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

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There are several contentious issues remaining in the development of genetically modified (GM) wheats. This paper summarizes current knowledge and critical issues for commercialization including evolution of GM wheats, agronomic competitiveness, consumer acceptance, traits, regulatory issues, segregation, identity preservation, production and marketing risks, and discusses the marketing system likely to evolve.

Key words: genetic modification, marketing, transgenic, wheat.

Introduction

Development and adoption of genetically modified (GM) wheats have important implications for many aspects of the wheat production and marketing system. In contrast to other grains and oilseeds, commercialization of GM wheats is proceeding concurrently with a fairly extended process of public scrutiny, which has focused on several issues affecting GM wheats. These include agronomic competitiveness, consumer acceptance both domestically and internationally, their effects on international trade, and issues related to identity preservation (IP), segregation, and testing. These issues are complicated by the dichotomy in demands for GM wheats, with some markets being more averse than others, and the fact that there are a number of wheat traits that could be developed through these techniques, in addition to the current emphasis on Roundup Ready wheat (RRW).

The purpose of this paper is to summarize the 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, international trade, testing, segregation and identity preservation, and production and marketing risks. The final section provides a summary and discussion of implications.

Background: GM Wheats

Development of GM wheats has lagged behind that of other grains and oilseeds for varying reasons: Wheat genetics is more complex; wheat is a smaller volume crop; exports are of greater relative importance; import country regulations are less well defined; and competition among exporting countries is more intense and compounded by radically different marketing systems.

There are several initiatives for development of GM wheats. In North America, these have been primarily on the Roundup Ready trait, although there is extensive research on a wide range of GM traits (e.g., fusarium resistance and drought resistance, among others). Most development in North America is focused on Hard Red Spring (HRS) wheats, though recent work is underway in Mexico for drought tolerance (Centro Internacional de Mejoramiento de Maiz y Trigo, 2004).

If approved in the United States or Canada, there would be no limits on the adoption of these traits, except to the extent that individual companies could impose a limit or tolerance level. If the traits are approved in Japan, wheat could be imported, but products would be subject to labeling laws. Because 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), which would allow for a 1% tolerance along with labeling requirements and some yet-to-be-specified form of traceability system. The EU has since adopted a policy that includes a 0.9% tolerance for labeling and a 0.5% tolerance for GM material unavoidably present but declared safe. The policy includes a system of traceability. Developments in these countries are pending and will impact the evolution of GM wheat adoption.

Monsanto (2001) has indicated they would not release RRW unless approval of the trait occurs in the United States, Canada, and Japan, and a viable testing and segregation system is developed. Most stakeholder groups have positions, including the National Association of Wheat Growers (2004), US Wheat Associates (2001), the Farm Bureau (2004), the North Dakota Grain Growers Association (2002), the American Bakers Association (2001), and the Canadian Wheat Board (2001). In virtually all cases, the position reflects that biotech wheats are desirable, mostly looking to second-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 the needs of buyers.

Agronomic Competitiveness

Widespread producer acceptance of GM crops (corn and soybeans) in the upper Midwest would seem to indicate the willingness of producers to accept GM wheat when it becomes available. Not surprisingly, there has been a general decline in planted acreage of wheat and barley over the past 30 years. This decline accelerated in recent years and resulted in increased planting of corn, soybeans, and canola, particularly since the introduction of GM varieties in these crops. This shift in acres is in large part due to the increased returns realized with these GM crops as well as the impact of vomitoxin, which adversely affected wheat and barley.

There are two primary sources of agronomic advantages for RRW: yield increases and reduced dockages. Results from a recent study (Blackshaw & Harker, 2002) indicated yield advantages of 4–16% versus conventional weed treatment.

Reduced dockage content is the second agronomic benefit of RRW. High dockage content has been a major long-term problem for northern-tier wheats that has resulted in problems for importers and handlers and is an issue affecting the attractiveness of US hard wheats relative to competitor countries (Wilson & Dahl, 2001). Roundup Ready wheat has the impact of reducing weeds and, therefore, weed seeds contained in dockage. Research indicates that adoption of RRW in HRS wheat areas would have the following impacts (Wilson, 2001): reduced weed seeds, which comprise 62% of wheat dockage content; reduced cost of dockage removal throughout the marketing system; and reduced dockage resulting in cost savings of about 5.5¢/bu (versus current system costs of 8.4¢/bu), or $1.32–2.73/acre. Taken together, Monsanto has indicated that these agronomic benefits would increase net returns by $15–20/acre.

Research on GM Traits in Wheat

Research and development of GM traits in wheat has grown since the early 1990s. This section provides a summary of the research on GM traits in wheat. Data were assembled from a number of sources[1] and illustrate that research has grown dramatically since the early 1990s. The United States is the dominant (albeit not the only) player in trait research. Herbicide tolerance is the main trait under development, followed by product quality, fusarium resistance, and others. Finally, there are numerous diverse organizations involved in trait development, including private companies, state universities, federal governments, and others.

The implications of these are important for the wheat marketing industry. First, debate and/or discussions regarding GM traits are more comprehensive than that of debate on RRW, for which regulatory approval has been applied for in the United States and Canada. Second, Syngenta (2002) has indicated a proposed launch date of 2007 for fusarium resistance for improved grain quality. (Fusarium is likely the number one problem in small grains). Third, new research has been initiated on drought resistance in Mexico and Hard Red Winter (HRW) wheat. Finally, there is extensive research on varying forms of product quality. These include enhanced protein quality, nutritional content, novel starch types (functionality), reduced allergens, and improved freshness, storability, and shelf life for baked products. Increased shelf life, improved taste, and greater nutritional value are potential consumer benefits and may improve acceptance (Mayer, 2002; Biane, 2001). All of these suggest that at some time in the future, the market, regulatory, institutional, and organizational regimes will have to deal with a multitude of GM traits simultaneously.

Consumer Attitudes and Willingness to Pay for GM Wheat

The American Bakers Association sponsored a survey that studied consumers' preferences regarding biotech wheat and grain-based foods (World Grain, 2002).[2] Three major attitudinal segments were identified: (a) *loyalists* (50%), or loyal bakery product consumers who say they would keep buying bakery products if they contained GM wheat; (b) *potential switchers* (40%), or consumers who are voicing concern by saying they would switch to non-GM or buy fewer baked goods if GM wheat were in a product; and (c) *market exit* (5%), or consumers who already have or will stop buying wheat-based baked goods.

Some of the findings from the survey included: (a) Consumers are early in the judgment process—only one

1. *In particular, from the Australian Government Department of Health and Aging, Office of Gene Technology Regulator (2002); BIOBIN (2002); Canadian Food Inspection Agency (2002); and Information Systems for Biotechnology (2002).*
2. *Directed by Thomas Hoban, Professor of Sociology and Food Science, North Carolina State University.*

in two Americans is familiar with GM food issues in general and just 16% are familiar with GM wheat; (b) acceptance of GM wheat is at the same level as GM corn, tomatoes, and oil, which are already in production; (c) the number of potential switchers saying they would switch from GM wheat bakery products is identical to GM corn products;[3] and (d) 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. 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.

Several studies have sought to identify consumers' willingness to pay, in this case, for information about ingredient content in products. Lusk, Jamal, Kurlander, Roucan, and Taulman (2004) summarize much of the recent work in this area. They concluded that consumers on average place a premium of 29–44% for non-GM foods. These results were affected by a number of factors. Higher premiums were associated with surveys of Europeans, hypothetical products, and contact over the phone or by mail. Premiums also varied by product type, with meat products having greater premiums than oil. One study included prospective products produced from wheat; results indicated that about 7% of the buyers would potentially not buy (i.e., interpreted as a nil bid) products containing GM ingredients (VanWechel, Wachenheim, Schuck, & Lambert, 2003). Numerous demographic and informational factors impact how much buyers would pay for products produced with non-GM ingredients. The effect of biased information (e.g., in an advertising campaign) on acceptability and/or willingness to pay a premium for non-GM products differs by product. Buyers were willing to pay an average premium of 6.7% more for cookies and 11% more for muffins with non-GM ingredients.

GM Wheat and International Trade Issues

An area of conflict in the commercialization of GM wheats is that of international demand and competition. These issues are contentious and divergent amongst organizations and institutions. The reason for this is that the product is not yet approved; hence, any analysis or suggestion is somewhat speculative.

Early in the evolution of discussions about RRW, US Wheat Associates published a list of countries that would potentially be averse to the purchase of GM wheats. Since then, US Wheat Associates conducted a survey of buyers to assess their aversion to GM wheats (Forsythe, 2002). This was a survey of customers in key strategic markets to determine their willingness to accept GM wheat (Gillam, 2002). 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% of buyers from South Asia said they would reject the wheat. If the country had regulatory approval of the trait, buyers from each country (with the exception of Japan) indicated they would accept some GM wheat with a tolerance. Representatives of 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 were some consumer benefit that could be marketed.

Several studies have addressed issues of RRW in Canada. The Canadian Wheat Board identified 10 countries as "at risk," having publicly stated their concerns regarding GM wheat and indicated the possible termination of Canadian Western Red Spring (CWRS) wheat imports. Based on this, one third of Canadian exports are at risk, with the major concerns being Japan, Iran, and Brazil. Thus, GM wheat would need to be diverted to countries that accept it at lower prices, which would result in lower pool returns (Kuntz, 2001).

One recent study used real options to analyze the optimal timing of the release of RRW in Canada (Furtan, Gray, & Holzman, 2002). It captures the key sources of uncertainties associated with the irreversible decision of releasing a trait. Results are based on the inability to segregate RRW from conventional wheat. The authors concluded that releasing RRW would be akin to the market for lemons.

The US Department of Agriculture Foreign Agriculture Service (2004) recently released unpublished results of a survey of its attaches around the world. Findings indicated that there had been 12 (out of 99) inquiries about biotech wheat from government officials and 24 from importers and processors; the issue has been raised in official meetings in 11 countries. The responses seemed to be most encouraged about biotech wheat due to it having a marginally lower price, but 23 countries had concerns about consumer acceptance.

3. 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).

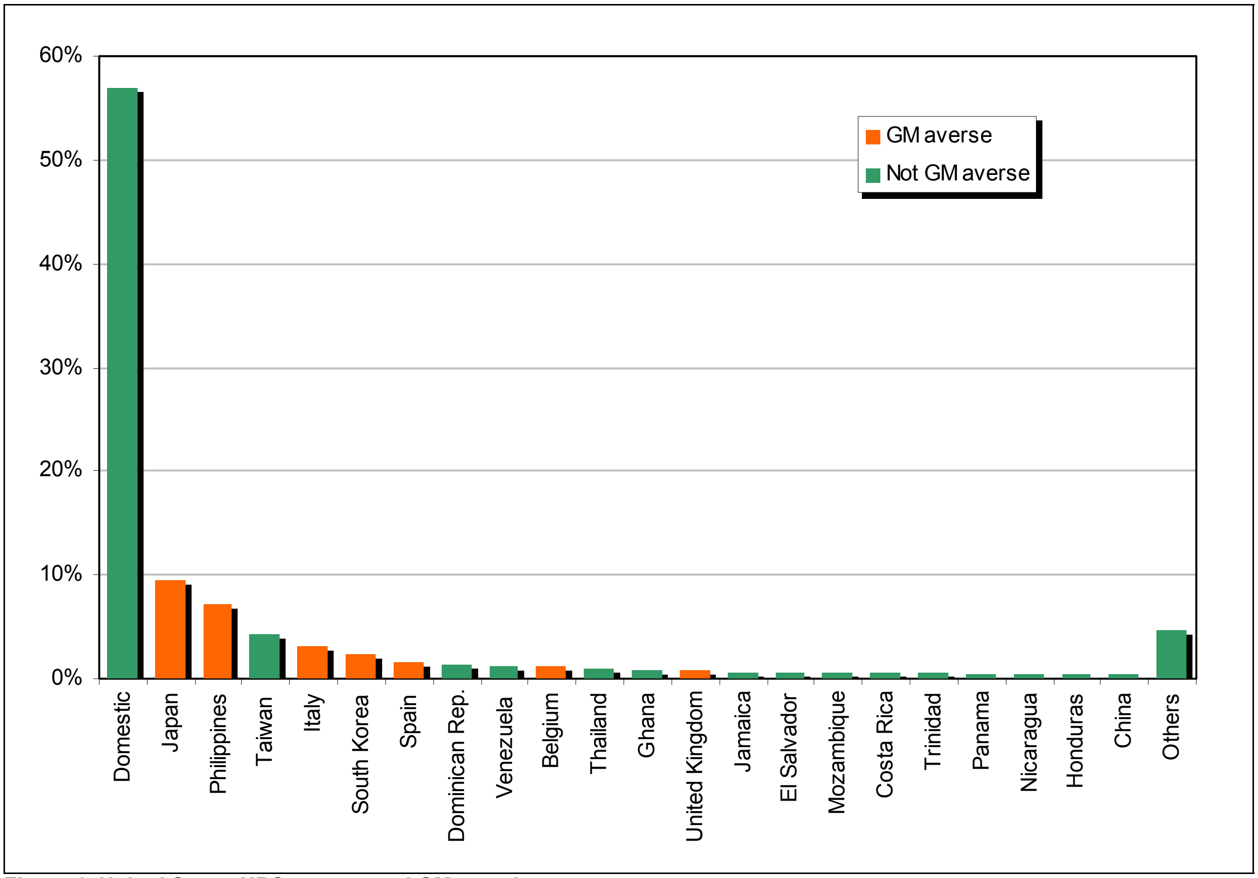

Figure 1. United States HRS exports and GM aversion.

Seventeen countries indicated they would not buy biotech wheat, and 18 indicated they would insist on IP of nonbiotech wheat; five indicated they would not continue to buy other classes of wheat from the United States. Many (23) of the countries had concerns about the "lack of host country approval" and concerns that consumers would not accept the product (32). Concerns in some countries included: EU—environmental release and status of regulatory procedure in the United States; France—questioning public acceptance; Japan—food safety and consumer acceptance; South Korea—status of development and approval in the United States; United Kingdom—industry concerns; and Philippines—compliance with existing regulations governing risk assessment of GM varieties.

Using these data, Figure 1 illustrates the importance of alleged buyer aversion (assuming nonaverse) to GM wheats to the United States. The US domestic market is by far the dominant market and (as suggested here) is nonaverse. 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% of the market would be GM tolerant, and the remaining would be potentially averse.

The nonaversion assumption of the US domestic market is debatable. Some important considerations in this assumption are: (a) 70% of grocery products sold in the United States contain GM ingredients; (b) results of most surveys (summarized previously) suggest that US consumers are more tolerant of products produced with GM ingredients; and (c) in the case of bread, numerous ingredients are already made from GM grains or oilseeds. Furthermore, a large component of the US market is nonbranded wheat products (i.e., food service, private label, and industrial foods) for which aversion would be nonapparent.

There are several important points in understanding the data and their interpretation and assessment of foreign buyer acceptance. First, prior studies (Blaine, Kamaldeen, & Powell, 2002) noted the tendency for consumers to indicate one thing in surveys, whereas 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 and similarities and food safety. Second, the regulatory process in many countries is evolving or may not have the scientific sophistication of that of the United States. As a result, some countries (e.g., the Philippines, China, and Mexico) may very well adopt the position that if a trait were approved in the exporting country, it would allow its importation (concurrent with certification).

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.[4]

Identity Preservation and Segregation

With the introduction of GM crops, there is a spectrum of alternative procurement strategies that can be adopted. Ultimately, buyers determine the elements of their procurement strategy. These can range from spot transactions simply on grade and nongrade factors to full integration into grain production and handling. Intermediate solutions contain varying forms of testing, contracting, and IP. Definitions of what constitute an IP system vary. Dye (2000) defined IP as a "traceable chain of custody that begins with the farmer's choice of seed and continues through the shipping and handling system." Wilcke (1999) refers to IP as separate storage, handling, and documentation of separation; Sonka, Schroeder, and Cunningham (2000) define it as a coordinated transportation and identification system to transfer product and information that make a product more valuable; and Buckwell, Brookes, and Bradley (1998) and Lin, Chambers, and Harwood (2000) 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 germplasm or breeding stock to the processed product on a retail shelf.[5]

Numerous studies have examined IP and segregation costs for a range of commodities using different methodologies (summarized in Table 1). Costs of segregating IP grains from these studies range 1–72¢/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 quantifies risks or the exposure to risk of the agents.

Finally, most of the work on segregations has focused specifically on GMOs. Bullock, Desquilbet, and Nitsi (2000) examined costs of GMO/non-GMO segregation from seed to market in the United States.[6] Although 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 testing protocols were specified as part of the system.

Economics of Testing and Tolerances

Two tests are being used for other grain and are proposed for analyzing for the presence of RRW, commonly referred to as strip tests and PCR (polymerase chain reaction) tests.[7] Characteristics of these tests and their costs (excluding sampling costs) are shown in Table 2 for single-trait events.[8] 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 0.2–3.6¢/bu.

Grain marketing firms will have to develop testing strategies encompassing the cumulative activities

4. *This section was largely adapted from Wilson and Dahl (2002).*

5. *Several firms have initiated IP programs where sales and segregation are by specific variety or location. The Minnesota Crop Improvement Association operates IP programs for 99.5% non-GMO soybean grain and seed, 99.0% 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, 2002). Other examples of IP systems include CWB-Warburtons, Pro-Mar Select Wheat of Idaho, and AWWPA.*

6. *The Directorate General for Agriculture, Commission of the European Community (2000) 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.*

7. *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. Furthermore, there is no need to test for event GA21, which in corn currently requires a PCR test, because strip tests are not accurate (J.P. Tobin, Monsanto Co., personal communication, August 27, 2002).*

8. *These costs were as of 2001. Since then, proposed costs for these tests have declined.*

Table 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 <0.5¢/bu
Jirik (1994)	Survey of elevator managers and processors	11–15¢/bu
Hurburgh, Neal, McVea, & Baumel (1994)	Cost accounting model for high-oil soybeans	3.7¢/bu
McPhee & Bourget (1995)	Econometric model of costs for terminal elevators	Increasing grades handled increases operating costs 2.6%
Hermann, Boland, & Heishman (1999)	Stochastic simulation model	1.9–6.5¢/bu
Maltsbarger & Kalaitzandonakes (2000)	Simulation model for high-oil corn	1.6–3.7¢/bu
Nelson et al. (1999)	Survey of grain handlers	6¢/bu (corn) 18¢/bu (soybeans)
Bullock, Desquilbet, & Nitsi (2000)	Cost accounting	30–40¢/bu (soybeans)
Dahl & Wilson (2002)	Survey	25–50¢/bu
Wilson & Dahl (2001)	Survey of elevator mgrs. for wheat	15¢/bu
USDA ERS (Lin, Chambers, & Harwood, 2000)	Cost accounting adjustments to survey results for specialty grain handlers	22¢/bu (corn) 54¢/bu (soybeans)
Smyth & Phillips (2001)	Analysis of GM IP system for canola in Canada, 1995–96	21–27¢/bu
Gosnell (2001)	Added transportation and segregation costs for dedicated GM elevators	15–42¢/bu (high throughput) 23–28¢/bu (wooden elevators)
Sparks Company (2000)		38–45¢/bu (non-GM canola) 63–72¢/bu (non-GM soybeans)

Table 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	3,000	300
0.1	99	4,650	400
Strip Tests			
1.0	95		7.5

Note. Data from D. Giggax, Monsanto (personal communication, July 1, 2002). Based on batch testing in 150 seeds/batch.

including sampling and the physical testing and reporting of results. Tests increase the cost of handling GM and non-GM grains; 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, 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.

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 results identify the optimal testing strategies of a GM/non-GM system versus the existing non-GM system (Table 3). The optimal strategy would be to test every fifth 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%. An average of 0.02% of importer flows had GM content greater than tolerances, which represents the buyers' risk of accepting quality that does not meet tolerances. On average, 10% of non-GM shipments are diverted to the GM segregation throughout the handling system. This is the sellers' risk of having shipments rejected. Most of the diversions are due to adventitious commingling, although some are due to effects of testing accuracies and sampling. Add-

Table 3. Optimal testing strategies, costs, and risks.

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 tolerance	.02%	.01%	0.10%
Rejection at importer	1.75%	2.34%	10.10%
Costs (¢/bu)			
Additional costs/ non-GM bu	2.0	4.4	7.8
Risk premium	1.0	0.4	4.2
Total (additional costs + premium)/ non-GM bu	3.4	5.7	13.4

ing cost elements results in total costs of 3.4¢/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.

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 and facilitates segregation at the point of first receipt—albeit at the risk of adventitious commingling at the grower level due to grower truth telling. 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). Costs increased from 3.4¢/bu for the base case to 5.7¢/bu with no variety declaration. No variety declaration and no testing were used to reflect the inherent system risks and the value of testing. With no testing, rejection rates at the importer were 10%—significantly higher than either the no variety declaration case or the base case. Costs were higher than either of the other cases (13.4¢/bu).

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.[9] Currently, the wheat industry exports wheat with inclusion of a certificate letterhead statement, which indicates that "there are no transgenic wheat varieties for sale or in commercial production in the United States at this time." This certificate accompanies approximately 50% of US wheat exports, at the request of the buyer. When GM wheats enter into commercial production, an alternative certification process will have to be adopted.

Generally, for other grains, buyers specify in their contracts whether a test is conducted and who should conduct the test. A strip test is normally used for individual traits of interest. The PCR test is used if a buyer specifies grain that excludes all GM traits. Testing is normally done by private labs (e.g., SGS, Thionville, Louisiana Grain Services). The labs provide certificates certifying the test results, and buyers would accrue the costs (or they are embedded in their prices). The USDA could conduct the test and certification, if requested.

Trade for RR soybeans is governed by contract terms, and traders do not provide certificates. Instead, they provide a process including IP from the farm to the elevator. Testing is done by grain firms, and only selectively may use a third-party lab. These processes are conducted at the origin. Upon arrival at the export elevator, grain is loaded directly onto vessels and certified that it is loaded directly after going through a scale.

A certificate has been required for StarLink corn. The process is similar, but in addition, the Federal Grain Inspection Service (FGIS) provides a procedure[10] and a statement indicating "they observed the barge being unloaded... and it was IP'ed from the barge to the vessel...." In this case, there is minimal testing—that which is done by the trading company for themselves—and any certification is limited to the above. If a test is applied, the FGIS procedures have language that can be used in the certificate and accommodates StarLink testing results on a composite sample.

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9. *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.*
10. *See USDA GIPSA (2001a, 2001b).*

The USDA Grain Inspection, Packers, and Stockyards Administration (GIPSA) currently has the ability to provide certification of GM content upon request. However, no such requests have been made to date. Instead, testing and certification for GM content currently is provided by independent testing companies or by the supplier. The 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.

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.

Agronomic Risks

Sources of grower risk include volunteers in subsequent crops,[11] pollen drift, and on-farm adventitious commingling. The literature suggests the level of risk of volunteers to be about 31% of fields infested with an average density of 9 plants/m^2 in the first year (Thomas & Leeson, 1999). The percentage of fields infested and densities decline as years since the last wheat crop increase. By Year 5, only 9% of fields were infested with an average density of less than 1 plant/m^2. These results indicate that there is a positive incidence, but it declines through time and is dependent on variety and agronomic practices. Using reasonable assumptions about planting rates and other factors, these risks translate to a probability of about .009 in Year 1 (which would 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.[12]

Pollen drift in the case of self-pollinated GM wheats is relatively modest compared to cross-pollinated crops such as corn. Studies for wheat suggest that the rate of outcrossing is generally less than 1% but can range as high as 5% with pollen drifting 5–48 meters. Hucl and Matus-Cadiz (2001) indicate this may result in higher than acceptable levels of off-types occurring in isolation strips of 3–10 meters. Outcrossing varies by variety, with Oslo and Roblin varieties having higher incidence. Hucl (2002) indicated that most varieties had outcrossing levels less than 1%; even within 30 cm of the pollen source, outcrossing levels are generally less than 5%.

Handling Risks

Although 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 the USDA's Agricultural Research Service found that contamination is 4% if elevators are run nonstop. However, after three minutes, contamination declines to 0.2% (i.e., probability = .002; Casada, Ingles, & Maghirang, 2001). These findings are corroborated by Hurburgh (1999), who suggested the sources of adventitious commingling at the elevator/handling function to be: handling, 0.3%; shipping, 0.3%; and mixing, 1%; for a total of 1.6% or a probability of .016.

Risks to Organic Production

An important problem is that targeted areas for GM wheat development are the same as those regions in which there are fairly large concentrations of organic grain production (Brummond, 2001). The market for organic grains and oilseeds has risen significantly since 1998, in large part because it is a way to ensure that the products purchased are non-GM.

Marketing practices in this sector have evolved to use zero tolerance. However, the USDA's organic standards are based on production practices.[13] As GM grains are developed, issue of tolerances and testing in this sector will undoubtedly escalate. The USDA's National Organic Program is intended to assure consumers that the organic foods they purchase are produced, processed, and certified in consistency with national organic standards. Under the USDA's new organic rules, products carrying the label must be produced without hormones, antibiotics, pesticides, synthetic fertilizers, or genetic modification. Genetic contamination of organic

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

*12. At an average infestation rate of 9 plants/m^2, this equals 36,434 plants/acre. At 14,000 seeds/lb, 2.6 lbs (or 0.04 bu) would be required to generate 36,434 plants/acre. Assuming a normal seeding rate of 1.5 bu/acre, the rate of infestation is equivalent to 2.89% of the planting rate. If infestations are likely to occur with a probability of 0.31, then the expected infestation rate is 2.89% * 0.31 + 0 * 0.69 = 0.9% in Year 1 and would decline thereafter.*

13. The USDA standards for organic production do not refer to a tolerance, but rather to excluded practices. Labeling restrictions apply tolerances based on how the product is sold.

crops due to pollen drift would not violate the regulation. However, this does not lessen concerns of organic growers, whose marketing practices have evolved to use zero tolerance as a selling point. In addition, organic growers are concerned about the ability to find non-GM wheat seed sources in the future.

Conclusions and Implications

The potential economic gains associated with biotechnology development in states producing HRS rank second only to California (Gianessi, Silvers, Sankula, & Carpenter, 2002). In response, many wheat producer and marketing organizations have taken positions to conditionally support developments in GM wheats. In virtually all cases, these positions reflect that biotech wheats are desirable, especially when looking to second-stage benefits; that research on biotechnology wheat should continue; but also that GM wheats (particularly RRW) should not be commercialized until systems involving IP and testing are developed to satisfy needs of buyers. Moreover, there are pressures for adopting GM wheat. One is from a combination of yield increase, cost reduction, and reduced dockage in the case of RRW. Another source of pressure is the increased profitability of competing GM crops, which have taken acres from conventional crops. Third is the prospect of second-stage benefits associated with GM wheats. There is extensive research associated with numerous GM traits in wheat, including herbicide tolerance, fusarium and drought resistance, and quality attributes. However, given the comprehensiveness and preliminary nature of these traits, we are unable in this paper to quantify the benefits and costs across all prospective GM traits in wheat. Nevertheless, an assessment of the benefits and costs remains valid and is certainly an area for further research.

Marketing System Implications

The marketing system will have to respond to the increased differentiation among countries and, ultimately, among buyers within a country, concurrent with more technological choices in production. The 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 to be adopted by buyers for branded versus nonbranded (e.g., private label, food service) products. This would also occur internationally between countries with and without tolerance limits or other requirements for the traits and those with approved traits.

In response, the marketing system will evolve to accommodate these technologies and demands. To facilitate this dual market, the following needs are important. Domestic and international buyers averse to GM wheats will need to specify tolerance levels and tests to be adopted in their purchase contracts. Buyers with non-nil tolerances (to the 1% level or slightly less) should be able to purchase non-GM wheat with nominal additional costs using contractual restrictions. Those buyers wanting nil tolerances will have to be more aggressive in their procurement strategies, working more closely with suppliers and targeting origin regions and facilities. Buyers and growers will need to be less random in their marketing functions. Prior to making purchases, buyers will have to predetermine and inform sellers and producers of desired traits and attributes; growers will have to supply more information with respect to production (varieties, agronomic practices, etc.) and delivery (time and place).

Growers will likely have to declare varieties at the point of first delivery. This would provide low-cost information that would be useful to the handler in segregation. If such a system were not adopted, the costs and risks would escalate sharply. In addition, this would have the impact of facilitating marketing by varieties (or groups of varieties), which may become a component of contract specifications.

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. Over time, price differentials will evolve among wheats with different GM trait content. The price differentials will very likely evolve to be similar to the cost differentials to the system. 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. Differing certification processes will likely emerge in response to the differentiated demands and requirements. This may very well involve certification by third-party private testing companies or by official government agencies.

References

American Bakers Association. (2001). *American Bakers Association biotechnology position statement*. Washington, DC: Author. Available on the World Wide Web: http://www.americanbakers.org/pubs/biotech_paper_2001_for_web.pdf.

Askin, T. (1988). *The cost of grade segregating to primary elevators*. Winnipeg, Canada: Canadian Grain Commission.

Australian Government, Department of Health and Aging, Office of Gene Technology Regulator. (2002). *Record of NDLRs as notified to the gene technology regulator*. Available on the World Wide Web: http://www.health.gov.au/ogtr/gmorec/nlrd.htm.

Biane, A. (2001). *Future implications of food biotechnology on the baking industry* (speech to the American Bakers Association). Las Vegas, NV: Sara Lee Bakery Group.

BIOBIN. (2002). *Field trials in OECD countries*. Paris: Organization for Economic Cooperation and Development. Available on the World Wide Web: http://www.oecd.org/ehs/biobin.

Blackshaw, R.E., & Harker, K.N. (2002). Selective weed control with glyphosate in glyposate-resistant spring wheat (*Triticum aestivum*). *Weed Technology*, *16*, 885-892.

Blaine, K., Kamaldeen, S., & Powell, D. (2002). Public perceptions in biotechnology. *Journal of Food Science*, *67*(9), 3200-3208.

Brummond, B. (2001). *Genetically modified organisms: How they affect organic agriculture in North Dakota*. Fargo, ND: North Dakota State University Extension Service. Available on the World Wide Web: http://www.ag.ndsu.nodak.edu/biotech/papers/brummond.pdf.

Buckwell, A., Brookes, G., & Bradley, D. (1998). *Economics of identity preservation for genetically modified crops*. Wye, England: CEAS Consultants.

Bullock, D.S., Desquilbet, M., & Nitsi, E.I. (2000). *The economics of non-GMO segregation and identity preservation*. Urbana, IL: University of Illinois Department of Agricultural and Consumer Economics.

Canadian Food Inspection Agency. (2002). *Summary of confined research field trials*. Ottawa, Ontario: Canadian Food Inspection Agency, Plant Products Directorate, Plant Biosafety Office. Available on the World Wide Web: http://www.inspection.gc.ca/english/plaveg/bio/triesse.shtml.

Canadian Wheat Board. (2001). *CWB biotechnology position statement*. Winnipeg, Canada: Author. Available on the World Wide Web: http://www.cwb.ca/en/topics/biotechnology/index.jsp.

Casada, M., Ingles, M.E., & Maghirang, R. (2001). *Report of preliminary findings for a study of value-added and identity preserved grain handling in commercial elevators*. Manhattan, KS: USDA ARS Grain Marketing and Production Research Center.

Centro Internacional de Mejoramiento de Maiz y Trigo [CIMMYT]. (2004). In quest for drought-tolerant varieties, CIMMYT sows first transgenic wheat field trials in Mexico. Mexico City: Author. Available on the World Wide Web: http://www.cimmyt.org/english/webp/support/news/dreb.pdf.

Dahl, B.L., & Wilson, W.W. (2002). *The logistical costs of marketing identity preserved wheat* (Report No. 495). Fargo, ND: North Dakota State University Department of Agribusiness and Applied Economics.

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). Available on the World Wide Web: http://europa.eu.int/comm/dg06/publi/gmo/full_en.pdf.

Dye, D. (2000, June). *Building the identity preservation system of the future* (speech presented at the 2000 Institute of Food Technologists). Available on the World Wide Web: http://www.cargill.com/today/speeches.

Farm Bureau. (2004). *Agricultural biotechnology - domestic*. Washington, DC: American Farm Bureau Federation. Available on the World Wide Web: http://www.fb.org/issues/backgrd/biotech-dom04.pdf.

Forsythe, D. (2002). *GM wheat: Customer acceptability survey results from Asia*. Washington, DC: U.S. Wheat Associates.

Furtan, W.H., Gray, R.S., & Holzman, J.J. (2003). The optimal time to license a biotech lemon. *Contemporary Economic Policy*, *21*(4), 433-444.

Gianessi, L.P., Silvers, C.S., Sankula, S., & Carpenter, J.E. (2002). *Plant biotechnology: Current and potential impact for improving pest management in U.S. agriculture - An analysis of 40 case studies*. Washington, DC: National Center for Food and Agricultural Policy.

Gillam, C. (2002, October 9). *Asian opposition to biotech spring wheat steadfast*. Reuters.

Gosnell, D. (2001). *Non-GM wheat segregation strategies: Comparing the costs*. Unpublished master's thesis, University of Saskatchewan, Saskatoon, Canada.

Hermann T.J., Boland, M., & Heishman, A. (1999). *Economic feasibility of wheat segregation at country elevators*. Manhattan, KS: Kansas State University. Available on the World Wide Web: http://www.css.orst.edu/nawg/1999/herman.html.

Hucl, P. (2002, November). *Outcrossing of wheat*. Paper presented at the 56th annual meeting of the Canadian Weed Science Society, Saskatoon, Saskatchewan, Canada.

Hucl, P., & Matus-Cadiz, M. (2001). Isolation distances for minimizing out-crossing in spring wheat. *Crop Science*, *41*, 1328-1351.

Hurburgh, C.R. (1999, December). *The GMO controversy and grain handling for 2000*. Paper presented at the Iowa State University Integrated Crop Management Conference. Available on the World Wide Web: http://www.exnet.iastate.edu/Pages/grain/gmo/99gmoy2k.pdf.

Hurburgh Jr., C.R., Neal, J.L., McVea, M.L., & Baumel, P. (1994). *The capability of elevators to segregate grain by intrinsic quality.* Paper presented at the 1994 Summer meeting of the American Society of Agricultural Engineers, St. Joseph, MI.

Information Systems for Biotechnology. (2002). *Field test releases in the United States*. Blacksburg, VA: Information Systems for Biotechnology, Virginia Tech University. Available on the World Wide Web: http://www.isb.vt.edu/cfdocs/fieldtests1.cfm.

Jirik, P.J. (1994). *Identity preserved grain marketing*. Unpublished master's thesis, Saint Mary's College, Winona, MN.

Kuntz, G.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.

Lin, W.W., Chambers, W., & Harwood, J. (2000, April). Biotechnology: U.S. grain handlers look ahead. *Agricultural Outlook*. Washington, DC: United States Department of Agriculture.

Lusk, J.L., Jamal, M., Kurlander, L., Roucan, M., & Taulman, L. (2004). *A meta analysis of genetically modified food valuation studies*. Unpublished working paper. Available on the World Wide Web: http://www.agecon.purdue.edu/staff/jlusk/meta%20analysis.pdf.

Maltsbarger, R., & Kalaitzandonakes, N. (2000). Studies reveal hidden costs in IP supply chain. *Feedstuffs*, *72*(36).

Mayer, S. (2002). *Genetically engineered wheat: Changing our daily bread*. Derbyshire, UK: GeneWatch UK.

McPhee, T.L., & Bourget, A. (1995). *Cost of grain and grade segregation at terminal elevators in Canada*. Winnipeg, Canada: Canadian Grain Commission.

Monsanto. (2001). *Extending Roundup Ready® benefits to wheat* (Bulletin #00401065). St. Louis, MO: Monsanto Company Wheat Industry Team.

National Association of Wheat Growers. (2004). Biotechnology position statement. In *National Association of Wheat Growers 2004 policy resolutions* (p. 28). Washington, DC: Author. Available on the World Wide Web: http://www.wheatworld.org/pdf/2004%20NAWG%20Resolutions.pdf.

Nelson, G.C., Josling, T., Bullock, D., Unnevehr, L., Rosegrant, M., & Hill, L. (1999). *The economics and politics of genetically modified organisms in agriculture: Implications for WTO 2000* (Bulletin 809). Urbana, IL: University of Illinois Office of Research Consumer and Environmental Science Department.

North Dakota Grain Growers Association. (2002). *North Dakota Grain Growers Association 2002-2003 resolutions*. Bismarck, ND: Author.

Smyth, S., & Phillips, P.W.B. (2001). *Identity-preserving production and marketing systems in the global agri-food market: Implications for Canada*. Saskatoon, Canada: University of Saskatchewan.

Sonka, S.R., Schroeder, C., & Cunningham, C. (2000). Transportation, handling, and logistical implications of bioengineered grains and oilseeds: A prospective analysis. In *Agricultural transportation challenges of the 21st century.* Washington, DC: USDA Agricultural Marketing Service; Urbana-Champaign, IL: National Soybean Research Lab.

Sparks Company. (2000). *The IP future: Identity preservation in North American agriculture*. Memphis, TN: Sparks Company.

Strayer, D. (2002). *Identity-preserved systems: A reference handbook*. Boca Raton, FL: CRC Press.

Syngenta. (2002). *Tomorrow's products*. Available on the World Wide Web: http://www.syngenta.com/en/products_services/tomprod.aspx.

Thomas, A.G., & Leeson, J.Y. (1999). Persistence of volunteer wheat and canola using weed survey data. In *Proceedings of the 1999 National Meeting* (p. 88). Sainte-Anne-de-Bellevue, QC, Canada: Expert Committee on Weeds.

United States Department of Agriculture Foreign Agricultural Service. (2004). Unpublished results of a survey of FAS attaches on Importer Views on GM Wheats.

United States Department of Agriculture Grain Inspection, Packers and Stockyards Administration. (2001a). *Testing for StarlinkTM corn—Lateral flow test strip method* (GIPSA Directive 9181.1). Washington, DC: United States Department of Agriculture Federal Grain Inspection Service. Available on the World Wide Web: http://www.usda.gov/gipsa/reference-library/directives/9181-1.pdf.

United States Department of Agriculture Grain Inspection, Packers and Stockyards Administration. (2001b). *Revision to Starlink testing and certification procedures*. Washington, DC: United States Department of Agriculture Federal Grain Inspection Service. Available on the World Wide Web: http://www.usda.gov/gipsa/biotech/starlink/191.pdf.

U.S. Wheat Associates. (2001, April 17). *U.S. wheat calls for identity preservation system before commercialization of GM wheat* (news release). Available on the World Wide Web: http://www.uswheat.org.

VanWechel, T., Wachenheim, C., Schuck, E., & Lambert, D. (2003). *Consumer valuation of genetically modified foods and the effect of information bias* (Report No. 513). Fargo, ND: North Dakota State University Department of Agribusiness and Applied Economics.

Wilcke, B. (1999). *Segregating genetically modified crops*. Minnesota Extension Engineer. Available on the World Wide Web: http://www.smallgrains.org.

Wilson, W.W. (2001). *Economics of dockage removal from wheat in the United States and Canada* (research prepared for Monsanto Company).

Wilson, W.W., & Dahl, B.L. (2001). *Evaluation of changes in grade specifications for dockage in wheat* (Report No. 458). Fargo, ND: North Dakota State University Department of Agribusiness and Applied Economics.

Wilson, W.W., & Dahl, B.L. (2002). *Costs and risks of testing and segregating GM wheat* (Report No. 501). Fargo, ND: North Dakota State University Department of Agribusiness and Applied Economics.

World Grain Co., Ltd. (2002). *Bakers survey U.S. consumer attitudes on GM wheat*. Bangkok, Thailand: Author. Available on the World Wide Web: http://www.worldgrain.com.

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