is actually reduced by lowering inputs of fertilizers and other products."

MEETING FORMAT

The meeting format included two keynote presentations—one by a leading spokesperson for sustainable agriculture from the Center for Rural Affairs, Charles Hassebrook, and the other by an agricultural biotechnologist from a development-stage agricultural biotechnology company, Robert M. Goodman. Hassebrook emphasized that "agricultural research is really a form of social planning" and "the aim should be to develop a set of research goals by which the public research agenda reflects and addresses the needs of society." Goodman, on the other hand, emphasized the role of biotechnology. "Genetic manipulation is a proven technology that can be used to address whatever the future agenda is for agriculture" and "genetic manipulation is the proven environmentally safe way to address production challenges—both economical and environmental." These agenda-setting talks are in section three of this report.

Each of the four subject areas—biopesticides, herbicide tolerance, animal disease, and animal growth promotants—was addressed by proponents for technological, economic, environmental, sociological, and ethical viewpoints. These presentations are grouped under each of the four subject areas and may be found in section four. In most cases the authors had strong position statements to make, bringing divergent viewpoints to a common forum. Several of the authors' position statements reveal an order of magnitude of differences. Possibly the greatest difference was between the extremely pro- herbicide technology paper and the extremely anti-herbicide social and ethical paper on herbicide tolerance. This lack of heretofore direct communication and understanding of alternate perspectives underscored the need for this NABC meeting.

These often provocative presentations were used as input for the workshops where the major outcome of the meeting was developed. Each subject area had a workshop, co-chaired by individuals from different disciplines and viewpoints to facilitate balanced discussions. There was also some effort to assure a broad mix of viewpoints among the participants in each workshop.

The workshops chairs were asked to promote dialogue between disciplines and viewpoints so that understanding could develop. Such dialogue occurred, but the distances in positions were so great that the participants agreed that they could not progress beyond disagreement on some issues during the limited period of the exchange. One such example, the labeling of biotechnologically-produced foods resulted in an agreement to disagree. There was agreement, however, that participants departed from the meeting with a much broadened base of information on biotechnology and sustainable agriculture and awareness of differences within and among various groups. The workshops were encouraged to require documentation for statements and, if such could not be provided, to note that such statements were only hypotheses at this stage. Some progress was made in this area although acceptable documentation may vary between disciplines.

Following two days of intense discussions, each workshop identified several major issues and key topics requiring additional research. Policy alternatives were also generated. The workshop reports are presented in the next section of this report and represent the major contribution of the NABC meeting. There was more consensus generated than expected from this diverse group of over 200 participants, although most discussion was at a general, rather than a specific level. This First Annual NABC Meeting represents an important initial step.

CONCLUSIONS

Some general conclusions can be drawn from this enlightening and provocative meeting on biotechnology and sustainable agriculture.

Learning Experience—The presentation-workshop format involving a diverse mix of disciplines and viewpoints provided a broad-range learning experience for all participants.

Continuing Technological Steps—Agricultural biotechnology products were not seen as major revolutionary steps, but rather as continuing technological steps in agriculture with varying impacts from modest to, in a few cases, dramatic.

Product rather than the Process—There needs to be an evaluation of the impact of a technological product on sustainable agriculture, irrespective of the process.

Needs Driven—Agricultural biotechnology is driven, for the most part, by needs of the customer, i.e., consumer, farmer, rather than the potential of the technology.

Public Input to Decision Making—There is a need for more meaningful public input into decisions on public sector agricultural research in general and agricultural biotechnology specifically.

Products for Family Farms—Biotechnology products need to be applicable and affordable to low input small family farms.

Information Need—There is a lack of information on different biotechnology products and alternatives, especially for farmers, consumers and the public. There is inadequate information available and a lack of understanding of sustainable agriculture. Scientists/technologists need to better understand and respond to the public.

Creative Information Dissemination—More creative information dissemination and education must be developed for farmers, consumers, and society. Negative public response often results from lack of information. Real versus perceived risks need to be discussed much more thoroughly and responded to more seriously.

Multidisciplinary Dialogue—True multidisciplinary dialogue is needed where the opportunity for productive reasoning can occur in a non-threatening, respectful environment without the need to protect vested interests.

RECOMMENDATIONS

After two and a half days of dialogue and disagreement, several specific policy suggestions or recommendations on biotechnology and sustainable agriculture reported out of the various workshops are listed below. Many similarities as well as some differences will be seen.

Biopesticides

—Encourage more public input into decisions concerning biopesticides and sustainable agriculture utilizing research advisory groups, public hearings for regulatory decisions, and an ombudsperson as a liaison with the public.

—Redirect public research to promote sustainable agriculture through establishing a system of competitive grants for sustainable agriculture.

—Modify environmental and agricultural policies to be consistent with sustainable agriculture.

10 —Integrate use of biopesticides with other techniques of sustainable agriculture.

Herbicide Tolerance

—Provide public sector funding for research on the environmental, economic, and social impacts of current and alternative systems of weed control including herbicide-tolerant crop/herbicide combinations.

—Initiate major public and private research efforts on the environmental, economic, and social impacts of agricultural systems.

—Determine how farm policy affects the adoption of different weed control techniques.

—Provide public funds to foster innovation at the producer level for use of alternative methods that are environmentally, socially, and economically superior to conventional methods.

Animal Disease Control

—Help assure the food safety of animal products utilizing biotechnology.

—Optimize environmental and management practices and systems for production of healthy livestock and assurance of well being and freedom from disease utilizing biotechnology.

—Establish trusting relationship's between livestock producers and health service providers with the products of biotechnology reaching all types and sizes of producers.

—Increase level of support to disseminate delivery systems to foster animal health products for a sustainable agriculture.

—Provide products of biotechnology that complement good husbandry practices for disease control.

Animal Growth Promotants

—Broaden public input into determining public biotechnology research programs.

—Establish public education programs regarding products of biotechnology.

—Develop special competitive grants programs innovative information delivery systems for farmers who may be disadvantaged by biotechnology products.

—Produce societal impact statements on forthcoming technological innovations.

Expansion of the above recommendations as well as additional information on each topic is found in the workshop reports and the papers. This report is unique in providing the diverse viewpoints and discussion that is an integral part of the debate on biotechnology and sustainable agriculture. As President Eaton said, "We will make our best contribution.. .by soliciting what we know to be highly diverse points of view and attempting to find convergent and constructive solutions to what are very complex problems."

NABC Report 1 makes a major contribution to the initiation of this process. Continuing dialogue and education will be needed to extend the process. The process must be continued if we are to safely and efficaciously utilize the power of biotechnology to evolve a more sustainable agricultural system.

2 *Workshop Reports*

Integrating Biotechnology and Sustainable Agriculture

The workshop participants were charged with the following tasks:

1 To focus on the “new" molecular and cellular biotechnology

2 To develop a workable definition of sustainable agriculture

3 To prioritize the major issues and identify the non-issues that were brought up but which did not have a significant role to play

4 To identify key areas where additional research is needed in order to determine the receptivity and efficacy in the use of biotechnological products

5 To set forth recommendations for use in the formulation of policy alternatives

6 To indicate areas of concensus and non-concensus

Co-chairs: Atttte K. Hollander
Associate, The Conservation Foundation
H. Alan Wood
Virologist, Boyce Thompson Institute for Plant Research
Rapporteur: Fred Evans
Philosophy, Iowa State University

Biopesticides

14 This report is a summary of the issues, research needs, and policy alternatives that participants raised and discussed in the conference workshops concerning the relation between biopesticides and sustainable agriculture.

I CHARACTERIZATION OF BIOPESTICIDES AND SUSTAINABLE AGRICULTURE

The workshop participants began their deliberations by formulating working definitions of “sustainable agriculture” and “biopesticides". They agreed to characterize “sustainable agriculture" in terms of its goal: The goal of sustainable agriculture is equilibrium, i.e., viable agriculture production with either regeneration or no net loss in the long term of natural resources and desirable social structures.

Noting that “-cide” means “kill" and that biotechnologists could develop biopesticides that just repel or otherwise inhibit pests in some non-lethal manner, the group agreed to define biopesticides in terms of “control”: Biopesticides are genetically engineered or naturally occurring biological agents that can be used to control pests.

Although they agreed on these working definitions of sustainable agriculture and biopesticides, many of the participants indicated that they would feel more comfortable if the report emphasized certain qualifications or elaborations in relation to the two definitions. Some of the more important of these qualifications and elaborations are:

Flexibility is a key aspect of sustainable agriculture, and there is a need for the delineation, implementation, and diversification of practices specific to sustainable agriculture.

Sustainable agriculture implies that the farmers practicing it will usually be the owner-operators of their farms.

Sustainable agriculture involves the tendency to reduce the number of inputs employed in agriculture.

In sustainable agriculture, one focuses on the functioning of the total agri-system and not just on a number of the system's specific features.

Sustainable agriculture is a means of meeting the needs of both farm families and the broader community, including the consumers of farm products and the smaller rural communities that serve farmers.

Short-term profitability is a means of ensuring the long-range viability of sustainable agriculture.

Biopesticides do not amount to a "magic bullet" that can promote sustainable agriculture in separation from other farm practices.

Genetically engineered biopesticides can occur in several forms, including transgenic plants designed to express insect toxins (e.g., Bacillus thuringiensis), plants engineered to contain plant virus coat proteins, and microbial pesticides such as viruses and fungi. One should therefore be careful in generalizing about the impact of biopesticides on sustainable agriculture.

On the basis of these definitions, qualifications and elaborations, the group then discussed how biopesticides might affect and contribute to the goals of sustainable agriculture. The discussion was divided into three parts: issues, research needs, policy alternatives.

II ISSUES

The group identified a variety of issues, needs and questions relating to the role that biopesticides might play in sustainable agriculture.

1 Impact on Desirable Social Structure—Because past agricultural practices and innovations have sometimes undermined the goal of preserving desirable social structures such as family farms and rural communities, workshop participants were concerned how the use of

biopesticides would affect these structures. They agreed that the impact of biopesticides on these structures depends on a variety of factors, including the following:

The use of biopesticides in conjunction with other sustainable agricultural techniques. Reliance on genetically engineered biopesticides in exclusion of other non-conventional practices could violate the ideals of "self-sufficiency" and "diversity" often associated with sustainable agriculture.

Level of agricultural management skill. Biopesticides will probably require a higher level of management skill than do traditional chemicals. This higher level of management skill is desirable if it promotes owner-operator management practices, but is undesirable if the level of skill is so high that it requires outside assistance incompatible with the goals of sustainable agriculture.

Level of financial investment required of farmer. If biopesticides require a high financial investment from farmers, then they will not provide a viable option for the smaller farmer.

2 Economic Viability of Biopesticides—If biopesticides are going to be available as a component of sustainable agriculture, they must be feasible to develop and implement. If only a small group of farmers are interested in using them—for example, only those practicing sustainable agriculture—then biotechnology companies may not be able to receive a sufficient return on their investment to justify the costs of their research and development.

3 Biopesticides in relation to a safe environment—The group felt that biopesticides would contribute to sustainable agriculture only if adopters and policy makers gave adequate attention to a number of environmental issues, including the following:

Agricultural practices involving biopesticides can contribute to resistant pest populations. Related weedy plants could cross-pollinate with the genetically engineered plants and become more resistant to the predators and conditions that previously controlled them.

If biopesticides are used only at the economic threshold to pest damage, that is, in a manner consistent with the practices of Integrated Pest Management, then they will be less likely to contribute to unwanted resistance in other organisms.

Biopesticides can disrupt other aspects of the environmental system. For example, some biopesticides might be harmful to beneficial organisms and prove difficult to monitor in relation to their environmental fate. Some of the participants suggested that such monitoring can never be adequately performed, while others felt that although monitoring is sometimes limited by the present state of technology and knowledge, it is not a major concern in relation to endogenous biopesticides.

If the genetic alterations of biopesticides are well characterized in advance, this could possibly limit unpredicted effects of releasing such organisms in the environment.

The chance of unintended environmental effects could also be limited by using biopesticides in conjunction with a crop rotation system.

We cannot claim that biopesticides as a class are always safer than chemical pesticides, though many biopesticides will be. In general, the goals of sustainable agriculture will be better served if we consider the balance between safety and effectiveness when comparing and deciding between biopesticides and chemical pesticides.

4 Promoting Diversity—Because biotic diversity at all levels promotes long-term stability of agri-systems, it would be more in accord with sustainable agriculture to adopt a strategy of developing diverse types of biopesticides rather than only one or two major varieties.

III RESEARCH NEEDS

The participants listed a number of research endeavors that they felt would advance the goals of sustainable agriculture and address the issues discussed in the previous section. They also emphasized that these endeavors would require integrated, interdisciplinary approaches between molecular biologists, ecologists, and the members of other disciplines. The following types of research were more frequently mentioned as important:

—Development of a consolidated data base in the areas of microbial and agricultural ecology, which would help us learn more about the possible consequences of the environmental release of biopesticides;

—Development of control and containment mechanisms such as conditional lethal genes;

—Consideration of ways to make biopesticides economically more viable;

—Ascertainment of the effect of public versus private research arrangements on diversity, for example, whether the tendency of private research to focus on high yield crops might reduce the diversity of biotechnologically engineered plants;

—Ascertainment of the degree to which public funds are being directed towards sustainable agriculture;

—Documentation of the degree to which current patenting practices inhibit the sharing of information necessary for the development of biopesticides compatible with sustainable agriculture;

—Development of methods by which biopesticide researchers can equitably compensate Third World countries for the (often unacknowledged) use of the genetic material contained in the landraces of many Third World countries;

—Reduction of the level of managerial specialization and expertise required for farmers who might utilize biopesticides;

—Documentation of the methods used by non-conventional farmers to produce their crops, thereby adding to our store of knowledge on sustainable practices;

—Collection of data concerning regional variability in sustainable agriculture practices;

—Promotion of the training of plant breeders, a disappearing art in the U.S. but still needed despite the development of new techniques for breeding plants;

—Elucidation of the differences between the conceptual systems (views of nature and of the relationship between humans and nature) underlying sustainable agriculture and biotechnology, and the practices which these systems tend to sanction or prohibit (the ethical dimension of agriculture).

IV POLICY SUGGESTIONS

The members of the group formulated a variety of specific policy suggestions, listed below:

1 More public input into decisions concerning biopesticides and sustainable agriculture—The workshop participants expressed a need to develop better mechanisms for public input into “major decisions” that have an impact on society and that are made by a variety of groups

that influence the direction of biopesticide development and use. These groups include federal and state regulatory agencies, land grant universities, and private industry. Appropriate mechanisms for delivering these policy inputs vary. Depending on the case, public input might be needed prior to decisions concerning research projects, the release of genetically engineered organisms into the environment, or the commercialization of new products. In particular:

Advisory group's—Public input is needed to help direct research investments towards areas that are consistent with sustainable agriculture. To be useful, these inputs must occur prior to the time such investments are initiated.

Public hearings—Many people feel that the current system by which federal agencies solicit input on regulatory decisions is too passive, usually involving only notification in official publications. A preferred approach would involve public hearings at the regional level, at least on issues that are particularly controversial.

Ombudsperson—In relation to university research concerning biopesticides or sustainable agriculture, an ombudsperson could serve as a liaison with the public.

2 Redirecting Research to promote sustainable agriculture and development of "special" agricultural products—State governments and/or some other funding sources should establish a system of competitive grants to promote sustainable agricultural research. Citizens should have a role in formulating the criteria for awarding them.

Land grant universities should work exclusively on the development of products that promote sustainable agriculture and that are prohibitively costly or otherwise unattractive for private companies to develop. In order to inform farmers about new conventional agricultural products developed by private industry, however, extension specialists should be involved in field testing them. Many members of the group therefore agreed that the original proposal should be modified. Although a much larger proportion of land grant funds should go into areas outside the corporate sphere of interest, this should not be done to the exclusion of involvement with products developed by private companies.

3 Modify environmental and agricultural policies—Some aspects of current environmental and agricultural policies should be modified

in order to prevent unintended side effects that undermine the goal of sustainable agriculture. For example, a land set-aside program apparently contributed to the wheat streak mosaic in Kansas.

4 Integration of biopesticides with other techniques of sustainable agriculture—The group returned repeatedly to the point that if sustainable agriculture farmers are going to utilize biopesticides ,then they must integrate them with other techniques of sustainable agriculture. Furthermore, such integration requires a clear idea of the full meaning of sustainable agriculture.

Does sustainable agriculture signify only environmental equilibrium or regeneration, or is it a "form of life" that suggests a "deeper" and/or more creative relation to the environment, a more equitable relationship among the persons working the land, and a stronger bond between these persons and the broader community of which they are a part? Because the characterization of "sustainable agriculture" will take on different nuances in different situations, it must remain definite enough to allow for an effective contrast with conventional agriculture and yet flexible enough to meet evolving needs and knowledge. In particular, the criteria for sustainable agriculture should be generated at least in part through dialogue among extension agents, farmers, and other concerned members of the community.

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Herbicide Tolerance

The participants of the workshop were asked to address a number of questions concerning herbicide-tolerant plants and sustainable agriculture; for example—what are herbicide-tolerant plants? Who is interested in their development and why? What will be the effects of herbicide-tolerant plants on the amount and the mix of herbicide use? How will this affect the rural population? What are the alternatives? What is the role of public and private research in all of this?

Probably the most important result of the workshop is not a recommendation, but rather the exchange of a wide variety of opinions and ideas among the many participants with a wide spectrum of perspectives and backgrounds represented. Early in the discussions, some participants were surprised that issues they thought to be trivial were seriously contested by others. The discussions were intense at times, and there was an "absorption" of differing opinions as the workshop progressed. This mutual enlightenment was reflected clearly in the evolution of the participants' statements and comments throughout the meeting, and the resulting learning process was valuable.

Though "progress" was made and consensus was reached on some points, the time frame was too short and the original starting points too far apart to come up with strong policy recommendations. This is reflected in the general nature of the recommendations which follow.

I ISSUES

The following contaisn a summary of the discussion on different issues.

1 Herbicide-tolerant plants and sustainable agriculture: a state of the art—The massive "opinion gap" between the participants' viewpoints is reflected in the groups' inability to reach a consensus on a working definition of "sustainable agriculture". It was agreed that although consensus could not be reached on a single definition, the discussion should proceed, but with the understanding that there were a variety of definitions for the term "sustainable agriculture" which reflected low- to high- inputs. If sustainable agriculture was defined in a narrow sense, i.e., without synthetic chemical inputs, herbicide-tolerant plants would not have a role. Furthermore, there was a common concern that safe, high quality foods and feeds be produced without damaging the natural resources for present and future generations.

It was recognized that in the past, selective herbicide weed control and herbicide-tolerant plants have been a natural combination: herbicide-tolerant plants were at the origin of many current chemical weed control practices. Biotechnology provides the possibility of broadening the range of herbicide-tolerant plants beyond those which could be developed through traditional plant breeding methods. A number of herbicide chemicals have been targeted. Certain non-selective herbicides, such as glyphosate, and some of the newer selective herbicides such as the imidazolinones and sulfonylureas are the focus of considerable research in the development of herbicide-tolerant plants.

Both private firms and public institutions have, on their own or in cooperation, heavily invested in research and/or development of herbicide-tolerant crops, even though the motivation for the research may be different

Z The impact of herbicide-tolerant plants—There was no clear answer to the question of whether herbicide-tolerant plants would tend to increase or decrease herbicide use. Some feared that it would increase chemical use and thereby add to the environmental burden, while others insisted that herbicide-tolerant plants could reduce the amount of herbicide use.

Also, skepticism was expressed during the discussion that herbicide-tolerant plants would allow manufacturers to dispense with the older, less selective herbicides. The point was made that weeds tolerant to new low-dose herbicides have appeared at "an astonishing" rate and unless multi-resistant crops or multicrop-resistance was developed, the adaptation of weeds to new herbicides would not allow the effective and quick replacement of the "older" pesticides by chemical pesticides.

The discussion about the impact of herbicide-tolerant plants on the rural population focused on the "efficiency effect" of herbicide-tolerant plants. An increase in production efficiency would increase output, thereby lowering prices and reducing the demand for labor in the agricultural sector. A number of people expressed their concern about this effect, and especially about the expected further reduction of the small farms. Others argued that the only way to ensure the profitability of U.S. farms in the long run is to introduce efficiency-improving technologies such as herbicide-tolerant plants in order to improve or sustain the competitiveness of U.S. agriculture in the world markets.

II ALTERNATIVES

A wide range of potential alternatives were proposed and discussed. These included new biological and new chemical approaches as well as alternative farming systems, such as different tillage and crop rotation practices.

There was general agreement that we needed more information on how these alternative technologies compare to one another or to the currently used technology in terms of efficiency and environmental effects. This information was considered essential to provide a common foundation of knowledge needed to come up with policy recommendations.

Some argued that the attitude of the consumer is an increasingly important issue in the comparison of alternative weed control technologies. In the opinion of these participants, some alternative agricultural systems which are less hazardous for the environment may be less efficient and would—if implemented—result in increased production costs and ultimately result in higher food prices. The extent to which the consumer is willing to pay higher prices for such products clearly influences this notion of "efficiency".

III RESEARCH

As stated in the previous section, there was a consensus that we need more information about the alternative practices. In addition, it was argued that insufficient resources were being appropriated for the study of alternative agricultural systems of weed control. It was proposed that more public sector funds be used to study weed control approaches, such as:

—crop rotation,
— use of weed growth suppression techniques such as allelopathy and cover crops,
—cultivation techniques such as ridge tillage,
— fungal pathogens of weeds,
— development of crop plants with improved competitive properties,
— selective insect pests of weeds,
— determination of weed population thresholds without adverse effects on yields,
— integrated weed-management programs
— intercropping and timing of planting approaches.

There was a fair consensus that it would be good to alternate approaches, but no concensus on how effective these approaches might be. However, there was no agreement about the kind and amount of support this project should receive, or how such a project might impact on other research programs. One participant felt strongly that it was important that not all public research funds go into "the dazzling science of molecular biology."

IV POLICY RECOMMENDATIONS

At the conclusion of the workshop, the following recommendations were made:

•/ Funding should be provided to the public sector to conduct research on the environmental, economic and social impacts of current and alternative systems of weed control. Part of this research should focus on herbicide-tolerant plant/herbicide combinations.

Z Major public and private research should be undertaken on the environmental, economic and social impacts of agricultural systems.

3 A study should be conducted to determine how farm policy affects the adoption of different weed control techniques.

4 If some of these alternative forms of weed control prove to be environmentally, socially and economically superior to conventional methods, public funds should be provided to foster innovation at the producer level for these alternative forms.

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Disease Control in Animals

The biotechnological issues confronting society are those of food availability, cost, quality, and human as well as animal health. The health of farm animals is intimately related to a complex web of causation involving production systems, agents and environments. Diseases appear to be an innate phenomenon related to the interdependent influence of a myriad of factors involving agents, environments, and hosts. The manipulation of these factors affects animal health and disease not only on a local or regional scale, but globally, particularly as the United States imports and exports animals and animal products internationally. It is critical that researchers and the public become sensitized to the influences of current practices of farm animal agriculture as they affect the health of animals and humans as well as the ecosystem. Such an awareness compels us to address those issues that relate to sustainable agriculture, including an emphasis on concerns for long-term food and water resource capacities.

Current biotechnological developments present significant factors in human intervention that can be employed to enhance animal health, improve on disease control techniques and increase the quality and availability of food, fiber, and other products generated from animals. Economic, social, political and other human sectors that play a role in animal health and welfare are affected by evolutionary and revolutionary technological changes.

I RESEARCH AND DEVELOPMENT

The participants in this workshop agreed that adequate consideration and research support must be provided by significant public as well as private sector generated funds. These monies should be allocated to appropriate institutions in order to generate and disseminate knowledge about the benefits as well as the costs of the products of biotechnology. Research and development efforts in biotechnology will affect animal health and welfare and food production on a global scale. As we become cognizant of the concept of an integrated world ecosystem, we accept that these global changes will affect the health and welfare of human beings as well as animals.

It is recommended that the evaluation of disease control products that emerge through research and development of the biotechnological enterprise incorporate a sustainable agriculture orientation with a specific emphasis on resource preservation, maintenance of environmental quality, and awareness of consumer/society/animal welfare, farm and agribusiness structure issues.

II ISSUES

The following are issues for research consideration set forth by participants of this workshop. It is duly noted that there was disagreement on the merits and relationships of some of the issues, and these are noted with an asterisk [*]. Nonetheless, the participants agreed that all issues should be set forth for consideration.

1 Whether an animal disease surveillance mechanism needs to be set in place to identify problems facing the agricultural sector, irrespective of the type of management system that is being used.

— Members of the workshop suggested that it would be prudent to trace disease prevalence in various types of farming systems, the causes of diseases, and the economic costs/effects of these diseases and their effects on product quality.

2 Whether there are certain types of animal diseases for which control and/or eradication is not cost effective for the individual producer, but which may be of much higher value when social and economic concerns are considered.

3 Whether small farming operations yield fewer problems with diseases in animals than large operations, or whether the disease problems are related to the quality of management in each system.

4 Whether animal disease problems relate primarily to the quality of management regardless of size of the operation and/or type of production system. Assuming quality of management to be constant, whether there are different disease patterns that correlate to size and environment of the operation.

5 Whether the effects of alternative technological innovations can be designed to improve on the overall social and economic structure of agriculture.

6 Whether biotechnology will result in products or germplasm that will encourage management practices that are not conducive to overall animal welfare.

*7 Whether the implementation of the products of biotechnology will be size neutral, thus maximizing the opportunities for people to own and operate small to medium-sized farms.

'8 Whether large-scale environmentally controlled farming operations have "pushed" animals too far in their abilities to produce food and fiber products to the detriment of the welfare of those animals.

*9 Whether research is needed into issues related to the physiological and behavioral needs, fear, stress, and frustration of animals raised in environmentally controlled operations or in the alternative, whether there is an overemphasis on anthropomorphism [human beings attributing cognition to animals where none exists].

10 Whether the increase in disease control capabilities caused by biotechnology products might pose a further threat to the humane treatment of those animals due to their ability to sustain production under adverse conditions.

11 To conduct research that leads to an examination of current extension agriculture procedures used to inform the agricultural sector of needed biotechnological information for use by a wide range of educational sources; educators, producers, and consumers.

I11 POLICY RECOMMENDATIONS

1 Biotechnology should be utilized to help assure the safety of animal products for human use and consumption.

Z Biotechnology should be utilized to optimize environmental and management practices and systems for production of healthy livestock and for development of strategies and products that assure well being and freedom from disease.

3 Disease control should be predicated on the establishment of trusting and unbiased relationships between livestock producers and health service providers in the agricultural sector. The fruits of biotechnology need to reach all types and sizes of producer operations in a cooperative effort that uses public service institutions to supplement efforts made by industry.

4 Those involved in research, development, and implementation of the products of biotechnology must study and encourage efficient and effective dissemination of animal health biotechnology information for use by a wide range of educational sources. An increased level of support should be developed in order to disseminate information delivery systems to foster animal health products for a sustainable agriculture.

5 An increased level of study in the areas of technology must be encouraged in order to identify behaviors and social structures of the animal community. This knowledge base can then be utilized for the purposes of developing management systems and skills for improving livestock production, profitability, and livestock welfare.

6 Products of biotechnology should complement disease control measures obtained by good husbandry practices that should include:

—freedom from hunger and malnutrition
—freedom from thermal/physical distress
—freedom from injury and disease
— freedom to express most normal behavior
— freedom from fear

7 Animal disease control programs supported by public funds should be conducted with a particular consideration for:

—the general welfare of animals
—the preservation of the environment
— the provision of wholesome food products
— social and demographic impacts
—economic impacts on food production
— the preservation of germplasm diversity

8 Disease results in the suffering of animals and major economic loss for producers and consumers. Biotechnology offers a methodology to alleviate much of this suffering and loss. Research development and implementation of the products should be promoted and encouraged, concomitant with a sensitivity to animal welfare, the environment, the size of livestock production operations, and to the public health.

9 Biotechnology research and extension programs should be aimed at maximizing the numbers of opportunities for people to own and operate farms.

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Animal Growth Promotants

Workshop participants focused their discussion on the polypeptide animal growth promotants (somatotropins) which can be produced using biotechnological production processes. Other growth promotants were briefly mentioned (e.g., the steroid-based hormones used in cattle feeding for many years, and the chemical repartitioning agents [beta-adrenergic agonists] likely to become available as feed additives in the near future); however, the public concerns which have been voiced about bovine somatotropin (BST) in the dairy industry led to most discussion centering on BST and the closely related porcine somatotropin (PST), which are likely to become commercially available in the dairy and pork industries in the near future.

I ISSUES

After developing a list of over twenty potential issues associated with animal growth promotants, the group identified several that were the most important for more thorough discussion and debate. These included:

— consumer acceptability and related issues
— social impacts when technology is adopted (who wins? who loses?)
— lack of access to the biotechnology development process
— structure of agriculture and regional development implications
— technology transfer to farmers
— economic implications—price levels, etc.

Other issues of concern covered a broad spectrum, including:
— animal safety and welfare, public health, and environmental implications
— unnecessary delays in approval process, perhaps linked to inadequate governmental organizational structure
— patenting and product labeling issues
— nutrition, management intensity, and genetic base requirements to achieve maximum benefits
— rural community and sustainable agriculture implications
— international competition implications

The first four issues received the most attention by workshop participants and a synopsis of the discussion and conclusions are present below.

1 Consumer acceptability—The consumer acceptability of products emerging from agricultural biotechnology was viewed as critical to the commercial viability of the somatotropins in animal agriculture. Products that cannot be sold because of the technology used will stifle the adoption of that technology. Several points were made that relate to the potential consumer acceptability of these products.

There was fairly broad agreement that consumers should be informed about the product characteristics and the processes used in producing their food. It was argued that consumers should be informed as to the presence or absence of "hormones" in their meat and milk products. Labeling the nutritive characteristics of the product and the technology used (which would be almost unique if applied to biotechnology products) could have either positive or negative purchase implications, depending upon consumer perceptions and connotations. Different types of "hormones" (polypeptides versus estrogenic) have quite different risks and health implications, but poorly informed consumers might tend to lump all products of those technologies in the same category.

Labeling related to production practices could unduly alarm some consumers and cause them to boycott those products. Yet, it was felt product labeling should not be protective of any special interest group, e.g., dairy farmers who could get hurt if milk developed a negative consumer perception. It was pointed out that scientific tests are inadequate to distinguish between products produced with and without growth hormones, so administering any label requirements could be difficult. Even if government-mandated labeling was not required, it was suggested that product merchandisers may embark on "negative advertising" by promoting the absence of added growth promotants in their products to capitalize on consumer concerns or fears (especially if conclusive evidence on changed product composition is not available to eliminate consumer doubts and perceived safety risks associated with using the product).

Consumer labeling of the nutritive characteristics of pork produced using PST could be advantageous, since fat is sharply reduced, and lean tissue is increased with little change in palatability (though that could be an issue). With BST, milk fat content would change slightly, but little significant change in other milk components would likely occur. These changes might not be viewed as sufficiently positive to offset possible consumer concerns about "hormones" in milk, even when there may be no detectable differences in milk from treated or untreated cows. An additional question was raised about increased animal stress in the production process, and its possible effect on the quality of the consumer end products.

The group concluded that consumer education and information programs are essential, so that consumer choices would be based upon accurate perceptions about the products and the process of production. Some participants felt that televised debates on the pros and cons of these new technologies should be considered as part of the information process. It was noted that Federal and Drug Administration (FDA) restrictions on companies undergoing new animal drug application review and clearance limit what these companies can say regarding safety and other consumer concerns prior to FDA approval. Consequently, these limitations may prohibit companies from providing much scientific data to alleviate public concerns or fears that may arise about new products prior to FDA approval.

2 Social impacts—who wins? who loses?—The social impacts of new animal growth promotants were considered a major concern. Especially important was who will gain or lose as a consequence of these new technologies. The group first identified the "players" in the process who might be affected—consumers, food merchandisers, food processors, farmers, farm input suppliers, government, taxpayers, rural residents, and of course, the biotechnology (often pharmaceutical and animal health) companies developing these products.

In the process of discussing possible impacts, it became clear that the impact of BST in the dairy industry, if PST and beta adrenergic agonists in the pork industry could be significantly different due to, among other factors:

—significant consumer product improvements likely in pork, but not in milk, and

—government price support policies and surpluses in the dairy industry.

At the same time, some issues or concerns are very similar, such as farm size structure implications, and consumer acceptability.

The bulk of the discussion focused on farm-level implications of these new production technologies. It was clear from other speakers that these growth promotants would enhance production efficiency. The workshop members concluded that early adopters of these technologies could benefit most, economically, but they would also be assuming additional risks. Some participants felt that management sophistication would be the critical factor determining who would be an early adopter and benefit most from these new technologies. While management sophistication can be found in all farm size classes to some extent, larger operations would generally have the management skills to rapidly benefit from these new technologies. Also, confinement pork operations would be more adaptable to injection or implantation required in the first generation porcine somatotropin products. Thus, small family farmers in both the dairy and pork industries were considered more likely to be at a competitive disadvantage due to the slow adoption of BST and PST, or failure to use it most effectively.

If the efficiency of input utilization improves in these industries more than consumer markets expand, pinpoint suppliers could be affected in several ways. Input suppliers whose business activity is related directly to animal numbers could have less demand for their products and services—e.g., veterinarians, animal health product suppliers—if animal populations declined. Feed use could decline in the pork industry, especially feed grains. If very large operations benefit the most, and the tend to buy fewer inputs from local suppliers, agribusiness in rural communities could be adversely impacted. Biotechnology/animal health product companies which successfully develop the new growth promotants will share in the economic benefits.

Meat packers and dairy processors may benefit from increased supplies or improved quality products. An improved international competitive position for U.S. dairy and pork industries could be result (if the products are cleared and adopted in the U.S. earlier than in competing countries, and if trade barriers are not raised on products from these technologies). However, other competing industries or countries could lose.

Consumers should benefit from lower prices for dairy products and pork and improved fat/lean composition in pork products. However, the beneficial consumer price impacts in dairy would be dependent upon political actions to reduce price supports as production costs decline, and some persons would question whether that is likely.

Government budget costs could be affected in several ways. If it is socially desirable to provide more information to assist technology transfer for small and medium-sized farmers, extension and education costs could increase. If the number of farmers and farm workers leaving these industries increases, costs associated with adjustment could rise. Dairy price support program costs could decline, while feed grain program costs could increase.

3 Lack of access to development process—Some farmers and other workshop participants objected to the public's lack of participation in determining what projects and products were emphasized in the biotechnology research and development process. The group recognized that private companies involved in biotechnological research and development are driven more by economic considerations than social goals (e.g., small versus large farm considerations), and they may need to maintain secrecy about their research program and product development alternatives until patent applications have been filed. However, the group felt that publicly supported research (and, to some extent, private companies) ought to be more responsible to societal goals rather than large farmers and agribusiness. They encouraged a broader social responsiveness, suggesting more public input in determining research priorities in the areas of biotechnology and sustainable agriculture. The group felt that some good initiatives would include:

—university research administrators discussing research priorities with public interest groups
—more universities developing active bioethics programs similar to one at Iowa State University
—more public funding for bioethics and sustainable agriculture programs

They also felt that farmers need to be more active in:

—discussing their research needs with legislators and university administrators

—supporting expanded state and federal funding for the programs mentioned above

4 Structural and regional implications—The group acknowledged with concern the likely accentuation of growth rates of large scale, sophisticated livestock production operations, in the areas where those large scale operations are currently located (often outside the midwest). How can we direct biotechnological research to achieve social goals like sustaining small, independent agricultural operations? Or are we demanding a system that consumers are unwilling to pay for? Should our policy be directed toward keeping small farmers operating, or having a social safety net to assist them in adjusting to other work or locations? Does biotechnology and sustainable agriculture research offer solutions, or are they likely to be contributors to the perceived problems?

II POLICY RECOMMENDATIONS

The workshop felt that an economically-sound family farm system and a sustainable rural economy were desirable social goals. They recognized that expanded research on biotechnology or sustainable agriculture was not sufficient to achieve these broad social goals. However, such research could assist in achieving these goals if appropriate research priorities and funding were forthcoming. Several policy recommendations emerged from the workshop.

1 Advisory groups reflecting a broad spectrum of the public ought to be required in determining appropriate directions for university and government publicly supported biotechnology research programs.

The feeling of inadequate public access was strong. Broader participation in discussion of general research directions could improve the social responsiveness of these programs, and also increase public support of the research and end-products of the research.

2 Public education programs regarding products from biotechnology need to be undertaken by public agencies (universities, Extension, U.S. Department of Agriculture [USDA], etc.) and the private companies developing these products.

The workshop felt that consumers have a right to know about the product characteristics and processes used in producing their food. Also, the group felt that university and government educators and extension specialists should bean essential part of biotechnology research programs, to chip away at a major issue likely to plague products from biotechnology—the public's concerns and lack of good information about these products.

3 A special competitive grants program (USD A) should be federally funded to support innovative information delivery systems focused on small, medium-sized, minority and beginning farmers.

One important policy goal should be to alleviate inadequate farmer information on biotechnology and sustainable agriculture, and facilitate improved technology transfer to small and medium-sized farmers and others likely to be competitively disadvantaged due to inadequate information to make adoption decisions on these new technologies.

4 All biotechnology research groups (public and private) should be required to do societal impact assessments and contribute strategies for ameliorating adverse impacts likely to be associated with their forthcoming technological innovations.

To aid in public policy development and general consumer and farmer information programs, the group felt that there should be societal impact analysis of biotechnology research programs and forthcoming commercial products should be made publicly available and discussed prior to product introduction.

5 Labeling of biotechnological consumer products remained an important, but unresolved issue. Should meat or milk be labeled as products of growth hormones, or somatotropins, or growth promotants?

There was fairly general agreement that food manufacturers should label nutrition content on products from biotechnology in cases where there are significant changes in product characteristics. However, there was significant disagreement whether there ought to be food product labels indicating the biotechnology process used in production. Some felt that consumers ought to know whether a product was produced via genetic engineering. Such labels on food products typically are not required for other agricultural technologies. Others felt that such labels and consumer fears could kill the chances for technological progress from biotechnology in agriculture, perhaps without good reason. So while the group recommended a strong public biotechnology education program, they could not agree to recommend requiring biotechnological process labeling on food products as a part of a consumer information program.

3 *Keynote Addresses*

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Biotechnology, Sustainable Agriculture, and the Family Farm

$8 I would like to begin by emphasizing the importance of public debate about biotechnology and the fundamental purposes of public involvement in agricultural research and biotechnology. Public involvement has been important all along, but biotechnology increases the power of agricultural research to shape life and society and thereby makes consideration of these issues more important.

Agricultural research is really a form of social planning. The decisions as to what research is done and what kind of technology and farming systems are perfected, not only shape technology, but they shape agriculture, life in rural communities, social and economic structure, and the environment. Care needs to be taken to make sure that the goals of society are reflected in agricultural research priori-ties, especially publicly funded agricultural research. Who will control technology and technological research, and will the process be a democratic one?

The aim should be to develop a set of research goals, as well as a priority setting process by which the public research agenda reflects and addresses the needs of society. After all, in a democracy, it is important that if, in fact, technological research is a form of social planning, it moves society in the directions that the people want to go. The broad public and the citizenry should have a role to play in setting these directions.

The development of a more sustainable system should be the goal of agricultural research. A sustainable agriculture includes sustaining and protecting the quality of the environment, protecting the ability to produce food for future generations, and sustaining the family farm and agricultural communities. It is not enough to have an agriculture that is environmentally sound if it destroys family farms and rural communities. Part of this agricultural vision needs to be sustaining opportunity in rural communities. I propose five subgoals to guide agricultural research toward developing a more sustainable agriculture.

THE IMPORTANCE OF THE FAMILY FARM

We need to strive to develop farming systems that create as many opportunities as possible for people to own and operate their own farms. One of the things that characterizes the nation's heartland is a relatively egalitarian social structure. Unlike the deep south and many of the major cities in the nation, this part of the country has not historically been characterized by sharp social divisions. Heartland communities have not been divided into a class of people who own farms, another class of people who manage farms, and yet another class of people who provide the labor. Instead, the owner of the farm is also the manager and the worker and that is the preference of the people in this region. Poll after poll of people in Iowa and the rest of the heartland show a broad preference for trying to maintain as many smaller, family farms as possible. However, this is not just a matter of emotion or personal preference; a large body of research shows that the family farm creates healthier communities than industrial style agriculture.

A study prepared by Dean McCannel of the University of California provides an overview of the various studies that look at the relationship between the structure of agriculture and the well-being of rural communities. McCannel's conclusions are as follows:

> "As farm size and absentee ownership increases, social conditions in the local community deteriorate. We have found depressed median family incomes, high levels of poverty, low education levels, social and economic inequality between ethnic groups, etc., associated with land and capital concentration in agriculture. Communities that are surrounded by farms that are larger than can be operated by a family unit have a bi-modal income distribution, with a few wealthy elites, a majority of poor

laborers, and virtually no middle class. The absence of a middle class at the community level has a serious negative effect on both the quality and quantity of social and commercial services, public education, local government, etc."

The case is clear that by maintaining broad opportunity in the family farm system, farmers as well as communities benefit.

HEALTH CONCERNS

Agricultural research should develop farming systems that enhance human health. This issue has gotten a lot of attention recently, given the Natural Resources Defense Council's report on chemical health effects on children. However, a bigger health crisis concerning farm chemicals and agriculture may exist right here in the heartland.

Some epidemiological studies clearly show the health risks involved in farming today. Study after study show elevated rates of leukemia in particular, and cancers in general among farmers and the people living in farm communities. One of the more interesting studies in Kansas, for example, found that farmers who use herbicides for more than twenty days a year have six times the rate of non-Hodgkin's iymphma, a form of leukemia. Agricultural methods that do not endanger the health of the people who farm must be established.

ENVIRONMENTAL CONCERNS

Farming systems that enhance the quality of the natural environment, rather than degrade it, need to be developed. Many problems exist in agriculture today and changes need to be made. There are four areas especially in need of attention.

The first area concerns soil erosion. As of 1985, about 25 percent of the land farmed in this country was eroding faster than new soil could form. In other words, 25 percent of the land is being farmed in a way that will ultimately result in a loss of soil and crop productivity. This simply has to change. Society cannot continue to destroy the soil and the ability of future generations to feed themselves. Some progress has been made since the 1985 farm bill was passed, but there is still a lot of work to be done.

Secondly, there is the problem of groundwater contamination. Studies in Iowa indicate that 25 percent of the people in the state drink water from wells that have been contaminated by farm chemicals. There is also a recent study of some of the irrigated areas of Nebraska, where 30 percent of the wells tested had atrazine in them.

Thirdly, the nation's dependence on nonrenewable sources of energy, particularly petroleum, need to be reduced. Recent studies indicate that domestic supplies of petroleum are likely to be exhausted early in the next century, and world supplies of petroleum are likely to be exhausted by the middle of the next century. There is no choice but to learn to farm in ways that are less dependent on petroleum.

Lastly, farmers must be concerned about their use of biological resources. In order to maintain a resilient food system that is not vulnerable to pests and disease, genetic diversity and a large, stable, and balanced population of various organisms must be protected.

Agricultural research programs should strive to advance these goals as they simultaneously continue to strive for economically viable farming systems. Food must be produced efficiently and a productive system of agriculture maintained that allows the people living on the land to make a profit and stay in business.

Can agricultural research in general, and biotechnology in particular, help achieve these goals? 11 can, but only if today's overall direction of agricultural research and biotechnology is changed. In addition to changing the direction that research will take, the decision making process concerning what research is undertaken must also be changed. The current research path might best be described as supporting an industrial system of agriculture. Biotechnology itself is promoting and supporting more of an industrial system than a sustainable system of agriculture. These two systems embody very different approaches to the use of technology and the relationship between people and technology.

INDUSTRIAL SYSTEMS

Industrial systems embody some of the well-established trends that are found in agriculture today. The trend is toward fewer and larger farms, with less opportunity for people in agriculture. This trend is moving agriculture away from the system where the person who works on the farm also owns and controls it, to a more industrial system, where one class of people own and make the decisions, and another class of people do the work.

Industrial systems embody some very clear agronomic trends, such as monocropping, continuous corn production systems, or systems that simply are not very diverse, like corn and soybean rotations.

Industrial agriculture concentrates livestock in confinement systems on a few very large farms. Unlike sustainable systems, industrial systems use technology to reduce the role of people in agriculture. They reduce both the amount of labor involved in agriculture, and the sophistication of labor involved in a way that allows one person to farm more land and more of the farm labor to be provided by unskilled and poorly paid employees. This facilitates the industrial structure.

Industrial systems also use technology to override natural systems. Instead of trying to find ways to work in concert with nature, systems are used that conflict with nature, such as growing continuous corn. To avoid the inevitable problems that intensify when the same crop is grown on the same land every year, technology is used to override the natural systems. For example, we use chemicals to solve fertility problems, disease, or to control corn rootworms associated with monocultures. In many instances, biotechnology is being used in the same way chemicals have been used—to reduce the labor and the sophistication of labor involved in agriculture and to override natural systems.

This presents many of the same problems that chemicals have caused over the years. If corn with Bacillus thuringiensis, (Bt) is used in the field to control corn borers and rootworms, it will not be long until most of these pests become resistant to Bt, and another biological magic bullet will have to be found. As with chemicals, greater and greater risks with safety will have to be taken, simply to meet the evolution of the pest.

SUSTAINABLE SYSTEMS

Sustainable systems look at the relationship between people and agriculture differently than industrial systems. Sustainable systems enhance the role of people in agriculture, rather than reducing it. For example, in an industrial system a dollar might be spent on chemicals in order to replace two dollars worth of labor. In a sustainable system, the farmer would spend one dollar worth of additional time on hands- on management and the managing of natural systems to replace two dollars worth of chemicals. It is a very different approach, but it tries to enhance the role of people in agriculture and make it profitable for more people to be involved.

Sustainable systems might use biotechnology to gain a better understanding of natural systems so that farms can work more in concert with nature. Or, biotechnology might promote sustainable agriculture by finding new uses for the crops that have been added to rotations in sustainable systems. Better markets must be found for crops like alfalfa and oats to make it more profitable to grow them in rotation with corn.

CURRENT DIRECTIONS IN BIOTECHNOLOGY

Unfortunately, much of the current emphasis on biotechnology research supports industrial systems. For example, no area of biotechnology research has been the focus of more investment than the development of herbicide-tolerant crop varieties. While there is no clear evidence of the exact impact of herbicide-tolerant crop varieties on the volume of herbicide use in agriculture, it is very clear that the development of herbicide-tolerant crop varieties will continue the trend of making farmers more dependent on chemicals for weed control. What it would do to the exact volume may be an issue for debate, but it clearly moves in the direction of continuing complete dependence on farm chemicals for weed control. It also has some pretty clear structural impacts. For example, if a corn variety is tolerant to Roundup®, which kills almost any plant on contact, it would be more feasible to rely totally on chemicals for weed control, reduce the role of people, and totally eliminate mechanical weed control. This encourages a system that makes it possible for one person to farm more acres and for fewer people to farm the nation's land.

There should be alternative biotechnological approaches to weed control. Crop varieties that are better suited to light mechanical weed control should be developed. The use of a rotary hoe and some light row cultivation does not contribute to soil erosion and does not use large amounts of fuel. Some work is being done at the University of Wisconsin, to develop more cold-tolerant cucumbers that will germinate and emerge faster in the spring. If a variety of corn, sorghum, or soybean could be developed that would grow to a height of six inches during the cool spring weather in half the time that current varieties take, weeds could be more easily controlled mechanically.

The control of weeds need not be dependent on risky chemical products. This is the way for people to use their skilled labor to make a profit at the same time that we broaden the role of people in agriculture and the potential for family farming.

With respect to pathogen and insect control, a whole new series of biological products are being developed, including genetically altered microorganisms and new plants, to take the place of farm chemicals and allow farmers to grow the same crop on the same piece of ground, year after year. In the future, there will probably be major efforts in biotechnology to control corn diseases such as gray leaf spot and head smut, which are really only a problem if continuous corn is grown.

This research supports industrial systems. To support sustainable agriculture, we should instead focus on the study of agroecology to gain a better understanding of how all the various organisms in agricultural ecosystems interact, how they effect each other, and how they are affected by farming practices. From this understanding, new farming systems might be developed that would create the proper balance of life where more of the beneficial organisms and fewer of the harmful organisms would exist. Biotechnology can help farmers reach this balance.

Biotechnology enables scientists to put markers in microorganisms in the soil so they can study how a change in farming practices might effect the population of different types of organisms. This is a positive way of using biotechnology and depending on the marker used, it would not have to carry much environmental risk at all.

In addition, biotechnological research should focus on developing crop varieties resistant to those diseases and pests that persist even in sustainable systems where the crops are rotated. Disease problems, such as leaf rust in corn and leaf blight, are not really a problem unique to continuous corn. The types of diseases that cannot be controlled simply by using rotation, should be a higher priority in biotechnological research. Unless the growth of continuous corn is to be encouraged, there is no reason to focus research efforts on the problems related to this method. It is a questionable practice to focus on the problems of continuous corn, because there are a whole range of adverse environmental problems associated with it and it lends itself to industrial systems rather than family farm systems.

Likewise, if we are to have a sustainable agriculture, research cannot merely focus on the disease problems of corn, wheat, and cotton. Instead a diverse set of crops must be studied. The U.S. Department of Agriculture (USDA) is proposing a plant genome mapping system that will begin to map the genetic makeup of major crops. Early reports indicate that this system will focus only on the four major crops. Such a limited focus will do little to improve the profitability of sustainable systems which include rotation crops such as oats and alfalfa. If all research efforts simply address the disease problems of corn and soybeans, these crops will be the most profitable to grow.

Another area of concern is the development of new uses for farm commodities. There is no area in research today that is more politically attractive among the farm state members of Congress. A bill was attached to the Senate Trade Bill two years ago, which never became law, but would have made a $70 million appropriation to find new uses for farm commodities using biotechnological research. That bill was mainly focused on wheat, cotton, and soybeans. Instead of developing markets only for these crops, a much higher priority should be placed on finding new uses for a more diverse set of crops, including forage crops. Ways to make crops such as native grasses more profitable should be looked at. Native grasses could be planted on highly erodible land without excessive erosion. We also need greater emphasis on developing new uses for rotation crops, such as oats and alfalfa.

Along these lines, some interesting work has been done in developing grass varieties that contain less lignin. The fascinating thing about native grass is that it can produce as much energy per acre as corn; it is just that the energy in such grass cannot be digested because it is bound up by lignin. If native grasses could be used to feed cattle instead of corn, it would be good for family farming, because it would tie cattle production to the land base. It would also be better for the environment, if highly erodible land were planted in grass instead of in corn.

LIVESTOCK RESEARCH

With respect to livestock, bovine growth hormone research does not promote sustainable agriculture. There is wide agreement that bovine growth hormone is going to lead directly to a reduction in the number of family farms, and that should be a concern. The claim that bovine growth hormone promotes feed efficiency should be questioned. It may require redefining the way feed efficiency is understood. It maybe true that more milk can be produced from a given amount of corn and soybeans by using bovine growth hormone, but it also makes dairy herds more dependent on corn and soybeans instead of on forages. If forages are to be grown to protect the soil and make farm systems sustainable, a better forage-based system must be developed that produces more milk effectively. In a sense there is more feed inefficiency with the use of bovine growth hormone, because it creates feed requirements for dairy cattle that the natural resource base cannot provide sustainably.

Instead, major initiatives in livestock research should be mounted in two directions: low investment livestock production systems and a livestock system that fits the resource base. Unless some low investment systems are implemented, there will not be much opportunity for young people to get started in farming. There must be a way for these young farmers to get a foothold in agriculture without a lot of money and by using their management skills. If such a system was developed, it would be very helpful to the future of family farming.

Instead of focusing on disease problems like pseudorabies, which is principally a problem resulting from the close confinement of hogs, the disease problems in low-investment systems should be addressed. Issues such as animal parasites, developing animals that have better hair cover to make them more tolerant to temperature extremes, and other means of adapting animals to fit low-investment family farm systems, should be studied.

Biotechnology can make a contribution to sustainable agriculture, but there is danger in thinking that just because it is an exciting new science, there should be a lot of money spent on it. People are convinced that it is the key to competitiveness. Biotechnology can contribute to sustainable agriculture, but it should not be the emphasis.

If a sustainable system is really going to work, more emphasis must be placed on studying agroecology. When studying agricultural systems, more attention needs to be focused on discovery rather than on invention. Biotechnology can make a contribution, but it must not be as overemphasized as it is today. Biotechnology tends to be more ideal for product development, but this is not the most important goal for sustainable agriculture.

RESEARCH MANAGEMENT

It is vital that public control over technology and technological research be regained. In the next farm bill, Congress needs to state very clearly why it is investing so much money on agricultural research, and what it wants from its investment. The government's emphasis should be on family farms, and environmentally sustainable agriculture. Congress also needs to establish procedures to make sure that the purposes set forth in a bill are in fact reflected in the research decision-making process of the land grant university. When competitive grants are made, these factors must be taken into consideration. A portion of the formula funds that go to every land grant university, should be withheld until the land grants show that they have established a research priority-setting process that reflects Congressional goals.

Finally, the public needs to extend its reach into private sector research. After all, if research is social planning, the public has a role to play in every aspect of it. Of course, the public is already involved in private sector research by subsidizing it heavily through research and development tax credits, it is not just a question of how involved the public should be. The public should declare what kind of research it wants. New investment in research facilities receives a 20 percent tax credit.These credits should only be given for research that reflects the direction that society has chosen.

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Policy Alternatives in Sustainable Agriculture

Modern agriculture is a very recent development when considered in terms of evolution and human history. It is best considered as an experiment in progress. Its contrasts with the agriculture that has fed humankind for most of its history are quite dramatic. The land-races of major food crops that were grown for centuries in subsistence farming agroecosystems were genetically very diverse, environmentally stable, and carried polygenic disease and pest resistance, but were very low-yielding by today's standards. Farms were small, labor-intensive and characterized by a mix of species, both plant and animal. It is generally held that the agriculture of primitive humans and even of the early decades of industrialized agriculture in the late nineteenth century were less damaging to the environment than today's agriculture has proven to be. Whether or not this is so, it is indisputable that modern agricultural practices are among the many factors that threaten the long-term stability of the earth's environment. Changes are called for in adjusting agricultural practices to serve the long-term need fora more sustainable agriculture.

Economic and environmental concerns about sustainability and agricultural practices of today come at the same time that scientific advances have occurred in our understanding and control over genetics. The consequences of this new knowledge are already beginning to work their way into agriculture. Practical application comes with the ability to isolate specific genes and transfer them between organisms that are unrelated, providing the recipient organisms with new traits.

Equally powerful are new technologies that bring new power to traditional breeding, from restriction fragment length polymorphism (RFLP) mapping to somatic embryogenesis.

Sustainable agriculture requires a system of farming based on the premise that agriculture, first and foremost, is a biological process. In practice, this means that a sustainable agriculture attempts to mimic the key characteristics of the natural ecosystem while still maximizing the yield of one or more components. To do this, it strives to build complexity into the agroecosystem, to cycle nutrients efficiently, and to maintain the primacy of the sun as the energy source driving the system. The management focus on sustainable agriculture is on long-term optimization of the system as a whole, rather than its short-term exploitation. The farmer and the researcher must select strategies that balance the need for high yields each year with the longer-term biological requirements that contribute to ecological stability. This requires a sophisticated approach that emphasizes stewardship, and also requires an understanding of the internal relationships of the agroecosystem with special emphasis on population dynamics and nutrient monitoring.

Pesticides, when used, are used with caution, and in such a way as to avoid disruption. When they are employed, they must meet the criteria of low toxicity against mammals, limited persistence in the environment, low environmental mobility, and be specific to target organisms. Both management and technological components need to be called upon to make sustainability work.

Any realistic agenda for sustainable agriculture must provide a safe, abundant, and affordable source of food and fiber for a growing population while redressing the adverse effects of past practices. The challenge is great and the outcome desired will not be achieved quickly. All technology, not just biotechnology, is a component of the answer. Consumer demands, land use planning, the skills and abilities of farm managers, the research agenda, and the incentives under which companies and public technology development will work, all need to be addressed in the policy arena.

To achieve a sustainable agriculture that embodies ecological values, the national agricultural and economic policy must encourage or mandate practices consistent with these values. Many of the longer-term benefits of sustainable agriculture, such as reduced damage to soils and to water quality will not be reflected in the short-term economic calculations of farmers, whether they are industrial farmers or small family farmers, unless policies are in place that provide the possibility of short-term economic success as well.

CENETIC MANIPULATION

Genetic manipulation is a proven technology that can be used to address whatever the future agenda is for agriculture. Plant genetic manipulation responded to, rather than dictated the changes in agricultural production imperatives in the past. As in the example of the modern, mechanically harvested tomato crop, the history of the development of processing tomatoes illustrates how modern plant breeding has tended to reduce genetic variability as a crop is genetically modified to fit a particular agricultural management system. It was done very successfully. The range of genetic variability found in primitive tomato cultivars was distilled to yield a relatively narrow breeding germ plasm base and homogeneous varieties required to fit into that production system. Genes already present within the genus of Lycopersicon have been recombined by a cross-pollination and selective breeding with those traits necessary for mechanical harvesting; single genes as well as polygenic traits. Traits that would decrease reliance on the use of chemicals were not among the many improvements that were made in modern tomato cultivars. The history of the development of modern tomato cultivars indicates that genetic manipulation is a powerful tool that can be used to modify plants to fit the requirements of management systems in agriculture.

The first genes of agricultural interest to be tested using the new technology were those conferring tolerance to herbicides. Early attention was focused on the herbicide N-phosphonomethylglycine or glyphosate, a potent inhibitor of the pathway leading to synthesis of aromatic amino acids in bacteria and in plants. Two independent research groups set out to genetically modify resistance to this herbicide in the early 1980s and both have had some degree of success.

A field trial conducted by my colleagues last year examined tomato plants treated with the herbicide at the two to three leaf stage. The transgenic plants treated at a pound per acre with the active ingredient of the herbicide showed that the plants were essentially fully resistant to the herbicide. The expected weed control advantages were seen in these trials.

Contrary to the claims of some critics of biotechnology, some herbicide tolerances may result in lower overall uses of herbicidal chemicals and lower input costs for growers. Glyphosate tolerance in tomatoes grown for processing is one case in point. Herbicides currently play a major role in processing tomato production, because weed control is crucial to achieving satisfactory yields. Competition with weeds early in the season causes yield reduction and delays harvest. At harvest, weeds can hinder mechanical harvesting.

Current practices with processing tomatoes in the California Central Valley, which is about a quarter of a million acres and accounts for 80 percent or so of the nation's processing tomato crop, include at least one pre-plant and pre-emergent application, as well as a lay-by herbicide application next to the plant row after emergence. As many as nine different chemicals have been recommended for spray and soil incorporation, and typically at least three of those are applied on each acre. With the use of a glyphosate-tolerant tomato, a post-emergent application of the herbicide would economically control weeds without harming the tomato crop. The herbicide has a very wide phytotoxicity spectrum, but low mammalian toxicity, a relatively short environmental half-life, and is systemic in the plant. This could result in significant decreases in overall herbicide usage and because glyphosate is much less toxic than many other recommended chemicals, in use with tomatoes, it would also provide advantages in the environment. Fewer applications mean lower overhead costs in time spent and chemicals applied, landless traffic through the field would avoid soil compaction.

A colleague, Dave Stalker, has examined resistance to the contact herbicide Bromoxynil, which is widely used in small grains. Small grains are naturally tolerant to the herbicide because a non-phytotoxic product is made in the plant before the compound gets to its site of action in the chloroplasts. This herbicide has an extremely short half-life in the soil. There is some evidence, in certain formulations, of problems with transdermal exposure to applicators, but its environmental profile is very favorable. This resistant trait has recently been put in cotton, where it will increase weed control efficacy and markedly decrease the cost associated with using soil-incorporated pre-plant herbicides.

One of the most straightforward applications of genetic engineering to decrease crop plants' reliance on chemical protectants, are new uses of the toxin genes from Bacillus thuringiensis, or Bt. Bacillus thuringiensis is a bacterium that produces a group of related proteins that are lethal to many moth and butterfly larvae. Other groups of insects and other life forms are unaffected by the Bt proteins. The protein is encoded on plasmids within the bacterium. It is targeted against lepidopteran larvae, although there is some evidence of Bt strains that also have activity against certain coleopteran pests during their larval stages as well. In agriculture, insects are voracious and a problem during their larval stages. Bacillus thuringiensis toxin can currently be purchased for home garden use as an emulsion that is sprayed on plants. It has been in use in one way or another for about twenty years.

The Bt gene has been isolated and characterized in a number of labs over the last several years, and there are at least three ways in which genetic modification can be used to improve the use of Bt. The first is to attempt to do better than mother nature in designing improved, more efficacious toxins, perhaps having different modes of action or different spectra of activity against insect pests. The second is to put the toxin into different bacteria with the ability to colonize different parts of the plant that might, for example, not be accessible by the spraying of Bt itself. A third approach, which is related in its objective to the second, is to engineer the crop plant itself to produce Bt toxin levels that would make the plants insect tolerant.

Several strategies have been proposed to address the possibility of the development of pest-resistant populations after exposure to plants expressing Bt toxin. Several factors may deter development of pest resistance and their management would ensure success. There are a number of Bt toxin genes, and the range of susceptible insect species is somewhat different for each.

The concurrent use of more than one engineered Bt toxin gene, each with a different toxicity profile, would be one approach to reduce the possibility of pest-resistance development. Using genetic engineering techniques, the expression of this and other toxin genes could limit the overall levels so as to control populations rather than kill insects outright, or to limit Bt to particular plant tissues during that time of development, when the protection of the plant is the most important.

It has been proposed that mixtures of transgenic and non-transgenic plants can be developed as multi-lines, thereby reducing the overall impact on the pest population but still controlling pest populations below economic threshold levels.

The concurrent use of different strategies with different modes of action, perhaps combined with integrated pest management (IPM) using of some of the more environmentally acceptable chemicals, could yield management systems to control insect pests, while reducing the reliance on the persistent and broad spectrum insecticides that are commonly used, but that also affect beneficial insects.

DISEASE RESISTANCE

Biotechnology can also contribute to sustainable agriculture in the area of disease resistance. An impressive example comes from the work of Roger Beachy and his colleagues. The coatprotein gene of the tobacco mosaic virus (TMV) was inserted into tomato plants. After inoculation with the virus, the transgenic plants are clearly tolerant to, if not resistant to, infection by this virus. This technique has been demonstrated now in at least six different plant virus families. It has been field tested in tomatoes against TMV resistance, and field trials are going on with potatoes for coat proteins of two different potato viruses.

Another strategy that has been used to show reduced damage, at least in greenhouse tests, is using the phenomenon of satellite viruses. This is an approach that could potentially be used in perennial crops where the satellite RNAs associated with some plant virus families can be used to ameliorate or reduce symptomatology.

When talking about disease resistance, the big issues with regard to chemical use are nematodes and fungi. Our knowledge base in this area is very small, and therefore it is an area that needs increased levels of research funding. Fungal resistance, especially, is a topic that requires a lot of work and once the genetic work is successful, some of the major products may be displaced.

Systemic acquired resistance has been recognized for twenty years or more and has been researched at Calgene Inc. for several years. Limited pathogen attack on the lower parts of the plant, confers a degree of resistance in the upper parts of the plant. There is alot of work going on in a number of labs around the world to get a better understanding of the genetic basis of this resistance. It may not work adequately in the field yet, but improvements are expected.

RECOMBINANT DNA

A final example of the contribution of recombinant DNA and its associated technologies is the use of molecular markers in plant improvement and breeding programs. The DNA sequences of the genes of individuals within a species or from closely related sexually compatible species can differ in subtle ways. These differences can be revealed as variations in the pattern observed when total DNA is isolated and cut with restriction enzymes, then probed with specific probes for various genes. The technology can be useful in managing breeding programs, in identifying and manipulating single genes and chromosome regions contributing to quantitative traits, such as water use efficiency. Undoubtedly, this technology will be applied to other complex characters, such as horizontal disease resistance that facilitates the breeding of these complex traits.

These examples illustrate some, but not all of the targets and tools being used to approach goals that could be consistent with the sustainable agriculture agenda. There are encouraging signs that this agenda is gaining acceptance more and more broadly. As mentioned earlier, genetic solutions to problems now addressed by chemicals, are on the stated agenda even of the more progressive agricultural chemical players. And the press—both lay and business—is seeing the opportunity and promoting it. Any realistic agenda for sustainable agriculture must, in my view, take us forward from where we are today. It must provide a safe, abundant, and affordable source of food and fiber for a growing world population while redressing the adverse effects of past practices. That is to say, the challenge is great and the outcome desired will not be achieved quickly. We face a long and difficult future. That is why getting started today is urgent.

There is, in my view, however, a regrettable and unconstructive outlook on the future of agriculture that counsels reducing the level of technology rather than seeking to solve or avoid technological problems with different approaches. I find the recent remarks of two very different commentators on the future of science and technology in addressing humankind's needs encouraging—to restore the environment and maintain a productive agricultural base for economic growth.

In a wide ranging commentary first published in the Washington Post, Gus Spaeth of the World Resources Institute answered—"yes, it can and must"— to the question "Can technology save us from the pollution it has caused?"

> "Reconciling the economic and environmental goals societies have set for themselves will occur only if there is a transformationtion in technology—a shift, unprecedented in scope and

pace, to technologies, high and low, soft and hard, that facilitate economic growth while sharply reducing the pressures on the natural environment.

"In this limited sense at least, one might say that only technology can save us. That is a hard thing for a congenital Luddite like myself to say, but, in a small victory of nurture over nature, I do now believe it. I do not diminish the importance of lifestyle changes—some go hand-in-hand with technological change—and I applaud the spread of more voluntary simplicity in our wasteful society. But economic growth has its imperatives; it will occur. The key question is: with what technologies? Only the population explosion rivals this question in fundamental importance to the planetary environment.

"The good news is that many emerging technologies offer exciting opportunities and can help us move in the right direction. The bad news is that no 'hidden hand' is operating to guide technology. We must think hard about the interventions that will be needed to bring about this greening of technology.

"The two fundamental processes of technological transformation are discovery and application. The first is the realm of research and development. Science and engineering must have the financial support and the incentives to provide us with an accurate understanding of the Earth's systems and cycles and the effects of human actions. They must deliver to us a new agriculture, one redesigned to be sustainable both economically and ecologically, which stresses low inputs of commercial fertilizers, pesticides and energy. We must make the market mechanism work for us, guiding technological innovation that should not be micromanaged by government. Today, natural-resource depletion and pollution are being subsidized on a grand scale around the globe. To get the prices right, we must begin by removing subsidies and making private companies and governments 'internalize the externalities' so that prices reflect the true costs to society, including the costs of pollution. The world's emerging biotech industry provides many of the tools needed for environmentally sustainable growth."

The other commentary is from Lane Palmer, the wise editor emeritus of Farm Journal. In the concluding lines of an article entitled "Promises—and Threats— of Biotechnology", he wrote:

> "Once we have proved that a new product is safe and economic, we should adopt it. We cannot worry about which of the current producers—foreign or domestic—it will put out of business, or we risk becoming modern-day Luddites.
>
> "The U.S. is blessed with an almost unlimited acreage of fertile land. Many other developed nations—especially Japan and Germany—are not. We can count on them to substitute technology for acres wherever they can. Our answer is to do likewise, whenever new technology will lower our costs. The answer is similar for competing with the developing countries. They will seek every opportunity to use their low-cost labor to a competitive advantage. Again, new technology is the most promising means of competing with them and maintaining our markets. Some will sacrifice their environment if necessary. We must pursue technology to keep both our markets and our environment.
>
> "The last resort of the naysayers is to impugn the good name of science. They will try to frighten our citizenry into opposing change with the argument that we are placing too much reliance on science. They will cite anew other instances where 'science has been wrong'. People who make such accusations or implications have their own definition for the word 'science'. They think of it as a huge body of knowledge assembled over the years to which scientists turn for their answers. Well, it is not science that errs; it is our use of science, or more likely, our failure to use science, that leads us into errors.
>
> "Science is not a huge body of truth. Science is a carefully constructed method or procedure by which we can discover our errors and move toward truth. Perhaps the best analogy I can offer involves another word that gives us the same kind of difficulty—'democracy'. Now the genius of our political system is not that our Constitution contains all the final laws and regulations for governing a nation. Rather, our Constitution is the best procedure ever devised for discovering and correcting our political errors and moving toward freedom and justice. The scientific method can serve the same function in maintaining and adapting

our physical and biological environment—that is if we will just use it."

And finally, in words of my own, I am convinced that the farm of the future will be more management intensive, and that management will require a wider range of tools—that is technology—to be successful in producing an abundant safe food supply. Genetic manipulation is the proven environmentally safe way to address production challenges—both economical and environmental. I am personally very concerned about the rural infrastructure of this country. I come from and live in a rural area. But the increasingly sophisticated management, the increasing capital intensity, and the increasing competitive nature of agriculture viewed globally clearly dictate difficulties for unsophisticated managers and undercapitalized farms. These are serious problems. Let us not make it worse by regulating science and technology at its source. This is a clumsy tool to accomplish an important social, ethical, and political agenda.

4 *Lectures*

Biopesticides

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Biopesticides: An Overview

Scientists have known since the 1890s that insects are vulnerable to diseases. However, it was not until the early 1950s that field demonstrations by Steinhouse in California led to the commercial production of biopesticides. The federal government registered the first microbial product in 1948, the bacterium Bacillus popillae, to control the Japanese beetle in turf. Although many entomopathogens of insects have been isolated and described, only a few have any real potential as microbial pesticides. Interest in microbials has accelerated since the late 1960s for several reasons: 1 environmental concerns due to dependence on chemical pesticides and their effect on groundwater pollution, residues on food crops, and nontarget organisms; Z development of resistance to chemicals; 3 interest in integrated pest management; and 4 recent developments in biotechnology; i.e., recombinant DNA technology.

Most entomopathogens must be ingested in order to cause an infection. The exceptions are the fungi, which infect externally and the nematodes which actively seek out and attack their host. Some may question whether nematodes should be considered as an entomopathogen; however, most insect pathologists do include them in this category and they are being actively commercialized for control of soil insect pests. Although some organisms such as bacteria and fungi can be produced in liquid culture, the viruses and microsporidia are still produced in vivo.

The speed of kill by biopesticides is slow as compared to most chemical pesticides. This is a problem in the eyes of the public who have been conditioned to the fast-acting results provided by chemical pesticides. There is a recognized need to educate the public about the mode of action of microbial pesticides and their potential use in integrated pest management systems. Characteristics of the major groups of entomopathogens that are used as biopesticides are discussed in the following sections.

NEMATODES

Nematodes occur naturally in soils and they possess a very wide host range. They are relatively easy to mass produce and apply, however, their persistence in soil is limited to a few weeks. Since they are exempt from Environmental Protection Agency (EPA) registration requirements, they are being actively pursued by industry as a control alternative. Several laboratories are focusing on application technology for using nematodes against soil insects, and they are providing new formulations that include nematodes encapsulated in calcium alginate gels or desiccated species applied with baits. Results from field trials using nematodes have been inconsistent. The soil system as a medium is very complex, consequently moisture, pH, texture, and antagonistic organisms can effect the efficacy of nematodes individually or collectively.

FUNGI

There are about 750 species of fungi that are known parasites or pathogens of arthropod pests in terrestrial and aquatic systems. Fungal epizootics can sometimes decimate populations and their effect can be very dramatic. Fungi are unique in that they infect through the cuticle rather than per os, so they have potential use against insects with piercing/sucking mouthparts.

There are ten genera that are amenable to semisolid fermentation and are being mass-produced by industry and government agencies throughout the world. There is a concerted effort by industry in the U.S. to develop Beauvaria bassiana as a soil biopesticide. It is being used against the pecan weevil in Georgia, the lesser cornstalk borer in Florida, as a prophylactic treatment on cottonwood cuttings in nurseries, and even in gallery injections for pests such as the carpenterworm. Beauvaria bassiana is registered in France by a company called Calliope. Another company in Colorado has recently requested permission from EPA to conduct small field testing of a Brazilian isolate of B. bassiana for control of the fire ant. Unfortunately, as in the case of many microbials, levels causing excellent mortality rates in the lab have not been efficacious in the field. Microhabitat conditions, especially temperature and relative humidity, are critical for germination and infection by fungi and frequently compromise field efficacy.

PROTOZOA

Among the protozoa, the only group considered to have potential as a biopesticide is the microsporidia. Microsporidia generally produce chronic rather than acute disease in insects, consequently their effect on populations is not as dramatic as the epizootics caused by bacteria, fungi, or viruses. However, they do cause debilitating effects on pests such as prolonged development, reduced fecundity, and, in some cases, behavioral changes. Microsporidia are reported to act as a stressor in insect populations, thus predisposing individuals to attack by other organisms such as viruses. Many microsporidia are vertically transmitted transovarially to subsequent generations, which is a desirable characteristic not common to other entomopathogens. They are known to infect over 100 different species of mosquitoes and several major forest defoliators such as the spruce budworm, gypsy moth, and forest tent caterpillar.

One species, Nosema locustae, is registered in the U.S. as a bait formulation for grasshopper control. However, microsporidia, like nematodes and fungi, probably have greater potential when used in inoculative or augmentative releases to effect classical biological control.

BACTERIA

Among the entomopathogens, bacteria and their toxins are the subject of most interest in the field of biotechnology. One species, Bacillus thuringiensis (Bt), is an ideal organism for large-scale commercial production because it can be produced in submerged cultures with standard methods and fermentation equipment. Annual sales of Bt have been estimated at $35-45 million per year representing approximately one percent of the $5 billion in pesticides marketed worldwide.

The commercialization of Bt expanded in the late 1960s with the isolation and development of the HD-1 Kurstaki strain. This strain, which was approximately 15 times more efficacious than other available strains, was accepted as the International Standard and is recommended for use against at least 50 different lepidopteran pests.

Over the years, the acceptance and use of Bt products has been hindered by their inconsistent performance in the field. This in turn has been reflected by the emergence and departure of several Bt producers in the past five to ten years.

The interest in and development of Bt related research has exploded in recent years, due mainly to the isolation of new strains, the emergence of genetic engineering, and our interest in the delta endotoxin, which is produced in the fermentation process. Bacillus thuringiensis is a spore-forming bacterium that, when cultured under the appropriate conditions, forms a crystalline parasporal inclusion body called a crystal protein which contains the delta endotoxin. Usually one crystal is produced per cell, although in some strains there are up to three crystals per cell. One strain, Bt var. israelensis, exhibits a high level of insecticidal activity for mosquito and black fly larvae. It has been used successfully against both pests in Africa, Germany, and in abatement districts in the United States and is extremely important in public health programs. Other strains have been isolated and recently registered by EPA that are active against Coleoptera (Bt var. tenebrionis and var. San Diego). There is a flurry of commercial interest to develop and evaluate these strains against the Colorado potato beetle, the elm leaf beetle, the yellow mealworm, and other coleopteran pests.

A tremendous amount of effort is going into the research and deveopment of Bt. For example, certain strains can be induced to produce 25 to 30 times the normal amount of endotoxin by modifying the culture media or temperature; other strains have been developed with toxic proteins that decompose more slowly in the environment. A combination of strains has been found to be synergistic against hard to kill species; sprayable, starch-encapsulated formulations are now being developed for use against the corn borer. These formulations protect Bt from ultraviolet radiation and can also be used to incorporate phagostimulants. Both these processes have been known to enhance persistence and effectiveness in the field for up to 12 days.

One commercial biotechnology firm has developed a novel insecticidal delivery system for the delta endotoxin, called MCAP®. The toxin is microencapsulated within a nonviable cell of Pseudomonas fluorescence, which is a soil inhabiting, plant colonizing, nonpathogenic microbe. This process seems to enhance field persistence. Genetic engineering technology is also capable of producing recombinant organisms of P. fluorescence and Escherichia coli.that express the delta endotoxin of Bt. Some foresee the day when many major insect pests will have a tailor-made Bt product available for use against it.

INSECT-RESISTANT TRANSGENIC PLANTS

Molecular biologists using gene insertion techniques have produced a third approach to pest control—plants that produce insecticidal or antifeedant proteins continuously in the field. The first prototype products, tobacco and tomato plants that produce delta endotoxins of Bt to control larvae of the hornworms, have already undergone one or two seasons of field trials. Field tests of genetically engineered cotton have been approved by APHIS (the Animal and Plant Health Inspection Service). The agency is currently reviewing applications for field trials using soybeans, alfalfa and potatoes. Based on experience with traditionally bred crop lines, it is projected that the first genetically engineered insect resistant seed will reach the marketplace between 1992 and 1995.

There are both advantages and disadvantages associated with the development of transgenic plants. From the grower's perspective, there would be a reduction in application costs, equipment, chemicals, and the application itself. The protection would be effective independent of weather conditions and there would be better plant coverage, especially of those tough-to-reach plant parts. All of this would translate into greater profits. From industry's perspective, the cost to discover, develop, register, and produce a new chemical is estimated at about $25 million and up. Conversely, the cost of a new crop variety has been estimated to be closer to $ 1 to $2 million. From the environmentalist's perspective, there is no concern about spray drift, groundwater contamination, and effects on nontarget organisms because the endotoxins are part of the plant tissue. Documenting the safety to humans will be easier, since an inserted gene would be fully characterized and there would be no need for residue analysis or toxicology.

Regarding disadvantages, there is concern that resistance may develop sooner since the toxin will be exposed continuously to the target pest; some evidence of this has been reported when Bt was used against the Indian meal moth in storage bins. Some regulatory uncertainties still exist that could make the burden of registration potentially prohibitive. Theoretically, a modified crop could be considered a pesticide by EPA, a food additive by the Food and Drug Administration (FDA), and a plant pest by APHIS.

Currently, there are some limitations concerning the insertion of genes into major crops, particularly grains. There are also some questions regarding patent availability and whether or not an invention or investment could be protected.

VIRUSES

More than twenty groups of viruses are known to be pathogenic for insects. Of these, the most interest has been directed toward nuclear polyhedrosis viruses (NPVs), and, to a lesser degree, the granulosis viruses. These viruses belong to the family Baculoviridae, and are referred to as baculoviruses. The virions, or infectious agents, are cylindrical and enclosed within an inclusion body that is polyhedral in shape, thus they are called polyhedral inclusion bodies or PIBs. These inclusion bodies are similar to a bacterial spore or a fungal conidium in that they are resistant to desiccation, very stable, and thus can be stored in a viable state for many years.

Disease caused by viruses are usually fatal. Death of larvae usually occurs three to six days after the first symptoms appear, however this may be delayed for several days under varying meteorological conditions in the field. Epizootics caused by viruses, especially in forest insects, are dramatic and frequently cause total collapse of populations. Unfortunately, these epizootics usually occur only after very dense, defoliating populations are stressed by lack of suitable host foliage; by this time the damage and impact caused by the pest population has already been realized.

The first virus registered in the U.S. was Elcar® (1975) for control of Heliothis sp. on cotton, however since then, commercialization of viruses has been at a standstill. Subsequently, the federal government was involved in the development and registration of three forest insect viruses. The reluctance of industry to develop and register viruses can be attributed to their host specificity and the lack of predictable and expanding markets for viral products. On the other hand, more than 150 commercial laboratories are using baculoviruses as an expression vector system to manufacture proteins. Viruses can be engineered to produce massive amounts of protein in a short period of time. Some recent development in the use of baculoviruses are listed below:

—The University of California has recently obtained an experimental use permit to evaluate codling moth granulosis virus on pear, apple, and walnut. This pilot production project is a joint venture between a nonprofit grower's cooperative, IR-4, and the California Legislature.

—In many Third World countries, conditions are ideal for developing baculoviruses, because inexpensive labor is abundant; producing viruses in live insects is a very labor-intensive industry. Most of these countries do not have the hard currency available to import chemical pesticides or even commercially produced Bt. There are several good examples where government sponsored farmer cooperatives are producing baculoviruses for the control of agricultural pests. These include the viruses for the velvet bean caterpillar in Brazil, alfalfa looper in Guatemala, beet army worm in Thailand, and the cotton Ieafworm in Egypt.

—Field efficacy of the gypsy moth virus, Gypchek, was improved substantially by the addition of an inexpensive sunscreen to the tank mix. The product, Orzan LS®, is a lignosulfonate and a waste by-product of the pulping industry.

—Agricultural Research Service scientists, in collaboration with industry, have successfully produced quantities of the gypsy moth NPV in a new fat body cell culture system. This could be a major breakthrough in the commercialization of this virus product.

The potential role of biotechnology in the development of baculoviruses is unlimited. Recombinant DNA technology offers many new avenues to improve the pathogenicity and effectiveness of baculoviruses. From 1986 to 1988, scientists in England obtained permits to release a genetically altered baculovirus in a screen-contained small-scale field tests. They inserted an innocuous genetic marker to follow the fate of the virus in the environment and distinguish it from naturally occurring viruses in the field.

In 1989, scientists at the Boyce Thompson Institute for Plant Research received EPA approval to release a genetically disabled isolate of Autographa californica virus, (cabbage looper) into field plots in order to follow its survival and spread under natural conditions; in this case the polyhedrin gene has been deleted. Using genetic engineering, it may be possible to improve viral pesticides by inserting toxin or hormone genes to improve direct toxicity, alter behavior, or arrest development in target pest populations.

REGULATORY ISSUES

Microorganisms intended for use as pesticides are subject to the Federal Insecticide, Rodenticide and Fungicide Act (F1FRA). The guidelines for the registration of biorational pesticides, referred to as Subdivision M guidelines, were issued by EPA in 1982. A revision of FIFRA guidelines which has been pending since 1986, has just been released by EPA and is now available. Some of the requirements for Tier-1 testing have been relaxed, which is certainly good news for those who are trying to register microbial products.

A statement of policy on microbial products of biotechnology and nonindigenous microorganisms was issued in the Federal Register in June of 1986. Microbials are distinguished from conventional chemical pesticides by their unique mode of action, their low use volume, and their target species specificity. Each new variety or strain of microbial pesticide must be evaluated and may be subject to additional data requirements. Genetically engineered organisms used as pesticides will be subject to additional data on a case-by-case basis depending on the organism, the patent organism, and the proposed use pattern.

The major categories of data required will still include product chemistry, wildlife and aquatic toxicology, and environmental fate. Satisfying these data requirements qill be expensive and time-consuming. The recent development of new strains of Bt and increased submissions of recombinant products by new biotechology companies has put tremendous strain on the EPA and has slowed the processing of new registration and experimental use permits. Obviously, the goal of regulatory oversight should be to ensure safety while minimizing unnecessary or counterproductive regulatory burdens.

CONCLUSION

Microbial pesticides can play an important role in pest management systems, either as a principal or supplementary control tactic. However, they are not a panacea and should not be considered as such. There is a need to continue the isolation and evaluation of new and more virulent strains of microorganisms for potential use as microbial pesticides. Along these lines, the introduction of new exotic organisms against native pest insects should be pursued and insect pathologists need to be personally involved in foreign exploration for these organisms. Although there have been a few successful applications of this classical approach to biological control, the approach has been underutilized.

The success in using microbial pesticides has been compromised by a lack of research and development in the area of formulation and aerial application technology; methodologies being used were developed years ago for applying chemical pesticides. The most promising microbial products will fail unless we learn how to apply them properly and enhance their persistence on foliage.

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Biopesticides and the Environment

The United States today produces an abundant amount of food with high cosmetic standards, and uses nearly one billion pounds of pesticides to achieve these standards. Americans eat a great deal of food; in fact, the average American consumes 1,500 pounds of food per person per year. There is a constant battle to protect the food supply from various organisms that attempt to share it, such as insects, weeds, diseases, or rodents.

INCREASED PESTICIDE USE

The United States uses an enormous amount of pesticides, nearly one billion pounds are applied annually for pest control. Despite the use of pesticides and all other controls, 35 percent of all potential world food production is lost to pests, primarily insects, diseases, and weeds. After the 65 percent that is left is harvested, another group of organisms, insects, microbes, rodents, and birds take an additional 20 percent. Despite the use of pesticides and other controls, nearly one half of all the potential food production is lost worldwide.

In the U.S., since 1945, there has beena33-fold increase in the use of pesticides, yet preharvest crop losses to pests have actually increased from nearly 20 percent in 1945 to 37 percent today. Data from the U.S. Department of Agriculture (USDA) indicates that from 1945 to 1988, there has been approximately a tenfold increase in the use of insecticides in agriculture. Despite this tenfold increase, crop losses due to insects has nearly doubled, from seven percent to 13 percent.

The reason for this relates to the changes in biotechnology in agriculture, the way crops are cultured and managed.

In 1945, nearly 100 percent of the corn was grown after soybeans, after wheat, or after oats, and again, according to USDA, the average crop losses in corn in 1945 was 3.5 percent. There has been a 1000-fold increase in the use of insecticides in corn since 1945. In fact, corn is the largest user of insecticides in agriculture today, having finally edged out cotton. Despite that fact, crop losses to insects in corn have increased from 3.5 percent to 12 percent, nearly a fourfold increase in crop losses, with more than a 1000-fold increase in the use of insecticides. The reason is that crop rotations have been replaced with continuous corn crops, thus intensifying insect problems. Continuous corn crops also increase weed problems and disease problems; thus more fungicides and herbicides have to be used.

The biotechnological changes that have been made in agriculture have encouraged pest problems. More insecticides have been used in an effort to stay even, but despite the increased use, farmers have not been able to sustain control.

ENVIRONMENTAL AND PUBLIC HEALTH IMPACT OF PESTICIDES

The estimated environmental and public health costs of using pesticides in the United States are minimally one billion dollars annually. This cost includes human deaths and hospitalization, elimination of natural enemies of pests, and the destruction of crops by pesticide drift. According to USDA and the Environmental Protection Agency (EPA), the U.S. is currently spending $1.2 billion annually just for monitoring pesticides in well water and groundwater. More realistically, the environmental and public health costs of using pesticides in the United States are costing the nation somewhere between $2.2 and probably closer to four billion dollars annually.

Some nations have become very concerned about their environmental and public health problems. Two years ago, Sweden passed legislation to reduce pesticide use by 50 percent during the next five years. Denmark and Holland passed similar legislation and they are making excellent progress. Clearly, there is public and political concern about the environmental problems associated with pesticides.

BIOLOGICAL CONTROLS

Biopesticides are biological materials used for pest control, but they have no relationship to pesticides, other than the fact that they can be cultured and applied. Viruses, bacteria, protozoans, fungi, and nematodes can be used for the biological control of pests. A few of these controls can be released permanently, as in the case of milky disease, which is used to control the Japanese beetle.

Certainly, in the use of natural enemies, biopesticides play a very important role in agriculture and in protecting crops. Part of the problem with using insecticides or other pesticides in crop production is that these controls kill the natural enemies of pests along with the pests themselves. This problem seldom occurs with biopesticides.

The United States and the rest of the world have actually made poor use of biological controls. Of the 60,000 species of pests in the world, only about 0.2 percent are a "classical" type of biological control where a biocontrol agent is introduced and does not require further manipulation. Pesticides normally pay a four dollar return per dollar invested; however, the economics of biological controls are much better, ranging from $30-$ 100 return per dollar invested. These costs include research costs.

VIRUSES AND OTHER BIOLOGICAL CONTROLS

Over 800 viruses that infect insects have already been identified, and there are probably three to five times more that occur in nature worldwide. All of these viruses could be utilized, some may require genetic engineering because they are not as virulent enough for biocontrol.

One virus is very effective against the cabbage looper. A healthy cabbage looper is green in color, while a virus infected looper has a whitish or yellowish appearance. Twenty-four hours after showing the whitish or yellowish color, the cabbage looper is dead.

The virus that attacks the cabbage looper is so pathogenic that genetic engineering is not necessary. If two infected caterpillars are put into 100 gallons of water, stirred, and applied to an acre of land, the virus from just two caterpillars will kill 98 percent of all the cabbage loopers on that acre of cabbage crop. People have been trying unsuccessfully for 20 years to get this virus approved for use on crops, such as cabbage or lettuce, but EPA and the Food and Drug Administration (FDA), have refused to approve the use of this virus on food, despite the fact that everyone has eaten this virus. The EPA and FDA are very concerned about culturing this virus and adding more of it to food. Hopefully, EPA and FDA will approve this virus for use sometime in the near future, because it really is a safe and effective control.

Biopesticides have been approved for use on non-food crops like cotton and trees. For example, biopesticides have been developed and approved for use against the gypsy moth, the Douglas-fir moth, the sawfly, and against the cotton bollworm.

The "new association" technique of selecting biological control agents has been developed and is three times more effective in achieving successful biological control than before. It not only improves the success of introductions for biocontrol, but it has also opened up the opportunity to use biological control for native pests. Since 30 to 60 percent of the U.S.'s major pests are actually native pests, this technology has opened up a whole new area of attack on native pests that were not susceptible to old, classical biocontrol.

A great many organisms can be made use of for biological control. The two successes in bacteria are Bacillus thuringiensis (Bt) and Bacillus poppillat, and both have worked very effectively in biocontrol. There are already at least 500 known species of bacteria that affect insects and many more undiscovered species worldwide. Fungi and protozoans are a little more difficult to handle and manipulate for biological control, but there are still possibilities. There are probably 2,000 to 3,000 species that infect insects and have the potential to control insects. There is a rich variety of microbial species available for use in biotechnology and biological control.

RISKS OF BIOPESTICIDES

Although at least one particular strain of Bt works effectively against caterpillars, not all caterpillars are bad. There are, in fact, caterpillars that belong to various species of butterflies and moths that are on the endangered species list. If Bt were applied near or on these endangered species, it would kill them. Also some strains of Bt have been found to be detrimental to beneficial earthworms.

When biopesticides are applied, the host or the pest population can be significantly reduced. This application may affect some beneficial insect parasites and predators of pests. When biocontrol parasites and predators are eliminated, it takes a while for them to come back, and this begins the cycle of having to reapply biopesticides to maintain control.

Of course, there is always the potential for gene transfer or the moving of genes from one microorganism to another. This is not a great hazard, but it certainly is a potential environmental risk. Mutations could also occur. If Bt mutated, it might switch from attacking caterpillars to attacking beneficial beetles. A great many beetles are beneficial as predators in controlling pests in agriculture.

There are 400,000 species of plants and animals in the United States, and 99 percent of these are beneficial and essential to agricultural production. The honeybee and wild bee, for example, are important in pollinating $30 billion worth of crops in the United States. Insects and microbes are important in degrading livestock wastes. These "small" organisms play a vital role in keeping agriculture productive.

RISKS OF TESTING AND RELEASING BIOPESTICIDES

Generally, genetic engineering of microbes, such as viruses, bacteria, nematodes, fungi, protozoa for insect control and other pest control, have proven safe. There appear to be minimal environmental problems associated with the release of these organisms based on working experience with these organisms in agriculture and forestry. Although an organism has desirable characteristics, once it is released the environmental effects cannot be predicted with 100 percent accuracy. The genetic engineers were incorrect when they made the statement that there have been no environmental problems associated with the introduction of crop plants into the United States. When examining the literature on all the crop plants that have been introduced in the United States, we found that a total of 128 species of crops have become serious weed pests. Some have become major weed pests, like Johnson grass and pigweed.

During testing of genetically engineered organisms, how will scientists control the test organism if the organism is released and it becomes a pest? The literature reveals that rarely have pest species been exterminated once released in the environment. Out of 10,000 species of pests in the United States, only two have been successfully exterminated and with an enormous cost. These pests were the Mediterranean fruitfly and the citrus canker pathogen.

Thus, there is concern about the release of a genetically engineered organism. Once a genetically engineered organism is released in nature, it is different than a pesticide, because pesticides do not reproduce. Based on past experiences, once genetically engineered organisms are released in the environment, the odds of ever controlling them is practically nil. This does not mean that genetic engineering and biotechnology have nothing to offer, they offer many opportunities for reducing pesticide use in sustainable agriculture.

Today genetic engineers are saying, "We know what we are doing, leave us alone. We've released this organism and it had no problems". We should remind society of nuclear engineers in the 1950s, who were giving us the same assurances when environmentalists and others were raising questions about the safety of nuclear energy. There were no problems after the first 12 nuclear plants were built and no problems after the next 70 were built, but then suddenly several problems occurred.

The odds of hazardous events happening in the release of genetically engineered organisms in the environment are small, but problems can happen. It would only take one disastrous event for genetic engineering and biotechnology to lose credibility with the public. It is hoped that we will be cautious and enact suitable regulations to protect the environment and genetic engineering technology.

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Biopesticides and Economic Democracy

In my work on the social impacts of new technologies, I have dealt with a wide variety of issues related to the new biopesticides. As a Peace Corps volunteer in Botswana, I tried to grow vegetables for the market in an environment which fairly teemed with all manner of pests from caterpillars to elephants. There was little we could do about the elephant—but we fought insect pests like the caterpillars with a variety of pesticides such as Chlordane and Malathion. And those pesticides worked—they killed the pests, they kept blight off the tomatoes, and they killed the caterpillars on the cabbages.

But though these insecticides worked, I was uncomfortable using them. I read the labels, and did not like the cavalier way in which my colleague, a missionary farmer from North Carolina—mixed and applied them. I also had to wonder about the usefulness of pesticides to local people—we were, after all, there to help them. But even though the chemicals worked, few people could afford them. Fewer yet could read the labels and mix them safely and properly. And there was the disturbing tendency for any impermeable container to be used for water storage.

The pesticides carried certain benefits, but they also carried certain costs. This Janus-like character is true of any new technology. The balance of costs and benefits is as much a function of the social, economic and environmental conditions in which the technology is deployed as it is of the characteristics of the technology itself. Even in the advanced industrial nations, though pesticides did indeed confer benefits, their use also entailed substantial costs both to the user and to society as a whole.

Ten years ago in Botswana, I was not aware of alternatives to chemical pesticides. Today, they are in the headlines of the news. For example, there has been the development and the promise of a broad range of biopesticides: pheromone traps, engineering cross resistance in plants, encoding toxin genes in plants, encoding insecticidal or anti-viral or anti-fungal genes in rhizobacteria. And biotechnology promises to greatly facilitate the development of such biopesticides.

BIOTECHNOLOGY UTOPIA

McManus (see page 65) provided a litany of benefits that could accrue to the development and use of these new pest control technologies. Biotechnology can be used to develop new pesticides that are "biorational" and contribute to environmental sustainability—because they may be less toxic to people and other nontarget organisms; kinder and gentler to our environment in general. They may also contribute to social and economic sustainability—because they may be less energy intensive, less costly, and because they may permit farmers to begin reducing purchased inputs.

There is indeed great promise. There are many in the business and academic worlds who emphasize that promise. That emphasis on promise is characteristic not just of approaches to biopesticides, but to biotechnology in general.

That emphasis is seen in crop biotechnology—for example, a Northrup King advertisement shows wheat growing next to the Egyptian pyramids with the question "Could the world's deserts be made to bloom again?" The apotheosis of this approach is an advertisement from Monsanto showing a corn plant growing in barren desert with the slogan "Will it take a miracle to solve the world's hunger problems?" The implication of the advertisements are that biotechnology is miraculous; permitting the growth of wheat and corn even in the desert. More than this, the advertisements suggest that biotechnology is a miraculous solution to world hunger.

The advertisement by Monsanto is disingenuous in at least three important ways. First, it presents a goal that no one seriously intends to pursue: growing corn in a barren desert. Second, it implies that there is a technical solution to the problem of world hunger, a problem that is as much or more sociopolitical than technological. And third, it uses the miraculous and metaphysical as an explanation.

Monsanto is guilty of the very hyperbole it criticizes in those who question the way biotechnology is being developed. The invocation of technological utopia is no less hyperbolic, no less an exaggeration, than invocations of technological apocalypse. And there is actually a good deal more of the former than the latter.

This innovation of the apparently magical character of biotechnology is again apparent in an advertisement from Pioneer Hi-Bred International depicting a medieval alchemist, and containing the slogan "Biotechnology, science or alchemy? Biotechnology is, of course, science. But why not the alchemical analogy; DNA as the new Philosopher's Stone, capable of changing base life to gold, to products to profits? Companies naturally have an interest in emphasizing the promise and minimizing the possible problems of a technology because they expect to make money. The technological imperative—legitimated with reference to technological utopianism—often has a financial imperative behind it.

PROBLEMS

The public has heard this technological utopianism before from business, academics, the government, and from the press. There is reason to distrust technological utopianism. There is a real problem of what to do with nuclear and toxic chemical waste. Now newspapers carry headlines, such as "Bomb site cleanup is put at billions". But in 1959 the Atomic Energy Commission was saying "Waste problems have proved completely manageable..." Currently there is worry about toxic waste dumps and their leakage. But only a few years ago there were advertisements such as Monsanto's, "Without chemicals millions more would go hungry". And this from the same company now engaged in the development of biological pesticides.

How is the public to respond to the assertion that biological pesticides are the solution and that deliberate release of such biorational organisms—miraculous though they may be—is entirely safe and benign? Caution is needed, but note that caution does not mean rejection. The criticism is of the way biotechnology is being developed, not a criticism of biotechnology per se.

This suggestion of caution is reinforced by the caution of others. A recent report titled, "Ecologists wary about environmental releases" from a committee of prominent ecologists (nearly 100 reviewed the paper) published in Ecology, challenges arguments put forth by those in industry and academic circles who would like to see faster development and commercialization of genetically engineered biological pesticides.

Here is a fundamental problem. Individuals are not involved in the development of these technologies. Yet they will certainly affect individuals directly or indirectly. Should one embrace what appears to be great potentials in biotechnology, when one is uncertain as to the balance of costs and benefits. If individuals not involved in the process, how can they make an informed decision on issues? Or, if someone who is trusted or who has been designated as the public's representative is not involved, how can the public decide?

Out of this problem arises a second problem. Technologies have differential effects on people—some win, some lose. Not only are there both costs and benefits, those costs and benefits are borne in different proportions by different social groups. An example is the well-known case of the mechanical tomato harvester, whatever the level of gains elsewhere in society, those who lost their jobs suffered substantial costs. The next gains to society may be positive, but what are the ethical implications of excluding from the technology development process those who are actually damaged?

ECONOMIC DEMOCRACY

The central social and economic issue in the development of biopesticides—indeed, in the development of biotechnology globally—is the question of economic democracy. Citizens of the United States enjoy political democracy—they can vote, and thereby influence political decision making. More than that, they can belong to a political party and by being involved in party activities can help shape party policies and objectives. Political democracy means the right to actively participate in political institutions; not just to vote yes or no on a candidate, but to help select the candidate to run for office.

There is no parallel institutional structure for participation in economic decision-making. There is not the right—directly or indirectly—to participate in decision making at Monsanto or Eli Lilly or Chrysler or General Foods. It might be argued that economic democracy exists inasmuch as there is a "vote" on a new technology by deciding to purchase it or not. But this is a degraded sort of economic democracy parallel to Soviet political democracy in which a candidate is presented and citizens vote yes or no. Even the Soviets are moving away from that model now.

Full economic democracy is not a feature of the American economy at this time. It should be. The fundamental social and ethical task to be undertaken in regard to the new biotechnologies is the development of institutions to provide full economic democracy—institutions that would allow for participation in the development of new technologies by a broad range of social interests. Participation in the direction of the research and development process is needed.

How? Through what mechanisms? At what levels? By what groups? There are few people looking for such mechanisms. There is no doubt that it will be difficult. But the point is to make a reasonable beginning because broader social participation in technological development is both ethically appropriate and socially rational.

Broader participation is ethically appropriate because those who stand to be affected by an economic decision should have a right to participate in that decision. The emphasis is on the word "participate". This does not mean "veto".

Broader participation is ethically appropriate because the effects of a new technology are not always predictable. If they cannot be predicted, and if there are going to be unforeseen losses for some, then collective responsibility is needed for important decisions.

Broader participation is socially rational because if there are formal institutional mechanisms for ensuring popular participation, there is a provision for collective responsibility and therefore for conflict reduction. If there is a problem, it is a community problem.

Broader participation is socially rational because enlarged participation will bring useful additions of information to the development of technologies. Lay people have experience and knowledge of a problem that experts cannot duplicate. As described in an article titled, "Scientists at the source: farm families are 'adopting' agriculture biotechnologists", one biotechnology company is already taking farmers' indigenous knowledge seriously. What farmers know about the production process or what patients know about their disease can be applied to the development of new technologies.

Broader participation is socially rational because debate over the desirability of competing technological directions highlights the possibility of generating options. It is socially rational to maintain a diversity of possible technological paths. Why is solar energy not pursued? Why are insights not being gleaned from Amish agriculture? When narrow interests predominate in setting technological trajectories, it must be asked what are the opportunity costs of taking that path, what may be the lost alternatives, the foregone options?

Robert Goodman, (see paper page 52) pointed out that farmers have a very short range of attention when it comes to their profitability. The same is true of corporations. There may be good, ethical people in companies, but they must sell technologies for profit. If private corporations are the only ones developing new technologies, to what extent does the need to make a profit drive them down one particular technological path as opposed to another? AH alternatives must be considered including those technologies that are socially useful, but not privately profitable.

Public institutions, especially Land Grant Universities (LGUs) are in a position to pursue these alternatives. They will be pivotal institutions for generating a participatory trajectory. If any measure of economic democracy is to be achieved in agricultural colleges, agriculture will have to play a leading role. But who are these institutions serving? There has been criticism at least since the 1970s suggesting that agribusiness is the principal social group served by the LGUs. Agribusiness is already and has long been participating in the shaping of public research agendas. While the LGUs are enlarging participation in agenda setting, private companies are expanding their already dominant role.

The increasing penetration of universities by industry is a general tendency within higher education at the moment, especially in the area of bioscience. During the last ten years a wide range of contractual and non-contractual arrangements have been established between universities and private businesses in the field of biotechnology. Companies have made their needs known. Monsanto does not provide $62 million to Washington University without expecting something in return. What companies get are a wide range of benefits for their dollars; influence over research agendas, patent rights, licensing rights, early looks at new technologies, and a window on university techniques. The result is the “commodification of the university".

Universities are becoming quite literally marketplaces for knowledge. And as universities become marketplaces, they respond to those who have the deepest pockets. There is plenty of demand for lots of different research out there in society, as economists, would point out, it is “effective demand”—that is, demand backed by dollars—that gets a response. While universities are certainly not ivory towers and never have been, should they not at least be semi-autonomous from the dominant economic powers? If technological options are going to be established and maintained, then the continued penetration of universities by narrow economic interests cannot be permitted.

A related problem that has accompanied the commodification of the university is the overemphasis on biotechnology and an underemphasis on other areas of biology. An advertisement from United Agriseeds, now subsidiary, shows a corn breeder covered in cobwebs, and states, “Some plant breeders are more patient than ours at United Agriseeds”, saying in essence that classical plant breeders will not be needed anymore because gene transfers will all be done by genetic engineering. This advertisement is a social indicator of the funding and employment shifts that are underway. Already biotechnology is favored in both research support and when hiring at USDA and in colleges of agriculture.

It is not that research support should not grow for biotechnology, but rather that other areas should not be slighted in the process. This is crucial in the area of biopesticides. If agroecology and sustainable agriculture are to be seriously pursued, then money will have to be directed towards ecology, which has been and continues to be appallingly underfunded.

Lastly, a social and ethical issue that is too little addressed is the total federal research and development budget. The allocation to ecology and molecular biology has been relatively limited. In 1987, 70 percent of federal research and development expenditures went to defense. For every dollar that went into agricultural research, forty dollars went to defense. This is ethically indefensible and socially irrational. The defense budget is an agricultural and sustainable agricultural issue. If the nation is going to move towards a sustainable agriculture, the resources must be made available to it.

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Economic Aspects of Biopesticides[*2]

During the conference a lot was heard about the problems with conventional pesticides, the potential of biopesticides, and the promise of sustainable agriculture. But, consider for a moment:

What if, through public or private research, a set of "ethically appropriate", "socially rational", and environmentally beneficial, biological pest control products are developed,.. . .and nobody wants them?

It has happened before. In fact, the pest control toolbox is filled with effective techniques that either have not been commercialized or, while currently available, are not widely used because they cost too much or present other disadvantages to their potential users.

I will briefly review the current economic situation with regard to pest control, indicate the basic economic criteria for success of biopesticides, and derive a few policy implications.

'When this speech was prepared and presented, Dr. Reichelderfer was with the U.S. Department of Agriculture as Associate Director of the Resources and Technology Division, Economic Research Service.

[2]The term "biopesticides," is used broadly in these remarks to refer to: biological control alternatives relying upon the use of natural pest predators, parasites, and pathogens; bioengineered pest parasite, predator, or pathogen species; and bioengineered plant varieties possessing resistance to pests or pesticides.

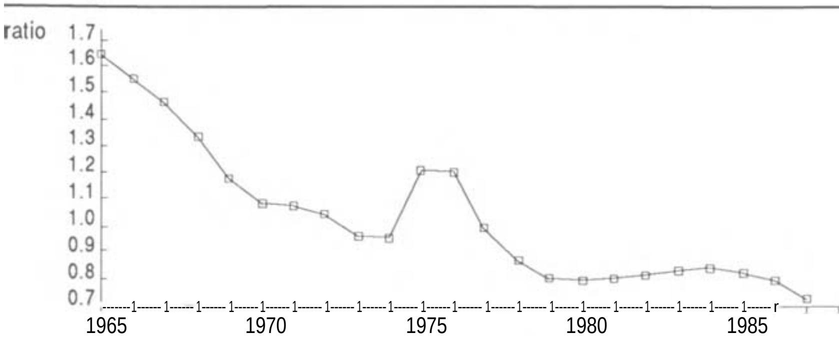
FACTORS INFLUENCING PESTICIDE USE

Why do farmers, as a group, depend so heavily on chemical pesticides, and appear often to use more than is necessary[1]?- There are several reasons.

First, chemical pesticides are ever-cheaper substitutes for other increasingly high-cost agricultural inputs (Daberkow and Reichelderfer, 1988). Pesticide prices have risen over the last 40 years. But, they have risen at a far slower rate than have agricultural wage rates and land values (Fig. 1 and Fig. 2). The result is that, relative to land-extensive pest control techniques such as crop rotation, or techniques that

Figure 1—Agricultural wage rates

Figure 2—Land values



require a lot of labor or time, pesticides have become cheaper over time. In fact, the economic theory of induced innovation would suggest that current land and laborsaving pest control technology was developed in direct response to farmers' needs and market demands as wage rates and land values skyrocketed (Hayami and Ruttan, 1985).

Second, farming has always been a risky venture, with volatile markets and unpredictable weather events like drought and hail. Anything that can help reduce the uncertainty associated with farming is viewed as desirable. Much of what we consider an overuse of pesticides, is, from the perspective of the farmer, completely rational. If there is an unknown chance that a pest may be present, and a cheap, prophylactic application of a pesticide will take care of the problem, should it arise, it makes some economic sense to use it even if you don't know with certainty that there will be a need for it. Thus the appeal of Du Pont's 1988 advertisement for Preview® herbicide, which states that, "Until farming becomes more predictable, there's Preview®".

Pest control techniques that save time and effort have also become more valuable as management time has become more precious to the farmer. New techniques for managing soil fertility, soil conservation, livestock feed rations, and commodity marketing strategies are a few of the many things that compete with pest control for scarce management time. The time allocation problem is even greater under low input, sustainable agriculture (LISA) systems, which are more sophisticated and complex than conventional production systems. Couple this with the trend towards off-farm work as a way to cope with the income uncertainty of farming, and time can quickly become a limiting factor. This explains the appeal of Dow Chemical Company's 1988 ad for Tandem® herbicide: "Tandem® puts time on your side".

Third, there is the influence of farm policy. Current commodity programs provide farm income support which is tied to the level of production of particular commodities and depends upon acreage reduction schemes to control commodity surpluses. The commodities receiving government support include, quite by coincidence, crops which are among the more chemically dependent of agricultural land uses. The use of annual acreage reduction programs for supply control has further reinforced the trend towards development and use of land-saving agricultural inputs, such as pesticides. The base acreage system, the accounting mechanism used for our elaborate farm income support process, discourages the diversification of farming activities that is essential for adoption of LISA systems (Fleming, 1987).

Fourth, we need to recognize that farmers, in order to sustain their way of life, must respond to market signals provided through prices. Prices for export crops are now going up, meaning that each unit of additional yield is worth more. A problem with the market for agricultural commodities is that it does not recognize the environmental costs of how we produce the commodities.

FACTORS AFFECTING THE ECONOMIC FEASIBILITY OF BIOPESTICIDES

The current situation as described above provides clear signals regarding the factors that need to be considered to make biopesticides in a sustainable system competitive with conventional agricultural protection and production practices. The following summary highlights some of the more important factors in determining the economic feasibility of biopesticide development and utilization. (See also: Carlson, 1988; Reichelderfer, 1985; and Reichelderfer, 1981.)

The "bottom line" for farmers is that the net returns accruing to the use of biopesticides must be equivalent to or greater than those gained through the use of conventional pesticides. Otherwise, there is little incentive for change. Some determinants of a pesticide's potential benefits are obvious; others less so.

Efficacy of the biopesticide. Unless the biopesticide is available at lower cost than the chemical pesticide it would replace, its technical effectiveness must be at least the same as that of its alternative. As efficacy increases and all else is constant, the probability that a biological pest control technique is economically feasible improves.

Pest spectrum. Simultaneous occurrence of several pests of the same general type has a negative impact on economic feasibility of species-specific biopesticides. If chemical methods can control all coexisting pests of a certain type, and if the available biopesticide is specific to only one of these species, use of the biological alternative, all else constant, will likely result in little or no relative benefit. Control action would still have to be taken against the coexisting pests. If that action, like the use of a broad-spectrum herbicide, is both necessary and effective against all coexisting pests, any cost of using a species-specific biopesticide would appear unjustified. Biopesticides with broad- spectrum activity would be more desirable and also have greater commercial feasibility.

Crop price. The benefit of any pest control action is directly related to the price of the crop on which control is to take place. The higher the unit price of the crop needing protection, the greater the per-unit value of reducing the pest population and the greater the premium placed upon rapid, dependable, and efficacious pesticidal action.

Market price of the biopesticide. Obviously, the price one pays for a new pesticide alternative weighs heavily on the users' determination of the technique's economic feasibility. All else equal, the lower this price to the user, the greater the economic feasibility of the technique. However, if the biopesticide presents a special advantage, such as low human toxicity or reduced leaching potential, and is sufficiently efficacious, users may be willing to pay a premium (a higher price).

Variability in effect on pests. Risk and uncertainty are important features of economic feasibility. The more variable or otherwise risky a technique is viewed, the lower its economic feasibility from the perspective of its potential users. Risk-averse users, especially, prefer consistency over the possibility of a periodically outstanding effect. They will actually pay a premium (a higher cost) for a technique that has consistent results. The risk associated with using a highly variable biopesticide adds a user cost that adversely affects its economic feasibility.

User costs of implementing biological pest control. While the market price of some biopesticide materials may be less than or equivalent to chemical pesticide alternatives, use of the biopesticide may require acute management skills or additional time or effort, whether in the field or at the desk. It is important to keep in mind, as the farmer does, that time, management, and labor are not free. The costs of using a biopesticide can be as important in determining its economic feasibility as is the cost of purchasing it.

Personal, family, farm worker, or livestock health risk is a special form of user cost of some chemical pesticides that is receiving increased attention by farmers. Abbot Labs capitalizes on the safety advantages of biological alternatives through its 1989 advertisements for Dipel®, which stress the reduced, potential health-related user costs of that material.

Additional factors come into play to determine the commercial availability of biopesticides. Commercial feasibility is influenced by a range of considerations, including the following:

Distribution and frequency of target pest problems. If a pest problem occurs only in a limited area/or infrequently, the expected profits from commercialization of a biopesticide targeted to that problem would be unlikely to cover the costs of research, development, and registration of the material. Thus, commercial feasibility is greatest for biopesticides against widespread, frequently occurring or multiple pest species.

Proprietary rights to the biopesticide. If the rights to manufacture and sell a biopesticide cannot be protected for a sufficient period to cover its research, development, and registration costs, it is not likely to be commercialized.

Registration costs. As requirements for materials' use registration increase, the probability of investment in research and development (R&D) declines for materials with uncertain profit potential. Public concern about the potential environmental effects of biotechnological experimentation could result in increased registration costs for some biopesticide materials.

BIOPESTICIDE RESEARCH

If 1 were in charge of a commercial firm, I would be gearing biopesticide research towards materials that are highly efficacious and certain in their effect against a consistently occurring, light or moderately damaging, single major pest on a high valued crop. Of course, I would make sure that the biopesticide could be sold at a competitive price and would not require large amounts of time, management, or labor to use. And I would have to be guaranteed that a patent could be obtained and that the material's registration costs were not prohibitive.

Products that meet these criteria will be commercially feasible. But, they don't provide products for use in small markets or one-shot markets. I find it difficult to blame seed, pesticide, and other input industries for not investing the significant amounts of capital required to develop products for markets that are too small or unprofitable to cover costs.

But here is where the public sector has a role to play. Public sector R&D can fill the gaps by concentrating its own increasingly scarce resources on:

—The development of environmentally beneficial pest control methods and products for specialty crops, forestry, and other limited markets;

—Conducting high risk, long term research on techniques that may, eventually, be patentable; and

—Funding R&D on techniques that are inherently unpatentable.

THE ROLE OF PUBLIC POLICY

Because agricultural commodity markets fail to incorporate the environmental costs of agricultural production, and, given the expressed social goals of reducing environmental costs and developing a truly sustainable agriculture, the debate needs to focus on how alternative public policy instruments can be used to resolve conflicts.

Directing public research is one policy tool, but it is not a panacea. As the preceding discussion illustrates, merely making new, "rational" technologies available through public research does not guarantee that those technologies will be adopted. Economic incentives, a favorable market, and a supportive agricultural policy environment must also be in place.

Modification of farm policies to assure their compatibility with environmental goals comprises another set of policy options. Among the suggestions made as debate over the 1990 farm bill has developed are various alternatives for: 1 changing the base acreage system, the accounting mechanism currently used to determine commodity program payment levels; 2 decoupling farm income payments from production levels; 3 eliminating commodity price supports that influence farmers' agricultural chemical use rates; and 4 using environmental criteria to target acreage reduction programs—any or all of which could to some degree reduce the aggregate level or adverse environmental consequences of chemical pesticide use (Fleming, 1987). Such proposed actions could also affect farm incomes, feed prices, the U.S. agricultural trade balance, and the structure of our agricultural input industries (Reichelderfer, 1989).

Environmental regulation, feed, fines, and taxes are direct policy interventions. Many state governments are taking the regulatory or input taxation approach. For example, California's Proposition 65 would make it unlawful for some agricultural producers to use certain registered pesticide materials. Connecticut's Potable Drinking Water law makes farmers whose pesticide use results in water contamination liable for the costs of cleaning up the water or supplying alternative drinking water sources. Iowa has imposed a tax on fertilizer sales to fund groundwater monitoring programs. (See Batie & Diebel, 1989 for a comprehensive review of state policies, most of which have been enacted within the last five years). One effect of accelerating environmental regulation is that it provides a market incentive for private R&D on environmentally benign substitutes for current agricultural chemicals. If regulation or taxation increases the user cost of chemical pesticides, then it is more likely that biopesticides can effectively compete for market share. At the same time, however, some farmers' incomes are decreased by regulatory action (though others' may increase because commodity prices may rise as the cost of production goes up), and consumers bear a large share of the costs imposed by environmental regulation or input taxation.

CONCLUSIONS

The economic and social implications of biopesticide research and development, like those for other areas of biotechnology, are very uncertain. Highly variable market conditions strongly affect farmers' management decisions. But, to the extent that farm and environmental programs modify those decisions, and research provides new options for consideration in the decision making process, economic and policy factors will be the principal guides for the direction of both private and public pest control research.

I remain very optimistic about the future potential for increasing the compatibility between agricultural production and environmental quality.

REFERENCES

Batie, Sandra and Penelope Diebel, 1989. "Managing Agricultural Contamination of Ground Water: State Strategies," Working Paper, Department of Agricultural Economics, Virginia Polytechnic Institute and State University.

Carlson, Gerald A, 1988. "Economics of Biological Control of Pests," American Journal of Alternative Agriculture, 3 (2-3): 110-116.

Daberkow, Stan G. and Katherine H. Reichelderfer, 1988. "Low Input Agriculture: Trends, Goals, and Prospects for Input Use.", American Journal of Agricultural Economics, 70 (5): 1159-1166.

Fleming, Malcolm H., 1987. "Agricultural Chemicals in Ground Water: Preventing Contamination by Removing Barriers Against Low-Input Farm Management," American Journal of Alternative Agriculture, 2 (3): 124-130.

Reichelderfer, Katherine H., 1981. "Economic Feasibility of Biological Control of Crop Pests," in (G. Papavizas, editor) Biological Control in Crop Protection, Totowa, NJ: Allanheld, Osmun Publishers, pp. 403-417.

-----, 1985. "Factors Affecting the Economic Feasibility of the Biological Control of Weeds," (E.S. Delfosse, editor) Proc. VI International Symposium on the Biological Control of Weeds, Agriculture Canada, pp. 135-144.

-----, 1989. "Environmental Protection and Agricultural Support: Are Trade-offs Necessary?" National Center for Food and Agricultural Policy, Discussion Paper FAP89-03. Washington, DC.: Resources for the Future.

Herbicide Tolerance in Plants

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Herbicide Resistance in Plants[1]

The first discovery of a triazine-resistant weed (common groundsel) was in western Washington in the late 1960s. The subsequent widespread and frequent occurrence of other triazine-resistant weeds over the past 20 years have made triazine herbicide-resistance the best known and most studied case of herbicide-resistance. Triazine-resistance has also been of great interest because of the importance and extensive use of this group of herbicides. If other single target site residual herbicides (e.g., diuron) were used as extensively and continuously as the triazines, they would have almost certainly led to resistant biotypes.

Although weeds have taken longer to evolve herbicide-resistance compared to insect pests and pathogens, biotypes of 40 broadleaves and 15 grass weed species are known to have developed resistance to triazine herbicides somewhere in the world. A total of 45 weed biotypes (29 broadleaves and 16 grasses) have evolved resistance to 14 other types of classes of herbicides, making a grand total of 100 herbicide-resistant weed biotypes to date. Only 21 of the triazine-resistant biotypes and 16 biotypes resistant to other herbicides have been found in the U.S., but one or more of these resistant biotypes have invaded 39 states, six provinces of Canada and 27 other countries.

’LeBaron noted that this paper was represented as the President of the Weed Science Society of American and as a weed scientist, rather than a representative of CIBA-GEIGY Corporation.

Past experience has shown that weeds resistant to triazines can be managed or restrained within a reasonable limit. In the U S. the total area of land or crops infested with triazine-resistant weeds is still relatively limited (estimated to be about 3,000,000 acres) and does not seem to be expanding rapidly, except in a few states where continuous corn or no-tillage farming is being practiced or good alternative herbicides are not used. In most areas of the U.S. where triazine-resitant weeds have evolved it has not even been necessary or desirable to cease using the triazine herbicide of choice, due to the many susceptible weeds that are still usually prevalent. In a few cases, the resistant biotypes have even disappeared.

It is very important for nonbiologists to understand that an essential requirement of herbicides is that they control all weeds throughout the season. This may be from 5 to 25 species, not just the one or two pests that insecticides and fungicides usually try to control. If all but one species is controlled, little has been accomplished because that species will take over. This also makes it difficult for weed scientists to deal with weed thresholds because if the "escapes" are resistant to the herbicide used, within one or two years the field will likely be a solid stand of resistant weeds. Even if they are susceptible escapes, many weeds tend to expand to fill up the space available, which again is different from insect and disease pests. Most herbicides must also have some soil persistence in order to control weeds that germinate later in the season.

Over the 45 years that modern herbicides have been developed and used extensively, there have been many cases of differential tolerance within various weed species, such as intraspecific resistance to 2, 4-D, Dalapon®, and other herbicides. There are seen many examples of evolution toward interspecific herbicide tolerance. Researchers who have been trying to control weeds for some time have learned in many ways that nature is neither an exact nor fixed science. Nothing remains constant and weeds have been around a lot longer than scientists have. Weeds have learned to adapt and evolve to survive.

Some of the modern chemical tools have been so spectacular compared to the cultivator and hoe that we have become accustomed to seeing clean, weed-free fields, and become a bit complacent. Even when triazine resistance evolved, an easy way to circumvent these interlopers was found, with a new generation of spectacular herbicides (e.g., sulfonylureas, imidazilinones) which are effective at grams per acre instead of pounds per acre. They are just what was needed to help solve environmental concerns and other problems while adding dimension and flexibility to our weed control technology. Again weed scientists marveled at the success and potential of their inventions, but did not look back to see what nature was doing. Within the past few years, an increasing number of weeds have evolved resistance to these and several other new types of herbicides.

NEW ROLE OF HERBICIDE-RESISTANT CROPS

Knowledge about herbicide sites and modes of action has been essential in the research and understanding of herbicide-resistance mechanisms. Herbicide-resistant weeds have also been valuable scientific tools, contributing greatly to the understanding of herbicide modes of action, plant biochemical and physiological processes, molecular genetics, physical structure, and anatomy. However, it is interesting and significant that the mechanisms of resistance developed by weeds are often different from the mechanisms of selectivity to those herbicides in most crops. This is certainly true with the most prevalent and thoroughly studied cases of herbicide-resistance, including the triazines, dinitroanilines, and acetolactate synthetase (ALS) inhibitors.

For example, in the goosegrass (Eleusine indica), weed biotyped resistance to trifluralin, the tubulin in the roots, is apparently altered so that dinitroaniline herbicides are not effective in preventing tubulin polymerization into microtubules, which is assumed to be the mechanism of action of these herbicides. However, selectivity in most crops to these herbicides is believed to be due to the ability of their tap roots to rapidly grow through the treated soil layer or differential lipid content in seeds, thereby avoiding significant herbicide exposure.

Resistance mechanisms in weed biotypes to ALS inhibitors are apparently due to an alteration in the gene coding for acetolactate synthetase, resulting in various forms of insensitive ALS enzymes, the main target site of these herbicides. Crop tolerance, however, seems to be mostly dependent on differential metabolism.

Research to date indicates that most of the triazine-resistant biotypes lack the normal triazine binding sites in their chloroplasts, whereas crop selectivity is due mainly to metabolism or translocation differences. Triazine-resistant velvetleaf (Abutilon theophrastis) in Maryland is an exception in that resistance is due to enhanced glutathione transferase activity.

While most crops and weeds are susceptible to paraquat, paraquat-resistant horseweed (Conyza) biotypes may be insensitive to the herbicide due to elevated levels of superoxide dismutase and other enzymes, or to differential binding or distribution of the herbicide in the weed.

Recent research on the physiological basis of mecoprop resistance in chickweed indicated that resistance is due to reduced mecoprop binding at the sites of action in resistant plants. Data on mechanisms of most other types of herbicide-resistance in weeds are still not complete.

RESISTANT WEEDS AND CROPS AND THE FUTURE OF HERBICIDES

Resistance to the ALS inhibitors and other newer herbicides has already become a very serious issue. Industry, especially Du Pont, has responded quickly and appropriately to completely modify their marketing strategy and research programs to manage potential weed resistance to their sulfonylureas. Such responsible reaction of the part of the industry must be encouraged and supported. Everyone connected with agriculture should view herbicides as important nonexpendable tools that must be preserved for future generations. It is gratifying to hear and see more about product stewardship than ever in the past. Past performance in pest resistance management and use of our insecticides and fungicides, both in industry and on the farm, has often been irresponsible and shameful, and has contributed much to a poor public image. There must be better in management of herbicides and resistant weeds.

Of special concern is the occurrence of cross-resistance to many herbicides within the same species. The few cases to date are still a long distance away. The most noted examples are Lolium rigidum (annual ryegrass) in Australia and Alopecurus (blackgrass) in theU.K. However, it is very worrisome that multiple cross-resistance to herbicides can occur in plants, apparently by similar mechanisms (metabolic detoxification, e.g., mixed function oxidases) to some insects which rapidly evolve resistance to insecticides. Such efficient oxidation of foreign organic chemicals may prevent almost any herbicide from reaching the target site intact. When I first saw the one known case of diclofop methyl resistant ryegrass in Australia about three and a half years ago, and I learned that it was cross-resistant to most sulfonylureas, I warned them that they were potentially facing the worst case of herbicide-resistance I knew of in the entire world. This has proven to be the case, as this multiple-resistant weed has become widespread throughout most of the cereal producing areas of Australia. The solutions to this problem will not be easy, and cultural and agronomic methods will have to be included as well as, or possibly in place of chemical methods. Because of the striking ability this weed has for developing resistance to many herbicides, not only in Australia but in other parts of the world, Lolium is the housefly or Colorado potato beetle of the plant kingdom. A diclofop methyl-resistant Lolium multiflorum (Italian ryegrass) was recently discovered in Oregon. It was found to have some degree of cross-resistance. This genus must be respected, and we must avoid in any way possible evolving such plants with multiple resistant potential.

Because of much lower application rates, with less perceived human, animal and environmental exposure and risks, a very strong perception exists among government agencies and policymakers that the new sulfonylurea herbicides will replace many of those in current use. This perception comes at a time when some of the earlier herbicides are being discontinued or are in trouble because of economics, reregistration requirements, toxicology and environmental concerns. There will be a great need for the older herbicides and other tools of agricultural technology in the future. Chemical herbicides must be a major part of the agricultural technology in the decades ahead to provide the constantly greater demand for food, fiber and shelter, with greater cost effectiveness. But other means of pest control must not be discarded, nor should there be too much dependence on chemicals alone. Herbicide-resistance is acting as a self-imposed limiting system of nature, and nature sets the rules—be flexible or lose.

With the first invasion of resistant weeds, prompt action is essential in order to avoid serious and more permanent problems. Preventive action to avoid herbicide-resistant weeds from developing in the first place is definitely the best strategy. It is virtually essential in all cases of herbicide-resistance to have other classes or types of herbicides, with alternate sites and mode of action, available. In some countries and situations, control of triazine-resistant weeds has not been successful, resulting in rapid invasion and almost total loss of these herbicides in the area.

I have great concerns and doubts whether we can be as successful in avoiding or managing the more recent resistant biotypes as we have been with triazine-resistant weeds in the past. Not only are herbicide-resistant weeds appearing after fewer repeat annual applications of some of the newer herbicides, but there seems to be me species that have potential for resistance. It is likely that many, if not all, weeds possess some ability to evolve resistance to these herbicides. In addition, the resistant biotypes are apparently equally fit and competitive once they evolve, unlike most biotypes resistant to triazine herbicides.

Both wisdom and understanding developed on pest resistance to pesticides must be utilized, as well as greater marketing control and self-restraint than has thus far been demonstrated in U.S. agriculture, must be exercised in order to protect or prolong the use of the sulfonylurea and other herbicides with a single site of action and high risk for resistance. The following changes or strategy rules will be required:

—These herbicides should be marketed only in combinations, especially in major crops, if other types of herbicides are available as suitable partners.

—Crop and herbicide rotations should be used whenever possible. In rotations, avoid those with the same weed spectra.

—Use of long residual ALS herbicides should be avoided or minimized.

—Use the lowest rates possible.

—Minimize the number of applications per season, and use only every two or three years.

—Education and cooperation of industry management, marketing, sales, extension, farmers, and others is essential.

—Government agencies and policymakers must realize that all possible herbicides must be retained as potential mixing partners.

— Industry should not develop and market ALS resistant crops or crops resistant to only one herbicide with a high risk for resistance for the purpose of greatly expanding their use. This approach should be used to enhance tolerance in crop varieties, to avoid carry- over injury, for specific and limited special problems, and for minor acreage and high value crops. A major objective of developing herbicide-resistant crops should be to provide more flexibility in control of resistant weeds.

—These herbicides should be used in crops only where several other good mixing partners, cultivation, and other weed control options are available.

—Cultivators or other mechanical weed control options should remain available. Conservation tillage systems may not be a long-term or continuing option.

—If possible, industry should continue to develop chemicals in this class that will inhibit all types of ALS enzymes and overcome this resistance.

—Develop other herbicides that do not have a single site of action and are not as likely to induce resistance.

—Lastly, do not throw away the hoe, but rogue out the weeds that escape if resistance occurs or is suspected, or use systems that preferentially control resistant weeds.

98 Many politicians and those who like to tell farmers how to farm mention that herbicide-resistant weeds are one more reason for abandoning herbicides in favor of other methods. This is fine if other methods are actually available, profitable and environmentally desirable. But resistant weeds require that all possible herbicides be retained so that farmers have all possible options. Nature plays no favorites. Weeds, as with insects and diseases, will tend to survive and evolve resistance to any method used to control them.

I can agree with proponents of sustainable agriculture that we have at times depended on herbicides too much, or have expected too much from them. However, we should not ask farmers to get by without herbicides, and no one who likes to eat should try to compel them to do so. Rather, we must learn to better manage herbicides and preserve them by learning to use them as essential tools while avoiding and managing resistant weeds. We must also make further scientific breakthroughs or improvements in formulations, application technology, and handling methods to reduce human and environmental exposure and risk. These new low-rate herbicides must continue to be an important part of our future defense against weeds.

There is no way that biological and other nonchemical methods of weed control will totally replace chemicals in our lifetime. If anything has been learned in the past 40 years, it is that we will need all the help we can get to keep ahead of the pests, and to depend on only one tool or method against major pests is a sure road to failure and scientific heresy. Chemicals will continue to be essential and the main line of defense against weeds, and will help to produce the crops and pay for the research on biological controls, biotechnology, and sustainable agriculture while other tools are being developed.

As implied above, genetic engineers should reevaluate their strategy in developing herbicide-resistant crops. Five years ago, there were over 100 scientists or laboratories working on triazine resistant crops. This interest has greatly decreased for a number of valid reasons. The shift in priority has been toward ALS inhibitors and glyphosate. To scientists who are working on such a project for the purpose of using one of these specific herbicides exclusively and continuously, I strongly recommend that you drop the effort. Not only will it take longer to get the crop ready and approved for commercial introduction than originally planned, and resistant weeds may have already invaded your market, but if your herbicide of choice is used repeatedly, it will likely be only a few years before it will have resistance problems.

On the other hand, scientists should continue developing herbicide-resistant crops with the objective of offering growers greater weed control options and flexibility in the types of herbicides that can be used, especially as a strategy to control herbicide-resistant weeds. This research effort could also be justified by enhancing the natural selectivity of the target crop or reducing potential carry-over injury to rotational crops.

Most biotechnologists justified the need for genetically engineered crops as a way to get rid of pesticides. Now with the same kind of registration requirements and scrutiny that chemicals have always been subjected to required, biotechnologists are appalled at the confrontations and opposition. We need to be honest with each other and recognize that not only are biotechnologists working with live organisms that can reproduce, but in most cases, they are considering replacing a chemical with a chemical. While there may be some benefits of plant development, confinement of the toxicants, human or environmental risk, etc. there could even be more hazard from natural pesticides in engineered plants versus those treated with synthetic chemicals, unless they do not remain in the edible part of the crop and the plant residue is handled as a hazardous waste. But my major concern is that the farmer needs all the help and options available, and we should not consider that biotechnology and biocontrol are in competition or conflict with chemicals, nor immune from resistance. It may be that pests can soon evolve resistance to the "natural" chemical or method, as well as those externally applied.

HERBICIDES AND LISA

Herbicides have already made great contributions to low input and sustainable agriculture. The Low Input Sustainable Agriculture (LISA) philosophy promotes conservation tillage, as do all weed scientists. However, without herbicides, there would be little or no conservation tillage in most crops. Soil conservation programs, agricultural sustainability and production efficiency are, and will continue to be, absolutely dependent upon herbicides. This does not mean that mechanical (e.g., tillage, moving), biological (e.g., mycoherbicides, allelopathy, cover crops), and other tools are of no value. However, these methods will continue over the next 20 to 30 years, at least, to be very limited in application, even though their development and use needs encouragement wherever they fit the problem. There are many ways that herbicides can and are being used to protect and enhance the environment for use by humans, birds and animals, and in most cases, they will be safer and have less environmental impact than other weed control tools such as mechanical tillage, biological (live organism) controls, etc.

The switch from the moldboard plow and cultivator to conservation tillage systems makes us more dependent on herbicides, but the benefits more than compensate for the risks. This trend should be continued and increased where it can be advantageous to agriculture, as well as the environment. Conservation tillage not only protects 50 to 90 percent of essential topsoil that would otherwise be permanently lost by water and wind erosion, but it prevents much more than just inert soil moving into streams, rivers, lakes and air. This reduced erosion, combined with the erodable cropland that has been planted to grasslands or woodlands have already saved more than half a billion tons per year of top soil. Much more soil will be preserved if the projected 40 million acres (11 percent of total cropland) is set aside over the next two years and better herbicide programs could be developed to make farmers more confident that the weeds can be controlled without tillage. Some watershed studies in recent years have shown a reversal from major losses to net gain in soil. The Environmental Protection

Agency (EPA) and the public are increasingly concerned about pesticides in groundwater since analytical advances have allowed us to measure very low and often meaningless levels of synthetic chemicals in water, mostly traceable to point-source contamination. Virtually nothing is known about natural pollutants or mutagens that have been and may still be in drinking water. Some scientists need to study the effects of herbicides versus tillage practices on the movement of natural toxins (e.g., organics, inorganics, and microorganisms) into our water and air, including their potential mutagenic or health effects, identification, characterization, and quantification. Herbicides have had beneficial effects on water quality through conservation tillage; the whole picture needs to be seen.

Furthermore, it must not be assumed that LISA or alternate farming methods have no environmental impacts. They may, in fact, cause exposure to more toxic or objectional contaminants than do herbicides. For example, I would prefer to drink water coming off of or from under a field treated with herbicides and commercial fertilizers rather than a field treated with 10 to 20 tons per acre of cow manure. We do not know everything that manure contains, and it may be that very little of it reaches groundwater, but there could be contaminants in runoff water. We need to know what the effects and comparative risks are, and not assume that LISA is a safer way to farm than using synthetic chemicals. There is not, never has been, and never will be zero-risk agriculture or life.

Another concern about LISA, or any arbitrary reduction in the use of herbicides, is the phenomenon of biological changes with time. In many situations, the weed populations and pressure are not the same as 30 years ago. Where herbicides have been extensively used, some species have almost disappeared and the weed seed density in the soil is often much reduced. This is not obvious or easy to measure, especially to nonbiologists, because there are still many weed seedlings that germinate each spring. This phenomenon is even contributing to some of the short-term successes from cutting back on herbicides. But, the full effect of reducing or eliminating herbicides will not be seen the first year. Nature will adapt and take advantage of any nitch available, and the weed infestations and species will likely get worse with time.

PUBLIC AND POLITICAL PERCEPTIONS

The main problem in agriculture today is not the technology, but public perceptions. There is no significant exposure or risk to human health or the environment from herbicides in food or groundwater; we are at serious risk of solving the wrong problem. Ignorance, fear and emotions must be replaced by education, reason and rational thought and action. There is the option of dropping herbicide use and purchasing only food produced without them, but we will not remain competitive in world agriculture. We will depend more and more on imported foods, our surpluses will disappear, we will have less control on the quality of our food, and the greatest agricultural technology in the world that is responsible for providing by far the highest quality and variety of food at the lowest prices that this country or any other has ever known, will be in jeopardy.

With considerable misgivings, I am prompted to say that what we most likely need in this country and some others in the developed world is to experience a little famine. It is only because of our surplus and efficient production without farmers always being the economic benefactors that we have such vocal opponents to herbicides. With only two percent of our population on the farm, our graneries and supermarkets full, and people who do not have an appreciation for how sensitive the balance is between feast and famine, some difficult choices lie ahead. We need to learn to live with herbicides and solve the right problems.

In summary, nothing will come out of biotechnology, biocontrol organisms, or other presently perceived and much talked about technology that will substantially replace chemicals for weed control in the foreseeable future (20 to 40 years). I hasten to add that there will be very useful tools and technology developed to help us do better in selecting the more acceptable herbicides, using lower rates, reduce the leaching and environmental impact of those used, getting more of them to their sites of action, improve the integration of other control methods for best management practices, use of biologicals for control of major or nixous weeds which cannot be adequately controlled with herbicides, and other improvements for the protection of both crops and the environment. But just do not try to do it without chemical herbicides or agriculture will fail to be competitive, profitable, sustainable, or environmentally sound.

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Should the Development of Herbicide-tolerant Plants be a Focus of Sustainable Agriculture Research?

Should the development of herbicide-tolerant plants be a focus of sustainable agricultural research? According to an Environmental Protection Agency (EPA) publication from 1985, herbicides comprised roughly 60 percent of the pesticides used in the United States, about 500 million pounds of the roughly 860 million pounds of pesticides used annually in this country. Of these 860 million pounds of pesticides, including herbicides, estimates are that perhaps at most, 1 percent reach their target pests. The rest simply contaminate soil, water, crops, and farm workers.

What are the effects of this excessive use of herbicides^ Herbicides are designed to kill plants. Although there are a few exceptions, herbicides tend not to be acutely toxic to animals, that is, they generally do not have immediate toxic effects. A number of herbicides have, however, been implicated as chronic toxins, chemicals that have long-term health effects. Use of 2,4-D, for example, has been linked with non-Hodgkin's lymphoma in farmers and there is substantial evidence that Alachlor, the most heavily used herbicide on corn, is a carcinogen.

How does this effect usi The National Academy of Sciences estimated in a 1987 report that 31 percent of the oncogenic risks of pesticides on fresh foods is attributable to herbicides. But perhaps the most serious environmental effect of herbicides is the contamination of groundwater. Until the late 1970s, few thought that pesticides could possibly leach through soil into groundwater. When discussed, leaching was deemed virtually impossible. Then in the late 70s, the insecticide Aldicarb was discovered in numerous wells on Long Island, and since then, the list of pesticides detected in groundwater has continued to grow. The EPA decided to compile the existing data on groundwater contamination in the United States, and their report was published in December 1988. The EPA has designated classes of pesticide detections ranging from those that are unconfirmed, where data is of unknown quality, to confirmed detections that are attributable to certain agricultural practices. In almost all confirmed cases of detection, groundwater contamination is due to agricultural use and a large percentage of the pesticides found are herbicides. Eight different pesticides have been detected in the groundwater in Iowa and the state with the most pesticides detected is New York, with twenty-one.

Two things make this contamination particularly scary. First, over 50 percent of the United States population depends on groundwater for drinking, and so are exposed to contaminants many times every day. Second, once contaminated, groundwater cannot generally be cleaned up.

HERBICIDE-TOLERANT PLANTS

Biotechnology has been touted as being able to do a lot things, from allowing us to create corn that fixes its own nitrogen, to creating crops that will save us from the drought and heat resulting from the greenhouse effect. But at least for now, researchers do not have the knowledge to fulfill many of these promises. Herbicide-tolerant plants, on the other hand, are an application of biotechnology that has become possible.

Herbicide-tolerant plants also have the potential to be tremendously profitable. It is no secret that most agricultural chemical companies now own seed companies, and the combined interest in seeds and herbicides could offer considerable financial rewards, especially when seeds promote the use of a herbicide that is already patented. If one believes the 1987 biotechnology newsletter, Agricultural Genetics Report, sales of herbicide-tolerant plants could come close to $6 billion a year by the turn of the century. Seeds that tolerate Roundup® could boost Monsanto's sales of this herbicide by $150 million. Seeds that tolerate the herbicide Basta—and plants which resist Basta® are about to be tested in Minnesota—would bring the German firm, Hoechst an additional $200 million in sales. Industry clearly recognizes this profit potential. The Rural Advancement Fund International in North Carolina has compiled a list from published sources, of institutions doing research on herbicide-tolerant plants. They find that at least 21 enterprises have launched 68 research programs on herbicide- tolerant plants.

What are the environmental implications of all these herbicide- tolerant plants, if they are developed^ There has been a lot of discussion about the risks of releasing genetically engineered organisms. It has been widely agreed among government officials, industry representatives, scientists, and environmentalists that the main risk of using herbicide-tolerant plants is that they may cross-pollinate with wild relatives and transfer genes conferring herbicide tolerance. This could increase the problems farmers have with herbicide-resistant weeds.

Most crops have few, if any, wild relatives with which they could hybridize in this country. Because most major crop plants in this country were imported from other continents, it is on these continents—primarily inThird World countries—that problems can be expected. Although gene transfer is a legitimate concern in this country, it is not a major concern.

EFFECTS OF HERBICIDE-TOLERANT PLANTS ON HERBICIDE USE

More of a concern than the risks of using herbicide-tolerant plants are the purposeful effects of herbicide-tolerant plants on herbicide use. Proponents of herbicide-tolerant plants argue that as more herbicide-tolerant crops are developed, farmers will be able to replace older, more dangerous chemicals with newer, more environmentally benign herbicides. The U.S. Department of Agriculgure (USDA) has granted many permits under the Plant Pest Act for field tests of herbicide-tolerant plants modified with recombinant DNA techniques. (Through a quirk of the law, the USDA only regulates field tests by plants modified with rDNA techniques, not plants modified with microprojectile techniques, cell cultures, or other methods.) Plants that resist three classes or types of herbicides have been field-tested; plants that resist glyphosate, bromoxynil, and the sulfonylureas. Advocates of herbicide-tolerant plants argue that glyphosate and bromoxynil degrade rapidly and that the sulfonylureas are used in such small quantities that they will have negligible harmful effects. Because these herbicides are toxic to most crops, herbicide-tolerant plants are needed to make these herbicides more useful. But, there are a number of problems with this argument. Most importantly, all the effects of these newer herbicides may not be acknowledged. Glyphosate, for example, is not acutely toxic to mammals and is widely alleged to be safe, but it seems that in at least one of its chemical formulations, Monsanto's Roundup®, is acutely toxic to some fish, aquatic vertebrates, and, in very large dosages to humans. Glyphosate degrades quickly in most soil types, but glyphosate can persist in runoff water and be carried downstream. Although I have not seen the data, there is some evidence now that bromoxynil causes birth defects. Sulfonylurea chemicals are toxic to plants in minute quantities, and these herbicides do not degrade very quickly. Slight pesticide drift can have disastrous consequences for crops and native vegetation. In Franklin County, Oregon, for example, potatoes, carrots, fruit trees and other crops were damaged after the sulfonylurea herbicide Oust® was applied to roadsides in 1985. Local farmers subsequently went to court and won damages from the county and Du Pont, the herbicide's manufacturer. Farmers in Iowa are in a similar situation this summer. Numerous farmers used American Cyanamid's herbicide Sceptor® on soybeans last summer. Sceptor® is a modern herbicide that is toxic in very small quantities. Because of last summer's drought, the herbicide did not degrade and is now threatening corn planted in last year's soybean fields. American Cyanamid is funding research to develop crops that tolerate the imidazolinones, the class of herbicides that includes Sceptor®.

Even if newer herbicides are safer than older ones, they may still have significant undesirable effects. Should newer herbicides be promoted instead of developing products and practices that lessen or provide alternatives to herbicide use?

Work on herbicide tolerance is not limited to allegedly safe chemicals. According to a recent survey of publications by the Rural Advancement Fund International, crops are now being engineered to resist a number of herbicides that leach into groundwater, including Lexone®, Sencor®, Treflan®, and atrazine. Lexone®, Sencor®, and atrazine are listed by EPA as possible carcinogens, but because these plants pose no direct environmental or health risks, there is no mechanism for the public to have any influence over their development.

Proponents of herbicide-tolerant plants argue that newer herbicides are effective at lower application rates than other herbicides, so herbicide-tolerant plants could reduce the amount of herbicide needed for weed control. There are problems with this argument. In some circumstances, herbicide tolerance will clearly increase use. For example, one of the major limiting factors on Atrazine application rates has been the problem of Atrazine carry-over. This new herbicide persists in the soil and damages the subsequent crops, such as soybeans and oats. If Atrazine-tolerant soybeans were developed, they could greatly increase the rate of Atrazine application on corn without damage to subsequent crops.

Herbicide tolerance may blunt the economically motivated reduction in herbicide use taking place on some farms. In recent years, some farms in the corn belt have shifted from broadcast application of herbicides—application on the entire field—to banding of herbicides—application just on crop rows. Weeds between rows can be easily controlled by mechanical cultivation. Even farmers who broadcast herbicides generally cultivate once, partly because herbicides rarely provide 100 percent weed control. If herbicide tolerance would allow farmers to gain 100 percent weed control without mechanical weeding, it would discourage the shift to banding.

Proponents of herbicide-tolerant plants also argue that herbicide-tolerant crops will give farmers a larger number of options for weed control. However, herbicide-tolerant plants may increase problems with herbicide-tolerant weeds through gene transfer and also through their effects on patterns of herbicide use. If herbicide-tolerant crops cause certain herbicides to become very widely used, weeds resistant to these herbicides are likely to evolve. Farmers will then not be able to use these herbicides even when they are legitimately needed, such as in integrated pest management programs.

WEED CONTROL RESEARCH FOR SUSTAINABLE AGRICULTURE

Herbicide-tolerant plants could cause substantial problems for agricultural and natural ecosystems, as well as human beings, and research on herbicide-tolerant plants should not be a part, and certainly not a focus, of sustainable agriculture research programs. What sort of weed control research should be supported as part of sustainable agriculturei Weed control measures that could lessen our dependence on herbicide use include crop rotation, cover crops, inner cropping, breeding crops to enhance allelopathy, timing tillage and planting to take better advantage of weed and crop germination times, engineering crops for increased cold tolerance so they emerge earlier, biological control with pathogens or insect herbivores, new integrated pest management strategies, and mechanical control.

One promising technique is ridge tillage. Ridge tillage is a cultivation method that reduces or eliminates the use of herbicides while retaining erosion control. Studies have shown that ridge tillage is about as effective as conservation tillage for erosion control. To use ridge tillage, a farmer builds a series of ridges and valleys across his or her fields. Crops are grown on the ridges and the wheels of farm equipment roll through the valleys. Once ridges are put into a field, they are permanent and do not have to be put in again. At spring planting time, a farmer goes through the field with his tractor and shaves off the top of the ridges. This removes any existing weeds and the seeds are then planted. As the plants emerge on the first cultivation, the farmer goes through again and cultivates by taking dirt off the top of the ridges and throwing it down in the valleys, which covers the weeds. On the last cultivation, the farmer takes dirt from the valleys, and throws it back up on the plants, again, to cover weeds and also rebuild the ridges. If herbicides are used in ridge tillage, their application can be reduced because it is easier to focus herbicide applications on ridges than with other techniques.

Ridge tillage is not for all farms. 11 does not work on sandy soil, but it is a good example of the kind of weed control options that should be researched and developed. Ridge tillage is not a panacea, but it is the sort of technique with which weed control strategies can be built.

OTHER USES OF HERBICIDE-TOLERANT PLANTS

Herbicide-tolerant plants could be developed for uses other than in conventional agriculture. Future homeowners, for example, might seed their lawns with herbicide-tolerant grass, and transportation officials might seed right-of-ways along roads and railroads corridors with herbicide-tolerant ground covers. Foresters may plant herbicide-tolerant trees in newly logged areas. Research to develop herbicide-tolerant trees is already underway.

Herbicides are used in forestry before and after tree seedlings are planted. Before tree seedlings are planted, newly logged areas are treated with herbicides to kill competing vegetation. After planting, herbicides are used to free commercially valuable trees from competition with other trees. At present, only a fraction of forests are aerially sprayed with herbicides. This fraction varies substantially with forest ownership, with forest terrain, and with the tree species harvested. The U.S. Forest Service sprays more often than small landowners.

Other methods to remove unwanted vegetation include mechanical control, injecting unwanted trees with herbicides, and burning. These other methods are relatively expensive. The Forest Service would like to increase herbicide spraying. Forest Service researchers believe that, "herbicide use would be more widespread and efficient if cultured tree species were immune or highly resistant to commonly-used herbicides". The biotechnology company Calgene and the Forest Service have produced, in a joint project, genetically engineered poplar trees that have limited tolerance to the herbicide Glyphosate®. The Forest Service is also planning a project to develop jack pine and poplar that tolerate the herbicides Hexazinone® and Glyphosate® respectively. This project is being done at the Forest Service's Rhinelander, Wisconsin Experiment Station using tissue culture techniques.

Herbicides can harm wildlife habitats, both by directly effecting the health of wildlife and also by changing plant community composition in forest areas. Uses of herbicide-tolerant trees could also effect the long-term productivity of forests. After clear cutting, tree seedlings are commonly planted six to fourteen feet apart. Pioneer vegetation, such as brambles, shrubs, and vines, grows rapidly over the newly-opened area and competes with tree seedlings. In a famous experiment at Hubbard Forest Research Station, scientists clear-cut a section of a watershed and prevented regrowth of plants with herbicides. Without pioneer plants to stabilize the soil, new plants were washed away and the quality of the site rapidly diminished. Clearly, if the use of herbicide- tolerant trees leads to similar suppression of pioneer vegetation, forests will deteriorate.

It is also ironic that the Forest Service is developing herbicide- tolerant trees at the same time as four Forest Service Management Regions and the Northwest Office of the Bureau of Land Management have prepared draft environmental impact statements (EIS) promoting reduction of herbicide use as the "preferred" alternative. These draft EISs, result of a lawsuit settlement, must consider the effect of vegetation management practices on natural ecosystems as well as timber production.

Herbicide-tolerant trees may make short-term economic sense for foresters, but designed as they are to increase herbicide use, they are incompatible with land stewardship. Using them in government forests would be a strong expression of timber primacy, the idea that forests are managed for timber production, not conservation and recreation.

CONCLUSIONS

The development of herbicide-tolerant plants is being advanced without constraint or enough adequate thought. Whether considering herbicide- tolerant trees or atrazine-resistant crops, herbicide-tolerant plants have the potential to increase our problems with these chemicals. This is not to say that there cannot be any benefits to herbicide-tolerant plants. It would certainly be better to have the farmers plant fields with herbicide-tolerant plants and treat them with Glyphosate® or sulfonylureas rather than plant them with non-resistant crops and treat with an herbicide known to contaminate ground water, such as Alachlor. But given alternative forms of weed control, it would be better to use weed control methods which minimize chemical use. Public sector funding could help the development of weed control alternatives that, unlike herbicide-tolerant plants, the industry has not found potentially profitable. After all, that is in large part why government research exists.

110 Government funding for sustainable agricultural research is limited. We should be investing these scarce dollars in techniques that, over the long haul, will change agriculture so that it does not degrade our environment or threaten human health.

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Is Genetically Engineered Herbicide-resistance (GEHR) Compatible with Low-input Sustainable Agriculture (LISA)?[1]

The idea of selecting crop plants for their ability to flourish in the presence of herbicides is not new. Even before molecular biologists introduced the techniques of gene splicing, researchers used traditional techniques to create varieties of, for example, wheat. Wheat seeds were soaked in ethyl methanesulfonate and then grown in soil treated with an s-triazine herbicide, terbutryn[1]. Most of the seeds failed to come up, but those that survived produced wheat seeds tolerant of terbutryn. In the same study, tomato seeds were soaked in the ethyl methane sulfonate, producing tomato plants with increased tolerance for the herbicide diphenamid. The seed industry has recognized the importance of herbicides resistance research since at least the late 1970s when the commercial sugarcane breeding program in Hawaii began screening all new varieties for tolerance to chemical weed killers.[2]

Genetic engineering speeds up the process of producing those varieties. Researchers in Canada used molecular techniques to transfer genes from weeds resistant to the herbicide atrazine into rapeseed and rutabaga, allowing “atrazine [to] be used on crops in northern latitudes, where field conditions render other forms of weed control ineffective”.[3] Du Pont has bred tobacco plants resistant to its sulfonylurea

'This text is excerpted from “Genetically Engineered Herbicide-resistance,” a two-part article that appears in the Spring and Summer 1990 numbers of the Journal of Agricultural Ethics, and is reprinted by permission of the Journal Editors.

compounds, Calgene has bred tobacco and tomato plants resistant to Monsanto's herbicide glyphosate ("Roundup®"[4]), and Monsanto has produced petunias that can grow in the presence of this popular chemical.[5] Forestry and chemical lawn industries are watching with great interest as private labs and public universities apply more and more sophisticated genetic engineering techniques in herbicide- resistance research. Much of the research is funded with public tax dollars, and much of it is going on at land grant universities whose charge is, in part, to educate and help to improve the well-being of "the industrial classes."

The beneficiaries of genetically engineered herbicide-resistance (GEHR) research would include not only the companies that successfully market the seed and chemical packages but farmers and consumers as well. For example, farmers, who face tougher species of weeds every year might have more efficacious and safer chemicals available. Consumers, more and more of whom appear to be worried about pesticide residues on and in vegetables, fruit, and meat, may be able to buy produce grown with less dangerous herbicides. Despite its potential advantages, however, GEHR technology might also bear significant costs. Leaving aside for the moment agronomic questions like whether GEHR crops will actually work in the field or how long it will be before weeds resistant to the new chemicals appear, consider ethical questions that have been raised.

Some express reservations about the propriety of crossing unrelated plant species. Jeremy Rifkin, for example, has argued that it offends God to cross plants with weeds when the two species cannot be crossed by natural means of reproduction.[6] Is it right to violate species boundaries set up by "natural law"? This question may appear extreme to some plant geneticists and breeders, but it deserves the attention of moral philosophers interested in agriculture.

Others have expressed concern that new labor-saving technologies may displace farmers. Genetically engineered herbicide-resistant crops might increase the productivity and efficiency of an hour of a farmer's time, but what would that mean for farm and rural economies that are already unstable? For two hundred years, technologies have substituted for labor and farmers have been forced out of agriculture. Is this a trend that we want to continue? Is it socially desirable that the poverty rate in nonmetropolitan areas now exceeds that in cities? Do we want another farm technology that might contribute to more farm foreclosures? On the other hand, could GEHR crops help some marginal farmers become more productive, help them to compete better with foreign competitors, and thus revitalize rather than destroy our rural economies? The potential social and economic effects of GEHR crops on rural income levels and distribution is another question needing examination.

Some have worried about the medical and environmental safety of the final product. Will GEHR potatoes really be safe for humans, or will toxic residues remain in or on the vegetables? Will GEHR field corn harm pigs that eat it or adversely affect cows that graze where its residues remain? Will toxic compounds accumulate in the tissues of fish in streams collecting GEHR runoff? Given the magnitude of ecological problems we now face, problems such as soil erosion, groundwater pollution, and the destruction of rainforests in developing countries growing export crops, should we not try to imagine less environmentally taxing ways of growing food? The environmental impact of GEHR crops also needs investigation.

Another worry concerns the economic power of the large chemical firms investing in GEHR crops, powerful multinational companies like Monsanto and Du Pont. Will this technology allow a few chemical companies to strengthen their hold over an industry that is already oligopolistic, forcing American farmers to pay inflated prices for seeds and chemicals? Will consumers eventually pay higher food prices? The economic power of the chemical industry marketing GEHR crops deserves attention.

Finally, some are worried about who we are as a people, our communal identity. Genetically engineered herbicide-resistant crops might make American agriculture more dependent on chemical-intensive and capital-intensive practices. Is this the direction in which we want to go? If we follow this course, do we risk rendering our food supply vulnerable to attack by a single virulent organism or resistant weed? Do we want to encourage exploitive attitudes toward nature? Our cultural sense of ourselves is another matter meriting attention.

Moral questions like these cannot be answered by scientific analysis. To make ethical judgements well requires that we possess the facts, and no one who closes their eyes to the science of agricultural biotechnology will be able to make informed moral decisions about it. But science at its best gives us accurate descriptions of problems.

Ethical judgments require philosophical reflection having to do with prescriptive analysis. Where scientists ask "What is going on?" and "What can be done?" philosophers ask "What ought to go on?" and "What should be done?" Answering the ethical questions requires the use of the best available data and scientific theory, but it also requires the use of the best available humanistic reflection and philosophical theory.

An adequate discussion of the morality of agricultural biotechnological research designed to facilitate the prevention or killing of weeds must take into account a broad range of issues. Looking at weeds from a holistic perspective, one that recognizes all of the relationships necessary to establish a plant as a weed, gives rise to many intriguing questions. For example, why is it that virtually every acre of corn grown in the United States in the past decade has been sprayed with atrazine, alachlor, or a similar herbicide? Is it because farmers have been financially motivated to try to capture that extra four to twenty percent of yield? Or is it because of some unspoken aesthetic working powerfully in the rural unconscious, defining for the modern agribusiness farmer how a cornfield should appear? And this: Why are both public and private institutions so interested in genetic engineering techniques that will produce corn and bean plants able to grow in the presence of stronger doses and mixes of these chemicals? Is it because certain varieties of crabgrass have developed a resistance to atrazine and sterner measures are needed to deal with them? Or is it because giant seed and chemical conglomerates want to prolong the life of old moneymaking compounds?- Is it because new chemicals will soon replace the old suspected carcinogens and give us a safer rural environment? Or is it because molecular biologists have the single-gene replacing technology needed to give tomato plants resistance to glyphosate and, having it, want to use it? Or this: Now that atrazine has turned up in the wells of some farm families, why are land grant universities doing research to find crops that can be grown in the presence of stronger doses of it? Is it because farmers desperately need extra income for their squeezed pocketbook? Or is it because weed scientists at those universities have research projects and labs geared up for answering questions about chem* ical means of weed control and not for answering questions about cultural means thereof?

I do not have space here to answer all of these questions. (Interested readers may wish to have a look at the longer version of this article in the Journal of Agricultural Ethics.) I will address only the question named in my title, How compatible is genetically engineered herbicide-resistance (GEHR) technology with the goals and values of low-input sustainable agriculture (LISA)?

THE COMPATIBILITY OF GEHR AND LISA

Farmers brought low input and sustainable rotation schemes with them to the United States from Europe, often rotating wheat, oats, and barley over a five or six year period with corn or beans interspersed with years when the land would lay fallow or be used for pasture. These cultural practices have now largely disappeared from American agriculture, being replaced by monocultures or bicultures heavily dependent on purchased inputs. (It is worth noting, however, that rotation schemes have not been completely displaced. Practical Farmers of America, an Iowa based organization which claims to have many members, recommends a five year rotation in which corn, soybeans, corn, oats, and hay are grown in successive years.)

Low input sustainable agriculture techniques like multi-year rotations are regaining credibility as the agricultural establishment begins to give them some attention, and yet LISA is not the norm for controlling weeds, as recent history proves. Before the Second World War with its huge governmental expenditures on chemical research and development, farmers used comparatively few synthetic chemicals on their fields. By 1949, however, they were spraying 25 different herbicides on 23 million acres of corn, wheat, and turf. By 1959, one year after the introduction of atrazine, the number of chemicals had quadrupled, and the number of acres treated had almost doubled. Still, the 100 or so herbicides and the 52 million acres receiving them represented less than 15 percent of total crop land in the U.S. in 1959. The explosion occurred in the 1960s, especially with the introduction of Alachlor® in 1969. By 1974 over half of all crop acreage was receiving herbicides, a total of more than 160 million acres. The percentage of money spent on herbicides has also constantly increased. Whereas nitrogen and insecticide costs were dominant in 1951, 58 percent of a farmer's expenditures on chemicals went to herbicides in 1974.[8] By 1978, the tonnage volume of herbicides sold by the agrichemical industry was second only to that of fertilizer.[9]

As herbicide use went up, so did total yields of crops and total values of crops lost to weeds. According to one estimate, 100 million bushels of soybeans were lost in 1970, a typical year, because of competition from weeds. This was the equivalent of what would have grown on 4 million acres.[10] As the value of crops lost to weeds went up, so did farm purchases of herbicides. By 1974, farmers were spending over one billion dollars each year on different chemicals designed to kill weeds.[11]

Why does herbicide use keep increasing? One reason is that the herbicides, while wiping out a huge percentage of some species of weeds, do not kill all of the individuals in that species. Some biotypes within the targeted species have a higher tolerance to the chemical. They survive the application, and reproduce quickly in fields where more fit competitors have been removed by the herbicide. This is known as selective pressure. Together with the fact that there are likely to be some weed species that are not killed by the herbicide, the fact of differential tolerance within species makes it necessary for the farmer to begin using more and different herbicides in succeeding years.[12] Use of the phenoxyzcetic herbicides for example, while controlling certain weeds, led to an increase in “chickweed, knotgrass, redshank, speedwells and hempnettles.”[13] Other examples are wild carrots, a weed that seems to thrive on propazine, and the birdsfoot trefoil, which grows well “after Simazine® treatment”, and finally, “of green foxtail and crabgrass after atrazine treatment.”[14] Each “new generation” of chemicals is soon met by species of chemical-resistant weeds, much as each new generation of insecticides is eventually confronted with mutant bugs that can tolerate the bug killer. For example, several years after the phenoxyacetitates were introduced in 1945, foxtails became a major problem. 2,4-D Selectively kills some broadleaf (dicot) weeds in corn, wheat and grass seed fields with little or no damage to grasses. But foxtails, a tough perennial monocot, were never controlled by 2,4-D. Understandably, Midwestern farmers jumped when CIBA-GEIGY introduced Atrazine® for use on corn in 1958.

Here was a third “new generation” of herbicides, and some corn farmers adopted it hoping that the pre-emergent would deal with their foxtails and quackgrass. By 1977, it had become the number one herbicide in the number of crop acres treated and in total dollar sales in the U.S. [15] No wonder industry officials took to calling the s-triazines “remarkable,” “a new dimension in . . .corn growing”.[16]But atrazine did not control crabgrass and foxtails, and the search for new chemicals continued.

In 1968, a triazine-resistant weed called common groundsel was discovered in western Washington.[17] But more common than the development of resistant biotypes such as these atrazine-resistant weeds, is selective pressure shifting the population of the weed species toward preexisting tolerant biotypes. So crabgrass, which was never controlled by atrazine, continued to plague monocultured corn fields, and the way was paved for a fourth "new generation", consisting of acetanilides like Monsanto's Alachlor® in 1969 and benzothiadiazines like BASF's Bentazon® in 1973.[18]

So the story goes. Contrary to what one writer claimed as recently as 1982, there is little evidence to show that resistance to herbicides has actually occurred, at least 100 herbicide-resistant weeds have been identified and weed populations tolerant of almost every herbicide known have been discovered.[19] Advertisements in farm journals now regularly recommend that farmers mix trade chemicals such as "Banvel®" with 2,4-D, MCPA, Glean®, Ally®, Finesse®, or Harmony® to "control tough broadleaves like kochia and wild buckwheat, and sulfonylurea herbicide-resistant weeds like Russian thistle and prickly lettuce."[20]

Is the recent popularity of LISA cutting into the popularity of herbicides^ There is no evidence for this claim yet. In 1976,165 herbicides were used on 200 million acres with total sales at $850 million. In 1986, total sales in the U.S. alone were worth 3.6 billion dollars.[21] By 1987, one third of all crop land in the U.S. received treatments of either atrazine or Alachlor, and these and other herbicides were applied to over 95 percent of the acres devoted to corn and soybeans, and over 60 percent of those devoted to wheat.[22] In 1982, a single company sold over a billion dollars of herbicides.[23]

But is GEHR compatible with USA's values? That may depend upon how we define LISA. There are many definitions currently being used. The state of California, for example, requires that its "organic" farmers operate for three years without applying any synthetic chemicals to their crops. Only in the fourth year can their produce be legally certified as organic. If you were to adopt this definition for LISA, GEHR crops would by their very nature be incompatible with sustainable agriculture because the seeds are designed to be used with synthetic chemical sprays.

A less stringent definition is found in Wendell Berry's definition of good farming. Good farming for the Kentucky poet, essayist, and farmer, is simply "farming that does not destroy either farmland or farm people," a definition that leaves room for GEHR technology. I can imagine a judicious farmer using GEHR crops and herbicides once or twice every five or ten years while practicing the Practical Farmer's multi-year rotation.[24] On the second definition of LISA, GEHR is theoretically compatible with LISA.

The U.S. Department of Agriculture (USDA) offers another definition according to which LISA means, an economically profitable system which relies on each farmer's interdisciplinary knowledge. A democratic and individualistic kind of farming in which decisions about chemical use are made at the local level, USDA's idea of LISA insists that important decisions be made by farmers at the local level rather than at the national level by farm programs or experts. According to this definition, LISA farming aims at reducing, but not necessarily
 eliminating, synthetic chemical use.

Genetically engineered herbicide-resistance technology is theoretically compatible both with Wendell Berry's definition of good farming and with USDA's definition of LISA. But the real world differs from the world of theory. How compatible are GEHR and LISA likely to be in practiced Consider that modern agriculture is a highly inflexible system, not very amenable to piecemeal change. The rapid expansion in the use of herbicides after World War II went hand in hand with the use of industrially produced pesticides to control insects, synthetic anhydrous ammonia—and now ureas—to supply nitrogen, manufactured super-phosphates to provide phosphate, large amounts of capital to purchase the inputs, and large tracts of land over which to spread the costs. This produced an agriculture that exemplifies Charles Perrow's definition of a complex and tightly linked technological system.[25] As commercial nitrogen is used to stimulate the growth of high yielding varieties, it stimulates the growth of weeds as well. (In 1965, corn farmers applied 75 pounds of nitrogen per acre. In 1987, they were using over 130 pounds per acre.[26]) Herbicides are then needed to control weeds. Next, insecticides become important as pests are introduced from abroad through internationally connected markets in seeds and produce. Finally, because the technologies used are increasingly expensive (a pound of Atrazine sells for about $2.40, the newer alachlor for about $4.50, and glyphosate for approximately $22.00), farmers must have access to increasing amounts of capital for operating expenses.[27]

Despite the common wisdom that each farmer is an independent entrepreneur, the fact is that farmers have relatively few choices about their operations once they make the decision to enroll in government subsidy programs. When they make that choice, they almost invariably use high-input techniques and monoculture or bicultures. When they choose to go to a corn and soybean rotation in order to keep their acreage base, they must often choose to downplay the use of livestock while emphasizing crop production. This requires that they use purchased fertilizers, purchased herbicides, and that they use fungicides and pesticides.

It is almost impossible to play one part of the game while not playing all of the others. Choosing farm programs means choosing bicultures, large combines, large amounts of capital, large fields, and tons of purchased inputs. If you use 2,4-D to control weeds, sooner or later you will need insecticides to control corn-leaf aphids stimulated by the herbicide.[28] Sooner or later, you will also need fungicides to control smut and Southern corn-leaf blight that seem to accompany 2,4-D use. Once you start growing corn in a monocultural nonrotation, or corn and beans in a two year rotation, it is virtually impossible to change to a four or five year rotation without sacrificing your acreage base and, with it, your eligibility for essential government payments.

Contrary to popular wisdom, farmers are not autonomous businesspersons and farming is not a flexible system. You either play the whole high-input game or you are forced out of business. This is why the values of LISA will be so difficult to move from theory to practice. This is why many farmers who would like to move toward low-input systems have such difficulty figuring out what their first step should be. If they give up pesticides one year, their yields will be unable to service their debt load. If they give up large fields, their big combines will not be able to pay their way. Many farmers do not know how they could even slightly modify their game plan without jeopardizing their families' future. They are enmeshed in a tightly coupled system.

Will GEHR chemicals and crops help those farmers to make the transition out of modern chemical agriculture? The answer depends on whether the companies investing in GEHR technology want to market the product to low-input sustainable farmers. In this context, remember that research and development of GEHR technology is very expensive, and is being pursued at present primarily by large multinational corporations. When GEHR seed and chemical packages are ready to be marketed, they will be promoted by the advertising wings of these conglomerates. Will giants like Monsanto, CIBA-GEIGY and Dow Chemical try to recuperate their research and development costs by selling GEHR technology to smaller, quasi-organic farmers who will buy their seeds and herbicides only once every five or ten years? Or will they do as they have done in the past, direct their marketing departments to target sales toward big farmers and big cooperatives that can buy seeds and chemicals in bulk? In my judgement, the latter scenario seems most likely. If I am right, GEHR technology, far from reversing the trend of the last century toward fewer and larger farms, will add impetus to the trend as new comparative advantages are introduced for larger, chemical-and capital-intensive, farmers.

Genetically engineered herbicide-resistant crops promise to make American agriculture an even more tightly knit system, not a more flexible one. It makes little difference whether you adopt a rigid or loose definition of LISA. Even if GEHR and LISA are compatible in theory, they are not likely to be compatible in fact.

NOTES

1 Moshe J. Pinthus, Yaacov Eshel, and Yalon Shehori, "Field and Vegetable Crop Mutants with Increased Resistance to Herbicides", Science 177 (25 August 1972): 715-716.

2 Webster H. Sill, Jr. Plant Protection: An Integrated Interdisciplinary Approach (Ames: Iowa State University Press, 1982), pp. 201, 286. Sill cites M. Pinthus, V. Eshel, and Y. Shehori, "Field and Vegetable Crop Mutants with Increased Resistance to Herbicides", Science 177 (4050): 715-716.

3 Charles M. Benbrook and Phyllis B. Moses, "Engineering Crops to Resist Herbicides," Technology Review (November-December 1986): 57.

4 Cf. JoAnne J. Fillatti, John Kiser, Ronald Rose, and LucaComai, "Efficient Transfer of a Glyphosate Tolerance Gene into Tomato Using a Binary Agrobacterium Tumefaciens Vector" Bio/ Technology 5 (July 1987): 726-730.

5 Cr. unpublished draft of a paper by Loren W. Tauer and John Love, "The Potential Economic Impact of Herbicide-Resistance Corn in the United States," (Cornell University: Department of Agricultural Economics, November 1988): 1; Anonymous, WSSA Newsletter [Weed Science Society of America] 16 (1988): 8; Charles M. Benbrookand Phyllis B. Moses, (1986), p. 57; Charles M. Benbrook and Phyllis B. Moses, "Herbicide Resistance: Environmental and Economic Issues," staff paper, Board on Agriculture, National Research Council, Washgton, D.C., n.d., pp. 8, 9; and John P. Quinn, Joseph M. M. Peden, and R. Elaine Dick, "Glyphosate Tolerance and Utilization by the Microflora of SoilsTrested with the Herbicide," Applied Microbiology and Biotechnology 29 (November 1988): 511-516.

6 Jeremy Rifkin, Algeny: A New Word—A New World (Harmondsworth: Penguin, 1983).

7 Tauer and Love (p. 1) cite two studies: W. F. Lagrone and R.D. Krenz, "Corn Production Practices in Selected States" (University of Nebraska, Lincoln: Department of Agricultural Economics Report No. 108, 1980); Michael Hanthorne, Craig Osteen, Robert McDowell, and Larry Roberson, "1980 Pesticide Use on Field Corn in the Major Producing States," (U.S. Department of Agriculture: ERS Staff Report No. AGES820202, February, 1982).

8 E.F. Adler, W.L. Wright, and G.C. Klingman, "Development of the American Herbicide Industry," in Jack R. Plimmer, ed., Pesticide Chemistry in the Twentieth Century (Washngton, D.C.: American Chemical Society, 1977), p. 37.

9. Furtick, in Pimentel (1978), p. 60.

10 Adler et. al., p. 42.

11 Adler, et. al., p. 49.

12. Richard Levins and Richard Lewontin, The Dialectical Biologist (Cambridge: Harvard University Press, 1985), p. 236.

13. Trevor J. Martin, "Broad versus Narrow-Spectrum Herbicides and the Future of Mixtures," Pesticides Science 20 (1987): 290. Martin identifies himself with Bayer, UK.

14. Enrico Kneusli, "The s-Triazine Herbicides, " in Plimmer, ed., p. 87. Knuesli identifies himself with CIBA-GEIGY, Switzerland.

15. Adler, et. al., p. 54.

16. Knuesli, p. 87.

17. Homer M. LeBaron, "Management of Herbicides to Avoid, Delay and Control Resistant Weeds—A Concept Whose Time Has Come," unpublished paper presented at the 42nd Meeting, Western Society of Weed Science, March 14, 1989, p.l. Cf. LeBaron and Janis McFarland, "Overview and Prognosis of Herbicde Resistance in Weeds and Crops," unpublished paper, CIBA-GEIGY Corporation, n.d., p. 3 and Table VIII; and Steven R. Radosevich, "Herbicide Resistance in Higher Plants," in George P. Georghius, ed., Pest Resistance to Pesticides (New York: Plenum, 1983), pp. 453-479. Radosevich notes that "there are few examples of formerly susceptible weed species that have developed resistance...." Further, as he explains, "in every case [of herbicide resistance to atrazine] resistance has occurred in the field after approximately ten years of successive atrazine.. .or other s-triazine treatment" (pp. 453,460). The problem appears to be related as much to cultural practices (such as monoculture) as it does to the chemicals involved.

18. Adler, et. al., p. 51. Cf. Knuesli, in Plimmer, ed., p. 87. For explaining the relationship of atrazine and crabgrass, I am indebted to my colleague at Iowa State, Richard S. Fawcett.

19. Sill (1982) writes that "Resistance to atrazine herbicides has been reported in a few localities in North America on a few annual weeds.. .but in most situations.. .no weed resistance has been reported" (p. 79). Cf. LeBaron (1989), who lists the weeds and the herbicides they tolerate.

20. Advertisement forBanvel®, Oregon Farmer-Stockman 112 (April 1989): 11. Banvel® is a registered trademark of Sandoz, Ltd. and Glean®, Ally®, Finesse® and Harmony® of E.I. du Pont de Nemours & Co.

21. According to the Economic Analysis Branch, Office of Pesticide Programs, EPA, cited in Table 1 of LeBaron and McFarland, p. 11. Total sales wordlwide of all pesticides were estimated to be 16 billion dollars in 1986.

22. Stan G. Daberkow and Katherine H. Reichelderfer, "Low-input Agriculture: Trends, Goals, and Prospects fo Input Use," Ameri-

can Journal of Agricultural Economics (December 1989): 1159. Two thirds figure from Benbrook and Moses, p. 55.

23. The company was Monsanto. According to Jack Doyle, Altered Harvest: Agriculture, Genetics, and teh Fate of the World's Food Supply (New York: Viking, 1985), pp. 214-215, half of Monsanto's total sales are from Roundup®. See also Philip C. Kearny, "Introduction," Plimmer, ed., p. 37.

24. Wendell Berry, "A Defense of the Family Farm," in Gary Comstock, ed. Is There a Moral Obligation to Save the Family Farm?(Ames: Iowa State University Press, 1987), p. 348.

25. Charles Perrow, Normal Accidents (New York: Basic Books, 1984), Cited by Joseph Rouse, Knowledge and Power: Toward a Political Philosophy of Science (Ithaca: Cornell University Press, 1987): 230. Perrow Introduced these terms, Rouse explains, "to illuminate the occurrence of what he calls 'normal accidents' in certain high-risk technological systems. These are accidents that are due 123
not so much to the malfunction of a single component of a system as to multiple failues whose combination was not anticipated. He claims that such accidents are to be expected in systems that are complex and tightly coupled" (p. 230).

26. Daberkowand Reichelderfer, p. 1160.

27. For relative prices of herbicides, see Benbrook and Moses, p. 58.

28. "2,4-D increases insect and pathogen pests on corn.. .In 1974 field tests.. .corn leaf aphid populations numbered 3116 per tassel compared with only 1420 per tassel in an untreated corn field.. .European corn borer attackes on 2,3-D exposed plants were significantly greater (70 percent) than on untreated plants (63 percent)...2,4-D corn had more southern corn leaf blight lesions and significantly larger corn smut galls. David Pimentel, (1978): 180. Cf. David Pimentel, "Down on the Farm: Genetic Engineering Meets Ecology," Technology Review (January 1987): 28.

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Potential Economic Impact of Herbicide-resistant Corn

There have been no economic studies completed on herbicide-tolerance of crops oron very many biotechnological products. Some argue the reason is because little money has been allocated for economic research in biotechnology. Others argue that these new products are not yet available, so how can economic impacts be measured^ However, economists can perform analyses given facts and assumptions, but it is very important that the results be useful and not misleading; the results do not have to be 100 percent accurate. As these products move closer and closer to completion, then economic estimates can be refined.

The potential economic impact of using herbicide-tolerant corn depends upon a number of factors. One, of course, is the cost difference of the new herbicide and seed technology compared to the old. The cost difference will influence a farmer's acceptance and adoption of a specific technology. Yield improvement from better weed control is also an important factor. Together, the cost difference and the yield increase potential will influence the adoption rate.

All of these factors influence farmer behavior which effects prices and the production of other crops. The only way to sort through all of these changes is to employ a model. We used the AGSIM model built by R.C. Taylor at Auburn University, to determine the impact of herbicide-tolerant corn on U.S. agriculture. The model simulates supply and demand of the major crops in ten multi-state regions plus

Illinois. The major crops considered are corn, soybeans, cotton, milo, barley, oats, and alfalfa. The model simulates supply and demand for ten years, beginning in 1987. Demand is comprised of three segments: demand for livestock feed, demand from domestic consumers, and export demand.

The supply component of this model consists of acreage and yield per acre. Total acreage is a function of annual farm income. As annual farm income increases, the total acreage in agriculture in a region increases. The allocation of this acreage between crops depends upon the relative profitability of each crop. This is a somewhat unique approach to econometric models. When supply curves are typically estimated, they are estimated as a function of prices with technology embedded in the estimated function. It's very difficult then to determine how those supply curves should be shifted with new technology. In contrast, the impact that new technology will have on profit can be determined. In this case, the impact of the new herbicide-tolerant technology is determined through its per acre profitability, including both the lower cost of growing corn per acre, and the increased yield. The model will determine the profitability using input prices and commodity prices which change over time.

Table 1

Average annual losses in corn production from weed pests under 1983 control technologies.

AGSIM Region	Average Losses
Illinois	4.7
Other corn belt	3.9
Great Lakes	12.6
Northern Plains	2.9
Southern Plains 1/	8.4
Delta	20.7
Mountain 1/	8.4
Northwest 1/	8.4
Northeast	2.1
Appalachia	12.1
Southeast	8.2

1/Average of all other regions

Source: National Agricultural Pesticide Impact Assessment Program

The regional definitions used in Table 1 include the U.S. Department of Agriculture (USDA) regions plus Illinois. In order to determine the impact of herbicide-tolerance, the current yield loss due to weeds was determined by using numbers from the National Agricultural Pesticide Impact Assessment Program, which was a study done by the USDA. There are some problems with the survey, but it provides a consistent estimate across the United States. There might be other studies that are better for specific crops or regions but in this case, consistent estimates across all the regions were needed. In some regions, there's not much loss from weeds under current technology. In the case of the corn belt, it is only about 4 percent.

Table 2

Scenario definitions lor AGSIM simulations of herbicide tolerance in U.S. corn production.

scenario	adoption profile 1/	regional availability and time period for adoption	maximum acreage adopting	cost per acre
			(percent)	(dollars)
1	A.	all regions, 1991-1996	48	26
III	B.	all regions, 1991-1996	71	13
IV	B.	Illinois, 1991-1996	71	13
	C.	other regions, 1993-1996 66		

1/SeeTable3.

A number of scenarios were run but only three are shown in Table 2. In scenario I, the technology was made available in all regions simultaneously, beginning in 1991. The adoption rate increases annually via a logistics curve. The maximum acreage adopted is 48 percent and the cost per acre of the herbicide-tolerant technology is J26. Current chemical cost control of weeds varies by region, but it averages about $ 14-J15 per acre. The cost increase would include the cost of additional herbicide, as well as the additional cost of the seed.

The next scenario (III) again assumes all regions adopt beginning in 1991. The maximum acreage adoption is 71 percent and the cost is $13 per acre, which is slightly lower than current weed control technology costs. The 71 percent eventual adoption rate may seem rather high, but this would entail resistance to many different herbicides, as well as different seed varieties.

The last scenario (IV) deals with the impact of one region having the technology before any of the other regions. One region where the technology might be available first is the corn belt. The model looked at the availability first in Illinois starting in 1991, and then all other regions starting in 1993.

Table 3

Adoption profiles for AGSIM scenarios.

year	adoption profile A	B	C
	percent of acreage adopting		
1991	6	9	
1992	13	20	
1993	25	38	20
1994	37	55	38
1995	44	66	55
1996	48	71	66

The adoption profiles in Table 3 show the annual percentage of the corn acreage using the herbicide-tolerant technology. Adoption profile “C" only comes into play for those regions which adopt beginning in 1993, after Illinois adopted in 1991. After observing what happened in Illinois for two years, the percentage of adoption in other regions would be expected to be high their first year.

In Table 4 the yield increase in bushels per acre was determined assuming complete control of weeds. Complete weed control would probably not be economically feasible, but was assumed for the purpose of analysis. The yield increase is fairly minor in the corn belt. The most significant yield impact would be in the South. The last two columns are the net cost change at the two technology prices per acre, $26 and $13. The first net cost change is basically double current chemical weed control costs, and the other one is about current costs.

Table 5 shows the net revenue per acre from adoption the first year by region under the different scenarios. The average return per acre for the corn belt under scenario I, assuming complete weed control at $26, would only be about $4 or $7. That is not a significant net benefit to farmers. However, there are regions that have more significant weed problems who benefit much more.

Table 4

Changes in yields and in weed control costs by region for herbicide-tolerance technology. 1/.

region	yield increase	net cost change at two technology prices per acre	
		$26	$13
	bushels per acre	dollars per acre	
Illinois	5.47	10.05	-2.95
Corn belt	4.29	10.08	-2.92
Lake	12.92	8.67	-4.33
Northern plains	2.96	16.84	3.84
Southern plains	10.08	17.04	4.04
Delta	14.00	10.27	-2.73
Mountain	10.97	13.15	0.15
Northwest	11.63	9.79	-3.21
Northeast	2.05	10.54	-2.46
Appalachia	10.32	9.25	-3.75
Southeast	5.33	11.45	-1.55

1/ Applies only to the acreage using the herbicide-tolerant varieties.

Tables

Net revenue per acre from adoption of herbicide-tolerance technology in first year of availability.

	scenario		
	I	II	III
		dollars per acre	
Illinois	7.74	20.74	20.74
Corn belt	3.42	16.42	16.37
Lake	30.79	43.79	43.67
Northern plains	-7.58	5.42	5.39
Southern plains	19.09	32.09	31.99
Delta	40.08	53.08	52.94
Mountain	23.87	36.87	36.77
Northwest	36.81	49.81	49.68
Northeast	-3.17	9.83	9.81
Appalachia	26.54	39.54	39.43
Southeast	7.17	20.17	20.12

Scenario III, with a lower technology cost, is much more profitable. Since Illinois was the first state to adopt the technology in scenario IV, its net profit is the same as under the second column. The other region's net profits are lower because Illinois has already had two years of adoption and has increased corn production, lowering corn prices in the process.

There is a debate as to the sales price of this technology. Farmers currently buy most of their seed corn treated with herbicides. One strategy that herbicide and seed companies might use is to keep their prices constant and try to gain market share. This strategy might be more profitable than increasing price.

Table 6

Change in economic surplus (benefits) compared to AGSIM benchmark 1991-1996.

Group & year	scenario 1	scenario II	scenario III
		million dollars	
Consumers 1/			
1991	196	321	42
1992	614	1016	130
1993	1216	2015	891
1994	1837	3038	2051
1995	2276	3261	3261
1996	2460	4055	4055
Producers *21*			
1991	-138	-158	-19
1992	-253	-243	-28
1993	-479	-462	-375
1994	-607	-506	-357
1995	-641	-451	-581
1996	-600	-325	-541

1 / Domestic and foreign. 21 Net crop and livestock income above variable costs.

The model shown in Table 6 separates the impact on consumers from producers. As is the case with most new technology, consumers gain because there is a greater quantity of corn being produced at a lower price. Consumers also include foreign consumers of American export products. Note that the producers in aggregate experience a decrease in farm income. Producers include all crop and livestock producers, not just corn producers. This decrease occurs because when farmers adopt this profitable technology, it increases the output of corn, causing the corn price to fall, and farmers' incomes to decrease. This does not mean that the new technology is not profitable, because the old technology falls in profitability, too. When consumers' and producers' benefits are summed, the net benefit to society is positive.

Table 7

Change in corn net income above variable costs compared to AGSIM benchmark: by region, 1991-1996.

Regions, year	scenario 1	scenario II	scenario III
		million dollars	
Illinois			
1991	-28.44	-38.33	15.14
1992	-56.78	-73.31	36.68
1993	-103.63	-131.39	-53.87
1994	-145.34	-179.43	-94.69
1995	-171.34	-210.07	-160.83
1996	-184.09	-224.84	-202.42
Delta			
1991	0.51	1.26	-0.26
1992	1.54	3.49	-0.49
1993	2.96	6.65	2.23
1994	4.68	10.35	6.12
1995	6.24	13.55	9.85
1996	7.43	15.82	13.16

In scenarios I and III in Table 7, the net aggregate income of corn producers in Illinois is negative. However, in scenario IV, where Illinois had this technology for two years before any other region, Illinois corn producers have an aggregate benefit of $15 million the first year, and $36 million the second year before other regions begin to adopt. The Delta area has an increase in aggregate farm income under this technology, even if those farmers were not the first to adopt. If Illinois adopts first, the Delta region will, of course, have a negative net income during those initial years, but after the Delta region adopts, the net income becomes positive. Because there is a significant weed problem with corn in the Delta area, they benefit even if corn prices fall.

Table 8

Changes in corn acreage under scenario III by region, 1991 and 1996.

	year	
	1991	1996
	thousand acres	
Illinois	8.62	-100.71
Corn belt	18.49	-245.82
Lake	23.84	93.02
Northern plains	1.54	-103.58
Southern plains	4.53	-15.68
Delta	3.73	54.54
Mountain	0.35	-1.33
Northwest	0.46	-0.60
Northeast	1.14	-35.70
Appalachia	24.57	131.60
Southeast	22.59	-2.78
U.S.	109.85	-227.03

Table 8 shows the changes in corn acreage by region in 1991 and 1996 under scenario III. Initially there is an increase in corn production, because for the first year, farmers in this model base their decisions on the past year's corn prices. After a greater supply of corn is produced, the first year corn prices are lower. Eventually, by 1996, because of the decreased profitability of producing corn per acre, corn acreage is reduced in most regions, except for regions of the country that have the most significant weed problems, such as the Delta and Appalachian areas. The change in acreage in weed prone areas is very minor because, despite new technology, these areas do not produce very much corn to begin with.

Table 9 shows the impact on U.S. corn prices per bushel. The initial impact is very small, but by 1996 the price impact can be rather significant. Whenever complete weed control is assumed with significant adoption, quite a substantial yield increase and price decrease result.

This technology not only affects corn producers, it affects soybean producers as well because the decrease in corn profitability shifts corn acreage to soybean acreage. For the most part, many corn producers are also soybean producers. This increase in soybean acreage increases soybean production and the soybean price falls.

Table 9

Change in commodity prices compared to AGSIM benchmark: U.S. 1991 -1996.

	scenario		
Crop & year	1	III	IV
		cents per unit	
Corn (bushel)			
1991	-2.6	-4.7	-0.6
1992	-5.3	-9.4	-1.1
1993	-9.6	-17.0	-11.2
1994	-13.5	-23.6	-17.6
1995	-15.9	-27.9	-24.5
1996	-17.0	-29.9	-28.5
Soybeans (bushel)			
1991	0.9	2.9	0.3
1992	-0.6	2.4	—
1993	-2.9	1.3	5.8
1994	-6.8	-2.3	1.6
1995	-11.6	-8.0	-3.8
1996	-15.3	-12.9	-9.9

For the first three years in scenario III, the soybean price actually went up. This was an unexpected result. In those initial years, extra corn had to be used for something, so it was used for livestock production. Livestock producers need to supply their animals with protein in the form of soybean meal. This causes a slight increase in the soybean price until significant acreage moved into soybean production, reducing its price.

In summary, assuming a complete elimination of losses from weeds and a $13 per acre substituting technology, U.S. corn production would increase about 2 to 4 percent. Corn prices might be lowered by 20 or more cents. Acreage in the corn belt will shift slightly to soybeans, while the shift outside the corn belt would be to alfalfa and other crops. Early regional adoption is beneficial to the region that uses new technology first. Consumers gain from greater output and lower prices while aggregate farm income falls.

A full report of this research can be found in Tauer and Love, "The Potential Economic Impact of Herbicide-Resistant Corn in the USA," Journal of Production Agriculture, (1989):202-207.

Disease Control in Animats

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Disease Control in Animals

When cows are tied, fed, and machine milked in the stalls, and the number of cows per worker is no more than 25-35, the rationing of roughages and concentrates can be prepared for the individual. Before milking, the cow's udders can be washed and the foremilk can be inspected for health reasons. Faults in milking machine operation and overmilking can be easily avoided. Lack of appetite and disease can be recognized early and individual treatments given. If antibiotic treatments are given to individual cows, their milk can be excluded from sale for the appropriate time period. Estrus can usually be detected, insemination promptly arranged, and inspections for pregnancies can be readily made. Yield and other records can be well kept, and decisions on breeding, drying off, and culling can be well based. The opportunity for boss cows to bully, and the behavioral effects of the comings and goings of individual cows or small groups can be monitored and minimized, making the atmosphere in the cow shed one of quiet confidence.

LARGE COW HERDS

When cows are loose housed and more than 100 cows are dealt with by one stockman, the same attentions are still essential to biological efficiency. In practice, their provision depends largely on layout, equipment, procedures, skill, and care in the milking parlor, because it is there that cows are controlled and closely seen. Inspection of the foremilk and udder washing are taken care of at this time. In fact, washing is important for hygiene and acts as a stimulant for cows to let down their milk quickly. The rationing of concentrates is usually done with mechanical aides.

Faults in machine operation can be avoided. Yield records can be kept, but care must be taken to ensure that high-yielding cows have enough opportunity to eat concentrates. Roughages have to be fed elsewhere and cannot be individually rationed. Sufficient time has to be allowed for all the observations and tasks to be done well and special effort needs to be made to maintain a quiet, confident atmosphere.

The method used to identify individual cows and communicate information about them from one stockman to another become especially important in large herds. The effectiveness of a stockman's work also depends largely on tasks outside the milking parlor. Detection of fallen appetites, other than for concentrates and of estrus require careful observations. Veterinary inspections, treatments, and artificial inseminations have to be taken care of, preferably in pens near the exit of the milking parlor. Other important problems concern feeding the cows roughages, keeping the cows reasonably clean, assembling the animals for milking, dispersal after milking, picking out individuals for special attention, and avoiding behavioral difficulties due to boss cows and excessively large groups.

In practice, the maintenance of herd health, reproductive performance, and the job satisfaction of workers are liable to be inadequate when over 60 cows are kept per stockman and the emphasis is on high labor efficiency.

In J.R. Rayburn's simplified scenario of the two kinds of production systems, namely, a smaller scale, as opposed to a larger scale system, there can be trade-offs, as well as slip-ups. Animal well-being can be accommodated, supported, and ensured in either of these hypothetical settings. Much of the success of either system with respect to animal well-being has to do with the attitudes of the people who work directly with the animals, as well as the attitudes of those who design and supervise the operation of the systems.

Again, it is no small matter to get the job done. The critical aspects of dairy cow care emphasize the continuing complexity of animal husbandry at the production level.

ANIMAL NEEDS

When critics of animal farms cite examples of cruelty to animals, they are referring to farms, large or small, intensive or extensive that are run by poor producers. Inhumane treatment leads to unhealthy, unproductive animals, thus poor stockmen tend to be among the first to go out of business. It has been suggested that farm animal suffering falls into one of three categories: abuse, neglect, or deprivation. Abuse refers to obvious, active cruelty and neglect to obvious passive cruelty. State and federal legislation outlawing both abuse and neglect have been passed for many years now.

Progressive animal producers neither condone nor encourage abuse or neglect. Abuse and neglect constitute stress, and are clearly counterproductive, so their intentional practice by farmers would be irrational. Deprivation, however, is a subtle form of cruelty and the most difficult to assess. Deprivation involves the denial of less vital resources, the actual requirements which have yet to be established. Whether animals living in intensive production systems are suffering from deprivation is a major issue being discussed by humane activists, farmers, and scientists. If this is the case, economical and practical means of alleviating the deprivation will need to be discovered and developed. The humane and economic aspects of environmental design and management are best served, when the scientific approach to the identification and fulfillment of needs is taken. When an animal's needs are not being met, its welfare is more or less jeopardized by definition. But, it should be remembered that a particular decrement in welfare does not necessarily place an animal in an ethically unacceptable environment. It has been suggested that agricultural animals have a hierarchy of needs along the lines of Abraham Maslow's scheme for humans, and that an animal's basic needs are being met in most of the intensive production systems.

First and most basic, are the farm animal's physiological needs; the needs for feed, for physical biological elements of the environment, and for health care. These are already relatively well understood, and for the most part are being adequately met and fulfilled at the farm level.

Intermediate to an animal's physiological needs are the animals' safety needs. Though protection from harmful environmental elements is important, safety needs are somewhat less rigorously tended to than physiological needs are. Accidents, predation, poorly designed, manufactured, and operated equipment and facilities still exact tolls that can be reduced.

Last in the hierarchy are the animal's behavioral needs. The question among most scientists today, is, whether there is reasonable evidence supporting the existence of behavioral needs in agricultural animals. No such need has been established, although many scientists believe that behavioral needs might exist, however difficult they may be to elucidate and document.

WELFARE ASSESSMENT

Of course, fundamental to assessing the welfare of a farm animal are the answers to two questions. First, does an animal have subjective feelings and second, what indicators reveal these feelings? Although the question of subjective feelings has not been dealt with seriously until about ten years ago, the conclusion is that animals do have feelings and mental experiences that ultimately need to be taken into account.

The indicators that reveal these feelings, are exceedingly difficult to interpret. Knowledge of an animal's mental activities at this time, can only be understood by indirect experimental evidence, so conclusions must be considered tentative. Attempts to quantitatively evaluate suffering or the welfare of animals residing in various farm environments has proved futile so far. There is a consensus that the eventual welfare of farm animals will be assessed by an integrated system of indicators from four categories: reproductive and productive performance, pathological and immunological traits, physiological and biochemical characteristics, and behavioral patterns.

The behavioral, ethical, and psychological needs of farm animals has not yet been determined. This breakdown of needs does not yet exist in the science of ethology. At present, health, reproductive, and productive traits continue to be the most measurable, and the most practical indicators of fitness between agricultural animals and production environments.

More has to be learned about the fundamental psychological and behavioral process before progress can be made in describing and fulfilling an animal's holistic needs. The cognitive and motivational processes have to be better understood before it will be possible to answer questions concerning animal suffering resulting from a lack of adequate housing. In other words, does a hog that has never seen a mud hole ever dream of one, ever want one, or ever need onei The cognitive processes in farm animals are beginning to be understood and seem to suggest that the old saying, “out of sight, out of mind” really applies to these animals.

ANIMAL SUFFERING

Does an animal suffer when it lives in an environment where it confronts a frustrating or frightening situation? Ian Duncan and Marian Dawkins have observed through careful experimentation, that indirect evidence about an animal's subjective feelings can be accumulated.

Theoretical frameworks have been suggested to help investigate the role of behavior in an agricultural animal’s adaptability and overall well-being. In reference to the Edinburough Hog Park, Ian Duncan points out:

> “States of suffering such as frustration and fearcan be recognized when the behavioral indicators are known. This approach has been successful with domestic fowl in that the husbandry conditions and procedures likely to lead to frustration and fear are now known, allowing steps to be taken to reduce them. Behavior can be observed in an enriched environment in order to understand its function and development. This approach has been successful with hogs and has enabled a husbandry system to be designed which almost certainly safeguards welfare.”

Unfortunately, theory in this area of science still greatly outweighs the tangible evidence. Nevertheless, it would be imprudent to study the evidence from one category, be it behavior, health, physiology, or productivity without including information from the other categories. Attempts should be made to further identify and quantify correlates among traits in the various categories. Overall well-being presumably occurs if desirable traits from each category are met.

For example, if food is being delivered to a hungry hog too slowly for the hog’s taste, the resulting frustration can increase the rate of secretion of glucocorticoid hormones, and could have negative consequences on the hog’s health and welfare. Providing a device, such as a chain to nibble on, will enable a hungry hog to control its food intake, reduce frustration, and cause the rate of glucocorticoid secretion to return to normal.

There is considerable and rapidly-increasing evidence that an animal's nervous, endocrine, and immune systems engage in crosstalk in all possible avenues. Keith Kelley has said that certain activities in the lymphoid cells may be behaviorally conditioned. Changes in the endocrine system may affect lymphoid cells, and likewise, products of the immune system may affect the endocrine system.

Infectious diseases may alter the behavior of an animal, and vice versa. Benjamin Hart, says,

> "It is quite logical to expect animals, and people to also have evolved non-immunologic disease-fighting strategies, including behavior patterns, that might serve as a first line of defense before the non-specific and specific immunologic systems are activated, and that would complement and potentiate immunologic processes. The possible permutations of interrelationships among etiologic factors contributing to specific infectious diseases of agricultural animals are innumerable, but at present, these possibilities are mostly theoretical."

In the growing chicken, however, there is recent evidence that as many as six stressors—namely, ammonia, beak trimming, toxicidiosis, electrical shock, heat stress, and noise stress—do combine in additive fashion, to affect feed intake, growth, and several other pertinent physiological, immunological, and pathological traits. This linear additivity of multiple stressor effects on such a wide variety of traits, strongly suggests that some single process is acting as a clearinghouse for many or all of the stresses that simultaneously act upon an animal.

STRESS INDICATORS

Gary Moberg has suggested that the best indicator of an animal suffering stress is the development of what he calls a pre-pathological state. That is, a stress-related change in biological function that threatens the animal's well-being. His very first example of pre-pathological states was suppression of the immune system. Several critical phenomena associated with neurological and physiological immunomodulation have been characterized. A stressor's influences on immune responses are complex, and depend not only on stressor characteristics, such as intensity, frequency, and duration of the stress, but also on the time when the stressor impinges in relation to the course of the immune response. Stress however, is not always immunosuppressive.

Some stressors can actually increase host-resistance to pathogenic microbes and enhance certain immune responses. An animal's ability to control and predict the occurrence of stressors is another critical factor in the influence of stress on behavior and function.

The possibility that changes in the activities of mononuclear cells caused by stress can deleteriously affect host-resistance to disease and thus serve as indicators of animal well-being, has not yet been settled. Recent emphasis has been on describing the consequences of stressors on specific aspects of immunocompetence. The complexity and discrepancies among the observed effects does not permit a functional interpretation of the results at this time. It is reasonable however, to postulate that immune traits are sensitive reflectors of the overall well-being of an animal.

GROWTH PROMOTANTS

The pork industry is interested in using repartitioning agents to affect hog growth, which would make pork products more acceptable to consumers and the pork business more profitable for producers and processors. Not much is known yet about the effects and side effects of these new agents on the health of hogs, but it would be wise to anticipate possible problems when integrating these technologies into existing systems of pork production. Swine management regimens may need to be changed in order for these new agents and procedures to be implemented in the industry.

Two important aspects of the hog's life that might be affected by transgenic manipulation, beta adrenergic agonists, and porcine somatotropin happen to be thermoregulation and certain behavioral patterns. For example, the combined effects of somatotropin treatment would be on the cool end of the scale. A 12 degree Celsius increase in the lower critical temperature would be partly offset by a six degree Celsius decrease due to a higher heat production rate. The net effect would be six degree Celsius decrease in the upper critical temperature due to higher heat production rate and a six degree increase in the lower critical temperature of a 75 kg hog due to somatotropin treatment. The treated hog would be considerably more sensitive to cool or cold environments. At the other end of the temperature scale, the hogs would also be more sensitive to high temperatures.

Casual observations of hogs being fed a beta adrenergic agonist have led to the conclusion that the treated hogs may be more active than normal, more alert, more excitable, and up more often and for longer periods, because the agents mimic the effects of the sympathetic nervous system. This tentative conclusion needs to be confirmed in carefully controlled experiments. If the results of this research confirm this conclusion, then the hog's environmental requirements would warrant investigation.

This is an example of the potential effects of the products of biotechnology and how they may affect implementation at the production level.

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Environmental, Health and Safety Issues

The environmental, health, and safety issues of disease control in animals is a serious concern. The Farm Animal Division of the Humane Society is evaluating the costs and benefits of intensive animal agriculture that affect farmers and allied industries, consumers, farm animals, and the environment. The Humane Society of the United States believes that this study will offer approaches to these issues and a much-needed, long-range perspective.

The majority of approaches to disease control in farm animals miss their mark by treating only the symptoms of production-related disease, and do not provide long-term solutions to environmental health and safety issues. Approximately one billion dollars of pharmaceuticals and disease additives are given annually to livestock and poultry in an unsuccessful effort to cease their varying degrees of suffering. The obsession with high production yields has played havoc not only with society's health, but with the animals and the environment. People in recent years have begun to question the future sustainability of this system as agriculture begins to compete with other sectors for fossil fuels, water, and land. The subtle balance among animals, plants, soil, water, and the sun have been disregarded, and this disregard has been encouraged by agribusiness. According to the Congressional Office of Technology Assessment (OTA), in less than 15years, one million more farms will have disappeared. These will be mostly small to moderate-sized operations that cannot afford to invest in the expensive emerging technologies outlined in the OTA report. Given this trend, how can the impact of agriculture on the environment be better monitored? Should these gene-inserting, embryo-transferring, electronically-monitoring, computer-modeling, mechanical-harvesting, energy-gobbling, chemically-dependent technologies of the future be assessed more fully? American farmers collectively owe banks and other lending agencies more than the combined debt of Brazil, Mexico, and Argentina. In truth, American farmers and ranchers have become a kind of debtor nation within themselves.

The Humane Society is being asked by their constituency to assess the impact of livestock and poultry development on the environment.

If there is a fault in development, perhaps it is the fault of society as a whole for not taking the time to consider the long-term consequences of their actions. With every action there is a reaction, and an interconnectedness is revealed. Product revelations that open new territories are waiting for manipulation and exploration. Short-term economic incentives are more often than not the only driving force, with private industry the major beneficiary.

While over $5 billion has been invested in developing genetically engineered organisms, less than one tenth of one percent of that money is spent on assessing the risks associated with the developments. The environmental health and safety issues of disease control in animals has broad implications.

EXAMPLE: BOVINE SOMATOTROPIN

Bovine somatotropin (BST) is a protein growth hormone that is injected into dairy cows and regulates and increases milk production. Bovine somatotropin is expected to be approved by FDA for commercial release in 1990. A veterinarian by the name of Dr. Francis Kelfetz, who is a Professor of Veterinary Medicine at the New York State College of Veterinary Medicine in Ithaca, New York, is also a member of the American Veterinary Medical Association. He observes the following:

> "Most of the studies that have been published about BST have been with cows that have been very well managed. Would the same results prevail under less than optimal management conditionsi Studies of bovine somatotropin under average to poor management conditions should be done as well, and management should be recognized as a key factor. Everyone agrees that BST works, but the most important issue is cow safety. We do

not want the cows to last through just one lactation. The long-term effects of BST are not known, and studies have covered only a period of four to five lactations. The adverse effects of longevity to the cow on its reproductive efficiency and on its immune system are not known. Metabolic effects have not been studied adequately.'

According to the Kiplinger Agriculture Letter, "Biotechnological development of the bovine growth hormone might complicate an industry whose milk flow needs to be eased back, not increased."

Consumers today are questioning food safety more than ever, and as a nation, they have received more information in the past ten years than in the previous fifty. Much of the information has been food-related, environment-related, and health-related. Perhaps BST milk should be identified as BST milk, and if it is, consumers may wonder whether it is pure or not. There are a lot of questions that need to be thought about and answered before products are rushed on the market.

SOCIAL AND ECONOMIC IMPACT OF BST

This new technology could ultimately lead to the displacement of dairy farmers who refuse to use BST. Rural homelessness is a growing reality. The front page of this month's New YorkTimes contained an article entitled, "Rural Homelessness, New Product of U.S. Farms". Donald and Marilyn Bayloff, farmers in their early sixties, lost their 280-acre place near Dennison, Iowa. The farm had been in their family for over one hundred years. Fifty years ago there were over six million farmers, and today there are only 2.2 million.

The dairy industry has experienced overproduction and economic disaster in the past, and dairy farmers have poured tons of milk onto the ground because the surplus drove the price of milk down below what its production cost was. Why does biotechnology want to improve a system which is already capable of overproduction and heighten an already tragic situation in rural communities?

Compared with 50 years ago, the average farmer today uses about one quarter the labor, but nearly three times the mechanical power. They have spent over $6 billion for tractors, trucks, cars, and machinery. Each year they spend around $9.5 billion to fuel, lubricate, and maintain this fleet. They spend roughly $19 billion for feed and seed, and nearly $6 billion for fertilizer and lime each year. They use about

22 times the fertilizer and farm chemicals as 50 years ago. At the same time the farm population has declined by nearly 27 million over the past half century. Farmers now are only 2 percent of the total population.

As a nation, production capacity has probably gone much further than farmers ever dreamed it would. Farmers never saw the early demise of farming while dreaming about the future of agriculture. Society must examine the social impact of technological developments. Rural communities have been the backbone of the United States, and an injustice is done to these farmers and society when people like the Bayloffs are allowed to lose their farms.

DISPLACEMENT OF TRADITIONAL AGRICULTURAL COMMODITIES

In developing countries, biotechnology has the potential to displace traditional agricultural commodities on a massive scale. We still do not know the full impact of monocultural agriculture. The Humane Society of the United States is inclined to support more diversified systems. Until developing nations have the opportunity to diversify their agriculture, it is inappropriate for other countries to displace their traditional agriculture commodities. U. S. companies are presently using biotechnology to produce natural vanilla flavor in the laboratory, and this could result in the loss of over 50 million U. S. dollars in annual export earnings from Madagascar, where three quarters of the world's vanilla beans are being produced. Approximately 70,000 small farms on this island are engaged in the production of vanilla beans.

Similar attempts are being made to produce alternative sweeteners, which are to be used as sugar substitutes. If the U.S. and European corporations are successful in commercializing thomatin, it will result in the erosion of traditional sugar markets and a drop in world sugar prices. An estimated eight to ten million people in the developing world will be threatened by this loss.

Amir H. Jamal's* statement on the socioeconomic impact of new biotechnologies in the Third World brings some important questions to the forefront, and some crucial considerations for the more affluent northern hemisphere's industrialized society and its scientific community to ponder. Before an understanding of the proper role of biotech-

* Jamal was a participant at the Socioeconomic Impact of New Biotechnology on Basic Health and Agriculture in the Third World seminar, held March 7-12, 1987 in Uppsala, Sweden.

nology can be reached, the needs of the world and what genuine development should occur must be considered. If, for instance, science is truly in the service of humanity, then what do the poorest of humanity require in the form of technical toolsi Consideration must be given to which tools should be applied, and whether traditional or conventional technologies meet a need more safely and with less disruption. If so, these technologies should be used. If these conventional tools will not suffice, then society should consider biotechnology, and even then, great caution should be applied. It is becoming increasingly clear that both the physical and social risks may be considerable.

Have all the possible impacts of BST and other uses of biotechnology been identified? What is the urgency to put these products on the market? Who benefits? These questions and others must be identified and answered at all levels. The risks must be assessed and identified before biotechnology can be incorporated into the world. To quote from the Journal of the American Veterinary Medical Association,

"Suddenly, something goes wrong, and the experiment produces a vicious monster bent on the destruction of humanity."

INTERDISCIPLINARY APPROACHES

The Humane Society believes that biotechnology can best be applied within the parameters of a humane, sustainable and socially just agriculture, resulting in positive planetary development, and that requires large-scale involvement. The Humane Society is encouraging an interdisciplinary approach to animal agriculture. In an effort to apply biotechnology within humane sustainable agriculture systems, an interdisciplinary approach is necessary. Identifying the questions as well as finding the answers is essential.

In March 1987, 28 participants from 19 countries met in France at a seminar on the socioeconomic impact of new biotechnologies on basic health and agriculture in the Third World. Their consensus read as follows:

> "In discussing the nature of the new biotechnologies and their significance for humanity, we recognize that, in agriculture, for instance, while biotechnology may promise to increase production and reduce costs, it is more likely to accentuate inequalities in the farm population, aggravate the problem of genetic erosion and uniformity, undermine life support systems, increase the vulnerability and dependence of farmers and further concentrate the power of trans-national agribusiness."

On March 11,1989, representatives of animal agriculture, academia, including government, and the Humane Society of the U. S. met in Ocean City, Maryland, to discuss issues related to the future of farm animal agriculture. The consensus there was:

> "Whereas there are costs and benefits in animal agriculture that affect farmers and allied industries, consumers, farm animals, and the environment, including wildlife, it is the consensus of this meeting that a conference be held to address these issues in the spring of 1990."

In the Ocean City, Maryland workshop participants resolved to hold The Future of Animal Agriculture Trends and Issues Conference in the eastern region on March 28-30,1990, with a midwestem, southwestern, and western conference to follow. Three general topics were identified for the conferences: The costs and benefits of animal agriculture to producers; the environment; and animal welfare.

The Humane Society of the United States, after much deliberation and research, identified a connection between their goals as an organization and those organizations or businesses that produce products in a less intensive, more holistic way. These people are looking at the impact of their techniques on the environment, on the animal's welfare, and on producing a healthful product.

The Farm Animal and Welfare Council in England has defined husbandry practices that are widely accepted throughout the animal protectionist and welfare sectors. These practices allow livestock and poultry to more fully enjoy the five basic freedoms. These freedoms are:

—Freedom from hunger and malnutrition.
—Freedom from thermal or physical disease.
—Freedom from injury and disease.
—Freedom to express most normal behavior.
—Freedom from fear.

Given these freedoms animal husbandry operations need less sub-therapeutic antibiotics and additives.

As an animal protection organization, the Humane Society has made it a major responsibility to establish and ensure a quality of life for animals that recognizes the need to respect the sanctity and interconnectedness of all life. The Humane Society of the United States, with a constituency of one million, adopted the Humane Sustainable Agriculture Program as organizational policy this past April. The Humane Society believes that this program will implement positive long-term solutions to not only farm animal concerns, but wildlife and environmental concerns as well.

Today the media is filledwith account after account of the devastation of the planet. The ranking Minority Leader of the Senate Subcommittee on Operations, Senator Robert Casten, Jr., Republican from Wisconsin, recently said,

> "I see evidence all the time of this environmental devastation, and it inevitably results from unsustainable farming practices. As agriculture is our biggest business, according to the Kiplinger Agricultural Letter, 'Farm and Food Facts', it is a whopping 5800 billion a year industry. This accounts for 40 percent of the total capital assets of all manufacturing corporations in the United States. I think we can safely assume because of this that it could have some devastating impact to our environment. However, if you could prove me wrong, I'd really like it."

NABC's first annual meeting entitled Biotechnology and Sustainable Agriculture Policy and Alternatives is an example of an interdisciplinary action, and the importance of making the connection between biotechnology and sustainable agriculture is timely if civilization's destructive trend is to be averted.

The issue of disease control in farm animals has far-reaching implications and must be carefully examined. What are all the costs and benefits? Short-sighted parameters must no longer be used when assessing the costs and benefits. The interconnectedness of all life will not allow for this. Far-reaching answers must be developed; answers that encompass a secure future and offer a plan of approach, a blueprint that generations to come will follow, and that will give direction for appropriate steps in planetary stewardship.

Biotechnology must be treated as a newborn infant. It must be nurtured and given much more time to develop. Without this time, the United States, as well as other countries may be devastated. The Bogeve Declaration states: "A rational biotechnology policy must be geared to meet the real needs of the majority of the world's people and the creation of more equitable and self-reliant societies while working in harmony with the environment."

REFERENCES

Batie, Sandra and Penelope Diebel, 1989. "Managing Agricultural Contamination of Ground Water: State Strategies," Working Paper, Department of Agricultural Economics, Virginia Polytechnic Institute and State University.

Carlson, Gerald A, 1988. "Economics of Biological Control of Pests," American Journal of Alternative Agriculture, 3 (2-3): 110-116.

Daberkow, Stan G. and Katherine H. Reichelderfer, 1988. "Low Input Agriculture: Trends, Goals, and Prospects for Input Use," American Journal of Agricultural Economics, 70 (5): 1159-1166.

Fleming, Malcolm H., 1987. "Agricultural Chemicals in Ground Water: Preventing Contamination by Removing Barriers Against Low-Input Farm Management," American Journal of Alternative Agriculture, 2 (3): 124-130.

Reichelderfer, Katherine H., 1981. "Economic Feasibility of Biological Control of Crop Pests," in (G. Papavizas, editor) Biological Control in Crop Protection, Totowa, NJ: Allanheld, Osmun Publishers, pp. 403-417.

-----, 1985. "Factors Affecting the Economic Feasibility of the Biological Control of Weeds," (E.S. Delfosse, editor) Proc. VI International Symposium on the Biological Control of Weeds, Agriculture Canada, pp. 135-144.

-----, 1989. "Environmental Protection and Agricultural Support: Are Trade-offs Necessary?" National Center for Food and Agricultural Policy, Discussion Paper FAP89-03. Washington, DC.: Resources for the Future.

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Biotechnology and Disease Control in Animals: Social and Ethical Issues

Given the condition of the web of life on this planet after 10,000 years of agriculture and the consequent exponential growth of human population and human consumption patterns, do we need biotechnology and sustainable agriculture? The earth very much needs sustainable agriculture in the pragmatic sense, but whether or not sustainable agriculture needs biotechnology is an issue. There is a great enthusiasm about biotechnology, and the enthusiasts are promising much good. Well, I like enthusiasm as much as the next person, but let us see where it is coming from. For one thing this enthusiasm flows from the deep and ancient wheels of our civilization, a civilization that began when the Mesopotamians expanded their economy and their society by tending sheep and tilling barley a hundred centuries ago.

Almost ever since, we have placed the highest value on bringing nature under human control. It is almost a religion or pathological obsession. We should be aware of the past and control our enthusiasm for every powerful new tool that we come up with for controlling nature. 1 see parallels in biotechnology.

Biotechnology requires sophisticated tools and expertise which makes it expensive, limits its use, ownership, and control. This is the first and greatest social and ethical issues of all. With respect to disease control in animals, who will have this tool of biotechnology? More importantly, who will control it? Will it be all of us, the potential victims of some accident, some mistake or some misdirection? Or will it be controlled by private interests for the private gain of those who because of the competition in the industry keep the technology as their patentable property and their goals and activities away from public view, (probably secret)?

These are serious political questions. It would be nice to assume that democracy and justice will prevail, but it would be stupid to make that assumption. When one considers the power of these technologies and the enthusiasm for them, and the quarters from which the enthusiasm is coming and the blindness that usually accompanies it, we might as well face the fact that we could already be on the wrong track with biotechnology.

What is the impact of biotechnology on the environment, on consumers, farming, and the animals on the farms? Biotechnology is being developed and applied for use in the areas of: diagnostic tests; products that will enable farmers to diagnose animal diseases quickly; immunization new vaccines against a wider range of afflictions and products for the regulation of animal immune systems and gene transfer and other genetic manipulations that are used to create strains of animals that have an enhanced immune response, disease resistance, and new antibiotics that work against a wider range of diseases.

DIAGNOSTIC TESTS

The new diagnostic tests could employ monoclonal antibody technology to make a product that a lay person (e.g., farmer) could use to make a rapid, on the spot diagnosis of animal disease. Like litmus paper, the product could be dipped into the animal's body fluid, and after processing, the farmer could determine what the disease was, or whether or not a disease agent was present. Whether or not such new diagnostic tests would create adverse social or ethical problems depends on how accurate they are, how they are used, and what sort of farms they give an advantage to.

On the positive side, diagnostic ability would give farmers a wider edge against diseases by allowing earlier and more specific treatment. With early detection, the effected animal or animals could be isolated sooner and could perhaps reduce the risk of infection to the rest of the herd. This would help the farmer follow a more sustainable agricultural strategy, by preventing disease rather than using powerful, dangerous drugs to eradicate disease after it has broken out. If the diagnostic tests are so employed, animals would benefit from a reduction in diseases. Farmers would benefit in the reduction of veterinary costs and other overall herd health care costs. If the health of the herd is improved by a shift away from disease-busting drugs to prevention, then consumers would benefit from a reduction in the incidence or likelihood of toxins or drugs in the food chain.

If a products' diagnostic effectiveness does not live up to its advertiser's promises, what happens? The farmer is getting somewhat less of a diagnostic tool than he or she is counting on, and this could be a serious problem. An inferior diagnostic test in the hands of a less than conscientious farmer, could be a formula for disease disaster. The farmer would be relying on an easy diagnosis, an easy solution, and an easy management system. In such a situation, a disease outbreak could easily get out of hand by the time the farmer gets around to calling the veterinarian.

If the farmer misreads the directions or misuses the diagnostic test, then the farmer might administer something to the animal that might only make matters worse. The diagnostic might promise too much in the way of simple solutions for complex disease problems, and where disease is concerned, mistakes are often irreversible.

If a diagnostic test is inexpensive, it will be accessible to the farmers involved in LISA, low input sustainable agriculture. If a diagnostic test is expensive, it will be used more by the capital-intensive, larger, factory-type operations, and thus give them an edge over the rest of the farming spectrum. In this case, the product would aid an operation that would have an adverse impact on the environment, on consumers, and on family farms. If the price makes the diagnostic test accessible to lower income or lower input farmers, it could give these farmers an edge over the corporate animal factory. Such diagnostic tests would seem to be most applicable to the operations with the smaller herds and the smaller flocks, rather than to large operations with tens of thousands of animals. It would be impractical for a large-scale operation to test each individual animal.

ANIMAL IMMUNIZATION

Improved immunization in animals would emphasize disease prevention rather than disease control and would shift farmers away from using so many drugs. If the new vaccines and the new immune system regulators are cheap enough and easy to use, then they could aid sustainable agriculture with a low-cost way to control disease and parasites.

It is doubtful, however, that such powerful tools for disease control will be widely offered at low cost. The manufacturers of these products tend to recoup the years of research and development costs by setting high profit margins once the products are on the market. Once these high profit margins are in place, the pharmaceutical industry does not usually allow the prices to drop. It is not always true that competition brings the prices down, sometimes they stay up. It is more likely that the manufacturers would be designing vaccines and immune system regulators for the animal production systems at the larger end of the production scale.

Large operators would be the most likely target of new products, because they have more to offer an investor. Large operations have virtually taken over egg and poultry production, and they have been taking on an increasingly larger share of the hog and dairy production in the past few decades. These operations have disease problems of their own, and from the point of view of the manufacturer, these farms are better, larger, more affluent, more stable, better informed, and a better return on the investment of research and development money. It is difficult to imagine the agribusiness pharmaceutical industry investing a great deal of research and product development money in new vaccines and immune system regulators for the set of disease problems that are peculiar to low-input operations. Farmers using LISA are not big buyers, and the manufacturers are not likely to develop products that address their disease problems. It is likely, then, that the new vaccines and immune regulators will be designed primarily for the poultry, hog, and dairy industry where large numbers of animals are confined in a controlled environment. In this environment, disease problems are related to crowding, stress, and airborne disease agents. The constancy of these conditions, and the constancy of certain diseases makes large operations the most likely candidates for profitable product development, such as new antibiotic products and the new strains of specific disease-resistant animals.

GENETIC ENGINEERING

The genetic engineering of animals for specific disease resistance would probably have the most clear-cut impacts on farm structure. Because of the high investment of capital and expertise that is required to carry out the genetic alteration of animals, only the well capitalized firms will be able to successfully conduct these research programs and develop these products. For various reasons, these firms would be likely to put high price tags on their products. The U.S. Supreme Court has recently supported the idea of patenting the products of this research, which would give a firm a monopoly over its creations. The firm would feel justified in recouping its research and development costs by charging a high price. Moreover, the purchasers of specific disease resistant animals would have to pay royalties or some kind of a premium for these special animals.

Additionally, the development of disease resistant animals may further reduce genetic diversity. Instead of actually preventing diseases, the narrowing of the gene pool might open up the animal industries to disease vulnerability.

ANIMAL WELFARE

At first glance, the new vaccines, antibiotics, immune system regulators, and disease resistant animals would seem to improve animal welfare. If an animal is disease free, then animal welfare is high, but this may not always be the case. There is more to animal welfare than the simple absence of disease. There are social, emotional, and psychological factors that generally do not concern producers unless they interfere with production.

If the architects of biotechnology are attempting to nullify, circumvent or override these factors so that an animal can produce despite the environment or living conditions provided, then all-around animal welfare will sink to the lowest common denominator. This trend has already been seen in controlled environment-intensive operations where a combination of isolation, subtherapeutic doses of antibiotics, and the use of potent drugs have made mass production profitable. Without these intensive management tools, controlled environments would probably produce nothing but disease outbreaks and dead animals.

What would happen if these environment-intensive operations obtain the tools from biotechnology? The confinement buildings could be filled with animals that are virtually disease proof, because of the new vaccines, the immune regulators, or disease resistant genes. Would it not be possible to sustain maximally profitable production under even more severe isolation, physical restriction, and crowding? Animal living conditions and animal stress could become even worse than they are now, and yet production would increase.

It is quite likely that animal welfare would worsen, because the new tools would increase overhead, which would have to be recovered through increased production. Production could be elevated, as it usually is, by increasing animal numbers, which could be accomplished without the previous restraint of disease induced by stress, crowding and other close-confinement conditions. If biotechnology is to take this direction and foster an increase in animal production, farm animals would not be the only ones to suffer the consequences. When animal production is dominated by mass production operations, there will be adverse impacts on consumers, the environment, and on the rest of the spectrum of farming.

IMPACT OF HIGH-INPUT INTENSIVE ANIMAL PRODUCTION SYSTEMS

The impacts of high-input intensive animal production systems on consumers, will cause a deterioration of the overall quality of the meat, milk, and eggs produced. The more extreme manipulations of genetics, growth cycles, and living conditions seems to produce animal products that are watery, flabby, bland, colorless, and artificial. This may be one of the factors behind the shift away from animal products in recent years.

There are increased human health risks that are attributable to the substitution of antibiotics and drugs for labor intensive animal care methods. Two hazards face the consumers of the factory animal product. There is the greater likelihood that an animal product may contain a residue of a toxic drug or chemical used in disease prevention. There is also an increased chance of contracting an animal-borne disease such as food poisoning from Salmonella which may have become resistant to one or more of the antibiotics routinely used in these large systems.

The huge confinement operations affect the environment by creating a constant odor problem; infestations of flies, mice, and other pests; as well as stream and groundwater pollution. Many of these operations are so specialized, that it is uneconomical or inconvenient to redistribute the animal wastes back onto the croplands. In some places, waste is dumped or contained in holding ponds or treated and added back into animal feeds. Thus, nitrogen and other valuable nutrients found in waste are not returned to the soil. This is certainly not a sustainable agricultural practice.

Factory facilities tend to require feeds that will store easily and move through the pipelines, augers, and other moving parts of automated feeding systems. These large operations also require feeds that will put weight on animals rather quickly, so they can move a large number of animals per year through their expensive buildings. They will use mostly grain concentrates and other high-protein feedstuffs. To furnish these in sufficient volume, corn, soybeans, and other feed crop farmers have had to resort to chemical fertilizers, pesticides, herbicides, and many other environmentally invasive high-input methods.

If biotechnology is geared towards the biggest operations and they take over production, there will also be an impact on farm structure. The impact is best illustrated by what has happened in the poultry business. Many a farm family used to make a decent living by producing chickens and eggs for local markets. Today, these poultry farmers are virtually all gone because pharmaceutical, grain, feed, and other well-capitalized companies replaced them with antibiotics, automation, and quick- grow chickens. Eggs, chickens, and turkeys are very cheap now, but at what cost to the environment, the farmers, the farm communities, and to the chickens themselves? The broiler chicken cannot even walk anymore. Now that is a small consideration when you figure that it is going to be eaten in seven weeks, but it is just another sign of the times. By quietly researching and developing biotechnological products before the impacts are known, those who have the greatest investments in the present modes of agricultural production could work to resist rather than to assist the increasing need for sustainable agriculture.

Consumers do not want cheap, bland, “plastic” animal products that have been mass produced; they want color, taste, quality, and purity in their foods. Even the supermarkets, who scoffed at carrying organic food five years ago, are now trying to get organic food on their shelves. Consumer demand, together with increasing public concern for the environment, could soon make sustainable agriculture very profitable.

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Economic Aspects of Disease Control in Animats

Animal health concerns are not new to agriculture and breakthroughs occur with regularity, representing advances in technology. Likewise, the need for evaluation of new animal health technologies is not new. Standard tools such as budgeting, cash flow analysis, systems simulation analysis, and welfare analysis are required to measure benefits from new developments in animal health and disease control.

ANIMAL DISEASE CONTROL BENEFITS

Benefits derived from improvements in animal health or disease control can be diversified and far ranging, affecting producers, consumers, agribusinesses, and government agencies. Producers gain from reduced animal mortality levels, whereas diseases decrease feed efficiency, reproductive success, rate of weight gain, labor efficiency, and increased treatment and medication costs. Producers also benefit from disease control through reduced use of medication and decreased probability of self inoculation. Disease control can also reduce production variability, resulting in more uniform products and more consistent marketing times. Producer losses from farm-originated infections may also be lessened, as may losses from animal or animal product condemnation.

Improved control of diseases which are species-specific can benefit selected producers by increasing consumer demand based on the confidence that the product is more “wholesome”.

Agribusinesses can benefit from improved animal disease control, as meat packers and processors would have a higher quality, more uniform product. Consequently, the time required for sorting, handling, and disposing of damaged or condemned products would be reduced, and health risks for meat inspectors, meat packers, and practitioners would be lessened.

ANIMAL DISEASE CONTROL CONCERNS

Consumers clearly benefit from improved animal disease control through lower prices, higher quality, and consistency in availability of meat and animal products. Consumers are concerned with at least four aspects of disease control which relate to product quality: safety of the product with regard to natural disease characteristics (lack of bacterial infections, zoonotic disease, etc.); safety of the product with regard to compounds added or techniques used during production or marketing (use of known carcinogens, etc.); humane treatment of animals during the production process; and the effects of disease control methods on the environment.

The methods of animal disease control influence consumer satisfaction with the product and affect overall consumption patterns. Improved disease control not only reduces the likelihood of problems created by natural disease, but also creates a positive product image. Consumers are more likely to buy a product they perceive to be free from disease or contamination, e g., poultry products free from salmonella.

While disease control techniques improve product quality in terms of organism levels, they may introduce compounds that create as much consumer concern as the disease organisms themselves. For example, meat preservatives may have carcinogenic potential, and concerns about the safety of meat from animals treated with growth hormones or food additives is everpresent.

Despite rigorous testing and careful development procedures, consumers may react negatively to products created using "new" techniques, such as gene splicing.

Many people are concerned about animal physical discomfort caused by producing animals through the use of implants, hormone treatments, etc. These factors may affect the consumer's perception of quality or acceptability.

Environmental issues as they relate to animal disease control measures are also a concern. Antibiotic usage and residue levels in animal products and the environment have received a lot of public attention. Consumers may react to perceived environmental problems by boycotting products or attempting to alter the regulations on product use. An understanding of consumer concerns is important in order for scientists to educate the public about disease control methods, thereby avoiding adverse public response.

EXTERNALITY, DISEASE CONTROL AND SUSTAINABLE AGRICULTURE

Sustainable agriculture is defined as the development of systems which promote responsible natural resource stewardship and long-term farm profitability. Externalities have an impact on the level of sustainability and are intimately related to natural resource use since resources such as water, air, and a disease-free environment do not have clear property rights. Because property rights are not exclusive for many resources, externalities exist when producers do not consider the effects of their actions. Members of society and future generations will eventually reap the benefits and costs of current natural resource use.

Sustainable systems remain profitable through time by the careful use and management of resources. When externalities become a part of the decision making process, society's resources are used for the benefit of everyone concerned.

An externality is defined as an action by one individual that affects the level of well-being of another individual. Externalities can be both positive and negative. For example, a person polluting a stream to avoid the high cost of waste disposal does not usually consider the effects on individuals further downstream, a negative externality.

Externalities from animal disease control are of two types: externalities created by the spread of disease mechanisms and externalities created by the agents used to control disease. Society must deal with both of these off-site effects of disease control or non-control in determining optimal resource allocation.

There are many externalities in animal disease control. For example, a farmer who eliminates pseudorabies from the swine herd reduces the probability that the neighboring swine or cattle herds will become infected. On the negative side, when a pork producer allows sulfa residues to be spread in the environment through improper feeding and handling procedures, health hazards are created. The most common method of ensuring that externalities are taken into account is through quantity and pricing regulations, or changes in ownership patterns. An example of a quantity regulation is the banning of a particular chemical, while a tax on its use is a pricing method of control. Ownership can be recognized and protected through legal changes which, for example, give a downstream firm the right to clean water.

Animal disease control measures in conjunction with sustainable agricultural systems can create additional externalities and regulatory problems. The reduced use of animal health products due to genetically improved animals may reduce externalities which result from chemical residue (positive externality). Alternatively, the use of animal wastes as fertilizer in a sustainable system may increase the danger of groundwater contamination (negative externality). New disease control techniques, such as genetically engineered vaccines, may help eliminate some diseases and lead to environmental improvements (positive externality), but vaccines may delay the movement toward good management practices and increase the disease reservoir in the environment through carrier animals not showing clinical signs (negative externality). Improved diagnostic tests may reduce the need for prophylactic treatment and the use of environmentally damaging chemicals (positive externality).

Another problem in the chemical treatment of animal diseases is that animals develop a resistance to the compound over time. Furthermore, some chemicals destroy both beneficial and harmful organisms in the animal. Therefore the benefits of current chemical treatment must be balanced against chemical effects on future immunity.

Biotechnology offers the opportunity to reduce the development of compound resistance by reducing the need for chemical control through (new and improved) disease-resistant genetic material. Naturally immune animal populations are more sustainable than those dependent on chemical controls. Unfortunately, animals immune to one disease may be more susceptible to others.

Since there are no clear answers as to the effects of new disease control agents on the environment, agricultural research needs to consider both external and internal effects in carrying out cost/benefit analyses for new products.

ANIMAL DISEASE CONTROL ADOPTION ISSUES

The adoption of animal disease control technologies involves producer evaluation of a number of factors. Forces such as management intensity, the availability of information, financing, production systems, and available resources will all influence the success of disease-control technology.

Management intensity—Technological advancements will magnify the need for effective and intensive management. (Effective use of many animal health products requires improved production management and cost efficiency.) Complex technologies require a clear understanding of animal biology, integrated production relationships, disease population dynamics, epidemiology and thorough record- keeping practices. Baseline data is needed when evaluating cost- effective animal health management decisions that depend on an extensive knowledge of production levels.

Operations with inefficient management gain little from adopting disease-control techniques, while operations with top-level management will be in a position to utilize new technologies effectively. This will place a premium on management, emphasizing the differences between well- and poorly- managed operations.

Information—Large farm operations have effectively streamlined the process of gathering information and are highly specialized. In comparison, smaller producers may have difficulty staying abreast of current animal health advancements. Better communication between the private and public sectors may improve the dissemination of information, but only the highly specialized, large operations will easily internalize, gather and organize the complex information base. Other operations will need to incorporate the information base from outside sources.

Financial Concerns—Some animal health products will introduce a level of instability into the industry during the adoption and adjustment process. Superior business management skills will be necessary in order to effectively manage this instability. The successful adoption of a technology will be much more likely for operations in a solid financial position. The upfront cost of information gathering, purchase fees, and set up will have an impact on farms, depending on their size. The effective use of a product may necessitate using particular production facilities that would require remodeling to existing buildings. Survival will be difficult for those operations already in a weak financial position.

The adoption of technologies will depend partly upon a producer's ability to absorb increased risk levels. The new health management strategies may perform very well when all production factors function in unison, however, if one of the factors is out of sync, production may be dramatically reduced. This further amplifies the increased pressure for intensive management to control production variability.

Resource Quality—Animal health products may require improved resource quality and they may be more effective in certain types of production systems. The production environment may be related to product effectiveness.

Specified Products—Some animal health products may lead to the production of a specialized product, such as drug or residue-free products. The need for effective marketing to take advantage of product premiums would increase, and may require product identification from producer to consumer. Open markets typically do not handle identification and separation of specialty products well, but the need for marketing techniques such as production and/or marketing contracts may evolve.

ANIMAL DISEASE CONTROL METHODS

The basic methods of disease control include: medication, vaccination, eradication, and genetic resistance or natural immunity. In some situations medication and/or vaccination may be low-cost and highly effective. This may appear to be an easy and highly economical decision, while for others, herd condemnation with mandatory slaughter may be quite effective and economical.

When evaluating disease control and prevention programs, attention has to be given to the program's impact on the breeding herd. What may appear to be very economical and highly effective may be only a short-run phenomena. Evaluation of the system over the long-run may lead to different conclusions. For example, herd replacements tend to be selected from lines that perform best under the disease management strategies already in use. These animals perform best under vaccination, medication and eradication programs and thus reduce the expression of disease resistance (Govora and Spencer, 1983). A selected population may perform well under heavy disease control product use, but the population may not perform well if the products are withdrawn from the market.

Eradication programs have been successful for some diseases, however these tend to be costly. One method of eradication is that of depopulation or slaughtering an entire herd. The economic value of herd members that are naturally immune to disease has been overlooked by all economic studies to date. These immune animals can be used to build a replacement herd for disease resistance. The long-term economic value of these naturally immune animals may be quite high. The mandatory slaughter of breeding livestock may be eradicating multiplier animals which are not immune to a specific disease (Warner, et al., 1987).

Screening animals for disease resistance may bring economic and societal benefits. Screening could include genetic screening, serological tests, and other diagnostic tests.

ANIMAL DISEASE IMMUNITY

Sustainable agriculture has two concerns: to be economically and environmentally sustainable. Improved animal disease resistance has the potential to improve profitability and enhance the environment. Animal health is tied to animal genetics and to an animal's immune response to disease. It has been shown that the major histocompatibility complex (MHC) has an influence on an animal's immune response and disease resistance (Dorf, 1981). For example, the economic traits of chickens such as survival rate, feed efficiency, egg production, fertilization rate, hatchability and growth rate are also associated with MHC (Bacon, 1987). Lamont points to reasons for selecting for genetic resistance to disease (Lamont, 1989). Genetic resistance can lead to reduced use of vaccinations and other products as well as offering increased protection as vaccinations lose their effectiveness as a result of viral irritation. Lamont concludes that a potential exists for improving production efficiency and animal health by working with the MHC through both conventional breeding and genetic engineering.

Production traits can be positively or negatively associated with disease resistance. Govora and Spencer (1983)have indicated that it is feasible to improve disease resistance and selected production traits. However, disease resistance is typically disease specific; and information on the positive and negative relationships is needed.

ANIMAL DISEASE CONTROL COST CASE STUDIES

A National Animal Health Monitoring System (NAHMS) pilot study conducted at Ohio State University estimated annual dairy disease costs at $ 163 per cow. This included nearly $28 for drugs and biological and veterinary services (Miller, 1987). Lost milk production was estimated at $33 per cow. The University of Missouri farm business dairy results showed an average per cow cost of $40 in 1985 and $41 in 1986 for drugs and veterinary services (Bennett, 1986, 1987). The Missouri data also pointed out wide farm to farm fluctuations in these costs.

The percentage of herds and animals in the Iowa State NAHMS pilot study which had positive titers for selected diseases is shown in Table 1. While many of the herds had antibodies to several disease agents, little is known about the cost of disease in the form of reduced productive efficiency, death loss, etc.

Table 1

Percentage of herds and animals with positive titers for disease.

Positive	% herds positive	% animals positive
transmissible gastroenteritis	52	24
Mycoplasma byopneumonia	70	43
Hemophilus pleuroneumoniae	89	47
Pseudorabies	15	7
Porcine pervovirus	92	68
Swine influenza	70	43
Eperythrozoenosia	19	3
Swine dysentery	85	27

Data taken from: Owen, W. J. Initial Analysis of a Valid Food Animal Disease Database for Iowa. *Iowa State Journal of Research,* Vol. 62, No. 2, November.

The Iowa State NAHMS pilot study on swine estimated disease costs at $12,034 per farm (Owen, 1987). Annual per farm estimates ranged from $406 to $54,358. Such a wide range reflects the varying size of operations as well as the varying effectiveness of management. Monthly costs per sow ranged from a low of $1.50 to a high of $41.80. Annual disease costs averaged $8.40 per head of slaughter animal. Primary losses occurred from pneumonia ($1.26), still birth ($0.87), salmonellosis ($0.47), diarrhea ($0.47) and hemophilus ($0.33) (Owen, 1988). Since these losses represent observable losses, they are likely to be underestimated. Losses such as reduced weight gain, reduced litter size, etc. typically go unnoticed and are not considered, but for some diseases these losses may be large.

The major disease cost is "animal loss" or primary death loss. At $4.96 per head of slaughter animal, it represented 59 percent of reported disease costs ($8.40 per head of slaughter animals). The major costs from animal disease are not disease prevention or treatment costs but losses from death and reduced animal production efficiency. Therefore, greater efforts must be made to measure reduced animal productivity. Current variables that are studied overlook some of these significant disease costs.

Pseudorabies—(PRV; Aujesky's disease) is a disease of swine with a long history in the United States. Beginning in the 1970s, PRV was recognized as a major contributor to large losses in swine herds. Because of the increased severity of pseudorabies, there has been a strong effort to understand the disease, develop improved methods of control, better vaccines and diagnostic tests, and analyze the benefits and costs of eradication versus herd by herd control.

In 1984 a pilot project was begun in Marshall County, Iowa, with the intent of eradicating PRV from the county. The project also investigated the costs of three alternative eradication procedures. By using data collected from positive herds, the costs of pseudorabies outbreaks was also measured.

Table 2

Valuation of losses due to clinical PRV.

Type of loss	cost
Term abortion	$348.66
Abortion at 3 months	340.14
Stillborn or mummified hog	37.20
Death of a baby pig	47.63
Death of a growers/finishers	56.90
Open at 60 days (sow sold)	308.97
Open at 60 days (sow rebred)	103.98
Open at 30 days (sow sold)	231.50
Open at 30 days (sow rebred)	39.16

Source: Hallam, Zimmerman, Beran." The Cost of Clinical Pseudorabies in Iowa Swine Herds", *Iowa State University, Agriculture and Home Economics Experiment Station Cooperative Extension Service,* AS-590, December 1987.

Using pilot project data, Hallam, Zimmerman and Beran (1987) evaluated PRV costs and associated cleanup costs. The cost per instance of clinical PRV is reported in Table 2. These losses were then multiplied by the occurrence probability from the sample data to determine the expected loss from a PRV outbreak.The losses are reported in Table 3. They range from $20 to $40 per sow depending on the assumptions used. The results imply that the typical 100 sow herd would differ by the sum of $2000 to $4000 from an outbreak.

Table3

Rale of losses per sow and costs due to clinical PRV.

Type of loss	rate of loss per sow	cost per sow (non-seedstock) non-replacement	replacement	cost per sow (seedstock)	
Term abortion	0.030	$10.33	$6.22	$36.77	
Stillbirths/mummies	0.155	5.77	3.45	18.65	
Death of a baby pig	0.361	17.19	9.75	49.81	
Death of growers/finishers		0.004	0.26	0.15	$0.66
Open at 60 days (sow sold)		0.008	2.47	1.38	9.52
Open at 60 days (sow rebred)		0.008	0.83	0.80	1.04
Open at 30 days (sow sold)		0.015	3.47	1.47	16.68
Open at 30 days (sow rebred)		0.015	0.59	0.57	0.72
Reduced rate of gain in survivors		0.044	0.29	0.00	0.29
Total per sow (case if sow sold)			39.78	22.42	132.38
Total per sow (case of sow rebred)			35.26	20.94	107.94

Source:Hallam, Zimmerman and Beran. "The Cost of Clinical Pseudorabies in Iowa Swine Herds," *Iowa State University, Agriculture and Home Economics Experiment Station Cooperative Extension Serivce,* AS-590, December 1987.

The costs of eliminating PRV from 23 swine herds in Marshall County, Iowa, were also estimated using Pilot Project data. Cleanup of PRV used depopulation-repopulation methods, test and removal methods and a program of controlled vaccination with offspring segregation. The details of these plans are discussed in Zimmerman et al. (1989), and the results are summarized in Table 4 on the following page.

The most expensive plan was depopulation with a per sow herd cost of $204. The most economical plan was test and removal with a cost of $7.79. The most commonly used plan of offspring segregation had a per sow cost of $40.84. While the method of test and removal was very inexpensive, it is only appropriate when prevalence within the herd is very low. The large cleanup costs, when compared with the costs of an outbreak, imply that few infected herds will have the incentive to eliminate disease from their herds unless they cannot vaccinate and have a high probability of future clinical signs. The infected producer may decide to live with PRV and not eliminate the disease since the costs of cleanup exceed the expected costs due to future outbreaks. The producer, however, does not consider the effects of this decision on the probability of his neighbor's herd contracting the virus. Eradication efforts will probably need the cooperation and financial support of many producers and the government.

Table 4

PRV cleanup costs by method.[3]

	Depopulatlon/repopulation feederhog finishers n+3	farrow to finish n=1	test and removal n=5	Controlled vaccination with offspring segregation n=l4
Veterinary services	$0.01	$0.88	$0.54	$0.74
Vaccination-vaccine	0.00	46.88	1.75	7.20
labor	0.00	7.50	0.32	0.56
PRV Surveillance-testing & tagging	0.08	9.97	4.51	4.15
labor	0.01	0.95	0.67	0.38
Cleaning and Disinfecting	0.01	10.70	0.00	0.96
Isolation and Segregation				
facilities	0.23	8.73	0.00	0.00
labor	0.05	7.50	0.00	0.23
transportation	0.00	3.95	0.00	0.00
Downtime	0.00	106.60	0.00	0.00
Losses at sales of culled breeders	0.00	0.00	0.00	26.62
Total producer bosts	0.30	145.93	0.99	28.75
Total program costs	0.09	57.73	6.80	12.09
Total costs	0.39	203.66	7.79	40.84

Source: Hallam, Zimmerman and Beran. 'The Cost of Clinical Pseudorabies in Iowa Swine Herds," *Iowa State University, Agriculture and Home Economics Experiment Station Cooperative Extension Service,* AS-590, December 1987.

A study of a large swine production operation in North Carolina estimated PRV losses at $16.21 per sow farrowed (Kleibenstein, eta/., 1988). Losses ran for 17 weeks after the outbreak and amounted to 5.28 percent of the hogs born during the outbreak period of one to four weeks. This same study showed the losses from "high loss" disease (primarily transmissible gastroenteritis) to include 14.04 percent of the hogs born. Respiratory diseases reduced production levels by approximately nine percent. With the assumption that a typical swine operation has 7.8 hogs (U.S. average) per sow, per litter. Pseudorabies vaccine cost per hog was $2.09.

The Iowa NAHMS study showed that seven percent of the hogs had positive titers for PRV (Owen, 1987). Extrapolating to a national scale, if seven percent of the 80 million market hogs produced annually are infected with PRV, it means that 5.6 million hogs are infected. If this assumption is true and the losses associated with PRV were to be reduced by half, the cost savings would be approximately $5.9 million annually (5.6M hogs x 50% loss reduction x $2.09 [vaccine cost per hog]).

Using data from the Iowa Pilot Project and other surveys, a benefit cost analysis of a national eradication program was completed (Hallam, etal., 1987). The analysis considered the costs and benefits of a 10 year eradication plan. It was assumed that states were to follow different protocols depending on disease severity. The benefits of eradication included eliminated clinical disease, vaccination, and reduced testing costs. Nonclinical disease costs were not included since the data was not available or of questionable quality. The discounted value of these benefits was determined to be J 136.4 million using a 10 percent discount rate and $271.5 million using a six percent discount rate. The total cost of the program to producers and the government was $134.4 million using a 10 percent rate and $155.8 million using a six percent rate. The benefit cost ratio was not large, but the program has already been undertaken.

Swine slaughter check and panel—A Missouri swine panel study showed direct swine health expenditures ranging from $0.59 to $4.59 per hog (Kliebenstein, etal., 1983). Total confinement and mixed housing systems tended to have higher per hog expenses. The two leading expenses were for pneumonia and atrophic rhinitis prevention and control. This range in health expenditure costs is consistent but narrower than that shown in the Iowa State NAHMS report. The Missouri study showed that the primary disease seasons were the fall and winter quarters. Forty-eight percent of the hogs in the winter and 40 percent of the hogs during the fall were reported to have health problems.

A slaughter check study showed the two primary morbidity events in swine were pneumonia and atrophic rhinitis (AR) (Boessen, et al., 1988). Losses from pneumonia for a “batch" producer averaged $1.09 per hog. For a continuous producer, losses averaged 1.5 cents per hog, per day of $5.48 per hog production space per year. Losses from AR were $0.95 per hog in a “batch” production system and 1.3 cents per hog per day or $4.75 per hog production space per year in a continuous production system.

Biotechnology offers much to the development of sustainable agriculture. Benefits of cost effective and sustainable technology are diverse, affecting producers, consumers, agribusiness firms and government agencies. It must be recognized that some products have both benefits and costs associated with their use, and some may reduce problems while increasing others. Thus prudent evaluation is needed in both the development and use of biotechnological products.

As with many new technologies, there are no clear answers concerning a product's impact on society and the environment. Nonetheless, potential impacts require careful analysis. The potential for catastrophes must be properly evaluated if society is to bear risks that may provide only a few benefits. Socially optimal disease control measures must account for all costs and benefits—the direct as well as the indirect and external.

A review of the cost analysis of selected diseases shows that economic analysis of animal disease control alternatives are an important component of disease control policies. These costs need to be evaluated at both the societal and production level.

Producer adoption of animal disease control techniques will involve a number of factors, including management intensity, information availability, financing, production systems, and available resources. These factors will affect producers in different ways, and thus costs and benefits are not likely to be distributed evenly.

Animal disease control strategies will not transform below-average managers into above-average managers, as many new technologies emphasize improved management intensity as a part of the technology package. Management strategies should be in place before a product is adopted, and this should make implementation smoother. Producers need to have healthy management in order to successfully utilize new products and technology, and appropriate management information needs to accompany the introduction of new technologies.

REFERENCES

Bacon, L.D., 1987. "Influence of MHC on Disease Resistance and Productivity", Poultry Science, 66:802.

Bennett, M., (1987). 1986 Dairy Enterprise Business Earnings and Costs. Farm Management Newsletter FM87-5, Missouri Cooperative Extension Service.

Bennett, M. (1986). 1985 "Dairy Enterprise Business Earnings and Costs". Farm Management Newsletter FM86-3, Missouri Cooperative Extension Service.

Boessen, C., J.B. Kliebenstein, R. Covert, K. Moore and C. Burbee,, 1988. "Effective Use of Slaughter Checks to Determine Economic Losses from Morbidity in Swine". Proceedings of the 5th International Symposium of Veterinary Epidemiology and Economics, Copenhagen, Denmark.

Dorf, M.E., ed, 1981. "The Role of the Major Historanpatibility Complex in Immunobiology," Harland Press, New York, NY.

Govora, J. S., and J.L. Spencer, 1983. "Breeding for Immune Responsiveness and Disease Resistance, "Animal Blood Groups and Biochemical Genetics, Vol. 14.

Hallam, A., J.J. Zimmerman and G. W. Beran, 1987. "A Benefit Cost Analysis of the Proposed National Pseudorabies Eradication Program: Summary Report" in Proceedings of the United States Animal Health Association Ninety-first Annual Meeting, Salt Lake City, UT.

Kliebenstein, J.B., D. Patterson, K. Moore and D.G. Thawley, 1988. "Economic losses from pseudorabies in a swine farrowing operation". North Central J. ofAgr. Econ..

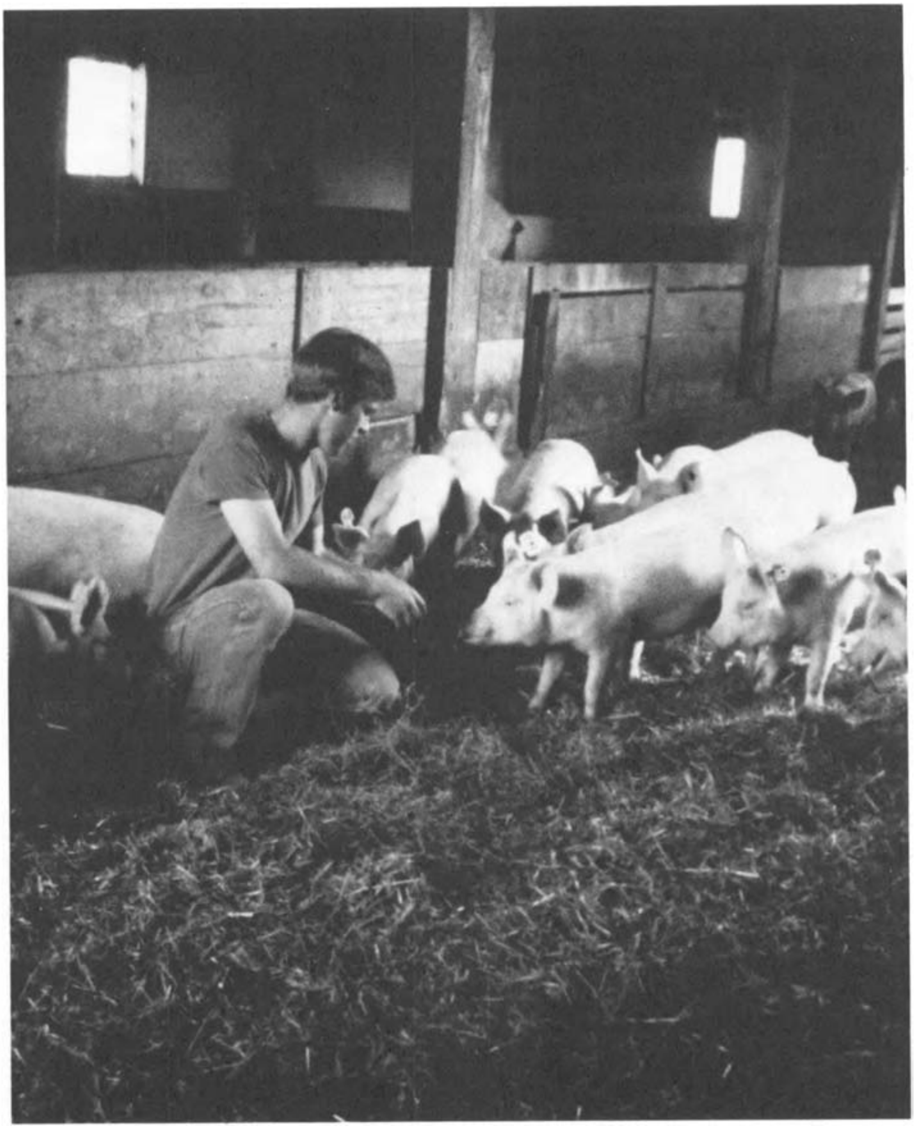
Kliebenstein, J.B., C.L. Kirtley and L.A. Selby, 1983. "A survey of swine production health problems and health maintenance expenditures". Prev. Vet. Med., Vol. 1.

Lamont, S.J., 1989. "The Chicken Major Histocompatibility Complex in Disease Resistance and Poultry Breeding "Journal of Dairy Science, Vol. 72, No. 4.

Owen, W. J., 1988. Unpublished data, Iowa State University School of Veterinary Medicine.

Warner, C.M., D.L. Meeker and M.F. Rothschild, 1987. "Genetic Control of Immune Responsiveness: A Review of Its' Use as a Tool for Selection for Disease Resistance,"Journal of Animal Science, Vol. 64.

Zimmerman, A.J Hallan and G.W. Berna, 1989. "The Cost of Eliminating Pseudorabies from Swine Herds in Iowa", Preventive Veterinary Medicine.



Animat Growth Promotants

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Sotnatotropins

HISTORICAL DEVELOPMENT

In the early 1930s, it was reported that injections of crude pituitary extracts increased growth rates in growing animals and milk production in lactating animals. Subsequent studies led to purification from pituitary extracts of two peptide hormones—prolactin and "growth hormone" or somatotropin—which are important to growth and lactation. Prolactin has many functions ranging from regulation of limb regeneration and salt balance in amphibians to regulation of mammary growth and function in many mammals. It was named prolactin because it was measured (assayed) on the basis of stimulation of mammary growth in rabbits and rodents. Similarly, the term growth hormone arose from the original assay method which was based on growth promotion. When it became evident that "growth hormone" had many actions in addition to growth promotion, its name was changed to somatotropin. The name prolactin has not been changed to better describe its diverse functions.

Early investigators, working with rodents and rabbits, demonstrated that prolactin was essential to mammary development during pregnancy and to maintenance of lactation. Without replacement therapy with both prolactin and cortisol, lactation in rats without a pituitary (hypophysectomized) is severely depressed and, as a result, their pups lose weight and many die. These observations led to the general view that prolactin was "the" pituitary hormone essential to lactation even though early publications indicated that somatotropin was active in enhancing milk production in ruminants while prolactin was not. Hormone preparations used during this period were not pure and we knew little of species specificity. This caused considerable confusion regarding apparent interspecific differences. Also, most experiments on lactation were conducted using intact animals where results are more difficult to interpret than those obtained from animals in which confounding effects of endogenous secretions are prevented by removal of appropriate endocrine glands. The critical experiment which established the essentiality of somatotropin for lactation in ruminants was conducted by Cowieer al. (1964). Using hypophysectomized, lactating goats, they found that somatotropin was essential to the maintenance of lactation while prolactin was not.

This and many other studies cited by Hart et al. (1979), and Bauman and McCutcheon (1986) had established by the mid 1960s that somatotropin enhances growth and lactation in farm animals. Application of this knowledge in the animal industry awaited developments in biotechnology required to produce an adequate supply of somatotropin.

CHEMISTRY OF SOMATOTROPINS

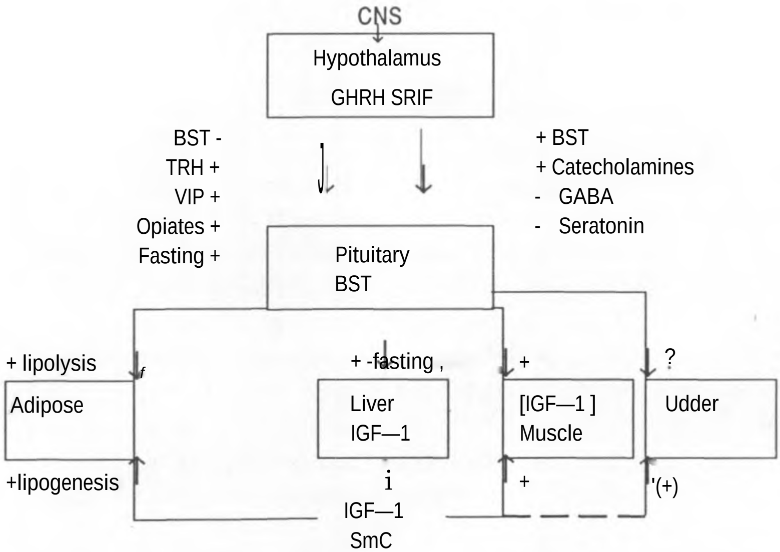
Somatotropins are large, complex peptide hormones comprised of 190-199 amino acids. Peptide hormones include insulin, prolactin, somatotropin, luteotrophic hormones and follicle stimulating hormones. These hormones differ from steroid hormones such as estrogen, progesterone and glucocorticoids in a number of important ways. Peptide hormones are proteins with molecular weights ranging from 4 to 22 kg/mole while steroid hormones are small molecules ranging from 0.2 to 0.3 kg/mole. Peptide hormones are not active when administered orally while steroid hormones are. For example, insulin must be injected into diabetics requiring hormone therapy while birth control pills containing estrogen and progesterone can be taken orally. This is because peptide hormones cannot be absorbed until they are degraded to their component amino acids in the digestive tract (as with all proteins) while steroid hormones are small and readily absorbed, unchanged by the digestive tract. Because peptide hormones are highly complex, they and their activities vary greatly across species. Homology among peptide hormones is a measure of similarity in amino acid sequences between two peptides. As homology decreases, the likelihood that a hormone from one species will act in another species decreases. For example, homology between bovine, rat and bovine somatotropins is over 85 percent while homology between human somatotropin and bovine somatotropin (BST) is only 70 percent. As a result, BST is active in sheep and rats and completely inactive in supporting growth when injected into humans. Steroid hormones differ from species to species but the differences are small, for example, estrogens from one species or estrogen analogues such as diethylstilbestrol can be expected to be active in all species. A final difference between peptide and steroid hormones is that they differ in their mode of action at the cellular level. Peptide hormones bind to receptors on the cell membrane and exert their action from that site. Steroid hormones enter the cell and are transferred to the nucleus of the cell where they exert their action.

REGULATION OF SOMATOTROPIN SECRETION

The regulation of somatotropin secretion is quite complex as shown in Fig 1. As is true for most pituitary hormones, primary control is dependent upon the balance between a releasing factor (growth hormone releasing hormone [GHRH]) which stimulates secretion and an inhibiting factor (somatostatin or somatotropin release inhibiting factor [SRIF]) which decreases secretion. Growth hormone releasing hormone is a peptide comprised of 48 amino acids and is secreted by the hypothalamus or lower brain. Injection of GHRH increases somatotro-

Figure 1

Diagrammatic representation of the regulation of somatotropin secretion and actions.



pin secretion and, indeed, has been considered as an alternative to administration of somatotropin to enhance growth and milk production. Conversely, formation of antibodies against SRIF, a peptide of 28 amino acids; to reduce SRIF levels results in increased somatotropin release and can enhance growth. This approach has also been considered as an alternative to somatotropin administration. A number of additional peptides, neurotransmitters and other compounds including opiates modify somatotropin release either directly or by modifying GHRH and/or somatostatin secretion or action (Fig 1). Opportunities for modification of somatotropin secretion through manipulation of these "other" factors undoubtedly exist but have not been explored thoroughly.

mechanism(s) of somatotropin action

Administration of somatotropin, specific to a given species, clearly enhances growth rate (ADG) and efficiency (feed/gain) in farm livestock favoring protein over fat accretion at lower feed intakes. It is just as clear that BST administration enhances milk production in dairy cattle. Mechanisms whereby somatotropins produce these responses are not fully understood and, thus, any discussion of mechanism (below) must contain some speculation.

Several mechanisms involved in growth promotion by somatotropin are summarized in Figure 1. It is now clear that a primary action of somatotropin is to enhance the formation and secretion of insulin-like growth factor 1 (IGF-1) by the liver. Insulin-like growth factor 1 is also called somatomedin C (SmC) to indicate that it mediates somatotropin action. Circulating levels of somatotropin do not differ between toy and standard poodles but amounts of IGF1 secreted by the liver do differ causing the differences in size. This illustrates the essential role IGF-1 secretion by the liver in muscle and, probably, acts to increase rates of protein accretion by increasing rates of protein synthesis. The increase in the rate of protein synthesis may be a direct effect on biosynthetic capacity in muscle cells or an indirect effect due to increased satellite cell proliferation leading to increased numbers of nuclei per muscle cell which, in turn, increases biosynthetic capacity.

Until recently, it was considered anomalous that circulating levels of somatotropin become elevated during fasting in many species. The effect somatotropin has upon adipose tissue is to increase capacity for fat mobilization (Iipolysis). This was considered consistent with elevated somatotropin, the need for fat mobilization during fasting and reduced fat accretion in fed animals injected with somatotropin. However, IGF—1 stimulates fat synthesis (lipogenesis) and storage. Therefore, if somatotropin increases circulating levels of IGF—1, one would expect the lipogenic effects of IGF—1 to counterbalance the lipolytic effects of somatotropin in adipose tissue. Now, we know that liver cell membrane receptors required for somatotropin binding in liver decrease during fasting, such that the elevated somatotropin levels are not recognized by liver and IGF—1 secretion is not increased. Thus, during fasting somatotropin increases, thereby increasing lipolytic capacity in adipose tissue but IGF—1 secretion by liver and adipose lipogenic capacity are not increased so the net response in adipose tissue is mobilization of fat.

With respect to lactation, the exact mechanism(s) of BST action are not known but some insight is emerging. Three major factors control milk production by the mammary glands: blood nutrient concentrations, blood flow to the udder, and biosynthetic capacity of the udder. Although fatty acids in blood increase slightly when somatotropin is injected into cows in early lactation, changes in blood nutrient concentration due to somatotropin administration are small or absent and certainly not sufficient to explain the increase in milk production reported (Bauman and McCutcheon, 1986). Blood flow to the udder increases in parallel with milk production while arteriovenous differences (uptake) of nutrients from blood remain relatively constant. Thus, it appears logical to conclude that mammary metabolic/biosynthetic capacity is increased by BST treatment resulting in increased product concentrations in venous blood and, in turn, a demand for greater blood flow. Current thoughts are that the effect of BST upon milk production is mediated by IGF-1 and is due, at least in part, to increased numbers of secretory cells, increased biosynthetic capacity per secretory cell or both of these.

REFERENCES

Bauman, D.E. and S.N. McCutcheon. 1986. "The effects of growth hormone and prolactin on metabolism". In Control of Digestion and Metabolism in Ruminants, ed. L.P. Milligan, W.L. Grovum and A. Dobson. Prentiss-Hall, Englewood Cliffs, NJ.

Cowie, A.T., G.S. Knaggs and J.S. Tindal. 1964. "Complete restoration of lactation in the goat after hypophysectomy"./. Endrocrinol. 28:267.

Enright, W.J., L.T. Chapin, W.M. Morely, S.A. Zinn and H.A. Tucker. 1986. "Growth hormone releasing factor stimulates milk production and sustains growth hormone release in Holstein cows". J. Dairy Science, 69:344.

Evock, C.M., T.D. Etherton, C.S. Chungand R E. Evy. 1988. "Pituitary porcine growth hormone (pGH) and a recombinant pGH analog stimulate pig growth performance in a similar matter"./. Anim. Science. 66:1928-1941.

Hart, I.C., J. A. Bines and S.V. Morant. 1979. "Endocrine control of energy metabolism in the cow: correlations of hormones and metabolites in high and low yielding cows for stages of lactation". J. Dairy Science. 62-270.

Nichol, C.S. 1974. "Prolactin physiology". In Handbook of Physiology. Vol. 4, part 2, chap. 32. American Physiological Society. Washington DC.

Reichlin, S. 1986. "Somatostatin: Biosynthesis, regulation of secretion, and role in growth hormone regulation", pp. 405. In Human Growth Hormone, eds. S. Raiti and R.A. Tolman. Plenum Medical Book Company, NY.

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Environmental, Human and Target Animal Safety Issues of Animal Growth Promotants

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What is an animal growth promotant? This is a collective term not restricted to products of biotechnology which includes a number of different strategies to increase the rate and efficiency of animal product formation (eggs, meat, milk and wool). The following is offered as a contemporary definition as viewed by those involved in animal production research: Growth promotants—strategies to increase the rate and efficiency of animal product formation with improved composition and desirability by the consuming public, free from harmful residues and environmentally neutral. Unfortunately a very negative perception exists, particularly with reference to somatotropin, and this negativism is due to misinformation widely distributed in the popular press. Granted, anabolic steroids are considered a growth promotant; however, anabolic steroids are not restricted to diethylstilbesterol (DES). In fact, DES is now removed from use in production agriculture . Strategies to use naturally occurring compounds and mimics in low supplemental levels have been developed to meet the above definition.

As an attempt to clarify the public perception of what constitutes a growth promotant, the following classification is offered:

Metabolic modifiers
—* beta andregenec agonists;
—* somatotropin
—* transgene manipulations
—anabolic (steroid-like mimics) implants
—enhancer of futile energy cycles
—* immunomodulation

Extrasomatic Modifiers
—antibiotics and probiotics
—anticoccidiostats
—anthelmintics.
Management Strategies
—restricted feeding
— compensatory growth
— rearing the intact male
—forage feeding systems.

Strategies vary with livestock species, clearly global geography and conditions of local legislation, as apparent in the U.S. Again, public perception is that growth promotants are used by the agricultural sector to the advantage of the livestock producer with blatant disregard for public welfare and the environment. Bringing a compound from the laboratory bench to the marketplace involves the approval of a very intricate mechanism of "checks and balances".

CHECKS AND BALANCES

During the initial research and development phase of a compound, the first check would fall to the ethics of the investigator. After initial discovery, questions are considered such as: Are the undesirable side effects noted in the use of the compound in the target species? Does the compound demonstrate selectivity with respect to the endpoint desired? Can the results be replicated at other locations? Is the compound worthy of commercialization? Amazingly, few compounds survive beyond the initial discovery stage and most are dropped.

Scientists, either in the public or private research sector, operate by stringent rules and regulations. These include institutional research, animal care committees that review experimental protocols for compliance to formal and informal guidelines, as established by fund granting agencies such as the U.S. Department of Agriculture (USDA) and the National Institutes of Health (NIH), and professional peer review of results submitted for publication. Due to recognized deficiencies in some environments, most research institutions in the U.S. are striving for uniformity by adopting standards such as those proposed by the American Association of Laboratory Animal Science.

(‘designates developments collectively referenced as "biotechnology" advances. At present none are approved beyond use in a research environment or in controlled field tests.)

Following the discovery phase, a compound may survive into the marketing phase, and checks and balances at this stage are more familiar to the public. As pertinent to animal agriculture, The Center for Veterinary Medicine of the Food and Drug Administration (FDA) has the primary responsibility for the new drug application review process. The Food Safety Inspection Service (FSIS) would have jurisdiction for the introduction of transgenic products into the food chain. The Animal and Plant Health Inspection Service (APHIS) regulates, in part, the use of animal biologies, transportation of transgenic products and surveillance monitoring. Approximately 14 Federal agencies interact and regulate the marketing and use of agricultural chemicals.

Public watchdog organizations operate at both the discovery and marketing phases of a compound. These include consumer and environmental activist groups which pose queries often resulting in legitimate research investigations. Other activist organizations raise issues concerning the ethics of animal research. This offers yet another level of "checks and balances". Unfortunately, an impasse is often encountered, because despite all attempts to recognize and improve animal welfare considerations, those involved in animal production find the issue of "animal rights" contrary to desires or "rights" of mankind.

EXAMPLE: PORCINE SOMATOTROPIN

To address the topic of animal growth promotants, porcine somatotropin (PST) was selected. Investigational PST is a mimic of the 191 amino acid protein naturally secreted by the anterior pituitary and is primarily involved with nitrogen metabolism and long bone growth. Porcine somatotropin is produced by recombinant DNA technology and is available in considerable quantities for research purposes through several companies seeking registration approval. The impetus to examine PST efficacy relates to a very specific problem of the pork industry. Biomedical recommendation has advised the public to reduce the intake of animal fat, particularly saturated fatty acids, to reduce the risk of developing coronary artery disease. Pork is commonly believed to be a fatty meat and therefore some regard it as unhealthful. In part, this may explain why per capita pork consumption has remained static for about 20 years. As part of a larger issue, recommendations to re-duce human lipid consumption from the current figure of 38 percent of total caloric intake to 30 percent will require the composition of meat to be altered dramatically. Growth promotants, specifically those which alter nutrient partitioning exemplified by PST, may provide livestock agriculture the means to adjust commodity production to benefit publie health. Animal product consumption provides the human population with a large portion of high quality protein and several important vitamins and minerals; therefore, lowering the contribution fat intake derived from animal products is a worthy undertaking.

Based on several dozen research reports, PST can reliably improve the rate of body weight gain by approximately 10-15 percent in growing hogs, reduce the quantity of feed required per unit of body weight gain by 25 percent, increase edible meat yield by 5-10 percent and reduce fat deposition of hogs by 40-80 percent, depending on the dosage. Voluntary feed intake has consistently been reported to be reduced by 10 percent as a result of PST treatment. These effects are consistent with the classification of PST as a nutrient partitioning agent and are not magic. Mechanistically PST is altering intermediary metabolism such that the hog is metabolically much younger. The carcass composition changes desired by the consumer are realized by improved production efficiency; therefore, producer adoption should occur quickly. Rather than create a pharmacolic milieu to alter growth patterns, PST represents a biological strategy permitting the animal to more fully express the genetic potential for lean tissue growth.

ENVIRONMENTAL SAFETY

The current decade was viewed as one of concern and action with respect to environmental quality. Some countries in Europe have enacted legislation in an attempt to minimize the environmental impact of technological advances. The Netherlands serves as an example. A country approximately the size of the state of New Jersey has a human population of 14 million and a swine population of 20 million. This livestock population requires 102,000 tons of nitrogen for feed purposes per year. Currently, standards have been established to impose an environmental impact tax on nitrogen and phosphorous as pollutants. Based only on the improvement in feed conversion efficiency, PST would reduce nitrogen pollution by approximately 3,600 tons annually. Phosphorous loss to the environment would decrease by a similar magnitude, but other strategies such as the use of phytase in the feed may be of greater consequence. In itself, PST would not correct all issues associated with environmental quality, but as part of a larger integrated strategy this growth promotant may contribute to the improvement of the environment. Intensive animal production management systems as found in The Netherlands, Iowa and Illinois could benefit indirectly from this technological advancements

HUMAN SAFETY

Somatotropins are extremely species-specific and follow a phylogenic hierarchy of biological activity such that PST would not have biological activity in the human, whereas human somatotropin would be active in hogs. Residues of the peptide, should they exist, would be denatured during the cooking process of treated pork and further degradation would occur in the digestive tract of humans. These factors all contribute to the conclusion that PST as a residue would not pose a threat to the human population. However, the perception of biologically active residue(s) persists.

Based on research data reviewed in several manuscripts, increased levels of PST resulting from treatment is cleared from the circulation in 15 hours following administration. Using validated assay methods, PST has not been detected in the meat of treated animals. Treatment of young growing hogs enhances rate and efficiency of body weight gain. Furthermore, withdrawal from treatment does not result in a decompensation of beneficial effects; therefore, a sustained beneficial effect can be realized long after treatment withdrawal. This would permit a lengthy withdrawal period prior to the marketing of treated pork should regulatory approval mandate.

On the proactive side, cardiovascular disease is the leading cause of mortality in industrialized societies and the biomedical community has concluded that this mortality is largely caused by the consumption of saturated fats in excess quantities mainly from animal products. Use of PST would allow the production of extremely lean animals and trimmed pork as a commodity would be approximately five percent lipid. Intramuscular lipid concentration of fresh pork is small compared to other meats. By substantially reducing the lipid content of pork, PST may reverse the public image of pork as a fatty and, therefore, unhealthful product.

TARGET ANIMAL SAFETY

An inherent joint problem in swine which relates to stiffness and feet and leg problems is known as osteochondrosis. Porcine somatotropin, possibly by accelerating rate of growth, was associated with an increase in the incidence of this problem in early experiments. Subsequently, adjustment of the dietary calcium and phosphorous concentration has greatly reduced this problem.

Unlike the dairy animal treated with bovine somatotropin (BST), hogs treated with PST have a narrow window of response, or dose response range. This means that there is approximately a fivefold difference between the dosage required for biological effect and the dosage for maximum effect without adverse effect of appetite. This will require prudent use by producers and recognition that "more is not better".

As a consequence of the increased lean body mass, heat production resulting from basal metabolism increases 17 percent. This may require greater ventilation rates, particularly in warmer production environments.

Pale-soft-exudative pork is a meat quality problem of the pork industry which is associated with a lethal genetic disorder known as porcine stress syndrome. Treatment of hogs with PST results in a paler pork as judged from instrumental appraisal. Whether this is a true form of pale-soft-exudative pork is debatable. No indication of porcine stress syndrome resulting from the use of PST has been noted. A slight decrease of meat tenderness reported as a result of PST could relate to the mechanism of action; animals are physiologically less mature.

Some critics have implied that growth promotants, particularly PST and BST, will compromise the immunocompetence of the treated animal. Few studies have addressed this issue, but one report found PST to increase macrophage function such that immune system function would be enhanced. Theoretically this would decrease the risk of disease in treated hogs.

The major deterrent to the adoption of PST at present is the development and refinement of a drug delivery system. Ideally, this delivery device would be implantable with the capability of delivering the peptide for a 30 day period in a pulsatile manner, cycling every 24 hours. This is a major bioengineering challenge which is actively being investigated by several companies.

CONCLUSION

PST, as well as BST, is not a doomsday technology designed to create meat animals of monstrous proportions. Agricultural research efforts are not directed at an increase of livestock population numbers. The objective of somatotropin as a technological advancement is to improve the quality of the meat product so that consumer acceptability is improved and simultaneously improves production efficiency. PST clearly meets these objectives.

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Social and Ethical Implications of Animal Growth Promotants

INTRODUCTION

American agriculture is on the threshold of a major technological revolution, one that will be propelled by the combined forces of the electronic age and a new wave of innovations based upon biotechnology. This revolution portends sweeping changes, both in terms of enhanced farm productivity/efficiency and in the potential for a major restructuring of the agricultural industry.

This paper examines two soon to be released products of this biotechnological revolution, bovine (BST) and porcine (PST) somatotropin. Both BST and PST are naturally-occurring hormones, produced in the pituitary glands of animals, that accelerate metabolism and growth rates. Recent biotech advances have permitted scientists to "manufacture" these substances in mass quantities, thereby making their use economically attractive in the swine and dairy industries. Both products are currently being tested by the Food and Drug Administration (FDA) and should be on the market within the next two years. This paper, using an ex-ante model of adoption, examines the receptivity of Iowa pork producers to PST.

PREVIOUS STUDIES ON SPEED OF ADOPTION AND IMPACTS

Virtually all of the research on farmers' propensity to adopt growth hormones has focused on BST; adoption studies of PST are virtually nonexistent. Two early studies of BST had a dramatic impact on the public imagery of the virtues and likely impacts of this product. In

1986, a much publicized Congressional Office of Technology Assessment (OTA) report concluded that biotechnological innovations would have revolutionary impacts on U.S. agriculture, bringing a dramatic decline in the number of farms and a startling increase in the concentration of agricultural production. It was also concluded that adoption of the new technologies would initially be concentrated on large, highly capitalized operations, thus further solidifying the economic advantages enjoyed by those units and accentuating the trend toward a dual farm structure.

The other study, conducted by scientists at Cornell University introduced the possibility of significant increases in milk production (by as much as 40 percent) from BST use. Through ex-ante assessment, a rapid adoption of BST was projected, with an estimate that two-thirds of New York dairy operators would adopt the product in the first year of its availability. It was concluded that the introduction of BST would accelerate the already rapid changes taking place in the dairy industry, and bring the demise of up to 1000 dairy herds annually in New York State alone.

More recent studies have shown relatively smaller productivity increases (10-15 percent) from BST, and slower rates of diffusion of this product among farm operators. Fallert, for example, argued that the effects of BST on the dairy industry will be less dramatic than earlier thought, and concluded that BST will merely reinforce a thirty year trend toward increased efficiency and diminished farm numbers. Recent studies also suggest that there is substantially more farmer resistance to BST than was initially predicted. Upwards of a third of the dairy operators in California and Wisconsin, for example, are not planning to adopt this product.

Societal impacts anticipated from the diffusion of growth hormones have ranged widely and have included an acceleration in the displacement of farm families, lessened viability and survival of rural communities, and increased degradation of the natural environment. The public response to growth hormones, especially BST, has been profoundly shaped by these perceived negative outcomes and has led in some states to legislative initiatives to place a moratorium on their use in some states.

That most of the public controversy has thus far centered on BST and comparatively little on PST is a result of the fact that:

1 socioeconomic impact studies have focused almost exclusively on BST and have projected major increases in milk production and a commensurate displacement of dairy farmers, 2 dairying normally has a high level of centrality in the total farming system, whereas pork is typically part of a more diversified operation, and 3 whereas BST brings substantial production increases in a food product for which there is already a chronic surplus, PST acts as a repartitioning agent and facilitates the production of a leaner, improved meat product.

THE IOWA PST STUDY

To assess the farmers' receptivity to PST, an ex-ante adoption study of porcine somatotropin was recently conducted. Two groups, a representative sample of Iowa pork producers (N=250) and a purposive national sample of large-scale pork producers (N = 19) participated in the study. The Iowa sample averaged 1,100 slaughter hogs marketed annually, compared to 181,000 slaughter hogs for the national sample.

Awareness of PST among the Iowa producers is quite low, especially when compared to awareness levels for BST (which recently have averaged about 80 percent of all dairy operators). Only 17 percent of the Iowa sample perceived themselves as well or very well informed about PST, compared to 81 percent of the large-scale producers.

SPEED OF ADOPTION

Ex-ante adoption studies permit the projection of social and economic impacts of innovations that are not yet commercially available. These studies require the preparation of scenarios that define parameters of the innovation. Generally, the scenarios are developed with current "state-of-the-art" knowledge and identify both the relative advantages and potential disadvantages of the product. Benefits of PST included in this study's scenario were improved feed efficiency, increased daily weight gain, improved carcass composition, and an attractive financial return on the operator's investment. Costs of PST included increased labor requirements (in the form of bi-weekly injections), increased protein requirements, more intensive management systems, the possibility of lower market prices, and the potential for adverse consumer reaction to the use of hormones.

A benefit/cost scenario was presented to the respondents, and, after securing their general reaction to the product, they were asked how quickly they would adopt it. The Iowa respondents were cautious—only two percent said that they would likely adopt PST immediately for use on their farms, and an additional 22 percent anticipated they would likely adopt the product within a year. Twenty-five percent said they would adopt PST in one to two years and seven percent would take more than two years. Thirty-five percent of the Iowa sample said they would not adopt PST.

In comparison to the Iowa sample, the national sample of large scale producers were enthusiastic about PST, with 32 percent planning to adopt it immediately, and another 37 percent within the first year. Ten percent said they would take more than a year to adopt, and five percent (one operator) did not expect to ever adopt it.

Revised versions of the scenario (in which financial return and number of injections required were altered) were presented to the respondents to gauge the significance of these changes for their speed of adoption. As expected, increased financial returns brought accelerated adoption—a $5:1 rate of return, instead of the $3:1 rate specified in the scenario, jumped the first year rate of adoption from 24 percent to 50 percent among Iowa producers and from 69 percent to 90 percent among large-scale producers. A reduced return of $2:1 led to 17 percent of the Iowa sample and 47 percent of the national sample adopting in the first year.

Alterations in the delivery system of PST also had a pronounced impact on the anticipated speed of farmers' adoptions. Dropping the required number of injections from four (as specified in the scenario) to two increased the number of first year adoptions from 24 percent to 50 percent among Iowa producers and from 69 percent to 79 percent among large-scale producers. Conversely, doubling the number of required injections from four to eight prompted a significant decrease in first year adoptions, which fell to five percent of the Iowa sample and 42 percent of the national sample.

CORRELATES OF ADOPTION

Ex-ante studies of the adoption of BST have generally shown early adopters to be better educated, more efficient, and milking larger herds than persons adopting later or nonadopters. These findings have prompted the conclusion that large, more capital intensive farming operations will reap disproportionate benefits (windfall profits) as a result of their increased outputs, lower per unit production costs, and higher profits in the marketplace from early adoptions. Because of increased productivity and lower market prices, persons adopting later are typically denied these financial benefits. For the Iowa sample, positive relationships were found between speed of adoption and size of the hog operations, knowledge of PST, innovativeness, risk orientation, and perceived consumer acceptance. Age was not important for speed of adoption and education and acres farmed were of only minor importance.

WHO BENEFITS?

An industry representative has recently concluded that the introduction of PST will be a "win-win-win" situation, with the interests of hog producers, packers, and consumers all being served. When asked for their perceptions of the likely beneficiaries of PST, the Iowa sample was divided on their assessments. Whereas 80 percent perceived that large operators would benefit from PST, only 42 percent and 18 percent, respectively, anticipated that benefits would also accrue to medium and small-scale producers.

Large-scale producers were generally more optimistic about the equity of PST impacts, with 47 percent anticipating that small producers would benefit, and 63 percent and 79 percent, respectively, feeling that medium- and large- scale producers would benefit. Sixty-two percent of the Iowa sample and 84 percent of the national sample felt that meatpackers would benefit from PST, while 33 percent of the Iowa sample and 95 percent of the national sample saw consumers as beneficiaries. A sizeable proportion of the Iowa sample (40 percent) were uncertain whether PST would benefit or harm consumers.

CONCLUSION

Ex-ante studies of adoption have been heralded as permitting the prediction of future conditions and as informing public policy about potential impacts of innovations prior to their release. But it is clear that current agricultural policy cannot prevent potentially adverse outcomes, such as labor displacement from the introduction of new technologies, even if these outcomes are accurately predicted. The question is thus "whether, the ex-ante study*!" Increased public and scientific debate on this question seems warranted. A possible starting point for this debate has been suggested by Dupuis and Geisler, who note that ex-ante studies need to pay greater attention to the institutional structures that undergird agriculture. They conclude that the claimed scale neutrality of new technologies, such as BST and PST, are not inevitable, but only a possibility that depends upon existing institutional contexts. Ex-ante studies can play an important role by identifying institutional barriers to the equitable transfer of new technologies and by providing needed information for better anticipation and structural consequences of their adoption.

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Impact of Animal Growth Promotants on the Dairy Industry

Bauman's early experiments at Cornell indicated increased milk production due to the administration of bovine somatotropin (BST) during the last two thirds of the lactation period. Milk production normally falls consistently after peaking at approximately 90 days after calving. However, the persistency of production in animals given BST was substantial. With a 40 mg. dose, a 41 percent increase in production took place during the time of administration. This translates into a 26 percent increase on a full lactation basis. Lower dosages, particularly 27 mg. per day, also achieved good results; 36 percent during administration or 23 percent on average for the lactation. From these numbers, it appears that when the product comes on the market, it will be at a somewhat lower dosage rate than Bauman's optimal results. Food and Drug Administration (FDA) labels will most likely appear for dosages lower than 40 mg.

BST DOSAGE RATES

Once FDA approval is given, it is likely that there will be a number of labels for different companies, each with different dosage rates and delivery methods. The farm operator will be able to choose amongst the various labels and different methods of administration. Administration choices will include daily injections and sustained release injections. The sustained release injection will release a product over a longer period of time; two, three, or four weeks, so that only one injection has to be given for that period. A farm operator will need.to select the dosage level and timing of injections from the available array.

What are the implications of BST use? The milkyield increases can reach 25 percent. In some experimental herds, yield increases in the field have actually been a little higher. However, production increases can also be zero. Feed efficiency improvements can range as high as 8 to 11 percent depending upon the production level and the response rate of the cow.

ECONOMIC IMPLICATIONS

Based on feed efficiency improvements, there will be production cost reductions ranging from five to nine percent. When BST is used, cows must be fed additional forage and concentrate in order to produce additional milk. This increased intake is proportional to the milk that a cow produces, so the savings, as far as feed efficiency is concerned, are strictly due to spreading the cost of the maintenance portion of the ration over more milk production.

Thus, the potential economic implication of protein synthesis regulation is to reduce the total nutrient requirements for the national dairy herd, not for the individual animal. Reductions in the national herd size from 11 million animals down to eight or nine million will occur. A decrease in total livestock feed requirements will mean a decrease in land requirements for feed grains and forage, and changes in both feed and land prices.

Possible alterations in regional production patterns may also occur. As poorer quality lands are no longer needed, they will go out of dairy production, and production could move onto better land in the Corn Belt and elsewhere. Consumer prices should become somewhat lower and there will be an increased demand for some of the products from the industry. Herds are going to have to be better managed to be productive with BST, and the improved management will improve product quality.

STRUCTURAL IMPLICATIONS

What are the structural implications for the average farm? As noted, management intensity will need to be substantially increased. Higher literacy skills, computer skills, and analytical skills will be required to run the dairy farm of the future. Good management skills will be absolutely critical for the successful adoption and use of BST.

Synergism will exist between different technologies. If herds are to be managed properly, computers will have to be utilized, particularly for large herds. Using the computer to collect and analyze data and to actually perform day-to-day operations previously handled by labor, will mean increased consistency in carrying out the management function with a savings in time and money. Other technologies can be used to further improve herd management. For example, robotics and controlled environmental housing will be adopted during the last half of the 1990s.

Although BST is generally considered “scale neutral" (that is, it can be used by small or large farms without bias in terms of profitability), but when management capability is taken into account, BST is no longer scale neutral. In this case, larger farms have an advantage, so the economies of scale are going to play an important role. Also, economics of scale are important when other technologies are used in conjunction with BST. Most of the synergistic technologies are capital intensive. This will add additional capital intensity to the sector, and there will be financial impacts that go beyond the purchase price of BST itself.

PRODUCTIVITY AND PROFITABILITY

The productivity and profitability of top producers in the dairy industry is growing more rapidly than that of average producers. This is a difficult hypothesis to test, because of data limitations, but there is some evidence from the New York dairy farm business summaries. If it is true, it places increasing economic pressure on those operators that are below average or are above average, but not in the top ten percent. Some of the below average operators are only going to survive if they have no debt.

Biotechnology is going to impact the best managed farms the most, because the early innovators are going to benefit before prices in the market begin to drop. The spread between the top decile farms and the rest of the group is widening, and biotechnology and BST in particular, will probably increase that gap over time.

DAIRY FARM SURVIVAL

Which farm operators are going to survive as resource commitments in the dairy sector are reduced? The successful innovators are going to be the survivors. Early innovators and people with production and business management skills are going to have an advantage. If farmers have a quality resource base that enables them to grow good forages, they will have an advantage. If farmers have sufficient scale economies to actually manage their operations rather than do the work themselves, and they have sufficient capital available to add other technologies to support BST, they have a better chance to survive. If the financial health of a dairy business is good and they are specialized, they have a better chance of surviving.

Failure to adopt BST could possibly lead to the demise of the farm. There will certainly be a loss of market share for the industry, which very few of the critics of BST recognize. The dairy industry is always in a market share battle with other food products, and if the industry fails to keep its cost structure reasonable in relation to competing food products, they are going to lose market share to other portions of the food sector.

In the short term, the use of BST will put some dairy farmers out of business, but if BST is not adopted, more farmers will be lost in the long run. The failure to adopt new technology in general means a lower standard of living for society because, in the end, consumers benefit by the adoption of new technology.

PUBLIC POLICY

Public Policy is very unresponsive to uncertainty, and dairy farming is entering a stage of substantial uncertainty. Adjustment to the dairy industry may be inhibited by imposing additional public policy constraints. Policy has to be designed to foster the removal of excess capacity in the industry. The industry is already 20 percent or more in excess in terms of the number of dairy farmers needed to have a free market in milk without BST. Obviously, adding the additional production capability due to the use of BST, is going to make this situation worse. A socially acceptable policy to remove excess capacity must be implemented. The removal of price supports and the income support program of public policy is going to be important. Public income should emphasize education, human services, and social safety nets. This would make for an improved and healthier dairy sector in the long run.

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Impact of Animat Growth Promotants on the Meat Industry

What are the differences in the effects which growth promotants might have in the dairy and the meat industries? Little product quality change will be evident in the dairy industry. In the pork industry, the repartitioning effect in growth promotants is quite dramatic. A 35 percent reduction in fat in the carcass is likely. While part of that reduction is in trimmable fat, the impact on human health is still going to be significant.

THE DAIRY INDUSTRY VERSUS THE MEAT INDUSTRY

The protective government policy in the dairy industry versus the relatively unfettered policy in the beef and pork industries and the broiler industry, make a difference in how these industries are perceived. The chronic surpluses in the dairy industry provoke a standard question. "Why do we need more milk? We already have surpluses!" In contrast, the meat industry is basically a market clearing process where prices are cyclical, as they are in farming. Prices in the dairy industry are kept artificially high, but if the price supports were to be changed by Congress as the cost of production goes down, then the benefits of lower costs and higher production could be passed on to consumers.

To clearly determine the impacts on these industries, the competition must be analyzed. Studies that research only one small section of a larger industry with significant competition among consumer products may not be fully reliable. Any advances in biotechnology are likely to be beneficial, but it depends on the relative advances in biotechnology among competitors like beef, pork, and poultry, not just the absolute advances in any one particular biotechnology.

Consumer attitudes and perceptions are critical and must be taken into account, especially in the dairy industry. People are fearful of drinking any milk that contains hormones, but the average consumer does not distinguish the difference between steroid-based hormones and polypeptide hormones. This is the kind of confusion and perception that could make a great difference in the potential acceptance of food products from these growth promotants and their viability as a commercial technology.

PST PERFORMANCE IMPACTS

Even though porcine somatotropin (PST) is called a growth hormone, the growth impact is relatively small, and may encompass only an eight day difference in reaching market weight. Feed efficiency shows a 25 percent improvement when PST is used during the primary feed- using period (which is from about 110 pounds up to about 240 pounds). This translates into about 100 pounds less feed per hundred weight of each animal.

Carcass fat composition also improves with PST use. This improvement can mean 35 percent less fat and 15 percent more lean meat. It must be noted that the market hog's carcass weight as a percent of live-weight also decreases slightly.

PROCESSING EFFICIENCY

If one third of a hog's low-value fat is pared off, packers may be more willing to slaughter market hogs at heavier weights. It doesn't take any more time to process a 240 pound hog then it does to process a 280 pound hog. The only reason this is not done now is that the pared off fat has to be either sold as lard or tossed into the tank. If a 280-pounder would have the same amount of fat as today's 240-pounder, the result is another 40 pounds of live hog, and an even higher proportion of lean meat. Fewer sows will be needed to meet the same level of ultimate consumption. Structural implications in terms of the numbers of breeding stock and perhaps the number of farmers could be more significant.

PST PROFIT AND STRUCTURE IMPACTS

As PST is adopted by the pork industry, the improved feed efficiency reduces cost and increases profits. In addition, a carcass merit premium results because there is less fat on the carcass.

Farmers usually react to profitability by expanding. Production will increase, prices will drop and then stabilize, and profits will return to longer-term competitive equilibriums. Consumers will benefit in terms of lower prices as a result of the increased production, as well as in the leaner product.

Feed producers will also be affected by PST use, because 25 percent less feed is required. Feed grain producers would be somewhat hurt, and there would probably be a drop in the corn price along with the longer term effect of less acreage required. On the other hand, there would be an increased need for protein or lysine supplements, so oil seed producers would likely benefit. In addition, with less feed required, the manure output would be reduced.

If a farmer ends up with fewer breeding stock, that might cut down on veterinary services and the supplies required. If PST would enhance immunity, this might also reduce the need for veterinary services.

If a heavier slaughter of animals results, more labor and space would be required for the finishing part of the operation and comparatively less for the farrowing process.

The resulting number and size structure of producers is often raised as an issue. It is not necessarily size, but management sophistication that really makes a difference in the successful use of PST. Larger, more specialized operations are more likely to make effective use of this relatively sophisticated technology. In the long run, there might be an increased tendency to shift away from the small and intermediate size to the larger pork production operation. The areas most likely to increase their share of production would be North Carolina, Missouri, Arkansas and Nebraska, where the largest size producers are concentrated.

5 *Reports*

Council Members Report

Technology has allowed American society to flourish this century. Advances in electronics, aeronautics and computers have had profound and far-reaching impacts. The more recent development of biotechnology —the management of living systems on a cellular or molecular level to benefit humankind—has the potential for similar, broad-reaching effects.

In contrast, there are now various efforts to probe biotechnology's social, economic, and ethical implications, to anticipate its strengths and shortcomings, and to guide its development. The National Agricultural Biotechnology Council (NABC) was created, in particular, to work toward the safe and efficacious development of biotechnology for agriculture. A primary goal of NABC, which was created in 1988 with the support of The Joyce Foundation of Chicago, is to assess how biotechnology can best serve agriculture, and to advise policy makers on specific opportunities.

The Council views biotechnology as a process almost as old as agriculture itself. Cheese, bread and beer are all products resulting from the application of the simplest tools of biotechnology, natural microbial organisms, to the basic foodstuffs of milk and grain.

What is new, however, is that recent advances in the science of molecular biology—the study of living organisms at the level of genes and their products—allow the design of more precise and useful biotechnological tools. These tools are being used to alter living organisms to meet modern needs. For example, plants can be custom designed to better resist pests; or to l.r/e improved nutritional qualities. Animals can be produced whose meat is more healthful, although some people consider the hormones to produce such meat to be unhealthy. Milk can be produced at lower cost, and microbes can be custom designed to produce vaccines and hormones to promote human and animal health.

Moreover, biotechnology can allow agriculture to be more sensitive to the environment. Modern farming faces a dilemma not known in the history of agriculture. Demands for novel and/or expanded production are being made at the very same time that increased sensitivity to environmental issues is encouraging farmers to become more careful and cautious producers. Several technologies introduced in the 20th century have allowed agricultural productivity to more than double. But many gains were made at the expense of the environment; undesirable fertilizer and agrichemical residues, for example, have contaminated soil and water. There is now new awareness, in both urban and rural communities, that the land cannot sustain or increase yields in the face of constant abuse. Biotechnology, however, offers tools that will allow agricultural products and processes to preserve non-renewable resources, and thus, to be more compatible with the environment. In the future, biological control systems for pests an diseases may replace agrichemicals, and applications of expensive, synthetic nitrogen fertilizers may be reduced via the use of biological fertilizers.

Most importantly, biotechnology is distinguished from other, earlier technological achievements by its breadth and scope. The achievements of the classical agricultural disciplines, such as weed science, entomology, plant pathology and agronomy, were made gradually and incrementally over decades. Advances in biotechnology promise to be swift, broad-reaching and dramatic. For this reason, the NABC has committed itself to detailed study of the social and scientific implications of biotechnology.

The Council's strategy is to bring together diverse disciplines, including the natural and social sciences and the humanities, to generate creative thinking on policy alternatives. Advice is drawn from all regions of the country, both rural and urban. This permits the development of a national forum with real objectivity. Most importantly, it also allows scientists to make productive linkages with individuals who will apply their work. This, in turn, generates a more complete understanding of the long-term impact of biotechnology, including both its benefits and drawbacks.

Because the first commercial products of modern, agricultural biotechnology will be introduced soon, and there is much agreement that these products should be used to enhance the economic viability of farming, to improve food quality and to promote environmental quality, the Council decided to focus its first annual conference on Biotechnology and Sustainable Agriculture: Policy Alternatives.

Holistic management, economic tradeoffs, scale neutral systems and residue testing were subjects that appeared often during the meeting, which was held May 21-24, 1989, at Iowa State University in Ames, Iowa. To some of the more than 200 in attendance, sustainable agriculture translated into concerns for family farms and rural communities. To others it meant agriculture practiced with a long term view, more humane treatment of animals or minimal use of synthetic pesticides. Some perceived sustainable agriculture as a system where land, labor, information and management were substituted for chemicals. That the conference did not come up with a final definition of sustainable agriculture was not a surprise, or a disappointment. Sustainable agriculture remains an evolving concept. It is best defined by the diverse issues addressed at the conference. And there were many. The invited speakers represented a broad range of disciplines, from philosophy and ethics, to law and economics, to animal science and molecular biology. At the workshop session, provocative discussions took place among natural and social scientists, applied and basic scientists, consumer advocates, environmentalists and farmers. For many, it was the first opportunity to discuss issues with those outside their immediate discipline. Interdisciplinary teams tackled a better understanding of the relationship of sustainable agriculture to herbicide tolerance in plants, biopesticides, animal growth promotants and disease control in animals. Despite the disparate backgrounds and interests of the participants, significant consensus was built. Recurring themes emerged from the workshops' deliberations.

A special concern was that a public agenda, as defined by farm and rural communities as well as a broader base of consumers, be used to guide the public development of biotechnology. The development of science is traditionally spurred by the initiative of individual scientists and then guided by public and private funding. That process may be inadequate for current needs. Private industry, it was noted, provides superb support for biotechnological developments that promise short-term commercial gains. But there is less vigorous support for developments that may have long-term rewards or no commercial value at all, even though they may fill a particular public need. It was suggested that public funding for biotechnology be bolstered and carefully directed to fill these voids.

"Can technology save us from the pollution it has caused?" asked Robert Goodman, of Calgene, Incorporated, Davis, California. "Yes", was his answer. "We must think hard about the inventions needed and then guide technological achievement," he said.

In particular, it was suggested that publicly-funded agencies might focus more on the development of environmentally beneficial pest control for specialty crops, such as forestry, and others with limited commercial value. Scale neutral technologies, that do not need high investment, merit additional attention. Also, public agencies could stress support for aspects of biotechnology that are high-risk or inherently unpatentable, in the same way they support the development of orphan drugs. There was concern, too, that mechanisms be established to assure that social and ethical issues receive a higher priority on the public's research agenda.

Economics impinged on many discussions. Although the specific details of economic concerns varied from discussion to discussion, two issues appeared repeatedly: that the price of agricultural commodities fail to reflect true costs; and that farmers are often compelled to meet short-term economic objectives which are inimical to the long-term goals of sustainable agriculture. A suggested first step toward resolving these problems is an assessment of the true costs of agricultural production, including government subsidies and the environmental and health costs of common agricultural practices. If the pricing system was adjusted to reflect these hidden costs, consumer interest in and farmer commitment to sustainable agriculture might be enhanced. The economics of farming might be altered enough to allow agriculture to adopt the long-term management goals needed for sustainable agriculture.

The challenge of implementing sustainable agriculture was evident in economist Katherine Reichelderfer's comment that "Not even the most 'ethically appropriate', 'socially rational' or environmentally beneficial pesticide will be widely adopted by farmers if costs are too high in relation to its productivity...."

Agricultural economics, as it relates to the use of sustainable agriculture and biotechnology, was identified as a subject that requires much additional research.

Many speakers stressed that the implementation of biotechnology on the farm requires special skills, such as data analysis and advanced management techniques. But that requires farmers to have access to the latest information from unbiased sources. A startling example of the importance of continuing education on the willingness of farmers to consider a new technology was shown in the studies of farmer adoption of bovine (BST) and porcine somatotropin (PST). Eric Hoiberg and Gordon Bultena, both of Iowa State University, and Peter Nowak, of the University of Wisconsin, noted in their presentation that, "ex-ante studies of the adoption of BST have generally shown early adopters to be better educated .. .than persons adopting later or non-adopters." In their own studies of Iowa farmers adopting PST, ".. .positive relationships were found between speed of adoption and size of operation (and) knowledge of PST ..."

In general, the larger private farms, with considerable advisory support, made better use of these new technologies. One possible conclusion from these studies is that failure to have easy access to current information could be an institutional barrier to the transfer of new technologies. Another is that public agencies have a responsibility to help assure access to needed information.

A recurring theme of the conference was the need to promote diversity in agriculture, both in the industries that support agriculture and on the farm ecosystem itself. Sustainable agriculture requires a variety of techniques, used at different times for different situations. Yet industry and farmers often limit their own options. For example, the subject of weed control was dominated by discussion of chemical controls. Interest from farmers and industry on the development of mechanical means for weed control seemed meager. Rebecca Goldburg, of the Environmental Defense Fund, however, described various non-chemical alternatives for weed control. "Such techniques", she said, ".. .industry has not found profitable to research or promote, but with which public sector researchers could build environmentally benign weed control strategies."

Still, there was widespread support for promoting diversity in the farm ecosystem. Traditional plant and animal breeding techniques have dramatically reduced genetic diversity and this genetic uniformity has made American agriculture vulnerable to insect pests, diseases and climatic fluctuations. Monocultures lack the broad spectrum of natural defenses found in polycultures. However, the tools of biotechnology, which include improved gene transfer and selection techniques, may correct this.

The challenge to feed, clothe and house an expanding global human population demands that agricultural systems be wisely managed to sustain productivity, over the long-term. Biotechnology offers the tools for achieving this. Yet, history has shown that scientific progress is spurred by idealism tempered by realism. Our goal is to bring together concerned, informed individuals who will generate the wisdom needed to assure that an ideal balance is struck for agricultural biotechnology. The NABC conference on Biotechnology and Sustainable Agriculture: Policy Alternatives is a first step in that direction.

—written by Anne Simon Moffat, based on interviews with NABC members at the time of the meeting.

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Fellows Report

This conference attracted more than 200 participants representing a great variety of universities, research organizations, governmental agencies, advocacy groups, and agribusiness enterprises. Thus the goal of assembling a broad group of constituencies was realized at the outset.

RATIONALE

The face of American agriculture has changed greatly over the past two centuries. From Eli Whitney's cotton gin to the motorization of farm equipment by Henry Ford and his successors, to the chemical-intensive agriculture brought on by "better living through chemistry," technological changes have increased agricultural productivity and altered farming methods, dramatically changing the way we live. And now, biotechnology is expected to affect agriculture even more profoundly through its power to change the genetic makeup of our crops and livestock in ways previously thought impossible.

The ways we have adapted technology to agriculture (some would say agriculture to technology) have also brought negative consequences, producing an array of problems such as massive soil erosion, pollution and depletion of water supplies, and socioeconomic dislocations in

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rural communities as concentration of production increases. Sustainable agriculture as it is defined today attempts to ensure agriculture's future by addressing critical problems such as these. By promoting the long-range viability of agriculture and rural communities, sustainable agriculture would ensure a future agricultural complex in which the gains promised by biotechnology can be implemented.

Sustainable agriculture, which seeks to control technological inputs, and biotechnology may at first seem like strange bedfellows, but closer examination suggests that they can be made complementary. For the two to work in concert, however, it is important to consider each in the context of the other—a non-traditional approach. For example, if we agree that agriculture must be sustainable into an unknown future, agricultural research policy must take sustainability into account, so as to ensure that biotechnology will also serve that goal. To explore the confluence of biotechnology and sustainable agriculture was the challenge faced by this conference, and its reason for being.

ORGANIZATION

The format of the conference was designed to examine how sustainable agriculture might be interrelated with each of four categories of biotechnological products: herbicide-resistant crop plants, biopesticides, animal growth promotants, and agents for disease control in animals.

Each product category was examined from four broad perspectives: technical overview; social and ethical issues; environmental, health, and safety issues; and economic aspects. (This four-point perspective was based on the model used at Iowa State University in courses dealing with technology and social change.)

Following keynote presentations, each combination of product category/perspective was addressed by an expository lecture. These lectures were interspersed with workshop/discussion sessions organized by product category. Reports of those four workshop groups accompany this report.

PROBLEMS OF DEFINITION

A comprehensive definition of biotechnology might be difficult, but the organization of the conference around biotechnological product groups provided a working definition, and there seemed to be little confusion about the meaning and scope of biotechnology as an activity.

Defining sustainable agriculture was more difficult. In the keynote address, Charles Hassebrook, a leading thinker in the integration of biotechnology and sustainable agriculture from the Center for Rural Affairs, Walthill, Nebrasksa, gave a lucid and broadly based exposition of the nature of sustainable agriculture, including a description of some opportunities for biotechnology. Nonetheless, the subject of sustainable agriculture was largely ignored in some of the discussion groups that followed.

Perhaps some participants had only recently been exposed to the full concept of sustainable agriculture, and were relying on incomplete notions acquired in the past. Others appeared to be less knowledgeable about biotechnology than about sustainable agriculture. Whatever the reasons, it was clear that some participants could not conceive of biotechnology and sustainable agriculture outside of an adversarial relationship.

To be more generous, perhaps the newness of the idea that biotechnology and sustainable agriculture might be used toward common goals, made it too difficult to assimilate without more time for reflection. If this is true, the greatest benefits of this conference may be realized long after it is over, as participants carry learning gained from it into their future activities.

Hassebrook's directions for a sustainable agriculture included the following components:

—Maximizing opportunities for owner/operator farms.
— Enhancement of health of both farmers and consumers.
— Enhancement of environmental quality: water, air.
— Conservation of non-renewable resources: fossil fuels, soils, genetic resources
—Maintenance of economic viability.
—Broad public political control.
—Coordination of all of these considerations.

Other speakers expanded this definition even further, to include maintenance of healthy rural communities, development of healthy international interrelationships and, in Ralph Hardy's words in his charge to the conference, consideration of "even the aesthetics of the countryside."

PROBLEMS OF VIEWPOINT

Even if all participants could have reached a consensus on definitions for both biotechnology and sustainable agriculture, it is not likely that much agreement on appropriate direction s for the future would have followed as a matter of course. The difference in viewpoint toward technology as we have usually accepted it and sustainable agriculture as we aspire to practice it might have been too great for that.

As Hassebrook pointed out, "modern" agriculture (including agribusiness) is based on an "industrial model" in which mechanical and chemical technologies are used to reduce human input, largely ignoring or overriding natural systems. This industrial model also creates scale inequities which, while they may realize short-term efficiencies, tend to concentrate production in the hands of the few, a movement which many believe ultimately results in greater concentration of political power, accompanied by inordinate control over our food supply.

Whether right or wrong, much of this is antithetical to the goals of sustainable agriculture, which seeks to reduce chemical inputs, to humanize and democratize agriculture and rural communities and, above all, to measure efficiency in terms of sustainability over the long term. Considering all this, it is not surprising that most of the conclusions of this confernce were very general. Clearly, communication and understanding among interested groups with diverse needs and viewpoints must be improved before conferences such as this can be expected to recommend many specific guidelines for agricultural policy. That is the challenge that has come from this conference for the use of future organizers.

CONCLUSIONS

The problems that emerged in this attempt to relate these two very different entities: biotechnology and sustainable agriculture, highlight the need for an integrated philosophy of agriculture, looked at both as complex of technologies and as a component of culture. We need the wisdom and the will to find directions for agriculture and agricultural research that will serve us will in the post-industrial age. In doing so, we must recognize, as Hassebrook pointed out, that agricultural researcvh is inescapably a form of social planning; the only real choice is whether to plan well or poorly.

Even though this conference provided few immediate answers, it served as an important first step by raising many important questions, and giving us much to think about in designing future steps. If this lead is followed, we should be able to design a public policy for a future agriculture that can make use of biotechnological advances in appropriate ways, while preserving sustainability of soils, environment, and human resources.

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