1997

# NATIONAL AGRICULTURAL BIOTECHNOLOGY COUNCIL REPORT

NABC REPORT 9

# *Resource Management in Challenged Environments*

*Edited by* Ralph W.F. Hardy, Jane Baker Segelken, and Monica Voionmaa

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*Resource Management in Challenged Environments*



Photos on the cover are courtesy of the University of Saskatchewan.

Photo Caption: Examples of challenged environments on crop plants, including drought and weeds. Transgenic crops are now being used as a strategy for weed control but not yet for drought.

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*Providing an open forum*
*for exploring issues in*
*agricultural biotechnology*

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NABC Report 6, *Agricultural Biotechnology & The Public Good* (1994)

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Ralph W.F. Hardy
NABC President

Jane Baker Segelken
NABC Executive Coordinator

# PREFACE

The NABC Report 9 — Resource Management in Challenged Environments — comes from the NABC annual meeting, hosted June 1-3, 1997 by NABC member institution University of Saskatchewan — the first NABC meeting in Canada.

Major financial and people investments in all aspects of agricultural biotechnology by the public sector and industry in Saskatoon are providing the basis for Canada to be a major participant in agricultural biotechnology. The industrial and public sector concentration in agricultural biotechnology is probably greater than in any other community in North America.

Agricultural biotechnology gained momentum in 1997. One-third of farmers in the United States and a smaller fraction in Canada have used agricultural biotechnology inputs with maybe 30 million acres of transgenic crops grown in 1997. Agricultural input industries — agrochemical companies — are investing more than five billion dollars to consolidate seed and other inputs for crop production, and also to integrate vertically into the food, feed and biobased industrial products business. The food products from transgenic organisms probably have now been eaten by almost every person in the United States — cheese, milk, and food products of canola, corn, and soybeans. The farmer and consumer use in Canada is smaller to date than in the United States because of Canada's slower governmental approval rate.

NABC 9 focused on the use of the new agricultural biotechnology products and processes in geographically and environmentally challenged environments. All agriculture, especially crop agriculture, is environmentally challenged. There are the somewhat predictable never-ending challenges of pest insects, diseases, and weeds. The transgenic crops being grown provide new approaches to weeds, diseases, and some pest insects. The more unpredictable challenges of weather — temperature and rainfall — have not yet been minimized with agricultural biotechnology.

More than 100 participants gathered for three information-packed meeting days in Saskatoon, Saskatchewan, Canada. There they shared their views on how to best use the new agricultural biotechnology products to meet the needs of producers and consumers. One of today's most critical challenges is the need to feed an increasing world population. Recent advances in agricultural biotechnology have led to the development and commercialization of many products that promise to sustain and/or increase food production.

This report summarizes the presentations and the workshop dialog at that meeting. While many of the examples discussed were the most developed of the agricultural biotechnology products now entering the marketplace (herbicide tolerance and insect resistance), there is early stage research on drought tolerance, salt tolerance, and aluminum tolerance. Products and processes designed to address the unique needs of challenged environments represent a tremendous opportunity for agriculture, and discussion and identification of emerging issues were initiated in the open forum with broad representation.

The annual meeting is the major NABC activity. The NABC member institutions propose meeting topics to the NABC Council which then selects the subject and provides guidance to assure that speakers and workshop cochairs represent the total dimension of viewpoints. Host institutions make special efforts to have broad representation at the meeting, including academia, government, industry, public interest, farming, and others. There is not only an opportunity but an expectation that each attendee will speak, listen, and learn through participation at plenary sessions, dialogue in the workshops, and attendance at the workshop summary presentations.

The workshop reports are the most important part of an NABC meeting, and are placed at the beginning of the Report, followed by the presentations by plenary and other speakers. Each year, 7,000 NABC Reports are printed and distributed worldwide to leaders in industry, government, academe, public interest groups, the media, and other interested individuals.

Although some still believe that human safety and environmental risk are continuing issues in agricultural biotechnology, others see equitableness, including access, as a major emerging concern. The NABC is the only established open forum to help promote understanding of the many diverse viewpoints, and provide an opportunity for addressing concerns about agricultural biotechnology.

The unique NABC continues to be a vibrant force on the agricultural biotechnology playing field, offering people with diverse views the chance to speak, to listen, and to learn.

Ralph W.F. Hardy
NABC President

Jane Baker Segelken
NABC Executive Coordinator

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PART I

# RESOURCE MANAGEMENT IN CHALLENGED ENVIRONMENTS

# *Resource Management in Challenged Environments*

J. D. Knight, R. E. Farrell, B. L. Harvey, and J. J. Germida
*University of Saskatchewan*

## NABC 9: An Overview

One of the promises of modern biotechnology is that it will increase productivity in challenged environments. Thus the topic of the ninth annual meeting of the National Agricultural Biotechnology Council (NABC), "Resource Management in Challenged Environments" was extremely appropriate and made even more so by conducting the meeting in Saskatchewan, an agricultural region facing a continually challenged environment. It became evident from the plenary and workshop sessions that little progress has been made toward achieving the goal of increased productivity. Not only were genetic manipulation of traits such as heat, cold, salt, and drought tolerance proving to be much more difficult than initially perceived because of their multi-gene nature, but problems also were evident in social awareness and acceptance of biotechnology in various sectors. One recurring concern was the reduction in public research funding and the trend toward privatization — focusing agricultural research on economic benefit and away from research for the public good.

The meeting was organized around three plenary sessions and concurrent morning and afternoon workshops that focused on three central themes: biodiversity conservation, regulatory and economic aspects of accessing international markets, and social issues facing rural agriculture communities. From very different perspectives, the two speakers in the first plenary session introduced the issues facing agricultural biotechnology today, generating considerable debate. Speakers in the second plenary session brought often contradictory perspectives to the issues, representing viewpoints of industry, organic farming, consumers, and environmentalists. The final session was represented by a single speaker, Professor Timothy Reeves from CIMMYT in Mexico. He highlighted global implications of biotechnological research and our social responsibility to use any means possible to solve the world's hunger problem. As Eugene Sanders, vice provost and dean of the College of Agriculture, University of Arizona, pointed out in his summary of the meeting, all of the sessions generated significant discussion in three general areas: first, sustainable agriculture means different things depending on the specific location and nature of the agricultural enterprise; second, diversity also varies greatly in meaning depending on the specific case; and third, advances in agricultural biotechnology will continue to suffer from difficulties in educating the general population.

In addition to the provocative and often controversial nature of the speakers, the success of NABC 9, like past meetings, was successful because of the widespread participation and enthusiasm of those attending the meetings.

## Plenary Session Highlights

### Plenary Session 1

*Robert W. Herdt, Director for Agricultural Sciences and Acting Director for Global Environment, The Rockefeller Foundation*

Herdt began the meeting by identifying an impressive array of perceived promises of agricultural biotechnology: to increase productivity and our ability to “feed the world,” to increase the investment in agricultural research, to expand the range of gene sources, to develop a sustainable system, and to produce specific products, such as pharmaceuticals by introducing new genes into plants. The promise that plant biotechnology may raise innate productivity, he suggested, relies on the belief that because plant genes can be manipulated there must be a way to apply this knowledge, rather than a demonstrable strategy for doing so. Furthermore, the promise to “feed the world” requires that the biotechnology be applied to address the needs of the developing world, whereas fact efforts directed at applications for developing countries are small, especially when compared to those for industrialized countries. Still, Herdt does see definite progress being made toward achieving the remaining goals. Clearly, the advent of biotechnology has stimulated further research and there is little doubt that genetic engineering will make new sources of genes available for use in plants. Herdt’s major criticism was that the direction of biotechnological research is now largely under the control of the private sector, which brings into question the concept of property rights associated with biological organisms. Herdt was reluctant to address the issue of sustainability. He cited the potential reduction in pesticide usage with the introduction of the Bt gene into crops but also pointed out the potential for an increase in insects resistant to Bt, reducing the usefulness of this relatively benign pesticide. Clearly, alongside each promise is a potential pitfall — if only in the public’s perception of the technology. Herdt contends that the potential dangers associated with genetically engineered crops are small compared to the potential benefits, and he remains optimistic about the future role of agricultural biotechnology.

*Mark Winfield, Director of Research, Canadian Institute for Environmental Law and Policy*

Challenging the claim that agricultural biotechnology is essential to meeting the food needs of a growing world population, Winfield outlined the arguments presented by a variety of organizations, communities, and developing world governments that have been at the forefront of this challenge. His first concern related to the ethical and philosophical issues raised by genetic engineering. Many individuals are disturbed by the idea of genetic manipulation and question whether human beings are capable of making appropriate decisions with respect to this technology. Winfield's second concern was the potential effects on the environment and human health of biotechnological products. He cited specific examples and raised more general concerns about the risk of reducing biological diversity by the implicit drive to breed uniformity into plants and animals. The third aspect of his critique challenged the value and purpose of many of the applications of the emerging technology. He claimed that many applications do not establish more ecologically sustainable food systems and instead are technological fixes to fundamentally social, economic, and political problems. Central to all three of his criticisms was his perception that both the Canadian and U.S. federal governments have refused to address these issues while continuing to subsidize the development of biotechnology heavily.

## Plenary Session 2

*George Lee, University Coordinator, Agricultural Research, University of Saskatchewan*

Lee set the stage for the workshop by presenting the Canadian Prairies as a challenged environment where we work “close to the margin” of environmental limitations on agriculture. He cited the role of technology in prairie history, recognizing both its favorable and unfavorable impacts. He also identified some of the changes and challenges facing today's agricultural milieu.

*Rick Walter, Director, Canadian Institute of Biotechnology*

Walter took the theme of the meeting one step further and invited his audience to meet the challenged environment of low public awareness. He began by educating us to the international regulatory situation and public attitude toward agricultural biotechnology in selected regions. He outlined the regulatory system in place for obtaining product approval in Europe, Japan, Australia, and North America and identified the role of antibiotech lobby groups such as Green Peace in each area, pointing out the importance of such groups in providing a reality check on our progress. Walter then narrowed his focus to public opinion polls carried out in North America. He cited an increase in public awareness of biotechnology between 1993 and 1995 but little progress toward public understanding. A common thread through all of the NABC meetings over the past decade was the recommendation that public awareness be increased. He challenged members of the NABC not only to recommend it but to meet it head-on — claiming that the products of biotechnology are a reality and that the consumer has a right to make informed decisions.

*Raphaël Thierrin, Food and Fibre EcoStrategies*
Presenting the organic farming perspective on agricultural biotechnology, Thierrin identified the main potential threat from biotechnology as disabling or eliminating organic agriculture. He did not suggest that biotechnology should be eliminated, but recommended the development of policy that will allow several distinct food production technologies to exist. According to Thierrin, the organic industry feels most affected by three facets of agricultural biotechnology: dissemination of transgenic plants through the ecosystem; availability (or nonavailability) of nontransgenic seeds and feed sources; and rapid insect resistance to Bt. Current organic production standards do not allow genetically modified organisms. Practically speaking, this means keeping bioengineered products (consumer products and seeds and feeds) completely separate from organic products. Thierrin stressed that agricultural technology needs to be developed in a manner that will enable all agricultural practitioners to benefit from it, including ensuring that the benefits of future plant breeding are not lost to the organic industry. He stressed that as other types of biotechnology applications are developed, their impact on organic agriculture should be assessed, and technologies that make organic agriculture impossible to practice should be discontinued.

*Joyce Groote, President, Industrial Association of Biotechnology*
Groote began her discussion by reminding us that biotechnology is a tool to develop new products, not an end in and of itself. While the industry is a developer, manufacturer, and user of biotechnology, it would not exist if the products did not meet environmental, consumer, and community needs. She stressed that a more holistic approach must be taken to address the needs of and impacts on the entire system. Groote also reminded us of Canada's leading role in biotechnological research and application. She speculated that if the industry left Canada we would not become biotechnology — free but would continue to be users of the technology because of the exportation of products by other countries. Instead, we would fall behind competitively and economically. Groote emphasized a systems approach to solving today's problems with sustainability and integration as the priorities.

*Sheila Forsyth, Chair, National Agricultuel Environment Committee*
Addressing the question of the role of agricultural biotechnology in challenged environments, Forsyth raised a series of questions meant to help us find our way through the social, economic, environmental, political, and ethical maze that biotechnology presents. According to Forsyth, the debate around biotechnology is not so much what we can do with it but whether we should be doing it — weighing the risks and benefits. One example of the many interesting scenarios she presented is as follows. If a scientist discovers a way to eliminate the allergenic component of peanuts using biotechnology but does not act on the idea and people continue to die, is this an abuse of the knowledge or is it an acceptable consequence because the technology changes the genetic code of a plant and therefore is not considered allowable by some? If we implement a technology that should not be used we have clearly failed. But, if we do not implement a technology that we should have then have we similarly failed? Which is worse? With challenges such as these Forsyth forced us to consider the various perspectives toward biotechnology.

## Plenary Session 3

*Timothy Reeves, Director General, CIMMYT*
As the only speaker in the third plenary session, Reeves gave an impassioned talk about the current state of global food security and the role of agricultural research. He began by giving some statistics on food insecurity and malnourishment in the developing world and cited the current trend of stagnating and sometimes falling yield growth rates in many areas. A common theme throughout his talk was the necessity for expanding research in developing countries and increasing collaboration among developed-country research institutions, international agencies, and the developing country's own research institutions. Reeves proposed implementing all appropriate science and technology, including conventional breeding and genetic engineering and biotechnology, to solve the global food crisis. Reeves contends that it is unethical to withhold solutions to problems that cause thousands of children to die from hunger and malnutrition.

# Workshop Speakers

## Biodiversity Conservation for Sustainable Agroecosystems

*Brad Fraleigh, Special Adviser, Biodiversity and Genetic Resources, Agriculture and Agri-Food Canada*

Fraleigh began the first workshop session of the morning by identifying some of the issues related to biological diversity in sustainable ecosystems, with particular focus on the impact of biotechnologies. Much of his discussion was in the context of the Convention on Biological Diversity, a legally binding international treaty that is the first legal and conceptual framework for the consideration of agricultural biodiversity at the global level. Fraleigh pointed out that there is little doubt that the conservation of genetic resources is essential for maintaining genetic diversity. He outlined some of the conventional conservation methods and expressed the need to expand the use of many of these techniques to a broader range of germplasm conservation. He also cited the concerns of some regarding whether advanced methods will soon replace conventional gene banks that will enable existing DNA sequences to be stored and resynthesized at will and will enable the synthesis of new sequences. Fraleigh stated that one of the biggest issues facing the Convention on Biological Diversity is the realization by all countries that they must harmonize the need to benefit from these technologies with the need to protect the biological safety of the environment. The latter part of Fraleigh's discussion focused on the difficulties many developing countries, in particular, are having in reconciling these goals and questions of technology transfer between developed and developing countries.

*Geoffry Hawtin, Director General, IPGRI, Rome*

In the afternoon workshop session, Hawtin brought an international perspective to the question of the role of biotechnology in the maintenance and use of crop genetic diversity. Like several of the previous speakers, he expressed concern over the increasing trend to reduce publicly funded research and the growing concentration of biotechnological expertise in the private sector. He also discussed *in situ* and *ex situ* methods for conserving genetic diversity, stressing the need for improvements in maintaining and documenting collections worldwide to ensure that the widest possible range of genetic diversity is conserved. Furthermore, he identified the need to apply biotechnological methods to conservation efforts, rather than the current focus on engineering plants for specific needs or environments. Hawtin addressed the issues of ownership and access to genetic diversity, citing the need for international access if we are to realize the full potential of biotechnology for improving the human condition and protecting the natural environment.

## REGULATORY AND ECONOMIC ASPECTS OF ACCESSING INTERNATIONAL MARKETS

*W. H. Furtan, Director, Centre for Studies in Agriculture, Law, Environment, University of Saskatchewan*

Furtan introduced the second workshop by addressing the issues of regulation and the economics of accessing international agricultural biotechnology markets. He described the Canadian federal government 's rather complex system for regulating biotechnology and related products by the. The complexity of the system seems to lie in the overlapping jurisdiction of regulatory bodies, as well as differences in opinion as to what is acceptable and safe. From an economic point of view, this regulation is expensive and slow for firms seeking to introduce new products, making investment in Canada expensive and risky. Furtan also addressed the area of intellectual property rights. With the increase in privately sponsored research in the agricultural sector in Canada, the need to protect intellectual property becomes even more important. According to Furtan, ineffective and inefficient regulation will not only force firms to locate elsewhere but will negatively affect farmers' competitiveness if a technology is not made available to them at the same time it is made available to competitors. The final issues addressed by Furtan were consumer acceptance of genetically engineered products of biotechnology and the rules set out by the World Trade Organization (WTO) affecting trade of these products in the international marketplace. Furtan stressed Canada's need to lower the costs of doing business in order to compete in the international market place.

*Margaret Gadsby, Director, Regulatory Affairs, AgrEvo*

Gadsby painted a very chaotic picture of the international systems regulating exportation of agricultural biotechnology products and processes. There is no uniformity in regulations among countries or even regions considering the importation of biotech products, and many countries have no regulatory processes in place. The industry needs to find a controlled, stepwise approach that balances the sequential pattern of regulatory clearances and the slow maturation of public awareness and acceptance with the needs of the export trade to keep commodities moving freely. Gadsby proposed six recommendations intended to minimize the needless confusion and complexity that exist to today and implored everyone engaged in biotechnology to embrace their role in educating, communicating, and lobbying for a science-based global system that will facilitate trade.

## BIOTECHNOLOGY AND SOCIAL ISSUES IN RURAL AGRICULTURAL COMMUNITIES

*Michael Gertler, Professor of Sociology, University of Saskatchewan*
Gertler led the third concurrent workshop of the morning by identifying many of the social issues brought about by biotechnology that are currently facing or potentially threatening, rural agricultural communities. He extended the concept of agricultural sustainability from a purely environmental context to include sustainability of the community structure. He discussed ten specific issues ranging from the costs and risks of biotechnology to the farmer, to the lack of farmer participation in setting research agendas and the narrowing of public research agendas. One common theme was the unbalanced effect biotechnology has or will have on a community, depending on factors such as farm size and diversity, the education level of the farmer, gender, and fundamental belief systems. Gertler concluded by moving from considering individual communities to considering the impacts of biotechnology on the global community. As an example, he cited the historic evidence of relegating peasants to marginal lands. According to Gertler, should biotechnologies make farming these lands commercially feasible, a new round of evictions and appropriations by the rich and powerful would be expected.

*Bob Stirling, Professor of Sociology and Social Studies, University of Regina*
In the third concurrent workshop session, Stirling gave a sociological comparison of how rural populations incorporate traditional machinery and biotechnology into farming practices. He outlined a proposal for industrial management and drew parallels with farming and the manner way the farming industry has progressed historically. Stirling argued that rural people have had more success incorporating machinery than biotechnology into their farm lives. He maintains that there is a public knowledge, autonomy, and control over machinery that does not exist with biotechnology and that this knowledge is shared and passed on by custom, contributing to the community social structure. Stirling proposed protecting local knowledge of farm technology in the law and trade agreements, as well as limiting the proprietary knowledge claims of companies through patents and trade incentive programs.

## Luncheon Speaker

*Murray McLaughlin, Deputy Minister of Agriculture and Food, Saskatchewan*

McLaughlin gave a very positive speech about the role of agricultural biotechnology in Canada and the centralization of research and production in Saskatchewan. He emphasized that biotechnology as a tool for agricultural science is here to stay and will be increasingly used on a global scale. Those countries that adopt the technology early will help ensure that their agricultural industries remain viable. McLaughlin noted nine Canadian organizations that are involved with awareness of biotechnology and cited Canada's strong research infrastructure for supporting ag-biotech research. He then narrowed his focus to the province of Saskatchewan and specifically the city of Saskatoon, discussing the features that make it ideally suited as a center for agricultural biotechnology. He stressed that the key to Saskatoon's success has been the right mixture of people, facilities, and resources and the willingness of research, business, and government to work together to make Saskatchewan globally recognized.

# *NABC 9 Summary*

## Resource Management in Challenged Environments

Eugene Sander
*Vice Provost and Dean, College of Agriculture*
*University of Arizona*

One of the goals of biotechnology is to use modern molecular genetics to solve agricultural problems dealing with plant and animal stress in challenged environments. Hence, the overall theme of NABC 9 — "Resource Management in Challenged Environments" — was extremely appropriate, especially since the meeting was held in Saskatoon, Saskatchewan, an area where growing seasons are short and the environment for agriculture is challenging. While the topic is extremely timely, it was apparent from the plenary sessions at NABC 9 that biotechnology has not yet provided significant solutions for modern agriculture in challenged environments. This is likely because important characteristics such as heat, cold, salt, and drought tolerance have been less investigated at the molecular level than agrichemical tolerance, pest and pathogen resistance, nutritional composition, and ripening, which constitute the transgenic crops commercialized. In addition, heat, cold, salt, and drought tolerance may be multigene traits that will require more sophistication in producing useful transgenics.

On Sunday evening in Plenary Session I , we heard Robert Herdt, director for agricultural sciences and acting director for global environment at the Rockefeller Foundation, discuss "Agricultural Biotechnology in the Twenty-first Century: Promise and the Pitfalls." Herdt outlined an impressive array of promises, starting with feeding the world, improved product characteristics such as the Flavr-Savr™ tomato, pest resistance, increased yields, and unique plant metabolites. He also pointed out significant pitfalls, including the fact that very little work had been done on crop characteristics important in the developing world, ie., the so-called international traits. He also outlined other issues, including pesticide resistance, tolerance to herbicides, and the potential for unintended results, both social and scientific, as a result of applying DNA technology to plants. Also in Plenary Session I, we heard Mark Winfield, director of research, Canadian Institute for Environmental Law and Policy, discuss "Agricultural Biotechnology and Sustainable Development."

In his provocative talk, Winfield challenged the concept that agricultural biotechnology could feed an increasing global population. He further espoused the idea that public discomfort with biotechnology grows as the public becomes more informed about the scientific issues and that the production of transgenic plants and animals goes against fundamental, natural laws. These two presentations generated considerable debate about the issues of biotechnology in solving important agricultural problems.

Plenary Session II addressed “Perspectives on Biotechnology for Agriculture in Challenged Environments.” In developing the charge to the meeting, George Lee from the University of Saskatchewan eloquently pointed out that biotechnology is not a “yes or no” issue; it is a “how” issue. This concept was reinforced by Joyce Groote, president of the Industrial Association of Biotechnology, who emphasized that biotechnology is actually a series of tools that can solve important biological problems, especially as they relate to medicine and agriculture. Rick Walter, of the Canadian Institute of Biotechnology, discussed the international regulatory climate and commented on some of the survey data on public attitudes. Walter also pointed out the problems in interpreting survey information as it relates to consumer acceptance of agricultural products that involve the use of biotechnology. He issued a call for action to develop a communication strategy to decide who does what and to prepare regular progress reports so we can track our progress in a variety of areas. Presenting the perspective of an environmentalist in a very provocative talk entitled “Biotechnology: Evolution or Revolution, Friend or Foe?” Sheila Forsyth, chair of the National Agriculture Environment Committee, discussed biotechnology from the standpoint of a “evolution or a revolution.” She accurately, pointed out that the key to the use of biotechnology is safety and that there will have to be a balance between risks and the ability to feed the world. Raphaël Thierrin from Food and Fibre EcoStrategies gave us the perspectives of organic agriculture on biotechnology. His message was mixed, indicating that the organic agriculture industry would pick and choose between various biotechnologies. For example, he indicated that a biotechnology-derived solution to drought tolerance might be acceptable to practitioners of organic agriculture but that Bt-containing potatoes were definitely not acceptable because of the pesticide-resistance issue.

In Plenary Session III, we had the opportunity to hear Timothy Reeves from CIMMYT in Mexico discuss global challenges and agricultural production. This excellent talk highlighted several fundamental issues: first, improved agricultural technology will allow people to have enough to eat; second, yield efficiency that minimizes agricultural inputs is of great importance; and third, at least initially, classical plant breeding will continue to be important in improving heat and drought tolerance, especially in maize. His analogy between loss of life in airline disasters and starvation emphasized that on a worldwide basis we forget how many people starve each day.

The presentations given in the plenary sessions generated significant discussion, which included the following:

- Sustainable agriculture means a variety of things depending on the specific location and the nature of the agricultural enterprise,
- Diversity has great variability in meaning depending upon the specific case, and
- Advances in agricultural biotechnology will continue to suffer from the difficulties of educating an intelligent but scientific illiterate population that increasingly gets information in 30-second sound bites.

Finally, the luncheon speaker, Murray McLaughlin, the deputy minister for agriculture and food from the province of Saskatchewan, very correctly pointed out that we probably will never reach total agreement on the use of biotechnology in agriculture and that this lack of agreement might be a good thing because it could promote progress in solving the problems of agriculture using these new tools.

# PART II

## WORKSHOP REPORTS

# *Biodiversity Conservation for Sustainable Agroecosystems Workshop*

## Co-chairs

Marie Boehm
*Center for Studies in Agriculture, Law and Environment, University of Saskatchewan*

Bob Morgan
*Saskatchewan Wheat Pool*

The Biodiversity Conservation for Sustainable Agroecosystems Group considered several aspects of the relationships among biotechnology, biodiversity, and sustainability. Members of the group represented a wide range of backgrounds — from biotechnology and ecology to policy-making — and thus had varying degrees of knowledge of, and expectations for, biotechnologies. Despite this, the group was able to reach consensus on many important issues. It was generally agreed that the new biotechnologies, based on the manipulation of DNA, are different only in degree from the techniques that early farmers and plant breeders have used to select and develop crops. It was recognized that biotechnologies can have both positive and negative affects on biodiversity and that the challenge is to ensure that the impacts are positive, because loss of biodiversity poses a significant threat to agroecosystem sustainability.

## Public and Private Responsibilities

There was considerable discussion about the roles and responsibilities of publicly funded versus private (for profit) organizations in the development and application of biotechnologically altered crops. Private industry has worked mainly on the development of improvements in major high-value crops that are grown on large areas, where the products developed will likely return a profit on investment. There is an unmet need, however, in regions where crops are more locally adapted and farmers are poor. There may be an important role for public plant breeding in regions of the world where there is large potential to increase the productive capacity of traditional systems, with little possibility of earning much direct economic return on the investment.

## Conservation of Genetic Resources

The role of public institutions in the conservation of genetic resources, both *in situ* and *ex situ* was also debated. *In situ* conservation refers to maintaining populations in the location where they evolved, for example in farmers' fields or natural areas. *Ex situ* conservation is maintenance of collected genetic material under controlled conditions away from their place of origin. Given that there is a strong link between biodiversity and sustainability, the group stressed that funding mechanisms to maintain and expand *in situ* and *ex situ* conservation programs in the public interest must be instituted. Management of agricultural sector resources was also mentioned as an important facet, particularly with reference to the major world crops (i.e., cotton). As control of those crops is being concentrated within only a few companies, original genetic resources from other sources are being lost.

Benefit sharing, based on mechanisms designed to ensure fair and equitable distribution of profits from genetic material, particularly between technologically advanced countries and developing countries, was considered to be a major challenge that will have to be addressed so that international, mutually beneficial partnerships can be developed. If developing nations perceive that industry is profiting from their genetic resources without compensation, access to those gene pools may be denied.

## Issues

The Biodiversity Conservation for Sustainable Agroecosystems Group identified several issues related to the role of biotechnology for biodiversity in sustainable systems.

## Research requirements

Research is required to better understand the role of biodiversity in the sustainability of agroecosystems and natural ecosystems. Three particular areas that require study are:

- Methods of conservation (*in situ, ex situ*). This requirement includes identifying the human, financial and institutional resources to adequately maintain viable *ex situ* collections and for *in situ* preservation of areas that are particularly rich in genetic resources.
- Assessment of the overall value of biodiversity. Diverse genetic resources are a valuable resource to crop breeders and may directly determine the sustainability of agroecosystems. Biodiversity is also important to the persistence of natural systems, which provide ecosystem services that are less directly related to the provision of food and fibre for humans than agroecosystems, but have an important role in the regulation of planetary conditions.
- The impact of biotechnologies on biodiversity. Loss of genetic diversity related to biotechnology occurs as local varieties are replaced

with genetically improved, uniform varieties and where genetic modifications allow crop adaptation to environmentally marginal conditions, replacing natural plant communities.

| Sustainability | Environmental | Economic | Social |
|---|---|---|---|
| Ecosystem | | | |
| Species | | | |
| Gene | | | |

## Economics

- Financial resources are required to maintain germplasm resources. Funding for the continued maintenance of germplasm banks was considered to be an important factor in maintaining genetic diversity. Access could be severely curtailed if intellectual property rights (IPR) allow blocks of germplasm to be tied up for long periods. The group agreed that there is a direct link between intellectual property rights, access and biodiversity.
- Marketplace decisions have implications for biodiversity. It was suggested that a paradigm shift has occurred as funding from tax-based dollars for public plant breeders has been reduced while the role of plant breeders and other researchers for private interests has increased, a trend that is aided by IPR agreements. Modern monoculture systems of major commercial crops are suited to the commercial system, but in traditional agricultural systems a market failure has occurred. Private breeders, under pressure to build on the best varieties, are reducing crop diversity, which will have long-term implications for biodiversity. Examples were cited of the loss of many landraces or varieties of crops, from apples to cotton, over the past thirty years.
- Market value of biodiversity. The overall value of biodiversity is not known. It was suggested that attempts be made to quantify its economic value.

## Communications

- The group felt that communications were important at all levels, from education in schools to education of policy-makers and the public. Scientists have a responsibility to provide information that can be used by the public, who are often presented with “scary” rather than objective, science-based information. Scientists must also educate policy-makers about the long-term consequences of policy and marketplace decisions so that irreversible loss of biodiversity in the long-term can be avoided.

- The group discussed the need for communication efforts among developed and developing countries on the expectations both sides may have of the value of genetic resources in Southern nations. The communication should address both the expectations and the consequences of those expectations so that the parties can work towards developing a relationship/agreement which is fair and equitable to all. If this does not occur, more and more of the discussions become bilateral rather than multilateral, increasing the complexity of international agreement and enforcement. As developed nations begin to establish IPR regulations, and with examples of their exploitation of genetic resources in the past, developing nations are struggling to develop mechanisms to ensure that they receive fair and equitable compensation for the genetic material they have provided. An inability to reach agreement about how to share in the benefits of gene-based technology could result in the refusal of developing nations to provide access and in increased difficulty in creating partnerships based on trust and benefit sharing.

## Responsibilities/Accountability

- The group discussed the changing role of government in the area of biotechnology research. As discussed in previous sections, there has been a major shift from plant breeding in the public sector to the private sector. Private industry can serve the requirements of modern agricultural systems that are based on the monoculture of major crops, although there is a danger of reduced genetic diversity if a few adapted cultivars replace many crop varieties. Public support may be required to serve traditional farming systems. Biotechnology could be used to improve traditional systems without requiring a production shift from minor crops with many land races to major, genetically uniform crops; a large direct return on such investment could not be expected.
- The responsibility for development of consistent regulations and enforcement protocols for the biotechnology industry lies with local, national and international governing bodies. Issues ranging from biosafety to food security and IPR to identity preservation will need to be addressed within countries and among nations to ensure continued access by breeders in developed countries to genetic resources in developing countries, to facilitate partnerships between public institutions and private industry, and to allow trade and shipment of commodities among nations. This is particularly important with the globalization of industry and with a technology as fluid as biotechnology.

## RECOMMENDATIONS

The potential of biotechnology to further the welfare of humanity with improved biological products such as food, fiber and energy sources is dependent upon the biological bank of genes encompassed by the term biodiversity. It is a serious concern that the preservation of genetic diversity is threatened by changes in social and economic conditions surrounding the agricultural and human food and feed industry.

- *Recognize and communicate, for urgent action by policy makers, the impact of biotechnology on biodiversity of agricultural crops, livestock and natural systems.*
- *Contact appropriate USDA, USAID, and AAFC officials asking that they address issues associated with funding for maintenance and utilization of germplasm banks. The private sector should be encouraged to contribute through in-kind assistance, donations of germplasm, and consideration of biodiversity issues in their research priorities.*
- *Ask the Secretariats of relevant international organizations operating internet web-sites (FAO commission on Genetic Resources, the Convention on Biological Diversity, the Global Environmental Facility, etc.) to structure their sites in such a way that search engines will be able to identify documentation related to biotechnology.*
- *Create win-win situations to preserve and sustain resources, and to ensure fair and equitable sharing of benefits by finding direct mechanisms within the academic and non-governmental organization (NGO) communities to develop effective partnerships between developed and developing nations.*
- *Develop educational programs at all levels emphasizing critical thinking about the role of biodiversity and the implications of biotechnologies.*
- *Recognize that the loss of biodiversity is a significant problem. Stakeholders and governments should develop systems to identify issues, gather information, set policy, build support structures, and monitor and apply policy.*

# *Regulatory and Economic Aspects of Accessing International Markets Workshop*

## Co-chairs

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The group attending the Regulatory and Economic Aspects of Accessing International Markets Workshop was charged with exploring the consequences of agricultural biotechnology on marketing of agricultural products. The group considered a number of issues surrounding the international licensing, production and consumption of products arising from agricultural biotechnology programs. The group focused on several areas; international regulations, economic profitability, intellectual property rights, social and economic equity of producers and consumers, and access to biotechnology for research. Despite the diversity of people and perspectives, the group was able to weave a common set of recommendations on several priority issues.

## Priority Issues

The following issues were identified by workshop participants as the key issues affecting the movement of agricultural biotechnology into international markets. Other related issues were discussed, and where appropriate, these are incorporated into this report. Consideration of these issues through extensive discussion led to development of recommendations.

### Lack of uniformity in international regulatory policy

Introduction of genetically modified organisms (GMO's) into many international markets is hindered by the varied regulatory requirements of different countries. Often, countries will not accept data generated in other countries, requiring costly repetition of testing. At times, regulatory decisions are based on information unrelated to the efficacy or safety of the product. Also, delays in acquiring regulatory approval can result in the inability to introduce a new product during its marketable life.

One major recommendation grew out of this discussion. We should strive for harmonization among international regulatory organizations by:

- *providing examples of the lack of harmonization to governments already participating in multilateral negotiations;*
- *emphasizing the importance of making science-based regulatory decisions, with the ultimate goal that decisions be product- rather than process-based;*
- *urging timely regulatory approval in order to: facilitate international trade, expedite access by farmers/consumers, and provide a level playing field for GMO's with traditional materials; and*
- *encouraging mutual recognition of appropriate regulatory decisions.*

## Enforcement of Intellectual Property Rights

Introduction of new genetics into many international markets has been prevented or deterred by the lack of, or ineffective enforcement of, intellectual property rights laws. This is especially true in the developing countries where advanced technology could be beneficial. The expenses of product development and acquiring regulatory approval are too great to risk losing control of the material upon introduction into a new market.

Through whatever means available, governments in developing countries should be encouraged to enact laws and policies that effectively protect intellectual property. These laws and policies should:

- *emphasize the 'public good' aspect of intellectual property protection for addressing world hunger and poverty;*
- *encourage harmonization of patent policy for higher life forms; and*
- *foster research access to biotech materials while respecting intellectual property rights.*

## Understanding Consumer Perceptions

Consumer acceptance of GMO's is a concern. While much has been said about the problems associated with public opinion surveys, it is important to understand the underlying reasons for various perceptions in specific international markets. Consumer acceptance of non-traditional materials is often affected by social, cultural, or religious influences that may not be reflected in public opinion surveys. Furthermore, the benefits of adopting new technologies are often poorly understood by producers and consumers. Large industry developers/marketers are often seen as the sole beneficiary.

Support should be provided for research to elucidate the basis for consumer perceptions of GMO's in specific international markets through:

- *surveys that reflect social and cultural biases in consumer perceptions; and*

- *educational programs to illustrate the sharing of benefits among the various stakeholders in technological advances.*

## Lack of coordination in research and development

Coordinated effort among the various players involved in agricultural biotechnology is viewed as essential in optimizing the benefits to be derived. Improved coordination is needed both within and between public, private and international contributors. A critical component of this coordination is the need to increase access to material for research purposes.

Efforts should be made to develop a systems approach to coordinate research and development programs. Disciplinary, organizational, and institutional barriers to improve coordination must be identified and eliminated.

## Minor use crops/applications

The high cost and risk involved in biotechnology development has, by necessity, resulted in concentration of efforts on crops and traits that optimize potential returns on investment, i.e. the major crops. There is a need for application of biotechnology to the minor crops in the developed world. In many international markets, especially the developing countries, the needs for advanced technology involve minor crops and traits that may not be considered economically viable in more sophisticated markets. Furthermore, existing regulatory policies are often disincentives to efforts targeted for these markets.

In order to increase access to advanced technology, efforts to develop regulations and technology applications that are 'minor crop friendly' should be undertaken. A coordinated program similar to the IR 4 program for obtaining pesticide registrations for minor use crops, is needed to address this issue.

## Availability of risk capital

One of the primary barriers to technology and product development for agricultural uses is a shortage of investment capital. While many factors converge to this end, there needs to be recognition at both the public and private levels that such investment is essential for the common good in both domestic and international markets.

## Labeling

There is substantial controversy regarding the labeling of products of agricultural biotechnology. Considerable confusion exists at many levels over the definitions of biotechnology and GMO's, often resulting in demand for labeling requirements that do not accurately reflect reality. For example, it would not seem appropriate to require special labeling for a product which has not been modified in any way simply because it was produced through a novel process. Equally as important as the public's right to know is the necessity to avoid misleading or misinforming the public with inappropriate labeling.

Every effort should be made to encourage international acceptance of reasonable, science-based labeling laws and policies that are product- rather than process-based.

## Other Identified Issues

Several other issues were discussed, but not fully developed, in the workshop. They were:

- There is no standardized definition of agricultural biotechnology that is accepted by all groups worldwide. As a result, processes or products may or may not be considered as agricultural biotechnology under varying regulations in different countries.
- The costs associated with complying with the varying regulatory and labeling requirements of different countries make it difficult for small and mid-size companies to get products registered, and therefore compete internationally.
- Regulations governing agricultural biotechnology within a country may fall under several different agencies.
- The increase in productivity through the use of agricultural biotechnology may further hasten the trend toward larger farms in the developed countries, and thus contribute to the decline of smaller, traditional family farms.

Finally, it is important to point out that encouraging a systems approach to dealing with agricultural biotechnology regulations, research and development programs, and consumer and producer issues of safety and acceptance is the responsibility of all participants in the system. Each group (producers, private industry, policy makers, researchers, and consumers) has its own unique role to play. This approach rests on the principle that we must endeavor to meet the needs of the present without compromising the ability of future generations to meet their own needs. Therefore, stewardship includes maintaining or enhancing the vital agricultural resource base for the long term, and consideration of social responsibilities such as consumer health and safety both in the present and the future.

# *Biotechnology and Social Issues in Rural Agricultural Communities Workshop*

## Co-chairs

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The Biotechnology and Social Issues in Rural Agricultural Communities Workshop Group considered a number of issues with respect to the impact of biotechnology upon producers as well as communities, with a focus on the possible long term ramifications of this technology. Participants had a difficult time focusing on possible outcomes, since biotechnology and its potential impact is caught up in a plethora of change in farms and communities which have multiple causes. For example, farm structure change, with the disappearing middle-sized farm and reduction of the number of family farms, is ongoing and may also be increased with adoption of biotechnology as part of an industrial agriculture model.

There was no obvious consensus that biotechnology was, or was not, any different that any other technology. Biotechnology is another development in the trend of technologies. However, participants perceived that ambiguity about the future of agriculture is impeding both producer adoption and public acceptance of new products from biotechnology. A better understanding is needed of economic and societal trade-offs based on full cost accounting of benefits and costs. Involvement of producers and communities in the early stages of communication and education initiatives would be desirable. This process must be truly consultative with adequate resources for both sides of the debate.

Some of the problems, such as gene drift and genetics 'technology use' (i.e. Monsanto) contracts, may pose a liability that should be clearly defined and may present new agronomic and social stresses compared to the adoption of traditional technologies. Scientific experimentation has not focused adequately on these problems.

## Producer Issues

A number of factors were identified as the most important producer concerns with new agricultural biotechnology products, including:

- Timely access to a range of technologies is key to competitiveness and reducing environmental impacts.
- Product efficacy concerns will require that producers work with extension to evaluate new products under their particular production systems.
- Farm safety and environmental impact with respect to agricultural biotechnology products should be considered by regulators. It was suggested that these impacts may be analogous to but qualitatively different from crop chemical safety.
- There should be a sharing of risks and liabilities through stringent contract and technology use agreements. What portion of the liabilities will rest with the producer and what will the agricultural impact indicate? Additional information will be required on technology use agreements. Producers are concerned that they will become "renters" of proprietary germplasm and information, rather than relying on local knowledge and experience.
- Options for different production systems would be appreciated by producers. For example, additional research on both organic agriculture and biotechnology is desirable for sustainable agriculture systems.
- Producers require access to peer-reviewed unbiased science-based information via a public extension service. This will require additional resources to provide an expanded service. Knowledge transfer to farm with respect to biotechnology is slow due to complexity and lack of a focused effort in information flow.
- Direct contact and liaison with university and research community by producers would assist in developing mechanisms for identifying research needs. There was some concern that producers have insufficient capital to be influential.

## Community Issues

A number of points were identified with respect to public needs and concerns. These are:

- Public concern over the safety of biotechnology-based food products and a need for assurance of food quality with respect to biotechnology and industrial agriculture.
- Importance of knowing the limitations of science and public agriculture research.

- Impact of new technologies with respect to social networks within and beyond local agricultural communities. Increasing dependence on new technologies, such as biotechnology, to gain competitive advantage may erode community loyalty and neighborliness.
- Impact on number of farms.
- There may be new realities and configurations for communities. Biotechnology contributes to a changing culture of agriculture which will make it more or less attractive to different people.
- Resource management issues such as stewardship and precision agriculture will affect rural communities.
- Relationships among researchers and rural communities may change. Research may increase, according to corporate need and sponsorship, rather than in the interest of farmers or rural communities.

It was pointed out that rural communities would require redefinition in an environment where research is decreasing and communities struggle with reduced transfer payments in health, education and road assistance, as well as challenges in adding value to commodities. There is also a concern that among this competition and specialization communities would lose the ability to organize for the common good and community development. Will communities focus on issues such as stewardship/land use, legislation for livestock enterprises, and the review of "neighboring" codes?

There is a concern that genetic engineering could be blamed for enhancing existing problems, for example, herbicide resistant weeds.

There appears to be doubts about the trustworthiness and reliability of the biotechnology industry, particularly with respect to food products, human health, and costs to consumers. This may be due to the link between government and industry in funding research. As a visible leading element in the application of high-tech to the production of food, biotechnology becomes a focus for broader concerns about a range of issues with respect to an industrialized model in agriculture. These include questions of control over productive resources, agenda setting, agriculture ethics, food quality, and health.

## Recommendations

1. *Appropriate public service agencies (Extension) should provide producers with access to information on production contracts and their possible implications.*
2. *Provide additional resources to public extension service in order that access to information and education can be provided on biotechnology. Producers must have access to peer-reviewed science-based information on the impact of biotechnology, organic agriculture, and other sustainable agriculture technologies on farms and rural communities.*

3. *Conduct case studies to provide information on how biotechnology, organic agriculture, and sustainable agriculture technologies are being used successfully on farms. Identify potential positive and negative implications for the industry and rural communities.*
4. *Establish ways to develop proprietary control over biotechnology to the mutual benefit of public and industry in order to ensure continued support for public research.*
5. *Reveal the potential gains and costs of biotechnology through systematic broad-based social impact assessments.*
7. *Evaluate field efficacy of biotechnology products as they are used at the farm level through allocation of a portion of public research funds.*
8. *Publicly fund research and surveys to establish the nature and extent of concern about agricultural biotechnology. Some of the participants did not support this view.*

## PART III

## KEYNOTE ADDRESSES

# Agricultural Biotechnology in the 21st Century: Promises and Pitfalls

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I will begin with some brief definitions that I find useful when talking about biotechnology. I restrict biotechnology to mean techniques involving the use of molecular biology of DNA. These techniques facilitate two related but different applications: the extremely specific identification of the DNA in a biological organism, and the transfer and biological functioning of DNA from one organism to another. The first has led to the ability to detect the presence or absence of genes in plants and animals using techniques collectively called molecular markers. The second has led to the ability to transfer genes from one organism to another, that is, transformation. These two abilities generate both the promises and the pitfalls of biotechnology.

This paper considers how these biotechnology abilities may be applied to plants. Four broad goals have been pursued relative to plants: to change product characteristics like storability or taste, to incorporate resistance to insects, diseases, or agrichemicals such as herbicides, to increase innate yield potential, and to enable plants to produce products they were heretofore incapable of producing. In turn, a number of promises have been identified, including the following:

- The potential to raise agricultural productivity and thereby the hope that we will be better able to feed the world.
- An increase in agricultural research investment.
- A reduction in pesticide use in agriculture, a more sustainable agricultural system, and other environmental benefits.
- The use of genes from new sources.
- The production of pharmaceuticals from plants.

For each of the promises, however, one can identify potential pitfalls, and the following can be enumerated:

- Are we focusing attention on the genes that will give the traits that will increase productivity?
- Are we paying enough attention to the problems that will have to be solved to feed the word?
- Will the property rights that accompany the increased investment mean that the benefits are inappropriately concentrated?
- Will the technology lead to an increase in the intensity of pesticide use rather than a reduction?
- How will biotechnology contribute to sustainable agriculture?
- Is it really practical to produce pharmaceuticals using plants?

## Increase Productivity

The promise that plant biotechnology may raise innate productivity rests largely on the belief that because it opens so many possible ways of changing the genetics of plants there must be a way to apply that knowledge to increase productivity. Photosynthesis, the basic process by which plants use the sun's energy, water, nutrients, and carbon dioxide, is known to use only a small fraction, less than 10 percent, of the sun's energy. It stands to reason that there may be a way to increase that proportion and thereby increase innate productivity, but to date no generally accepted means for doing so has been found.

Likewise, making plants more drought-resistant, or able to better use available water, would seem to offer great opportunities to increase productivity. But little progress has been made in achieving greater drought resistance, and little of the energy of biotechnology is directed toward this goal. Incorporating into cereal crops the capacity to fix nitrogen biologically is another approach that would seem to increase productivity, but again, progress has been slow.

More positively, biotechnologists have developed new approaches to creating hybrid crops, opening the possibility of hybrid wheat and hybrid rice, as well as other hybrids. As these strategies are proven they likely will lead to higher yields. There are also other traits that may lead to increased yields — one that increases the starch content of potato, and another that keeps sorghum leaves green for a longer period of time than normal, extending the period of grain filling and thereby promising higher yields.

## Feed the World

The challenge of feeding the world is reflected most dramatically in the observation that per capita food production in Sub-Saharan Africa has fallen by 20 percent over the past 30 years, leaving that region in desperate need of additional food production. Furthermore, that area faces the challenge of the most rapid rate of population growth of any region. Over the past 30 years, per capita food production increased in most countries outside Africa, especially in Asia. There the challenge remains high, driven by rapid growth of per person income.

An acceptable long-term solution to feeding the world requires most countries to have a reasonable degree of food self-reliance, meaning that countries either produce their own food or produce and export something else with which to purchase food. For largely rural countries, the alternatives to food are most often other agricultural products. Hence it is reasonable to ask to what extent biotechnology is being used to address the agricultural needs of the developing world.

For the results of biotechnology to be applied in a specific place, the plants incorporating those results will have to be field tested, and seeds incorporating the traits will have to be multiplied and distributed to farmers. Data on field tests indicate, therefore, the prospects for contributions from biotechnology in the next few years.

Clive James and Anatole Krattiger from the International Service for Applied Agricultural AgroBiotechnology (ISAAA) have tabulated the data on field trials of genetically engineered crops. Some 3,700 trials have been conducted through the end of 1995. About 40 percent of those trials have been of crops that have been transformed to be herbicide resistant. About 22 percent were of crops transformed for insect resistance or product quality, and another 15 percent or so of crops were transformed to be resistant to fungal or virus diseases. Some 555, another 15 percent, have been crops transformed with other traits. Except for this last category, which includes a few tests each on a wide variety of traits, none of the field trials to date have been directed specifically at increasing productivity. Of course, it is likely that some increase in yield will be observed in plants that are pest resistant, but the direct objective is quite different, supporting the observation that limited resources are directed at increasing productivity.

Some of the traits that may be most needed in the developing world, in addition to productivity increases, include the ability to tolerate low soil fertility, the ability to tolerate soil salinity or alkalinity, the ability to reproduce apomictically, and techniques for producing biological pesticides. In addition, molecular markers for these and other desirable traits would contribute to advances in the genetic improvement of crops through plant breeding.

Application of biotechnology to address the needs of the developing world requires that it be applied to crops of interest to the developing world. James and Krattinger show the distribution of field tests among crops. Almost 30 percent of all field trials have been conducted on maize, a crop of importance in the developing world, especially in Africa. But, the other crops that have been the focus of attention — tomato, canola, cotton, tobacco, potato — are of little or no food significance in developing countries.

Maize yields in developing countries may be affected by biotechnology if genes useful in tropical countries are discovered in the course of the massive work being done on maize in the United States. Although most of the work on maize is being done by private firms, some of the discoveries may be made available for application in developing countries, either at no cost or at low enough cost as to make their use commercially feasible. Biotechnology applications on cassava are further in the future, as are those on smallholder banana and other crops of importance in the developing world.

It is unlikely that the balance of work between the industrialized and developing worlds will change soon because only a small amount of the estimated $2.5 billion of research spending on agricultural biotechnology around the globe is carried out in the developing world. The best available estimates suggest that between $50 and $75 million per year is spent on agricultural biotechnology in the developing world, about half of that by the Consultative Group for International Agricultural Research (CGIAR) Centers. The rest is divided among private research (multinational and local) and government-supported research.

A functioning global agricultural research system — the CGIAR — exists, but over the past five years the financial support for that system has weakened, in no small part because of falling support by the United States. Whereas in 1992 the United States was the single largest donor, providing $48.1 million to that system, in 1996 that figure fell to $30.5 million, even though the system is acknowledged to be one of the most effective uses of foreign assistance to which the United States contributes.

The CGIAR, which is extremely effective at research that can be shared across countries, can be complemented by efforts that enable countries to adapt the research findings to their particular situations. There is still a great need to improve the national capacity for agricultural research and management in developing countries, especially in Africa.

I know of five coherent, coordinated programs directed specifically at enhancing biotechnology research on developing-country crops: one supported by the United States Agency for International Development (USAID), one by the Dutch government, one by the McKnight Foundation, one by the Rockefeller Foundation, and one by the Asian Development Bank.

The USAID-supported project on Agricultural Biotechnology for Sustainable Productivity (ABSP), headquartered at Michigan State University, was implemented by a consortium of U.S. universities and private companies. It is targeted at five crop/pest complexes: potato/potato tuber moth, sweet potato/sweet potato weevil, maize/stem borer, tomato/tomato yellow leaf virus, and cucurbits/several viruses. An outgrowth of the earlier USAID-supported tissue culture for crops project, ABSP builds on the network of scientists associated with that project.

The cassava biotechnology network, sponsored by the Netherlands Directorate General for International Cooperation, held its first meeting in August 1992. It aims to bring the tools of biotechnology to modify cassava so as to better meet the needs of small-scale cassava producers, processors, and consumers. More than 125 scientists from 28 countries participated in the first network meeting. Funding to date has been about $2 million. An important initial activity is a study of farmers' needs for technical change in cassava, based on a field survey of cassava producers in several locations in Africa. Funding beyond 1997 is not assured.

The Rockefeller Foundation's support for rice biotechnology in the developing world started in 1984. The program has two objectives: to create biotechnology applicable to rice and produce improved rice varieties suited to developing-country needs; and to ensure that developing-country scientists know how to use biotechnology techniques and are capable of adapting them to their own objectives. Approximately $70 million in grants have been made by the program through 1996. A network of about 200 senior scientists and 300 trainee scientists are participating, in all the major rice-producing countries of Asia, as well as several industrialized countries. Researchers in the network transformed rice in 1988, a first for any cereal. Transformed rice has been field tested in the United States, and a significant number of lines transformed with agronomically useful traits now exist. Molecular maps are being used to assist breeding, and some rice varieties developed by advanced techniques not requiring genetic engineering are now being grown by Chinese farmers.

The McKnight Foundation has provided about $12 million for biotechnology research on agriculturally important problems to teams of researchers from advanced and developing-country labs. This innovative program used a global call for proposals and competitive process to award the grants across a range of subject matter of interest to the investigators. The research under the first set of grants is currently under way, but no plans have been announced for further funding.

The Asian Development Bank provides about $300,000 annually to fund the Asian Rice Biotechnology Network that links the International Rice Research Institute (IRRI) and Asian countries so they can share information and cooperate in the development of tools of biotechnology for rice.

It is unlikely that these five focused crop biotechnology efforts, taken together, entail in excess of $35 million annually, or about one-half of total agricultural biotechnology research spending in the developing world, which is likely between $50 and $75 million annually. China, India, Egypt, Brazil, and a few other countries have a reasonable base for plant biotechnology.

It is evident that the efforts directed at biotechnology for developing-country agriculture are small, especially when compared to those directed at the industrialized world. Still, some important contributions should come from the former. Training of developing-country scientists under various programs provides a small cadre of plant molecular biologists in developing countries.

The Rockefeller Foundation's support of rice biotechnology is beginning to pay off in the form of new rice varieties available to some Asian farmers. In China, a rice variety produced at the Shanghai Academy of Agricultural Sciences through anther culture and which incorporates genes for resistance to pathogens and cold has been field tested on over 3,000 hectares in Anhui and Hubei provinces, resulting in yields from six to 24 percent higher than the most popular previous varieties.

Rices with several different genes for resistance to two major rice diseases, blast and bacterial blight, have been produced using genetic markers. These are being field tested for the durability of their resistance, which is expected to be high. In addition, dozens of genetically engineered rices are being evaluated in facilities in Asia. We expect that the contributions to rice yield increases from biotechnology in Asia will be on the order of 10 to 25 percent over the next ten years. These increaseswill come from improved hybrid rice systems, largely in China, and in other Asian countries from rice varieties transformed with genes for resistance to pests and diseases.

The speed with which varieties get into farmers' hands depends largely on national conditions — the closeness of linkages between biotechnologists and plant breeders; the ability of scientists to identify the most limiting conditions, identify genes that overcome those constraints, and get those genes into good agronomic backgrounds; and the efforts plant scientists and others have put into crafting biosafety regulations.

## Increase Research

The advent of biotechnology has stimulated agricultural biotechnology research. It has certainly encouraged a significant increase in private corporate research. The potential pitfall associated with this increase is the intellectual property rights conditions that go along with private research. Some observers believe that the cost of seeds may be higher than it would be if the research were done by the public sector, although there is a question of whether the same results would be forthcoming from the public sector. It is clear that the fact that property rights can be enforced, because of the capability to very closely identify biological organisms and their components, has stimulated great inventive efforts. But some voices question the appropriateness of property rights associated with nature.

## Reduce Pesticides

The potential of biotechnology to reduce pesticide use has been one of the major points stressed by its supporters. Genes for resistance to insects and plant viruses are projected to replace the use of pesticides by farmers. The first broad-scale commercial production of crops with *Bacillus thuringensis*, the first of such genes, was conducted in 1996. Many other such genes are being tested, supporting the idea that biotechnology will lead to a reduction in the use of pesticides.

Critics of biotechnology point out that herbicide-resistant genes encourage farmers to use more of those chemicals than they might otherwise, shifting the balance in the other direction. In addition, there is concern by "organic" farmers who apply *Bt* directly to crops that its widespread introduction into genetically engineered crops will put so much pressure on pests that insects resistant to *Bt* will be created, thereby eliminating the usefulness of that relatively benign pesticide.

### Sustainable Agriculture

The idea that biotechnology will hasten the age of sustainable agriculture has been promoted by some. But the concept of sustainable agriculture has been defined in so many different ways by so many different people that it is difficult to determine what would have to happen to make agriculture sustainable and whether biotechnology will help bring it about.

### New Gene Sources

There is little doubt that genetic engineering will make new sources of genes available for use in plants. The genes that code for the Bt toxin come from bacteria, the genes that code for the coat protein of viruses have been inserted into plants to make them resistant to the virus, genes that enable cowpeas to have natural resistance to insects have been inserted into cereal crops, and so on. This transgenic capability is one of the characteristics that have generated the excitement about biotechnology. But this capability also generates unexpected consequences, mainly apprehension about the technology.

Some people's opposition to genetic engineering is based on ethical grounds: they believe that transferring genes across species is too close to the act of creation and therefore not something people should do. Others oppose genetic engineering because of the unknown possibilities that may result — of new viruses emerging from transformed plants, or of proteins that cause allergic reactions being unknowingly transferred into plants. And while those who have examined the scientific information about the probabilities of such events indicate they are small, apprehension remains because the probabilities are not zero. Still others oppose biotechnology because it has led to the patenting of genes, a practice they oppose on the grounds that genes are not inventions but rather parts of nature.

A significant number of people have expressed the fear that genetically engineered crops may not be safe. In the United States, those responsible for ensuring that the food supply is safe base judgments about food safety of genetically engineered crops on consideration of the nature of genes that have been inserted and the nature of the plants into which they have been inserted. If no evidence of danger exists and no reasonable argument for danger can be made, products can be grown and consumed. As of the middle of 1997, 20 genetically engineered crops have been approved for general commercial production without restriction. The regulatory bodies have found no evidence of any danger associated with their production or consumption.

The apprehension that food made from genetically engineered crops may not be safe is strong in some European countries. Surveys show that as much as 60 percent of people in some countries believe genetically engineered crops may not be safe, while in the United States only 21 percent hold that belief.

Fears have led some to demand that genetically engineered crops or foods made from such crops should be labeled. In the United States there is not strong support for the idea, but in some European countries there is considerable support.

## Summary

Plant biotechnology promises many advantages. It may significantly improve the productivity of agriculture, help feed people in developing countries, reduce the use of pesticides, and lead to a more sustainable agricultural system. Some people question each of these promises, but the balance of scientific opinion holds that the potential dangers associated with genetically engineered crops is small, especially compared to the potential benefits for regions of the world that will require considerably increased production over the coming years.

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# *Agricultural Biotechnology and Sustainable Development*

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The Canadian Institute for Environmental Law and Policy (CIELAP) was founded in 1970 as the Canadian Environmental Law Research Foundation. It is an independent, not-for profit, environmental law and policy research and education organization. Over the last 15 years, CIELAP has been involved extensively in environmental law and policy development related to biotechnology. In 1984, CIELAP organized the first conference in Canada on environmental law and policy issues regarding biotechnology, and it has participated in many consultations regarding biotechnology and the environment with Environment Canada, Health Canada, Agriculture and Agri-Food Canada, and the government of Ontario.

The Institute has produced major publications regarding biotechnology, including a major overview study in 1995 of environmental, social, economic, and ethical issues related to biotechnology completed for the Ontario Ministry of Economic Development and Trade. The institute has also published a Citizen's Guide to Biotechnology, which has been well-received by a wide range of audiences.

## Introduction

The biotechnology industry and some governments, particularly those of Canada and the United States, argue that the development of agricultural biotechnology products is essential to meeting the food needs of a growing world population. Indeed, they often contend that we will face a serious crisis if these technologies are not widely adopted, permitting the more efficient production of food.

This perspective on the importance of agricultural biotechnology has been disputed from several directions. Environmental and consumers' organizations, members of the farm and academic communities, and several governments in the developing world have been at the forefront of this challenge. Serious ethical concerns have been articulated in relation to many of the products that have been developed, especially in the area of animal husbandry. In addition, questions have been raised regarding the likely environmental and human health impacts of agricultural biotechnology products and, perhaps most significant, regarding the value and the purpose of many of the applications of the technology which are emerging.

In particular, it is argued that the many of the applications of agricultural biotechnology that have been developed to date are unsupportive of environmentally sustainable agriculture. In fact, it is contended that in some cases, they will actually undermine more ecologically sound agricultural practices. Furthermore, it is argued that the proponents of the global diffusion of agricultural biotechnology as a solution to the question of securing the world's food supply are proposing a technological solution to a problem that is fundamentally social, economic, and political, rather than technological, in nature.

This paper seeks to provide an overview of these critiques and of their implications for public policy in Canada and the United States regarding biotechnology in general, and agricultural biotechnology in particular.

## Concerns Regarding Biotechnology and the Environment

The critique of the current trends in modern biotechnology is principally grounded on three elements. The first relates to the ethical and philosophical issues raised by modern biotechnology, particularly genetic engineering. The second arises from the potential direct environmental and human health impacts of applications of the technology. The third challenges the value and purpose of many of the applications of the technology that have emerged, particularly in the agricultural field.

## Ethical/Philosophical Concerns

Public concerns regarding biotechnology arise from many sources. At the most fundamental level, many individuals are disturbed by the notion of manipulation of the genetic material of other species, and particularly the movement of genetic material between species. They regard genetic engineering as a qualitatively different technology from traditional plant breeding or animal husbandry techniques.

Many hold the species barrier to be a law of God or of nature, believing that species have an inherent integrity and that the violation of this status is an act of extreme arrogance on the part of human beings. Others question, in light of past experiences with eugenics programs and other efforts to "improve" humanity, whether human beings have the wisdom to make appropriate decisions with respect to a technology of this scope and power. Questions of this nature were recently highlighted in the debates that followed the announcement of the successful cloning of a sheep named "Dolly" in the spring of 1997.

In Canada and the United States these concerns have been compounded by has been the absolute refusal, until very recently, of governments to address the ethical and social issues raised by biotechnology. At the same time, governments have continued to provide heavy subsidies for the development of the technology. This behavior has been in sharp contrast to the approach taken by a number of Western European governments, which have facilitated societal debates around these issues and demonstrated a willingness to act on the results of such discussions.

The government of Canada formally acknowledged the significance of ethical and social issues related to biotechnology in its April 1997 response to a report of the House of Commons Standing Committee on the Environment and Sustainable Development on the Regulation of Biotechnology in Canada. The Standing Committee's recommendations had emphasized the need to deal with the ethical issues raised by modern biotechnology. The government's response also included a commitment to the establishment of an independent advisory commission to examine the societal and ethical issues raised by biotechnology. However, the membership, form, and structure of the commission have yet to be established.

## Direct Environmental and Health Effects

The second source of concern regarding agricultural biotechnology products relates to their potential direct effects on environmental and human health. A report recently prepared for the Organization for Economic Cooperation and Development (OECD) ranked the environmental impacts of the commercialization of biotechnology as one of the ten most important new environmental issues facing the world, along with such challenges as global warming and environmental terrorism. In the late 1980s, ecologists and members of other disciplines identified a range of potential negative effects arising from the release of genetically engineered organisms into the environment. These potential impacts included

- the creation of new pests, such as the escape of a transgenic salt-tolerant rice from cultivated fields into estuaries,
- the enhancement of the effects of existing pests or creation of new pests through hybridization or gene transfer to related plants or microorganisms,

- the enhancement of the effects of existing pests as a result of the selective pressures provided by plants modified for pest resistance or intensified pesticide use arising in conjunction with the modification of plants for pesticide resistance,
- infectivity, pathogenicity, toxicity, or other harm to nontarget species, including humans,
- disruptive effects on biotic communities, resulting in the elimination of wild or desirable natural species through competition or interference,
- adverse effects on ecosystem processes and functions, such as nutrient cycling,
- incomplete degradation of hazardous chemicals by microorganisms employed in such applications as bioremediation and waste water treatment, leading to the production of even more toxic by-products.

In addition, concerns were raised regarding the more general risk of reducing biological diversity in any given ecosystem as a result of the introduction of products of biotechnology. Such risks were explicitly recognized in the 1992 United Nations Convention on Biological Diversity. At a more fundamental level, it has been pointed out that biotechnology can threaten biodiversity through its implicit drive to breed uniformity in plants and animals, and furthering and encouraging monocultures.

It is important to realize that these environmental and health risks are not limited to the introduction of genetically engineered or modified organisms. Naturally occurring organisms can behave as "exotic" species when introduced into ecosystems of which they are not native inhabitants. In addition, the introduction of a naturally occurring species into a natural habitat can have disruptive effects if the species is introduced in very high concentrations or quantities. It also has been argued that certain naturally occurring species of microorganisms that have potential to be used in bioremediation and other applications may be opportunistic human pathogens.

Methods for predicting the consequences of the deliberate introduction of new life forms into the environment are still very much under development. The state of science to assess ecological impacts continues to lag far behind development of new products of biotechnology. This has been largely a consequence of public policy decisions regarding the funding of research in universities and governments, particularly the introduction and expansion of requirements for partnerships with the private sector by university researchers. This problem has been particularly acute in Canada and has resulted in the virtual absence of any research independent of industry support on the ecological impacts of biotechnology products, particularly in the agricultural field.

What science has emerged with respect to the potential environmental impacts of the introduction of products of biotechnology appears to confirm the validity of many of the concerns which had been theorized earlier. Recent findings have included the following:

- The long-term persistence of recombinant organisms and their genetic material in the environment can be expected.
- The commercialization of genetically engineered plants will allow transgenes coding for beneficial traits to be transferred to wild or weedy populations of these plants or their close relatives.
- The emergence of resistant pest populations in response to the commercialization of pesticidal plants is likely.
- Transgenic foods may producing allergic reactions.

More broadly, there are concerns regarding the highly reductionist nature of the current approaches to the environmental assessment of the products of biotechnology. In particular, questions have been raised about the failure to place products in appropriate ecological contexts for assessment, the failure to consider the cumulative effects of commercial-scale production, and the failure to assess products as elements of the systems of which they are integral parts (e.g., herbicide-resistant crops and herbicide use). There are also concerns in Canada regarding the failure of the regulatory system to consider adequately the issue of occupational exposure to biotechnology products.

Despite the growing evidence that significant environmental problems can be expected as a result of the commercialization of agricultural biotechnology products, the government of Canada has failed to establish any significant long-term programs to monitor and assess the environmental effects of the commercialization of genetically modified crops. Nor are any records being kept regarding the extent or location of the use of such crops or the extent of the introduction of genetically modified products into the food system. These weaknesses were highlighted in the government of Canada's suspension of the registration of a variety of herbicide-tolerant canola in the spring of 1997.

## Concerns over the Value and Purpose of the Emerging Applications of Biotechnology

The third and most fundamental aspect of the critique of agricultural biotechnology challenges the value and purpose of many of the applications of the technology which are emerging. Industry and government sponsors of the technology claim that it is essential to address the problem of securing an adequate food supply for a growing world population. It is argued that the technology will make agriculture more efficient and thereby allow more people to be fed with fewer resources.

This argument is open to challenge. At the most basic level, it appears to be founded on an extremely poor and highly simplified understanding of current global food supply and population issues. The challenges which humanity faces in these areas are fundamentally of a social, economic, or political nature. The absence of particular technologies is, at best, only a small part of the overall problem.

Past experience has demonstrated that efforts to address complex social, political, and economic issues of this nature through technological fixes almost invariably fail. The introduced technologies tend to deal only with the symptoms of much deeper societal problems. They do not, and indeed cannot, address their social,
economic, or political causes. If the introduction of new technologies is not dealt with in a culturally and socially appropriate manner, the result is frequently a deepening of the original problems.

In addition, many of the leading applications of agricultural biotechnology which are emerging are simply not relevant to the challenges facing the world's food supply, particularly in the developing south. This is made particularly clear by an examination of the two leading applications of the technology to crops in North America, the introduction of herbicide tolerance, and the introduction of insect resistance through the addition of Bt toxin genes.

The primary motivation for the development of herbicide-tolerant crops has been to secure market share for herbicide manufacturers, not to promote of more environmentally sustainable agriculture. This has been made clear in public statements by the firms that developed the technology. Furthermore, it has been argued that this application of biotechnology fails to recognize the causes of problems such as increased weed resistance to herbicides. These include inappropriate cropping patterns that promote weed populations. It is also argued that herbicide-resistant crops will entrench the dependence of agricultural production on external, capital, and energy-intensive chemical inputs, further narrow the genetic base employed for agricultural purposes, and increase farmers' dependence on specific agricultural supply firms. In the longer term, the selective pressure of more intensive herbicide use may lead to the emergence of even more resistant pests. A better approach might be to emphasize the development of alternatives to chemical pesticides for the control of agricultural pests.

The modification of crops for stress resistance may, under certain circumstances, have the potential to expand food production, but it may lead to serious problems as well. It was pointed out early in the development of genetically engineered crops that increased resistance to stress could lead to issues of invasiveness. Crops modified to produce Bt toxin demonstrate another problem related specifically to the introduction of resistance to pests.

It has been claimed that the introduction of pesticidal plants will reduce requirements for the use of chemical pesticides. Serious concerns, however, have been raised that the widespread exposure of insects to high doses of Bt toxin will result in the rapid emergence of Bt-resistant pest populations. This will not only render the Bt crops themselves useless but may also result in the more general loss of Bt as an effective biological pest control agent. Such an outcome could hardly be described as being supportive of ecologically sustainable agriculture.

In general, the applications of agricultural biotechnology that have emerged to date have been closely integrated with conventional, capital-intensive agricultural practices employed in North America and Western Europe. Such practices are not a viable option for farmers in the developing world, who lack access to the capital necessary to employ them. Indeed, their introduction in the south has been associated with the displacement of smaller-scale producers supplying local food markets by large-scale producers growing largely for export to northern markets. Such trends do little to improve food security in the south. Additional concerns have been raised in the developing world regarding the economic impact of the use of agricultural biotechnology products in the north to replace commodities that have traditionally been grown in the south.

More broadly, the applications of biotechnology that have emerged in the agricultural field do little to address the fundamental questions of environmental sustainability which have been raised regarding conventional agricultural practices. Rather, they seem designed to reinforce and further entrench such practices. Conventional practices have been widely criticized as being inconsistent with the principles of sustainable development because they rely on increasing inputs of capital- and energy-intensive products such as pesticides, fertilizers, and mechanical equipment, to maintain productivity in the face of a declining ecological capital base of soil, genetic material, and water, and are themselves associated with major environmental externalities.

Despite the significance of such questions about the value and purpose of many of the applications of agricultural biotechnology, one of the central features of the Canadian and U.S. federal governments' approach to agricultural biotechnology products has been their refusal to address such issues. Rather, regulatory systems have been focused narrowly on the direct effects of the introduction of genetically engineered plants, microorganisms, and other products of modern biotechnology into the environment. Issues related to the long-term effects or desirability of the technology have been determined to be outside the scope of the regulatory system, and, indeed, apparently beyond the legitimate scope of public policy debate.

## Conclusions

Agricultural applications of modern biotechnology, particularly genetic engineering, raise major ethical and social issues. North American governments are beginning to acknowledge the significance of these issues but have failed to address them in any meaningful way. This is true despite the lack of evidence of any public consensus in favor of the adoption of these technologies and the chance that public discomfort is likely to grow as more products enter the marketplace.

The science regarding the ecological effects of agricultural biotechnology products remains under development, but recent findings seem to confirm many of the problems that were theorized in the past. This should be a signal for caution. Nevertheless, governments continue to grant approvals for commercialization and are making no provisions for monitoring environmental effects. Serious questions must be raised in particular about Bt crops and other pesticidal plants.

Finally, the emerging applications of biotechnology in the field of agriculture appear to have little or nothing to do with the establishment of more ecologically sustainable agriculture and food systems in North America or elsewhere in the world. In fact, many of the emerging applications seem likely to entrench environmentally unsustainable practices more deeply. Many of the emerging applications are simply irrelevant to global food concerns. They are being proposed as technological fixes to what are fundamentally social, economic, and political problems.

The development of agricultural biotechnology in North America has been supported by the expenditure of large sums of public funds. The public is therefore entitled to a voice in decisions about the acceptability of these technologies and the value of further public investments in them. In Western Europe, governments have been engaging the public in meaningful dialogues on the implications of biotechnology for their societies and appear to be prepared to act on the results. It is time for North American governments to do the same.

# *Saskatoon's Success as a Global Agricultural Biotechnology Center*

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Today, Saskatoon, Saskatchewan, is known as a global agricultural biotechnology center. It has reached a level of business that is not matched anywhere else in North America.

I will briefly discuss agricultural biotechnology in general — issues and benefits, then some Canadian initiatives in this area, and concluding with the Saskatchewan initiative, Ag-West Biotech.

## THE AGRICULTURE AND AGRI-FOOD SECTOR

Agricultural biotechnology applications have been developed and some are entering the marketplace, even though agriculture has lagged behind the medical sector. Some key areas such as regulations and public awareness were different for agriculture. Products introduced in Canada include: herbicide-tolerant flax from the University of Saskatchewan; edible oil flax; herbicide-tolerant canola varieties from several companies; hybrid canola from AgrEvo; insect-tolerant potatoes (Nature Mark); Flavr-Savr™ tomatoes; and chymazin, an enzyme used for cheese-making.

Agricultural biotechnology offers the opportunity to increase crop production, lower farming costs, improve food quality and safety, and enhance environmental quality. Concerns have been expressed that the negative effects of biotechnology may outweigh the potential benefits. Like any new technology, there are social, economic, and political factors that influence the development, consumer acceptance, and producer adoption of agricultural biotechnology.

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Biotechnology and change are not new to agriculture. In the history of agriculture there have been constant changes produced by new technologies. In the era of mechanization the steam engine, the tractor, and mechanized equipment were introduced. Then in the chemical era pesticides and fertilizers were introduced. Hybrid varieties of crops became standard in some areas, as did feed additives for livestock. These technologies and others are still being introduced from what we today call conventional science, and they will influence production for the foreseeable future in many parts of the world. All of these changes that were often viewed as revolutionary at the time of their introduction had fundamental effects on agriculture, as well as significant social and economic impacts. Biotechnology is the beginning of the next revolution in agriculture.

The adoption of biotechnology in agriculture will be influenced by

- the relative benefits and costs of the technology compared to alternative inputs,
- producers seeking ways to increase profits by reducing production costs or satisfying changes in consumer demand,
- an expanded set of public interests, including food quality and safety, environmental quality, concerns about the impact of agricultural biotechnology on rural communities, and confidence in the regulatory system, and
- government programs and polices and their effect on the adoption of agricultural biotechnology.

Economic assessments of agricultural biotechnology reveal the type and direction of expected change and which groups (farmers, industry, consumers, regions, and countries) may be affected. A review of the studies on the economic impact of agricultural biotechnology provided two major conclusions:

- The economic impact of agricultural biotechnology is likely to be incremental rather than dramatic, and
- a significant amount of the economic benefit will be broadly distributed to consumers in increased supplies, stable prices, and higher-valued products.

Like any new technology, agricultural biotechnology has benefits and raises questions. These need to be acknowledged and addressed to make this paper complete. The issues surrounding agricultural biotechnology in Canada are:

- Regulatory: Ensuring that we have a scientifically sound regulatory process that meets our needs and is compatible with our major trading partners.
- Public awareness: At present, this is an area that is receiving a lot of attention as products enter the market.

- Finance: This is always an issue with emerging technologies — financial support for research and development and for new business start-ups.
- Research support: Ensuring the infrastructure exists to support new product development.
- Intellectual property: Two areas of concern are ownership and globally compatible patent systems.
- Human resource: As the industry expands, there is an increasing pressure on the educational system to meet the demand.

Some of the benefits surrounding agricultural biotechnology in Canada are as follows:

- Improved production: Better weed and pest control, improved fertility, and improved stress tolerance.
- Healthier animals: Improved disease control (vaccines), improved feed nutrition, diagnostics, and genetics.
- Improved quality: Quality is already good, but we will be able to tailor quality more to customer needs in the future.
- Managed exports: Guarantee quality of our exports by working with the customers to determine their needs.
- Viable agricultural industries: By the 21st century, biotechnology will be a key component of all agriculture globally. To be viable, our industry needs to be using the products of biotechnology.

In summarizing this section on agricultural biotechnology, there is one conclusion: as a tool for agricultural science, biotechnology is here and will be used globally in this industry. Countries that adopt the technology early will help ensure that their agricultural industry remains viable. Adoption of the technology includes the creation of a level of understanding by consumers within the country.

## Initiatives on Agricultural Biotechnology in Canada

In Canada there are a variety of initiatives that focus on agricultural biotechnology regulations, research, public awareness, and industry support. I will not provide details in this section but will provide a concept of the breadth of activity. Organizations involved with awareness of biotechnology include

- Industrial Biotechnology Association of Canada (IBAC)
  130 Albert Street, Suite 420
  Ottawa, Ontario, Canada, K1P 5G4
  Phone: 613-233-5586 Fax: 613-233-7541
  Contact: Joyce Groot, President

IBAC is an industry organization that deals with issues, regulations, and other concerns on behalf of industry.

- Canadian Institute of Biotechnology (CIB)

  130 Albert Street, Suite 420

  Ottawa, Ontario, Canada, K1P 5G4

  Phone: 613-563-8849 Fax: 613-563-8850

  Contact: Rick Walters, Executive Director

CIB is an institutional organization that provides its members with project support and awareness of issues on all aspects of biotechnology.

- Food Biotechnology Communications Network (FBCN)

  1 Stone Road West

  Guelph, Ontario, Canada, N1G 4Y2

  Phone: 519-826-3440 Fax: 519-826-3441

  Contact: Diane Wetherall, Executive Director

FBCN deals specifically with public awareness of biotechnology and food.

- Global Agricultural Biotechnology Association (GABA)

  201-407 Downey Road

  Saskatoon, Saskatchewan, Canada, S7N 4L8

  Phone: 306-668-6639 Fax: 306-668-5564

  Contact: Bob Morgan, Chair

GABA is an international organization that uses the Internet to communicate about agricultural biotechnology and international issues.

- Toronto Biotechnology Initiative (TBI)

  51 Hillside Drive

  Aurora, Ontario, Canada, L4G 6E1

  Phone: 905-727-3492 Fax: 905-713-0768

  Contact: John Clement, President

TBI is a public forum organization dealing with a broad base of awareness issues.

- Bio-Atlantech Inc.

  P.O. Box 6000

  Fredericton, New Brunswick, Canada, E3B 5H1

  Phone: 506-453-2366 Fax: 506-453-7170

  Contact: Bernier Roger

Bio-Atlantech is just getting established and will deal with agriculture, forestry, and aquaculture.

- Ontario Agri-Food Technologies Inc. (OAFT)

  1 Stone Road West

  Guelph, Ontario, Canada, N1G 4Y2

  Phone: 519-826-4195 Fax: 519-826-3389

  Contact: Murray McLaughlin

OAFT is a new organization designed to focus on the biotechnology aspect of the agri-food sector, with a primary interest in research and commercialization.

- British Columbia Biotechnology Association (BCBA)

  1122 Mainland Street, Suite 450

  Vancouver, British Columbia, Canada, V6B 5L1

  Phone: 604-689-5602 Fax: 604-689-4198

  Contact: Theresa McCurrey

BCBA is an industry organization for British Columbia that focuses on commercial development and awareness of all aspects of biotechnology.

- Ag-West Biotech Inc. (AWB)

  111 Research Drive, Suite 230

  Saskatoon, Saskatchewan, Canada, S7N 3R2

  Phone: 306-975-1939 Fax: 306-975-1966

  Contact: Peter McCann, President

AWB's mandate is to facilitate commercial development of agricultural biotechnology in Saskatchewan.

Besides these organizations, Canada has a strong research infrastructure that is primarily made up of Agriculture and Agri-Food Canada (AAFC), the National Research Council (NRC), and several universities across the country. AAFC has 18 centers of excellence located in various parts of Canada. The NRC primarily has the Plant Biotechnology Institute (PBI) in Saskatchewan that focuses on agriculture. Two of the key agricultural universities are the University of Guelph in Ontario and the University of Saskatchewan.

## Saskatchewan's Agricultural Biotechnology Initiative

The Saskatchewan agricultural biotechnology community is the best established in Canada and is an example of how working together can create dividends. The community has a very strong research base made up of independent institutions. That community, combined with Innovation Place, a research park, created the catalyst for Saskatoon to become a leading center in agricultural biotechnology. The next few sections will look at the components of Saskatoon that went into creating this global center.

## AG-WEST BIOTECH, INC.

In 1989 Ag-West Biotech, Inc. (AWB), was established with a mandate to facilitate commercialization of agricultural biotechnology for the benefit of Saskatchewan. The objectives of AWB are

- to identify and enhance the development of emerging technology for the advantage of Saskatchewan,
- to facilitate a high level of commercialization of technology from local and foreign sources,
- to help establish commercial partnerships, particularly between public and private sectors
- to establish an international leadership position for Saskatchewan,
- to promote positive awareness of agricultural biotechnology in the public forum, and,
- to facilitate the development of support systems for establishment of agricultural biotechnology

Over the last eight years, the agricultural biotechnology industry has grown from a base of five companies to more than 30 today. The companies are a mix of multinational and local start-up businesses, many of which are located at Innovation Place. AWB is a facilitator that has created the interface between industry, government, and the research and academic communities. The Saskatchewan community has come together to create the leading agricultural biotechnology community in Canada and has become a world leader in the field. AWB was the catalyst that brought all the players together. Having research, business, and government all working together has made Saskatchewan recognized globally.

The Saskatchewan community is made up of more than 700 people involved in public sector research and more than 400 in the private sector. The private sector is the one that is growing. Annually, well over $100 million is spent on research related to agriculture and biotechnology in Saskatoon. Three years ago the city of Saskatoon established a Regional Economic Development Authority. Its two main priorities for new business were agricultural biotechnology and value-added food production. In Canada, Saskatoon has been the only city with agricultural biotechnology as a priority. Others are starting to look at it.

## THE FARM SCENE IN SASKATCHEWAN

Agriculture is a primary business in Saskatchewan and has seen major changes over the years. During this century, these include mechanization and the use of chemicals. Biotechnology is leading the charge as we approach the next century. Farm size is growing, diversification is critical, and new technology is important for farming today and tomorrow, as the business of farming truly becomes a business.

Today, less than two percent of the Canadian population is on the farm. In 1950, it was more than 25 percent. This has created larger farms, improved production, and changes in technology. This trend is expected to continue for the foreseeable future. But I expect that biotechnology will also help maintain smaller farms, as well.

To continue to be viable in a global environment, Canadian agriculture will need to continue to adopt new technologies and to diversify. In Saskatchewan, the industry is actively diversifying and adding value.

Saskatchewan is the largest agricultural producer in Canada, of crops: wheat, barley, canola, oats, lentils, mustard, peas, fruits, vegetables, and others; and of animals: beef cattle, chickens, swine, bison, elk, deer, and wild boar.

Because of this large production, we have a very strong research community in the province. This research is focused on improved production, value-added processing, and new technologies. Linked with this production is the fact that Saskatchewan is a major exporter of agricultural products, therefore, we are constantly looking for opportunities to diversify and to add value to meet the needs of existing and new clients. To accomplish this, we work in partnership with the clients to ensure we are doing the right things to meet their needs.

## Our Business — Agriculture

To ensure our future, we need to know our business, but support for the business is just as critical. In Saskatchewan, our business is agriculture, and therefore, the decision to get involved in the agricultural aspects of biotechnology made sense. In a province with one million people and sixty million acres of agricultural land, it is sensible to focus on agriculture.

In agricultural biotechnology we have developed a direction and have worked together to create a competitive position. The effort has made Saskatchewan the leading province in agricultural biotechnology in Canada, and it gives us global recognition.

The following activities have helped develop and maintain that leadership position:

- Bio-products Center: Bio-pesticides and bio-herbicides are the primary targets for this center. The benefit is that center members are industry researchers at universities and federal labs, working together to facilitate the commercialization of technologies.
- Canadian Value-Added Cereal Consortium: This center focuses on cereal technology.
- Nutraceutical Center: This is a center is still in its planning stage, but it will focus on the concept of nutraceuticals.
- Global Agricultural Biotechnology Association (GABA): This is a global initiative designed to provide information on agricultural biotechnology issues and global bases.

- The Agricultural Biotechnology International Conference 98: The first conference was held in 1996, with representation from 24 countries and 700 attendees.
- Ag-West Biotech, Inc.: Other activities are managed by AWB.
- Information resources: Networking, bulletins, workshops, trade, and seminars.

The key to all of these activities is the establishment of a sense of working together in a team effort.

## KEYS TO SUCCESS

The success of the Saskatchewan biotechnology community has been attributed to three things:

- flexibility
- knowing your business
- knowing your customer

I believe that these three keys have been critical to our success in creating a viable agricultural biotechnology industry in Saskatchewan. If you combine them with the eight qualities identified in the book *In Search of Excellence* by Tom Peters, you will end up with a competitive position in the global marketplace.

The eight qualities Peters lists are:

- A bias for action: Excellent companies do not spend years planning new strategies. They are devotees of the do it, try it, fix it approach.
- Close to the customer: Excellent companies stay in touch with their customers and learn from them.
- Autonomy and leadership: Excellent companies foster leaders and innovators throughout the organization.
- Productivity through people: Top firms treat the rank and file as the root of quality and productivity gains.
- Hands on, value-driven: The most successful firms are driven by a sense of values they insist employees share.
- Stick to the knitting: All the excellent firms analyzed restrict themselves to fields they know well.
- Simple form, lean staff: Most of the excellent companies, although big, have simple forms with minimal layers of bureaucracy.
- Simultaneous loose-tight properties: Excellent companies know when to centralize and when to discourage conformity.

The following are excerpts on Saskatchewan from Ernst and Young's Fourth Report, on *Canadian Biotechnology Industry: Canadian Biotechnology 97 — Coming of Age.*

Saskatchewan is one of the world's key ag-bio players. These are some of the factors that put it ahead:

- Focus: Saskatchewan is one of the world's largest producers of agricultural products and has access to leading-edge research and development in the ag-bio field.
- Leadership: Roy Romanow, premier of Saskatchewan, is strongly supportive of ag-bio. The provincial government has provided infrastructure. Ag-West Biotech, Inc., formed in 1989 with the support of the provincial government, acted as a catalyst for teams of stakeholders in the community. There has been consistent focus on biotechnology from the federal and provincial governments, which the biotech community has succeeded in leveraging. In 1994, Saskatoon established the Economic Development Authority, whose first two priorities for economic growth were ag-bio and value-added agriculture.
- Infrastructure: The University of Saskatchewan provides a very strong and supportive environment, through the College of Agriculture and the Western College of Veterinarian Medicine as well as its involvement in life sciences. The Plant Biotechnology Institute of NRC, VIDO, Agriculture Canada, POS, SRC, and several other institutes and organizations enhance the infrastructure. Innovation Place, the research park, is a big component of the infrastructure, providing facilities and services for the growing business community in ag-bio.
- Financing: Large global corporations invest in Saskatchewan because there is a global market for its products. Saskatchewan benefits from several venture funds, including the Agri-Food Equity Fund and Ag-West Biotech, Inc. Two major banks, Royal Bank and the Canadian Imperial Bank of Commerce (CIBC), have established special financing arrangements for biotech in Saskatoon, and other initiatives are available through the Western Diversification Program (federal) and Saskatchewan Agriculture and Food (provincial).
- Technology transfer: The University of Saskatchewan has enabled and encouraged technology transfer and is establishing training programs that will provide scientists with the necessary business skills to prepare them for careers in ag-bio. The technology transfer effort of all the research institutes in Saskatoon is an important asset.
- Integration: The research community in ag-bio is well integrated vertically, enabling efficient and coordinated research along the entire value chain. This allows the sector to go beyond selling a commodity product to being the purveyor of value-added identity preserved products from DNA to the dinnerplate .

- International profile: Saskatoon is recognized globally as a key ag-bio center. In 1996, it hosted the world's first international ag-bio conference, ABIC 96, attended by more than 700 people from 24 countries. Nothing succeeds like success.

## SUMMARY

In Canada, 26 percent of the core biotechnology companies are devoted to agricultural biotechnology, compared with five percent in the United States. Their activities include the use of microorganisms, plant cells to create commercially viable products, and transformation of plants to improve specific qualities. Their goals are to increase the world's food supply, enable crops and animals to resist pests and diseases, increase the nutritional content of food, and improve production efficiency, while at the same time improving the environment.

Saskatoon is world-recognized for what it is today in agricultural biotechnology. Corporations are looking at ways to participate. Saskatoon's development as an agricultural biotechnology center happened because the ingredients were right — people, facilities, and resources.

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PART IV

# PLENARY LECTURES

# *Welcome and Charge to the Meeting*

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It is indeed a pleasure to welcome you to Saskatoon to participate in the ninth annual meeting of the National Agricultural Biotechnology Council. My task this morning is to provide a brief orientation to the meeting and to present some preliminary remarks that will help guide our thinking.

First, I wish to make the point that this meeting did not happen spontaneously. Many people played different roles over the years that led the course of events to this time and place. I want to first mention Murray McLaughlin, who, as president of AgWest Biotech, attended NABC 4 and upon returning to Saskatoon had discussions with us at the university and encouraged us to become members of the NABC. Murray's encouragement and support in this as well as in many other activities related to agricultural biotechnology, are firmly appreciated. One cannot speak of NABC meetings without mentioning Ralph W. F. Hardy. Ralph, as we all know, was instrumental in the formation of the NABC as a powerful institution; we owe him a debt, and his presence here is warmly appreciated. Finally, I wish to recognize the co-chairs of this meeting. Bryan Harvey and Jim Germida have spent a great deal of time and effort over the past couple of years bringing the program together, working with the NABC Council to iron out the details, and, most importantly seeing that everything goes smoothly. For these efforts I want to thank them personally, as well as on behalf of the university and the NABC.

For those of you who may be attending your first NABC meeting, I want to speak briefly about the format of these meetings. The NABC meetings are all about dialogue, discussion, and education. The NABC celebrates education. It is the focus of our activities – it is the prime reason for the existence of the NABC

— and the educational process at these meetings is carried out in a unique way. We have plenary sessions at which outstanding leaders present material for us to digest. These meetings start out in a very general way, with general discussions drawing our attention toward the issues around agricultural biotechnology. The meeting then moves to plenary sessions that are more specific, with particular items worked out in detail, and then moves to workshops. The workshops are a very important aspect of the NABC meetings. In them, the information that has been provided by the plenary speakers is augmented by specialists at a more focused level. Then discussion, dialogue, exchange of ideas, and work toward a consensus is undertaken. It is important to recognize that the results of these discussions will be summarized and that a publication will appear in the coming months that will record not only the thoughts of our key speakers but also the thoughts of the attendees as reflected in the dialogue in the reports generated in the workshops.

I want to thank you all for coming. I want to encourage you to participate fully and to gain through the process that has been laid out for you.

I now wish to turn your attention to a few thoughts about the Canadian prairies and about the setting in which this meeting takes place. About two years ago, when we were sitting around talking about the focus for this meeting, it came to us that one of the unique features about the prairies and about the agriculture that survives here is that it takes place in a challenged environment. We use this concept in our title, and the title "Resource Management in Challenged Environments" is very appropriate for the setting in which we find ourselves. On this beautiful June day it may seem that this is a hospitable and welcoming environment. Let me assure you that other parts of the year are less accommodating. The extreme range of physical limitations confront us in agriculture on these prairies. Saskatoon is at the apex of what we in Canada call the Palliser Triangle. This triangular area is bounded roughly by the Rocky Mountains at the U.S.-Canadian border on the southwest, the Red River as it crosses the American-Canadian border on the southeast, and Saskatoon at the apex. The area is an extension of the Great Plains. It is semiarid; at its extremes it becomes an arid area. It was, in the mind of the explorer Palliser, who first traveled it, an area not likely fit for settlement. He probably traveled these plains in one of the periodic drought cycles, and following his report it was some years before settlers ventured into this vast sea of grass. Surrounding the Palliser Triangle is a horseshoe-shaped area of more fertile soils but one that faces other limitations such as a short growing season, extremely severe winters, and considerable variation in rainfall.

In summary, the effect of these environmental challenges for agriculture on the prairies, we work very close to the margin. We work close to moisture and temperature limitations, and we are very much at the mercy of fluctuations in either of these variables.

In this environment, technology has always played a major role. Throughout the last hundred years, technological change has helped us deal with the narrow margins and has pushed back the limitations of our environment and our location in some rather remarkable ways. The production and export of grain from these prairies was almost impossible economically until the development of steel and steam in the transportation system. Steel-hulled boats driven by steam, as opposed to sail, changed the economics of moving grain over long distances in the last couple of decades of the nineteenth century and were a major factor in opening up the prairies as one of the bread baskets of the world. Early in the twentieth century, the development of a wheat that would come to maturity within the prairie growing season was another major technological breakthrough that reduced the environmental hazard of farming on the prairies. In addition, the development of dryland farming technology was an important breakthrough that made it possible to make a living from these plains. We are all familiar with the dust bowl of the 1930s. In Saskatchewan there was a smaller, but just as severe, drought period in the early 1920s, and developments such as the placing of the Swift Current Experimental Station in the heart of the dryland agricultural area were instrumental in allowing people in this province to learn to cope with the vagaries of dryland agriculture.

One of the ongoing battles farmers on these prairies faced was the rust epidemic in the cereal crops. Major advances, particularly during the 1930s and again during the 1950s, in developing varieties, particularly of wheat, that were resistant to the prevalent strains of rust led to the possibility of continuing to crop these vast semiarid areas.

In setting the stage for our thinking about agricultural biotechnology, it is important to recognize that technology has been, in a sense, the saviour of the narrow-margin agriculture of these plains, but at the same time we must recognize that all of the impacts of technology have not been favorable. As we have overcome one challenge, we often recognize that the methods we used have side effects that cause new problems, or second-generation problems, that we must then address. This is the setting in which we find ourselves. We continue to face challenges. We look to the development of agricultural biotechnology to resolve them. At the NABC Council meeting yesterday, we talked about the necessity and the means to continue the trend of a two percent annual increase in agricultural productivity. This is an ongoing challenge, and we will be looking to agricultural biotechnology for assistance. There are many other challenges. In Saskatchewan, as in most parts of the agricultural world, we recognize the changing face of the agricultural marketplace. As primarily an exporting industry, we must become more cognizant of our market imperatives. We also are becoming more cognizant of the questions of sustainability in agricultural production and of the social impacts of the changes in the structure of agriculture brought about not only by technology but by the changing face of trade, marketing, and sustainability needs.

In planning this meeting, we recognized that we must draw attention to these issues. Therefore, the meeting has been structured to address resource management in challenged environments, and the subtopics used to identify and explore this issue include the regulatory system, biodiversity, and social issues. The workshops are designed to challenge your thinking, to lead your thinking, and to position you to form opinions and action plans that can assist individuals and the total industry in moving forward to meet these challenges.

Finally, I want to remind you that the success or failure of this meeting — the value to you by attending this meeting — is totally dependent on the way you participate. I urge you to submerge yourself in these issues, to listen carefully to the speakers, and to join freely in the discussions and the formation of consensus statements that will take place during the latter parts of the workshop sessions. I wish you a successful and enjoyable experience over the next two days.

# *Consumer Perspective*


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I will describe the international regulatory situation as well as the public attitudes in several regions of the world (Europe, Japan, Australia, and North America). I will introduce a selection of results from North American surveys describing the public attitude environment, and I will then provide a brief synopsis of the NABC environment that has developed over the past decade. I will also attempt to draw some consistent threads among these challenged environments and offer some suggestions for where we go from here.

I will cover the complex and rapidly changing regulatory and government policy environment related to food biotechnology because regulatory policy in the developed world tends to reflect the moral, ethical and cultural sentiments of the voting public. I emphasize , however, that these are my personal interpretations of this rapidly changing environment, not to be confused with official government position statements.

Simply put, Europe is in a state of chaos. It has a large and ever-rising backlog of approval submissions that are not being adequately addressed. One of the complications is a dual approval system which governs product approvals by the European Commission, as well as the individual member state regulatory agencies. Product approval through this multilayered system is more onerous than equivalent approvals in other developed nations.

The European Union (EU) has a strong and well-coordinated antibiotechnology lobby led by Green Peace, which has attempted several highly publicized blockades of transgenic grain shipments at European ports. This lobby group has primarily focused on the controversial area of food labeling. A difference of opinion exists among EU member states related to labeling requirements. While the European Commission has stated that labeling is required only for health, safety, and nutrition, some states are considering mandatory labeling for all genetically engineered products, in part to erect nontariff barriers to trade but also to reflect the vigorous negative public sentiment. The application of these labeling policies to real-life situations may prove to be extremely complicated. The controversy has also moved into the retail market, and some outlets (Britain) are suggesting that they will not carry genetically engineered foods without mandatory labeling. The European Commission is providing U.S. $1.25 million over three years to advance public awareness and understanding of biotechnology across Europe, but this has not yet proven to be very successful because there are a wide variety of information needs and a relatively small amount of available funding.

Japan has recently put into place a regulatory framework to deal with biotechnology-derived foods. It has approved 19 products through this system and several more are expected over the next few months. Japan has also made a commitment to public awareness by establishing the Plant Biotechnology Information Centre, which provides information to the media and consumers, as well as offering seminars and a listing of product approvals around the world. There is little coordinated antibiotechnology effort in Japan. Japanese consumers appear to embrace the products of biotechnology more readily than do Europeans, but it is difficult to judge consumer buying sentiments because the regulatory system is very new and, though the products have been approved, transgenic foods have not yet reached store shelves.

In Australia, biotechnology has always had a high level of support from the federal government. In fact, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the major government research group in Australia, continues to drive much of the research agenda in that country. As is sometimes the case in Canada, the Australian federal and state governments do not always agree on issues. Biotechnology is no exception. There is no clear mandate at the federal or state levels for regulatory oversight. As a result, an informal regulatory system is being implemented without the requisite statutory authority for enforcement. The Genetic Manipulation Advisory Committee forms the backbone of this system, providing guidance on issues of health and environmental safety. The Australian Food Authority approves new food products and is now considering how to deal with biotechnology. Labeling guidelines were recently released for comment by both Australia and New Zealand, suggesting food labeling for health and safety or compositional or nutritional change. A more controversial issue is the suggestion that products that may contain more than five percent transgenic components also be labeled. How such a requirement will be interpreted for commercial products has yet to be determined. Most of the population appears to support the use of biotechnology, including its use for food products. The antibiotechnology lobby is not well organized and has not yet achieved much success. Equally important is the poor coordination of the industrial community, placing the industry in jeopardy if public sentiment begins to change.

North America is in an enviable position with a relatively stable regulatory environment and the lion's share of global product approvals. Both Canada and the United States have similar health, safety, and environmental regulatory oversight. Canada, however, requires pre-market notification for novel food products (including those produced with biotechnology) while the United States regulates foods after they have reached the market. The U.S. approval system for some biotechnology products (those similar to previously approved products) is being streamlined to reduce the regulatory burden and accelerate product approvals based on extensive experience with these products. Food labeling issues are being negotiated through the international food standards organization Codex Alimentarius. In both Canada and the United States, an interim labeling policy is in effect, requiring labeling when there is a health or safety issue or when there is a nutritional or compositional change. Interestingly, the antibiotechnology lobby has not been as successful in North America as in Europe, but there are a few outspoken individuals and the movement is becoming better organized. These groups provide a reality check on our progress. While North America has some positive influences, it is appropriate that we remain aware of these outspoken critics and their impact on public attitudes.

To better understand public attitudes, I thought it would be useful to review the findings of a selection of studies and public opinion polls carried out in North America. While polls are useful in providing information on attitudes, they are often biased by the style and content of questions, and they are poor at providing reliable statistics on the final consumer product purchase decision. Purchase decisions are based on a wide variety of criteria that differ from consumer to consumer.

As the bovine somatotropin (BST) issue was in full swing in the United States in 1994, a Task Force Report was developed to identify consumer reaction to rBST. There was a loud and highly publicized outcry from a variety of sources during the first few months of commercial release. This debate has continued in some regions of the United Sttaes and small pockets of resistance are being established in Vermont, Wisconsin, Maine, and a few other states. But despite this outcry, the Task Force Report noted a slight increase in national milk consumption. Labeling was embraced as the critical issue in these few regions and continues to be debated in some state legislatures. rBST has not yet received regulatory approval in Canada.

Thomas Hoban of North Carolina State University has developed a series of public opinion polls since 1993. His major findings show that the U.S. public was relatively unaware of biotechnology. Biotechnology products for health care and agricultural plant applications appeared to have strong support. Trust and credibility of information sources was also covered, and the results indicate that the members of NABC rank well in both categories.

The Decima and Optima studies carried out in 1993 and 1994 showed that Canadians, too, were generally unfamiliar with biotechnology but that we are a cautiously optimistic lot. Labeling of genetically engineered foods was strongly supported in these and most other consumer polls done around the world. Here again, the trust and credibility questions pointed to NABC members as holding a lofty position in both categories.

A Canadian Angus Reid poll showed a slight increase in awareness, indicating that the majority had heard of biotechnology by June 1995 but few understood it. The results, consistent with other polls, showed that most supported applications in plants, but there was less support for applications in animals. As well, female respondents appeared more concerned than their male counterparts.

The Trends survey, conducted by the Canadian Council of Grocery Distributors in 1995, showed that the awareness of biotechnology-derived foods was similar in both Canada and the United States, with U.S. consumers a little better informed. Even so, more than half the respondents had heard nothing or only a little about the topic. Half would purchase a biotechnology-derived product that had improved taste, and three-quarters would purchase a biotechnology-derived food product that had been developed for insect resistance. This survey also placed the views of Canadians toward their food into context. Their primary concerns were safety, nutrition, quality, and taste.

We are now undertaking a survey of public attitudes in Canada, the United States, and Europe using the same questionnaire, carried out in the same time frame. The results should help us compare attitudes in these regions and determine if attitudes have shifted, now that food products are on the grocery shelf.

I have given you a flavor of the regulatory situation in several nations, as well as a brief look at the public attitudes in North America. So, what do we (the NABC) do with this information, and where do we go from here? To begin answering these questions, I thought it might be useful to provide a snapshot of what the NABC meetings have accomplished to date. I am taking only a selection of results and have interpreted them in my own words. I suppose that the traditional disclaimer that these are the opinions of the speaker, not the NABC management, is in order.

NABC 1, held in 1989, recommended that more discussion with the public on research directions was in order. It also suggested that public education programs be established, as well as mechanisms for the public to offer input into decision making.

NABC 2 followed on this theme, recommending that consumers be empowered to participate in product development, that public debate on labeling issues be initiated, and that teaching materials be developed.

NABC 3 and 4 supported public discussion and dialogue, suggesting multiparty involvement in the funding allocation process.

NABC 5 and 6 recommended focusing on the early education system (K-12) and developing a public education plan.

NABC 7 and 8 suggested that we lead public discussion, focus on differentiated audiences, and develop materials to raise awareness.

There are some obvious common themes among these results. As is true of many other groups that provide recommendations, there was a recognition that we did not have enough information and more research was required. Perhaps there is some truth here, but it is somewhat self-serving as well. The call for more communication was consistent, as was the focus on the education system. Yet, each and every attempt to deal with the communication issues has resulted in interminable discussion. We have been consistently short on deliverables. We have left the action items to others while professing to be intimately involved in the process. There has been no follow-up on the recommendations, no coordinated effort to effect change, and precious little leadership from a group that holds high levels of both public trust and credibility.

So, where do we go from here? Products of biotechnology are in the stores; they are on our dinner plates. The products of biotechnology are now a reality and consumers continue to be poorly informed at best, possibly even unaware. It is our combined responsibility to make them aware. It is our combined responsibility to get the message of food biotechnology out. It is our combined responsibility to take the leadership position in this communications challenge.

Having been involved in the public information game since the late 1980s, I am increasingly frustrated with those who remain focused solely on the collection of information and the academic study of issues. I think it is interesting to consider the hundreds of thousands of dollars that this group alone has spent during the past decade, going to these meetings to discuss the issues and to make recommendations on communication with the public. I suppose it is appropriate, considering the audience, to ask, Where is the beef? It is time that we move beyond the abstract to the practical by building on the knowledge we have gained and applying it to concrete communication activities. We must close the ever-widening information gap that exists between science and the consuming public.

To initiate this shift in our actions, we can jointly compile a list of activities that involve the public and the educational system. We can combine the efforts of individual organizations into coordinated programs. We can identify gaps where our activities have had little impact and develop new activities to address those gaps. And finally, we can assign both human and financial resources to support these activities. We have not yet been effective in influencing public awareness, either on a community or an individual level. Perhaps it is time to change the focus of this group to meet the challenged environment of low public awareness. One Canadian organization attempting to address this gap is the Food Biotechnology Communication Network (FBCN), which represents consumer, farm, industry, and government organizations and provides information on food biotechnology. Two activities which the Canadian biotechnology community (including FBCN) are now developing are a communication strategy and an issues/crisis management plan. These activities identify and assign both responsibilities and resources. The NABC has an opportunity to undertake a similar role, but this will require significant change.

One scenario which I propose to implement such a change comes in four phases: First, we form a group to develop a communications strategy with input from the NABC members (possibly in conjunction with the FBCN), including stated objectives, target audiences, key messages and messengers, and activities that are targeted and timely. In phase two, we each identify how our own organization will become involved in meeting the deliverables outlined in the strategy and make this known to the NABC and other members. Then, we jointly initiate the strategy and the activities that we have identified. Finally, the NABC monitors the activities and, together, we evaluate our progress at each future NABC meeting, offering a reality check on progress made. This action plan would move us from talking among ourselves at each of these annual NABC meetings to instituting real change in public attitudes.

Today we have looked at the international regulatory environment. We have touched on the public attitudes environment, and we have reviewed the self-proscribed challenges in the NABC environment over the past decade. Continued chat among interested stakeholders is no longer suitable. For ten years, we have been hesitant to take up the gauntlet and face our most challenging environment, public awareness. We have an opportunity, over the next two days, to institute a process that will form an action plan and finally begin the implementation process. For once, let's meet this challenge head-on. Let's coordinate our efforts and effect real change.

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BIOTECanada has created an overview of the Canadian communication activities entitled: About Biotechnology: The Communications Experience. Copies are available via E-mail at cib@biotech.ca

# *Placing Several Eggs in Our Basket: Keeping Diversity in Agriculture*

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*Organic growers are facing a significant challenge. Will we be able to procure, in the long term, enough seeds and seedlings, or will we be disconnected from the progress of plant breeding programs? Will controls over the movement of products guarantee that our livestock feed does not contain transgenic soya, or will we need to forbid to farmers any purchase of soya?*

*Are natural insecticides made with Bt still effective in potato, vegetable, vine and fruit tree production, or will we soon be forced to go back to pick off potato beetles by hand? Who will hold back the wind which blows bio-engineered pollen and seeds on our fields?"* (Niggli 1996: 16)

Urs Niggli, Director
Research Institute of Organic Agriculture
Frick, Switzerland

## INTRODUCTION

This paper explains why developers and users of agricultural biotechnology need to be concerned over the possibilities that its side effects may disable one important agriculture sector, organic farming.

Organic agriculture deserves to have a future because it makes a contribution to society's public good and because it can be used to demonstrate how it is possible to obtain good yields of many crops without the benefit of biotechnology or of synthetic pesticides and fertilizers. Should these types of agricultural technologies fail in the future, it will be advantageous to learn from the organic production system. Thus, aside from purely altruistic motives, there is a pragmatic reason why all farmers need to ensure that biotechnology does not harm the viability of organic agriculture.

There are currently several distinct technologies for food production. This is a healthy mixture because each technology offers its own environmental advantages and each is capable of producing the yields needed to feed the world. What is dangerous is if one technology eliminates another.

Risk assessment and contingency planning dictate that several eggs be kept in the basket of agricultural systems to ensure that the public good is maintained, now and in the future.

## ORGANIC AGRICULTURE

Organic agriculture is a farming system "whose primary goal is to optimize the health and productivity of interdependent communities of soil life, plants, animals, and people" (Canadian General Standards Board [CGSB] 1997, p. 3). Organic farming avoids the use of chemical fertilizers, herbicides, pesticides, or growth regulators so as not to introduce into the environment substances that may compromise its integrity over the short term or cumulatively. Once crops leave the farm, various protocols ensure that no toxic chemicals are used to control pests such as rats or insects and that organic products continue to be segregated from nonorganic items (Organic Crop Improvement Association [OCIA] 1997, pp. 27-33).

Organic farming uses the tools provided by modern technology. In western Canada, it is not unusual to see growers use the same 54-foot-wide implements as their neighbors for seeding and harvesting. Organic production takes place on farms of similar size as conventional production, for example, from small, half acre herb farms to 4,000-acre grain operations.

An increasing amount of scientific research is taking place to enable organic farmers to develop production techniques adapted to all climatic and soil conditions. This research is reported at events such as the biennial International Federation of Organic Agriculture Movements (IFOAM) Scientific Conferences. IFOAM sets minimum, worldwide standards for the organic industry. The last conference, held in Copenhagen in 1996, attracted individuals from 92 nationalities and included more than 400 presentations.

## Rigorous Standards

The organic industry has developed an organic certification process which ensures that producers and processors follow internationally recognized standards, such as those of the Organic Crop Improvement Association (OCIA, 1997). Several nations are currently instituting uniform standards and accreditation mechanisms for their territory. In Canada, all organic certification processes will soon be brought under the same umbrella, with standards registered under the Canadian General Standards Board (CGSB, 1997). A similar process is under way in the United States, pursuant to the Organic Foods Production Act (Marbek Resource Consultants, 1996).

The certification process is very similar to an environmental audit (Thierrin, 1996). Standards are used as evaluation criteria, and an independent inspector is brought in to assess whether the farming operation can be certified as organic. The responsibilities of the organic inspector are to visit the farm, talk with the farmer, and write a report describing how the farm is managed, whether information in the certification application was correct, and whether the grower follows the organic standards. In addition, the inspector's report will usually include recommendations on how the organic producer could better address the organic standards or manage farm operations in a more ecological manner.

## A Growing Industry

The organic industry is currently growing by leaps and bounds in sales and number of acres of certified organic production. In the United States, $3.5 billion worth of organic products were sold in 1996, according to the Natural Foods Merchandiser (Pesticide Action Network, 1997). This is the seventh year in a row that sales have grown, at a pace of 20 percent a year in the recent past. In North America, however, only a small number of farms are organic. The U.S. Department of Agriculture (USDA) estimated in 1992 that 0.1 percent of U.S. agricultural land was in organic production and 0.2 percent of farms were certified organic (Marbek Resource Consultants, 1996). Slightly more than one million acres of organic land were in production in the United States in 1994 (Dunn, 1996). In European countries, where organic production is sometimes encouraged by government programs, percentages of organic farms can be significantly higher, for example, 7.1 percent of Swiss farms (Dietler, 1997) and 16 percent of Danish farms (Kloppenborg, 1996).

## An Industry That Contributes to the Public Good

Organic agriculture contributes to the public good because it is sustainable from two desirable perspectives: it does not harm the environment and its productivity is good. Thus farmers obtain a sufficient income, and the produce from organic farms helps to feed the world.

Showing that a food production system is sustainable for both the environment and the producer requires the analysis of three attributes:

- Environmental accounting
- Carrying capacity
- Sustained yield

These are taken from a list of six attributes developed to describe a sustainable agriculture system from environmental, economic, and social perspectives (Brklacich, Bryant and Smit, 1991).

## Environmental Accounting

Environmental accounting includes the identification and measurement of the natural resources base so that its protection, conservation, degradation, and use transfer can be monitored (Brklacich et al., 1991). Environmental risks are minimized because toxic chemicals are not used for weed or insect control. Furthermore, it has been shown that, at least in western Canada, the organic certification process can competently evaluate whether an organic farm uses resources in a way that is environmentally sustainable, and it can also ensure that the operator improves his or her management of these resources if the annual inspection reveals that there are problems (Thierrin, 1996).

## Carrying Capacity

Carrying capacity is the ability of the ecosystem to continue to be used for agricultural production. Because organic certification requires an annual inspection in which fields are visually inspected by an inspector and the condition of crops is documented, the farm's carrying capacity is monitored as part of the certification process. Should a negative pattern emerge, it will be noted, and corrections will be recommended to the grower. If recommendations are not implemented within a reasonable time period, the certification status will be denied, and marketing of products from this farm as organic will cease.

## Sustained Yield

The yields obtained by experienced organic farmers are very good because they pay close attention to soil fertility "by improving soil structure, increasing organic content, and balancing nutrients," as Steve McKaskle does, in the upper Delta in Missouri (Richards, 1996). Obtaining yields equivalent to 85 percent or more, compared to the yields of conventional farms, as Alberta producers Dwayne Smith and Ken Larsen regularly do (Smith, 1993; Larsen, 1997), is not without challenges. But it is possible, if meticulous care is taken to be aware of the local agricultural ecosystem, to understand its susceptibility to particular weeds and insects, to apply the appropriate preventive practices, and to use corrective measures only when needed.

There are occasional reports in popular farm newspapers that organic agriculture means low yield, and it is worth identifying here the reason for the discrepancy between the above paragraph and such reports. It is true that yields are lower during the three- to five-year transition from chemical to organic agriculture because, in such situations, the farmer has not yet identified which organic techniques and rotation system will work best in his or her ecosystem in order to grow the intended crops. Once this transition is complete, yields bounce back up.

Second, organic farmers often grow a greater diversity of crops than conventional farmers because most of them plant certain crops to encourage beneficial insects, or as part of a rotation designed to enhance fertility and to control diseases and pests (USDA, 1996). These measures reduce the yearly acreage dedicated to the farm's main crop and may give the illusion that the farm is not too productive for this particular crop. In fact, the productivity per acre may be as high as, or higher than that of a conventional farm.

## Agricultural Biotechnology and the Organic Industry

As mentioned in the quotation that introduced this paper, the organic industry feels most affected by three facets of agricultural biotechnology:

- Dissemination of transgenic plants through the ecosystem
- Availability of nontransgenic seeds and feed sources
- Rapid development of insect resistance to Bt

While the first two concerns have been slowly evolving for a while, the adoption of Bt plants in recent years has catalyzed the organic industry into a real fear because Bt is one of the most effective pesticides allowed under organic certification (OCIA, 1997). It targets and kills specific insects, is relatively harmless to people and other animals, and breaks down fairly quickly compared to synthetic insecticides (Swadener, 1994); these features make it unique. The use of Bt by organic farmers begs this question: Could bioengineered Bt crops be used by the organic industry?

Under current organic production standards, genetically modified organisms (GMOs) are not allowed. This could change in the future, if it can be absolutely demonstrated that bioengineering does not create unwanted side effects on food quality and on allergenic properties and that its ecological contribution is indeed limited to the intended effect, for example, insect control in the case of Bt plants. Even if the prohibition of GMOs is relaxed, it is very unlikely that Bt plants would be acceptable because the use that organic growers make of Bt is vastly different than its use as genetic material inside a plant.

## Insect Control by Organic Growers

Organic farmers use Bt selectively, whereas its use within each plant in a field makes it pervasive during the cropping season. As was mentioned in the discussion on sustained yield, organic growers rely on preventive measures and use corrective measures only when needed.

For cotton, an example of a preventive measure is to interplant bean and cotton: two rows of beans follow two rows of cotton, and so on. If insects discover one set of cotton plant rows, they are less likely to travel to other rows if they need to cross over a set of bean plants first (Fox, 1996). Bt would be used as a corrective measure only if there were enough insects to cause economically important damage. If the use of Bt was always this limited, insect resistance would develop slowly, as it has in 30 years of use for the diamondback moth (Swadener, 1994). Many other insects have so far failed to develop resistance. This contrasts with the three- to five-year time frame being predicted for development of resistant insects now that pesticide-producing plants are grown across the United States (Snow and Palma, 1997). Thus there is a fear that Bt may be lost as a useful insecticide for the next generation of farmers, whether they be organic or not.

Fortunately, several interesting strategies are being proposed to ensure the management of resistance: cultivating mixtures of host plants, maintaining non-Bt refuges, using highly toxic Bt plants (Snow and Palma, 1997). Although such solutions are not ideal for the organic industry, at least they represent a step forward. Some of these solutions may offer the possibility of partnerships between conventional and organic farmers, especially the creation and maintenance of refuges.

## Options for the Organic Industry

Organic production standards contain mechanisms to ensure that contamination from synthetic, potentially toxic substances does not occur on organic farms: buffer zones between organic and neighbors' fields, use of untreated seeds only, tolerance levels for contamination, the necessity of keeping beehives a minimum of two miles away from any sprayed crop. Except for beekeeping, these mechanisms are not useful to cope with the potential problems associated with agricultural biotechnology.

Instead, these options are being proposed by this author:

- Raising awareness
- Appealing for the use of appropriate technologies
- Labeling
- Litigation

## Raising Awareness

Raising awareness is done through a paper such as this one, to educate scientists and growers about the effectiveness of organic production and to show that there are good farming reasons why the organic industry is shying away from biotechnology.

## Appealing for the Use of Appropriate Technologies

Farmers and scientists need to know that valuable ecological knowledge may be lost if organic agriculture is not allowed to establish itself firmly, because pressure from other agricultural systems may prevent its principles from being applied. Hence it is necessary for you, the reader, to ensure that appropriate technological paths are taken to prevent this potential disaster.

Such paths should ensure that the benefits of future plant breeding are not lost to the organic industry so that new varieties of high-yield or disease-resistant seeds are available for organic growers. More generally, agricultural technology needs to be developed in an inclusive manner, which enables all sustainable agricultural practitioners to benefit from it.

## Labeling

Labeling of bioengineered consumer products is a topic that has generated copious literature in the recent past. Another type of labeling is of greater importance to the organic industry, namely labeling and segregation of bioengineered seeds and feeds to ensure that organic growers are not inadvertently planting herbicide-tolerant or Bt crops or feeding such crops to animals. The organic industry is able to move a great diversity of certified organic products in a labeled, segregated environment, and it believes that distributors of bioengineered products can do the same.

Once again, it is worth reiterating that organic growers are not likely to use products created through biotechnology in the near future because they already benefit from the interactions present in natural systems to grow crops. Hence, why risk the use of a technology that may harm ecological integrity?

## Litigation

In Canada, nuisance claims can be filed against individuals who knowingly develop or apply Bt plants technology in a way that is known to endanger the future effectiveness of Bt by all or by some, thereby causing irreparable damage to the public good, to the organic industry, or to an individual farmer. Such claims can be used for other applications of agricultural technology, too. A public nuisance claim can be launched by the attorney general or by an individual, depending on circumstances. A private nuisance claim can be used only by an individual whose land is directly affected by the other party's actions or inaction (Bird, 1983). I do not know whether the U.S. legal system has common law principles that support the above actions, but it is likely that similar legal recourses exist there, too.

The use of this type of litigation is unlikely because proof would be extremely difficult to obtain and because the organic industry has not yet mobilized itself to think and to act in this manner. Nonetheless, special circumstances could lead to a nuisance claim. It may be initiated, for example, if a group has been careful to monitor the activity of a company, of a scientist, or of a farmer, to issue a warning to the appropriate party about potential risks to the public or to an organic farmer, and to document inaction by these parties.

## CONCLUSION

I hope that this paper has helped to dispel myths surrounding the organic industry and to outline the seriousness with which this sector views the immediate threat posed by the secondary effects of agricultural biotechnology, especially to the effectiveness of Bt and the availability of seeds.

A few critical choices need to be made by the farmers and other decision makers who continue to develop Bt crops and other biotechnologies. One sound choice may be to recognize the organic industry as a valuable partner that acts in the public interest. Another reasonable choice is to recognize that the public interest requires the development of a variety of sustainable agriculture systems. The corollaries of such a choice would be that:

- future plant breeding and seed registration should include varieties that may be used by organic farmers.
- bioengineered crops used for feed should be labeled and segregated from other crops so that organic livestock operations are able to purchase appropriate animal feed.
- Bt resistance strategies should be designed effectively and perhaps even with the collaboration of the organic industry.
- as other types of biotechnology applications are developed, their impact on organic agriculture should be weighed before proceeding too far.
- technologies which make organic agriculture impossible to practice should be discontinued.

Already the potential threats of biotechnology have led, in the United States, to the unprecedented alliance of many environmental and organic agriculture leaders to ensure that the government exclude genetically modified organisms from the U.S. national organic standards. Can the formation of an organic industry legal defense fund be far behind, if the advice in this article is not heeded?

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# *An Industry Perspective*

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Biotechnology is coming of age, after many years of work on the regulatory process and policies, as well as public awareness, educational issues, and intellectual property. We are now recognizing that we need to assess every new tool we use or product we develop to ensure human survival. Sustainability, food security, health, and safety have become our goals for tomorrow.

This paper considers challenged environments from a variety of perspectives of which the industry must always be cognizant — from the natural environment to the business environment. Three key messages should be kept in mind. First, biotechnology is a tool with which to develop new products — not an end in and of itself. It offers a range of products that can address some challenges, as well as offering novel options and value-added products not previously available to producers, the processing/manufacturing industry, and the consumer. The race to take advantage of this tool is on around the world, and Canada now enjoys a leadership position. The initial products are here, and whether we are users of this technology or not, we will be consumers of imported products using the technology. The choice is ours as to whether we will benefit.

The second important message is that partnerships are important to the industry and to other stakeholders. Industry is continually forming strategic alliances, either among companies or between the research community and companies, in ways that are mutually advantageous. Each offers a strength that the other lacks. The same is true for the community at large. We need to listen to each other and work together as a whole, rather than as divided factions on different missions. Forums such as this should be looked at as opportunities to accomplish this goal and to learn what others are doing.

The third message deals with recognition, learned the hard way, that no single magic bullet exists. All new technologies or approaches we try have to be used in the context of long-term sustainability. To accomplish this, we need to look at the entire system and understand the effects of technology while we trying to achieve our goals.

This paper deals with challenges from the industry point of view, recognizing that no perspective exists in isolation. Each perspective must include others when addressing these challenges. For this reason, while industry is a developer, manufacturer, and user of tools of biotechnology, it would never stay in business unless these products meet environmental, consumer, and community needs. Industry also has an opportunity to become more competitive via responsible use of biotechnology in traditional sectors. On the other side of the coin, Canadians would have fewer jobs if the biotechnology industry left Canada — but we would still be users of this technology because other countries would be exporting their products to Canada. We would fall behind competitively and economically. It is in this context that the challenges are a matter of perception. The reality is that everyone must deal with the same set of challenges.

We must ensure that sufficient, high-quality food can be produced while also enabling agricultural producers to make a living in a way that is environmentally sustainable over the long term. Consumers are concerned about food security, safety, nutrition, and quality. To ensure long-term survival, the industry must ensure that products developed will satisfy all these needs. Finally, all members of the community must listen to each other and develop ways to work together to help make these things happen.

I would like to address this technology from the standpoint of the opportunities as well as issues. In its most global perspective, biotechnology promises to meet challenges of several major sectors. In the health care sector, new drugs will cure chronic, intractable, and often fatal diseases such as cancer, AIDS, and osteoporosis. Compared to its world market share, Canada has a disproportionate percentage of biotechnology health-care products. The potential to develop more nutritious, healthier, high-quality foods and ways to produce those foods clearly benefit agriculture. Animals and fish also can benefit in many ways, such as improved health because of resistance to diseases and infections. Environmental applications include products used for bioremediation — cleaning up the environment using biological systems. In forestry, potential products will be trees with resistance to both disease and insects as well as the ability to grow faster. And finally, biotechnology shows promise for bio-leaching in the area of mining.

These benefits can also be realized throughout the value chain. The producer has access to more efficient, low-cost production methods that can also be more sustainable than those available in the past. Processors may be able to process more food products through the use of purer, lower-cost alternatives such as transgenic chymosin to replace renin for cheese-making. Foods are becoming more nutritious, safer, and lower cost. What can this technology offer us as Canadians? We are leading in the development of these new products, and we can reap the benefits in terms of global competitiveness and its advantages for our economy. On an individual basis, this translates into a high standard of living, and more jobs from a healthy economy. This is where the developers of these products are important. These products will be useful not only to Canadians but to our export markets.

The biotechnology industry in Canada has developed over 20 years and is now enjoying a period of tremendous investment. Approximately 530 companies employing 23,000 Canadians use biotechnology as the main part or as a portion of their business. In 1996, $1.7 billion was invested in research and development, and annual revenues now exceed $3.5 billion. In addition, most of the companies are small and medium-sized, not multinational, as is the common perception. The industry is based on knowledge, innovation, and research.

The industry still faces scientific challenges. This is a challenging technology, and the science is still in its infancy in terms of understanding what genes code for which traits, locating and transferring genetic material from one organism to another, and finally expressing the genetic material in the intended organism. The industry still needs to ensure that its new products meet a variety of needs, including those of the business sector, the stakeholders, and the environment — not an easy task. In addition, there are cultural differences between scientists at universities and in industry and between the different sectors. As an example, the culture is very different in the pharmaceutical industry than in the agricultural industry. Public awareness issues and education are everyone's responsibility and industry is no exception. The industry is also faced with a shortage of highly skilled people needed to meet the growing demand for in the near term for scientists and managers. Regulations and policy will always be a challenge. Wherever possible, countries should strive to harmonize their regulatory requirements and approaches. Canada must provide a competitive regulatory environment and ensure these issues are addressed in both national and international ways.

I will highlight two of these issues — human resources and regulations policy. A report entitled *Building Long Term Capability Now* projected 8,000 new biotechnology jobs by the year 2000. Canada does not have the skills base to meet this demand. The experience or skills gap is in the following areas:

- Basic and applied research
- Technology development
- Product/process development
- Marketing and sales
- Management

The Biotechnology Human Resources Council (BHRC) has been established, with support from the Human Resources Department of Canada, to help develop people with the necessary expertise. The International Biotechnology Association of Canada (IBAC) will manage the day-to-day operations of this council, and an executive director will implement directions set by the BHRC Board of Directors. Meeting these needs will require partnerships with academia, government, and other organizations to develop training programs and consider immigration policies.

Industry is working to establish policies regarding food labeling, intellectual property protection, and biosafety. IBAC released a position paper at the international CODEX Alimentarius meetings, held last month, that looked at the various options available and their relative impacts. Small and medium-sized businesses depend on outside financing, and the high costs of this new area include that of intellectual property. Protecting assets through patents also provides the opportunity to exchange scientific information. In the area of biosafety, an international protocol for living modified organisms is under development that will mean that products cannot be imported or exported without prior notification and approval. It is anticipated that this protocol will be in effect by January 1999.

The community has taken key steps to start meeting today's challenges in biotechnology. National and regional biotechnology organizations have developed and agreed to the Biotechnology Accord, which provides working principles for cooperation and partnerships throughout the community. We are in the initial stages of implementing this accord and still need to define how we can best use it to coordinate our activities. An issues/crisis management team approach is being established to respond to issues as they arise. This will allow various members of the community to share information and to provide similar messages when necessary. Finally, the Food Biotechnology Communications Network is leading the development of a national communications strategy that should help coordinate various activities.

We still have some challenges to address. There are a significant number of representative organizations to coordinate, and we need to become more efficient in dealing with issues without duplication. The national organizations are focusing on this problem. Specifically, IBAC and the Canadian Institute of Biotechnology may merge into a single organization over the next two years. In addition, there are numerous activities under development across Canada that might be adopted or augmented. We need to consider how we can work with organizations initiating new activities. The NABC should be looking for such partnerships.

Finally, what is IBAC? We are a not-for-profit organization that was established in 1987 to represent the biotechnology industry. We have dealt with regulatory and policy issues in an advocacy role. We are now undergoing an evolutionary process that embraces "reasoned advocacy." Although regulatory and policy issues will always be a part of our mandate, we now embrace human resources, a much stronger communications role, support of research, and financial considerations. We are committed to facilitating a supportive environment for research and development as well as the commercialization of new products in Canada.

In conclusion, biotechnology has become an important tool that offers new alternatives to various sectors and stakeholder groups, from the producer to the consumer. It has helped place Canada in a strong competitive position internationally. As the use of this technology moves forward, we need to look for more ways to work together, for a variety of reasons, including the effective use of our resources to develop consistent messages. We need to tackle today's problems using a systems approach with sustainability and integration as our priorities.

Biotechnology is an important tool that can help develop alternatives in our move to more sustainable practices. To guarantee that Canadians have access to the responsible use of these alternatives, we need to work together to ensure that issues are dealt with and questions are answered. Finally, we need to ensure that biotechnology, like any new tool, is based on our understanding of whole systems rather than their parts. Challenges from different perspectives need to be addressed, ranging from what can be done scientifically in the development of new products for various users to what is needed. Other challenges include meeting human resource requirements, differences among the various use sectors, and, perhaps most important, public awareness.

# *Biotechnology: Evolution or Revolution, Friend or Foe?*

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## Abstract

The debate over the value of biotechnology is polarized and impassioned. In the early days of modern biotechnology, dealing with challenged environments in agriculture (drought conditions, cold weather, and others) seemed within reach. These solutions have not yet materialized, and the search continues. The product base developed to date includes herbicide-tolerant and pest-resistant plants, and public support for these products and the direction of biotechnology is sometimes uncertain. Belief systems, the way information has been communicated and the way decisions are made, affect perception and public support or opposition to a new technology. This paper approaches this issue by asking questions about some of the folklore and information on biotechnology and challenges people to examine the rationale for their position on biotechnology.

## Introduction

What is biotechnology's role for agriculture in challenged environments?

The National Agriculture Environment Committee (NAEC) is a farm forum for leaders from 22 Canadian farm organizations. The NAEC's purpose is to develop and implement proactive and interactive solutions and strategies for environmental issues facing agriculture. Biotechnology is one of many such issues. Membership in the NAEC is broad-based and includes commodity groups, general farm organizations, organic producer groups, and national associations and councils. We are, therefore, privileged to have a spectrum of opinions from those who embrace biotechnology with open arms and see it as the way of future farming to those who will not use genetically modified products. In fact, in the current draft of a standard for organic production in Canada under development, organic producers would be prohibited from using "genetically modified organisms that have been altered using recombinant nucleic acid techniques, somaclonal variation, electroporation, artificially induced mutagenesis, and similar techniques."

Last fall, NAEC members met with environmental representatives to discuss biodiversity and agriculture. At the meeting and at several subsequent meetings, we discovered a great deal of common ground and learned that we did not want to be separate communities, but rather a unified people concerned about doing a good job in and for the environment. For farmers, that is to provide safe, abundant, and nutritious food while ensuring that the environment on which their livelihood is based and on which the future of humanity relies is protected. At NAEC, we recognize a diversity of methods for farmers to care for the environment on the farm and also differing opinions about the use of biotechnology products. All have a common goal of sustainable agriculture, doing their jobs in a way that preserves the land, biodiversity, water, and air on which farming is dependent now and will be in the future. Given the diversity at NAEC, I will approach this talk in as schizophrenic a way as possible and try to answer questions with questions. I will also come at it from an NAEC perspective, that of a friendly forum where all opinions are considered.

Biotechnology has added an interesting dimension to farmers' lives and decisions. Farmers are on the front line of food production. On issues concerning biotechnology they are being pulled in several directions. Farmers need good clear information about biotechnology so they can make informed choices, understand the consequences, and, with long-term vision and planning, meet individual needs to farm in a sustainable way.

## The Challenges

As you read on, ponder the implications of the title of this paper. Is biotechnology an evolution of what has come before, or is it a revolution in the form we know of in the 1990s as being disastrous and destructive? Is it a friend or a foe? I leave that up to you to ponder and decide.

Biotechnology appears to be the subject of one of the most polarized debates ever, and it joins an interesting gallery of issues that similarly inflame and impassion, such as politics, religion, sports, nuclear energy, and pesticides. Why do these issues impassion and polarize? Let us examine this question from the perspective of biotechnology.

The pursuit of knowledge, and in particular the application of science, has resulted in innovations to improve our lot in life, provide us with a safer existence and good food, and allows us to discover and appreciate nature and what makes life, life. We humans have been modifying our environment for as long as we have existed. We build places to rest our weary bones at the end of a long day, and we select animals and plants we find valuable. We use biological entities to make value-added items such as yogurt, cheese, and bread and to harness the power of the biological co-inhabitants and physical aspects of the planet to provide us with food, energy, and shelter. Human ingenuity often means that we are attracted to new things, new ideas, and new products.

Biotechnology in its early days seemed to be a perfect innovative fit for the challenged environment — providing ways to combat drought, salinity, and the increasing march of pests, pest resistance, filling hungry bellies, and enabling nitrogen fixation in crop plants. Is it a dream come true? So far, there have only been peripheral nibbles at these problems. Not all the dreams have become reality. At present, most of the innovations are in the areas of herbicide tolerance, insect and virus resistance, and nutritional or process improvements such as slowing the ripening process. Jane Rissler and Margaret Mellon in their recent book *The Ecological Risks of Engineered Crops* noted: “Limits and other difficulties have led the biotechnology industry to sharply scale back its expectation for plant genetic engineering — at least for the foreseeable future. Increased yield, drought resistance, salt tolerance . . . have been set aside in favor of alterations with less sweeping implications . . . no longer mention ideas like nitrogen-fixing corn.” The potential is still there, but it will take longer to unzip the “ladder of life” — the DNA helix — and discover how it works.

Even biotechnology will have its limits, should the dire predictions of climate change leading to an increase in extreme weather conditions such as hail, tornadoes, and floods become reality. Waterlogging tolerance would be good as long as the plant does not float away. For hail control, my science fiction mind sees a field of broccoli programmed, upon the first hail stone, to work in harmony to produce a force field that repels the hail.

Humans continue to be innovative. The question is not so much whether we can do it, but whether we should: we need to weigh the risks and benefits. Humans have been engaged in risk assessment and management for ages: do I drive my car or take a plane? Do I go out on the field today or wait until it is not raining? Do I take this drug or not? It is this weighing of the risks and benefits that has polarized biotechnology because there is no universal understanding of acceptable risks or a meaning of benefits.

Much of the debate centers around

- belief systems,
- the way information is communicated, and
- the way decisions are made.

Let’s look at a few illustrations.

## Belief Systems and Perception

### The Tool Itself

Biotechnology as knowledge — is it good or evil? Is it forbidden fruit or a gift from God? Is it the latest or greatest or a doomsday technology? Is it the devil or a savior? Knowledge is normally viewed as neutral, not good or evil. How it is applied or sought can be good or evil. But the knowledge itself, even when it is discovered under wrong circumstances, can be neutral or lead to good things. Does knowing about the genes make life more interesting or does it take away from the mystery and the beauty of it — does it make us see "fearfully and wonderfully made" in a more beautiful light, or does it cast a pall that cannot be cleared away? Is it a forbidden fruit or a gift from God? Or is knowledge a gift from the intelligence of human beings? Should we pluck it or leave it on the tree? Is it hanging there because we are supposed to grasp it, or is it just there to tempt us? I leave you to decide whether the "tool" of biotechnology is innately good or evil; is it like a hammer, a tool to be used, or it is it somehow different? Is it objective or subjective?

## The Application of the Tool

Is using the tool playing God, or is it responsible science? Are we treading on holy or unholy ground or at least unconsecrated ground? Are there rules and principles that should not be broken or violated? I, for one, cannot pretend to be able to read the mind of God. I try in my own way to connect, to get direction, but like most limited humans I have only moments of oneness and the rest is a fog, but a comfortable fog, because I know that God is present. A few questions to ponder, then — either unanswerable or answerable, depending on your own paradigm and circumstances. If a scientist thinks of a unique way to make a new food or genetically modify a plant, do you treat that spark of genius as aberrant in all cases and discard it, or in some cases treat it as a logical and acceptable extension of other thoughts or as an inspiration? Is discarding it playing God? Is using it playing God? Do we consider it a gift from God or a result of human creativity and act on it? Do we consider it a thought from a brain created by God and, as good stewards of a gift, try to make use of it? Is it a risk to ignore it, to not be in the will of God, or is it a risk to seize it and take action and also possibly not be in the will of God? I heard a minister ask recently, after the story of the cloning of Dolly the sheep hit the news, why people thought that this was unique; had they not read Genesis? An interesting perspective.

DNA is essentially the staff and stuff of life. If God is in fact in control, then there may be limitations that will become obvious and perhaps may already have. If a scientist can get nowhere with a project, is that a tacit message that this is the wrong tree to bark up or a path not to be trod? Is complexity a protective measure put in place on purpose? A mystery or a puzzle we are not meant to crack? Or is it just that more elbow grease and thought are needed?

If we act on a technology that should not be used, then the sin of commission is exercised. Yet, if we do not act on a technology that we should have, then we commit the sin of omission. Which is worse? What are the consequences? If, as one speaker said at a recent Food Biotechnology Communications Network meeting, a scientist discovers through biotechnology a way to eliminate the allergenic component of peanuts or the aflatoxin in corn, and the idea is buried and people continue to die from allergic reactions, is this an abuse of the knowledge or is it an acceptable consequence because the technology changes the genetic code of a plant and therefore is not considered allowable to some?

## Other Concerns and Myths

### An In-Your-Face Technology

Unlike many other technologies, modern biotechnology is perceived to be always on one side of contrasting pairs — direct versus indirect; unnatural versus natural; internal versus external, integral versus peripheral; invasive rather than noninvasive — mainly because it deals with the genetic makeup of biological beings. Other technologies can be indirect, external, or peripheral. Chemicals are unnatural in many cases, but their effect is often indirect. Perception is important and not to be ignored. One-sidedness gives an appearance of imbalance, a lack of a level playing field, and can lead to nonacceptance. Some are not bothered by uncertainty and may even see it as an interesting challenge. It is still a matter of perception. Natural versus unnatural? Is unnatural necessarily good or evil, or vice versa, is natural good only? Of course not: needles are unnatural but they provide a means to deliver medicine or inoculations effectively; tornadoes and natural toxins are natural and they can kill.

### The History of Technology

People sometimes look backward to look forward. In so doing, they will confront both the triumphs and the concerns from the past, especially the litany of technology. Historically, humans can be xenophobic and afraid of the unknown. Ancient maps often portrayed the end of the charted areas as an abyss, with dragons lurking over the edge and the legend "there be dragons there." Both proponents and opponents of biotechnology point to the history of technology and highlight either the advances or the mistakes. Some see it as a litany of events that has led us down a path we should have avoided. Others see technology as liberating humans from the drudgery of heavy labor into a more joyful existence. People often view biotechnology as the latest generation of technologies that will change the world. Below is a listing of often-cited technological developments that have affected human existence.

### Agricultural

Humans began the agricultural revolution by the action of selecting plants and animals that provided food or a service to humans. Other plants, animals, and microbes were not selected. We caused a dichotomy in the creation from there on — those useful to us and others.

### Metal Age

The discovery of the utility of metals such as copper, bronze, iron, and others brought weapons, coinage as the beginning of trade without real goods, nails, wheel rims that could stand the rigors of travel, beauty (jewelry), and numerous other useful objects. A mixed blessing?

### Industrial

The discovery of new sources of power and other devices raised humans above the drudgery of backbreaking labor but also polluted the world. A liberating event that changed peoples lives but started us on the rat race to have more possessions?

### Chemical

The discovery of chemicals and products would make our lives better, but not without problems. DDT caused eggshell thinning in birds at the top of the food chain, but it also saved countless lives during the World War II, and continues to save lives from malaria in developing countries. The green revolution was a subset of the chemical revolution, with increased fertilizer use, the advent of pesticides, and new crops that promised to feed millions.

### Information

The computer has been a powerful tool for business and personal communications. It also may present unique medical and social challenges — carpal tunnel syndrome, vision problems, cocooning, and unlimited access to the world from your home.

### Biotechnology

The biotechnology movement or revolution promises new products and a brave new world unlike one we can imagine. Is it harnessing the power of biology or ruining the beauty of the world or nature?

No wonder there are skeptics and that we tend to be wary. On the one hand, the industrial revolution brought us smog in London and coal miners' lung; the green revolution and chemical products brought us *Silent Spring*, toxic lakes, contaminated soil and waterways, and garbage dumps that became toxic waste sites. What will biotechnology bring? Science fiction and Hollywood tingle our imaginations with stories based on biotechnology run rampant — *Jurassic Park, The Island of Dr. Moreau, The Attack of the Killer Tomatoes, The Day of the Triffids* — into reality, plagues (Outbreak).

On the other hand, will biotechnology be a sparkling introduction to a marvelous new world? Knowledge has been on the increase and has provided us with some wonderful things that have enriched us and given us safer and more fulfilled lives. Vaccines have taken away the scare of killer or debilitating diseases such as smallpox, measles, diphtheria, and polio. Plastics, though much maligned in some circles, provide an incredible and flexible building and manufacturing material. Synthetic fabrics have reduced allergies in some people. Computers. Need we say more about them? And techniques to preserve structural materials.

### Knowledge Brokering and Communications

Scientists, regulators, industry representatives, and others have been for years describing biotechnology as a continuum or stepwise approach, building on uses of biotechnology from ancient to modern times. This is meant to engender acceptance of modern biotechnology by connecting it to comfort foods such as bread and cheese and beverages such as beer and wine. Companies also sell biotechnology products as brand new, glitzy, and important advancements that will make your life better and that you would be remiss to ignore. People don't buy this. Why? Because it doesn't matter. The comfort zone logic implies that leaps in logic are somehow bad or wrong or do not lead to anything useful. And it implies that stepwise development is safe. Neither of these is true 100 percent of the time.

In fact, leaps in logic are good sometimes and provide a means of grasping a new idea that is far ahead of the mainstream and offers new opportunities. One stellar example is actually an ancient one — that of fire. We have adopted and adapted this discovery to great benefit. It gave us light, warmth and a way to cook our food so that our poor set of teeth could last a bit longer. It gave us pleasure — fireplaces, bonfires, and meeting places. We have developed it in derived forms to provide the same light, warmth, and heat for our time. Yet it is dangerous. This brings me to the third point, decision making.

## Decision Making: The Key Is Safety

Safety is determined by asking the right questions. It has traditionally been left to regulators to develop and set up systems to ask the right questions, review the information, and examine the results of the use of a technology. Regulators have been grappling for the past decade or so with what questions to ask regarding safety considerations for biotechnology — questions based on science: about the organism and how it interacts with the environment or with humans. Farmers have traditionally, perhaps wrongly in some cases, relied on and trusted scientists to judge whether a product should be on the market and whether it is safe. Farmers have the option to choose and use an approved and available product as they see fit, bearing in mind the rules for operation and the limitations of the product itself. Farmers are frankly confused about the breakdown in trust surrounding the regulation of biotechnology products. People who mistrust the process or the questions being asked have the option to get to know the regulatory groups, tell them about the uncertainty and concerns about the questions being asked, and get involved. They are willing to listen.

This leads us to the issue of the right to know, another hotly contested subject in biotechnology being discussed internationally as a labeling issue. Some questions are in order. Do we know everything about what we consume? Are we aware of the ingredients in the products we use to wash with and apply to our skin? We do not know what pesticides were used on imported goods, only that limits are set via international guidelines. Clothes are labeled, less for allergenicity and more for washing instructions. We don't know the recycled content of newspapers, plastic toys, and other goods or whether an animal has been treated with antibiotics. In agriculture, this issue will come to a head soon. Labeling of food is one of the most highly developed labeling processes in Canada.

A related issue may be what to do with a shipment of, for example, grain that is commingled (biotechnology and nonbiotechnology products together). Separation is considered to be, in most cases, impossible or very expensive to maintain. This issue is being peripherally considered by the Biosafety Protocol under the Convention on Biological Diversity. Commingled products could be subject to advance informed agreement as a living modified organism when many consider the product as safe and not requiring such action. Labeling such as "may contain genetically modified organisms" may also be used, adding to the expense and possible confusion for the public. There are already genetically modified soybeans, wheat, and canola that could be mixed with the general pool of grain crops.

Of primary interest in decision making is the predicted food crisis. In his book, *Who Will Feed China*, Lester Brown describes the need for water resources and the ramifications of the lack of them in Africa and other food-related issues. We need to examine this; we need to look for answers to some tough questions. Can we feed the world without biotechnology? Or is biotechnology, carefully weighed for risks and concerns, an important tool to feed the world? We need to ponder this.

Finally, where do we go from here?

- It is time that we were all more honest. We need to examine our hearts for what we say and do and be careful that they are honest and from good intentions, not selfish or self-righteous.
- We need to cut the rhetoric. Stop dragging out old stories that are unsubstantiated and examine facts carefully. Bust the myths. Stop using folk stories to illustrate opinions. Check the facts and get the right message out. Stop using only bad things to illustrate a negative litany about technology and industry development. Tell the good stories as well. But if a story is bad and the public needs to know, then we all should take on the role of being a whistle blower.
- Check that the right questions are being asked. This is everyone's duty.
- Check your motives. When objecting to a new solution for an urgent problem, remember that omission is also an ethical choice and can be considered ethically unacceptable. Are your goals noble? Are actions frivolous or value-added and needed? Are objections or support based on fact or fiction? Are you blocking or upholding something for no good reason (greed is not a good reason)?

- Is there truly concern for the future? Does the product offer a valuable addition or alternative for a consumer to choose? Are objections or support based on a philosophy that stands the test of fire and logic, or are they fanciful and modified by less noble things? Does or should a philosophy of local versus globalization, big versus small, multinationals as bad or good color opinions? Is there a reason to keep a product off the market or put it on the market? Is your view of consumerism wrongly affecting your judgement about a product or about how it is being marketed? In summary, is your belief system incorrectly affecting your choice when it shouldn't be?
- Weigh the risks and benefits in as wide a way as possible. Farmers are realizing the need to look at the big picture of sustainable agriculture, which includes social, economic, and environmental issues where practical and possible.

## Be Agents of Change

We need to be agents of change if we understand the needs, concerns, and desires of all. We all need some perspective on what we do. Consider the results of a survey of people over 90 years old who were asked, If you could do it (your life) all over again what would you do more of? They replied: reflect more, risk more, do more things that would live on. Stephen Covey, author of *Seven Habits of Highly Effective People* and *First Things First*, suggests these guideposts: to live, love, learn, and leave a legacy. I challenge you with these watchwords today, for the rest of the day and for the rest of your life.

# *Food Security and the Role of Agricultural Research*


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Despite impressive growth in food production in recent decades, the world is not food secure. Even if available food energy were evenly distributed within each country — which it is not — 33 countries would not be able to assure sufficient food energy (2,200 calories per person per day) for their populations.

Over 800 million people in the developing world, or 20 percent of the population, are food insecure, more than 180 million preschool children are malnourished, and many hundreds of millions of people suffer from diseases of hunger and malnutrition.

With two-thirds of the developing world's undernourished, Asia remains the main area of concern whereas food security is rapidly deteriorating in Sub-Saharan Africa. The number of undernourished people in the latter region almost doubled in two decades from 94 million in 1969-71 to 175 million in 1988 -90, and the proportion of the population that is undernourished rose from 35 percent to 37 percent. Between 1988-90 and 2010, the number of undernourished people is projected to increase by 70 percent to 296 million, 32 percent of the region's population. By 2010, almost half of the developing world's undernourished will be located in Sub-Saharan Africa, up from 10 percent in 1969-71.

Hunger is a consequence of poverty. An estimated 1.3 billion people live in households that earn a dollar a day or less per person. Fifty percent of these absolutely poor people live in South Asia, 19 percent in Sub-Saharan Africa, 15 percent in East Asia, and 10 percent in Latin America and the Caribbean. Almost one-half of the population of South Asia and Sub-Saharan Africa and one-third of that in the Middle East and North Africa live in poverty.

Poverty in the developing world is not expected to diminish much in the near future. The total number of poor people is projected to remain around 1.3 billion in 2000, although regional shifts in the distribution of total poverty are anticipated. Sub-Saharan Africa will increasingly become a new locus of poverty: the number of poor is expected to increase by 40 percent between 1990 and 2000, and the region's share of the developing world's poor is expected to increase from 19 percent to 27 percent over this period. South Asia will continue to be home to half the world's poor; the number of poor in that region is expected to decline by only 10 percent between 1990 and 2000.

Growth in food production in recent decades has been impressive. During the period 1961-93, cereal production worldwide more than doubled from 877 million tons to 1,894 million tons; in developing countries it almost tripled from 396 million tons to 1,089 million tons. Since 1950, grain production per person has increased about 100 kilograms per person worldwide and about 80 kilograms per person in developing countries as a group.

Of note on the food production front is the role of yield increases, which have been the source of 92 percent of the increased cereal production in the developing world between 1961 and 1990; expansion of area planted in cereal crops contributed eight percent. While cultivated area is still increasing in most developing countries, it is doing so at a low and declining rate. Yield trends in developing countries climbed steadily upward for the three major cereals — rice, maize, and wheat — between the 1960s and late 1980s. Yield increases were notably high in Asia: during 1961-91 rice yields doubled from 1.7 tons to 3.6 tons per hectare, wheat yields increased from 0.7 tons to 2.5 tons per hectare, and maize yields almost tripled from 1.2 tons to 3.4 tons per hectare.

Yield growth rates in some areas are stagnating and, in a few cases, falling. A slowdown in the rate of increase of yields of major cereals raises concern because increased yields will have to be the source of increased food production in the future. Most cultivable land in Asia, North Africa, and Central America has already been brought under cultivation, and physical and technological constraints, as well as environmental considerations, are likely to restrain large-scale conversion of potentially cultivable land in Sub-Saharan Africa and South America. The option of area expansion as a source of food production increases is rapidly disappearing, and even Africa will have to rely mostly on increased yields to expand food production.

Another cause of concern on the food production front is the leveling off during the 1980s and early 1990s of grain production per person for the world and for the developing countries as a group, after steady increases during the 1950s, 1960s, and 1970s. Since mid-1980, global grain production per person has decreased, and grain production for developing countries as a group has been constant. If corrective actions are not taken soon, this trend could turn downward, with potentially adverse repercussions, not just because the additional population needs adequate food but because factors in addition to population growth are pushing up demand for grain. While future demand for grain for direct consumption in developing countries is expected to grow at a rate only slightly above population growth, the expected growth rate in world demand for feed grain is more than twice the expected population growth rate. Once incomes increase beyond a certain level, demand for feed grain increases rapidly; most developing countries have incomes still below the level at which feed grain use increases rapidly.

## The Role of Agricultural Research

Existing technology and knowledge will not permit the necessary expansions in food production to meet needs. Low-income developing countries are grossly underinvesting in agricultural research compared with industrialized countries, even though agriculture accounts for a much larger share of their employment and incomes. Their public sector expenditures on agricultural research are typically less than 0.5 percent of agricultural gross domestic product, compared with about two percent in higher-income developing countries and two percent to five percent in industrialized countries.

Investment in agricultural research must be accelerated if developing countries are to assure future food security for their citizens at reasonable prices and without irreversible degradation of the natural resource base. Accelerated investment in agricultural research is particularly important and urgent for low-income developing countries, partly because these countries will not achieve reasonable economic growth, poverty alleviation, and improvements in food security without productivity increases in agriculture, and partly because so little research is currently undertaken in these countries. The negative correlation between investment in agricultural research and a country's income level is very strong. Poor countries, which depend the most on productivity increases in agriculture, grossly underinvest in agricultural research.

Agricultural research has successfully developed yield-enhancing technology for the majority of crops grown in temperate zones and for several crops grown in the tropics. The dramatic impact of agricultural research and modern technology on wheat and rice yields in Asia and Latin America since the mid-1960s is well known. Less dramatic but significant yield gains have been obtained from research and technological change in other crops, particularly maize.

Large yield gains currently being obtained in many crops at the experimental level offer great promise for future yield and production increases at the farm level. In addition to raising yield levels, research resulting in tolerance or resistance to adverse production factors such as pests and drought, leading to biological and integrated pest control, and to develop improved varieties and hybrids for agroecological zones with less than optimal production conditions reduces risks and uncertainty and enhances sustainability in production through better management of natural resources and reduced environmental risks.

Accelerated agricultural research aimed at more-favored areas will reduce pressures on fragile lands in less-favored areas. Future research for the former must pay much more attention to sustainability than in the past to avoid a continuation of extensive waterlogging, salination, and other forms of land degradation. But, a continuation of past low-priority on less-favored agroecological zones is inappropriate and insufficient to achieve the goals of poverty alleviation, improved food security, and appropriate management of natural resources. More research resources must be dedicated to less-favored areas, those with agricultural potential, fragile lands, poor rainfall, and high risks of environmental degradation. A large share of the poor and food insecure reside in these agroecological zones.

The low priority given to research to develop appropriate technology for less-favored agroecological zones in the past is a major reason for the current rapid degradation of natural resources and high levels of population growth, poverty, and food insecurity. Much more research must be directed at developing appropriate technology for these areas. Out migration is not a feasible solution for these areas in the foreseeable future simply because of the large numbers of poor people who reside there and the lack of alternative opportunities elsewhere. Strengthening agriculture and related nonagricultural rural enterprises is urgent and must receive high priority.

Following on the tremendous successes popularly referred to as the Green Revolution, the international agricultural research centers under the auspices of the CGIAR have recognized the importance and urgency of research to assure sustainability in agricultural intensification through appropriate management of natural resources. Thus management of natural resources and conservation and enhancement of germplasm are given high priority in current and future research by the centers.

Declining investment in agricultural research for developing countries since the mid-1980s by both developing-country governments and international foreign assistance agencies is inappropriate and must be reversed. While privatization of agricultural research should be encouraged, much of the agricultural research needed to achieve food security, reduce poverty, and avoid environmental degradation in developing countries is of a public goods nature and will not be undertaken by the private sector. Fortunately, while private rates of return may be insufficient to justify private-sector investment, expected high social rates of returns justify public investment. The major share of such investment should occur in the developing countries' own research institutions (NARS); there is an urgent need to strengthen these institutions to expand research and increase the probability of high payoffs.

The centers under the auspices of the CGIAR have a well-defined role to play in support of the work by NARS, namely to undertake research of a public goods nature with large international externalities and to strengthen the research capacity of the NARS and networking among NARS, international centers, and research institutions in the industrialized nations. Research institutions in the industrialized nations have played an extremely important role by undertaking basic research required to support strategic, adaptive, and applied research by the international centers and the NARS and by providing training for developing-country researchers. Collaboration among developed-country research institutions, CGIAR centers, and NARS in developing countries is widespread, but further strengthening is required to make full use of the comparative advantages of each of the three groups for the ultimate benefit of the poor in developing countries.

All appropriate aspects of science, including molecular biology-based research, must be mobilized to solve poor people's problems. Almost all of the investment made in genetic engineering and biotechnology for agriculture during the last 10 to 15 years has been focused on solving problems in temperate-zone agriculture such as herbicide resistance in cotton, longer shelf life for perishable products such as tomatoes, and a variety of other problems of importance in the industrialized nations. If we are serious about helping poor people, particularly poor women, and if we are serious about assuring sustainability in the use of natural resources, we must use all appropriate tools at our disposal to achieve these goals, including modern science. For example, modern science may help eliminate losses resulting from drought among small farmers in West Africa. Drought-tolerant varieties of maize that poor African farmers can grow could potentially be developed, along with crop varieties with tolerance or resistance to other adverse conditions, including certain insects and pests.

While some argue that it is too risky to use genetic engineering to solve poor people's problems because we may be unaware of future side effects, we believe that it is unethical to withhold solutions to problems that cause thousands of children to die from hunger and malnutrition. Clearly, we must seek acceptable levels of biosafety before releasing products from modern science, but it is critical that the risks associated with the solutions be weighed against the ethics of not making every effort to solve food and nutrition problems.

Effective partnerships between developing-country research systems, international research institutions, and private and public sector research institutions in industrialized countries should be forged to bring biotechnology to bear on the agricultural problems of developing countries. Incentives should be provided to the private sector to undertake biotechnology research focused on the problems of developing-country farmers. Failure to expand agricultural research significantly in and for developing countries will make food security, poverty, and environmental goals elusive. Lack of foresight today will carry a very high cost for the future. As usual, the weak and powerless will carry the major burden, but just as we must all share the blame for inaction or inappropriate action so will we all suffer the consequences.

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## PART V

## WORKSHOP SPEAKERS

# *Issues in Agricultural Biotechnology and Biodiversity for Sustainable Agroecosystems*

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Agriculture and Agri-Food Canada's *Strategy for Environmentally Sustainable Agriculture* (1997) defines an "agroecosystem" as an "ecosystem under agricultural management — an open dynamic system connected to other ecosystems through the transfer of energy and materials." While the importance for agriculture of such natural resources as soil, water, and air has long been recognized, the agroecosystem approach puts biological resources at the center of agricultural concerns. Our objective will be to identify some issues related to biological diversity in sustainable agroecosystems and to trace some of their implications, with a particular focus on the impact of biotechnologies.

Because the agroecosystem approach is defined by human management, these issues need to be addressed in a political and social context. The *Convention on Biological Diversity* (1992) is the first and foremost legal and conceptual framework for the consideration of agricultural biodiversity on the global level. This legally binding international treaty was presented for signature in June 1992 at the United Nations Conference on Environment and Development, also known as the Earth Summit. It entered into force in December 1993 and has been ratified by more than 120 countries, unfortunately not yet including the United States, although President Bill Clinton did sign it in 1993. The Convention addresses all life forms on earth, except for humans. Agricultural biological resources such as crops, farm animals, and microbial organisms important to agriculture are clearly within its scope. The objectives of the convention, as stated in its first article, are "the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over these resources and to technologies, and by appropriate funding." Article 2 specifies that "technology" includes biotechnology, defined as any technological application that uses biological systems, living organisms, or derivatives thereof to make or modify products or processes for specific uses. This is a very wide definition, conceivably including every agricultural activity from hand-milking to the most sophisticated genetic engineering. Subsequent articles of the Convention expand upon the role of biotechnology in relation to biological diversity. We shall briefly consider the contribution of advanced biotechnologies to the conservation and sustainable use of biodiversity of importance to agriculture and then attempt to identify wider issues in an agroecosystem and global context.

## CONTRIBUTION OF ADVANCED BIOTECHNOLOGIES TO BIODIVERSITY CONSERVATION AND USE

The use of advanced biotechnologies for the conservation of agricultural biodiversity has been described often and in depth over the past decade, in particular by Day (1989), by Towill (1989), who provided an extensive bibliography, and by the U.S. National Research Council's Board on Agriculture (1993). These authors inventoried and reviewed alternatives to conserving whole plants and animals such as *in vitro* culture (meristems or slow-growth techniques), propagules such as somatic embryos and synthetic seeds, and cryopreservation of cells, gametes, organs, and embryos. Advanced biotechnologies are also used to assist the transfer of genetic resources such as pollen collecting and conservation and *in vitro* techniques for collecting and shipping samples of germplasm. The U.S. Board on Agriculture recommended that research is needed to apply *in vitro* culture and cryogenic storage methods to a broad range of plant and animal germplasm.

The three papers cited above also documented the use of advanced biotechnologies to analyze the nature and extent of the biosystematic and genetic diversity of crop plants and their gene pools, including gene bank collections. Isoenzyme analysis was often used for this purpose in the 1980s. Newer techniques analyze diversity more directly at the level of DNA, such as restriction fragment length polymorphism (RFLPs), polymerase chain reaction (PCR), randomly amplified polymorphic DNA markers (RAPD), and DNA sequencing. These techniques are often applied to study specific genes or to distinguish between species but are not as frequently used to survey the diversity within a crop gene pool. We do not know nearly enough about intraspecies diversity in gene bank collections or in agroecosystems.

A huge amount of literature has been published on the application of advanced biotechnologies to the sustainable use of genetic resources for food and agriculture because these technologies have become a vital part of plant and animal breeding. A review of these methods, or even a listing of them, is beyond the scope of this paper. They have provided breeders with a new set of tools to complement the earlier contributions of population genetics and plant and animal physiology. These new tools include improved disease evaluation techniques; *in vitro* manipulation of cells, organs, and organelles, and the regeneration of whole organisms; genetic maps and markers; and genetic transformation. It is clear that the application of advanced biotechnological methods significantly increases the potential for wider use of genetic resources and will continue to do so.

Some authors question whether advanced biotechnological methods will soon replace gene banks or indeed make the conservation of the biodiversity of living organisms important to agriculture entirely unnecessary. In 1989, Day questioned whether in the future this technology will eventually replace conventional germplasm collection and plant exploration by providing a database that is sufficiently complete that not only existing DNA sequences could be stored and synthesized but new ones could be synthesized as well. In his view, this possibility was remote. He felt that for the foreseeable future we will continue to rely on the existing system. The U.S. Board on Agriculture (1993), began its chapter “Biotechnology and Germplasm Conservation” with the remark that biotechnology requires germplasm as both raw material and as a source of natural variation. It added that for economic and technical reasons it is unlikely, in the foreseeable future, that gene synthesis will make the physical storage of germplasm in the form of seeds, whole plants, or tissue cultures obsolete because they are not coordinated in a genome. We concur with this view.

## Impact of Biotechnologies on Agroecosystems

These new scientific tools have profound effects on agroecosystems. On the one hand, genetic engineering is improving the resistance of crops and farm animals to pests and to abiotic stresses, thereby reducing the need to use chemical inputs such as pesticides, fertilizers, and antibiotics. In Canada, pesticide use has decreased steadily over the past few years, partly as a result of new crop cultivars such as herbicide-resistant canola and partly because of the increased use of conservation tillage to combat soil erosion. Implicit in this trend is the conclusion that less use of chemical inputs will correlate positively with reduction in misuse of them, thereby reducing the pressure on biodiversity, both in agroecosystems and in marginal or nonagricultural habitats, and improving their sustainability.

On the other hand, some authors have promoted the idea that the use of advanced biotechnologies contributes to genetic erosion. The reasoning appears to be that one of the main causes of the loss of biological diversity in farmers' fields is the replacement of older varieties and landraces by newer cultivars and the replacement of small, diverse farms by more specialized operations. Thus any factor or technology that accelerates the development of better adapted, more productive cultivars would result in a higher rate of genetic erosion. In our opinion, this logic takes little account of the need for food security or of the role of *ex situ* conservation measures. Proponents sometimes simultaneously call for more on-farm diversity, less farming on marginal land, and increased food production. It is true, however, that unless genetic resource conservation measures are effective, potentially useful genetic diversity will be lost forever.

Are people part of the agroecosystem? One would think so, according to Agriculture and Agri-Food Canada's definition. In that case, social factors also enter the equation. The Biodiversity Convention defines sustainable use as "the use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations." If biotechnology results in enhanced food production, then one should expect attendant benefits such as greater food security and a greater role for agriculture as a motor of sustainable development, a line of thought that has been eloquently described in publications of the International Food Policy Research Institute.

With particular reference to developing countries, some authors consider that agricultural biodiversity is best conserved and more sustainably used in a system of traditional agriculture. Such management is subject to farmers' decisions about which crops to plant or which livestock to raise, and the reasons behind these decisions are not well known. *The Global Plan of Action for the Conservation and Sustainable Use of Plant Genetic Resources for Food and Agriculture* (1996), adopted by representatives of 148 states, recognized the need for a better understanding of the effectiveness of such biotechnologies as on-farm conservation, management, and improvement. As a result, some country representatives have called for an examination of the relationship between trade liberalization and agricultural biodiversity. They apparently expect that the results would legitimize the use of trade measures to protect traditional farming systems. These calls have been referred to the World Trade Organization's Committee on Trade and Environment by both the U.N. Food and Agriculture Organization's *Global Plan of Action for World Food Security* and the Conference of Parties of the Convention on Biological Diversity in Decision III/11 taken at their third meeting in November 1996 (UNEP 1994).

Cultural aspects of agricultural biodiversity have inspired other authors. Many people consider crop varieties and races of livestock to be part of their cultural heritage. Who doesn't have a favorite variety of baking apple or potato? This tendency is even stronger among indigenous peoples. The Convention addresses this concern in the context of *in situ* conservation, stating in Article

8(j), "Each Contracting Party shall, as far as possible and as appropriate . . . Subject to its national legislation, respect, preserve, and maintain knowledge, innovations, and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity, and promote their wider application with the approval and involvement of the holders of such knowledge, innovations, and practices and encourage the equitable sharing of the benefits arising from the utilization of such knowledge, innovations, and practices." Indigenous people are rarely static preservers of ancestral biotechnologies but tend to generate their own innovations and adopt others that suit their purposes, so the practical implications of this provision are far from clear.

Concern is also being expressed about the potential social effects of the replacement of traditional crops by new products. This issue is likely to take a progressively higher profile in coming years as new products are put on the market much more quickly than traditional farming societies are capable of adapting to the socioeconomic consequences. We can probably expect increasing calls for international measures to compensate for or to mitigate these effects.

The jury will likely be out for a long while concerning the overall sustainability of agroecosystems based on increasingly advanced biotechnologies. It is important to remember that biotechnologies are tools, and what counts is the uses to which they are put.

## Intergovernmental Negotiations Regarding a Biosafety Protocol

Faced with the ever-changing environment created by new technological advances and by the globalization of agricultural markets, all countries are realizing that they must harmonize the need to benefit from these technologies with the need to protect the biological safety of the environment. Many developing countries are finding it particularly difficult to reconcile these two complementary goals. This dichotomy was played out during the negotiation of the segments of the Convention on Biological Diversity that pertain to the relationship between biotechnology and biodiversity, and it is reflected in their final form. Two articles are particularly relevant — Article 16, "Access and Transfer of Technology," and Article 19, "Handling of Biotechnology and Distribution of Its Benefits."

Transfer of technologies was very much part of the benefit-sharing agenda of the Convention. The first paragraph of Article 16 states, "Each Contracting Party, recognizing that technology includes biotechnology, and that both access to and transfer of technology among Contracting Parties are essential elements for the attainment of the objectives of this Convention, undertakes . . . to provide and/or facilitate access for and transfer to other Contracting Parties of technologies that are relevant to the conservation and sustainable use of biological diversity or make use of genetic resources.” Terms of technology transfer were the object of lengthy negotiation; many developing countries held out for concessional transfers. Most developed countries, however, emphasized the role of intellectual property rights to stimulate innovation. The second paragraph of the article specifies that “access to and transfer of technology . . . to developing countries shall be provided and/or facilitated under fair and most favorable terms, including on concessional and preferential terms where mutually agreed . . . In the case of technology subject to patents and other intellectual property rights, such access and transfer shall be provided on terms which recognize and are consistent with the adequate and effective protection of intellectual property rights.”

Acting under the assumption that developing countries would be the major providers of genetic resources, their representatives also wanted to tie access to technology to the provision of genetic resources. The third paragraph of Article 16 states, “Contracting Parties, in particular those that are developing countries, which provide genetic resources, are provided access to and transfer of technology which makes use of those resources, on mutually agreed terms, including technology protected by patents and other intellectual property rights . . .” The fourth paragraph addresses private sector innovation. It reads that “Each Contracting Party shall take . . . measures . . . with the aim that the private sector facilitates access to, joint development and transfer of technology . . . for the benefit of both governmental institutions and the private sector of developing countries.”

Article 19, “Handling of Biotechnology and Distribution of its Benefits,” considers other aspects of sharing the benefits arising from the use of genetic resources. Its first paragraph provides for “participation in biotechnological research activities by those Contracting Parties, especially developing countries, which provide the genetic resources for such research,” and the second paragraph promotes “advance priority access . . . to the results and benefits arising from biotechnologies based upon genetic resources provided by those Contracting Parties.”

It is important to understand, however, that all of these provisions are to be implemented subject to mutually agreed terms and in respect of property rights. In addition to the provisions of the second paragraph, the fifth paragraph of Article 16 states, “The Contracting Parties, recognizing that patents and other intellectual property rights may have an influence on the implementation of this Convention, shall cooperate in this regard subject to national legislation and international law in order to ensure that such rights are supportive of and do not run counter to its objectives.”

These articles do not amount to a radical shift in terms of technology transfer. They illustrate the great interest of developing countries in developing better international cooperation in this field and reflect their great thirst for new technology, in spite of the best efforts of some green nongovernmental organizations to persuade them of the unmitigated evils of modern technology. Under these circumstances, any institution that establishes a mutually satisfactory partnership with a technology-hungry developing country can likely expect a long and profitable association.

The concern for biosafety emerges in Article 19 of the Convention. Paragraph three states, “The Parties shall consider the need for and modalities of a protocol setting out appropriate procedures, including, in particular, advance informed agreement, in the field of the safe transfer, handling and use of any living modified organism resulting from biotechnology that may have adverse effect on the conservation and sustainable use of biological diversity.” The next paragraph calls upon “Parties to provide any available information about the use and safety regulations . . . in handling such organisms, as well as any available information on the potential adverse impact of the specific organisms.” After much debate extending over several meetings, in November 1995 the Conference of the Parties to the Convention set in motion a negotiation process to develop a protocol on Biosafety, and established an Open-ended *ad hoc* Group on Biosafety, composed of government representatives, to elaborate it.

The second meeting of the Open-ended *ad hoc* Group on Biosafety took place May 12-16, 1997, in Montreal, Canada. According to the *Earth Negotiations Bulletin* (May 19, 1997), delegates discussed provisions regarding procedures for transfers of living modified organisms (LMOs); competent authorities or focal points; information-sharing provisions; capacity-building; public participation and awareness; risk assessment and management; unintentional transboundary movements; handling, transport, packaging, and transit; and monitoring and compliance. Many of these provisions were discussed in great detail. Participating countries fleshed out their preliminary positions on various areas of the protocol. In some less contentious areas, consensus was close to being reached, for example, on information sharing. For each specific area discussed, text elements were generated that expressed the range of views expressed.

Developing countries raised the issue of including the assessment of socioeconomic factors in the future protocol, which resulted in a call for a workshop at the next negotiating session in October 1997. The inclusion of socioeconomic issues, in particular potential effects on traditional farming systems, as a criterion for assessing LMOs before importing them, could have significant effects on international trade. Canada helped in raising awareness about how a future protocol could affect commodities, for example, whether requirements of the future protocol might impede shipments of grain that may or may not contain LMOs. In general, Canada has taken the approach of regulating products, not processes so that identical commodities would be regulated (or not) in the same way, independent of which biotechnology was used to develop them. Canada is expected to lead a workshop on this topic at the October negotiating session. The OECD's Expert Group on Harmonization of Regulatory Oversight in Biotechnology has suggested that it will give priority to discussing this workshop at its next meeting in Paris, France, June 26-27, 1997. The Biodiversity Convention Secretariat has proposed a fourth negotiating session for February 1998 and a final session in November 1998 to complete the protocol.

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# *Biotechnology in the Maintenance and Use of Crop Genetic Diversity*

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## Introduction

Recent years have seen an explosive growth in our understanding of heredity and in the tools we have to manipulate it to meet human needs and aspirations. Yet we live in an age in which more than 800 million people go hungry and species are becoming extinct at a faster rate than at any other time in human history. This paper attempts to explore some of the issues involved in the interrelationship between biotechnology, biodiversity, and sustainable agricultural production. It concentrates, in particular, on the implications of new biotechnologies for plant breeding and crop genetic diversity and indicates ways we can use the tools of biotechnology to help alleviate poverty, increase food security, and conserve the world's biological heritage.

## Crop Improvement and Biotechnology

Ever since the first crops were domesticated, some ten thousand years ago, farmers throughout the world have brought new species into cultivation and selected from them the plants best suited to their needs and circumstances. Down the millenia, as needs have changed and as human populations have moved to new environments, continued selection has given rise to an enormous diversity of planting materials. Even today, farmers in many parts of the world continue to adapt their crops to meet new needs, adding to the pool of genetic diversity.

Our understanding of biological processes has grown rapidly in this century, not least in the field of genetics. As a result, it has become increasingly possible to base crop breeding efforts on scientific principles, adding enormously to the speed and precision with which improved varieties can be produced. Our comparatively recent, but growing, ability to manipulate DNA provides plant breeders with an extremely powerful range of tools that have enormous significance for the future of agriculture.

The new DNA-based techniques have enabled us to understand and, hence, better manage and use the genetic diversity of cultivated plants and their nondomesticated relatives. DNA markers, linked to traits of agricultural, economic, or social importance, have enabled breeders substantially to improve the efficiency with which they can select parents and progeny. In addition, our growing ability to transfer genes between completely unrelated species or even to produce "designer genes" and to promote their expression in a new host's genetic background has opened up possibilities for introducing novel characteristics that are not presently found within the gene pool of the crop concerned.

It is this latter tool of biotechnology, often referred to as "genetic engineering," that provides us with perhaps the greatest opportunities for tailoring our crops to meet future needs. Yet this same set of techniques are cause for the greatest religious, ethical, social, and environmental concerns. Leaving aside religious objections to "tampering with life," if we are fully to realize the potential that these new technologies offer, society as a must whole weigh their pros and cons and put in place the necessary checks and balances to ensure that they support societal objectives and do not impose unacceptable risks or costs.

Many of the optimistic expectations, as well as the concerns, over the impact of genetically engineered crops are the same as those for conventional plant breeding, and they may or may not be amplified by the application of gene tranformation techniques. Some concerns, however, uniquely relate to the introduction of alien genetic material into our crops, food, and the environment.

In many cases, a trait introduced by genetic engineering can have a positive impact on environmental and human health and lead to sustainable increases in food production with fewer external inputs. For example, genes for resistance or tolerance to insects and diseases and to abiotic stresses such as cold, heat, drought, or salinity enable large and stable yields to be produced with a minimum input of agrochemicals. A good example is the case of black sigatoka, a devastating disease that affects bananas and plantains. Currently, plantation growers commonly spray their crops with forty or more applications of fungicide in any one season to control this disease. The majority of growers, however, are smallholders who cannot afford to spray and who suffer large reductions in yield and income as a consequence. Bananas and plantains are extremely difficult and expensive to breed by conventional means, and genetic engineering offers a major opportunity for developing varieties that are resistant to black sigatoka. The result will be higher yields and increased food security for smallholders, as well as a reduction in health risks to plantation workers and the environment.

Nevertheless, genetic engineering is still regarded by many with suspicion. In spite of its positive potential for agriculture, it remains controversial. Widely held concerns include the following:

- Much of the leading edge expertise in biotechnology lies in private sector companies that are interested in using the new techniques to develop products that will return a profit on their research investment. Thus high-value crops and major crops that are grown on large areas and that have wide rather than local adaptation generally receive far greater attention from private for-profit companies than "minor" crop species of more local importance. Yet the latter are often grown by poor farmers living in marginal and diverse agricultural areas and who may have few production alternatives. Although the increasing application of biotechnology in crop improvement and the related strengthening of intellectual property rights regimes are only one set of factors in the growing privatization of plant breeding, concerns have been voiced that the concomitant reduction in publicly sponsored breeding will have negative consequences for these farmers. Unlike the private sector, public plant breeding can, and frequently does, address social objectives, and continued public support for crop improvement is widely regarded as critical in situations of market failure, that is, when there is no possibility of capturing an adequate economic return on investment.
- In many parts of the world, plant breeding has resulted in large areas being sown to genetically uniform varieties. Even where a choice of varieties exists, they are often closely related. Although these varieties are often more productive than the local types they replace, increasing the genetic uniformity of crops can have consequences for long-term agricultural sustainability. The deployment of a few additional genes in such varieties through genetic engineering might reduce susceptibility to a particular pathogen or stress but do little to reduce overall vulnerability. The tendency to shift breeding efforts from conventional hybridization and selection techniques to a greater use of genetic engineering is likely to exacerbate the situation further, as breeders increasingly come to rely on the addition of one or two new genes to an elite, widely grown variety. Integrated approaches, which use both conventional breeding methods to help broaden the genetic base and more targeted gene transformations, could help reduce such vulnerability. Additional measures to promote the use of a larger

number of genetically dissimilar varieties would also help to reduce genetic vulnerability.

- Many of the early releases of genetically engineered varieties have incorporated genes for resistance to herbicides — especially glyphosate. In some cases, the varieties are sold as part of a package that obliges the farmer to use a particular brand of herbicide. There are concerns about the potential negative effects of the increased herbicide use that such varieties are likely to provoke and about the tendency for agrochemical companies to get involved in plant breeding for the purpose of developing and promoting such packages. It is undoubtedly true that farmers will adopt a packaged variety only if it is to their economic advantage to do so. Nevertheless, the growing practice of packaging raises a more fundamental question: to what extent do improved economic returns for farmers and the production of cheaper food justify the potential long-term consequences of such practices for human and environmental health?
- The potential risks associated with the release of genetically modified organisms (GMOs) into the environment have been widely publicized, and several countries have adopted national biosafety regulations. The parties to the Convention on Biological Diversity are currently negotiating an international biosafety protocol to the convention. But many countries still lack appropriate regulations, and there is evidence that the field testing of genetically engineered organisms has, on occasion, taken place in these countries specifically to avoid the more restrictive regulations elsewhere. In this regard, the research centers of the Consultative Group on International Agricultural Research (CGIAR) have taken the stance that they will field test GMOs only in countries where national regulations exist.

## The Conservation of Genetic Diversity

Genetic diversity provides the basis for all plant breeding efforts. Traditionally, plant breeding has relied on landraces and improved varieties and, to a lesser extent, on cross-fertile undomesticated ancestral forms as sources of genes for desired traits. More recently, particularly with the development of tissue culture methods such as embryo rescue techniques, it has become possible to use species that are less closely related to the domesticated crop as gene sources. Once regarded as a leading-edge tool of biotechnology, such techniques for interspecific hybridization have now become almost routine and in many circumstances have been superseded by the more powerful and targeted approaches that have been made possible through the development of genetic engineering.

It is now becoming increasingly possible to transfer genes between almost any organisms and to induce them to express the desired trait. For example, there have been many successful attempts to transfer genes for insect resistance from *Bacillus thuringiensis* to a range of different crop plant species. The total diversity of interest to plant breeders has thus, at least in theory, been extended from the crop of concern and its wild relatives to the entire gene pool of all life forms.

Despite these advances and our growing ability to manufacture “artificial” genes, breeders continue to rely heavily on genes from within the gene pool for a crop and its wild relatives and are likely to do so for many years to come. Yet many of these gene pools are threatened, and urgent measures are needed to conserve them. The threat comes from many sources. In 1996, the Food and Agriculture Organization (FAO) of the United Nations published its *Report on the State of the World's Plant Genetic Resources for Food and Agriculture*, which lists the following among the major reasons for the loss of genetic diversity:

- Replacement of local varieties with new ones
- Land clearing and environmental damage
- Overgrazing and overexploitation
- Changing agricultural systems
- Civil strife
- Legislative and political factors

It is ironic that the major reason given for the loss of crop genetic diversity is its replacement by the products of breeding. Breeders, perhaps more than any other group, have a vested interest in the conservation of plant genetic resources; yet, as in crop improvement for marginal areas, there is a market failure in the case of the conservation of genetic resources. In the face of reduced public financing for plant breeding, it is critical that funding mechanisms be found to continue and expand conservation programs in the public interest.

Conservation can take place both *in situ* and *ex situ. In situ* conservation means maintaining plant populations in the location where they acquired their characteristic properties, for example, as landraces in farmers' fields or as wild plants in nature reserves or other protected areas. Under these conditions, plants can continue to evolve under human or natural selection. *Ex situ* conservation involves collecting material and conserving it in gene banks away from their place of origin. Such gene banks may consist of collections of seed samples in cold storage, living collections growing in the field, or collections of plant tissues maintained *in vitro*, possibly cryopreserved at very low temperatures using liquid nitrogen. Materials maintained *ex situ* are generally easier for plant breeders to access, and a well-managed collection will have useful data on the accessions it holds. Modern information systems enable large quantities of data to be assembled and made widely available, for instance over the Internet, thus greatly increasing the usefulness of these collections.

Unfortunately, many collections are not well maintained. In many parts of the world there are insufficient human, institutional, and financial resources to maintain the materials and regenerate them to sustain their viability. Indeed, 95 percent of the countries submitting information on regeneration during the process leading up to the International Technical Conference reported the need for a far higher level of regeneration. In addition, many of the accessions held in *ex situ* collections are insufficiently or poorly documented.

The 150 countries attending the FAO International Technical Conference on Plant Genetic Resources for Food and Agriculture, held in Leipzig, Germany in June 1996, adopted the Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources. This plan calls for urgent attention to be given to safeguarding existing collections throughout the world and to regenerating their accessions. The lack of resources to do this at the national level in many countries requires that the international community assist in the task.

With the growing use of genetic engineering as a crop improvement tool and the consequent widening of the gene pool of potential interest to plant breeders, conservation needs have expanded. It is clearly impractical, for both financial and technical reasons, to consider developing systems for the *ex situ* conservation of all genetic resources of potential interest. Thus special attention needs to be given to *in situ* methods, both to help ensure that the widest possible range of genetic diversity is conserved and to promote its continued evolution under natural and human selection pressures. Our current understanding of the scientific basis for *in situ* conservation of genetic diversity is limited, however, and further research is urgently required to underpin the development of effective and efficient *in situ* management systems.

## The Role of Biotechnology in Conserving Genetic Diversity

New biotechnological methods have a key role to play not only in the use of agrobiodiversity through marker-assisted selection or gene transformation but also in its conservation. Until DNA-based molecular genetic techniques became available for widespread application, our understanding of diversity was largely confined to the phenotypic level. Now, however, such techniques provide an important tool to help increase our understanding of events at the genotypic level.

Molecular genetic techniques can, for example, enable us to gain a better picture of the patterns of genetic diversity in *ex situ* collections and provide the means to assist in their management. They can help in identifying duplicate accessions and assembling core collections (a subset of accessions that aims to include the maximum genetic variation). They also provide a tool for monitoring, and hence controlling, genetic drift during regeneration and for characterizing and evaluating collections.

Molecular genetic data can also be used to monitor genetic erosion in the field and, especially when coupled with computer-based geographic information systems (GIS), can be very useful for surveying and mapping the spatial distribution of genetic variation. Such distribution information is particularly valuable for targeting collecting expeditions and for identifying areas of high genetic diversity for *in situ* conservation.

The development of new varieties requires the movement of genetic resources within and between countries. Materials collected in the field are transferred to gene banks at home or abroad. From gene banks, samples are distributed to plant breeders, who in turn send out materials for testing in multiple locations, often to several different countries, and for multiplication and distribution of seed to farmers. DNA-based techniques are becoming increasingly useful in helping to ensure the safe movement of genetic resources and to make certain that diseases are not distributed along with the plant materials. Diagnostic probes, such as for detecting virus diseases, can assist greatly in the identification of infected materials. Other biotechnologial techniques, such as certain tissue culture methods and heat treatments, can be used therapeutically to help clean up infected materials.

Tissue culture techniques are also valuable for conserving species that are vegetatively propagated or that produce seeds that cannot be dried for storage at low temperatures without losing their viability. Large collections of such plants can be maintained as tissue cultures growing in petri dishes or test tubes. These may be maintained in growth chambers and on culture media that minimize the growth rate of the cultures and thus maximize the period of time needed between successive regenerations. The possibility of storing plant tissues at very cold temperatures, down to -196° C, using liquid nitrogen, is of particular interest for their long-term conservation. This biotechnological method, known as cryopreservation, is becoming possible for an ever-increasing number of species.

## The Policy Environment

In the 1970s and early 1980s, plant genetic resources were widely considered the common heritage of humankind. Access by breeders was for the most part unrestricted. Expeditions to collect indigenous landraces and farmers' varieties were conducted throughout the world and there was a strong tradition of sharing materials among breeders.

In recent years however, intellectual property protections have increasingly been applied to the products of plant breeding — initially through plant variety protection measures but increasingly through patents as well —accompanied by the rapid expansion in the use of biotechnologies and the growing influence of the private for-profit sector. This has led many countries, especially developing countries rich in genetic diversity, to call for measures to protect their interests and to ensure that they share in the benefits derived from the use of their resources by others. Legislation is being enacted in many countries to regulate access to genetic resources, and there is a strong movement to implement farmers' rights which recognize the contribution of past, present, and future rural communities and indigenous people to the development and conservation of genetic resources. Such rights are seen as a counterbalance to the growing application of intellectual property rights to germplasm, especially in developed countries.

The Convention on Biological Diversity, which came into force in December 1993, encapsulates this new paradigm in an internationally legally binding instrument that explicitly recognizes national sovereign rights over the genetic resources existing within a country's territory. The earlier, nonbinding instrument, the FAO International Undertaking on Plant Genetic Resources, is now being renegotiated to bring it in line with the convention. The revised International Undertaking, which may become a protocol to the convention, seeks to establish multilaterally agreed upon terms and conditions for accessing plant genetic resources for food and agriculture. The outcome of these negotiations is likely to greatly influence the way plant breeders will access plant genetic resources in the future, whether for use in biotechnological or conventional breeding programs.

## CONCLUSIONS

Recent advances in biotechnology have opened up enormous and exciting possibilities for plant breeding. The development of varieties adapted to new environments, with resistance or tolerance to biotic and abiotic stresses or with new characteristics of interest to consumers, could make a substantial contribution to increasing productivity and alleviating poverty in a sustainable way. But, the global trend to reduce publicly funded research, for both economic and ideological reasons, and the growing concentration of biotechnological expertise in the private sector have aroused fears that the poorest segments of society will be neglected and will not share in the potential benefits that the new technologies could bring to their lives. They could even find their situation deteriorate as they become less able to compete with the increasing productive capacity of farmers who are well cared for by research and who have the means to purchase the new research products.

The use of genetic engineering gives rise to widespread environmental and health concerns, particularly with regard to the release and consumption of genetically modified organisms. Although many of these fears might prove to be unfounded, caution is certainly in order. As a result of global concerns over biosafety, a protocol to the Convention on Biological Diversity is currently being negotiated that, when implemented, should go a long way toward reducing the inherent risks.

Biotechnological methods contribute not only to our ability to use agricultural biodiversity, but also to the effectiveness and efficiency of our efforts to conserve it. Despite the promise that biotechnology holds for conservation, however, the financial resources necessary for conservation in general remain limited. It is essential that the international community find the means to make these resources available, especially to developing countries, which are home to the greatest diversity of potential interest to all humanity.

Issues of ownership and access to genetic diversity, as well as concerns over the application of intellectual property protection to the products of biotechnology, are currently receiving considerable attention in various international forums. The debates on these issues are complex and highly politically charged. Yet it is essential that they be resolved if the full potential contribution of biotechnology for improving the human condition and protecting the natural environment is to be realized.

# *Regulation and Economic Concerns for Canada's Biotechnology Industry*

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## Introduction

Biotechnology is a growing and important industry in most developed countries. The possibilities for commercial gain from biotechnology are thought to be enormous. Post modern economies are based on new ideas rather than natural resources such as, land, labor, capital, or strategic location (for example, the old silk trail). New ideas require investment to develop of new products and processes, that will create wealth of nations in the twenty-first century.

To create this wealth, institutional arrangements that lower the cost of investing in biotechnology research and development will be needed. For example, firms want to be certain their inventions will be protected from predators at a low cost. Without such protection, investors may move their investments elsewhere. Another important cost is related to the licensing of new products. In the business of new ideas, time is important because competitors will be close behind. Thus firms want a regulatory process that is quick and careful. Finally, access to world markets is important because no domestic market is large enough to absorb the cost of developing these new products. Therefore, access to foreign markets is an important issue in determining where firms will invest their money.

This new investment opportunity is largely contained in the private sector. Governments are supplying only regulations, along with some training and basic research, while the private sector supplies the capital and management. While this division of responsibility concerns some, the future biotechnology industry will be driven by private capital attempting to earn a return for private investors.

This paper will address the two issues of regulation and economics. First, the impact of regulations of biotechnology from a domestic and trade perspective will be examined. Second, the domestic market conditions for new products will be looked at, followed by discussion of some of the potentials and impacts these new products will have on Canadian agriculture. Obviously, the surface can only be scratched because these are complex issues.

## THEORETICAL ISSUES

The economics of regulation is a well-developed field of study. The early work in this field was done by George Stigler, who linked the economic performance of an economy to the existing regulatory environment. In this paper, a short description of a model of regulation is provided by Ulrich, Furtan, and Schmitz (1987).

If agricultural products are created through the use of two technologies (with or without biotechnology), it can be assumed that the consumer will view them as two different products. The production possibilities curve (Figure 1) depicts the trade-off that occurs in the level of production of the two different products. If the regulations block the amount of biotechnology the economy produces and the relative prices for the two products is $R_{0,}$ the production of only one product occurs at $X_1$. If the regulators allow both products to be sold, then production occurs at $Z_1$ along $R_1$. Clearly, the level of welfare in the economy has gone up because consumers can now purchase the type of product they prefer.

Over time, technology change will shift the frontier from $X_1Y_1$ to $X_1Y_2$ and the optimal production point will move from $Z_1$ to $Z_{2,}$ holding the relative prices constant. By blocking the introduction of biotechnology products, the agricultural sector loses more over time. If the relative prices change from $R_2$ to $R_{3,}$ then the production of biotechnology products drops but the sector is still better off at point $X_1$.

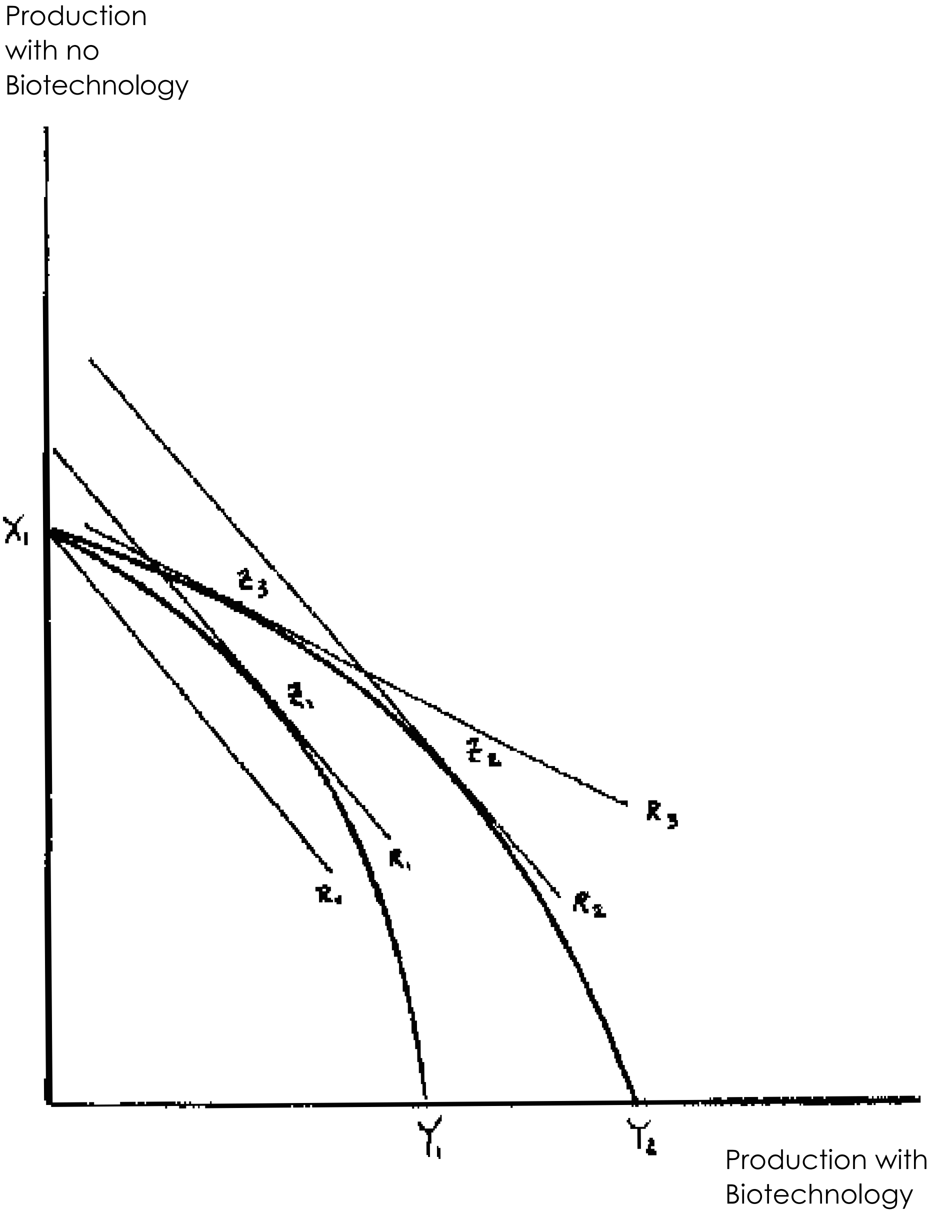
## REGULATION IN THE BIOTECHNOLOGY INDUSTRY

Regulation of agricultural biotechnology and related products is under the review of the federal government.[1] At least three departments are involved: Agriculture and Agri-Food Canada, Health Canada, and Environment Canada.

[1]Source: Ulrich, A., W.H. Furtan, A. Schmitz, 1987. The cost of a licencing system regulation: an example from Canadian prairie agriculture. Journal of Political Economy 95

Figure 1

Economic Impacts of Blocking Biotechnology in Agricultural Production (Ulrich, et al., 1987)



The principal department in charge of agricultural biotechnology is Agriculture and Agri-Food Canada, which regulates issues such as transgenic plants under the Seeds Act, microbial products such as animal feeds under the Feeds Act, microbial growth supplements under the Fertilizers Act, microbial pest control products under the Pest Controls Product Act, and veterinary vaccines and biologics under the Health of Animals Act. The Biotechnology Strategies and Coordination Office is under the direction of Agriculture and Agri-Food Canada and is responsible for importation and phytosanitary measures under the Plant Protection Act and the Health of Animals Act. It is also responsible for food safety and standards and prevention of fraud under the Canadian Agricultural Products Act. While this system is similar to that in the United States, and is consistent with the European Economic Community's premarket clearance, it still leaves the Canadian industry with a fragmented system.

Environment Canada is involved, as well, in the regulatory process. It is the responsibility of this department to set environmental assessment standards for food products. This is done in consultation with Agriculture and Agri-Food Canada but Environment Canada is responsible under the Canadian Environmental Protection Act for making certain that new food products resulting from biotechnology are safe.

Health Canada is concerned with food safety issues and particularly new food products using biotechnology. The formal regulatory process administered by Health Canada comes under the Food and Drug Act, but the policy that is in place has not yet been approved by the government of Canada. Anyone wishing to introduce a novel food must notify the Health Department 90 days in advance of marketing the product. The department is then given 98 days to request more information.

The Novel Food Regulations are clearly aimed at addressing consumer's concerns over food safety. They specify that before a novel food can be marketed in Canada the firm must notify Health Canada of the intention to do so 90 days in advance. A novel food is defined as

- a substance that has previously not been used in Canada or will result from a process that has not previously been used for food in Canada;
- an existing food that has been modified by genetic manipulation and exhibits one or more characteristics that were previously not identified in that food or food that results from production by genetically manipulated organisms exhibiting such new characteristics;
- food containing microorganisms that have previously not been used as food or to process food; and
- food that is substantially modified from the traditional product or is manufactured by a process that has been substantially modified from the traditional process.

An example is bovine somatotropin (BST), which is given to dairy cattle. Under this regulation, BST is a novel food and must therefore be examined by both Agriculture and Agri-Food Canada and Health Canada. Clearly, there is an overlap of jurisdiction, as well as a difference of opinion as to what is acceptable and safe.

From an economic perspective, this regulation is expensive for firms that introduce new products. Using an economic framework, this slowdown of technology and the extra cost make investment in Canada more expensive and more risky.

## Intellectual Property Rights

The area of intellectual property rights has grown in importance as countries recognize that the postmodern economy is built on ideas rather than on resources or population. For companies to invest and create wealth, they must be able to capture some of the wealth. If they are not able to capture wealth, they will have no incentive to invest. There are many reasons why companies may not be able to capture wealth, such as the nature of the good produced (public vs. private), market and institutional failures, and information problems. Institutional problems, such as having others steal your invention, can be corrected through legislative changes that provide affordable protection for innovators. This is why the issue of property rights is an important legislative concern and is a form of market failure. Countries disagree on how best to handle this issue. Some feel that by protecting innovations, rich countries will be able to advance their economies while poor countries will not be able to afford the investments. These people call for larger public investments in agricultural research. Others argue that private research is the most efficient way to allocate resources to much of the agriculture sector and this can be achieved only by protecting property rights, including intellectual property. Given the reduction in government budgets and the shrinking political power of agriculture, the latter group is the most likely to win the day for now.

In the case of agricultural biotechnology, there are two ways that new material can be protected and private investment facilitated: through patents and plant breeders' rights. Canadian law treats these two issues differently and, in the case of patents, differently than the United States.

To get an invention patented in Canada, four criteria must be met. The first is to demonstrate that the invention is new and has not been done before. Second, the invention must be proven to have some commercial value and not be trivial. Third, the invention must fall or fit into a predetermined category. Finally, it must demonstrate some progress or advancement. Once these criteria are met, an application can be made under the Patent Act to the commissioner of patents for Canada.

In a recent paper Churchill (1996), pointed out that Canada has not fully come to grips with its policy on the patenting of living material. Currently, this is an important difference between Canada and the United States, and it will be seen as a cost to investors in Canada when compared to the United States. This represents a large transaction cost in Canada and will lower the level of investment made in Canada in the area of agriculture biotechnology.

A second method to protect some biotechnology products and processes is the Plant Breeder's Rights Act. This act protects plants through the process of granting breeder's rights to certain varieties by restricting others from using the varieties without the payment of royalties. The term *plant variety* is defined to mean "any cultivar, breeding line, or hybrid of a prescribed category of plant that can be cultivated" (Churchill). The new variety must be stable, distinguishable from other varieties, and homogenous. While useful, this act provides only limited protection to intellectual property.

The final point that needs to be made is that there is a gradual consolidation of regulation on intellectual property protection in developed countries. Clearly, firms will go where they have the greatest chance of profit, and if a country taxes firms by failing to protect investments, they will move to more acceptable climes. This problem is forcing some countries such as Canada (that wish to attract this type of investment) to align their regulatory systems with those of the United States and the European Community. Canadian farmers also stand to lose competitiveness if new technology is not made available to them at the same time it is made available to their competitors.

## International Trade and Market Access

There are two issues of concern around market access and international trade. The first is consumer acceptance. There is no incentive to produce a product that consumers will not buy because of perceived (or other) concerns over safety. Second, there are rules that affect the trade of agricultural biotechnology products. Both of these concerns must be dealt with by firms that plan to introduce new products into the marketplace.

If farmers produce a product that some consumers will not purchase, it must be segregated from other similar products. The case in point is transgenic canola, which is acceptable in the Canadian, American, and Japanese markets but not the European market. This segregation must be done in such a way as to meet the standards of the market; that is, consumers want to be certain of the origin of the products they are consuming. Segregation of products is expensive, and its cost may block the introduction of new food products. Mayer (1996) examined this question and showed that the cost advantages of transgenic canola are such that farmers will grow the new varieties even with the cost of segregation. She estimated that Canadian prairie farmers would benefit in the order of $441 million annually if transgenic canola is accepted in all markets and $215 million annually if only Japan blocked the new product.

She also showed that the lack of market access can completely block the introduction of transgenic canola.

Since producers are growing transgenic canola, they must assume that consumers will purchase the product once it is on the shelf. A recent survey of consumers in the United States and Europe reported that 73 percent of those in America would purchase food derived from transgenic crops while only 15 percent in Europe would do so, if they had the choice (Wadman, 1996). This suggests that agricultural biotechnology is going to have a more difficult time gaining market access in Europe than in America. The situation in the Canadian market is not altogether clear; we have accepted transgenic canola but not BST.

The rules for trade in agricultural biotechnology products are set by the World Trade Organization (WTO). There is a recognition internationally that technology is outpacing the existing legal regimes in most countries. Also, most agree that investment dollars will flow to those countries that provide protection for intellectual property. Given these concerns, the WTO has set minimum standards for the protection of agricultural biotechnology products and trade in such products.

The WTO rules include: (1) love thy neighbors equally and not less than thyself, that is, rules for domestic firms must also be made available to others; (2) patent rules must be transparent, that is, individual firms must be able to find out exactly what the rules are and how they are applied; (3) the patent rules must be enforced by the home country; (4) any product or process is patentable for 20 years from time of filing; (5) there must be compulsory licensing of patents so that technology is available to other firms; and (6) the patenting of life forms is excluded.

The WTO has also set rules regarding trade in genetically altered feeds and foods. The sanitary and phyotosanitary standards require that the importation of new foods be based on the following four criteria: scientific basis, risk assessment, acceptable risk, and national treatment. While these rules sound good, there still is no agreement on how they will be applied. For example, whose scientific evidence or opinion will be accepted, and what is acceptable risk? The debate over the safety of certain growth hormones in cattle feed is an issue that some say is real and others say is just a poorly disguised trade barrier. This still leaves market access very much open to question.

## Conclusions

Agricultural biotechnology holds many promises for the future as a major investment opportunity. For Canada to compete with other major players, the costs of doing business in Canada in terms of regulation must be lowered and the appropriate institutional arrangements in place to protect intellectual property must be put in place. Market access remains a concern, but it can best be tackled through education and work with other trading nations through the WTO.

Furtan/Mayer/Hart

Canadian farmers need to be concerned with developments in the field of biotechnology. As they will be using and producing the products, their economic livelihood depends on the orderly regulation of this sector. To be certain this occurs, they are going to have to be actively involved in the process.

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# *Regulatory and Economic Aspects of Accessing International Markets*

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## COMMODITY CROPS: VISION VS. REALITY

In 1995, AgrEvo Canada's Liberty Link canola (variety Innovator) became the first crop derived from biotechnology to be registered in Canada. Having undergone seed production in the previous year, Innovator canola was grown on close to 40,000 acres in Canada in 1995 under a contract-to-crush closed loop delivery system. This system ensured that our first biotechnology-derived canola variety was directed only to approved destinations. Now in the third year of commercial production, with clearances in Canada, the United States, and Japan, Innovator canola is no longer being handled under special systems and will be entering the Canadian export stream at the 1997 harvest, with the agreement of the Canola Council of Canada. This paper discusses the regulatory and economic challenges encountered in moving this crop out of the research world and into the international export stream.

Canola is Canada's Cinderella crop. It is a crop Canada created, a market demand Canada developed, and an export trade sector Canada dominates. It is also a difficult crop to grow and keep weed-free. Fortunately, it is a crop that responds well to many modern genetic techniques and is one of the first major crops to be improved through the use of biotechnology. That is essentially why AgrEvo chose canola as its first target crop for improvement through biotechnology. Another factor that made canola suitable for a leading role in biotechnology is its processing characteristics. Any foreign protein that might have been present in plant parts is destroyed in the process of making canola oil. For the first food crops of biotechnology, this means that there is no risk to the public of exposure to foreign protein. Innovator canola is the first in a stream of products that respond to the Canadian farmer's need for enhanced possibilities for production of canola. Additional glufosinate-tolerant *Brassica napus* and *Brassica rapa* canola varieties have been developed (Independence, Phoenix, HCN14, Expo), and hybrids (PGS 3850, PGS 3880, InVigor 2063, InVigor 2153, InVigor 2173 and InVigor 2163) are at various stages of seed multiplication or production.

Canola is also a commodity crop that is mixed and handled in a co-mingled export stream that serves to guarantee the quality of the grain received by the end-use customer. Canadian canola reaches over 50 export destinations as seed, meal, and oil. These two features — responsiveness to biotechnology techniques and being a commodity crop — have made canola one of the first products of agricultural biotechnology to experience the regulatory and economic challenges of entering international markets. This paper reviews these challenges and recommends ways to address the future needs of the complicated world of export trade.

## Background

It is mid-1997; crop products of biotechnology have been with us for almost ten years, and our international regulatory system is still for the most part in its infancy. Canada, the United States, and Japan have fully functional, predictable regulatory systems in place. These countries are actively working to keep their systems timely and rigorous as the number of products increases exponentially.

Another group of countries is actively working to provide a regulatory framework for the same products. Mexico is moving forward as part of the North American Free Trade Agreement (NAFTA), while struggling to address its own unique issues (including being a centre of genetic diversity for corn). Within the European Union (EU), the United Kingdom's (UK) system has been the most predictable to date. As a result, the UK is the European country of preference for many importers. France has also been a highly favoured sponsor country. With the contradictory and confusing developments of this past spring, it remains to be seen if this status will be maintained. The EU system has moved significantly forward this year with the institution of the Novel Food regulation and significantly backward with the virtual collapse of the EU 90/220 environmental review process. In Australia, only a decorative carnation has been granted unrestricted approval for production and commercialization. Several food products have been reviewed but cannot be officially approved until new guidelines are in place. China is commercializing crops derived from biotechnology at a tremendous pace. To Westerners, the regulatory process being used is unclear. Meanwhile, the rest of the world has no process at all.

For a commodity crop outward bound to the rest of the world, this patchwork of regulations, nonregulations, and emerging regulations is a labyrinth of epic proportions.

## Regulatory Requirements

At least in theory, the core scientific data package required to address food safety, feed safety, and environmental risk should be the same everywhere. Numerous international forums have been held to discuss the concerns and to propose robust scientific approaches to addressing the issues. There is also a high level of awareness that while products of biotechnology need to be scientifically assessed to determine that they pose no unmanageable risks, these products hold great promise for feeding a hungry world and reducing environmental strain. A common theme is to avoid artificial trade barriers that would limit the use of these products.

The reality, however, is several steps away from the theory. Identifying responsible government officials and uncovering their local requirements (precise study requirements, formats of presentation, and acceptable statistical approaches) is a demanding exercise. Local requirements all too frequently result in additional studies with added costs and delays. Moreover, each country or region defines its decisions in a different scope. “Import,” “varieties,” “events,” “lines,” and “release” have different meanings in different jurisdictions. No wonder exporters have a hard time understanding exactly what is approved and what is not and what needs to be approved and what does not! Each local bureaucracy has its own unique formatting requirements. The United States will not accept Canadian submissions, although the reverse is true. Throughout it all, it becomes clear that there are those who are seeking to create facilitative systems and those who are seeking to create prohibitive systems to meet local economic strategies regarding imports versus local production.

Commenting on proposed guidelines through the World Trade Organization (WTO) is an industry necessity but a challenging one because the operational reality of guidelines is often totally unclear.

One must have considerable resources available to identify the people and the requirements, get the work done while specifications change, create a customized submission for each audience, and shepherd the package through the review process. Even if the review is strictly science-based and political influences do not influence the process (currently a rare event), considerable effort is needed. Because of the personnel and financial costs, only large corporations with extensive resources can hope to succeed. The customized country approach also means that simultaneous global submissions are an impossibility. Everyone wants it “their way” but no one wants to wait for the revisions to occur. Customized submissions mean sequential submissions, which, in turn, mean clearances in some countries before others. Needless to say, since the processing times are different everywhere, the time gap between clearances for various trading partners is large. The resultant patchwork of cleared “here” but not cleared “there” is tremendously complicating for trade. It is not surprising that the public is confused. What does it mean if one country says it’s OK, and one says it isn’t, and one hasn’t answered the question?

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## Economic Aspects

The regulatory process, whatever it is, has an economic impact. It determines what is possible, who the players will be, and often predestines the winners and the losers.

More and more countries are recognizing that agricultural biotechnology holds great promise. Those who saw only risks now see benefits, too. Germany, for instance, has completely reversed in its position on biotechnology, from being a major detractor to being a major proponent. That is not to say that risks are taken lightly, but rather that with proper scientific proof one can now move forward where previously no proof was considered adequate. This reflects a truly science-based approach. Industry is becoming more aware of regulatory complexity and its impact on trade. That is an important development because the industry lobby is always stronger than any individual corporate effect on trade issues of this magnitude. Most important, the introduced products are succeeding despite the uphill nature of the endeavor. Each sequential regulatory decision reinforces previous decisions.

The challenge that faces the industry is to find a controlled stepwise approach that balances the sequential pattern of regulatory clearances and the slow maturation of public awareness and acceptance with the need of the export trade to keep commodities moving freely. It is difficult to make allies and educate everyone who needs to be informed in an environment that changes daily and is highly charged with diverse political pressures. Nevertheless, in the case of food, the industry must be willing to discuss public acceptance professionally and responsibly in an honest and frank dialogue with consumers and their representatives. A product label is not the only way, or necessarily the best way, to convey information about food. The challenge is to find the right way to promote information sharing for each of a wide variety of products.

In addition to considering issues of public acceptance, the industry must also come to understand how local economic strategies are influencing developments in agricultural biotechnology and learn to react appropriately to this information. Not all antibiotechnology activities are based on public issues; many are economic strategies put forward by those who see an opportunity to win economic success by niche marketing against a glut of products of biotechnology. Only by recognizing these forces can industry focus its efforts where they will do the most good.

The Canola Council of Canada has undergone a tremendous education in agricultural biotechnology over the last several years. Its members devoted the time and effort to understand the near-term situation as well as the long-term trend. They have taken a strong position on when to go forward and at what pace. They are actively working to move the regulatory process forward internationally. This is what has to happen for industry to succeed. In some cases, this is an extension of previous activities, but in some cases it will represent a significant change in the nature of industry liaison activities. Again, the already big and the already powerful will have a distinct advantage, whether they are individual corporations or industry associations. To the public, this may be problematical because multi-national corporations are often viewed with suspicion, while local small companies are favored. In the regulatory system that has evolved, few, if any, small companies will be able to survive without major support.

## The Vision

In international regulatory circles, progress is measured in "inches," and the dedicated individuals who have struggled to get us where we are today deserve congratulations for the progress achieved. But we must do more. Today's patchwork of politics and science is a potentially volatile environment for traders. In many ways, this is nothing new for traders, but it is avoidable. Each one of us needs to promote the resolution of the needless international complexity and confusion that exists. Many needs are simple, but the solutions will be challenging to implement.

Recommendation 1: Experts must determine which decisions can be transferred between jurisdictions with confidence. Food and feed safety assessments would seem the most likely. If canola oil has been determined to be safe for humans in North America to consume, it is difficult to imagine the value of repeating the evaluation of risk in country after country. Such acceptance would increase consumer confidence. Acceptance of safety reviews is not just an issue between North America and other regions. Mutual recognition of decisions between EU member states is as important as between the EU and North American countries.

Recommendation 2: Experts must distinguish between high-risk and low-risk parts of the decision process and devote appropriate resources to each. Importation for processing is likely to be a relatively low-risk decision process and should not receive the same intensive evaluation as high-risk decisions. Submissions to allow use for growing and importation for processing need to be separated and rationalized.

Recommendation 3: Regional alliances need to be developed to cover relevant ecological risk zones. This approach would guarantee proper scientific rigor in all global reviews and ensure an economical approach that minimizes the need for redoing reviews.

Recommendation 4: Global expertise needs to be developed to ensure that enough people are trained to handle the workload that lies ahead. This implies that nations with existing expertise should take on a role as trainer. It should not be taken, however, as an invitation to develop duplicative systems in country after country. Capabilities must be developed. Bureaucracies need to be managed and efficient ways of going about the global business must be found.

Recommendation 5: The focus must be on science. If there are concerns about operational implementation, the challenge should be to develop the management plans and the educational training programs to address the concerns. Politics under the guise of science must end.

Recommendation 6: The strategies of the players need to be recognized. Some in the antibiotechnology lobby have relevant comments worthy of our consideration. Some are only looking for a niche-marketing opportunity. Some of these players are individuals, some are groups, and some are nations. To put our always limited resources to the best use, we must recognize the differences and communicate with those who will benefit from the information we have to offer and who have points of view we need to hear.

## Conclusion

Agricultural biotechnology holds great potential for feeding a hungry world and reducing the strain on the planet's environment. North America is leading in its development. Japan and Europe are not far behind. The products of agricultural biotechnology will circle the globe as exports and imports. Currently, international regulatory systems represent an uneven maze of pragmatism and politics that creates a nightmare for commodities grain traders and confusion for the public. Everyone engaged in agricultural biotechnology has a role to play in educating, communicating, and promoting a science-based global system that will facilitate rather than impede trade of agricultural biotechnology products.

# *Biotechnology and Social Issues in Rural Agricultural Communities: Identifying the Issues*

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## Introduction

Biotechnology, and specifically genetic engineering (GE), is promoted as a key to expanded agricultural production and sustainable rural economies. GE is offered as a response to limits encountered in conventional production systems, as a way to overcome environmental and resource quality barriers to increased food production, and as a green response to ecological problems originating both in and outside of, industrial agriculture. Biotechnology is also offered as a set of practices that will reduce the cost of production, increase efficiencies, and keep agrarian economies competitive in world markets. Agricultural biotechnologies are promoted as compatible with, and crucial to, sustainable development of rural agricultural economies — and, by extension, the farm communities involved.

Biotechnology cannot be understood merely as a set of powerful techniques. Rather, the development and application of biotechnologies must be contextualized, and this context is a partnership between scientists and agro-industry firms promoting an industrial agriculture in which high-tech inputs play a pivotal role. This reading of biotechnology was reflected in a brief definition proposed by Hindmarsh (1991): “Biotechnology is the scientific manipulation of organisms at the cellular level in order to produce altered, or novel, organisms that carry desired or programmed functions, invariably to facilitate industrial production processes.”

I will interpret social issues broadly in this discussion of biotechnology research, development, and application. Do the social relations promoted by GE enhance or constrain the achievement of a broad set of societal goals? In rural agricultural communities, the social issues include equitable sharing of costs and gains, freedom from coercion or involuntary participation, participation in decision making, accountability, and the social sustainability of communities, as well as the opportunity for many community members to own agricultural resources and to farm. Production systems that displace and marginalize people and communities should not be easily accepted as sustainable.

Markets and technologies are increasingly viewed as the natural arbiters of development, and criteria of economy and efficiency have been positioned ahead of all others (Levidow, 1993). But most economic issues are also social issues, as are questions of power, information, access, and risk. Ecological issues overlap with social issues because they jointly impinge on health, intergenerational equity, aesthetic values, and the social ecology of sustainable resource management. Ethical, philosophical, political, and cultural concerns are also social issues. I want to focus a portion of this discussion particularly on the cultural implications of agricultural biotechnology.

What rural agricultural communities are we talking about? Although many of these observations would apply to other regions north and south, the prairies of western Canada are uppermost in my mind. Even in this mostly agricultural portion of the rural landscape, farmers are a minority. Rural agricultural communities include many nonfarming households, with or without close connections to agriculture. Communities should be understood as complex phenomena with no single logic underlying their existence. There are ranching and farming communities, Hutterite colonies, Indian reservations, and recreational communities.

Moreover, whether growing or declining, the local settlement is not the only source of community. Its inhabitants may be more closely associated with communities based on shared involvement or interests — in politics, organic farming, holistic range management, exotic livestock, choral singing, nursing, education, or religion. Moreover, community is not assured: many have had to deal with an absence of community, or worse, a community that is unsympathetic to the fates of individuals.

Having opened the door for a wide array of social issues and having signaled that communities are heterogeneous and contingent, I will turn to specific issues arising from agricultural biotechnology research and commercialization. I have focused on ten reasons why agricultural biotechnologies may be, may become, or should be social issues in rural communities. Some of the concerns are long-standing and well documented. Others are new, not commonly articulated, or only latent possibilities. The issues are risks and costs borne by farmers, implications of industrialization and accelerated structural change, potential impacts on farmer-owned and regional firms, increasing tensions and divisions, loss of independence, changes in the culture of agriculture, loss of control, lack of effective participation in research agenda-setting, narrowing of research agendas, and neglect of alternative conceptions of sustainable agricultural development.

## Costs and Risks Increase without Assurance of Gain for Farmers

Although the case for the environmentally friendly character of GE is based, in part, on the promise of reduced need for pesticides, the evidence in terms of use levels is not convincing. Breeding for herbicide tolerance has been a major priority in the industry and is associated with increased reliance on herbicides (Hindmarsh, 1991). As herbicide use continues to increase, farmers, farm workers, and rural inhabitants are exposed. Epidemiological studies are constantly revealing new threats from agrochemicals once regarded as safe.

It is farmers who must deal with the problems of herbicide-resistant weeds, a problem more widespread than commonly acknowledged. It is farmers, also, who face new risks related to the transfer of herbicide tolerance from genetically engineered organisms (GEOs) to weeds — and the prospect that some GEOs will become problem weeds. Of local interest in this respect, the transfer of transgenic herbicide resistance from canola to field mustard has been detected under field conditions (Snow and Palma, 1997).

The use of expensive GE seed does not guarantee a commensurate increase in yields. Crop failure resulting from frost, hail, drought, flood, pests, or pathogens is always a possibility. Moreover, given price elasticities and problems of oversupply, expanded production does not necessarily translate into higher farm incomes at the sector level.

Supply companies and firms licensing particular GEOs are adept at charging what markets will bear. Economic benefits arising from these technologies are likely to be taxed away by those holding the patents. The contracts presented to farmers on a take-it-or-leave-it basis illustrate the unequal character of the relationship. Monsanto's Gene Agreement for Round-Up Ready Soybeans prohibits farmers from saving or from selling or supplying the seed to any person or entity. Growers pay a $5 per pound technology fee over and above the price of seed and royalties. The company takes no responsibility for performance of the product, but farmers are held liable for damages should they violate any part of the agreement. Monsanto has the right to visit the fields involved, without permission, for a period of three years (Shiva, 1997). In 1996, some Texas farmers who planted Bollgard, a GE cotton that produces Bt to fight bollworm, found themselves spraying for the pest the crop was supposed to repel. Monsanto claimed the plants performed as expected (Shiva, 1997; Commins, 1997).

Agrobiotechnology firms are patenting every process and organism they can and spending large sums litigating the competing claims. Calgene, recently acquired by Monsanto, has patented the production of canola transformed by any means. A Minnesota entrepreneur has patented all nutritive and therapeutic components of flaxseed. Rather than racing to publish their findings, scientists are racing to the patent office. One result is duplicated effort and much time spent trying to figure out what is still in the public domain (Rance, 1997b; Commins, 1997). Producers will end up paying the cost.

## Industrialization and Accelerated Structural Change in the Farm Sector

Biotechnology is being introduced in the context of the increasing industrialization of farming. As a leading aspect of this technical and organizational restructuring, biotechnology cannot be easily separated from the wider set of issues surrounding industrial agriculture. Moreover, biotechnology is important in the development of responses to the environmental, agronomic, and veterinary problems encountered when industrializing livestock and crop production. This may permit further development without addressing fundamental contradictions and inefficiencies.

As is true with many kinds of technology, biotechnologies may have implications for the survival of farmers who have specific attributes such as smaller or undercapitalized farmers, those with less formal education, or those who reject a strictly productivist approach. As has been documented with respect to high-yield or high-response cultivars developed as part of the Green Revolution initiative, technologies may not be resource-neutral even where they are scale-neutral in a technical sense (Bernstein, 1992). Though biotechnology is divisible, the level of investment required, the increased risk, and need for higher levels of management mean that larger and more capitalized farmers will benefit disproportionately.

Biotechnologies are expensive and are likely to be most successful in the market if they can be incorporated as components of production systems that reduce labor inputs and associated costs. Time and cost-saving, not soil conservation, have been the most important impetus for the adoption of zero-till systems (McMillan, 1997). Biotechnologies that allow farmers to expand their operations without adding labor are most likely to find acceptance. In the process, the concentration of agricultural resources in the hands of larger farmers is likely to be accelerated.

## Rapid Restructuring May Threaten Farmer-Owned and Regional Firms

Biotechnologies are associated with strong economies of scale in research, testing, licensing, and marketing. This has contributed to rapid concentration in the seed and agrochemical industry. It may also mean that farmer cooperatives — organizations in which farmers retain some measure of control — will find themselves at a competitive disadvantage compared to other firms. Cooperatives have relied heavily on public sector research. The privatization of biotechnology research may limit access to new developments. Given the resources needed and the prior patenting of many key processes, most cooperatives are not well placed to compete in the development of biotechnology. Strategic alliance with input firms is a possible strategy, but even if alliances can be negotiated, there are implications for the character of the co-operatives involved. Moreover, those that fail to make such alliances may face rapid demise (Ransom et al., 1995).

## Increasing Tensions

Biotechnologies are likely to create deeper divisions between farmers subscribing to different models or systems of production, between farmers and nonfarm rural populations, and between farmers and the nonrural public. Dairy farmers may be split on the merits of bovine growth hormone (BGH). Beekeepers experience a threat to export markets when genetically engineered crops become part of the local landscape (Tjaden, 1997). There is the prospect for increased litigation as farmers and suppliers contest the sharing of risk and liability and the enforceability of contracts.

Organic farmers may feel even more marginalized and excluded as farming and the rest of agriculture are repositioned to embrace these new technologies, but they may experience some increased demand from consumers distrustful of, or disaffected with, the new conventional forms of agriculture. Debates and groups are likely to become more polarized, despite sporadic efforts to kindle consensus or to find common ground.

## Farmers Lose Independence in Relations with Consumers

Farmers rely on processors, manufacturers, retailers, and the food service industry to handle relations with consumers. These firms have interpreted consumer preferences and demands in ways that promote flexibility and efficiency from the corporate perspective. Response to consumers has been selective and often proactive — attempting to remake consumers in the image of the food industry rather than to respond genuinely to consumers' concerns and desires. Farmers have relied on value-adding firms to set standards and create new tastes, but these firms have engaged in a long-term project to deskill the consumer with respect to knowledge about quality, nutrition, production, processing, and cooking. Farmers are trapped: if they wish to market their commodities in conventional channels, they must do so via intermediaries, and these intermediaries have great power over production practices.

As farmers become more closely linked to suppliers and processors, consumers are beginning to show signs of rebellion and rejection in the face of the perceived risks of industrialized agriculture. The popularity of vegetarianism and the precipitous drop in beef consumption in countries affected by mad cow disease are harbingers. Farmers stand to pay the highest price for any agroindustrial mishaps or backlash from consumers. Farmers face a difficult choice: whether to join with agribusiness public relations personnel in dismissing consumers' fears about biotechnology and industrial agriculture or to find new ways to reconnect with consumers who have a genuine interest in the conditions and practices surrounding food production. This is not a minor issue because consumers now far outnumber all other participants in the agri-food sector and the environmental movement is perhaps the most powerful social movement in the world today. If farmers do not want to be sideswiped by the irrational fears of consumers, they have to take more seriously the rational fears, as well as the aesthetic and ethical concerns with respect to livestock, the environment, and human health.

## CHANGES IN THE CULTURE OF AGRICULTURE

Farming tends to be organized along patriarchal lines. Men own most productive resources and dominate production decisions. There are signs of change in response to economic exigencies, changing demographics, and the initiatives of women. Nevertheless, the culture of farming and agriculture remains fairly macho and male-dominated. What do this fact and evidence that females are more likely to have reservations about agrobiotechnologies (Brandth and Bolso, 1994), imply for the future of women in farming and the agroindustries? This is not a trivial issue for women, and it is a source of vulnerability for family farming and farm communities. Women may become estranged from the new technologies and less willing to farm. Women and men who cannot relate to the new paradigm will be increasingly alienated, contributing to a loss of cultural diversity in farming and agriculture.

## FARMERS TRANSFORMED FROM SUBJECTS TO OBJECTS OF AGRICULTURAL PRACTICE

For many farmers, the cumulative effect of financial pressures, restructuring, and high-pressure promotion of high-tech farming systems leads to a feeling that they have been transformed into the objects of agricultural practice rather than subjects — that is, pawns rather than masters of their own destinies (Lind, 1995). They sense a loss of control, a mismatch in terms of information, and that they are market targets for private sector firms with strong links to public sector institutions.

The proliferation of new varieties may reduce the ability of farmers to make meaningful choices with respect to cultivars appropriate to their regions and cropping systems (Rance, 1997a). A related problem is the loss of information related to genetic diversity. Commonly used genetic materials and varieties promoted as different though they are similar make it harder for producers to exercise strategic choices with respect to diversification of varieties and breed lines. Moreover, it may be increasingly difficult to know whether it is worthwhile to pay a premium for a new variety. Farmers become more like consumers — less able to distinguish quality because of product proliferation, lack of information, and disinformation.

### No Effective Participation in Setting Research Agendas

Knowledge and information translate into economic and political power. In the world of high-tech inputs, farmers and other rural citizens are increasingly disadvantaged, unable to weigh or debate the merits and implications of proprietary products and processes. This will reduce the prospect for effective participation in the oversight of public research agendas, not to mention decisions related to research and development activities of private industry.

Reorientation toward biotechnology implies a redrawing of the social networks of researchers and changes in the corporate culture of research organizations. Emphasis on products generated in labs, greenhouses, and factories is likely to reduce interaction and identification with primary producers. The culture and concerns of the research community will shift to become more focused on corporate agroindustry partners and fellow scientists and less on farmers and rural communities. Farmers may end up with less access and voice with respect to research priorities and design criteria.

### Narrowing of Public Research Agendas

The orientation of university research toward biotechnology and funding from the private sector is likely to narrow research agendas to focus on innovations that can be sold at a profit, thereby accentuating the neglect of cultural practices, integrated pest management, alternative cropping systems, and low-input farming. Researchers will need to generate a patentable product that meets criteria for commercial success. Other focused initiatives that might lead to improvements in resource productivity, sustainability, or environmental safety — or to major cost savings for large numbers of producers — will be neglected.

The promotion of biotechnology leads to a lack of diversification in the research portfolio. It can also stifle critics and those interested in other kinds of innovation. The merits and potential of biotechnologies have been presold by politicians, university presidents, and deans of agriculture. Even senior professors may hesitate to admit reservations publicly, or to discuss alternatives.

The narrowing of debates around new developments is a real risk. Recently, North Dakota became the thirteenth state to pass legislation making disparagement of agricultural products a civil offense unless the critic has a reliable scientific basis for the assertion (Kesterton, 1997). It does not take a paranoid person to wonder where this policy might lead with respect to debates over GEOs. Some farmers are willing parties to the promulgation of such restrictive covenants. Others worry about a chilly climate for alternative visions.

## Neglect of Sustainable Agriculture and Sustainable Development

Even when agricultural biotechnologies are targeted at challenging environments, they may contribute to a crisis in resource degradation, whether the challenge comes from water shortage, salinity, climate change, or the concentration of livestock in feedlots. The apparent power of GE strengthens and perpetuates an engineering mentality with respect to nature, agriculture, and rural communities. As Martha Crouch has observed biotechnologies may allow producers to overcome the presenting problem, but they may also contribute to perpetuation of conditions that will lead to collapse (Canadian Broadcasting Corporation, 1994).

Biotechnologies give industrial agriculture a new lease on life. The social and environmental consequences may be serious. The surface success of the biotechnology diverts attention from holistic approaches involving the rethinking and redesign of production and consumption systems. As Crouch suggests, the technical limitations of biotechnologies make them intrinsically reductionist and too one-dimensional to deal adequately with what are mostly whole-system-level issues (Canadian Broadcasting Corporation, 1994).

Peasants in the developing world are often relegated to marginal lands. Should new technologies render commercial production feasible on such sites, historical evidence would suggest a new round of evictions and appropriations by the rich and the powerful. This example reveals the heroic oversimplification involved in claims made with respect to the promise of agrobiotechnology as an instrument to fight hunger (Canadian Broadcasting Corporation, 1994). The challenge in these environments is first of all political, and the need is for broad agrarian reform.

## Some Conclusions

GE has been compared to earlier breakthroughs in nuclear physics. The atom was cracked for military purposes, the agenda pushed forward by war and the Cold War. The military-industrial complex sought wider public acceptance by promoting the advantages of the atom for peaceful purposes. The gene-splicers working in the university-industrial biotechnology complex are seeking public support for an agenda driven by cold cash and corporate competition. Expensive and ethically challenged research and development efforts are sold to the public via appeals to environmental protection and alleviation of famine. The rationales are often as tenuous as earlier plans to use nuclear explosions for road building.

Many of the heralded ideas of conventional agriculture are now seen as ill-advised. After decades promoting specialization, extension departments have focused on diversification. Chem-fallow, zero-till, and continuous cropping are the new orthodoxies replacing widely promoted conventional fallow practices.

Many pesticides have come and gone as a result of resistance or other side effects. In turn, the claims surrounding agricultural biotechnology will also be modified as we discover limitations, costs, and alternatives. The problem this time, however, may be different. The capacity to introduce biotechnologies on a global scale and their association with an intensified, industrial agriculture mean that their impacts can be threatening to the planet as well as damaging to local ecologies, economies, and communities. Many rural people share such concerns. Their misgivings will not be allayed by public relations, scientific education, or appeals to the integrity of regulatory processes.

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# *Farm Knowledge: Machines Versus Biotechnology*

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## Introduction

"The computer does not impose on us the ways it should be used." The well-known Canadian philosopher George Grant (1986) uses this common assertion to develop a critique of modern technology. He points out that, indeed, technology does influence the uses to which it will be put. Technologies even influence the framework(s) that people will use to evaluate them. They are part of a paradigm of knowledge that helped to spawn them, that sets our educational institutions and our "civilizational destiny." Grant shows that even the word should, as it is used in our modern technologically rational society, conveys the conditional meaning – "one should if one desires to gain some end" – whereas in traditional societies it conveyed a universal "ought" or "must," that is, that we owe others with no "ifs." Further, the ways computers can be used for storing and transmitting information have and will increase the homogenizing processes in our society. The same was true for the car, and, no doubt, other technologies can also have the effect of homogenizing work, culture, and our way of life.

This paper attempts to understand, in light of Grant's thinking, some of the results of a recent study of farmwork and technology in a set of southern Saskatchewan communities, done by a research team at the University of Regina. Clearly the influence of modern knowledge systems and technology on the Prairie farm, as with industry, has been homogenizing (Taylor, 1994). I will argue, however, using two examples, that rural people have had more success maintaining public knowledge, autonomy, and control over machinery than over biotechnology. The paper concludes by offering some proposals for change.

## HOMOGENIZING TENDENCIES IN INDUSTRY

Two centuries ago, Adam Smith noted an important principle of capitalist production – dividing the task cheapens the cost. The principle, refined by Charles Babbage and taking on his name, identifies the need for managers to divide the total production of a commodity into small, detailed parts, most of which require very little skill to complete and are accomplished by cheap "detail" labor.

One century ago, his idea was being turned into a bogus "science" of management at the hands of Frederick Winslow Taylor. It had a new twist. Taylor recognized that workers possessed the knowledge of production; without breaking workers' hold on knowledge it would be difficult for managers to realize the gains promised in Babbage's principle. Broadly, Taylor's proposal for management can be summarized in three principles.

- Dissociation: Gather workers' knowledge, collate and codify it, and write it as rules for production. That is, identify the knowledge as distinct from those who hold it and who do the work.
- Separate conception from execution: Physically locate this knowledge in the planning department, where managers can take charge of it.
- Plan and control: Use this knowledge to separate the work into detailed steps. This planning will be aided by time and motion, flow control, and similar "scientific" studies. Assign workers with different skill levels and different wage levels to each step. Insist that they do their work exactly as planned.

David Noble (1977) has shown that Taylorism was part of a broader movement by large U.S. firms in the electrical, automotive, chemical, and related industries, with the cooperation of various departments of the state and some universities, to turn technology in their favor. It involved the rise of a new class of managers and engineers and resulted in large oligopolical firms having a major influence upon the development and implementation of technology in this century.

An important result of Taylor's "scientific management" and related dynamics of modern capitalism, according to Harry Braverman (1974), has been the increasing homogenization of the work force. A growing majority are being reduced to low-skill, "bad" jobs, while few have high-skill, "good" jobs. Of course, fractions of the work force have resisted this tendency, some more successfully than others. Overall, work has tended to become degraded and the work force deskilled.

The rate of productivity increases after World War II was high, as the technologies and management approaches of mass production became the norm in industry. But after the early 1970s this rate declined, setting off a major debate about its causes or even whether it was an important new trend. Typical data for Canadian business sectors are presented in Table 1. Most attention was placed on manufacturing, where average annual productivity increases dropped from 4.5 percent in the 1961 to 1973 period to 2.2 percent in the 1973 to 1986 period; but the service sector also slowed, as did agriculture.

Table 1: Average Annual Percentage Change in Productivity of Canadian Business, Selected Years

| Business sector | 1961–1973 | 1973–1986 |
|---|---|---|
| | Output per person/hour average annual percentage change | |
| Services | 2.6 | 1.3 |
| Goods | 5.0 | 2.2 |
| Manufacturing | 4.5 | 2.2 |
| Agriculture | 6.4 | 1.7 |

Source: Statistics Canada, Aggregate Productivity Measures, 1986, Cat #14-201.

The data suggest a major shift, which has come to be associated with a crisis of Fordism. There are competing explanations. “Numerical control,” the predominant technology of production during and after World War II, had perhaps run its course. Consumer markets may have become too differentiated for the conventional mass-production techniques. It is also likely that the great font of workers’ knowledge was becoming exhausted (Lipietz, 1992). The importance of workers’ knowledge to productivity is revealed in the strategies used to overcome the downturn, that is, “flexible specialization,” “responsible autonomy,” and other labor processes that claim to recenter workers’ knowledge and control of production activities.

So the basis of production and of accumulation and profit is labour, which is based in part on the ingredient knowledge, not concentrated in the hands of management or in the academy or in a computer but distributed among those who actually do the work. This is a body of local, public knowledge. When it is weakened, productivity is threatened. Of course, there may be other important reasons for protecting local knowledge. It may ensure a way of life. It may be moral.

## Parallels in Farming

As in industry, farm production is based on the knowledge and skill applied by farm families that do the work. Critics of the degradation of work in industry, such as Braverman, hold up farming as the counterexample. The structure of the farm sector means that farm families take the production decisions, because they own or control the property, and are in virtually perfect competition with each other, so they have a strong incentive to increase productivity. Hence they adapt, cope, invent, and innovate.

Where does the knowledge to farm come from and what are the trends? Answers to this question will show that farming is not as much a counterexample to industry as industry's critics may think. In the past, farming knowledge was passed down from generation to generation, that is, it was a "folk" or community knowledge. As farming becomes more commercial and industrial, however, the populations of successive generations of farm families have declined. Today, farming knowledge is produced and disseminated by state agencies such as universities and government research stations. But this source of knowledge is being diminished government cutbacks. For example, $4 billion has been cut in Canadian federal transfers to the provinces since 1994-1995, putting a strain on universities. Federal agricultural research has also been cut. In part, these cuts are to be replaced by contract research for private companies. But this change compromises the public nature of the knowledge. Dean Michael Martin, of the College of Agriculture, Food and Environmental Sciences, University of Minnesota, speaking to the U.S. Agricultural Outlook Conference recently, claimed that basing university research on private contracts "shortens the time horizons . . . of scientists . . . . You get a lot of problem solving but not necessarily a lot of knowledge discovery . . . . [It turns] very good scientists into very bad accountants" (quoted in *The Western Producer*, March 6, 1997).

In addition, the knowledge of how to farm is produced and disseminated by agribusiness companies. This source has been increasing in importance. Here the knowledge tends to be proprietary, protected by patents and intellectual property rights embedded in trade agreements. Sometimes this knowledge erodes folk knowledge, for example, by patenting knowledge that was previously folk knowledge, requiring end-use contracts from farmers, which limits their opportunity for innovation, modification, and generating new knowledge, or by patenting invention "processes," which limits the methodologies available to both farmers and public scientists for generating new knowledge (Shiva, 1997). The companies are becoming very large and the industries very concentrated, resulting in control of this knowledge by the few, with a strict orientation to accumulation (Heffernan, 1996).

Increasingly, the knowledge of how to farm is being removed from farm families and embedded in the industrial processes that manufacture farm inputs and process farm outputs, in the computer programs and Internet systems that facilitate and direct farm management, and so forth. Hence, farm technology, work, and knowledge are becoming more homogeneous and controlled by large companies, while local producers' knowledges are being eroded. This may explain the productivity slowdown shown in Table 1 and the tendency noted by some for yields to hit a plateau. But the process has not been monolithic. Fractions of farmers have resisted this tendency with varying degrees of success. A comparison of some social aspects of machinery technology with biotechnology can serve to illustrate this point.

## Farm Machinery

### Role of patents and control of knowledge

Major struggles over patents ensued between individual inventors and between firms in the 1800s. But the firms were small, competition was severe, and patent holders were often quick to license their patents to manufacturers who would work them. Indeed, much of the Canadian industry took root by licensing American and other patents. After World War I, patents became less important, at least until the advent of computer control, even though there were major improvements in auto electrics and battery technology, rubber tires, hitching systems, hydraulics, transmissions, diesel engine design, and injection systems.

### Response of farm families

While rural folklore is replete with stories about late adopters of machinery – especially tractor power – on balance, farmers enthusiastically embraced it. The tendency for farm families to capitalize their household income into machinery is well known. At the same time, farmers followed characteristic patterns of resistance. For example, they pushed for machinery regulation such as the Nebraska Tractor tests in the United States, the Royal Commission on Farm Machinery (Barber Commission), and the Prairie Agricultural Machinery Institute (for testing machinery) in Canada. They organized distribution and manufacturing cooperatives such as Canadian Co-op Implements, whose policy was to provide full product documentation and to try to use off-the-shelf parts in its manufacturing. Farmers invented machinery; our study area in southern Saskatchewan alone has yielded inventors of the swather, air seeder, several inventors of the disker, and many modifications of manufacturer's machines.

### Role of the state

The state became heavily involved in promoting machinery by generating and disseminating knowledge about machinery. Farm machinery was essential to the Canadian project of opening the Prairies to European settlement. The dry land farming movement, originating in Kansas and Nebraska, was promoted in Saskatchewan by no less a figure than the premier. Elaborating on this initiative, the Prairie provinces gave a major role to the agricultural engineering departments of their universities, emphasizing that the universities were to work closely with farmers. Such a "people's university" was one result of the progressivist element of the agrarian movement so important to prairie politics.

Further, in general, the law did not constrain farmers' machinery innovations.

The farm machinery companies adapted to this balance of power between themselves, farmers, and the state by adopting a stance of relative openness about their technology. One small example is that the post-World War I farm tractor training courses given by the manufacturers were amazingly detailed. Clearly the expectation was that farmers themselves would do major overhauls of their machinery.

So a relatively "open architecture" developed for farm machinery, and knowledge about machinery became part of rural folk knowledge and skill. The two world wars helped to develop mass knowledge about machinery, especially among farmers.

## BIOTECHNOLOGY

### Role of patents and control of knowledge

Patents have been essential to the success of the major companies in this industry from the start. Initially, the companies were not much oriented to farming. Even today, farm products tend to be only part of their broader business. Since the commercialization of hybrids, and especially since the advent of genetic engineering, however, there has been a frenzy of patenting and struggles over patents have become more intense. The firms are very large, the industries are oligopolies, and maintaining market share is any firm's major goal.

### Response of farm families

Traditional agricultural biotechnologies have existed in the public domain for many centuries, for example, in selective breeding and the use of yeast and bacteria to produce foods and beverages. Farm families have been active in reproducing this knowledge, for example, in breeding new strains of crops and livestock, as purebred livestock and elite and registered seed growers, in breed associations, and even in 4-H clubs.

### The role of the state

The state has also been active in traditional biotechnologies and has been closely allied with farmers through the research and extension activities of the experimental farms and universities. This initiative was crucial to the success of the Canadian Prairie frontier by producing new crop varieties better suited to the shorter growing season and resistant to drought, disease (rust), and insects (sawfly). As with machinery, this was part of the agrarian ideology of progressivism. This link between folk and public knowledge was dominant in agriculture in Saskatchewan until the 1970s. The law made the introduction of new varieties subject to regulation and close supervision but it did not make understanding the technology more difficult, and innovation by farmers was still possible, especially if they were tied into a network with university and experimental farm scientists.

### The case of chemicals

Before World War II, chemical use on the farm was an item of local and public knowledge, but after the war, chemicals were modified for agriculture and patented. They were widely adopted by “progressive” farmers, but the farm community had scant understanding of their makeup, properties, or how they worked. University scientists understood chemical technology well, but their traditional alliance with farmers changed. Extension and research work focused simply on the use of chemicals, and, increasingly, chemicals were invented by the companies.

So the “architecture” of biotechnology was not as open as that of machinery because most crop and livestock breeding was done by scientists. Nevertheless, farm people were often intimately involved and generally understood the process. An exception to this pattern after World War II was farm chemical technology.

## Local Knowledge in the Current Conjuncture

Computerized farm machinery has introduced a new threat to local knowledge and control. Proprietary knowledge is coded in the computer. Modular design is integrated with computer control systems. But farmers, drawing from past experience, are resisting. One strategy is purchasing used machinery while developing individual knowledge and community knowledge networks to facilitate repair and sourcing parts. The next stage will involve cracking computer codes and the growth of third-party suppliers. The law, combined with the structure of the industry, slows this process down but does not stop it. To date, computerized, modular machinery appears to offer no or few advantages that are important to farm families – better margins, safety, flexibility, control – so this is a viable coping strategy. In time, computerized control will become an element of farm folk knowledge.

Genetic engineering and new chemicals also introduce a potential threat to local knowledge and control. Proprietary knowledge is embedded in the product and sometimes also in the patented processes that produced it. Use by farmers is limited, and modification is prohibited by contract. Farmers are struggling to advance lines of resistance but without much success. Purchasing used products or chemicals is either illegal or not an option, hence adoption tends to be all or nothing. Community networks have developed but only limited extensions of knowledge and control have resulted, for example, finding new uses for diluted applications of popular chemicals, or pursuing legal actions against manufacturers when a product appears to fail. Facilities for reverse engineering the products are not widely available in the public domain and local groups have come to legal and financial grief in pursuing this path. Indeed, the manufacturing process is not well understood and almost never attempted by farmers. In general, patent law and the law regulating the manufacture and sale of genetically engineered and chemical products constrains farm innovation in these areas. Further, the research and invention capacities of the state have increasingly been captured by private firms. Hence, unlike farm machinery, under present trends it is doubtful that the new biotechnology will soon become embedded in farm folk knowledge.

## OPTIONS

Certainly, modern agricultural technologies do influence their use. Critics of tractor power pictured it as a “widow maker” and “agent of the devil,” perhaps with good reason. There are also grounds for concern over the thought of gene splicing labs in every farmyard. Even though biotechnology may have much deeper consequences than machinery for farming and rural life, the resulting social structures will be worked out in the characteristic struggles among farmers, companies, the state, and others.

The general point is that local farm knowledge is being eroded and, given its relevance to the viability of farm communities, ways have to be found to revive it. One well-known trend is revealed in out-migration of young people that our farm communities have raised, educated, and disciplined to the nonfarm labor market. In Saskatchewan, over 50 percent of the net farm migrants in recent decades left before the age of 30; for the most part, this source of population, knowledge, and skill regeneration is lost to the farm community forever. If public and local knowledge is to remain viable, at least a couple of options can be suggested.

In modern agriculture, independent public universities and state research agencies have been crucial generators of knowledge. The current trend to curtail this role and replace it with private generation of knowledge has to be stopped. As a corrective, the Canadian Consortium for Research proposes that the state develop a comprehensive science and technology plan, increase investment in science and technology, increase support of the research granting councils, improve funding of indirect research costs in the universities, increase support for social science and humanities research, improve students' access to postsecondary education, and restore funding for government labs and research.

Folk knowledge is knowledge shared and passed on by custom. Access to it and innovation based on it is also by custom and the observance of norms, traditions, and obligations, particularly about continuing to share it and pass it on to future generations. It is pluralist and democratic in its epistemological strategies. It is rooted in the everyday experience of production. Both the body of knowledge and its innovative potential need to be protected. A Canadian analogy is Indian land systems, which were also rooted in custom. The current effort to resolve Indian and Metis land claims involves the courts accepting evidence of customary use. This model can be adapted to the protection of the folk knowledge of farm populations. This would entail the protection of local knowledge in the law and trade agreements, as well as limiting the proprietary knowledge claims of companies through patents and TRIPs (PLEASE EXPLAIN ACRONYM).

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