Agribusiness and Applied Economics Report No. 509 January 2003

Issues in Development and Adoption of Genetically Modified (GM) Wheats

**William W. Wilson, Edward L. Janzen,
Bruce L. Dahl and Cheryl J. Wachenheim**

**Department of Agribusiness and Applied Economics
Agricultural Experiment Station
North Dakota State University
Fargo, North Dakota 58105-5636**

ACKNOWLEDGMENTS

Funding from the research conducted in this project includes: the North Dakota Grain Growers Association and a U.S. Department of Agriculture/IFAS project titled *Institutional and Market Factors Influencing the Biotechnology Adoption in Northern Grown Crops and Oilseeds*. Comments were received from William Nganje, Duane Hauck, Duane Berglund, and Al Schneiter. Special thanks go to Ms. Carol Jensen for document preparation.

NOTICE:

Table of Contents

Page

Table of Contents (Continued)

Page

List of Tables

List of Figures

Abstract

Development of genetically modified (GM) wheat varieties is proceeding; however, several critical issues remain the focus of contention. This project summarizes the current state of knowledge on some of these critical issues for commercialization of GM wheats. Background on the evolution of GM Wheats is presented. Then, agronomic adoption and competitiveness of GM crops; research on GM traits in wheat; consumer acceptance of GM crops (a separate section is included on issues related to consumer acceptance of GM crops); regulatory issues and status; international trade; testing, segregation, and identity preservation; and production and marketing risks are examined. Finally, there is a description of the likely marketing system to evolve and a discussion of outstanding issues.

Key Words: wheat, genetic modification, transgenic, marketing

Highlights

Development of genetically modified (GM) wheat varieties is proceeding, yet several critical issues remain the focus of contention. This project summarizes the current state of knowledge on some of these critical issues for commercialization of GM wheats. Several topics are examined including: background on the evolution of GM wheats; agronomic adoption and competitiveness of GM crops; research on GM traits in wheat; consumer acceptance of GM crops (a separate section is included on issues related to consumer acceptance of GM crops); regulatory issues and status; international trade; testing, segregation, and identity preservation; and production and marketing risks. Finally, there is a description of the likely marketing system to evolve and a discussion of outstanding issues.

Summary Facts from Existing Studies

While there are some unresolved issues in the development and commercialization of GM wheats, some of the findings from the existing studies are important. There are three important points on the evolution of GM wheats.

1) The potential economic gains associated with biotechnology development in grains in North Dakota rank second only to California. North Dakota could see the greatest production gain because of fungus-resistant barley and herbicide tolerant wheat.

2) Many wheat producer and marketing organizations have taken positions to conditionally support developments in GM wheats. In virtually all cases, the position reflects that biotech wheats are desirable, mostly looking to 2nd stage benefits; that research on biotechnology wheat should continue; but GM wheats [particularly *Round-up Ready*® Wheat (RRW)] should not be commercialized until systems involving Identity Preservation (IP) and testing are developed to satisfy needs of buyers.

3) There are three sources of pressure for adopting GM wheat. One is from a combination of cost reduction and reduced dockage in the case of RRW. Second is due to the increased profitability of competing crops (being recipients of GM technology) which has taken acres from conventional crops. And third is the prospect of 2nd and 3rd stage benefits associated with GM wheats. There is extensive research associated with numerous GM traits in wheat, including herbicide tolerance, fusarium resistance, and quality attributes.

Adoption and Agronomic Competitiveness of GM Grains and Oilseeds

1) *Worldwide Production of GM Crops*: Transgenic crops are being produced in 13 countries worldwide. In 2001, 68 percent of the global area of transgenic crops was in the United States, 22 percent in Argentina, 6 percent in Canada, 3 percent in China, and 1 percent in all the other countries. The four major crops comprising most of the commercial transgenic crops in the world are soybeans, corn, cotton, and canola.

2) *U.S. Production of GM Crops:* The adoption of biotech crop varieties has had the greatest growth and penetration in the United States. Acreage of biotech varieties of soybeans increased significantly in 2002. The widespread producer acceptance of GM crops (corn and soybeans) in the upper Midwest would seem to indicate a willingness of producers to accept GM wheat when it becomes available.

3) *Acres Shift to GM Crops*: There has been a general decline in planted acreage of wheat and barley in traditional growing regions over the past 30 years. In recent years, this decline has largely been replaced by planted acreage of corn, soybeans, and canola, particularly since the introduction of GM varieties in these crops.

4) *Agronomic Advantages of RRW*: There are two primary sources of agronomic advantages for herbicide tolerant wheat. These are yield increases and reduced dockage. According to Monsanto, RRW results in an average yield advantage relative to conventional crops of 11-14 percent. RRW also has the impact of reducing weeds and, therefore, weed seeds contained in dockage. Research has suggested that the adoption of RRW in Hard Red Spring (HRS) wheat areas would have the following impacts: reduced weed seeds which comprise 62 percent of wheat dockage content; reduced cost of dockage removal throughout the marketing system; and the reduced dockage would result in cost savings in the area of 5.5 cents/bu (versus current system costs of 8.4 cents/bu) or about $1.32 to $2.73/acre.

   Taken together, Monsanto has indicated that these agronomic benefits would increase net returns by about $15-$20/acre.

Research on GM Wheat Traits

There is extensive research using GM technology to develop specific traits for wheat. Most important are the following:

1) The United States is dominant, albeit not the only player in trait research.

2) Herbicide tolerance is one trait under development. This is followed by product quality, fusarium resistance, and others.

3) There are numerous diverse organizations involved in trait development. These range from private companies, state universities, federal governments, and others.

All of these suggest that at some time in the future, the market and regulatory and institutional/organizational regimes will have to deal with a multitude of GM traits simultaneously.

Consumer and Market Acceptance

There has been extensive research on consumer attitudes and acceptance of GM traits, both in the United States and other countries. Below is a synopsis of that analysis:

1) Consumers do not reject genetic engineering outright but objections focus on specific applications of the technology. Consumer support is linked to perceptions of direct consumer benefits.

2) International surveys suggest that Americans have greater support for biotechnology than Canadians and Europeans. Americans have a higher degree of trust in regulatory authorities than Europeans. And, Japanese and European consumers prefer international regulatory agencies and have less trust in national regulatory agencies than Americans or Canadians.

3) In contrast to other risks, concern for biotechnology is relatively low compared to other food safety issues.

4) When a connection is made between labeling and increased food costs, consumers were generally not willing to pay more for labels.

5) Surveys are generally poor predictors of actual consumer behavior as consumers often say one thing and do another.

6) The ABA recently conducted a survey of U.S. consumers about GM wheats. Highlights from this survey indicated:

    - Acceptance of GM wheat is at the same level as GM corn, tomatoes, and oil, which are already in production, but overall at this early stage, a plurality still say the risks of GM wheat outweigh the benefits.

    - The number of 'potential switchers' saying they would switch from GM wheat bakery products is identical to GM corn products. Few consumers have switched from GM corn. A wholesale switch from GM wheat is not likely to happen without a trigger event that would draw more attention to the issue or easy access to an alternative market to 'exit' to (e.g., organic or Non-GM wheat alternative).

    - Acceptance of GM wheat is likely to depend on the extent to which it is differentiated in consumers' minds from other more 'contentious' GM technologies, particularly animal applications.

Regulatory Issues

There are numerous regulatory issues related to GM crops.

1) Nearly every country has different approaches and each has their own regulatory framework. Regulation is a very dynamic issue with changes being reviewed and proposed in many countries on an ongoing basis.

2) In the United States, transgenic crops are subject to a tripartite regulatory system. The government agencies having a part in this system are APHIS (Animal Plant Health Inspection Service of the U.S. Department of Agriculture), EPA (Environmental Protection Agency), and FDA (Food and Drug Administration). The U.S. regulatory system focuses on determining the relative safety of biotechnology's end products and not on the processes by which they are created.

3) Restrictions and Labeling of Products Containing GM Ingredients: In addition to regulations on GM crops, there are a complex series of issues/restrictions related to labeling of products made from ingredients that are or might be derived from GM crops. These vary across countries.

4) European Union (EU) farm ministers agreed in November 2002 to require food and feed containing 0.9 percent or more GM grain to be labeled as genetically modified. They also agreed to a maximum permissible level of 0.5 percent for food and feed that accidently contains unauthorized GMOs (adventitious contamination).

5) Mandatory labels have been fiercely opposed by the U.S. food industry, which contends that such labels would raise concerns about the safety of GM foods and scare consumers away, in addition to increasing the cost of nearly all food products. Some 35 countries worldwide have, or are developing, mandatory GM labeling laws.

6) Food Safety: The National Academy of Sciences expert committee said they found no evidence that gene-spliced crops are unsafe to eat. They endorsed the central principle of the U.S. government's existing biotech regulations: that genetically engineered foods pose no special risk because they are produced by a new process. The American Medical Association's Council on Scientific Affairs supported agriculture biotechnology and stated, "There is no scientific justification for special labeling of genetically modified foods."

GM Wheat and International Trade Issues

Two of the fundamental issues in international trade are the potential for buyer acceptance and aversion to GM wheat and the welfare and strategic implications of GM wheat. Results from these indicate:

1) Some countries are thought to be averse to the importation of wheats containing GM content. The implied threat is that they will reject U.S. wheat because they do not believe that adequate segregation systems are in place to avoid GM "contamination."

2) Trade Volumes and Alleged Buyer Acceptance, the data illustrates that:

   - The U.S. domestic market is by far the domineering market and, as suggested here, is generally non-averse.

   - Aside from the U.S. market, the largest GM averse markets are Japan, the Philippines, Korea, and the EU countries (notably, Italy, Spain, and the United Kingdom).

   - Taken together, these results suggest that about 72 percent of the market would be GM tolerant, the remaining being potentially averse.

   - Some of the countries that are claimed to be averse to GM content in wheat are large importers of soybeans and corn, both of which have production of GM, at least from the United States. This suggests that these countries have established protocols to facilitate grains and oilseeds from regions in which there are known production of GM grains and oilseeds.

3) Canadian Impacts: Ten key export markets were identified that Canada risks losing due to being a first mover in the introduction of GM wheat. Results from Furtan, et al. indicate that:

   - If Canada were to register GM wheat, the markets that demand GM-free wheat would turn to other exporters where GM wheat is not registered, such as Australia, the EU, and the United States. Canada would then sell its wheat into those markets that are indifferent to GM wheat, such as China.

   - While GM wheat will make production cheaper, those agronomic benefits are more than out-weighed by the costs of segregation of GM wheat, the impact of lost export markets, and lower wheat prices.

4) United States Impacts: DeVuyst, et al. (2001) indicated that in most scenarios, U.S. producers stand to gain considerably due to GM wheat introductions, assuming a 4.8 percent cost savings for GM versus Non-GM wheat. Their results indicate that the United States may have a first-mover advantage even when importers of U.S. wheat do not accept GM wheat.

Segregation and Identity Preservation and GM Wheat Marketing

Definitions of what constitutes an IP system vary substantially and are sometimes posed as a mechanism to assure Non-GM marketing. An alternative would be systems of testing, segregation, and contract specifications to assure Non-GM content. Numerous studies have examined IP/segregation costs for a range of commodities using different methodologies. Results from these and implications for GM wheat marketing are identified below:

1) The estimated costs of segregating IP grains from these studies range from 1 to 72 cents/bu.

2) Economics of Testing and Tolerances: An alternative or complement to IP types of systems is the use of testing and tolerances.

    - Several companies are developing or have developed tests for GM wheats, and their proposed costs have been reduced in the past few years. Typically these would be applied at different points in the marketing system and, depending on the size of the unit, would convert to about 0.2 to 3.6 cents/bu.

    - Concurrent with any test is a tolerance which is normally specified in purchase contracts. There are two forms in which tolerances are applied. One would be those defined by regulatory agencies (e.g., the FDA and like agencies in other countries). Second, would be as commercial tolerances. Ultimately, there will be varying types of limits and tolerances specified by domestic and international buyers.

    - Testing has inherent risks and costs and is subject to error. Risks are defined as buyers receiving a product that should be rejected and sellers having a product rejected that should have been accepted.

3) Estimates of the Costs and Risks of Testing and Segregating GM Wheat. Results of a study specific to wheat identified the optimal testing strategies of a GM/Non-GM system versus the existing Non-GM system. Results indicated:

    - The optimal strategy would be to test every 5^{th} railcar at the country elevator when loading and to test every ship sublot when loading at the export elevator.

    - This testing strategy results in average rejection rates at the importer of 1.75 percent.

    - The total cost to the system was estimated at 3.4 cents/bu. The cost of the system includes additional costs of testing and rejection, and a risk premium to the handler due to the added risk of handling Non-GM in a dual marketing system.

- An important component of the system is some system of variety declaration, which could be envisioned as part of a closed loop system. A system with no variety declaration results in significant misgrading and raises costs substantially. Similarly, a system not including testing would raise costs upwards to 13 cents/bu.

Results indicated that a system based on testing and segregation can assure buyers of GM content at a low cost. While nil tolerance cannot be achieved through a system based on testing, the GM content can reasonably be assured at the 1 percent level. Second, the costs of a system based on optimal testing and segregation, inclusive of a risk premium, are much less than most systems that have been proposed on IP and other means to control GM content. Finally, many factors will affect the elements of an optimal testing system, costs, and risks. Most important among these are price discounts/costs for being out of contract and GM declaration at delivery.

Risks in GM Wheat Production and Marketing

There are potential sources of risk in GM wheat production. These include risks in production, handling, and to the organic sector.

1) *Agronomic Risks.* Most of the recent research suggests that there is risk of outcrossing and volunteers. However, in the case of wheat, these risks are relatively minimal.

2) *Risks to Organic Production*. Another important and impending problem in the case of GM wheats is the impact on the organic production sector.

Evolution of GM Wheats and Marketing System Implications

Existing research, as well as the experiences of other GM grains and oilseeds, suggests a number of implications on how the commercialization and adoption of GM wheats will evolve. This section is explorative about the likely evolution of GM wheat and suggests some of the implications for the grain marketing system.

Likely Evolution of GM Wheat

The evolution of GM wheats will likely evolve as, and in response to, the following pressures:

1) Further development and differentiation will persist in the other major grains, notably corn, soybeans and canola.

2) Pressures will escalate to commercialize the GM wheat traits currently in the research phase. These would likely be in order of herbicide tolerance (RRW), fusarium resistance, and then varying forms of quality traits.

3) Productivity of other small grains (e.g., barley, durum, others) will lag substantially, ultimately raising their costs and reducing acres of these crops.

4) There will be an escalation of specialization in several dimensions to accommodate GM wheats. More than likely, these would or could be by geographical regions, handling facilities, and potentially even at the grower level.

5) A dual marketing system will evolve to accommodate the co-existence of GM and Non-GM wheats (described below). The marketing solutions to the differentiated customers will be through adoption of systems of contracts, tolerances, testing, and price differentials.

6) Buyers and growers will be needing to be less random in their marketing functions. Prior to making purchases, buyers will have to predetermine and inform sellers/producers of desired traits and attributes, and growers will have to supply more information with respect to production (varieties, agronomic practices, etc.) and delivery (time and place).

Marketing System Implications

The motivation for the evolution above is really in response to the growing differentiation among countries and, ultimately, among buyers within a country, concurrent with more technological choices in production. In addition, asynchronous regulations, along with selected buyer resistance and indigenous differentiated demands, ultimately suggest that a dual marketing system (or a marketing system to facilitate coexistence) is inevitable. This is likely true in the domestic market even though labeling would be voluntary with different approaches likely adopted by buyers for branded versus non-branded (e.g., private label, food service) products. This would also occur internationally between countries with and without tolerance limits and/or other requirements for the traits and those with approved traits.

In response, the marketing system will evolve in what may be called a "dual market" to accommodate these technologies and demands. To facilitate this it is envisioned that the following will be important:

1) *Buyers:* Both domestic and international buyers averse to GM wheats will need to specify some tolerance level and testing is adopted. This will take the form of contracts, testing methodologies, and tolerances.

   Those buyers with non-nil tolerances (to the 1 percent level or slightly less) should be able to purchase GM wheat with a nominal additional cost using contractual restrictions. Those buyers wanting nil tolerances will have to be more aggressive in their procurement strategies, working more closely with suppliers, targeting origin regions and facilities.

2) *Growers*: Growers declare varieties at point of first delivery. Specifically, growers would make some type of declaration about whether the delivery contains a GM variety.

   There are three important implications or reasons for this. First, is that it provides low cost information that is useful to the handler in segregation. If such a system were not adopted, the costs and risks would escalate sharply. Second, this will have the impact of facilitating marketing by varieties, or groups of varieties, which may become a component of contract specifications. Finally, this may take the form of being implemented as a component of some type of closed loop system that would be facilitated by technology providers.

3) *Handling and Testing:* Competing models of handling and segregation will evolve. Initially, these may involve IP types of systems. Eventually, due to competitive pressures, improved testing, and greater knowledge by marketers, systems based on contract specifications, penalties, and testing protocols will likely emerge. The reason for this is that it would likely be lower cost than some proposed IP systems. Testing will likely be more comprehensive, strategic, and complex as suggested in these results. This would be in contrast to routine testing across shipments, origins, and buyers.

4) *Price Differentials:* Over time price differentials will evolve among wheats with different GM trait content. This will likely be not unlike current price differentials for measurable traits and attributes. The price differentials will very likely evolve to be similar to the cost differentials to the system.

5) *Protocols*: Protocols will evolve that will govern trade and marketing practices. These will likely be mechanisms that govern buyer-seller relations, as well as relations among growers, handlers, and technology companies.

6) *Certification*: Differing certification processes will likely emerge in response to the differentiated demands and requirements. This may very well involve certification by 3rd party private testing companies or by official government agencies.

Unresolved Issues and Future Initiatives

Commercialization and adoption of GM wheats poses many opportunities and challenges. Despite there being extensive research on the topic as summarized in this paper, there are also many unresolved issues. These are not inconsequential and are summarized below, the purpose being to motivate further work in areas to facilitate coexistence of differentiated demands and technologies. These include:

1) *Organic Product Marketing*: There are numerous opportunities in this sector, but there are also a number of challenges as noted above.

2) *Facilitative Government Intervention*: At least in the United States, there are already extensive regulatory processes at the federal level governing the relevant aspects important to GM wheat production. Thus, trying to replicate these by state may be fruitless. However, there are other facilitative mechanisms that will need refining in the case of GM wheats. These include 3rd party certification and seed stocks purity, among others.

3) *Research*: The prospects of GM technology in wheat poses many unanswered questions. These will go begging for answers and a research plan should be important to providing means to answers to these questions.

4) *Food Processors*: Food processors most likely will confront increased heterogeneity in product demands with segments becoming defined for organic, Non-GM, and indifferent. Firms in this sector will have to develop marketing, procurement, and processing sectors to match these evolving product market segments and technologies in production and processing.

5) *Informational Demands*: The demands for information about GM wheat will escalate. Buyers will be wanting information about traits under development, traits that have been approved, and where that production is geographically concentrated. Growers and sellers will demand the same, as well as the approval of traits by different domestic and international buyers. Thus, some mechanisms should be developed to efficiently and credibly provide this information.

6) *Extension/Education*: There are numerous demands for education by consumers, marketers, and growers. The latter would naturally fit into Extension programs about appropriate farm management practices. However, there will also be demand for education for handlers about testing, certification, market acceptance, and protocols.

7) *International Marketing and Outreach for GM Wheat*: Given the size, diversity, and state of knowledge among international buyers, there will be large demands for information within this sector. As the number of approved traits escalate, opportunities for international marketing and outreach will escalate.

Issues in Development and Adoption of Genetically Modified (GM) Wheats

William W. Wilson, Edward L. Janzen, Bruce L. Dahl, and Cheryl J. Wachenheim*

Introduction

In contrast to other grains and oilseeds, commercialization of GM wheats is evolving concurrent with a fairly extended process of public scrutiny. The path taken in the case of GM wheats is more elongated for numerous reasons.[1] Development and commercial adoption of GM wheats have important implications for many aspects of the wheat production and marketing industry. These developments provide numerous opportunities and challenges to the wheat marketing industry and have become particularly challenging for wheat for a number of reasons. First, wheat has not yet enjoyed the agronomic benefits associated with biotechnology and overall committed research as have soybeans and corn and, as a result, its agronomic competitiveness has been reduced and acres have been redirected to other grains and oilseeds. Second, there is dichotomy in demands for potential GM wheats, with some markets being more averse than others to GM content. Third, there are a number of end-use characteristics that could be developed through these techniques, in addition to the current emphasis on first-stage benefits.

The purpose of this paper is to summarize the current state of knowledge on some of the critical issues for commercialization of GM wheats. First, some background is presented on the evolution of GM Wheats. Separate sections are then presented on agronomic adoption and competitiveness of GM crops; research on GM traits in wheat; consumer acceptance of GM crops (a separate section is included on issues related to consumer acceptance of GM crops); regulatory issues and status; international trade; testing, segregation, and identity preservation; and production and marketing risks. The final section provides a summary of the facts identified in this paper, a description of the likely marketing system to evolve, and a discussion of outstanding issues.

1. Background: *GM Wheats*

This section provides a background description to the problem and some detail to its various elements.

Development of GM wheats has lagged other grains and oilseeds for varying reasons. Most important is likely the more complex genetics and the lack of a substantial effort in financial researcher commitment. Other contributing factors include: 1) wheat is a smaller

---

* Wilson is Professor, Janzen is Research Associate, Dahl is Research Scientist, and Wachenheim is Assistant Professor, in the Department of Agribusiness and Applied Economics, North Dakota State University, Fargo.

[1] The term GM wheat is used throughout this paper to be general and recognize that there are several traits prospectively anticipating being adopted. At the forefront is *Round-Up Ready*® Wheat, but others including fusarium resistant (Syngenta), drought resistant (DuPont), and varying forms of end-use trait enhancements are being developed.

volume crop within North America; 2) exports are of greater relative importance; 3) import country regulations are less well defined and vary much more for wheat; and 4) competition among exporting countries is likely more intense and compounded by radically different marketing systems regarding quality and trade practices.

These points notwithstanding, there are several initiatives for development of GM wheats. In North America these have been primarily on the *Round-up Ready®* trait, though there is extensive research elsewhere on a wide range of GM traits in wheat (e.g., fusarium resistance by Syngenta, drought resistence by DuPont, among others). Most development in North America is focused on Hard Red Spring (HRS) wheats, although there is a substantial effort in white wheat in Kansas and Nebraska. Experimental HRS trials are being planted in South Dakota, North Dakota, Minnesota (and no doubt elsewhere), as well as in the Canadian prairie provinces.

If approved in the United States and/or Canada, there would be no limits on the adoption of these traits, except for the extent that individual companies may impose a limit or tolerance level. If the traits are approved in Japan, wheats can be imported, but products would be subject to labeling laws. Since this trait is not (yet) approved in the European Union (EU), it would imply a nil tolerance. The EU proposed a policy (July 27, 2001) that has been under debate, which would allow for a 1 percent tolerance along with some form of yet to be specified system of traceability, and subject to labeling requirements. More recently, a proposal was made for a 0.5 percent tolerance and a 0.9 percent tolerance for labeling. Developments in these countries are pending and will impact the evolution.

Round-up Ready® Wheat (RRW) is an example of 1st stage benefits. Other 1st stage benefits should be commercially available by 2005 (Bloomer). However, 2nd and 3rd stage benefits will not be accessible till 2006 and beyond. In the case of wheat, 2nd stage effects would likely include enhanced protein quality, nutritional content, novel starch types (functionality), reduced allergens, and improved freshness and shelf-life for baked products. These observations were echoed by Biane indicating that consumer benefits in the case of wheat include extended shelf life, improved nutrition, and reduced allergens.

In summary, the pressures for adopting GM wheat, specifically RRW, come from a combination of cost reduction, reduced dockage, increased profitability of competing crops (being recipients of GM technology), and the prospect of 2nd and 3rd stage benefits associated with GM wheats.

1.1 Positions Taken by Major Industry and Interest Groups

An important element of commercialization of GM wheat is that all of the important stakeholder groups have positions. These include the National Association of Wheat Growers and U.S. Wheat Associates (and now complemented by the position of the Farm Bureau), the North Dakota Grain Growers Association (NDGGA), the American Bakers Association, the Canadian Wheat Board, and the Australian Wheat Board, among others. In virtually all cases, the position reflects that biotech wheats are desirable, mostly looking to 2nd stage benefits;

research on biotechnology wheat should continue, but GM wheats (particularly RRW) should not be commercialized until systems involving Identity Preservation (IP) and testing are developed to satisfy needs of buyers.

In the past year, several major wheat marketing organizations have taken positions that are important to the evolution of GM wheat marketing. Monsanto has indicated they would not release RRW until/unless approval of the trait occurs in the United States, Canada, and Japan and a viable testing and segregation system is developed.

The *U.S. Wheat Associates/National Association of Wheat Growers'* position is that they will "work with all segments of the industry to develop and ensure that a viable identity preservation system and testing program is in tact prior to commercialization of biotechnology products." In addition, they "support an establishment of a reasonable threshold tolerance for adventitious commingling of biotech traits in bulk wheat or products derived from bulk wheat in both U.S. and international markets."

The *North Dakota Grain Growers Association* addressed these issues and adopted the following resolutions in late 2002: 1) urges the Joint Biotech Committee to develop and execute a strategy to gain market acceptance of biotech wheat as soon a possible; 2) supports an increase in the investment in, and research of, biotechnology enhanced wheat products at North Dakota State University; 3) supports research, development, and the advancement of biotechnology for the opportunity it provides consumers, processors, and production agriculture, and encourages the education, promotion, registration, and customer acceptance of genetically enhanced wheat worldwide; 4) opposes any mandatory labeling for products made from crops that are enhanced through the use of biotechnology; and 5) opposes a moratorium on the research and development of biotech crops.

The *National Grain and Feed Association* also encourages biotechnology crop development. They would want that (among others): 1) as part of the registration process, the protocols for segregation, testing, and IP, etc., be provided to entrust segregation; 2) analytical tests be defined and approved by the U.S. Department of Agriculture (USDA) for purposes of determining the presence of GM content; and 3) the U.S. government should work toward commercially achievable thresholds for adventitious presence of GM grains in Non-GM grain shipments.

The *American Bakers Association* (ABA) believes "all biotech crops and ingredients must be accompanied by an efficient, inexpensive trait identification system with accuracy of detection to meet USDA/FDA/EPA and foreign customers' labeling or purity requirements." The ABA will "work with all segments of the grain and cereal foods processing industry to develop and assure that a viable segregation and testing program is instituted prior to commercialization of biotech products."

The *North American Millers' Association* (NAMA) suggests that technology providers and regulators place close consideration to: 1) thresholds–reasonable thresholds must be adopted to allow the movement of grains with adventitious admixture; 2) testing; and 3) identity preservation which they question as being the solution to marketing of biotech-based grains.

The USDA/GIPSA plays a prospectively important role in this evolution. To be responsive, in November 2000, they invited comments related to alternatives for marketing of grains given a market that houses biotech and non-biotech products. That agency is in the process of determining how to facilitate the evolution and commercialization of biotech grains. More recently, the GIPSA is proposing a system of *process certification* which could be used to ameliorate some of the problems associated with marketing of GM grains (USDA-GIPSA, 2002).

In addition to these, positions have been taken in the primary competitor countries. Noteworthy among these include that of the *Canadian Wheat Board* (CWB). Their objective is to ensure that the introduction of GM wheat and barley varieties for production, handling, and marketing will be accomplished in a manner that will satisfy customer requirements and result in net benefits to western Canadian farmers. However, the CWB believes that GM wheat should not be made available until proven technologies and associated protocols and procedures are intact to avoid commingling of transgenic and non-transgenic varieties. The CWB believes the segregation system should have the ability to test accurately, quickly, and economically for transgenic presence.[2]

The problem in wheat is compounded due to the fact that most of the effort is focused, at least initially, on HRS wheat which is the primary wheat class grown in northern tier states and Canada. Thus, Canada's position and adoption will have a critical impact of the post-adoption competition. Most important is that the mechanisms to facilitate adoption of GM wheats in Canada are different than those in the United States (e.g., variety approval process, variety kernel distinguishability, contract calls, the ability to add/create subclasses of wheat with specific characteristics).[3]

It does not appear the *Australian Wheat Board* (AWB) has a formal policy on this issue. However, various organizations in that country are studying the problem (ABARE; Foster). They note that the additional marketing costs of keeping GM grain separate during production and distribution is not inconsequential, even in that country which has extensive controls.[4]

---

[2] The CWB refined their position as "The preconditions for introducing a GM variety include a credible segregation system, effective testing and sampling methods, and reasonable tolerance levels for GM content" (Wilson, B.)

[3] All of these would suggest that it would likely be lower cost to adopt mechanisms to control for GM grains in Canada than in the United States.

[4] The Government of Australia currently has a major study ($3.65 million over four years) to assess costs of segregating products. Australia has also enacted labeling laws that became effective December 7, 2001 (*Feedstuffs* Staff Editor).

It is noteworthy that in March 2002, Syngenta and AWB entered into an agreement to develop wheat varieties which are competitive in Australia (Syngenta News Release, March 8, 2002). Specifically, this is a joint venture between the AWB and Syngenta "to breed and develop innovative and competitive wheat varieties for the Australian market....... The objectives of LongReach [the name of the joint venture] are not only to deliver varieties that are competitive for growers in the field, but equally to continue to improve grain quality and its suitability to meet end user and consumer needs."

In all cases, there is an insinuation that development of a GM wheat is good and should be pursued. However, it is clear that GM wheats should not be commercialized until some type of IP and testing system is developed to mitigate risks to buyers and certain tolerances set and agreed upon.

2. Adoption Rates and Agronomic Competitiveness of GM Grains and Oilseeds

The first trial of transgenic plants (insect resistant tomatoes) was conducted in 1987 with the first introduction of a genetically engineered plant (the FlavrSavr tomato) in 1994. From the first wide-scale planting of genetically engineered crops–Bt corn and cotton and Roundup Ready soybeans in 1996–the rate of adoption has been very dramatic. Production of these genetically modified crops is increasing globally. Growth is most evident in industrialized countries but is also growing in developing countries.

This section describes the evolution and growth in adoption of GM grains and oilseeds worldwide and in North America. In addition, issues related to agronomic competitiveness are summarized.

2.1 Global Growth

The global area tilled with genetically modified crops reached 52.6 million hectares (130.0 million acres) in 2001, up 19 percent from 44.2 million hectares (109.2 million acres) in 2000 (Figure 2.1). In 2001, 99 percent of this global transgenic crop area was grown in four countries–the United States, Argentina, Canada, and China (Figure 2.2). In 2001, 68 percent of the global area of transgenic crops was in the United States, 22 percent in Argentina, 6 percent in Canada, 3 percent in China, and 1 percent in all the other countries. In 2001 it was reported that 13 countries grew transgenic crops (James).

The four major crops comprising most of the commercial transgenic crops in the world are soybeans, corn, cotton, and canola (Figure 2.3). Adoption from a global perspective is shown by the percentage at which transgenic technology is used (Figure 2.4). The herbicide tolerant (HT) soybean is the most widely adopted GM crop. The high rate of adoption reflects cost savings associated with its production and ease of use, as well as soybean production being concentrated in countries in which GM varieties are approved, primarily the United States and Argentina.

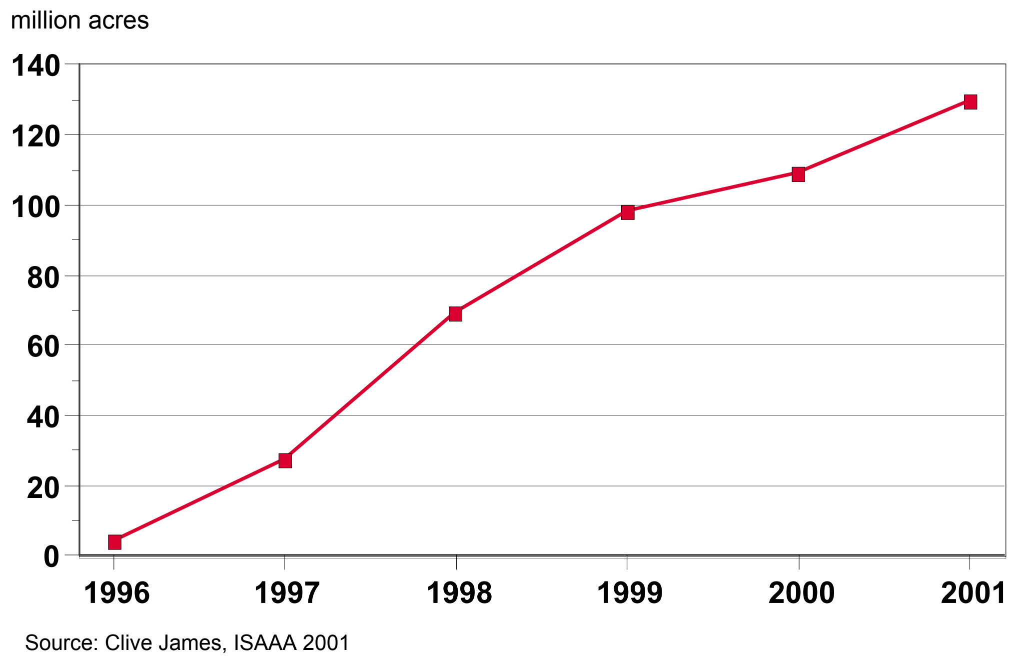


Figure 2.1. Global Area of Transgenic Crops.

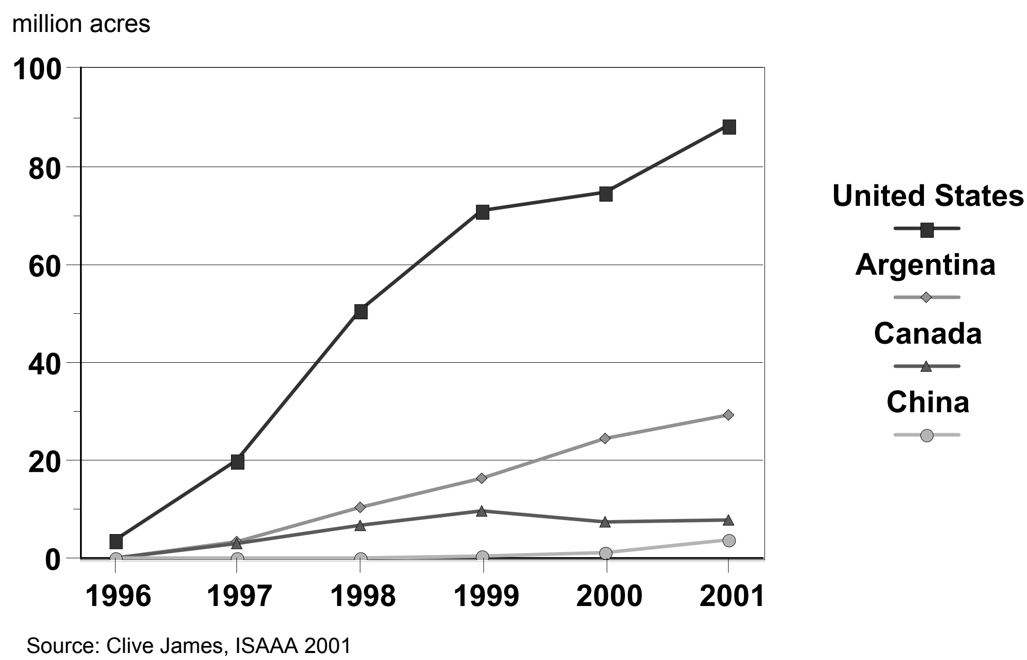
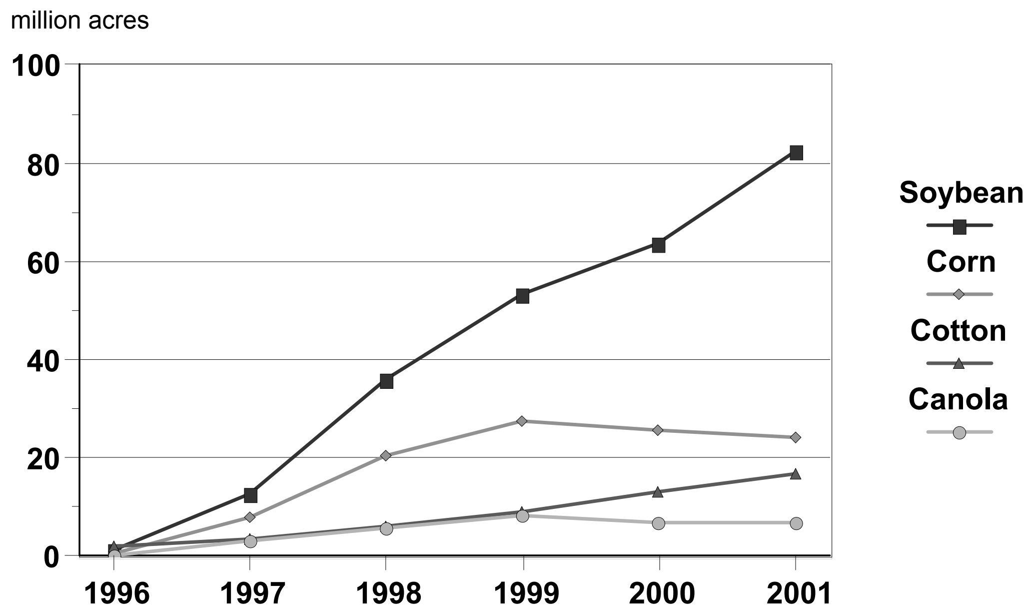
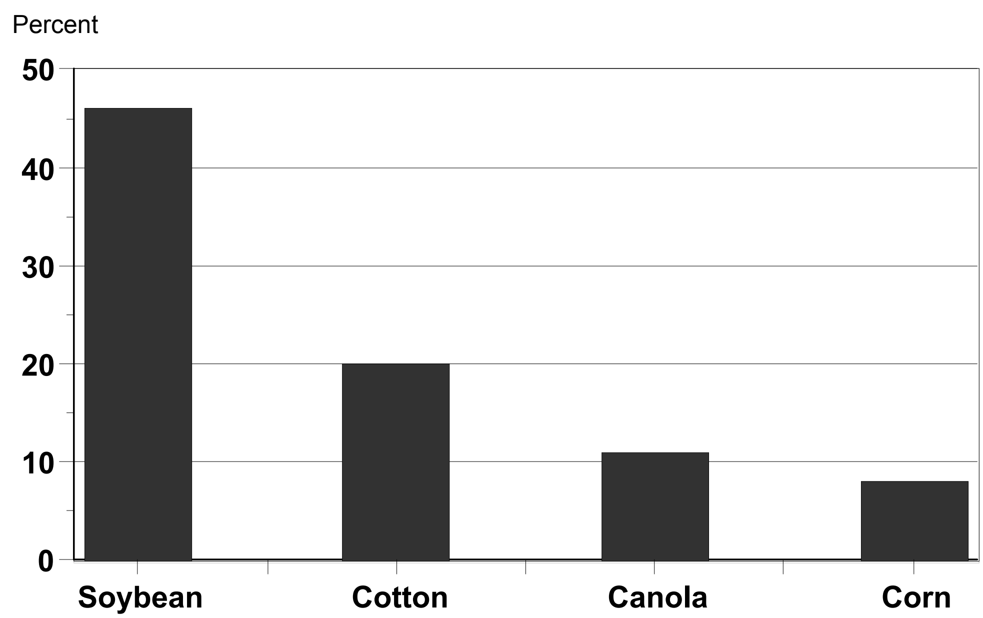


Figure 2.2. Global Area of Transgenic Crops, by Country.



Source: Clive James, ISAAA 2001

Figure 2.3. Global Area of Transgenic Crops, by Crop



Source: Clive James, ISAAA 2001

Figure 2.4. Global Area Adoption Rates, 2001 (Principal Transgenic Crops, Percent of Total Crop Area)

The Argentine Association of Seed Companies estimated that farmers used GM seeds for 90 percent of the record 10.4 million hectares planted to soybeans in the 2000/01 campaign, more than 20 percent of the area planted to corn and about 8 percent of the area planted to cotton (Crop Biotech Update).

Some planting is being imported into areas without government permission for growing GM crops. Brazil has had an import and production ban on genetically modified crops since 1998; however, GM soybeans, which are legal in neighboring Argentina, are being smuggled into Brazil to be sold and planted. Government officials estimate that some 4 million hectares of GM soybeans are being grown throughout the country. This accounts for some 25 percent of Brazil's soybean production (Pegg).

2.2 Growth in the United States

The adoption of biotech crop varieties has had the greatest growth and penetration in the United States. The growth of acreage planted to biotech varieties of corn, soybeans, and cotton, by trait, is shown in Table 2.1. Acreage of biotech varieties of soybeans increased significantly in 2002. Biotech corn acreage increased significantly in 2002, after slowing in 2000 and 2001 due to the StarLink controversy. Acreage of biotech cotton also increased in 2001. The USDA does not report GM statistics for canola.

In the upper Midwest the percentage of planted acres in biotech varieties of corn and soybeans by state for 2000, 2001, and 2002 is noted in Table 2.2. Planted acreage of biotech corn in each state noted continues to exceed the average for the United States. Planted acreage of biotech soybeans in 2002 increased significantly over 2001 in each of the states noted. Only in North Dakota and Minnesota was the percentage of biotech soybeans below the U.S. average in 2002.

2.3 Agronomic Competitiveness

Farmers are adopting genetically engineered crop varieties, particularly corn, soybeans and cotton, at a rapid rate. The widespread producer acceptance of GM crops (corn and soybeans) in the upper Midwest would seem to indicate a willingness of producers to accept GM wheat when it becomes available.

Table 2.1. United States: Percentage of Crop Acres Planted to Bt and Herbicide Tolerant Varieties

	1995	1996	1997	1998	1999	2000	2001	2002
CORN [1]								
Bt (insect resistant)	0	1	8	19	26	18	18	22
Herbicide tolerant	0	3	4	9	8	6	7	9
Stacked	0	N/A	N/A	N/A	N/A	1	1	2
	0	4	12	28	34	25	26	34
SOYBEANS								
Herbicide tolerant	0	7	17	44	56	54	68	75
COTTON [1]								
Bt (insect resistant)	0	15	15	17	32	15	13	13
Herbicide tolerant	0	2	11	26	42	26	32	36
Stacked	0	N/A	N/A	N/A	N/A	20	24	22
	0	17	26	43	74	61	69	71

(1) Estimates for HT and Bt CORN and COTTON for the years 1997 to 1999 includes stacked varieties (crops containing both Bt and HT genes). This suggests that for those years the percent of acres devoted to stacked varieties are included in both the Bt and HT crop estimates. For the years 2000 forward, the percent of acres in stacked varieties was identified.
Source: USDA/ERS, http://www.ers.usda.gov/briefing/biotechnogy/data/gmoacres1.xls, accessed August 2001, and USDA/NASS, *Acreage Report*, June 2002.

Table 2.2. U.S. Plantings, Farmer Reported Biotech Varieties, Percentage of All Planted Acres

State	**Corn**			**Soybeans**		
	2000	2001	2002	2000	2001	2002
ND	N/A	N/A	N/A	22	49	61
SD	48	47	66	68	80	89
MN	37	36	44	46	63	71
IA	30	32	41	59	73	75
NE	34	34	46	72	76	85
KS	33	38	43	66	80	83
US	25	26	34	54	68	75

Source: USDA/NASS, *Acreage Report*, June 2001 & June 2002

Existing Studies. A compilation of many papers and review documents about the yield of biotech crops and their environmental impacts are available at *AgBioWorld* (2002a,b). They report on crops already in commercial production–Bt and HT corn, HT soybeans, and Bt and HT cotton.[5] Although a few of the listed studies found no improvement or worse results, the vast majority show biotech crops to be superior to conventional crops from an agronomic perspective.

Producer acceptance is being driven by expectations of higher profitability. From an agronomic standpoint, the two factors that affect the profitability of any genetically modified, HT crop are relative yields and costs. In most cases, the higher input costs associated with higher seed costs and associated technology fees are expected to be offset by lower production costs resulting from reduced tillage costs and reduced pesticide use. Revenue is influenced by potentially higher yields resulting from less insect damage and competition from certain weeds. The convenience factor of simplifying the production system may also allow for greater economies of size in production operations.

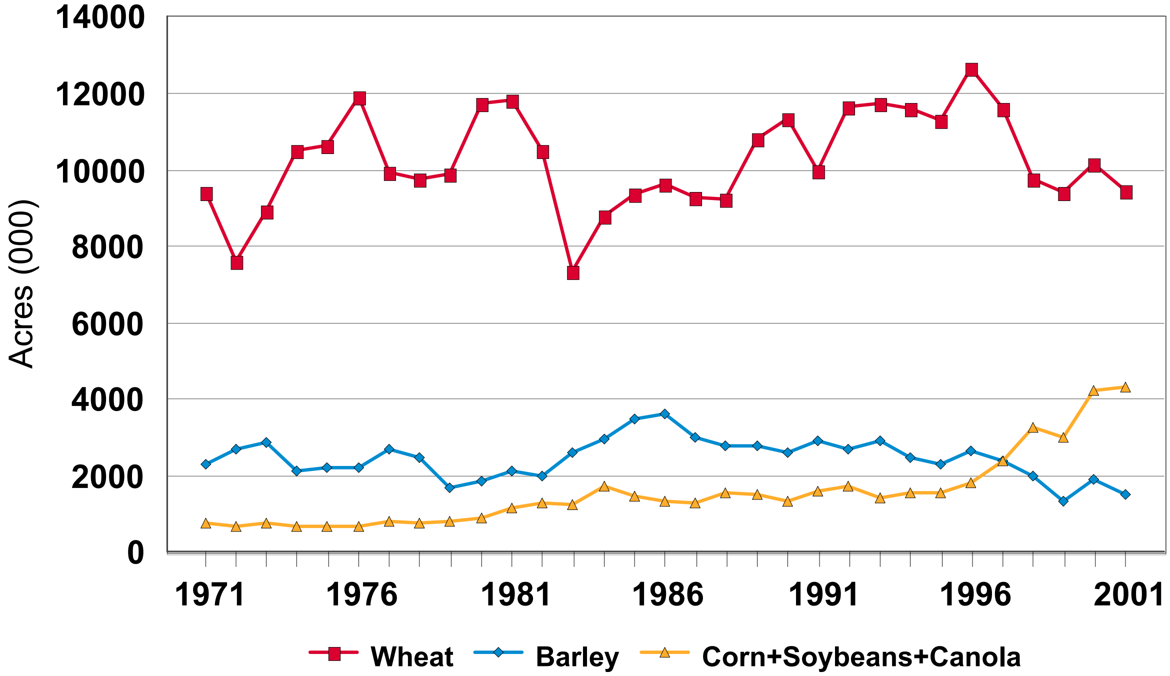
Agronomic Competitiveness and Acreage Shifts in North Dakota. There has been a historical change in gross returns for corn, soybeans, and wheat over the past 40 years in North Dakota (Table 2.3). Not surprisingly, there has been a general decline in planted acreage of wheat and barley in the state over the past 30 years. This decline is largely replaced by planted acreage of corn, soybeans, and canola, particularly since the introduction of GM varieties in these crops (Figure 2.5). This shift in acres is in large part due to the increased returns realized with GM crop varieties, as well as the impact of vomitoxin which began to adversely affect wheat and barley in some regions in 1993.

Table 2.3. Historical Change in North Dakota Corn, Soybean, and Wheat Gross Returns

	Gross Returns ($/acre)		
	Corn	Soybeans	Wheat
Average 1961-1965	34	38	38
Average 1997-2001	190	152	94
Change, %	449	304	148

Source: Derived from USDA/NASS data.

[5] Not all agronomic researchers agree on the improvement of agronomic competitiveness with the use of GM crops. Duffy indicated that while the use of HT soybean varieties results in lower herbicide and weed management costs, they also have higher seed costs and slightly lower yields. He noted there does not appear to be any difference in the per acre profitability between the HT and conventional soybean varieties. While yields for Bt corn were slightly higher than non-Bt corn, similar to HT soybeans, Bt corn produced a return essentially equal to the non-Bt corn.



Source: North Dakota Agricultural Statistics Service

Figure 2.5. North Dakota Planted Acreage

RRW and Agronomic Competitiveness. There are two primary sources of agronomic advantages for RRW. These are yield increases and reduced dockage.[6]

The most comprehensive measure for yield differences as reported by Monsanto indicates that RRW results in an average advantage relative to conventional crops of 4 bu/acre or a general expected increase of 11 to 14 percent. These are from data derived over a 3-year period and broad geographical regions.[7] In addition, results from a recent study (Blackshaw and Harker) indicated yield advantages ranging from 4 to 16 percent versus conventional weed treatment.

The second agronomic benefit is that of reduced dockage content. It is significant that a major longer term problem for northern tier wheats is that of dockage content (Dahl and Wilson). This has resulted in problems for importers and handlers and is an issue affecting the attractiveness of U.S. hard wheats relative to competitor countries. RRW wheat has the impact of reducing weeds and, therefore, weed seeds contained in dockage. Research has suggested that

---

[6] To the authors' knowledge, the only source of this information is from the material distributed by Monsanto, which is summarized here.

[7] Unpublished Data from Monsanto.

the adoption of RRW in Hard Red Spring (HRS) wheat areas would have the following impacts (Wilson, W.):

- reduced weed seeds which comprise 62 percent of wheat dockage content;
- reduced cost of dockage removal throughout the marketing system; and
- the reduced dockage would result in cost savings in the area of 5.5 cents/bu (versus current system costs of 8.4 cents/bu), or about $1.32 to $2.73/acre.

In addition to these, there are other alleged benefits related to adoption of RRW, as suggested by Monsanto. These are the future prospects of improved protein content, increased quality consistency, and increased crop safety (less crop injury). Taken together, Monsanto has indicated that these agronomic benefits would increase net returns by about $15 to $20/acre.

Holzman examined farm level impacts of adopting HT wheat. A simulation model was utilized to evaluate effects on yields and costs for standard crop rotations utilizing conventional and no-tillage systems with HT wheat. Results measured as discounted net returns indicated overall benefits of adopting HT wheat were positive, although highly sensitive to the types of crops and tillage system utilized by the producer.

A discussion paper by the Canadian Wheat Board (CWB) described the agronomic benefits and risks associated with the potential introduction of RRW in Canada. The major concerns addressed include control of volunteer RRW, gene spread, and herbicide resistance. Additional concerns discussed include crop tolerance and yield benefits, quality, and comparisons with other RRW systems. There is no firm conclusion as to whether the potential agronomic benefits of RRW outweigh the costs and risks. Grenier indicates that as system comparisons for RRW progress, it will be important to understand the agronomic factors that contribute to yield advantages for GM, or lack there of. Effects of the weed spectrum present and density will be important when assessing the competitiveness of GM compared to conventional herbicide use patterns. The concerns identified require continued research and evaluation from an agronomic viewpoint (Grenier).

2.4 Aggregate Impacts of GM Grains on the Upper Midwest

A recent comprehensive study produced by the National Center for Food and Agricultural Policy quantified significant increases in farm income, food production, and reductions in pesticide use that may result from wider use of agricultural biotechnology in the United States (Gianessi, et al.). The study was based on 40 studies of 27 crops across 47 states and was limited to cases for which successful transformation has occurred and for which there are at least preliminary results on performance for pest management. It compares observed and potential impacts of biotech crops versus conventionally bred crops, including only biotech cultivars to be used in pest management.

The study included two different case studies on wheat: viral resistant and HT varieties. The study on HT wheat was conducted in the four states that account for 92 percent of U.S. spring wheat acreage–Montana, Minnesota, North Dakota, and South Dakota. The potential economic gains in North Dakota rank second only to California (Figure 2.6). North Dakota could see the greatest production gain because of fungus-resistant barley and HT wheat (Figure 2.7). The total economic impact of biotech crops in the four states is summarized in Table 2.4.

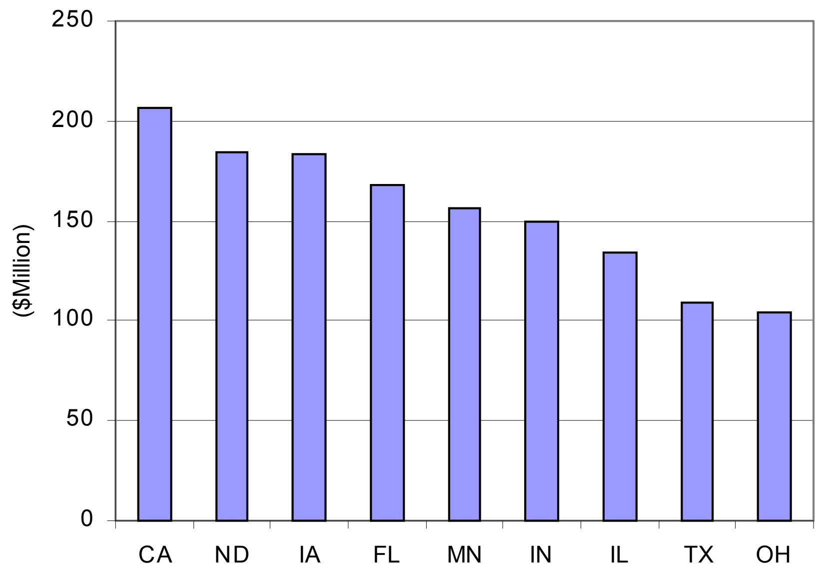


Figure 2.6. Total Annual Impact of Biotech Crops (by State)

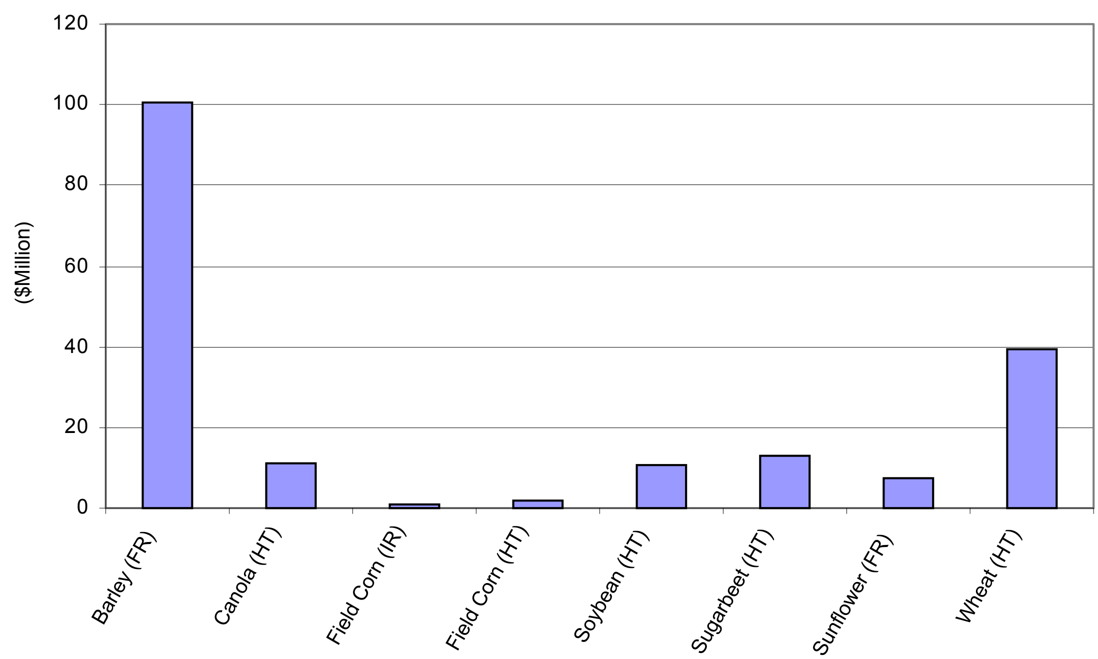


Figure 2.7. Estimated Total Change in Annual Revenues Due to Biotechnology Adoption: North Dakota Case Studies

Table 2.4. Impact of Biotech Crops by State

State	Added Income ($ mil)*	Pesticide Reduction (lbs active ingredients)
Minnesota	$156	5,145,888
Montana	$21	37,000
North Dakota	$185	86,732
South Dakota	$74	291,444

* Combines value of increased production and lower production costs if all biotech varieties studied are adopted.

In the case study on HT wheat, it is estimated that 33 percent of spring wheat in the above four states is not treated with herbicides to control Canada thistle, a key weed problem, because cost outweighs benefits, resulting in an average yield loss of 4 bu/acre. It is estimated that glyphosate tolerant wheat would control all major weeds in wheat and enable growers to increase their income by $12/acre. The aggregate of potential economic impacts of the adoption of HT wheat in these four states is shown in Figure 2.8.

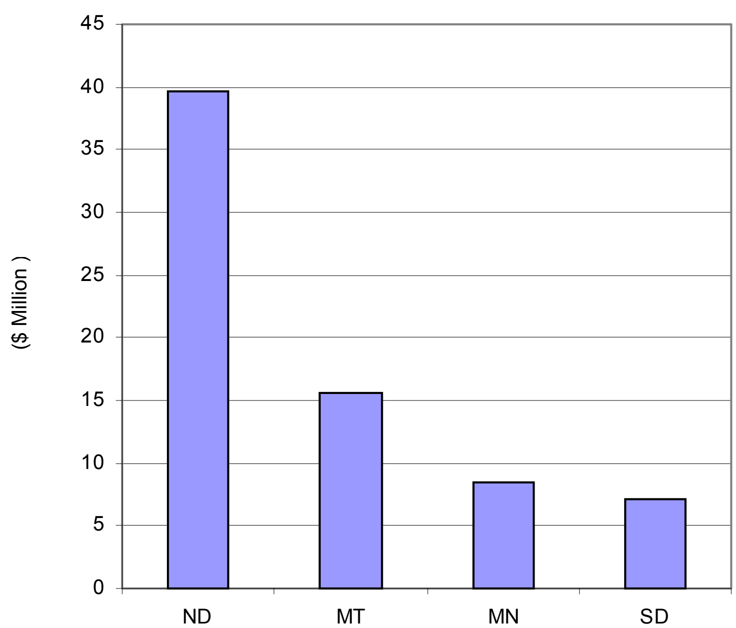


Figure 2.8. Aggregate Potential Impacts: Adoption of Herbicide Tolerant Spring Wheat

3. Research on GM Traits in Wheat

Research on development of GM traits in wheat has grown since the early 1990s. This section provides a preliminary summary of the status of research in GM traits in wheat. Data were assembled from a number of sources.[8] However, these should be viewed as non-comprehensive for the following reasons: 1) data for HRS trait development in North Dakota, South Dakota, and Minnesota are not reported, and 2) trials from Monsanto are not reported.

Nevertheless, the data is useful and suggestive of some important facts regarding GM trait development in wheat. Most important are the following:

- Research in this area has grown dramatically since the early 1990s and appears to have peaked in the later 1990s (Figure 3.1).

- The United States is dominant, albeit not the only player in trait research (Figure 3.2).

- Herbicide tolerance is only one trait under development. This is followed by product quality, fusarium resistance, and others (Figure 3.3).

- There are numerous diverse organizations involved in trait development (Figures 3.4 and 3.5). These range from private companies, state universities, federal governments, and others.

The implications of these are important for the wheat marketing industry. Of particular importance is that any debate and/or discussion regarding GM traits is more comprehensive than that of RRW which has already applied for review in the Untied States. Second, Syngenta (Syngenta, 2002) has indicated a proposed launch date of 2007 for "fusarium resistance for improved grain quality," which is likely the number one problem in small grains [Wilson and Dahl (2001) found the average discount for fusarium applied by elevators was 20 cents/bu]. Finally, there is extensive research on product quality of varying forms (e.g., protein quality, storability). All of these suggest that at some time in the future, the market, regulatory and institutional/organizational regimes will have to deal with a multitude of GM traits simultaneously.

[8] In particular, from: www.health.gov.au/ogtr/gmorecord/lr.htm; www.oece.org/ehs/biobin; www.inspction.gc/ca/english/plaveg/pbo/pbobbve.shtm; www.nbiap.bt.edu/cfdocs/fieldtests1.cfm.

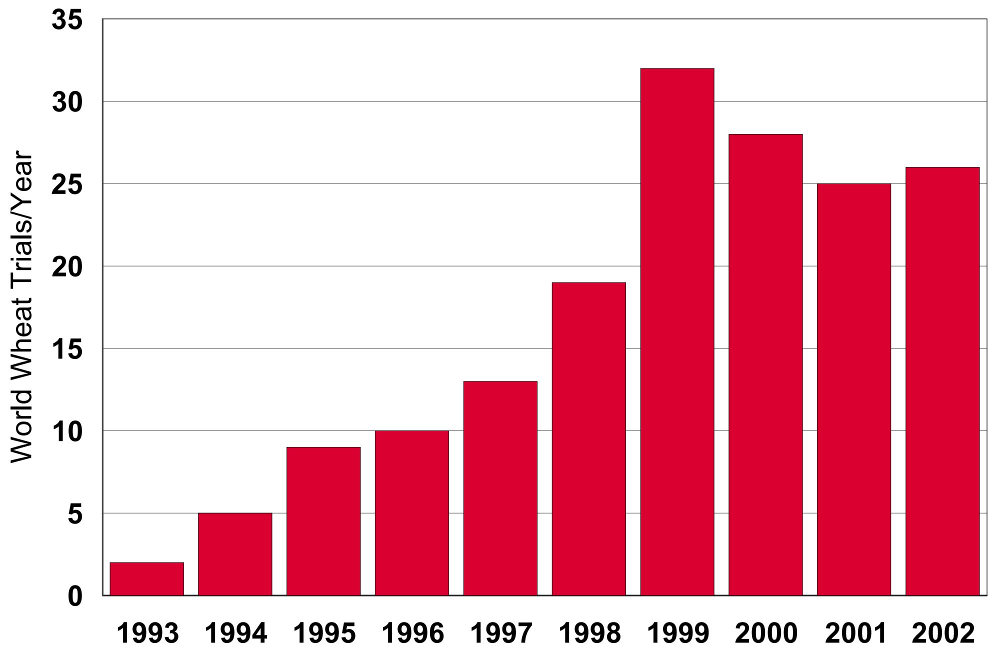


Figure 3.1. Number of World GM Wheat Field Trials by Year

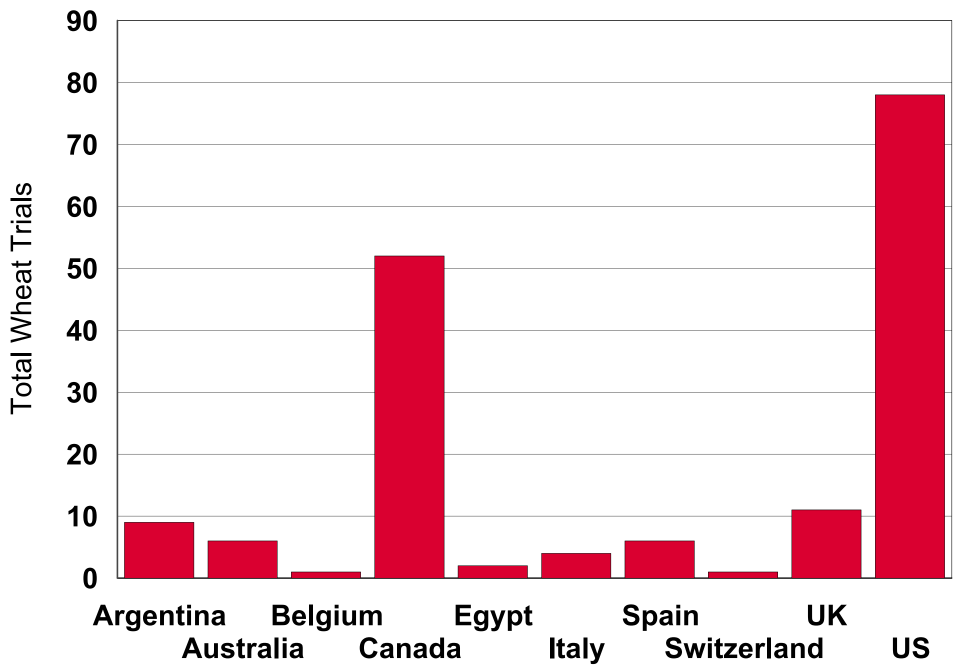


Figure 3.2. Number of Wheat GM Field Trials by Country, 1993-2002

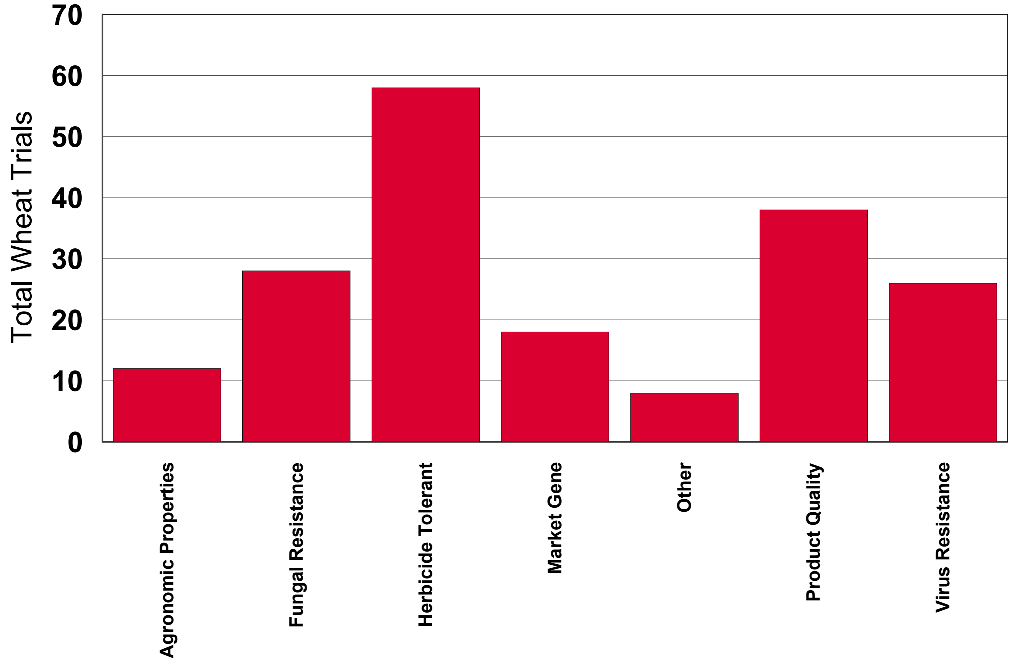


Figure 3.3. Number of World GM Wheat Field Trials by Trait, 1993-2002

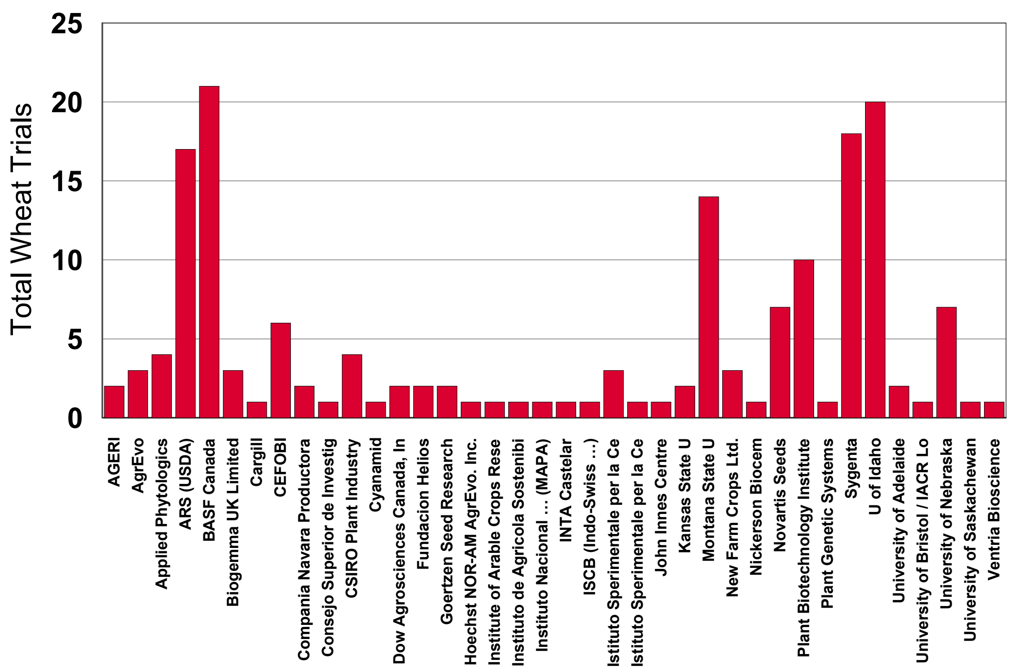


Figure 3.4. Number of World Wheat GM Field Trials by Organization, 1993-2002

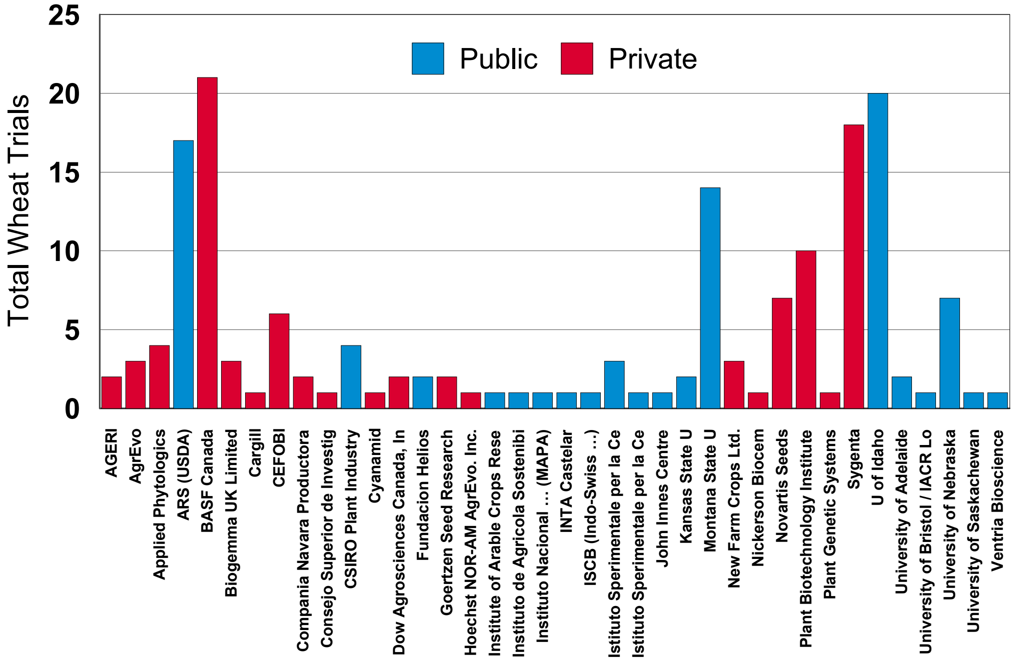


Figure 3.5. Number of World Wheat GM Field Trials by Type of Organization (Public vs. Private), 1993-2002

Review of recent literature suggests some of the innovations being pursued on developing end-use traits for GM wheats. These studies (PG Economics Limited) point to the following traits as being potentially achieved through biotechnology: altered starch content and composition, altered amino-acid profile, and altered protein content (gluten quality for bread making). Others noted that wheat quality traits will concentrate on major end-uses such as bread making; baking and noodle-making; and note that current end-use trait research focuses on modifying gluten and starch content, creating uniform kernel size; bolstering mineral content; and developing nutraceuticals of functional foods that could conceivably provide immunity to a disease to improve the health characteristics of traditional foods (Riley and Hoffman).

These represent potentially substantial changes in wheat research with:

> "The focus on genetic modifications of wheat will likely be different from that of corn hybrids, since the latter are designed to increase production efficiency, whereas the hope is that genetic modification of wheat will produce advances beyond higher yields or lower cost." (*Milling and Baking News,* April 3, 2000).

The main ways in which the quality of wheat is being genetically altered is to modify protein content to improve bread making qualities and carbohydrate composition to meet processing needs. Increased shelf life, improved taste, and greater nutritional value likewise are potential benefits transparent to the ultimate consumer and may improve consumer acceptance. Some work has already been undertaken to improve nutritional quality for humans and animals (Mayer). Biotechnology may also be applied to create pharmaceutical products that include enzymes, antibodies, vaccines, or specialty proteins for use in therapy and diagnostic techniques.

The most advanced developments underway in GM at this stage are related to input traits–herbicide tolerance and disease and insect resistance. Resistance to abiotic stress: drought, heat, cold, salt tolerance, and other environmental stresses are also being pursued. These traits may benefit consumers through lower costs though such potential benefits are not easily perceived by consumers.

4. Market Acceptance

Substantial debate exists regarding consumer acceptance of GM products. Of course, discussion of this topic is confounded by how consumer acceptance is being defined (e.g., attitudes, behaviors) and what products are considered in what circumstances (e.g., information, labeling). This section provides a summary of studies focused on consumer acceptance.[9] First, consumer attitudes on biotechnology are summarized, followed by a recent study on wheat, and then some studies on how consumers respond to varying types of information in making GM product purchasing decisions.

Consumer response to GM foods is influenced by perceptions of benefits and risks of GM food and by confidence or trust in government regulatory systems charged with risk assessment and management. A major difference in the levels of acceptance or concerns related to GM foods in the EU versus the United States is the level of confidence in the respective food regulatory systems. With the recent food scares in the EU related to "mad-cow" disease and foot and mouth disease, assurance is lacking in the European regulatory systems, particularly in Great Britain. This lack of trust is naturally carried over to GM foods.

Biotechnology is not as much of an issue for the vast majority of U.S. consumers according to a national survey by the Grocery Manufacturers of America (GMA). GMA concludes that U.S. consumers have confidence in the regulatory structure provided by government agencies like the FDA and EPA (*Farm & Ranch Guide*). American consumers also are much more trusting of scientists in general (Hoban 2000a). This confidence and trust are significant factors in the general acceptance or level of concern related to GM foods in the United States.

[9] Appendix 1 contains a separate detailed description of the state of knowledge about consumer acceptance and willingness to pay.

4.1 Market Concerns

Market concerns can generally be summarized into the following categories: ethical/social concerns, health/safety concerns, and environmental concerns.

Ethical Concerns. Ethical concerns relate to the very nature of genetic engineering and center largely around religious and moral issues. Is genetic engineering *unnatural* to the extent that we risk upsetting the natural order? Are we "tampering"with nature? With the current laws related to intellectual property rights, the issue of the "patenting of life" raises issues of morality. Social issues related to "sharing the wealth" and concerns about control of new technologies and industry concentration are also evident.

A note of interest is the fact that the Pontifical Academy for Life of the Vatican voiced a "prudent yes" to genetic engineering of plants and animals in October 1999. "We are increasingly encouraged that the advantages of genetic engineering of plants and animals are greater than the risks." (Biotech Knowledge Center).

Health/Safety. Health/safety issues include the possible (but as yet unidentified) hazards resulting from the consumption of food products derived from biotechnology. Main areas of concern in this context are toxicity, allergenicity, and nutritional value.

Supporters of GM crops argue that, in the U.S. at least, they are more thoroughly tested before the government approves them for human consumption than traditional crops. For example, testing for allergens is required for GM foods but not for traditional foods. Phillips [Biotechnology Industry Organization (BIO)] notes that "biotech crops are among the most tested products in the world and have been used in our food products for the last six or seven years and there have been no reported illnesses as a result of eating any of these food products." (Soyatech.com, posted June 25, 2001).

The Grocery Manufacturers of America estimate that 60 to 70 percent of processed food in the American market contains products of genetic engineering, e.g., sweeteners, such as high fructose corn syrup, and oils derived from corn, soybeans, and canola (Reuters). Differences in concerns about food safety in different countries are pointed out in Table 4.1, where the results of recent studies or surveys are compared. It is obvious that with only 2 percent of respondents expressing a concern about the safety of GM foods, consumers in the United States are generally accepting of biotechnology, in large part perhaps because they are generally unaware of the rapid developments in agricultural biotechnology.

Table 4.1. Concerns About Food Safety

What, if anything are you concerned about when it comes to food safety?	United Kingdom (1)	Australia (2)	United States (3)
	----------- Percentage of Respondents -----------)		
Food Poisoning	63	72	
Mad Cow Disease	61		
Growth Hormones	47		
Pesticide Use	46	68	10
Human Tampering of Foods		65	
Packaging			27
Food Handling			23
Contamination or Diseases			16
Genetically Modified Foods	43	58	2

(1) Study by the British Food Standards Agency, January 2001 (*AAP News*, May 10, 2001).
(2) Study by Quantum Market Research, late 2000 (*AAP News*, May 10, 2001).
(3) Survey for the International Food Information Council Foundation, January 2001.

Environmental. Environmental issues are the third major area of consumer concern. Some of the fears expressed are the potential for wild plants to become "super weeds," development of herbicide, pest, and virus resistance in wild plant relatives, risk of reduction in genetic diversity on agricultural ecosystems, and adverse effects on non-target organisms.

The primary environmental concern is that genetically enhanced plants may pollinate related plants and allow the genes responsible for herbicide resistance or pesticide resistance to "escape" into the wild leading to weeds and insects that are immune to modern chemicals (Singer). A much publicized concern is the fear that non-target organisms (organisms that are not pests, e.g., the monarch butterfly) may suffer damage from insect-resistant plants (such as Bt corn).

4.2 Consumer Attitudes

A national survey sponsored by the Grocery Manufacturers of America in October 2000 shows consumers in the United States are increasingly aware of agricultural technology but they have *not* changed their food consumption behavior. The survey found that only 10 percent of consumers worry a great deal that the foods they eat might not be safe. Almost two-thirds had little or no concern.[10] Hoban, a nationally recognized expert on public opinions about biotechnology, concluded: "Biotechnology is simply not an issue for the vast majority of U.S. consumers." (Grocery Manufacturers of America).

[10] The survey was designed and analyzed by Thomas Hoban, Professor of Sociology and Food Science, North Carolina State University.

A study carried out by INRS (a governmental agricultural research institute in France) shows that hostility towards GM in French public opinion does not reflect the actions of individuals' consumption. Two-thirds of French consumers would not be against genetically modified foods if they were labeled clearly (Stokes). A recent study by Biotechnology Australia (BA) has found for the first time there were more Australians prepared to eat GM foods than those who were not. As people were learning more about GM foods they were overcoming their initial fears (*AAP News*, June 2001).

The marked differences in consumer preferences across countries have given rise to a number of uncertainties that are reflected in the differences in regulatory actions discussed previously and in consumer responses to acceptance/rejection of GM foods. Most polls continue to show that Americans generally do not have strong opinions about genetically modified food, but opposition is stronger in Europe and increasing in Japan. A recent study indicated that preferences for GM foods differ sharply among Japanese, Norwegian, and Chinese consumers (McClusky and Wahl). In this case, most consumers in Japan and Norway wanted to avoid GM foods. However, those in China had positive attitudes about GM foods and would, in fact, be willing to pay a premium for GM rice over non-GM rice.

Studies on consumer awareness and attitudes toward biotechnology have concluded:

- A number of factors may impact how consumers perceive, and whether they are willing to pay for, products produced using biotechnology. Studies have found that: 1) Gender–men have greater awareness of biotechnology than do women; 2) Education–has a positive impact on both awareness and acceptance of the associated benefits; 3) Age–younger consumers and those who had read about or otherwise heard about biotechnology were more willing to buy GM foods (Hoban and Katic);[11] and 4) Men, and those more highly educated, had heard more about biotechnology, and that men, and more highly educated and younger Americans, more strongly approve of biotechnology than their counterparts. Approval also increases for specific products and benefits (versus biotechnology in general) (Hallman, et al.).

- Consumer *awareness* of biotechnology appears to have increased only slightly among American consumers since one of the first formal assessments of such during the early-1990s (Hoban, 2000a).

- Consumers are not well informed about biotechnology and freely admit to such, even while they tend to over estimate their understanding of food production technologies (Roper Starch Worldwide, Inc.; Hallman, et al.). The percentage of consumers who do not believe GM products are in grocery stores has decreased only slightly from a 1997 survey when the percentage was 37 (Hoban and Katic). Even today, less than half of consumers believe there are GM products in grocery stores (Hallman, et al.).

[11] The latter appears to contrast with Rousu, et al. (2002a) who found that participants in an experimental auction who perceived themselves at least somewhat informed about biotechnology bid far less for GM foods than those less informed.

A recent study provided a summary of numerous public opinion surveys on perceptions of biotechnology (Blaine, et al.). Below are some of the highlights of that analysis:

- Consumer acceptance of biotechnology is driven by a number of interrelated factors, primarily knowledge level, awareness of benefits, confidence and trust (citing Hoban 1996).

- Consumers do not reject Genetic Engineering (GE) outright but objections focus on specific applications of the technology.

- Consumer support is linked to perceptions of direct consumer benefits.

- International surveys suggest that Americans have greater support for biotechnology than Canadians and Europeans.

- In contrast to other risks, concerns for biotechnology are relatively low compared to other food safety issues.

- Americans have a higher degree of trust in regulatory authorities than Europeans. Japanese and European consumers prefer international regulatory agencies and have less trust in national regulatory agencies than Americans or Canadians.

- When a connection is made between labeling and increased food costs, consumers were generally not willing to pay more for labels (Angus Reid Group Inc.).

- Surveys are generally poor predictors of actual consumer behavior as consumers often say one thing and do another.

4.3 Labeling

An issue associated with GM food ingredients is labeling. Numerous surveys would seem to indicate that a majority of consumers favor mandatory labeling of food containing GM ingredients. But perhaps more significant than whether or not a food product contains GM ingredients is the "right to know." Some surveys indicate that while consumers say they have a "right to know" what is in their food products, many of them are likely to pay little attention to the label and even fewer are willing to pay more than a trivial amount to have that information. For example, Hallman, et al. (2002) found that , although 90 percent of Americans thought GM food products should be labeled as such, only 53 percent reported they would look at food labels for this information and only 45 percent expressed a willingness to pay more for Non-GM foods.

Consumers' preference for labeling of products containing GM ingredients is not the only viable alternative to labeling of food products regarding their GM content. Huffman, et al. (2002b) demonstrate that when consumers can accurately read market signals (i.e., can interpret information identically whether from voluntary or mandatory labeling strategies), a voluntary labeling policy provides higher welfare. In light of public ignorance of biotechnology and the extent of adverse controversy, it is unlikely that firms would voluntarily adopt a strategy of labeling foods as containing GM ingredients.

4.4 Consumer Attitudes on GM Wheat

The American Bakers Association (ABA) sponsored a survey that studied consumers' preferences of biotech wheat and grain-based foods. The purpose of the survey was to establish a benchmark of U.S. consumer attitudes on GM wheat (World-Grain).[12]

Three major attitudinal segments were identified from the survey results:

- Loyalists (50%) - Loyal bakery product consumers who say they would keep buying bakery products if they contained GM wheat.

- Potential Switchers (40%) - Consumers who are voicing concern by saying they would switch to Non-GM or buy fewer baked goods if GM wheat was in a product.

- Market Exit (5%) - Consumers who already have or will stop buying wheat-based baked goods.

The following are among the principal findings from the survey:

- Consumers are early in the judgement process: Only one in two Americans are familiar with GM food issues in general and just 16 percent are familiar with GM wheat.

- Acceptance of GM wheat is at the same level as GM corn, tomatoes, and oil, which are already in production, but overall at this early stage, a plurality still say the risks of GM wheat outweigh the benefits.

- The number of 'potential switchers' saying they would switch from GM wheat bakery products is identical to GM corn products. In reality, few consumers switched from GM corn. A wholesale switch from GM wheat is not likely to happen without a trigger event that would draw more attention to the issue or easy access to an alternative market to 'exit' to (e.g., organic or Non-GM wheat alternative).

- Acceptance of GM wheat is likely to depend on the extent to which it is differentiated in consumers' minds from other more 'contentious' GM technologies, particularly animal applications.

[12] Directed by Thomas Hoban, Professor of Sociology and Food Science, North Carolina State University.

The higher acceptance by those more familiar with the issue and increasing societal familiarity with genetic sciences suggest that acceptance of GM wheat will increase.

4.5 Measuring Willingness to Buy and Pay (for information) for GM Wheat

This section provides a summary of studies on consumer awareness, attitudes and willingness to pay, with a focus on GM wheats. Awareness and acceptance of the use of biotechnology are not synonymous (Hoban and Katic). Nor does acceptance of, or preference for, foods with particular characteristics (e.g., GM versus Non-GM) necessarily translate into willingness to pay a premium for such products (Lusk, et al. 2001b). A number of factors may (interdependently) result in a difference between what value consumers attribute to a product by self-reporting (e.g., in response to a survey question), versus by purchasing behavior (i.e., revealed preference).

A series of studies have sought to identify consumers' willingness to pay, in this case, for information about ingredient content in products. These studies use experimental auctions to elicit implicit values from consumers for products, many of which are not yet commercially available. Some of the important findings from these studies are:

- Lusk, et al. (1999) demonstrate that consumer reported willingness-to-pay is higher than willingness-to-pay when consumers are actually required to purchase the product.

- Lusk, et al. (2001a) assessed willingness to pay among students in a college-level agricultural class and concluded that 70 percent were unwilling to pay more for Non-GM (versus GM) corn chips.

- Huffman, et al. (2002b) found that participants would bid more for products presumed Non-GM. No demographic characteristics appeared to impact the discount for the GM-perceived products.

- Rousu, et al. (2002b) evaluated consumer acceptance of Non-GM foods with tolerance levels of 0, 1 percent, and 5 percent. Consumers bid less for GM tolerant foods, but the difference between bids for 1 and 5 percent tolerance products was not statistically significant.

Finally, one recent study included products produced with wheat products (VanWechel). Results indicated:

- About 7 percent of the buyers would potentially not buy (i.e., interpreted as a nil bid) products containing GM ingredients.

- Numerous demographic and informational bias factors impact how much buyers would pay for products produced with Non-GM ingredients.

- Results support the literature on consumer attitudes regarding product labeling. Product labels alone differentiated the standard from the Non-GM version of each product. Thus, only participants who actually read the labels could have differentiated between them. The price premium placed on those products with the Non-GM label indicates participants read the label.

- The effect of biased-information (e.g., in an advertising campaign) on acceptability and/or willingness to pay a premium for Non-GM products may differ by type of product.

- Buyers would be willing to pay an average premium of 8.6 percent more for bagged potato chips produced and labeled with Non-GM ingredients; 6.7 percent more for cookies with Non-GM ingredients; and 11 percent more for muffins with Non-GM ingredients.

5. Regulatory Issues

There are numerous regulatory issues related to GM crops. These include the testing and acceptance of new GM crops for commercial introduction and the introduction of food products containing ingredients from GM crops, both domestically and internationally. Nearly every country has different approaches and many have their own regulatory framework. Regulation is a very dynamic issue with changes being reviewed and proposed in many countries on an ongoing basis.

Numerous regulatory actions are consequently being proposed as governments react to consumer concerns and pressures. Several countries have or have proposed to create new agencies to specifically cover genetically modified crops. Approaches range from cautious acceptance to attempts to ban (growing and even imports), at least for the foreseeable future, all crops and products with GM traits. Each is approaching the testing, introduction, and acceptance of GM crops in their own manner and on their own time schedule.

Table 5.1 summarizes the current status of some of the regulations related to introduction, approval, and commercial acceptance of GM crops.

U.S. Regulations. In the United States, transgenic crops are subject to a tripartite regulatory system. The government agencies having a part in this system are APHIS (Animal Plant Health Inspection Service of the USDA), EPA (Environmental Protection Agency), and FDA (Food and Drug Administration). The U.S. regulatory system focuses on determining the relative safety of biotechnology's end products and not on the processes by which they are created (USDA-APHIS). Products regulated by these agencies and the aspect each reviews for safety are summarized in Table 5.2.

Table 5.1. Status of Regulations over GM Products

Argentina	Authorizing new GM products only if they have been approved in the EU. World's second largest producer of GM crops.
Brazil	Ban on growing GM grains for consumption, animal or human, and it is illegal to import gene-altered crops. Brazilian government, however, estimates that more than one million acres of illegal GMO soybeans smuggled in from Argentina are grown in the country.
European Union	Have not approved any new GMOs since April 1998. Proposed new laws will likely end the moratorium on bioengineered seeds and food but will impose very tough rules governing the planting of GMOs.
France, Denmark, Italy, Greece, Austria, & Luxembourg	Have said they will continue to try to block all new licenses for commercial growing of GM crops.
Germany	Has shelved plans for research on genetically engineered crops (January 2001).
Norway	Not an EU member but usually uses EU rules as a guideline. Has *not* condemned all GMOs, but recently refused to accept 3 GM products which have been approved by the EU.
Australia	A Parliamentary Committee gave the go-ahead for biotech crops in June 2000 when it ruled in favor of biotech crops as long as an independent regulatory process was involved.
India	Genetically modified seeds and food not allowed into India until their safety is scientifically proven (November 2000).
Indonesia	Several non-governmental organizations are trying to annul a recent ministerial decree which opened the door for the use of transgenic crops.
China	The development of transgenic technology is a major part of China's effort to develop high-tech agriculture; however, they are proceeding with caution in the commercial use of the technology.

Source: Various biotech related website postings.

Table 5.2. United States: Overview of Agency Responsibilities

Agency	**Products Regulated**	**Review for Safety**
USDA	Plant pests, plants, veterinary biologic	Safe to grow
EPA	Microbial/plant pesticides, new uses of existing pesticides, novel microorganisms	Safe for the environment. Safety of a new use of a companion herbicide.
FDA	Food, feed, food additives, veterinary drugs	Safe to eat

Source: *Food Biotechnology in the United States: Science, Regulation, and Issues*, Center for Rural Studies Report to Congress, June 2, 1999.

Many concerns about regulation of biotechnology grains in the United States were prompted by the StarLink controversy. This problem was never a matter of public safety, but a regulatory matter. Approval of this GM corn variety was granted for its use in animal feeds, but was not granted for use in human consumption. Segregation, an issue discussed in Section 7, proved to be a difficult task. To avoid this problem, the EPA has taken a position that it will no longer grant "split" product approval. Future approvals will be granted only after meeting all U.S. regulatory requirements for both human and animal consumption.

Comparing U.S and EU Regulatory Approaches. Under the EU regulatory regimen, sufficient scientific evidence of "no excessive risk" must exist before a crop can be approved for commercial use. The EU regulatory authorization is rather complex, as the approaches of different member countries must be reconciled and different regulatory structures integrated.

The EU attempts to set the level of risk it is willing to accept, and then takes precautionary action to prevent the use of transgenic crops that exceed this level. In the United States, the so-called "science-based" risk approach is grounded on available information and expert opinion, and transgenic crops are accepted unless compelling proof of danger is provided. The difference between the U.S. and the EU approaches might be characterized as the EU approach is "guilty until proven innocent," while the U.S. approach is "innocent until proven guilty." Another characterization of the differences in regulatory approach is that in the United States the focus is on the *product* while in the EU the focus is more on the *process*.

Canadian Regulations. Canada has three regulatory agencies responsible for products derived from plant biotechnology in Canada. They are: the Canadian Food Inspection Agency (CFIA), Health Canada (HC), and Environment Canada (EC). Like the United States, their review of crop varieties or foods containing novel traits is based on their traits, not the process or method used to produce those traits (Crop Protection Institute of Canada).

5.1 Restrictions and Labeling of Products Containing GM Ingredients

Regulatory aspects of GM crops and products containing or potentially containing GM crops are a hot and dynamic topic with discussions taking place in all parts of the world. In addition to regulations on the GM crops, there are a complex series of issues/restrictions related to labeling of products made from ingredients that are or might be derived from GM crops. Discussions are underway and proposed legislation is currently being considered in numerous countries. Table 5.3 outlines the status of regulations in key markets related to the sale and labeling of GM products.

Proposed new EU **"traceability"** rules for genetically modified crops will pose even stiffer requirements in the future. Along with labeling the rules, traceability would require records to be kept as products move "from the farm to the supermarket." They argue that the suggested tracing system is key for withdrawal of products in case of risk to human health or the environment, monitoring, and control and verification of labeling claims (SoyaTech, August 14, 2001).

Table 5.3. Labeling of GM Products

United States	There is currently *no requirement* to mention on the package label that the food contains GMO material unless the nutritional or health aspects of the food have been changed. *Mandatory* labeling of foods containing biotech ingredients is *proposed.*
Canada	Working on developing *voluntary* labeling standards for GM foods. The Canadian Health Food Association is pushing for *mandatory* labeling of genetically altered products.
Mexico	*Considering* implementing *mandatory* labeling of GM foods.
European Union / UK	Any foods containing genetically modified materials above a **0.9 percent** threshold *must* be labeled as containing "genetically modified" ingredients.
Japan	*Mandatory* labeling began April 1, 2001, for products with **5 percent** or more GM ingredients and exempts any ingredient that is not one of the top three ingredients in the food product. **Zero-tolerance** for unapproved biotech crop varieties, like StarLink corn, in its food products.
Korea	Effective in June 2001 labeling *required* when GM corn, soybeans, or soybean sprout is among the top 5 ingredients of a processed food product. Labeling *required* on commodity shipments of corn, soybeans, and soybean sprouts destined for direct consumption when GM component is **3 percent** or more.
Taiwan	*Mandatory* labeling on GMO foods scheduled to be implemented in three stages with raw corn and soybean products to be labeled by as early as 2003. *Mandatory* labeling of processed foods containing corn and soybean products would be delayed until 2005. Intends to use a **5 percent** tolerance level when implementing the labeling requirement.
Hong Kong	Proposing that food containing **5 percent** or more of GM material be clearly labeled.
Australia / New Zealand	New requirements on *mandatory* labeling of GM foods will take effect in December 2001. The new standard allows any one ingredient in a food to contain up to **1 percent** of unintended genetically modified material.
South Africa	Currently no regulations restricting the sale of GMO products, however, consultations on labeling have been initiated.

Source: Various biotech related website postings.

EU farm ministers agreed in November 2002 to require food and feed containing 0.9 percent or more GM grain to be labeled as genetically modified, starting next year. They also agreed to a maximum permissible level of 0.5 percent for food and feed that accidently contains unauthorized GMOs ("adventitious contamination"). Foods that contain highly refined ingredients that may be from GM sources, such as sugars and oils, are exempt from labeling in some countries, while not exempt in others.

An even more difficult issue is the potential requirement to label as GM, meat, milk and eggs from animals that have been fed feed containing GM ingredients. Even where GM crops have been approved for use in animal feed, complexities are arising as processors/retailers are removing products from their inventories that are derived from animals fed with GM feed ingredients. Should such meat, milk, and eggs be labeled as GM even though research studies show that any biotech protein traits are broken down in the digestive process of the animals?

Mandatory versus Voluntary. A significant regulatory issue is that of labeling of GM products, a much discussed and debated concern in all parts of the global economy. The primary issue with respect to labeling is the mandatory versus voluntary argument. One side argues for consumers' rights and the segregation and mandatory labeling of all GM foods while the other side believes that all foods produced from GM ingredients should not have to be labeled. The latter believe that labeling should occur only in certain situations and on a voluntary basis.

Proponents of mandatory labeling cite consumer choice, public mistrust, health issues, and consumer research concerns as the reasons for requiring labeling. It would provide consumers with their "right to know" and allow them to make "informed" decisions. The right to choose to consume or to avoid GM products may be a matter of religion, morality, taste, or more generally, of opinion.

Voluntary labeling concerns include safety, public confidence, potential ineffectiveness, costs, and impact on international trade. Those supporting voluntary labeling argue that the mandatory labeling of GM food products is impractical and not essential, since GM foods are no more dangerous than traditional foods.

Mandatory labels have been fiercely opposed by the U.S. food industry, which contends that such labels would raise concerns about the safety of GM foods and scare consumers away, in addition to increasing the cost of nearly all food products. Some 35 countries worldwide have, or are developing, mandatory GM labeling laws (SoyaTech, June 22, 2001).

Most foods produced from modern biotechnology are indistinguishable from conventional foods, in terms of appearance or other organoleptic qualities (Fulponi). The American Medical Association has taken the position that there is *no scientific justification for special labeling of genetically modified foods*, as a class, and that voluntary labeling is without value unless it is accompanied by focused consumer education (AMA).

Substantial Equivalence. The position of regulatory agencies in the United States on the issue of labeling is based on the concept of "substantial equivalence." If a biotech food or crop shares similar health and nutritional characteristics with its conventional counterpart, it is considered to be *substantially equivalent* and is considered to be as safe as its conventional counterparts. A GM food must be labeled only if it "differs from its traditional counterpart such that a common or usual name no longer applies to the new food, or if safety of usage exists to which consumers must be alerted." Consequently, biotech foods do *not* require special labeling in the United States. Unless the nutritional or health aspects of the food have changed (pose risk) in a substantial way, there is no need to mention on the package that the food contains GM ingredients. Although products of agricultural biotechnology are not subject to specific labeling in the United States, they are subject to the general labeling requirements applied to all foods under the Food, Drug, and Cosmetic Act.

Precautionary Principle. Europeans tend to exercise the "precautionary principle" which dictates that every technology must be proven safe before it can be used. A popular formulation of the principle states that nations are permitted to take steps to protect their nationals when there are uncertainties or unknown risks to human health or the environment. These precautionary measures may be taken even if some cause and effect relationships are not established scientifically. Precautionary regulation shifts the burden of proof from the regulator, who once had to demonstrate that a new technology was likely to cause some harm, to the innovator, who now must demonstrate that the technology will not. Under this standard of evidence, regulatory bodies are free to arbitrarily require any amount and kind of testing they wish (Miller and Conko).

5.2 Food Safety

Many of the arguments surrounding regulation and labeling of GM food products relate to food safety concerns and scares. Some are based on emotions, some on political issues, some are construed by many as marketing tactics. There has been one example where introducing genes from foods people are allergic to (Brazil nuts) has resulted in allergic responses being identified in the resulting product (transgenic soybeans). Development of this product was stopped, however, this problem may be solved by labeling (Nordlee, et al.; Kaeppler).

The National Academy of Sciences released an authoritative report in April 2000 in which their expert committee said they found no evidence that gene-spliced crops are unsafe to eat. They endorsed the central principle of the U.S. government's existing biotech regulations: that genetically engineered foods pose no special risk because they are produced by a new process (*BusinessWeek Online*, April 2000). The American Medical Association's Council on Scientific Affairs released a report in December 2000 that supported agriculture biotechnology and stated "There is no scientific justification for special labeling of genetically modified foods." (AMA). Still biotech opponents claim that inadequate research exists to definitely determine whether GM foods are safe to eat.

6. GM Wheat and International Trade Issues

One of the areas of greatest conflict in the commercialization of GM wheats is that of international demand and competition. These issues are contentious and divergent among organizations and institutions. The reason for this, of course, is that the product is not yet approved and hence any analysis and suggestions are somewhat speculative. Further, the major players have taken what may be interpreted as fairly strong positions about GM wheats (see pp. 2-5 of this paper for a summary of their positions).

This section provides a summary of two of the fundamental issues related to this problem. One of these is the potential for buyer acceptance and aversion to GM wheat. The other is a summary of studies on welfare and strategic implications of GM wheat.

6.1 Importer Acceptance and Aversion to GM Wheats

Although GM wheat is not yet available it is easy to understand there is concern about the potential impact it may have on exports and why producers and their associations are concerned. Several of the organizations involved in international wheat marketing have been trying to assess the acceptance of GM wheat to their customers.

U.S. Wheat Associates: Early in the evolution of discussions about RRW, U.S. Wheat Associates published a list of countries that would potentially be averse to the purchase of GM wheats (summarized below).

Since then, U.S. Wheat Associates conducted a survey of buyers to assess their aversion to GM wheats (Forsythe). This was a survey of customers in key strategic markets to determine their willingness to accept GM wheat. A synopsis of its content was distributed in a Reuters' news release (Gillam). Some of the points from that survey are noted below:

- Representatives for Chinese, Korean, and Japanese wheat buyers surveyed said they would not buy or use RRW. Eighty-two percent of buyers from Taiwan and 78 percent of buyers from South Asia said they would reject the wheat.

- If the country had regulatory approval of the trait, each country, with the exception of Japan, indicated they would accept some GM wheat with a tolerance. One country expressed that regardless of government approval, "contracts will stipulate no adventitious presence of GM wheat."

- The majority of the responses indicated there was a future for biotechnology in wheat if there is some consumer benefit that can be marketed.

Canadian Studies: Several studies have addressed issues of RRW in Canada. One of these identified "at risk" countries (Kuntz). Citing a CWB source, the 10 countries identified as "at risk" have publicly stated their concerns regarding genetically modified wheat and have indicated the possible termination of imports from the Canadian Western Red Spring (CWRS) wheat sector. Based on this analysis one third of Canadian CWRS exports are at risk of loss with the major concerns being Japan, Iran, and Brazil (Table 6.1).

Table 6.1. "At Risk" Markets for Canadian Western Red Spring Wheat

"At Risk" Countries	Volume of Canadian Spring Wheat Exports *	% of Total CWRS Exports
Algeria	55	0.4
Brazil	833	6.3
Iran	1,048	7.9
Italy	186	1.4
Japan	1,322	10.0
Malaysia	114	0.9
Morocco	19	1.0
South Korea	345	2.6
United Kingdom	264	2.0
Venezuela	257	1.9
TOTAL	4,443	33.0

* Volume derived as a 10-year average , 1989-98, 000's of tonnes.
Source: Kuntz.

Trade Volumes and Alleged Buyer Acceptance. Several figures were prepared for purposes here to illustrate the importance of alleged buyer aversion to GM wheats to the United States. These data were assembled as follows: U.S. Wheats Associates' initial estimates of buyer aversion to GM content were defined; imports of U.S. HRS by these countries were assembled for 1999/00; and the U.S. domestic market was included in these data (assuming non-averse).

These results are summarized in Figures 6.1 and 6.2. The results illustrate a number of important conclusions:

- The U.S. domestic market is by far the domineering market and as suggested here is non-averse (see below).
- Aside from the U.S. market, the largest GM averse markets are Japan, the Philippines, Korea, and the EU countries (notably, Italy, Spain, and the United Kingdom).
- Taken together, these results suggest that about 72 percent of the market would be GM tolerant, the remaining being potentially averse.

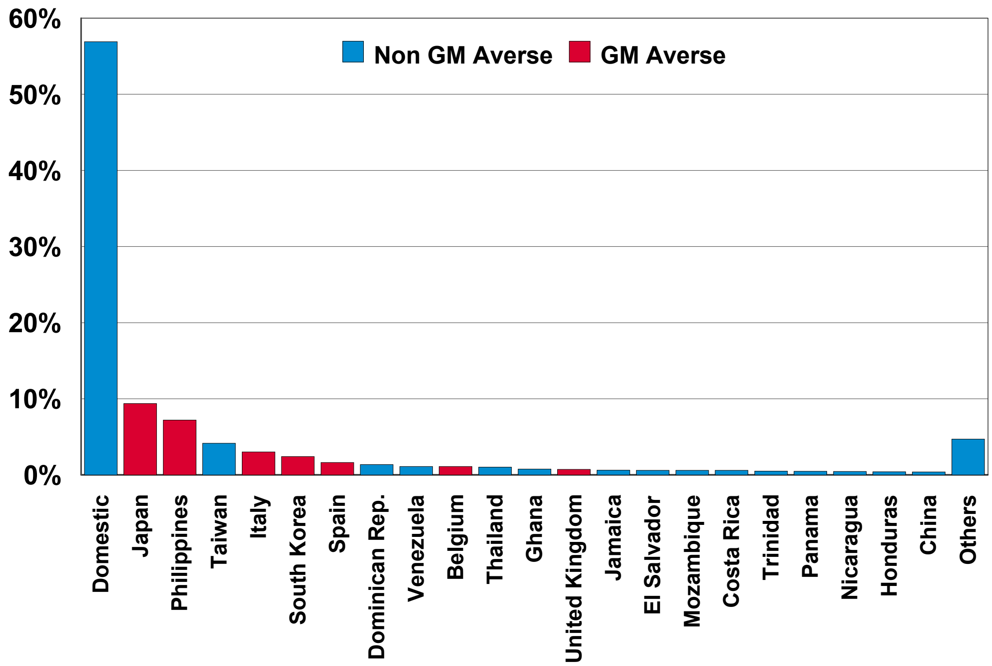


Figure 6.1. U.S. HRS Exports and GM Aversion

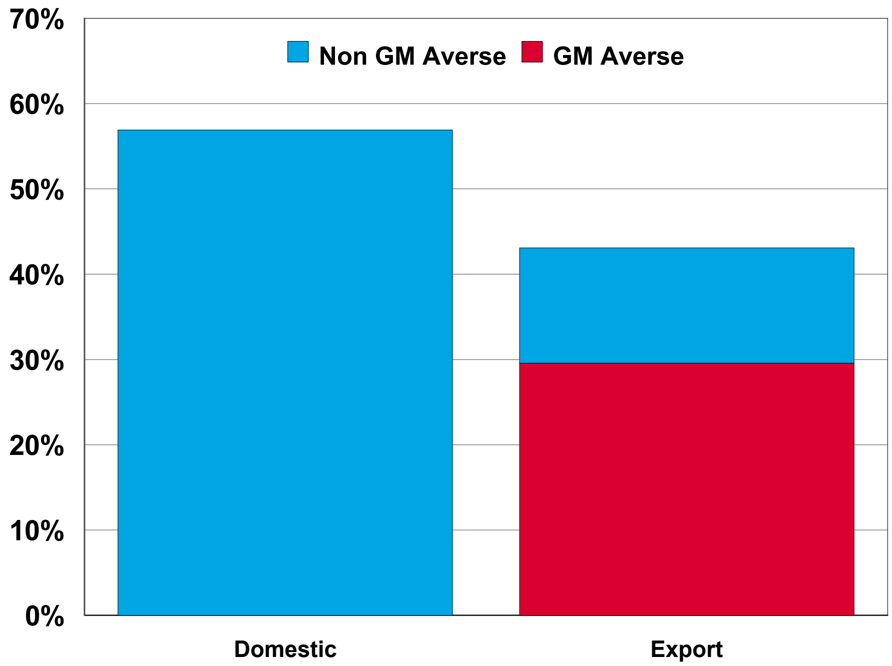


Figure 6.2. Percent of U.S. HRS Use (Domestic Consumption and Exports), 1999-00

The non-aversion assumption of the U.S. domestic market is debatable. Some important considerations in this assumption are that: 1) 70 percent of grocery products sold in the United States contain GM ingredients; 2) results of most surveys (summarized previously) suggest that U.S. consumers are more tolerant of products produced with GM ingredients; and 3) in the case of bread, numerous ingredients are already from GM grains and/or oilseeds. Further, a large component of the U.S. market is non-branded wheat products (i.e., food service, private label, industrial foods) for which wheat aversion would be non-apparent.

There are several important points in understanding the data and their interpretation and assessment of foreign buyer acceptance. First, reviews of survey results (noted in Section 4) noted the tendency for consumers to indicate one thing in surveys, but their actual purchase behavior differs. In the case of GM wheats, it is fully expected that buyers will be naturally averse to a trait prior to it gaining regulatory approval, and they may not be fully informed about the functional differences/similarities and food safety. Second, the regulatory process in many countries is evolving and/or may not have the scientific sophistication of that in the United States. As a result, some countries (e.g., the Philippines, China, Mexico) may very well adopt the position that if a trait is approved in the exporting country, it would allow its importation (concurrent with certification as such).

Finally, it is significant that some of the countries that are claimed to be averse to GM content in wheat, are in fact large importers of GM soybeans and corn, at least from the United States. These data are illustrated in Figures 6.3 and 6.4. These data indicate that among the countries being averse to GM wheat, Japan and Korea are large importers of U.S. corn and soybeans, as are the Philippines, Spain, and Italy. These data are not exhaustive as it is not possible to detect whether these countries' imports are GM or not. However, it is illustrative that apparently these countries have established protocols to facilitate grains and oilseeds from regions in which there are known production of GM grains and oilseeds (see section 7).[13]

[13] In the past, the Japan Starch and Sweeteners Industry Association (JSSIA) used IP to separate GM corn. However, the JSSIA recently informed "Japanese soft drink manufacturers, beer producers and other food companies that, because of costs and logistical considerations, it will no longer supply identify preserved, non-biotech corn to its customers" (Soyatech.com, 2003). This apparently has been in response to the educational efforts of the U.S. Grains Council.

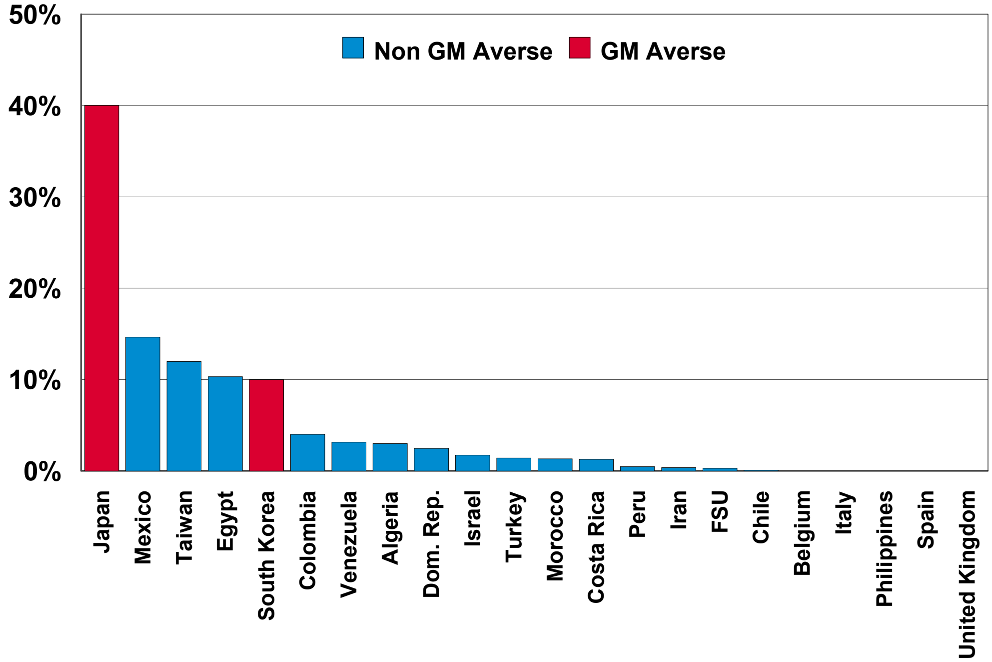


Figure 6.3. U.S. Corn Exports and GM Aversion

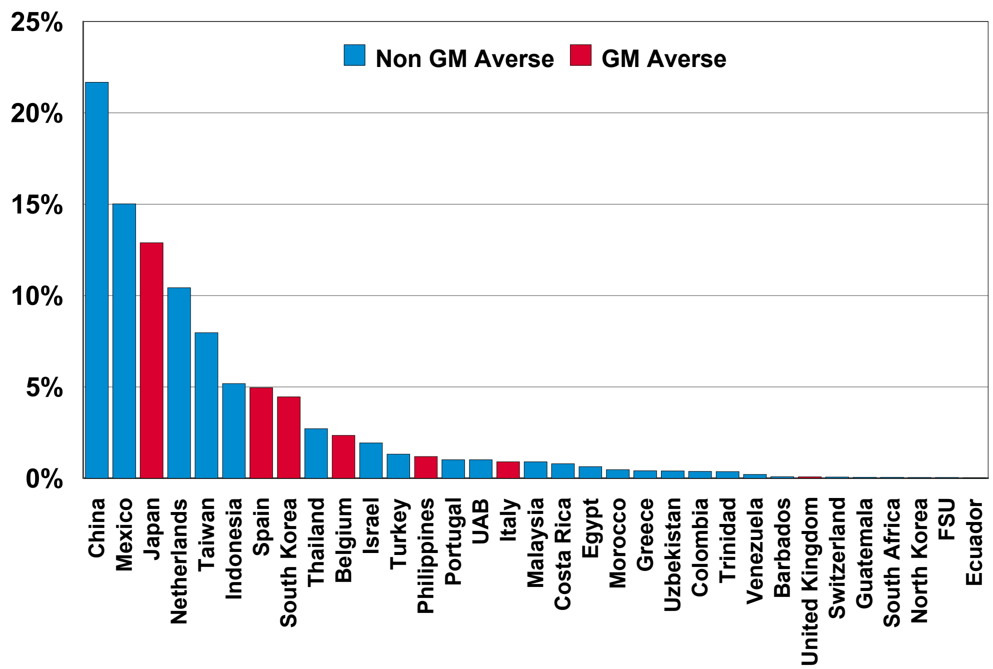


Figure 6.4. U.S. Soybean Exports and GM Aversion

6.2 Welfare and Strategic Effects of the Utility of GM Wheats

Several studies have addressed the potential welfare and strategic impacts of the introduction of GM wheat. These are summarized below.

Australian Study. A report by the Productivity Commission in Australia states the benefits of genetically engineered non-wheat crops and oilseeds outweigh the costs. This study is based on the premise that the United States and Canada would expand their use of GM technology and that Australia would not. They found that, in the long term, production and exports would be adversely affected because the country would lose market share to the United States and Canada if it did not expand its use of GM technology (Stone, et al.).

University of Saskatchewan Study (Furtan, et al.). Ten key export markets were identified that Canada risks losing due to the introduction of GM wheat. If Canada were to register GM wheat, the markets that demand GM-free wheat would turn to other exporters where GM wheat is not registered, such as Australia, the EU, and the United States. Canada would then sell its wheat into those markets that are indifferent to GM wheat, such as China. This study is based on the premise that Canada would be the first country to register GM wheat, and the other wheat producing countries would not produce GM wheat. They conclude, that while GM wheat will make production cheaper, those agronomic benefits are more than out-weighed by the costs of segregation of GM wheat, the impact of lost export markets, and lower wheat prices.

It was concluded that RRW should not be released in Canada until customers accept the technology and/or unless the cost of IP is less than $C0.01/bu for all growers or $C0.08/bu for growers adopting the trait.

North Dakota Study. DeVuyst, et al. (2001) developed a model to investigate international trade of wheat following introduction of GM wheat. The impact was explored for five plausible scenarios. Their results indicate that in most scenarios considered, U.S. producers stand to gain considerably due to GM wheat introductions, assuming a 4.8 percent costs savings for GM versus Non-GM wheat. Only in the most widespread adoption scenario do U.S. producers suffer from GM wheat introductions. Their results indicate that the United States may have a first-mover advantage even when importers of U.S. wheat do not accept GM wheat.

6.3 World Trade Organization Issues

The United States has failed so far in trying to persuade the EU to lift its de facto ban on approving new GM products and in adopting realistic tolerances for labeling.[14] Having failed to

[14] In a recent article it was suggested that as most of the major corn and soybean exporting countries had either already adopted GM versions of these crops, or are likely to in the future, consumers in importing countries will find it increasingly difficult to avoid them in their food purchases. One commodity analyst was quoted as saying: “Europe is learning its first lesson in the ‘beggars can’t be choosers’ world of agricultural reality - it’s GMO beans or no beans...” (Andrew Cash, as quoted in Barboza).

influence the EU, U.S. government administrators appear to be ready to challenge these issues in the World Trade Organization (WTO). Such an action is, however, unlikely to resolve the problem, but would risk turning the situation into a crisis situation or all out trade war. As Brussels acknowledges, the U.S. stands to win a WTO case. However, there is little reason to think a legal victory in Washington would cause the EU to open its market. Much more likely, it would stiffen political and popular resistance in countries opposed to GM foods (SoyaTech, December 30, 2002).

7. Segregation and Identity Preservation (IP)

One of the challenges to the commercialization of GM grains is creating the institutional and contractual mechanisms to facilitate a dual marketing system. This section provides a summary of previous studies on IP, a description of testing technologies, and summarizes results from a recent study on testing and segregation costs and risks for GM wheats.[15] Finally, a brief discussion on certification is provided.

7.1 Studies on Market Mechanisms, Testing, and Tolerances

With the introduction of GM crops, there is a spectrum of alternative procurement strategies that can be adopted. Ultimately, it is buyers that determine the elements of their procurement strategy. These can range from spot transactions simply on grade and non-grade factors, to full integration into grain production and/or handling. Intermediate solutions contain varying forms of testing, contracting, and IP (Figure 7.1)

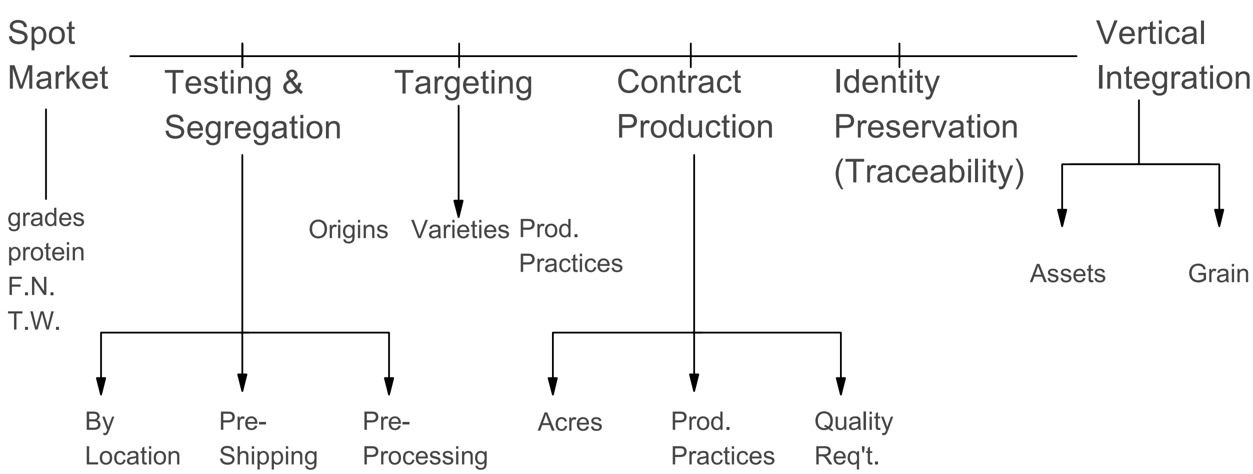


Figure 7.1. Spectrum of Procurement Strategies

[15] This section was largely adopted from Wilson and Dahl, 2002.

Identity Preservation and Segregation. Definitions of what constitutes an IP system vary. Dye defined it as a "traceable chain of custody that begins with the farmer's choice of seed and continues through the shipping and handling system." Wilcke refers to IP as separate storage, handling, and documentation of separation; Sonka, et al. define it as a coordinated transportation and identification system to transfer product and information that makes product more valuable; and Buckwell, et al. and Lin, et al. refer to it as a 'closed loop' channel that facilitates the production and delivery of an assured quality by allowing traceability of a commodity from the germ plasm or breeding stock to the processed product on a retail shelf. [16]

Numerous studies have examined IP/segregation costs for a range of commodities using different methodologies including surveys of elevator managers (Nelson, et al.; Jirik; Dahl and Wilson 2002; Wilson and Dahl 2001), cost accounting methods (Askin; McPhee and Bourget; Lentz and Akridge; Dahl and Wilson 2002; Wheeler; Kennet, et al.; Hurburgh, et al.; Bullock, et al.; Shoemaker, et al.; Sparks Co.; Smyth and Phillips), and simulation (Hermann, et al.; Maltsbarger and Kalaitzandonakes; Schlecht). These are summarized in Table 7.1. Costs of segregating IP grains from these studies range from 1 to 72 cents/bu. Among these, some are estimates in anticipation of what the process would be, some are a result of budget types of analysis of costs, some entail process verification and pure segregations throughout the system, but none quantify risks or the exposure to risk of the agents.

The economics of additional wheat segregation have been studied in the Canadian grain handling system using a number of different methodologies and over different time periods. The most recent of these was undertaken by Agriculture and Agri-Food Canada and summarizes much of the previous work in this area (Wheeler).

Finally, most of the work on segregations has focused specifically on GMOs. Bullock, et al. examined costs of GMO/Non-GMO segregation from seed to market in the United States.[17] While IP systems may provide process verification and retain segregations, typically, they would be incapable of assuring end-users that tolerances for adventitious materials are met unless, as part of the system, testing protocols were specified.

---

[16] Several firms have initiated IP programs where sales/segregation are by specific variety/location. The Minnesota Crop Improvement Association (MCIA) operates IP programs for 99.5 percent Non-GMO soybean grain and seed, 99.0 percent Non-GMO corn grain and seed, and an IP grain handler's facility program. The Canadian Soybean Export Association initiated a standard that outlines IP procedures for food grade soybean exports (Strayer). Other examples of IP systems include: CWB-Warburtons, Pro-Mar Select Wheat of Idaho, AWWPA, etc.

[17] The Directorate General for Agriculture, Commission of the European Community summarized much of the literature to date on costs of segregation, many of which focused on costs within the United States but also included studies from France and Brazil.

Table 7.1. Previous Studies on IP and Segregation Costs

Researcher	Methodology/Scope of Analysis	Estimated Cost of Segregation/IP
Askin 1988	Econometric Model of Costs for Primary Elevators	Increase of 2 grades handled increased costs < .5 c/bu
Jirik 1994	Survey of Elevator Mgrs. and Processors	11 to 15 c/bu
Hurburgh, et al. 1994	Cost Accounting Model for High Oil Soybeans	3.7 c/bu
McPhee and Bourget 1995	Econometric Model of Costs for Terminal Elevators	Increasing grades handled increases operating costs 2.6%
Hermann, et al. 1999	Stochastic Simulation Model	1.9 to 6.5 c/bu
Maltsbarger and Kalaitzandonakes, 2000	Simulation Model for High Oil Corn	1.6 to 3.7 c/bu
Nelson, et al. 1999	Survey of Grain Handlers	6 c/bu corn, 18 c/bu soybeans
Bullock, et al. 2000	Cost Accounting	30 to 40 c/bu soybeans
Dahl and Wilson 2002	Survey	25 to 50 c/bu
Wilson and Dahl 2001	Survey of Elevator Mgrs. for Wheat	15 c/bu
USDA-ERS (Lin, et al. 2000)	Cost Accounting Adjustments to Survey Results for Specialty Grain Handlers	22 c/bu corn, 54 c/bu soybeans
Smyth and Phillips, 2001	Analysis of GM IP System for Canola in Canada, 1995-96	21-27 c/bu
Gosnell, 2001	Added Transportation and Segregation Costs for Dedicated GM Elevators	15-42 c/bu High throughput 23-28 c/bu Wooden Elevators
Sparks Companies 2000		Non-GM Canola 38-45 c/bu Non-GM Soybeans 63-72 c/bu

Economics of Testing and Tolerances. Numerous companies have emerged for development of GM tests. These companies include: Biogenetic Services, Genetic ID, various crop improvement associations, and Strategic Diagnostics, among others.

There are two basic tests that are being used for other grain and are proposed for analyzing for the presence of RRW. These are commonly referred to as strip tests and PCR tests.[18] Characteristics of these tests and their costs (excluding sampling costs) are shown in Table 7.2. These tests are for "single-trait" events.[19] The PCR test is based on DNA technology and is more commonly used in international contracts. Strip tests are or would be more commonly used domestically. Typically, these would be applied at different points in the marketing system and, depending on the size of the unit, would convert to about 1/5 cent to 3.6 cents/bu.

Table 7.2. GM Testing Tolerances, Costs, and Accuracies

GMO Tolerance Tested for (%)	% Confidence Level (%)	Seeds	Cost per Test ($)
PCR Tests			
1.0	99	600	120
0.1	95	3000	300
0.1	99	4650	400
Strip Tests			
1.0	95		7.5

Source: Communications with Danny Giggax, Monsanto. Based on batch testing in 150 seeds/batch.

Concurrent with any test is a tolerance which is normally specified in purchase contracts. Technically, a tolerance is defined as the allowable variability from a standard. In the context of the grain trade, a tolerance for Non-GM is referred to as the maximum allowable GM content to still be considered Non-GM. Ultimately, it would be the buyer that would specify the tolerance and testing methodology as part of their purchase contract. However, the term threshold is often used interchangeably. The American Seed Trade Association defines threshold as "a level below which the adventitious presence of protein or DNA is considered *de minimis* from either a safety or marketing (quality) standpoint" (Schroeder).

There have been few economic studies on this topic in the case of grains. One exception is that of Hurburgh, et al. They developed economic engineering cost functions for testing and

[18] However, the PCR tests may be less appropriate in GM wheat because unlike corn, there is no need at present for a single PCR test to identify several biotech events that use the same marker gene. Further, there is no need to test for event GA21 which in corn currently requires a PCR test because strip tests are not accurate (Tobin).

[19] These costs were as of 2001. Since then, proposed costs for these tests have declined.

segregation costs and applied them in the case of corn. As GM grains become commercialized, inevitably, tolerances will need to be defined and/or those proposed will need refinement. There are two forms in which tolerances are applied. One would be those defined by regulatory agencies (e.g., the FDA and like agencies in other countries). Second, would be as commercial tolerances.[20] Ultimately, there will be varying types of limits and tolerances specified by domestic and international buyers.

In response, the grain marketing industry will have to develop testing strategies encompassing the cumulative activities including sampling and the physical testing and reporting of results. Tests increase the cost of handling GM and Non-GM grains, and costs escalate as the number of tests, and locations within the marketing system at which they are applied, increase. Increased testing reduces the potential for delivery of lots of undesirable quality to buyers.

Testing is complicated by the inherent risks of adventitious commingling that may occur at different locations and functions in the marketing system. Given that testing has a cost and is subject to error and can be conducted at several places within the marketing system, it is an economic problem involving costs and risks. Risks are defined as buyers receiving a product that should be rejected and sellers having a product rejected that should have been accepted. There is a fundamental tradeoff between risks and costs. Tighter tolerances result in increased costs and decreased risks.

7.2 Estimates of the Costs and Risks of Testing and Segregating GM Wheat

Most important in establishing these tolerances are that costs increase as tolerances are tightened, and that risks are mitigated by the use of tolerances. Government and grain industry participants have concluded that zero tolerance is an impractical concept.[21]

Wilson and Dahl (2002) developed a model to analyze the potential costs and risks associated with a marketing system based on testing and segregation. The model derives additional system costs at each stage of the marketing chain, tracks segregation flows throughout the system, and derives statistical properties on the proportion of lots with GM exceeding specifications within end-use flows. This system could be envisioned as being adopted with several different scopes. It could reflect an elevator that seeks to segregate within their own

---

[20] The experience of vomitoxin in wheat and barley is very analogous. Vomitoxin is regulated by the FDA with limits placed on its presence in the semi-processed crops (e.g. flour, malt). However, individual firms can and do adopt different tolerances, subject to the FDA regulations. Similarly, some importing countries adopted tighter tolerances than others, and in fact tolerances may vary across firms within a single importing country.

[21] The North American Millers Association (NAMA) has embraced testing of inbound grain, and opposes testing on intermediate or finished products... ...and that government mandated testing programs need not be adopted. Further, NAMA has conducted their own analysis in the case of StarLink corn. Results from that analysis indicated that the domestic industry quickly adopted contract terms and tests to control the adventitious presence of StarLink. They indicated that the samples testing positive for StarLink averaged 1.2 percent from October 2000 to June 2001. By fall 2001, this declined to “as close to zero as you can get” (Sjerven).

facilities, or it could be elevators specialized in handling GM versus Non-GM. Or, it could be a vertically integrated firm with some elevators specializing in GM versus Non-GM handling. Each type of adoption has occurred in the marketing of other GM grains.

The model incorporates risk in a number of variables and is solved using stochastic optimization. The primary sources of risk included farmer "truth-telling;" adventitious commingling occurring at several locations (farm, country elevator, export elevator, and transportation equipment) due to various factors (inadequate cleaning, etc.); sampling and inspection plans; and test accuracy.

The base case was defined to reflect the most likely system and protocols. These include: Export shipment to importers; GM adoption by farmers of 20 percent (based on market distributions of GM aversion of buyers); Grower declaration of GM content at the country elevator; Testing was allowed at any or all of the following locations: Country Elevator (CE) at receiving and/or loadout and at the Export Elevator (EE) at receiving and loadout; Testing technology at the export/import level was required restricted to the PCR tests; and Tests were conducted using PCR by importers. A PCR test at the importer is also applied at $120/test on every unit to impose an accept/reject mechanism for delivery of Non-GM wheat.

The results identify the optimal testing strategies of a GM/Non-GM system versus the existing Non-GM system (Table 7.3).

- The optimal strategy would be to test every 5th railcar at the country elevator when loading and to test every ship sublot when loading at the export elevator.

- This testing strategy results in average rejection rates at the importer of 1.75 percent. An average of .02 percent of importer flows had GM content greater than tolerances which represents the buyers' risk of accepting quality that does not meet tolerances.

- The proportion of flows in the Non-GM channel declined from 80 percent at the farm level to an average of 70 percent at the importer. Thus, on average, 10 percent of Non-GM shipments are diverted to the GM segregation throughout the handling system. This illustrates to a large extent the sellers' risk of having shipments rejected throughout the system. Most of the diversions are due to adventitious commingling which occurs in the system, though some are effects due to test accuracy and large samples containing units with both adventitious commingling and Non-GM which are represented by a single test.

- Adding cost elements results in total costs of 2.4 cents/bu when measured across all bushels and 3.4 cents/bu when attributed solely to Non-GM bushels. The cost of the system includes additional costs of testing and rejection and a risk premium to the handler due to the added risk of handling Non-GM in a dual marketing system.

Table 7.3. Effect of Variety Declaration and No Testing

Variety Declaration	Base Case	No Variety Declaration	No Testing & No Variety Declaration
Utility	1.0097	1.0071	1.02
Test (1=yes/0=no, Every nth unit)			
Country Elevator Receiving	0-0	1-5	0-0
Country Elevator Loading	1-5	1-5	0-0
Export Elevator Receiving	0-0	1-5	0-0
Export Elevator Loading	1-1	1-1	0-0
Buyers' Risk of Flows Exceeding GM Tol.	.02%	.01%	0.10%
Rejection at Importer	1.75%	2.34%	10.10%
Percentage of Flows Non-GM by Location			
Adoption Rate	80	80	80
Country Elevator in Store	82	78	82
Country Elevator Loaded on Track	77	51	82
Export Elevator in Store	77	39	82
Export Elevator after Loading	71	31	82
Importer after Test	70	31	74
Costs (cents/bu)			
Additional Costs/All bu	1.4	1.3	5.7
Additional Costs/Non-GM bu	2.0	4.4	7.8
Risk Premium	1.0	0.4	4.2
Total (Add + Prem)/All bu	2.4	1.7	9.9
Total (Add + Prem)/Non-GM bu	3.4	5.7	13.4

The model was used to analyze varying other scenarios that are important in GM wheat. Results from these are summarized below:

- Variety Declaration and Testing. In the base case, mechanisms are used to elicit information from growers on the GM content of their grains. This function would normally be included in "closed loop" marketing plans. It facilitates segregation at the point of first receipt, albeit at the risk of adventitious commingling at the grower level and due to grower truth-telling (below). A system with no variety declaration results in significant misgrading and diversion of flows from Non-GM to the GM segregation (i.e., the sellers risk is high). Total costs for Non-GM bushels similarly increased from 3.4 cents/bu for the base case to 5.7 cents/bu with no variety declaration.

- No Variety Declaration and No Testing. This was used to reflect the inherent system risks and the value of testing. With no testing, rejection rates at the importer were 10 percent, significantly higher than either the no variety declaration case or the base case. Total costs per Non-GM bushel were also significantly higher than either of the other cases (13.4 cents/bu).

- Effect of Price Differentials. Discounts are determined in part by contract specifications of individual buyers. Results indicated that lower penalties result in less intensive optimal testing strategy and a higher rejection rate by importers.

- Grower Truth-telling. Farmers are assumed to declare GM content at the point of delivery which allows the first handler to segregate and would typically be governed by some type of contract and/or elevator imposed mechanism. As farmer truth-telling declines, optimal strategies result in increased testing. There are greater false rejections in the system as grower truth-telling decreases and total costs also increase as farmer truth-telling declines.

Finally, Wilson and Dahl (2002) identified several important implications.

1) A system based on testing and segregation can efficiently assure buyers of GM content at a quite low cost. While nil tolerance cannot be achieved through a system based on testing, the GM content can reasonably be assured at the 1 percent level.

2) The cost of a system based on optimal testing and segregation inclusive of a risk premium are much less than most systems that have been proposed on IP and other means to control GM content.

3) An IP system to resolve marketing of GM would be much more elaborate in terms of monitoring, administration, etc., than a system involving tolerances and testing and, as a result, would be much more costly.

4) Many factors will affect the elements of an optimal testing system, costs, and risks. Most important among these include price discounts/costs for being out of contract and GM declaration at delivery.

5) Strict interpretation of the risk premium indicates this is the premium required for grain handlers to be indifferent between a dual system of Non-GM and GM or an existing Non-GM system. In order for Non-GM to gain a premium, sellers will have to provide proof that it is in fact Non-GM, buyers must be willing to pay this cost and, eventually through competition, price differentials will emerge to approximately reflect these costs.

Certification of GM Content in Export Transactions. An important aspect for international marketing of GM grains relates to how export shipments are being treated in commercial transactions.[22]

Currently, the wheat industry exports wheat with inclusion of a certificate letterhead statement. That statement indicates:

> "There are no transgenic wheat varieties for sale or in commercial production in the United States at this time."

This certificate accompanies approximately 50 percent of U.S. wheat exports, at the request of the buyer. When GM wheats enter into commercial production, some alternative certification process will likely have to be adopted.

For other grains, Japan has the most onerous, though workable mechanisms. Other countries are more sporadic in their specifications and include South American countries, Mexico, and Korea–all of whom would be considered irregular in their specifications. Below is a sketch of the general procedures followed for testing/certification of GM content in grains:

- Buyers specify in their contracts whether a test is conducted and who should conduct the test.

- Normally a strip test is used for individual traits of interest. In this case, typically, three samples are taken with 800 kernels each. If any test is positive, the sample is deemed positive. If a buyer specifies "Non-GM" inclusive of all GM traits, then the PCR is used.

- Testing is normally done by private labs (e.g., SGS, Thionville, Louisiana Grain Services). USDA could conduct the test and certification, if requested.

- A certificate is provided by the lab certifying the test results.

- Buyers would accrue the costs and/or they are embedded in their prices.

Trade for RR Soybeans are governed by contract terms and not by regulation. Traders do not provide certificates. Instead, they provide a process including IP from the farm to the elevator. Testing is done by traders as a check, and only selectively may ask a 3rd party private lab for a check. It is important that these processes are conducted at the origin. At that point, if it is found to be positive, the product is rejected prior to being exported. Upon arrival at the

[22] Results in this section are based on a set of informal interviews with grain trade participants and testing companies regarding their current practices with respect to GM corn and soybeans. The experience for most companies is that of Japan which has a highly autonomous system. Others are more periodic.

export elevator, the grain is unloaded from the barge and loaded directly onto the vessel and certified that it is loaded directly after going through a scale.

For corn shipments, a certificate is required for StarLink. In this case, the process is similar as described above. However, in addition, the Federal Grain Inspection Service (FGIS) provides a procedure (on their web page)[23] and does provide a statement (presumably similar to a certificate), that "....they observed the barge being unloaded ...and it was IP'ed from the barge to the vessel....[approximate language]". Thus, in this case, there is minimal testing, that which is done by the trading company for themselves and any certification is limited to above. If a test is applied, the FGIS procedures has language that can be used in the certificate and accommodates StarLink testing results on a composite sample.

USDA and GIPSA currently have the ability to provide certification of GM content upon request. However, to date such requests have not been made. All testing and certification for GM content are provided currently by independent testing companies or by the supplier.

USDA has played an important (and likely preferred) role in providing testing protocols to the private sector and then relying upon the private sector to conduct the actual testing and certification. If "the market demanded" that there be a USDA certificate of GM content, they could do so. However, to date such requests have not been made.

8. Risks in GM Wheat Production and Marketing

There are several sources of risks associated with adoption and production of GM wheat. Risks are incurred throughout this system. These include production (agronomic) risks, handling risks, and risks to the organic sector. Each are discussed below.

8.1 Agronomic Risks

There are three sources of grower risk. These include volunteers in subsequent crops,[24] pollen drift, and on-farm adventitious commingling.

Experience with volunteers has been limited in these crops for obvious reasons. The literature suggests the level of risk of volunteers to be in the area of 31 percent of fields infested with an average density of 9 plants/sq. meter in the first year (Thomas and Leeson). The percentage of fields infested and densities decline as years since the last wheat crop increase. By year 5, only 9 percent of fields were infested with an average density of less than 1 plant/sq. meter. These results indicate that there is a positive incidence, and this declines through time and is dependent on variety and agronomic practices. Using reasonable assumptions about planting rates, etc., these risks translate to a probability of about .009 in year 1 (which would

[23] See USDA-GIPSA, 2001a,b.

[24] Volunteer GM wheat would need to be sprayed out of RR crops that follow, such as canola or soybean.

apply if wheat were planted on ground that was planted to wheat in the prior year) and diminishes to virtually nil in the years following.[25]

Pollen drift in the case of self pollinated GM wheats is relatively modest compared to cross pollinated crops like corn. Studies for wheat have suggested that the rate of outcrossing is generally less than 1 percent but can range as high as 5 percent with pollen drifting from 5 to 48 meters. Hucl and Matus-Cadiz indicate this may result in higher than acceptable levels of off-types occurring in isolation strips of 3 to 10 meters. They indicated outcrossing varies by variety with Oslo and Roblin having higher outcrossing rates which may require larger isolation strips than for low outcrossing varieties.

In a recent presentation Hucl (2002) indicated:

- Previous studies indicated: Outcrossing of common wheat varieties from 1932 indicated an outcrossing rate of 0.1-1.0 percent (Harrington); in the 1980s, Griffin documented up to a 4 percent outcrossing rate.
- Most of the varieties had outcrossing levels under 1 percent.
- "within 20-30 cm from the pollen source, you generally find less than 5 percent outcrossing" and indicated that the "generally accepted definition for cross-pollenation refers to outcrossing rates in excess of 50 percent at these distances.
- The actual rate of outcrossing varies by variety in wheat.

Finally, Hurburgh (in the case of corn) indicated on-farm handling risks of adventitious commingling to have a probability of about .016. The most likely sources of mixing errors at the farm level were: planter box 0.6, combine 0.6, transport 0.2, handling-on-farm 0.3 or .017, excluding pollen drift.

8.2 Handling Risks

While handlers routinely segregate and blend grains as a primary function of their business, there is added risk of handling GM grains due to the possibility of adventitious commingling. A recent study by USDA/ARS found that if running elevators non-stop, contamination is 4 percent; after 3 minutes, it declines to .2 percent (i.e., probability=.002) (Casada, et al.). These are corroborated by Hurburgh who suggested the sources of adventitious

[25] At an average infestation rate of 9 plants/sq. meter, this equals 36,434 plants/acre and 14,000 seeds/lb; then 2.6 lbs. or 0.04 bu would be required to generate 36,434 plants per acre. Assuming a normal seeding rate of 1.5 bu/acre, the rate of infestation is equivalent to 2.89 percent of planting rate. If infestations are likely to occur with a probability of .31, then the expected infestation rate is 2.89% • .31 + 0 • .69 = 0.9% in year 1, and decline thereafter.

commingling at the elevator/handling function to be: handling .3 percent, shipping .3 percent, and mixing 1 percent, for a total of =1.6 percent or a probability of .016.

8.3 Risks to Organic Production

An important and impending problem is that targeted areas for GM wheat development are the same as those regions in which there is a fairly large concentration of organic grain production (Brummond). In fact, North Dakota is the state with the largest acres devoted to organic production, a sector which is growing fairly quickly. Marketing practices in this sector have evolved to use a term called zero-tolerance.

It is important that organic as a general class of food products has evolved to be a fast growing market. A recent survey by the Food Marketing Institute indicated the following trends in organic consumption (*Milling & Baking News*, December 31, 2002).

- More than 60 percent of American consumers believe that organic foods are better for their health.
- With the new organic labeling standards (see below), it is expected that consumers will better understand what they are buying.
- The most popular organic products are fruits and vegetables. Organic cereals, bread and pastas, were purchased by 27 percent of the shoppers.
- U.S. consumers are confused on issues of bioengineered foods.

North Dakota is one of the top states in acreage of organic grain production, a sector that is growing fairly quickly. In 1997, the top organic wheat producing state was Montana with almost 32,000 certified acres (out of 5,360,000), followed by North Dakota with almost 24,000 acres (out of 11,625,000 acres of wheat planted in the state). In 2001, North Dakota had an estimated 31,172 certified organic acres of wheat (out of 9,450,000 acres of wheat planted in the state). The market for organic grains (wheat, rice, corn, barley, and oats) and oilseeds (soybeans) has risen significantly since 1998, in large part because it is a way to ensure that the products purchased are Non-GM.

USDA standards for organic are based on production practices.[26] If GM grains are developed, the issue of tolerances and testing in this sector will undoubtedly escalate. The National Organic Program (NOP) established by the USDA is intended to assure consumers that the organic foods they purchase are produced, processed, and certified to consistent national

[26] There are USDA standards for organic production. However, these do not refer to any tolerance, but instead simply refer to excluded practices. Labeling restrictions apply tolerances based on how the product is sold.

organic standards.[27] Under the USDA's new organic rules, products carrying the label must be produced without hormones, antibiotics, pesticides, synthetic fertilizers, or genetic modification.

As GMO contamination of organic crops relates to genetic drift, the preamble to the NOP regulations, Applicability, Clarifications (1) Genetic Drift, states (USDA-AMS):

> "This regulation prohibits the use of excluded methods (which includes GMOs) in organic operations. The presence of a detectable residue of a product of excluded methods alone does not necessarily constitute a violation of this regulation. As long as an organic operation has not used excluded methods and takes reasonable steps to avoid contact with the products of excluded methods as detailed in their approved organic system plan, the unintentional presence of the products of excluded methods should not affect the status of an organic product or operation."

This, however, does not lessen concerns of organic growers whose marketing practices have evolved to use a term called zero-tolerance. In addition, North Dakota organic growers are also very concerned about the ability to find Non-GM wheat seed sources in the future.

9. Future and Unresolved Issues

While there are some unresolved issues in the development and commercialization of GM wheats, some of the findings from the existing studies are important. This section first provides a summary of the existing studies discussed above and are particularly relevant for wheat. Following that, the salient unresolved issues are identified. Then, we describe the likely market system that will ensue with the evolution of GM wheat, and in the final section make suggestions for future efforts and initiatives on this topic.

9.1 Summary Facts from Existing Studies

Background. As a point of departure, there are three important points on the evolution of GM wheats.

1) The potential economic gains associated with biotechnology development in grains in North Dakota rank second only to California. North Dakota could see the greatest production gain because of fungus-resistant barley and HT wheat.

2) Many wheat producer and marketing organizations have taken positions to conditionally support developments in GM wheats. In virtually all cases, the position reflects that biotech wheats are desirable, mostly looking to 2nd stage benefits; research on biotechnology wheat should continue; but GM wheats (particularly RRW) should not be commercialized until systems involving IP and testing are developed to satisfy needs of buyers.

[27] The NOP labeling standards are outlined in Appendix 2.

3) There are three sources of pressures for adopting GM wheat. One is from a combination of cost reduction and reduced dockage in the case of RRW. Second is due to the increased profitability of competing crops (being recipients of GM technology) which has taken acres from conventional crops. And third is the prospect of 2nd and 3rd stage benefits associated with GM wheats. There is extensive research associated with numerous GM traits in wheat, including herbicide tolerance, fusarium resistance, and quality attributes.

Adoption and Agronomic Competitiveness of GM Grains and Oilseeds

1) *Worldwide Production of GM Crops*: Transgenic crops are being produced in 13 countries worldwide. In 2001, 68 percent of the global area of transgenic crops was in the United States, 22 percent in Argentina, 6 percent in Canada, 3 percent in China, and 1 percent in all the other countries. The four major crops comprising most of the commercial transgenic crops in the world are soybeans, corn, cotton, and canola.

2) *U.S. Production of GM Crops:* The adoption of biotech crop varieties has had the greatest growth and penetration in the United States. Acreage of biotech varieties of soybeans increased significantly in 2002. The widespread producer acceptance of GM crops (corn and soybeans) in the upper Midwest would seem to indicate a willingness of producers to accept GM wheat when it becomes available.

3) *Acres Shift to GM Crops*: There has been a general decline in planted acreage of wheat and barley in traditional growing regions over the past 30 years. In recent years, this decline has largely been replaced by planted acreage of corn, soybeans, and canola, particularly since the introduction of GM varieties in these crops.

4) *Agronomic Advantages of RRW*: There are two primary sources of agronomic advantages for HT wheat. These are yield increases and reduced dockage. According to Monsanto, RRW results in an average yield advantage relative to conventional crops of 11 to 14 percent. RRW also has the impact of reducing weeds and, therefore, weed seeds contained in dockage. Research has suggested that the adoption of RRW in HRS areas would have the following impacts: reduced weed seeds which comprise 62 percent of wheat dockage content; reduced cost of dockage removal throughout the marketing system; and the reduced dockage would result in cost savings in the area of 5.5 cents/bu (versus current system costs of 8.4 cents/bu) or about $1.32 to $2.73/acre.

Taken together, Monsanto has indicated that these agronomic benefits would increase net returns by about $15 to $20/acre.

Research on GM Wheat Traits. There is extensive research using GM technology to develop specific traits for wheat. Most important are the following:

1) The United States is dominant, albeit not the only player in trait research.

2) Herbicide tolerance is one trait under development. This is followed by product quality, fusarium resistance, and others.

3) There are numerous diverse organizations involved in trait development. These range from private companies, state universities, federal governments, and others.

All of these suggest that at some time in the future, the market and regulatory and institutional/organizational regimes will have to deal with a multitude of GM traits simultaneously.

Consumer and Market Acceptance. There has been extensive research on consumer attitudes and acceptance of GM traits, both in the United States and other countries. Below is a synopsis of that analysis:

1) Consumers do not reject genetic engineering outright but objections focus on specific applications of the technology. Consumer support is linked to perceptions of direct consumer benefits.

2) International surveys suggest that Americans have greater support for biotechnology than Canadians and Europeans. Americans have a higher degree of trust in regulatory authorities than Europeans. And, Japanese and European consumers prefer international regulatory agencies and have less trust in national regulatory agencies than Americans or Canadians.

3) In contrast to other risks, concern for biotechnology is relatively low compared to other food safety issues.

4) When a connection is made between labeling and increased food costs, consumers were generally not willing to pay more for labels.

5) Surveys are generally poor predictors of actual consumer behavior as consumers often say one thing and do another.

6) The ABA recently conducted a survey of U.S. consumers about GM wheats. Highlights from this survey indicated:

    - Acceptance of GM wheat is at the same level as GM corn, tomatoes, and oil, which are already in production, but overall at this early stage, a plurality still say the risks of GM wheat outweigh the benefits.

- The number of 'potential switchers' saying they would switch from GM wheat bakery products is identical to GM corn products. Few consumers have switched from GM corn. A wholesale switch from GM wheat is not likely to happen without a trigger event that would draw more attention to the issue or easy access to an alternative market to 'exit' to (e.g., organic or Non-GM wheat alternative).

- Acceptance of GM wheat is likely to depend on the extent to which it is differentiated in consumers' minds from other more 'contentious' GM technologies, particularly animal applications.

Regulatory Issues. There are numerous regulatory issues related to GM crops.

1) Nearly every country has different approaches and each has their own regulatory framework. Regulation is a very dynamic issue with changes being reviewed and proposed in many countries on an ongoing basis.

2) In the United States, transgenic crops are subject to a tripartite regulatory system. The government agencies having a part in this system are APHIS (Animal Plant Health Inspection Service of the USDA), EPA (Environmental Protection Agency), and FDA (Food and Drug Administration). The U.S. regulatory system focuses on determining the relative safety of biotechnology's end products and not on the processes by which they are created (USDA-APHIS).

3) *Restrictions and Labeling of Products Containing GM Ingredients*. In addition to regulations on GM crops, there are a complex series of issues/restrictions related to labeling of products made from ingredients that are or might be derived from GM crops. These vary across countries.

4) EU farm ministers agreed in November 2002 to require food and feed containing 0.9 percent or more GM grain to be labeled as genetically modified. They also agreed to a maximum permissible level of 0.5 percent for food and feed that accidently contains unauthorized GMOs (adventitious contamination).

5) Mandatory labels have been fiercely opposed by the U.S. food industry, which contends that such labels would raise concerns about the safety of GM foods and scare consumers away, in addition to increasing the cost of nearly all food products. Some 35 countries worldwide have, or are developing, mandatory GM labeling laws.

6) *Food Safety.* The National Academy of Sciences expert committee said they found no evidence that gene-spliced crops are unsafe to eat. They endorsed the central principle of the U.S. government's existing biotech regulations: that genetically engineered foods pose no special risk because they are produced by a new process. The American Medical Association's Council on Scientific Affairs supported

agriculture biotechnology and stated, “There is no scientific justification for special labeling of genetically modified foods.”

GM Wheat and International Trade Issues. Two of the fundamental issues in international trade are the potential for buyer acceptance and aversion to GM wheat and the welfare and strategic implications of GM wheat. Results from these indicate:

1) Some countries are thought to be averse to the importation of wheats containing GM content. The implied threat is that they will reject U.S. wheat because they do not believe that adequate segregation systems are in place to avoid GM “contamination.”

2) *Trade Volumes and Alleged Buyer Acceptance.* The data illustrates that:

   - The U.S. domestic market is by far the domineering market and, as suggested here, is non-averse.

   - Aside from the U.S. market, the largest GM averse markets are Japan, the Philippines, Korea, and the EU countries (notably, Italy, Spain, and the United Kingdom).

   - Taken together, these results suggest that about 72 percent of the market would be GM tolerant, the remaining being potentially averse.

   - Some of the countries that are claimed to be averse to GM content in wheat are large importers of soybeans and corn, both of which have production of GM, at least from the United States. This suggests that these countries have established protocols to facilitate grains and oilseeds from regions in which there are known production of GM grains and oilseeds.

3) *Canadian Impacts*: Ten key export markets were identified that Canada risks losing due to being a first mover in the introduction of GM wheat. Results from Furtan, et al. indicate that:

   - If Canada were to register GM wheat, the markets that demand GM-free wheat would turn to other exporters where GM wheat is not registered, such as Australia, the EU, and the United States. Canada would then sell its wheat into those markets that are indifferent to GM wheat, such as China.

   - While GM wheat will make production cheaper, those agronomic benefits are more than out-weighed by the costs of segregation of GM wheat, the impact of lost export markets, and lower wheat prices.

4) *United States Impacts:* DeVuyst, et al. (2001) indicated that in most scenarios, U.S. producers stand to gain considerably due to GM wheat introductions, assuming a 4.8 percent costs savings for GM versus Non-GM wheat. Their results indicate that the United States may have a first-mover advantage even when importers of U.S. wheat do not accept GM wheat.

Segregation and Identity Preservation and GM Wheat Marketing. Definitions of what constitutes an IP system vary substantially and are sometimes posed as a mechanism to assure Non-GM marketing. An alternative would be systems of testing, segregation, and contract specifications to assure Non-GM content. Numerous studies have examined IP/segregation costs for a range of commodities using different methodologies. Results from these and implications for GM wheat marketing are identified below:

1) The estimated costs of segregating IP grains from these studies range from 1 to 72 cents/bu.

2) Economics of Testing and Tolerances: An alternative or complement to IP types of systems is the use of testing and tolerances.

   - Several companies are developing or have developed tests for GM wheats, and their proposed costs have been reduced in the past few years. Typically, these would be applied at different points in the marketing system and, depending on the size of the unit, would convert to about 0.2 to 3.6 cents/bu.

   - Concurrent with any test is a tolerance which is normally specified in purchase contracts. There are two forms in which tolerances are applied. One would be those defined by regulatory agencies (e.g., the FDA and like agencies in other countries). Second, would be as commercial tolerances. Ultimately, there will be varying types of limits and tolerances specified by domestic and international buyers.

   - Testing has inherent risks, costs, and is subject to error. Risks are defined as buyers receiving a product that should be rejected and sellers having a product rejected that should have been accepted.

3) Estimates of the Costs and Risks of Testing and Segregating GM Wheat. Results of a study specific to wheat identified the optimal testing strategies of a GM/Non-GM system versus the existing Non-GM system indicated:

   - The optimal strategy would be to test every 5^{th} railcar at the country elevator when loading and to test every ship sublot when loading at the export elevator.

   - This testing strategy results in average rejection rates at the importer of 1.75 percent.

- The total cost to the system was estimated at 3.4 cents/bu. The cost of the system includes additional costs of testing and rejection and a risk premium to the handler due to the added risk of handling Non-GM in a dual marketing system.

- An important component of the system is some system of variety declaration, which could be envisioned as part of a closed loop system. A system with no variety declaration results in significant misgrading and raises costs substantially. Similarly, a system not including testing would raise costs upwards to 13 cents/bu.

Results indicated that a system based on testing and segregation can assure buyers of GM content at a quite low cost. While nil tolerance cannot be achieved through a system based on testing, the GM content can reasonably be assured at the 1 percent level. Second, the costs of a system based on optimal testing and segregation, inclusive of a risk premium, are much less than most systems that have been proposed on IP and other means to control GM content. Finally, many factors will affect the elements of an optimal testing system, costs, and risks. Most important among these include price discounts/costs for being out of contract and GM declaration at delivery.

Risks in GM Wheat Production and Marketing. There are potential sources of risk in GM wheat production. These include risks in production, handling, and to the organic sector.

1) *Agronomic Risks.* Most of the recent research suggests that there is risk of outcrossing and volunteers. However, in the case of wheat, these risks are relatively minimal.

2) *Risks to Organic Production*. Another important and impending problem in the case of GM wheats is the impact on the organic production sector.

9.2 Evolution of GM Wheats and Marketing System Implications

Existing research, as well as the experiences of other GM grains and oilseeds, suggests a number of implications on how the commercialization and adoption of GM wheats will evolve. This section is explorative about the likely evolution of GM wheat and suggests some of the implications for the grain marketing system.

Likely Evolution of GM Wheat. The evolution of GM wheats will likely evolve as, and in response to, the following pressures:

1) Further development and differentiation will persist in the other major grains, notably corn, soybeans, and canola.

2) Pressures will escalate to commercialize the GM wheat traits currently in the research phase. These would likely be in order of herbicide tolerance (RRW), fusarium resistance, and then varying forms of quality traits.

3) Productivity of other small grains (e.g., barley, durum, others) will lag substantially, ultimately raising their costs and reducing acres of these crops.

4) There will be an escalation of specialization in several dimensions to accommodate GM wheats. More than likely, these would or could be by geographical regions, handling facilities, and potentially even at the grower level.

5) A dual marketing system will evolve to accommodate the co-existence of GM and Non-GM wheats (described below). The marketing solutions to the differentiated customers will be through adoption of systems of contracts, tolerances, testing, and price differentials.

6) Buyers and growers will be needing to be less random in their marketing functions. Prior to making purchases, buyers will have to predetermine and inform sellers/producers of desired traits and attributes, and growers will have to supply more information with respect to production (varieties, agronomic practices, etc.) and delivery (time and place).

Marketing System Implications. The motivation for the evolution above is really in response to the growing differentiation among countries and, ultimately, among buyers within a country, concurrent with more technological choices in production. In addition, asynchronous regulations, along with selected buyer resistance and indigenous differentiated demands, ultimately suggest that a dual marketing system (or a marketing system to facilitate coexistence) is inevitable. This is likely true in the domestic market even though labeling would be voluntary with different approaches likely adopted by buyers for branded versus non-branded (e.g., private label, food service) products. This would also occur internationally between countries with and without tolerance limits and/or other requirements for the traits and those with approved traits.

In response, the marketing system will evolve in what may be called a "dual market" to accommodate these technologies and demands. To facilitate this it is envisioned the following to be important:

1) *Buyers:* Both domestic and international buyers averse to GM wheats will need to specify some tolerance level and testing is adopted. This will take the form of contracts, testing methodologies, and tolerances.

Those buyers with non-nil tolerances (to the 1 percent level or slightly less) should be able to purchase GM wheat with a nominal additional cost using contractual restrictions. Those buyers wanting nil tolerances will have to be more aggressive in their procurement strategies, working more closely with suppliers, targeting origin regions and facilities.

2) *Growers:* Growers declare varieties at point of first delivery. Specifically, growers would make some type of declaration about whether the delivery contains a GM variety.

   There are three important implications or reasons for this. First, is that it provides low cost information that is useful to the handler in segregation. If such a system were not adopted, the costs and risks would escalate sharply. Second, this will have the impact of facilitating marketing by varieties, or groups of varieties, which may become a component of contract specifications. Finally, this may take the form of being implemented as a component of some type of closed loop system that would be facilitated by technology providers.

3) *Handling and Testing:* Competing models of handling and segregation will evolve. Initially, these may involve IP types of systems. Eventually, due to competitive pressures, improved testing, and greater knowledge by marketers, systems based on contract specifications, penalties, and testing protocols will likely emerge. The reason for this is that it would likely be lower cost than some proposed IP systems. Testing will likely be more comprehensive, strategic, and complex as suggested in these results. This would be in contrast to routine testing across shipments, origins, and buyers.

4) *Price Differentials:* Over time price differentials will evolve among wheats with different GM trait content. This will likely be not unlike current price differentials for measurable traits and attributes. The price differentials will very likely evolve to be similar to the cost differentials to the system.

5) *Protocols:* Protocols will evolve that will govern trade and marketing practices. These will likely be mechanisms that govern buyer-seller relations, as well as relations among growers, handlers, and technology companies.

6) *Certification*: Differing certification processes will likely emerge in response to the differentiated demands and requirements. This may very well involve certification by 3rd party private testing companies or by official government agencies.

9.3 Unresolved Issues and Future Initiatives

Commercialization and adoption of GM wheats poses many opportunities and challenges. Despite there being extensive research on the topic as summarized in this paper, there are also many unresolved issues. These are not inconsequential and are summarized below, the purpose being to motivate further work in areas to facilitate coexistence of differentiated demands and technologies. These include:

1) *Organic Product Marketing*: There are numerous opportunities in this sector, but there are also a number of challenges as noted above.

2) *Facilitative Government Intervention*: At least in the United States, there are already extensive regulatory processes at the federal level governing the relevant aspects important to GM wheat production. Thus, trying to replicate these by state may be fruitless. However, there are other facilitative mechanisms that will need refining in the case of GM wheats. These include 3rd party certification and seed stocks purity, among others.

3) *Research*: The prospects of GM technology in wheat poses many unanswered questions. These will go begging for answers and a research plan should be important to providing means to answers to these questions.

4) *Food Processors*: Food processors most likely will confront increased heterogeneity in product demands with segments becoming defined for organic, Non-GM, and indifferent. Firms in this sector will have to develop marketing, procurement, and processing sectors to match these evolving product market segments and technologies in production and processing.

5) *Informational Demands*: The demands for information about GM wheat will escalate. Buyers will be wanting information about traits under development, traits that have been approved, and where that production is geographically concentrated. Growers and sellers will demand the same, as well as the approval of traits by different domestic and international buyers. Thus, some mechanisms should be developed to efficiently and credibly provide this information.

6) *Extension/Education*: There are numerous demands for education by consumers, marketers, and growers. The latter would naturally fit into Extension programs about appropriate farm management practices. However, there will also be demand for education for handlers about testing, certification, market acceptance, and protocols.

7) *International Marketing and Outreach for GM Wheat*: Given the size, diversity, and state of knowledge among international buyers, there will be large demands for information within this sector. As the number of approved traits escalate, opportunities for international marketing and outreach will escalate.

References

AAP News. 2001. "Australians Now Prepared to Eat GM Foods: Survey." Australian Associated Press, Canberra, Australia, June 7.

AAP News. 2001. "Genetically Modified Food Worries Waning." Australian Associated Press, Canberra, Australia, May 10.

ABARE. 2001. *Genetically Modified Grains: Market Implications for Australian Grain Growers*. Australian Bureau of Agricultural and Resource Economics, Canberra, Australia.

AgBioWorld. 2002a. *Biotech Yield References*. Internet Document, Accessed December 30, 2002, http://www.agbioworld.org/biotech_info/articles/yieldref.html.

AgBioWorld. 2002b. *Scientific Journal Articles: General Safety and Safety Assessment of Specific Genetically Modified Crops*. Internet Document, Accessed December 30, 2002, http://www.agbioworld.org/biotech_info/articles/gen_safety.html.

American Bakers Association. 2001. "American Bakers Association Biotechnology Position Statement." September. Internet Document, http://www.americanbakers.org/pubs/biotech_paper_2001_for_web.pdf.

American Medical Association. 2000. "Genetically Modified Crops and Foods," Report 10 of the Council on Scientific Affairs, December.

Angus Reid Group Inc. 2000. "New thoughts for food: Consumers reaction to biotechnology in Foods." Global Report, May 1, Winnipeg, Manitoba, Canada.

Askin, Tom. 1988. "The Cost of Grade Segregating to Primary Elevators." Canadian Grain Commission, October 1988, Winnipeg, Manitoba, Canada.

Barboza, David. 2001. "As Biotech Crops Multiply, Consumers Get Little Choice." *The New York Times*, June 9.

Biane, Andre. 2001. "Future Implications of Food Biotechnology on the Baking Industry." Sara Lee Bakery Group, Speech to the American Bakers Association, September 11, Las Vegas, NV.

Biotech Knowledge Center. 1999. "Vatican Experts OK Plant, Animal Genetic Engineering," from the *St. Louis Post Dispatch*, October 22, Accessed June 2001, http://biotechknowledge.com/showlibsp.php3?uid=2428.

Blackshaw, Robert E., and K. Neil Harker. 2002. "Selective Weed Control with Glyphosate in Glyposate-Resistant Spring Wheat (*Triticum aestivum*)." *Weed Technology* 16:885-892.

Blaine, K., S. Kamaldeen, and D. Powell. 2002. "Public Perceptions of Biotechnology." *Journal of Food Science* 67(9), 2002:3200-3208.

Bloomer, J. 2001. "Biotechnology in Cereals." *Syngenta*, Speech to the American Bakers Association, September 11, Las Vegas, NV.

Brummond, B. 2001. "Genetically Modified Organisms: How They Affect Organic Agriculture in North Dakota." NDSU Extension Service, Walsh County, ND, http://www.ag.ndsu.nodak.edu/biotech/papers/brummond.pdf.

Buckwell, Alan, Graham Brookes, and Dylan Bradley. 1998. *Economics of Identity Preservation for Genetically Modified Crops*. CEAS Consultants, Wye, England.

Bullock, David S., Marion Desquilbet, and Elisavent I Nitsi. 2000. *The Economics of Non-GMO Segregation and Identity Preservation*. University of Illinois, Department of Agricultural and Consumer Economics, Urbana, IL.

BusinessWeek Online. 2000. "Commentary - Biotech Foods Aren't Out of the Woods Yet." April, Accessed April 2000, http://www.businessweek.com.

Buzby, J. C., J. A. Fox, R. C. Ready, and S. R. Crutchfield. 1998. "Measuring Consumer Benefits of Food Safety Risk Reductions." *Journal of Agricultural and Applied Economics* 30(July):69-82.

Canadian Wheat Board. 2001. *CWB Biotechnology Position Statement*. April 4, Internet Document, http://www.cwb.ca/publicat/biostate/index.shtml.

Casada, Mark, M. Elena Ingles, and Ronaldo Maghirang. 2001. *Report of Preliminary Findings for a Study of Value-Added and Identity Preserved Grain Handling in Commercial Elevators*. USDA-ARS Grain Marketing and Production Research Center, Manhattan, KS.

Center for Rural Studies. 2001. *Executive Summary: Attitudes Towards GM Organisms*. University of Vermont, accessed January 2001, http://crs.uvm.edu/btrpoll/2000/Gmo/.

Crop Biotech Update. 2001. Global Knowledge Center on Crop Biotechnology, ISAAA, Ithaca, NY, May 5.

Crop Protection Institute of Canada. 2001. "Plant Biotechnology in Canada." Etobicoke, Ontario, Canada.

Dahl, Bruce L., and William W. Wilson. 2002. *The Logistical Costs of Marketing Identity Preserved Wheat*. Agribusiness & Applied Economics Report No. 495, Department of Agribusiness and Applied Economics, North Dakota State University, Fargo, August.

DeVuyst, Eric A., Won W. Koo, Cheryl S. DeVuyst, and Richard D. Taylor. 2001. *Modeling International Trade Impacts of Genetically Modified Wheat*. Agribusiness & Applied Economics Report No. 463, Department of Agribusiness and Applied Economics, North Dakota State University, Fargo, October.

Directorate General, Commission for the European Communities. 2000. *Economic Impacts of Genetically Modified Crops on the Agri-Food Sector: First Review*. Working Document Rev. 2. Directorate General, Commission of the European Communities, April, http://europa.eu.int/comm/dg06/publi/gmo/full_en.pdf.

Duffy, Michael. 2001. *Who Benefits from Biotechnology?* Speech presented at the American Seed Association Meeting, December 5-7, Chicago, IL, http://www.leopold.iastate.edu/pubinfo/papersspeeches/biotech.html.

Dye, Dan. 2000. *Building the Identity Preservation System of the Future*. Speech presented at the 2000 Institute of Food Technologists, June, http://www.cargill.com/today/speeches.

Ervin, David E., Sandra S. Batie, Rick Welsh, Chantal L. Carpentier, Jacqueline I. Fern, Nessa J. Richman, Mary A. Schulz. 2000. *Transgenic Crops: An Environmental Assessment*. Henry A. Wallace for Agricultural & Environmental Policy at Winrock International (November):1-81.

Farm & Ranch Guide. 2000. "Biotechnology not an issue for most Americans." December 29.

Feedstuffs Staff Editor. 2000. "Mandatory GM Labeling Approved in Australia." *Feedstuffs* 72(33, August 7):5.

Forsythe, D. 2002. *GM Wheat: Customer Acceptability Survey Results from Asia*. U.S. Wheat Associates, Washington, DC, September 30.

Foster, M. 2001. *Genetically Modified Grains: Market Implications for Australian Grain Growers*, Australian Bureau of Agricultural and Resource Economics, Canberra, Australia.

Fox, John A. 1995. "Determinants of Consumer Acceptability of Bovine Somatotropin." *Review of Agricultural Economics* 17(January):51-62.

Fox, John A., James B. Kliebenstein, Dermot J. Hayes, and Jason F. Shogren. 1994. "Consumer Acceptability of Milk from Cows Treated with Bovine Somatotropin." *Journal of Dairy Science* 77:703-707.

Fox, J. A., J. F. Shogren, D.J. Hayes, and J. B. Kliebenstein. 1998. "CVM-X: Calibrating Contingent Values with Experimental Auction Markets." *American Journal Agricultural Economics* 80(August):455-465.

Franks, Jeremy R. 1999. "The Status and Prospects of GM Crops in Europe." *Food Policy* 24: 565-584.

Fulponi, Linda. 2000. *Modern Biotechnology and Agricultural Markets: A Discussion on Selected Issues.* Working Paper on Agricultural Policies and Markets. Organization for Economic Co-operation and Development, Directorate for Food, Agriculture and Fisheries, Committee for Agriculture, Paris, France.

Furtan, W. H., R. S. Gray, and J. J. Holzman. 2002. *The Optimal Time to Register Genetically Modified Wheat in Canada*. University of Saskatchewan, Saskatoon, Canada, Working Paper, http://www.usask.ca/agriculture/agec/working/Register%20GM%20Wheat.pdf .

Gianessi, Leonard P., Cressida S. Silvers, Sujatha Sankula, and Jannet E. Carpenter. *Plant Biotechnology: Current and Potential Impact for Improving Pest Management in U.S. Agriculture - An Analysis 0f 40 Case Studies.* National Center for Food and Agricultural Policy, Washington, DC, June 2002.

Giggax, Danny. 2002. Personal Communication, Monsanto, St. Louis, MO.

Gillam, C. 2002. "Asian opposition to biotech spring wheat steadfast." Reuters, October 9.

Grenier, Mike. 2002. *Agronomic Assessment of Roundup Ready Wheat (Discussion Paper)*, Canadian Wheat Board, Winnipeg, Manitoba, Canada.

Griffin, W. B. 1987. "Out-crossing in New Zealand wheats measured by occurrence of purple grain." *New Zealand Journal of Agricultural Resources* 30:287–290.

Gosnell, D. 2001. *Non-GM Wheat Segregation Strategies: Comparing the Costs*. Master's Thesis, University of Saskatchewan, Saskatoon, Canada.

Grocery Manufacturers of America. 2000. *GMA Survey Shows Americans Learning More About Biotechnology; Food Consumption Patterns Unchanged*. Press Release, Washington, DC, October 12.

Hallman, William K., Adesoji O. Adelaja, Brian J. Schilling, and John T. Lang. 2002. "Public Perceptions of Genetically Modified Foods: Americans Know Not What They Eat." Food Policy Institute Publication Number PR-0302-001, Rutgers University, New Brunswick, NJ, March.

Harrington, J. B. 1932. "Natural outcrossing in wheat, oats, barley at Saskatoon, Saskatchewan." *Scientific Agriculture* 12:470-483.

Hayes, D. J., J. F. Shogren, S. U. Shin, and J. B. Kliebenstein. 1995. "Valuing Food Safety in Experimental Auction Markets." *American Journal Agricultural Economics* 77:40-53. January.

Hermann T. J., M. Boland, and A. Heishman. 1999. *Economic Feasibility of Wheat Segregation at Country Elevators*. Kansas State University, Manhattan, http://www.css.orst.edu/nawg/1999/herman.html.

Hoban, Thomas J. 1996. "Consumers Will Accept Biotech Foods." *BT Catalyst*, Newsletter, North Carolina Biotechnology Center, Research Triangle Park, NC.

Hoban, Thomas J. 1997. "Consumer Acceptance of Biotechnology: An International Perspective." *Nature Biotechnology* 15.3:232-234.

Hoban, Thomas J. 1999. "Public Perception and Understanding of Agricultural Biotechnology." *Economic Perspectives*. Internet Document, October, Accessed September 15, 2000, http://usinfo.state.gov/journals/ites/1099/ijee/bio-hoban.htm.

Hoban, Thomas J. 2000a. "Biotechnology: Addressing Today's Core Issues for Better Food and Industry Growth." *Forum for Food, Beverage, and Consumer Products Leadership*, 2(6):95-105, October.

Hoban, Thomas J. 2000b. *Consumer Acceptance of Food Biotechnology*. Personal Correspondence.

Hoban, T. 2001. *Public Perceptions of Biotechnology*. Speech to the American Bakers Association, September 11, 2001, Las Vegas, NV.

Hoban, T. J., and L. D. Katic. 1998. "American Consumer Views on Biotechnology." *Cereal Foods World* 43.1: 20-22.

Hoban, T. J., & J. D. Miller. 1998. *Consumer images and impressions*. Paper presented at the Annual Meetings of the American Association for the Advancement of Science, Philadelphia, PA.

Holzman, Jeff. 2001. *The Economics of Herbicide Tolerant Wheat In Western Canadian Crop Rotations*. Unpublished Thesis, Department of Agriculture Economics, University of Saskatchewan, Saskatoon, Canada.

Hucl, P. 2002. *Outcrossing of Wheat*. Paper presented at the Canadian Weed Science Society, 56th Annual Meeting, November 27, 2002, Saskatoon, Saskatchewan, Canada.

Hucl, P., and M. Matus-Cadiz. 2001. "Isolation Distances for Minimizing Out-crossing in Spring Wheat." *Crop Science* 41:1328-1351.

Huffman, Wallace E., Jason F. Shogren, Abe Tegene, and Matt Rousu. 2002a. *Negative Information and Resistance to Adoption of New Technology: The Case of Genetically Modified Food*. Manuscript, Department of Economics, Iowa State University, Ames, IA.

Huffman, Wallace E., Jason F. Shogren, Abe Tegene, and Matt Rousu. 2002b. *Should the United States Initiate a Mandatory Labeling Policy for Genetically Modified Foods?* Manuscript, Department of Economics, Iowa State University, Ames, IA.

Hurburgh, C. R. 1999. *The GMO Controversy and Grain Handling for 2000*. Paper Presented at the Iowa State University Integrated Crop Management Conference, December 1-2, http://www.exnet.iastate.edu/Pages/grain/gmo/99gmoy2k.pdf.

Hurburgh, C. R., Jr,. J. L. Neal, M. L. McVea, and P. Baumel. 1994. *The Capability of Elevators to Segregate Grain by Intrinsic Quality*. Paper No. 946050, Presented at the 1994 Summer Meeting of the American Society of Agricultural Engineers, St. Joseph, MI.

International Food Information Council. 2002. "U.S. Consumer Attitudes Toward Food Biotechnology." IFIC, Washington, DC.

James, Clive. 2001. *Global Status of Commercialized Transgenic Crops: 2001*. ISAAA Briefs No. 245:Preview. International Service for the Acquisition of Agri-Biotech Applications, Ithaca, NY.

Jirik, Patrick J. 1994. *Identity Preserved Grain Marketing*. Unpublished Master's Thesis, Saint Mary's College, Winona, MN.

Kaeppler, Heidi F. 2000. "Food Safety Assessment of Genetically Modified Crops." *Agronomy Journal* 92:793-797.

Kamaldeen, S., and D. A. Powell. 2000. *Public Perceptions of Biotechnology*. Food Safety Network Technical Report #17, Department of Plant Agriculture, University of Guelph, Guelph, Ontario, Canada.

Kennet, Julie, Pauline Molder, and Murray Fulton. 1997. *Supply Chain Management: The Case of Canadian Milling Wheat*. Paper presented at the WRCC-72 Meeting, June 11-12, Las Vegas, NV.

Kuntz, Grant M. 2001. *Transgenic Wheat: Potential Price Impacts for Canada's Wheat Export Market*. Unpublished Master's Thesis, Department of Agricultural Economics, University of Saskatchewan, Saskatoon, Canada.

Lentz, T. D., and J. T. Akridge. 1997. *Economic Evaluation of Alternative Supply Chains for Soybean Peroxidase*. Center for Agricultural Business, Purdue University, West Lafayette, IN, Fall.

Lin, William W., William Chambers, and Joy Harwood. 2000. "Biotechnology: U.S. Grain Handlers Look Ahead." *Agricultural Outlook*. U.S. Department of Agriculture, Washington, DC, April.

Lusk, J. L., J. A. Fox, and C. L. McIlvain. 1999. "Consumer Acceptance of Irradiated Meat." *Food Technology* 53:56-59, March.

Lusk, J. L., M. S. Danield, D. R. Mark, and C. L. Lusk. 2001a. "Alternative Calibration and Auction Institutions for Predicting Consumer Willingness to Pay for Nongenetically Modified Corn Chips." *Journal of Agricultural and Resource Economics* 26(1):40-57.

Lusk, J. L., J. A. Fox, T. C. Schroeder, J. Mintert, and M. Koohmaraie. 2001b. "In-Store Valuation of Steak Tenderness." *American Journal Agricultural Economics* 83(3):539-550, August.

Maltsbarger, Richard, and Nicholas Kalaitzandonakes. 2000. "Studies Reveal Hidden Costs in IP Supply Chain." *Feedstuffs* 72(36), August 28.

Mayer, Sue. 2002. *Genetically Engineered Wheat - Changing Our Daily Bread*. GeneWatch UK, Derbyshire, United Kingdom.

McCluskey, J., and T. Wahl. 2003. "Reacting to GM Foods: Consumer Responses Surveyed in Asia and Europe." Washington State University, Internet Document, http://www.aenews.wsu.edu/Jan03AENews/Jan03AENews.htm#GMFoods.

McPhee, Terry Lynn, and Anita Bourget. 1995. *Cost of Grain and Grade Segregation at Terminal Elevators in Canada*. Canadian Grain Commission, Winnipeg, Manitoba, Canada.

Miller, Henry I., and Gregory Conko. 2002. "The UN's Bizarre War on Biotech." Posted on Techcentralstation, December 18, Accessed January 2, 2003, http://www.techcentralstation.be/2051/wrapper.jsp?PID=2051-100-100&CID=2051-121802M,

Milling and Baking News. 2000. "Major Changes Ahead in Wheat Research." *Milling and Baking News*, April 3.

Milling and Baking News. 2002. "Consumers Accepting Organics; Confused by Bioengineered Foods." *Milling and Baking News*, December 31.

Monsanto. 2001. *Extending Roundup Ready® Benefits to Wheat*. Monsanto Company, Wheat Industry Team, Bulletin #00401065, St. Louis, MO.

National Grain and Feed Association. 2001. *Agricultural Biotechnology Policy of the National Grain and Feed Association*. September 20, Internet Document , http://www.cwb.ca/publicat/biostate/index.shtml.

Nelson, Gerald C., Timothy Josling, David Bullock, Laurian Unnevehr, Mark Rosegrant, and Lowell Hill. 1999. *The Economics and Politics of Genetically Modified Organisms in Agriculture: Implications for WTO 2000*. Bulletin 809, Office of Research Consumer and Environmental Science Department, University of Illinois at Urbana-Champaign.

Nordlee, Julie A., Steve L. Taylor, Jeffrey A. Townsend, Laurie A. Thomas, and Robert K Bush. 1996. "Identification of Brazil-Nut Allergen In Transgenic Soybeans." *New England Journal of Medicine* 334(11):688-692.

North American Millers' Association. 2001. *Statement on Biotechnology.* Washington, DC.

North Dakota Agricultural Statistics Service. (Various Issues). *North Dakota Agricultural Statistics*. North Dakota Agricultural Statistics Service, Fargo, ND.

North Dakota Grain Growers Association. 2002. *North Dakota Grain Growers Association 2002-2003 Resolutions*. North Dakota Grain Growers Association, Bismarck, ND.

Pegg, J. R. 2002. "GM Foods Debate Hits Latin America." *Environmental News Service*, December 16.

Persley, Gabrielle J., and James N. Siedow. 1999. "Applications of Biotechnology to Crops: Benefits and Risks." *Council for Agricultural Science and Technology* 12 (1999):1-8.

PG Economics Ltd. 1999. *Wheat - Genetically Modified Crops: Economic and Strategic Issues Through the Food Chain.* Bioportfolio: Market Research and Consultancy Report. PG Economics Ltd., Dorset, United Kingdom.

Reuters. 2001. *Poll: Consumers Unaware of Biotech*. Reuters.com, March 26, http://dailynews.yahoo.com/htx/ap/20010326/hl/biotech_food_1.html ,accessed 06/27/01.

Riley, Peter A., and Linwood Hoffman. 1999. "Value-Enhanced Crops: Biotechnology's Next Stage." *Agricultural Outlook*, USDA-Economic Research Service, Washington, DC, March.

Roper Starch Worldwide Inc. 2000. "Consumer and Farmer Opinions about Food and Agriculture." Philip Morris Management Co., January 11.

Rousu, Matthew, Wallace E. Huffman, Jason F. Shogren, and Abebayehu Tegene. 2000a. *The Value of Verifiable Information in a Controversial Market: Evidence from Lab Auctions of Genetically Modified Foods*. Staff Working Paper #3, Department of Economics, Iowa State University, Ames, February.

Rousu, Matthew, Wallace E. Huffman, Jason F. Shogren, and Abebayehu Tegene. 2000b. *Are U.S. Consumers Tolerant of GM Foods?* Manuscript, Department of Economics, Iowa State University, Ames, May.

Schlecht, Shannon M.. 2001. *Logistical Strategies for Differentiated Wheat Classifications*. Unpublished Master's Thesis, Department of Agribusiness and Applied Economics, North Dakota State University, Fargo.

Schroeder, E. 2001. "Grain and Milling Industries Tackle Biotech Thresholds, Testing." *Milling and Baking News*, May 22.

Shoemaker, Robbin, Joy Harwood, Kelly Day-Rubenstein, Terry Dunahay, Paul Heisey, Linwood Hoffman, Cassandra Klotz-Ingram, William Lin, Lorraine Mitchell, William McBride, and Jorge Fernandez-Cornejo. 2001. *Economic Issues in Agricultural Biotechnology*. USDA-Economic Research Service, ERS Agricultural Information Bulletin No. 762, March.

Singer, Mike A. 2000. *Food for thought–Issues in agricultural biotechnology*. Chicago Fed Letter, The Federal Reserve Bank of Chicago, Chicago, IL, January.

Sjerven, Jay. 2001. "StarLink Recedes as a Threat, Not as a Burden." *Milling and Baking News* Vol. 80 (39, Nov 27):1, 26, 28, 30.

Smyth, Stuart, and Peter W. B. Phillips. 2001. *Identity-Preserving Production and Marketing Systems in the Global Agri-food Market: Implications for Canada*. University of Saskatchewan, Saskatoon, Canada, August.

Sonka, Steven R., Christopher Schroeder, and Carrie Cunningham. 2000. "Transportation, Handling, and Logistical Implications of Bioengineered Grains and Oilseeds: A Prospective Analysis." *Agricultural Transportation Challenges of the 21st Century*. USDA-Agricultural Marketing Service, Washington, DC, and National Soybean Research Lab, Urbana-Champaign, IL, November.

Soyatech.com (Soya & Oilseed Industry News). 2001. "Biotech is Pervasive Threat, says English Writer." Posted June 22, Accessed June 2001, http://www.soyatech.com/bluebook/news/viewarticle.ldml?article=20010622-8 .

Soyatech.com (Soya & Industry News). 2001. "Biotech Industry Conference Aims to 'set record straight' on GM Foods." Posted June 25, Accessed June 2001, http://www.soyatech.com/bluebook/news/viewarticle.ldml?article=20010625-7.

Soyatech.com (Soya & Oilseed Industry News). 2001. "Consumer organizations react to EU proposals on GM Labeling." Posted August 14, Accessed August 2001, http://www.soyatech.com/bluebook/news/viewarticle.ldml?a=20010814-5.

Soyatech.com (Soya & Oilseed Industry News). 2002. "A WTO case may worsen the dispute over GM foods." Posted December 30, Financial Times via NewsEdge Corporation, Accessed December 2002, http://www.soyatech.com/bluebook/news/viewarticle.ldml?a=20021230-4.

Soyatech.com (Soya & Oilseed Industry News). 2003. "Japanese Industry Group Will No Longer Separate GM Corn." Western Farm Press NewsEdge Corporation, Posted January 3, Accessed January 3, 2003, http://www.soyatech.com/bluebook/news/viewarticle.ldml?a=20030103-2

Sparks Company. 2000. *The IP Future: Identity Preservation in North American Agriculture*. Sparks Company, Memphis, TN.

Stokes, Trevor. 2001. "Growing French Acceptance of GM." *Trends in Plant Science* 6:2:53.

Stone, Susan, Anna Matysek, and Andrew Dolling. 2002. *Modeling Possible Impacts of GM Crops on Australian Trade*. Staff Research Paper, Productivity Commission, Melbourne, Australia.

Strayer, Dennis. 2002. *Identity-Preserved Systems: A Reference Handbook*. CRC Press, Boca Raton, FL.

Syngenta. 2001. *Generically Modified Grains: Market Implications for Australian Grain Growers*. Australian Bureau of Agricultural and Resource Economics, Canberra, Australia, Accessed December 27, 2002, http://www.syngenta.com.

Syngenta. 2002. "AWB and Syngenta seal deal to breed wheat of the future." March 8, http://www.syngenta.com.

Syngenta. 2002. *Tomorrow's Products*. Syngenta, Internet Document, Accessed December 2002, http://www.syngenta.com/en/products-services/tomprod.asp.

Thomas, A. G., and J. Y. Leeson. 1999. "Persistence of Volunteer Wheat and Canola Using Weed Survey Data." In: *Proceedings of the 1999 National Meeting*, p. 88. Expert Committee on Weeds: Sainte-Anne-de-Bellevue, QC, Canada.

Tobin, J. P. 2002. Personal Communication, Monsanto, St. Louis, MO, August.

USDA-AMS. 2002. National Organic Program, Questions and Answers. Agricultural Marketing Service, Internet Website, Accessed December 26, 2002, http://www.ams.usda.gov/nop/Q&A.html.

USDA-APHIS. 2002. *Agricultural Biotechnology: Frequently Asked Questions*. Animal and Plant Health Inspection Service, http://www.aphis.usda.gov/ppq/biotech/.

USDA-ERS. 2001. Agricultural Biotechnology Briefing Room Dataset. Economic Research Service, Internet Document, Accessed August 2001, http://www.ers.usda.gov/briefing/biotechnology/data/gmoacres1.xls

USDA-FGIS. 2001. *Agricultural Biotechnology: Sampling Grains for Biotechnology Identification*. Federal Grain Inspection Service, Internet Document, http://www.usda.gov/gipsa/biotech/biotech.htm.

USDA-GIPSA. 2001a. GIPSA Directive 9181.1 *Testing For Starlink™ Corn - Lateral Flow Test Strip Method.* Grain Inspection, Packers and Stockyards Administration, Federal Grain Inspection Service, Washington, DC, Internet Document, Posted Feb. 26, http://www.usda.gov/gipsa/reference-library/directives/9181-1.pdf .

USDA-GIPSA. 2001b. *Revision to Starlink Testing and Certification Procedures*. Grain Inspection, Packers and Stockyards Administration, Federal Grain Inspection Service, Washington, DC, Internet Document, Posted Feb. 2, http://www.usda.gov/gipsa/biotech/starlink/191.pdf.

USDA-GIPSA. 2002. *Process Verification: An Alternative to Traditional Inspection Services*. Grain Inspection, Packers, and Stockyards Administration, Federal Grain Inspection Service, Internet Document, Accessed August 28, 2002, http://www.usda.gov/gipsa/programsfgis/inspwgh/processver/processv.pdf, and notice to the *Federal Register*, "Facilitating the Marketing of U.S. Agricultural Products With New Testing and Process Verification Services," Vol. 67(151), August 6, 2002:50853-50854.

USDA-NASS. 2001. *Acreage Report, June*. National Agricultural Statistics Service, Washington, DC.

USDA-NASS. 2002 *Acreage Report, June*. National Agricultural Statistics Service, Washington, DC.

U.S. Wheat Associates. 2001. "U.S. Wheat Calls for Identity Preservation System Before Commercialization of GM Wheat." News Release, April 17, 2001. Internet Document, http://www.uswheat.org/.

Uzogara, Stella G. “The Impact of Genetic Modification of Human Foods in the 21st Century: A Review.” *Biotechnology Advances* 18 (2000):179-206.

VanWechel, Tamara. 2002. *Effects of Environmental Impact on Willingness to Pay for Genetically Modified Products*. Unpublished Master’s Thesis, Department of Natural Resources, North Dakota State University, Fargo.

Vogt, Donna U., and Mickey Parish. 1999. “Food Biotechnology in the United States: Science, Regulation, and Issues.” CRS Report to Congress, Congressional Research Service, The Library of Congress, June 2.

Wheeler, John. 1998. *An Overview of Grain Segregation Issues*. Agriculture and Agri-Food Canada Policy Development and Program Services. Ottawa, Ontario, Canada, November.

Wilcke, Bill. 1999. *Segregating Genetically Modified Crops*. Minnesota Extension Engineer. http://www.smallgrains.org/segregating.htm, September.

Wilson, Barry. 2001. “CWB Clarifies Position on GM Wheat.” *The Western Producer*. November 8, 2001:10.

Wilson, William. 2001. *Economics of Dockage Removal from Wheat in the United States and Canada.* Research prepared for Monsanto, May.

Wilson, William W., and Bruce L. Dahl. 2001. *Evaluation of Changes in Grade Specifications for Dockage in Wheat*. Agribusiness and Applied Economics Report No. 458, Department of Agribusiness and Applied Economics, North Dakota State University, Fargo, July

Wilson, William W. , and Bruce L. Dahl. 2002. *Costs and Risks of Testing and Segregating GM Wheat*. Agribusiness & Applied Economics Report No. 501, Department of Agribusiness and Applied Economics, North Dakota State University, Fargo, October.

World Grain Co., Ltd. 2002. “Bakers survey U.S. consumer attitudes on GM wheat.” Bangkok, Thailand, November 4, http://www.worldgrain.com/.

Appendix 1: Studies on Consumer Acceptance and Willingness to Pay

As evidenced from the literature, *awareness* and *acceptance* of the use of biotechnology are not synonymous (Hoban and Katic). Nor does acceptance of, or preference for, GM or Non-GM foods necessarily translate into willingness to pay a premium for such products (Lusk, et al. 2001b). A number of factors may (interdependently) result in a difference between what value individual consumers or groups of consumers attribute to a product by self-reporting (e.g., in response to a survey question), versus by purchasing behavior (i.e., revealed preference). These factors may include external or point of purchase influence (e.g., promotions, advertisements), consumer ignorance about or revealed indifference to ingredient sourcing for food products considered (e.g., products are not labeled, consumers are unaware of the implications of a product being produced with or without biotechnology), consumers who (un)knowingly report their stated preferences, or the difference between consumers in general and that subset of the population who make purchase decisions not only for themselves but for others (i.e., when a subset of the population is surveyed, it will include those who infrequently make food purchase decisions, even for themselves, as well as those who make food purchase decisions for, e.g., a household or institution). A key point is that, because research methods may have such a strong influence on findings and because the population and product(s) under consideration and methods use vary from study to study, one must be at least cautious when interpreting and comparing results. Finally, most research studies have elicited public perceptions of biotechnology in the abstract rather than looking at specific products or their characteristics, and those that consider more specific products or situations are often proprietary. Thus, we do not have much information about what consumers think about biotechnology and how they will help decide the fate of GM foods (Hallman, et al.).

There are a number of factors that influence how consumers perceive, and whether they are willing to pay for, products produced using biotechnology. For example, Hoban and Katic found that men have greater awareness of biotechnology than do women and that education has a positive impact on both awareness and acceptance of the associated benefits. They also found that younger consumers and those who had read about or otherwise heard about biotechnology were more willing to buy GM foods. [The latter appears to contrast with Rousu, et al. (2002a) who found that participants in an experimental auction who perceived themselves at least somewhat informed about biotechnology bid far less for GM foods than those less informed.] Hallman, et al. found that men and those more highly educated had heard more about biotechnology, and that men, and more highly educated and younger Americans, more strongly approve of biotechnology than their counterparts. Approval increased for specific products and benefits (versus biotechnology in general).

Acceptance of biotechnology arises from the benefits and risks consumers associate with the production of GM crops and consumption of the resulting food products. A large number and wide range of potential benefits and risks (disadvantages) are discussed in considerable detail in a number of papers (e.g., see especially Uzogara; Kamaldeen and Powell; Franks; Persley and Siedow). Benefits include, for example, experience with or potential for improved productivity and higher crop yields, reduced pesticide use, and improvements in the healthfulness of and nutrition provided by resulting food products. Risks can be divided into technology-inherent risks (risks associated with food safety and environmental effects) and technology-transcending risks (emanating from the political and social context in which the technology is used). Perceived risks include, for example, those associated with food safety and its impact on human health, fear of the unknown, and environmental impacts.

Consumer *awareness* of biotechnology appears to have increased among American consumers since one of the first formal assessments of such during the early-1990s (Hoban, 2000a). However, consumers are not well informed about biotechnology and freely admit to such, even while they tend to overestimate their understanding of food production technologies (Roper Starch Worldwide, Inc.; Hallman, et al.). For example, in a 1997 survey, 37 percent of respondents believed that GM products could not be found in supermarkets (40 percent believed they could) (Hoban and Katic). In a 2000 survey, a slightly lower 32 percent of respondents believed GM products could not be found in supermarkets, while 41 percent believed they could (Roper Starch Worldwide, Inc.). By this time, a vast majority of supermarkets in the United States contained GM food products. The level of consumer ignorance about biotechnology was reconfirmed by Hallman, et al. who found that only 41 percent of respondents to their 2001 survey knew GM products were in grocery stores and that 31 percent did not believe they were.

Although they are not well informed, in general (but not unanimously), the literature supports that Americans indicate an acceptance of biotechnology and a willingness to purchase GM products when they are queried by survey (e.g., Hoban, 1999; 1997). This is particularly true when the resulting food products have well-defined improvements in quality (e.g., more nutritious foods, foods that stay fresh longer) (Hoban, 2000b). Hoban and Miller found support among nearly two-thirds of American consumers for insect protected crops; but only 58 percent approved of additional uses of biotechnology that improve foods. Hoban (2000b) reported support for insect protected crops among only 51 percent of respondents. From a survey by Roper Starch Worldwide, Inc., 73 percent of consumers reported acceptance for the use of biotechnology as a tradeoff for not using chemicals in food production. A majority reported that its use is always or sometimes acceptable, although 25, 16, and 12 percent responded that it was never acceptable to use biotechnology to improve taste, production, and nutrition of food, respectively. These examples should emphasize the point that acceptance has a number of definitions.

Because U.S. consumers are increasingly but still not yet well informed about the use of biotechnology and GM food products, their opinions are not well formed, are subject to change, and can be influenced (Hallman, et al.). In the absence of prohibiting or restrictive legislation, the underlying empirical question of importance to participants from throughout the marketing channel is the relative willingness-to-pay by consumers for GM foods. A majority of existing literature assesses acceptance of biotechnology using surveys. However, work by Lusk, et al. (1999) demonstrates that consumer reported willingness-to-pay is higher than willingness-to-pay when consumers are actually required to purchase the product.

A growing number of researchers have, therefore, begun to use methods to assess revealed preference for GM foods, especially experimental auctions. Experimental auctions have the potential to provide more reliable measures of willingness to pay than hypothetical surveys. The specific benefits associated with experimental auctions are described in Fox, et al.

(1998). They have been used in a number of studies to estimate consumer demand for new food items (e.g., see Buzby, et al. 1998; Fox, et al. 1998; Fox 1995; Hayes, et al. 1995; Rousu, et al. 2002a, Huffman, et al. 2002b; Lusk, et al. 2001a,b).

An initial effort to assess revealed consumer willingness to pay for a product guaranteed to be produced without biotechnology is reported in Fox, et al. (1994). A Vickrey sealed-bid, second price auction was used to estimate consumer willingness to pay to replace milk from cows receiving bovine somatotropin (bST) with that from cows not receiving bST. The Vickrey second price auction has been frequently used in valuation experiments (Lusk, et al., 2001a). Average bids to exchange a glass of milk were positive, but most, particularly in two of three metropolitan areas, were either zero or exceeded $1, supporting the existence of market segments for bST-free milk. Providing information to participants about bST coincided with lower variance in average bid between rounds.

Lusk, et al. (2001a) assessed willingness to pay among students endowed with a bag of corn chips including GM ingredients to switch for Non-GM corn chips using first and second price auctions. All students were from Midwestern towns and enrolled in an agriculture major and most came from the farm. Not surprising given the nature of the population, students had little objection to GM foods and expressed a strong willingness to consume them. Seventy percent were unwilling to pay for Non-GM corn chips and the average bid was only $0.07 per ounce. As demonstrated elsewhere, there was evidence of a market segment that valued the Non-GM guarantee. Twenty percent of students were willing to pay at least $0.25 per ounce. The only variable statistically significant in explaining the probability a student would pay for Non-GM corn chips was the frequency of their chip consumption. The relationship was negative. The amount students were willing to pay for the Non-GM corn chips was influenced negatively by chip consumption and positively by regular exercise. Scale differential questions where participants indicated their degree of concern for GM foods were useful in predicting both the probability individual students would pay to exchange for Non-GM corn chips and the amount they would pay.

Huffman, et al. (2002b) used a random nth price experimental auction to assess willingness to pay for products under both voluntary (standard label versus Non-GM label) and mandatory (standard label versus GM label) labeling scenarios. Participants in two Midwestern cities bid on three products. Products were selected to represent highly processed (tortilla chips), refined and distilled (vegetable oil), and fresh (potatoes) products. Six groups bid on products with a label indicating only the name of the product and those also noting "This product is made without genetic engineering." Four groups bid on products with the plain label and those with labels indicating "This product is made with genetic engineering." Participants bid on either the GM (or implied GM) or Non-GM products in each round (i.e., bids by individuals for GM and Non-GM products did not occur simultaneously). Prior to bidding, participants were provided one page information summaries. Information provided was biased positive, biased negative, or verifiable (unbiased). [Rousu, et al. (2002a) used data from six of the ten treatments to evaluate the effect of asymmetric (biased) information on willingness to pay for products with GM ingredients].

Participants bid more for products presumed Non-GM. No demographic characteristics appeared to impact the discount for the GM-perceived products. The hypothesis that the average bid for GM and Non-GM food products are not different, regardless of labeling strategy, could not be rejected. For the GM labeled treatments (mandatory labeling scenario), bid order influenced bid price (Rousu, et al., 2002a). Participants bidding on products with the GM label in the first round paid a smaller premium for food with a standard label than those who bid on products with a standard label first. Females and consumers with lower incomes discounted GM foods less, although the differences were not large and generally not statistically significant. Those who perceived themselves at least somewhat informed about GM bid far less for GM foods, suggesting their prior-received information was weighted by a negative bias.

Huffman, et al. (2002a) used data from the four groups tested under the mandatory labeling policy scenario to evaluate the influence of information and demographic characteristics on the probability a consumer will be 'out of the market' for GM food products. When defined as a zero bid, ten percent of consumers were 'out of the market' over all products. The percentage was lower for oil than for less refined products of tortilla chips and potatoes. When 'out of the market' was defined as a bid less than two-thirds that of the non-labeled product, 'out of the market' consumers increased to 16.4 percent. Providing negative (positive) information about biotechnology increased (decreased) the probability a consumer would be 'out of the market.' Consumers who reported always reading labels for an initial purchase of a food item and those reporting they were at least somewhat informed about GM foods were more likely to be 'out of the market.'

Rousu, et al. (2002b) evaluated consumer acceptance of Non-GM foods with tolerance levels of zero, one percent, and five percent. Consumers bid less for GM tolerant foods, but the difference between bids for one and five percent tolerance products was not statistically significant. The products and experimental design followed that detailed in Huffman, et al. (2002b).

VanWechel used a random nth-price experimental auction to elicit and estimate the influence of information bias on consumer willingness to pay for foods with a standard NutriFacts label relative to foods also labeled with a Non-GM guarantee. Methods closely parallel those described in Huffman, et al. (2002b) and Rousu, et al. (2002a). Key differences include the composition of the participant population, type and form of products, product labeling, scope of information provided to participants and the timing of its introduction, and simultaneous (versus sequential) bidding on Non-GM and presumed GM products. One hundred twelve students from North Dakota State University (NDSU) were recruited to participate in the auction using a sample of convenience. Participants bid on each of three food products: individually wrapped muffins and chocolate chip cookies and bags of potato chips. These products include ingredients which are commonly produced in North Dakota and for which GM varieties exist (e.g., wheat, sugar) or already have been commercialized (e.g., corn, oil seeds, potatoes). Regardless of demographic characteristics, consumers universally purchase them. Individual serving, convenience-sized products were used to appeal to college students in the school environment.

Labeling products containing GM ingredients was rejected as a strategy for the current study. The current U.S. labeling policy for food products regarding biotechnology is voluntary. Products are required to be labeled only if they are not "substantially equivalent" to Non-GM products (Ervin, et al.). Huffman, et al. (2002b) demonstrate that when consumers can accurately read market signals (i.e., can interpret information identically whether from voluntary or mandatory labeling strategies), a voluntary labeling policy provides higher welfare. Furthermore, in light of public ignorance of biotechnology and the extent of adverse controversy, it is unlikely that firms would voluntarily adopt a strategy of labeling foods as containing GM ingredients. Subsequent to the second round of bidding, participants were provided and instructed to read biased information (biased positive or negative) about the effects of biotechnology on the environment or general information about North Dakota agriculture.

The presumed GM product reduced bids from those for the product labeled as Non-GM. This supported existing literature that demonstrates the average consumer is willing to pay a premium for food products guaranteed to be GM-free. The effect of information bias regarding environmental impacts of GM crops on willingness to pay for GM food products was unexpected and inconsistent with the hypotheses. Results indicate that positive-biased information resulted in increased bids for GM products, the anticipated result. However, negative-biased information also had a positive impact, and the resulting increase in GM-product bid was even greater.

There are a number of possible factors that may have contributed to this unexpected result including method of product labeling, participant characteristics, and the impact of unique market segments among the participating population. Use of a standard NutriFacts label versus one also containing the statement, "This product does not contain genetically modified ingredients" differentiated the GM and Non-GM products. The decrease in bid for the GM product supports the hypothesis that participants read and understood product labels. However, the Non-GM label contained information different than what is found today in the retail store. Participants who read either positive- or negative-biased information may have been more likely to recognize the Non-GM statement on the label, and because it may have been interpreted as "this product is different," increased their bid for the traditionally labeled product. This may have been the main contributing factor in numerous unexpected bids.

There was an unusually high level of familiarity with agriculture among the participating population. Those who grew up on farms (30 percent) and/or who are majoring in agriculture (14 percent) are presumed more knowledgeable about agriculture and more aware and, perhaps more accepting, of the role of biotechnology in agriculture. For example, agriculture majors perceived there to be little risk associated with consuming GM foods and considered themselves relatively well informed about biotechnology. Those relatively well educated about production agriculture technologies, including biotechnology, may not have been as receptive to the bias of information presented about the role of biotechnology in the environment.

Information bias did affect groups defined by major differently. Bids on GM products by agriculture majors increased after reading negative-biased information and decreased after reading positive-biased information, contrary to expectations. Alternatively, the information bias had the expected result on bids by sociology majors. It is reasonable that a group less well educated about biotechnology would be more responsive to information bias. It may also be that those already well educated did not carefully read or consider the information provided as they have more likely seen similar information presented previously (e.g., class, popular press articles).

Estimating the model by individual product produced the originally expected result for potato chips (but not for muffins or cookies): negative-biased information did influence participants to decrease bids for GM potato chips, even those whose academic major was agriculture.

To further investigate unexpected results, the level of risk participants assigned to the consumption of GM foods elicited in both pre- and post- auction questionnaires were compared. As expected, the perceived level of risk associated with GM food products increased for participants who read negative-biased information and decreased for participants who read positive-biased information. This supports the hypothesis that information can change participant perceptions about GM products, but contradicts the results of the tobit estimation.

Results support the literature on consumer attitudes regarding product labeling. The literature indicates a majority of consumers do read labels, and that some portion of consumers would pay more for Non-GM products (Center for Rural Studies). For example, Hallman, et al. reported that while 90 percent of Americans believe GM foods should be labeled, 53 percent reported they would look at the labels, and 45 percent expressed a willingness to pay more for Non-GM labeled food products. In the current study, product labels alone differentiated the standard from the Non-GM version of each product. Thus, only participants who actually read the labels could have differentiated between them. The price premium placed on those products with the Non-GM label indicates participants read the label.

The fact that negative-biased information about impacts of GM crops on the environment increased the risk participants overall associated with GM foods, and positive-biased information decreased the associated risk, supports the idea that consumers are receiving the intended message from the information. They are simply responding to it differently in their willingness-to-pay than was hypothesized. The finding that information bias had effects on relative bid prices contradictory to expectations when considered overall, but that the effect was as expected for those less likely to have been prior-educated about biotechnology, supports the need to use unique market promotion and advertising strategies for different market segments. Firms may need to more specifically focus promotional GM materials on well-defined target markets, especially those that may know little about the agriculture industry. This is also relevant to groups and individuals speaking out against, or for use of, biotechnology. Results demonstrate that some consumer groups will be more responsive to such campaigns. Other groups may be unresponsive, or the campaigns may even elicit an unintended response. Furthermore, if indeed those more aware/accepting of biotechnology and GM foods are less responsive to (negative) informational campaigns, another possible strategy is for firms to make the GM label customary. Rather than using resources to ensure products are GM-free, firms could simply label products as possibly including GM ingredients. Awareness from regular exposure may increase acceptance of GM foods.

Finally, results consistent with expectations for one product (potato chips), when the model was estimated for individual products, suggest that the effect of biased-information (e.g., in an advertising campaign) on acceptability and/or willingness to pay a premium for Non-GM products may differ by type of product.

Appendix 2. USDA National Organic Program (NOP) [28]

The Organic Foods Production Act and the National Organic Program (NOP) established by the U.S. Department of Agriculture are intended to assure consumers that the organic foods they purchase are produced, processed, and certified to consistent national organic standards. The labeling requirements of the new program apply to raw, fresh products and processed foods that contain organic ingredients. Foods that are sold, labeled, or represented as organic will have to be produced and processed in accordance with NOP standards.

Farm and processing operations that grow and process organic foods must be certified by USDA-accredited certifying agents. A certified operation may label its products or ingredients as organic and may use the "USDA Organic" seal.

Labeling requirements are based on the percentage of organic ingredients in a product.

100% ORGANIC
Products carrying this label cannot contain any non-organic ingredients.

ORGANIC
At least 95 percent of the product's ingredients must be organic.

MADE WITH ORGANIC INGREDIENTS
Must contain at least 70 percent organic ingredients. Should not contain added sulfites.

SOME ORGANIC INGREDIENTS
Products containing less than 70 percent organic ingredients can list them individually.

When the new regulations become effective, organic farmers and handlers will have 18 months to adjust their growing and processing operations and revise their product labels to conform to the new standards.

[28] The National Organic Program, Labeling and Marketing Information, USDA-AMS, (http://www.ams.usda.gov/nop/FactSheets/LabelingE.html, accessed 12/26/02)