

AGAINST THE GRAIN:

The Threat of Genetically Engineered Wheat

Nov. 2002

A Greenpeace report prepared by:

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Executive Summary

Genetic engineers are now tinkering with one of humanity's most important sources of food — wheat. It is a crop with enormous economic, nutritional and cultural significance. With rice and corn, wheat represents the core of global carbohydrate intake.

The introduction of genetically engineered (GE) wheat is currently on the horizon, although it has taken longer to develop and commercialize than the other dominant food crops (corn, canola, soybeans). While research is ongoing on several GE wheat varieties, Monsanto's glyphosate-tolerant wheat, known as Roundup Ready™ (RR) spring wheat, appears to be the closest to commercialization. Though the company is hedging on when the wheat will be marketed, Monsanto has stated it plans to apply for approval of RR wheat in the United States, Canada and Japan in 2002.

Significant opposition to the release of GE wheat, particularly RR wheat, has already emerged, and much of it in unlikely places. Many farmers are adamantly opposed to the introduction of RR wheat. Farmers see problems managing weeds, despite claims that Roundup Ready™ wheat will make weed control easier. And consumer and environmental groups are concerned about health and environmental damage.

There are six main reasons for the extensive opposition to GE wheat.

1. Major markets are opposed to GE wheat and the U.S. and Canada will lose wheat sales

The major U.S. export group, U.S. Wheat Associates (USWA), has identified strong opposition from importers of GE wheat. USWA notes that 44 percent of all exported spring wheat goes to the European Union, Japan and Korea — which have all stated repeatedly and definitively that they

will not accept GE wheat.¹ According to Canadian Wheat Board (CWB) estimates, customers representing two-thirds of Canada's wheat markets do not wish to purchase or receive GE wheat. The CWB also designates Canadian and U.S. domestic markets as opposed to GE wheat.²

Some examples of policies and statements from buyers of North American wheat include:

- The position statement of the Japan Flour Millers Association (JFMA), which controls more than 90 percent of the total wheat market share in Japan, says, "Japanese consumers are highly suspicious and skeptical about safety of GM farm products.... [F]lour millers strongly doubt that any bakery, noodle and confectionery products made of GM wheat or even conventional wheat that may contain GM wheat will be accepted in the Japanese market."³

- In Britain, the largest flour miller, Rank Hovis, the British and Irish Milling Association, and Warburtons, one of the UK's largest bakeries (which buys wheat from 900 Canadian contract growers), have all stated they will reject GE wheat. A Rank Hovis spokesperson noted that approval of GE wheat would mean the end of all its purchases of wheat from North America.⁴

- The CEO of Italy's largest mill, Grand Molini, agreed: "The European milling industry will simply not buy one more kilo of any U.S. wheat at all."⁵

- In France, a representative of the country's largest wheat miller stated that after GE wheat is introduced, France will stop buying spring wheat from the U.S.⁶

- Belgium's Andre & Cie SA, which supplies American-grown wheat throughout Europe, told U.S. Wheat that GE wheat could destroy the European market for American growers. A company spokesperson noted that its opposition to GE wheat was even stronger in 2002 than the previous year.⁷

- According to USWA, South Korean officials say they will not accept any GE wheat. Korea has some of the world's most stringent regulations on GE foods.⁸

- Representatives from other North American wheat buyers, including Egypt, Algeria, the Philippines, Indonesia, Malaysia, and Thailand have all indicated they will reject GE wheat.

2. Segregation of GE wheat will likely be impossible because the existing infrastructure can not provide the necessary guarantees of purity

GE wheat can contaminate non-GE wheat in several ways. There is the potential for contamination through pollen movement and outcrossing as well as during trucking and handling. The changes required to create a 100 percent purity system are enormous. As noted above, numerous export customers have stated they would refuse wheat with any level of GE contamination. Even Monsanto has repeatedly acknowledged that it will be impossible to ensure 100 percent purity of non-GE wheat once RR wheat is commercialized.

On the farm, contamination can occur during planting and harvesting operations when equipment is not properly cleaned, and spills occur. Trucking harvested grain off the farm is also a source of contamination. But the greatest contamination is likely to arise in the grain handling system. Neither the Canadian nor U.S. system is set up to segregate GE from non-GE wheat, and experts believe that major and expensive changes would be needed to accommodate GE wheat.

3. To accommodate GE wheat, the current Canadian wheat varietal registration system will have to be revised or abandoned, an action that will tarnish Canada's reputation for quality

In Canada, the current rules of the wheat varietal registration system would require that a new GE variety be

distinguishable from its non-GE analog system. Under these rules, GE wheat would not likely be considered distinguishable, and the registration would therefore be denied. There are currently proposals in place to weaken the varietal registration process, moving it closer to the lax system used in the U.S.

But Canadian wheat enjoys an unsurpassed reputation for quality, as a result of the variety registration system that assures consistent wheat for its customers. It appears that GE wheat could only be registered in Canada with a complete overhaul of the system, an action that would considerably weaken Canada's reputation for quality varieties.

4. Farmers will face significant management challenges if GE wheat is introduced, and there is little evidence that the claimed economic benefits will materialize

Biotechnology companies promise farmers increased yields, decreased pesticide use and overall economic gains from GE wheat. Yet in other GE crops, such promises have yet to be fulfilled. To the contrary, RR crops have brought many farmers increased dependence on toxic chemicals, yield losses, and increased costs from problems with Roundup-resistant volunteer plants.

Evidence thus far on herbicide tolerant crops shows that reliance on herbicides is not, on average, declining, nor are yields enhanced. Farmers who grow RR crops generally increase their number of herbicide treatments. Also, volunteers, because they are herbicide tolerant, are harder to manage and often require increased herbicide use.

Moreover, wheat farmers currently enjoy the right to save their seed for replanting, an option that would be lost once biotechnology wheat is widely grown. Even non-GE wheat farmers would need to buy seed certified as GE-free to avoid contamination, and thus would be unable to use their own saved seed. This will have significant seed cost implications. When added to increased chemical costs, potential yield declines and segregation, farmers are facing a serious economic risk from RR wheat, even without the specter of lost exports.

5. Ecological disruption could result from GE wheat introduction, including more ecologically detrimental pesticide use patterns and reductions in biodiversity

Gene flow from RR wheat could lead to unmanageable weeds, if weedy relatives of wheat acquire herbicide tolerance from the GE crop. Increased use of Roundup following the introduction of RR wheat could have direct and indirect effects on soil and water quality, wildlife and biodiversity. Such issues have already been raised for RR soy. One study has shown that glyphosate can harm beneficial soil bacteria that live in association with soybeans, while another showed a higher incidence of a fungal disease on soybeans treated with glyphosate.⁹

Water quality may also be at risk from RR wheat, as one study has found that glyphosate can be readily released from soil particles, and therefore may leach into water. Roundup can be toxic to fish, depending on several factors, but in some situations concentrations as low as 10 parts per million of glyphosate can kill fish.¹⁰ Contamination from spray drift to borders and neighboring native vegetation can cause damage to wild plants and flowers, depleting biodiversity by threatening the resources on which insects, birds and mammals depend.¹¹

6. GE regulatory systems in Canada and the U.S. are so deeply flawed that we can not be confident GE wheats will be safe for the environment and humans

Wheat, since it is so widely consumed in a minimally processed form, could be the first really major test of the impacts of a GE diet on human health. There is little evidence that regulators are capable of assessing the health impacts of what could prove to be the most significant of human GE food introductions. Given the refusal of governments in the U.S. and Canada to require mandatory labeling, there is no comprehensive way to monitor for long-term health consequences from widespread but untraceable GE food consumption.

A key failure of the U.S. and Canadian systems is regulators' inability to assess the potential for GE crops to cause the kinds of health and environmental problems discussed above. There are four levels to the systematic problems of current regulations:

1. The lack of a legislative framework for genetically engineered organisms. Unlike toxic chemicals, genetically engineered organisms that are released into the environment are alive, and can breed and reproduce in nature. But regulators have based rules for GE crops on existing legislation and regulations (with minor modifications) that were designed to deal with other substances and fraud prevention, not with releases of genetically modified organisms;
2. The ideological, regulatory and scientific assumptions that guide regulations are seriously flawed, leading to flawed procedures for assessing health and environmental risks;
3. Regulators have shown their limited ecological knowledge, by uncritically accepting industry applications for commercialization that contain poor quality ecological data; and
4. The bureaucracy and politics of regulatory agencies has created myopic decision-making.

All these elements contribute to a lack of knowledge about ecological and human health impacts that is central to concerns about the regulatory apparatus. The regulatory systems are poorly equipped to assess the interplay between GE crops and the host of organisms that interact with them, including humans.

Conclusions

The introduction of GE wheat is an unnecessary and dangerous risk. GE wheat would bring little or no benefit to farmers and would close existing markets for wheat exports from the U.S. and Canada. With the economic and ecological disruption that could result from the introduction of GE wheat, it would be dangerous to permit its approval and

commercialization. Given the current regulatory structure and capacities in the U.S. and Canada, there is every reason to fear that a thorough economic, environmental or health assessment of RR or other GE wheats will not be undertaken. **Thus, the environmental release and the commercial production of GE wheat, and its use in food, should be prevented.**

1. Introduction

Genetic engineers are now tinkering with one of humanity's most important sources of food — wheat. It is a crop with enormous economic, nutritional and cultural significance. Many religions honor it in scripture and ceremony, and it has been central to the diets of many cultures.¹² With rice and corn, wheat represents the core of global carbohydrate intake, with an estimated 2 billion people consuming it as a staple in their diet.¹³

Several biotechnology companies are in the process of developing genetically engineered (GE) wheat varieties with claims of farmer, processor and consumer benefits; however, Monsanto's glyphosate-tolerant (herbicide tolerant) wheat, known as Roundup Ready™ (RR) wheat, developed in collaboration with the Canadian and U.S. governments as well as several universities, is closest to commercialization. Monsanto claims their RR wheat will provide farmers with better weed control, reduce herbicide use, and reduce their weed control costs. Monsanto has been engaged in field testing RR wheat since 1994 and, although is increasingly vague about its timeline, probably hopes for introduction by 2005.

But significant opposition has emerged, much of it in unlikely places.¹⁴ Many farmers, including those planting GE corn, soybeans and canola, are adamantly opposed to its introduction. Wheat traders, millers and shippers with no official position against genetic engineering per se, speak out against it. Legislators are debating initiatives to prevent or restrict its commercialization. Their anxiety is multifaceted. A majority of the international customers who buy wheat from North America say they do not want it. Millers do not see advantages for them. Farmers see problems managing weeds, despite claims that Roundup Ready™ wheat will make weed control easier. Consumer and environmental groups are concerned about health and environmental safety. Monsanto, however, is pressing on, as though believing that opposition will ease once key jurisdictions like the U.S. and Japan have granted regulatory approval.

Opponents have sound reasons to be worried about GE wheat. Regulators have approved most GE crop applications without rigorous review of the environmental, health and agronomic implications (see Section 4.6); however, opportunities to stop the introduction of the technology are emerging. These themes are the focus of this report. The situation in both Canada and the U.S. is addressed, with some additional commentary on the implications for Canada since the introduction of GE wheat will affect its wheat trade in unique ways.

2. Some background on wheat

Canadian and U.S. Wheat Production and Markets. Wheat is a temperate climate crop, generally growing best in more arid regions where soil quality can be poorer. Approximately 40 million hectares (100 million acres) are planted annually to wheat in North America, about one-third of this in Canada. U.S. wheat production has an annual value of \$USD 2 to 8 billion, making it the fourth largest field crop and the leading export crop. Wheat is also the leading agricultural export in Canada, representing around \$Cdn 3 billion annually in export value. About 70 percent of the crop in Canada is exported, around 50 percent in the U.S. Canada is not a significant exporter of processed wheat products, although that capacity is slowly growing.¹⁵ Such products are a larger part of the U.S. domestic wheat economy, but still a relatively small part of total wheat exports. Of the top 50 (by capacity) milling operations in North America, only three are located in Canada.¹⁶ Globally, Canada has about 15 percent of market share, the U.S. about 26 percent.¹⁷ See Appendix 3 for a ranked listing of export destinations for Canadian and U.S. wheat.

There are several types of wheat grown in North America. Spring wheat is the main type grown in Canada (around 70 percent), whereas 70 to 80 percent of U.S. production is winter wheat. Over 90 percent of Canadian wheat is produced in Western Canada. Winter wheat in Canada is grown primarily in Ontario. Although wheat is grown in 42 U.S. states, 18 produce 90 percent of the crop. The most significant production areas are the central, north central and north western regions. Kansas is the largest producing state, and North Dakota produces 50 percent of the hard red spring wheat and 70 percent of the durum.

Global Wheat Production. The leading wheat producing countries are: China, the European Union, U.S. and India. These four plus Argentina, Australia, Canada, Pakistan, Russia, Turkey and the Ukraine account for 80 percent of total global production. The traditional leading wheat exporters are: U.S., Canada, Australia, the EU and Argentina.¹⁸

This situation, though, is in flux. Several traditional top wheat exporting countries have been hit hard by drought, including Canada. The entrance of non-traditional exporters such as the former Soviet Union countries (Russia, Ukraine and Kazakhstan and others) into the wheat trade may change the global market for wheat. According to U.S. Department of Agriculture (USDA) export forecast figures released in September 2002, these countries combined (their grain is known collectively as Black Sea grain) will be second only to the United States in exports in 2002-03. For this period, the USDA projects that the following countries will lead wheat production (million tons): EU (104.40), Russia (48.00), U.S. (45.89), Ukraine (21.00), Canada (18.00), Australia (15.00) and Argentina (14.00). In terms of wheat exports (million tons), the USDA projects the following export ranking for 2002-03 (million tons): U.S. (25.86), former Soviet Union excluding Baltics (15.66), EU (15.00), Australia (10.00), Canada (9.50) and Argentina (9.30).¹⁹

Wheat Processing Trends. The principal use of wheat is the production of flour. Different kinds of wheats produce different kinds of flour which are then used in a full suite of baked goods. Generally, flour from hard red wheat is used to make bread dough while cakes, pastries, and crackers are made from soft red wheat flour. Flour from hard and soft white wheat is used in the production of Asian noodles. Hard white wheat flour is desired for tortillas and soft white wheat flour has numerous uses including cakes, crackers, cookies, pastries, and muffins. Durum wheat is used primarily to make semolina flour, the basis for pasta production (see Appendix 1 for a description of wheat classes in the U.S. and Canada and their primary uses).

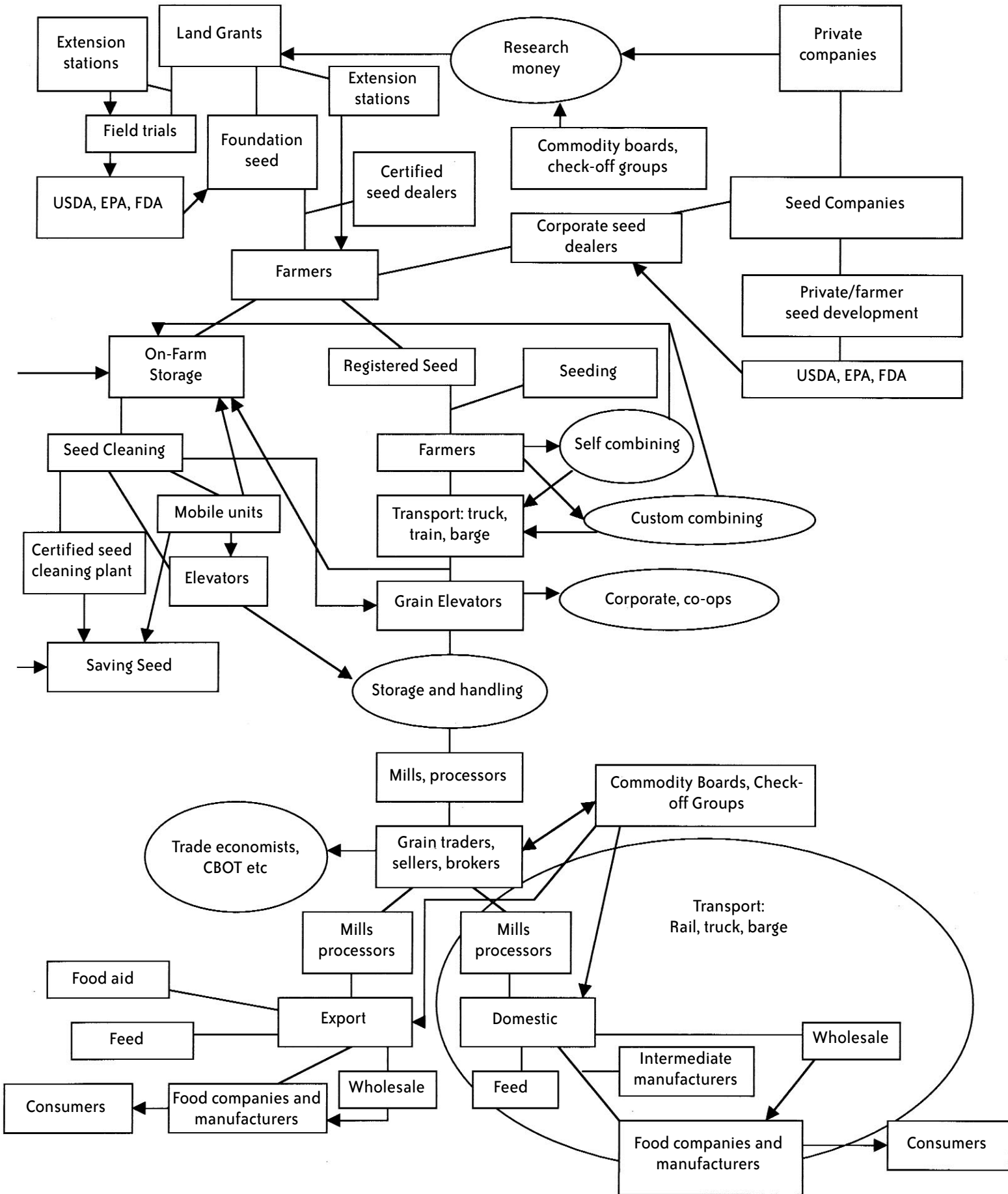
Animal Feed. There are annual fluctuations, but generally 10 to 20 percent of the wheat crop is consumed as animal feed, mainly high-yielding utility wheats, and hard red winter types. In Canada, all wheat classes except durum have feed grades for wheat crops of sufficiently low quality that are not suitable for human markets.²⁰

Farm to Table. The wheat sector involves many different players. Approximately 73,000 farms in Canada and 244,000 in the U.S. grow wheat, comprising about 15 percent of all farms in those two countries.²¹ Since wheat must be processed for human consumption, processors are an important part of the commodity chain. Processors include primary processors, such as flour millers, maltsters, and arguably grain brokers, who deal directly with these enterprises. Secondary processors include bread and confectionery bakers, biscuit and noodle manufacturers, brewers, and others, including food processors, feed manufacturers and alcohol fuel plants. In addition, there is an enormous export infrastructure that includes marketing agencies, standard setting bodies, truckers, railways, ships, elevators and terminals.

A flow chart prepared by the Dakota Resource Council, entitled *Wheat: From Seed to Table* (see Figure 1) illustrates the complexity of the U.S. wheat chain from seed to table, contributing to the problems related to segregation (see Section 4.2).

Figure 1: Wheat: From Seed to Table

Source: Dakota Resource Council, October 2002



3. The status of GE wheat development

3.1 The current GE technologies and their use in the development of GE wheat

To date, over 92 percent of GE crop introductions have been for herbicide resistance, virus protection, or Bt expression, and have usually involved the modification (insertions, deletions, altered regulation) of one to three gene sequences. These modifications have occurred primarily in corn, soybeans, cotton, potatoes, canola, and squash. Some of the RR wheat varieties in development employ some of the current first wave approaches,²² but new ones may be used in later applications (see Section 3.3).

The basic approaches which appear to be most commonly used to create GE wheats are the gene gun or *Agrobacterium* as a vector.²³ Viral or bacterial vectors are usually selected in part because they are normally very invasive, and *Agrobacterium* is normally so in many plants, with perhaps reduced effectiveness in cereals including wheat.²⁴ A gene promoter²⁵ is used to activate the inserted gene. Up to this point, the dominant promoter has been the CaMV 35s gene sequence, one that is derived from the pathogenic Cauliflower Mosaic Virus.²⁶ The dominant selectable markers²⁷ have been antibiotic or herbicide resistance. The antibiotic markers have been particularly controversial because of a perceived potential for the antibiotic resistance markers to be transferred to human disease organisms, thus inhibiting human treatment.²⁸

Donor genes are frequently considered confidential business information (CBI) so reporting of them is spotty in both field trial and research databases. It appears, however, that *Agrobacterium* is the dominant bacterial vector used in GE wheat applications, that neomycin phosphotransferase II (NptII), an antibiotic marker, is a dominant selectable marker, and that traits come from the following donors: algae, *Arabidopsis*, tobacco hornworm, mammalian antiviral systems, potato, rice, tomato, tobacco, maize, barley, oats, sorghum, wild relatives of wheat, and other wheat cultivars. Traditional nuclear genetic engineering, promoters and

selectable markers (e.g., CaMV 35s promoter and herbicide markers) are still being used.

3.2 When will the first GE wheat — Roundup Ready™ wheat — be commercialized?

GE wheat has taken longer to develop and commercialize²⁹ than the other crops that are dominant in food production (corn, canola, soybeans), likely because of its evolutionary biology. Its genome comes from three somewhat distinct plant lines which apparently has posed more challenges for breeders, including trait instability and gene silencing.³⁰ At this point, no GE wheats are yet on the market;³¹ however, Roundup Ready™ wheats of the hard red spring class (primarily a bread wheat) developed by Monsanto appear to be closest to commercialization in Canada³² and the U.S.³³ Although its preliminary U.S. work was on winter wheat, Monsanto has apparently now shelved its RR winter wheat program because the biology of winter wheat is even more complex than spring wheat.³⁴

There has been extensive laboratory and greenhouse work (which does not require regulatory approval) dating back to the 1980s (see Appendix 4 for a detailed review of GE wheat research in Canada and the U.S.). Field trials in at least five countries — Canada, U.S., Australia, Spain and the UK — involving a variety of GE wheat technologies have already taken place. Field trials of RR spring wheat, a precursor to applications for unconfined release (Canadian terminology) or unregulated status (U.S. terminology), appear to have been going on since 1994 in both Canada and the U.S. (for a full review of field trials in Canada and the U.S., see Appendix 2. Also in Appendix 2 is a summary of field trials globally).

Monsanto has applied to the U.S. Environmental Protection Agency (EPA) to use Roundup on wheat, a requirement of the EPA whenever a new herbicide use is proposed for plants. At this point, the EPA has declined to set a tolerance,

although this may be due to deficiencies in the submitted data package, rather than possible health or environmental problems that might be associated with glyphosate residues in wheat. In press reports, Monsanto officials stated they would file applications for unregulated status with the U.S. Department of Agriculture and the Food and Drug Administration by the summer of 2002. They also stated commercialization will proceed once regulatory approval is obtained in the U.S. and Japan and major concerns about segregation and agronomic problems are resolved. Recent company statements regarding their timeline for bringing the crop to market range from 2004 “at the earliest”³⁵ to an undefined future date several years away.

In July 2002, Monsanto spokesperson Michael Doane told reporters that the company was shifting its strategy from pushing RR wheat to first developing wheats with quality improvements.³⁶ Just a few weeks earlier, Monsanto’s Trish Jordan seemed to suggest that the introduction for RR wheat might be pushed back when she said that the variety is “not likely to be [commercialized] for quite a number of years yet.”³⁷

However, Monsanto quickly moved to quash the story. A month later, Jordan told *Food Chemical News*, “Our strategy for the introduction of RR wheat has not changed,” and stated that applications to market RR wheat would be submitted to U.S., Canadian and Japanese regulators “this summer”, though other reports say only that the submissions will be filed “this year.”³⁸

Since Monsanto stated it would start submitting documents required for unconfined release to Canadian regulators in 2001,³⁹ the timetable has continued to shift. Officials of the Canadian Food Inspection Agency (CFIA) have stated that no submission for unconfined release has yet been received (as of October 3, 2002). Monsanto’s application for food safety approval by Health Canada is rumored to have been submitted but unconfirmed as of November 8, 2002, as per Health Canada department policy which “does not permit disclosure to a third party whether specific products, including novel foods, have been submitted for safety assessment.”⁴⁰ In Canada, new herbicide uses also require federal approval, but Roundup application is already per-

mitted on wheat (to control it as a volunteer, or weed) and a maximum residue level for glyphosate has already been established (since glyphosate is used as a desiccant on wheat),⁴¹ so there are no regulatory hurdles at that end. Given the current requirements in Canada for varietal registration, if Monsanto received unconfined release approval in 2003 (which would be possible if they submit in the fall of 2002, given typical one year timelines for review by the CFIA), and then participated in three years of cooperative varietal trials, varietal approval would be unlikely before 2006. Since under the present system it normally takes three years to register a wheat variety and a further year to produce enough seed for sale,⁴² full Canadian commercialization would presumably be delayed relative to the U.S.

Although still at the confined release stage, Monsanto is currently operating private varietal registration trials with RR wheat that comply with the protocols used in the public cooperative registration system. The data from these trials will, following approval for unconfined release, be combined with data from public trials if cooperating farms can be found to participate.⁴³ By generating data for both an unconfined release application and varietal registration at the same time, it is possible several years could be shaved from the normal cycle.⁴⁴ Another development that might speed up full commercialization in Canada is the CFIA’s proposals to change the varietal registration system (see Section 4.3 below). If adopted in early 2003, these proposals would reduce the time required for co-operative trial performance testing to one year from the current three years.⁴⁵ A CFIA official has indicated that the agency anticipates commercialization would be possible within two years of a submission (barring any safety concerns), suggesting that the scenario described here is likely.⁴⁶

One strategy Monsanto has suggested it would pursue is to undertake a limited release of RR wheat on contract to millers and bakers.⁴⁷ The company also says the GE wheat would not be exported but go only to domestic buyers.⁴⁸ If they take this approach, they can avoid some of the varietal registration requirements associated with full commercial release which could allow an earlier, but limited, introduction. All this suggests Monsanto may want to have ways of introducing RR wheat in Canada and the U.S. at the same

time.

3.3 The next wave of GE wheat technologies

RR wheat, however, is not the only application under development. Some international buyers have expressed interest in GE wheat applications other than herbicide tolerant ones. Egypt is the world's highest per capita consumer of bread. With RR wheat approval on the horizon, the Canadian Wheat Board has listed Egypt as a market that rejects GE wheat,⁴⁹ but some Egyptian officials have indicated they would be more favorable to other GE applications, such as enhanced nutritional value, e.g., more iron and protein.⁵⁰ Warburtons, a UK miller that contracts with 900 growers in Canada for wheat and is outspokenly opposed to RR wheat, has acknowledged that fusarium is a major problem for the bakery, and that a GE wheat resistant to fusarium may be of interest to them.⁵¹ Some wheat industry officials have said they would have been happier if a consumer-driven, rather than producer-driven (like RR wheat), GE wheat was first on the market.⁵²

The next series of GE applications involve applying rDNA (recombinant DNA) technologies to a wider range of crops, including wheat; stacking traits together in first wave crops (e.g., herbicide resistance, yield characteristics); and more consumer and processor oriented modifications (flavor, color, texture, enhanced nutrition). These kinds of applications are likely, however, at least five years away from commercialization.

Further back in the pipeline are applications with large gene combinations: pharmaceuticals and vaccines; industrial enzymes; and enhanced animal nutrition. The applications are likely to become more complex as molecular geneticists come to understand more (in their terms) about the functions of specific genes, a field now being called genomics.

In addition to a wider variety of applications, genetic engineers are moving away from the first wave of controversial rDNA technologies involving gene promoters and marker genes. This is in part a response to significant criticisms of

first wave technologies. Some of the RR wheat varieties in development employ some of the old first wave approaches, but new ones may be used in later applications.

Traditional nuclear genetic engineering, promoters and selectable markers (e.g., CaMV 35s promoter and herbicide markers) are still being used, but movement toward other transformations (e.g., chloroplast genetic engineering), markers (Green Fluorescence Protein [GFP] from jelly fish, Cyanamide hydratase [Cah] and Bialophos [BAR]) and promoters is taking place (for example, 10 U.S. research GE wheat projects are examining new promoters, constructs and transformations). It's not clear from the databases the extent to which GE wheat is affected, but generally, genetic engineering research is moving toward strategies that allow the selectable marker to be functionally silenced or entirely deleted from the transgenic plant once it has performed its task.⁵³ Some gene promoter research is designed to overcome the biggest shortcoming of first wave gene promoters — that they typically induce continuous gene expression in all parts of the plant. Now researchers are trying to have transgenes expressed in specific tissues in the plant (e.g., in leaves, not in pollen) or at specific times during the plant's lifecycle. Other gene control systems in development, called inducible promoters, silence the transgene until specific treatments (e.g., an inducer chemical) are applied or particular growth conditions arise (e.g., drought, frost, insect feeding).⁵⁴

These next wave technologies will challenge the GE regulatory structures to an even greater extent than first wave applications, a theme addressed later in the report.

3.4 Technical problems with genetically engineering wheat

As discussed above, there have been technical difficulties with the genetic engineering of wheat. These difficulties may be rooted in some fundamentally flawed assumptions about the technology. In a review of the scientific literature, biologist Dr. Barry Commoner charges that the biotechnology industry relies on an outmoded theory that “an organism's genome — its total complement of DNA genes — should fully account for its characteristic assemblage of

inherited traits.” This theory, often referred to as the “central dogma” of genetics, erroneously assumes that the outcome of transferring a gene from one organism to another is always “specific, precise and predictable and therefore safe.”⁵⁵ Another erroneous assumption that has shaped the development of both the biotechnology industry and its regulation by governments, is that there is a one-to-one correspondence between a gene’s chemical composition, or sequence, and the structure of the protein that it produces.

Instead, science now shows us that a single gene can produce a variety of different proteins, resulting in more than one inherited trait per gene; and that complex interactions occur between genes and the proteins they produce, leading to unpredictable effects. Commoner warns, “The experimental data, shorn of dogmatic theories, points to the irreducibility of the living cell, the inherent complexity of which suggests that any artificially altered genetic system, given the magnitude of our ignorance, must sooner or later give rise to unintended, potentially disastrous, consequences. We must be willing to recognize how little we truly understand about the secrets of the cell, the fundamental unit of life.”⁵⁶

One of the largest hurdles to overcome is the unpredictable way in which applications can affect gene expression or silencing. Already, several unexpected sequences and expressions have been found in commercially released GE crops, and how many remain undetected is unknown.

This is a significant challenge in wheat, relative to some of the early modified crops, because of the size of its genome and evolutionary history. According to GE expert, Dr. Sue Mayer, “The genome of wheat is some 10 to 20 times larger than that of cotton or rice making it much more difficult to reliably genetically modify and transgene silencing, instability and rearrangement are common problems with GE wheat. The insertion of multiple copies of the transgene appears to underlay many of the problems which are experienced.”⁵⁷

It is these unforeseen events that have the potential to cause significant human health and ecosystem problems, particularly considering the varying environmental condi-

tions to which the plants will be subjected, with varying weather and soil conditions, interactions with diverse plant and soil biota, not to mention, exposure to humans.

As the science changes, the regulatory apparatus continues to depend on questionable assumptions about the technology and to rely on narrow assessment protocols and very limited measures for post release monitoring. If regulators do not improve their capacity to assess ecological and human health hazards, opposition to future GE applications will likely remain high (see Section 4.6 for more on this theme).

4. Why is commercialization of GE wheat being opposed?

There are six main reasons for the extensive opposition to GE wheat that has emerged in the past few years. Major markets are opposed and the U.S. and Canada will lose wheat sales, even if excellent segregation systems are put in place. Segregation of GE wheat from other wheats will likely be impossible because the infrastructure does not exist to provide the necessary guarantees of purity at an affordable price. The current Canadian wheat varietal registration system will have to be abandoned to accommodate GE wheat which will tarnish Canada's reputation for quality. Farmers will face significant management challenges if RR wheat is introduced, and there is little evidence that the claimed benefits will materialize. Ecological disruption will inevitably result from its introduction. And, finally, GE regulatory systems in Canada and the U.S. are so deeply flawed that we can not be confident GE wheat will be safe for the environment and for human consumption.

4.1 Loss of markets

4.1.1 Export markets

The reaction of international wheat buyers to the possibility of GE wheat introduction, particularly RR™, is generating fear amongst farmers, millers, manufacturers and government (see Appendix 3 for a ranking of major export markets in Canada and the U.S.). In Canada, some 70 percent of the crop is exported, largely in raw form, making Canadian farmers especially at risk for lost foreign markets.

In the U.S., the major U.S. export group, U.S. Wheat Associates (USWA), noted, "Buyers in Japan, the European Union and Korea have repeatedly and definitively stated they will not accept GM wheat, at any tolerance. Last year, buyers in those three countries bought 44 percent of total hard red spring wheat (HRS) exports."⁵⁸ North Dakota is the most vulnerable state in the near term, since it produces 50 percent of the hard red spring wheat that is the focus of early GE introductions, and about 50 percent of the state's crop is exported.⁵⁹ Some buyers have said they will contin-

ue to purchase North American wheat, but only if 100 percent purity can be guaranteed; many others say they will look for alternate markets for all their wheat purchases as soon as approval is granted because they do not believe such segregation is possible.

The Canadian Wheat Board has summarized the current status of accepting and rejecting GE markets, concluding that customers representing two-thirds of Canada's wheat markets fall into the rejecting category, as do the Canadian and U.S. domestic markets (see excerpt, Table 1).⁶⁰

Table 1. Canadian Wheat Board

Current State of Market Acceptance and Non-Acceptance of GM Wheat

Updated: September 26, 2002

GM Rejecting and Non-Rejecting Countries

Country	Status	Note
Algeria	Reject	Government prohibition against the import of GM crops.
Bangladesh	Not reject	Likely not to reject.
Brazil	Reject	Customers currently requesting non-GM certification.
Canada	Reject	Customers currently requesting non-GM certification.
Chile	Not reject	No comment received.
China	Reject	Pre-approval required for import.
CIS & Baltics	Not reject	No comment received.
Colombia	Reject	Customers currently requesting non-GM certification.
Cuba	Not reject	Likely not to reject.
Ecuador	Reject	Customers currently requesting non-GM certification, partial ban on imports.
Egypt	Reject	Customers currently requesting non-GM certification.
EU	Reject	EU moratorium against the approval of new GM crops, customers currently requesting non-GM certification.
Indonesia	Reject	Customers currently requesting non-GM certification.
Iran	Not Reject	No comment received.
Iraq	Reject	Customers currently requesting non-GM certification.
Japan	Reject	Customers currently requesting non-GM certification.
Libya	Not reject	No comment received.
Malaysia	Reject	Customers currently requesting non-GM certification.
Mexico	Reject	Customers currently requesting non-GM certification.
Morocco	Not reject	No comment received.
Peru	Not reject	No comment received.
Philippines	Reject	Customers currently requesting non-GM certification.
Poland	Not reject	No comment received.
South Africa	Reject	GM-free statement required for phytosanitary permits.
South Korea	Not reject	No comment received, although labeling required.
Sri Lanka	Reject	Government prohibition against the import of GM crops
Sudan	Not reject	No comment received.
Thailand	Reject	Customers currently requesting non-GM certification.
Tunisia	Not reject	No comment received.
Turkey	Not reject	Likely not to reject.
U.S.	Reject	Customers currently requesting non-GM certification.

Examples of major export buyers rejecting GE wheat include:

Japan

Japan is the top purchaser of U.S. hard red spring wheat, and accounts for around 11 percent of all U.S. wheat exports (second-biggest buyer of all wheat); it is also generally the fourth largest buyer of Canadian wheat.

In 2001, the Japan Flour Millers Association (JFMA), which controls more than 90 percent of the total wheat market share in Japan, adopted a position statement that declared, “Japanese consumers are highly suspicious and skeptical about safety of GM farm products, which may be hazardous to human health and environment. Under the circumstances, flour millers strongly doubt that any bakery, noodle and confectionary products made of GM wheat or even conventional wheat that may contain GM wheat will be accepted in the Japanese market.”⁶¹

In addition, the Japanese Food Agency, a major buyer of U.S. wheat, has stated that if GE wheat were marketed, Japanese consumers would likely shun all wheat products, and would return to eating rice only.⁶² This position was reiterated by the Japanese Food Agency in a new report released by U.S. Wheat Associates. The agency is quoted in the media as saying, “Japanese flour millers declare firmly not to use any insecure wheat which may or may not contain GM wheat. Japan might have to switch to a different country which does not produce any GM wheat....” The USWA report also says that Asian buyers of U.S. wheat — from China, Korea and Japan — remain largely opposed to the planned introduction of GE wheat. The report says that “there is currently an overwhelming rejection” of the biotechnology “Roundup Ready” wheat plant that Monsanto Co. has developed.”⁶³

European Union

The European Union is generally the 6th largest wheat customer for both the U.S. (buying 5 percent of all U.S. wheat) and Canada (buying 6 percent of all Canadian wheat).

United Kingdom

In 2001, Rank Hovis, Britain’s biggest flour mill, said it would not accept ‘any level’ of GE wheat.⁶⁴ By summer 2002, their opposition had hardened. A Rank Hovis spokesperson stated, “[I]f you do grow genetically modified wheat, we will not be able to buy any of your wheat – neither the GM nor the conventional. This has nothing to do with principle, or trade barriers. We just cannot sell it.”⁶⁵

Warburtons, a UK miller that contracts with 900 wheat growers in Canada said it was considering an immediate ban on the use of Roundup as a desiccant on wheat, in order to ensure that none of its farmers ever grows RR wheat. Bob Beard, the company’s purchasing director, said it is critical for Warburtons to make sure its customers perceive the bakery’s bread as being GM-free.⁶⁶

The British and Irish millers’ association told Reuters, “[O]ur customers in Europe don’t really want anything genetically modified, and it’s difficult to see that changing in the near future.”⁶⁷

Italy

A Canadian report on the Italian wheat market noted that Italian buyers were already worried over possible contamination by GE wheat, stating, “Fears towards possible contamination by Canadian GM-wheat are rapidly spreading and pose a potential threat.”⁶⁸ In 2002, Antonio Costato, the CEO of Grandi Molini Italiani SpA, Italy’s largest miller said, “The European milling industry will simply not buy one more kilo of any U.S. wheat at all” if Roundup Ready™ wheat is commercialized.⁶⁹ According to a newspaper report, Mr. Costato, who is also head of the European millers’ group Euroflour, said, “We will not only avoid buying GM wheat, but we will probably be forced to completely avoid importing from those countries/regions where it is known that GM wheat is grown.”⁷⁰

France

A representative of the largest wheat miller in France stated that “in 2003 GMO spring wheat will be introduced in the

U.S. and in 2004 France will stop buying Dark Northern Spring (DNS) wheat from the U.S.”⁷¹

Belgium

Andre & Cie SA, which supplies American-grown wheat throughout Europe, told U.S. Wheat Associates that it would not accept GE wheat, noting that GE wheat could destroy the European market for American growers. A company spokesperson noted that its opposition to GE wheat was even stronger in 2002 than the previous year.⁷²

Norway

A trader at Norwegian wheat importer Stakorn said, “We will never be in the market for [GE wheat]. If the U.S. goes ahead with this, we’d have to turn to Canada and Kazakhstan to get those supplies.”⁷³

South Korea

South Korea is the fifth largest buyer of HRS wheat from the U.S.. According to the U.S. Wheat Associates, Korea will not accept GE wheat.⁷⁴ The country has strict regulations on GE food that even forbid “non-GE” labeling on any foods that include a commercially grown GE crop among the main ingredients, even if that food tests negative for GE content.⁷⁵ A new USWA report says that Asian buyers of U.S. wheat — from China, Korea and Japan — remain largely opposed to the planned introduction of GE wheat.⁷⁶

Taiwan

Taiwan is the third largest customer for U.S. HRS wheat. Mandatory labeling of GE food exported to Taiwan takes effect Jan. 1, 2003, and GE wheat will not be accepted without regulatory approval.⁷⁷

Egypt

Egypt is the number one buyer of U.S. wheat, accounting for 16 percent of total exports in 2000. Speaking of Egyptian attitudes about GE wheat, a director at Louis Dreyfus Negoce said, “People just don’t want it.” One Egyptian trader stated, “If you have one grain in a thousand which is genetically modified, the consumer is going to refuse it.”⁷⁸

Dawn Forsythe, the USWA public affairs director said, “In the Middle East, the more they hear (about GE wheat), the more averse they become.”⁷⁹

Philippines

The Philippines is the second largest purchaser of HRS wheat from the U.S. Forsythe says, “Two years ago, when we went to talk to the Philippine flour industry about GM wheat, they didn’t know what it was. This year the first words out of their mouths were ‘don’t send us [genetically modified] wheat.’”⁸⁰

Algeria

Algeria accounts for 6 percent of Canadian wheat exports (#5 overall). The country has stated it would not import any genetically engineered wheat.⁸¹

China

China is Canada’s largest wheat customer, accounting for 15 percent of all wheat exports. Chinese government officials have acknowledged that the country’s stringent regulations on imports of GE foods are motivated by a desire to protect domestic wheat, corn and soy growers, suggesting that imports of GE wheat may be unwelcome.⁸² The Canadian Wheat Board currently lists China as a rejecting market in the event of commercialization.⁸³ A new report published by the U.S. Wheat Associates says that Asian buyers of U.S. wheat — from China, Korea and Japan — remain largely opposed to the planned introduction of GE wheat.⁸⁴

Indonesia, Malaysia, and Thailand

These countries have all indicated they will not accept GE wheat imports.⁸⁵

The North American wheat trade has been forced the last few years to pay more and more attention to the increasingly precise quality demands of major buyers, and this is clearly why it has been so affected by major buyer pronouncements about GE wheat.

In a recent farm report, Jim Stitzlein, market development

manager for Consolidated Grain and Barge, was quoted as saying, “We must listen better [to our customers].” Discussing the fact that the next wave of high-tech grain traits will leave even less room for error, he said, “We’re struggling with this issue now because we weren’t paying enough attention to our customers... Our commodity-based system didn’t respond well when customers started asking questions such as ‘where was the grain grown?’ or ‘what technology was added to it?’ As a result, we became a supplier of last resort.” Thinking back to the StarLink corn contamination disaster, he said, “Once other countries thought it might be there in our grain, they stopped buying our grain.” Worried about the new traits coming down the pipeline, Stitzlein predicted, “Somebody will find one or more of those traits in our grain. It will happen, even if it is through human error.”⁸⁶

The U.S. Wheat Associates has been working on a segregation plan and has formed a joint committee with Monsanto and the National Association of Wheat Growers to develop a credible Identity Preserved (IP) system. The system was scheduled to be in place by the end of 2001.⁸⁷

Yet, as of the publication of this report, there are still no signs that such an IP system has been or can be developed. A U.S. wheat co-op, Spring Wheat Bakers, recently acknowledged it has signed a deal with Monsanto to establish an IP system for GE wheat. Monsanto approached the company three years earlier, but an agreement was not reached until May 2002. Spring Wheat Bakers has a dubious track record for such a project: a year ago financial problems forced the co-op to shelve a similar IP wheat program.⁸⁸

Also in early 2001, the U.S. Wheat Associates, the National Association of Wheat Growers and Monsanto said they would review the positions of 17 major importers and mount a lobby campaign with the hope of favorably influencing them as RR wheat introduction gets closer.⁸⁹ By May, a Monsanto spokesperson optimistically denied reports that exporters were rejecting GE wheat, stating, “It’s easy for people to say no one wants it. But we know different because we’re already having discussions with people.”⁹⁰ But despite Monsanto’s optimism, buyer rejection continued to be heard. By March 2002, Monsanto spokesperson,

Trish Jordan, acknowledged on Canadian national television in response to a question about industry interest in GE wheat, “...if you talk about does anybody want to see genetically modified wheat introduced today, probably 100 percent of people would say no.”⁹¹

By August 2002, the U.S.’s position had shifted and Monsanto wasn’t pleased. A new U.S. Wheat Associates report announced that Asian buyers of U.S. wheat — from China, Korea and Japan — remained largely opposed to the planned introduction of GE wheat, noting an “overwhelming rejection” of Monsanto’s RR wheat. Mark Buckingham, spokesman for Monsanto was cited as saying the company was not impressed with the survey, adding, “While dialogue is taking place, deliberately generating controversy about acceptance seems to run counter to U.S. Wheat’s stated purpose of promoting opportunities for U.S. growers.”⁹²

In Canada, “the official Canadian Wheat Board (CWB) position on transgenic wheat or barley is that they should not be registered for production in Canada unless justified by consumer demand and until effective segregation of transgenics is feasible and affordable in the Western Canadian grain transportation and handling system.”⁹³ The CWB has stated it is working on segregation system options, although again there is no evidence that any progress has been made to guarantee purity of non-GE wheat. It’s worth noting that the Canadian Wheat Board position appears to be more strongly against RR wheat introduction than that of the U.S. Wheat Associates.

According to Canadian Wheat Board estimates, 82 percent of Canadian international buyers of Western Red Spring Wheat (by tonnage) and two-thirds of buyers in all classes do not want to buy GE wheat.⁹⁴ One study estimates the cost to Canadian farmers of lost spring wheat export markets at \$185 million/year.⁹⁵ The U.S. is also a major export market for Canada, so domestic opposition there to GE wheat is being monitored closely. The latest market acceptance/rejection report of the CWB lists the U.S. as a rejecting market.⁹⁶ For hard red spring wheats, the first class subject to RR wheat technology, about 65 percent of the U.S. customer base is currently opposed.⁹⁷

U.S. and Canadian farmers are clearly concerned about loss of export markets. Given that over half the North American wheat crop is exported, farmers are highly dependent on international customers. Problems marketing GE corn, soybeans and canola abroad have already been experienced, and since most Canadian and U.S. wheat producers have corn, soybeans or canola in their rotation, they have already been affected by this reality. Many also have already experienced the problems and costs of segregation. They have felt the financial effects of market share being captured by nations that have not approved a GE crop (see discussion in Section 4.2). A spokeswoman with the Canadian Wheat Board was cited in press reports as saying, "Our analysis shows that farmers could lose hundreds of millions of dollars a year in lost markets if this is mismanaged."⁹⁸

The global wheat market is highly competitive. With the current strong position of non-traditional wheat exporting countries into the market, such as the former Soviet Union countries including Russia, Ukraine and Kazakhstan (see Section 2), wheat producing countries like Canada and the United States cannot afford to take chances on a new technology that importers clearly do not want.

4.1.2 Domestic markets

Farmers in Canada and the United States must also be concerned about domestic markets. About 25 percent of wheat produced in Canada is sold domestically, with the domestic human wheat market representing about 8 percent of total wheat production,⁹⁹ and animal feed representing about 13 percent of the total.¹⁰⁰ It appears that Canadian domestic markets rely extensively on hard spring wheats for bread (up to 85 percent of milled domestic wheat), Western durum for pasta, and eastern wheats for cereals, pizza dough, doughnuts, cakes and cookies. In the short term, GE wheat development appears focused on Canada Western Red Spring (CWRS) (hard red spring) wheat and durum wheats. Consequently, certain sectors of the domestic market, e.g., bread, are more affected by RR wheat introduction than other sectors, e.g., cereals. Although the Canadian market for milled and manufactured products is small relative to total production (around 8 percent), these same millers

and manufacturers export to primarily rejecting markets so they have expressed concern about premature introduction of GE wheat and favor a market acceptability test prior to commercialization.¹⁰¹ The Canadian Wheat Board classifies the Canadian domestic market as one that rejects GE wheat in its September 26, 2002 analysis of market acceptance/non-acceptance of GE wheat (see Table 1).

In the U.S., with 70 to 80 percent of production in winter wheats, and the early GE development attention on spring wheats, it is not as clear how domestic markets will be affected. Overall, about a third of all wheat production is consumed domestically. Winter wheats are used in domestic production of yeast breads, hard rolls, bulgur, tortillas and oriental noodles. The percentage of hard red spring wheat production consumed domestically is higher than the average, about 50 percent, and the U.S. also processes a significant amount of spring wheat imported from Canada (see Appendix 3). U.S. millers and manufacturers have been more vocal than their Canadian counterparts to date since they export more value added products and are concerned about international market response. Although about half the U.S. wheat crop is consumed domestically, their comments have focused mostly on their international customers. From press reports, there is widespread miller and manufacturer skepticism that segregation at a level satisfactory to international customers is possible.¹⁰² The Canadian Wheat Board classifies the U.S. as a market that rejects GE wheat in its September 26, 2002 analysis of market acceptance/non-acceptance of GE wheat (see Table 1).

Monsanto believes RR wheat will provide improvements to millers (more consistent quality and kernel size and less dockage), but millers appear skeptical. Many believe that applications in the pipeline (e.g., fusarium-resistant wheat, wheat with modified dough strength, see Section 3 and Appendix 4) will be more useful to them than strictly agromonic applications. However, public acceptance will continue to influence their purchase decisions. The largest domestic wheat buyer in the U.S., General Mills, recently told the USWA that GE wheat was not "a risk our corporation would take," acknowledging that surveys of American consumers showed significant rejection of GE food.¹⁰³ CWB board chair Ken Ritter agrees that even U.S. customers are

wary. He said, “The U.S. is another large market for western Canadian farmers. The North American Millers Association has publicly expressed its position that crops that do not have wide market approval should not be placed on the market.”¹⁰⁴

4.1.3 Feed markets

GE wheat could end up in animal feed markets in three principal ways. The GE variety could be a feed grain, it could be a human food variety downgraded to feed quality, or non-GE feed grains could be contaminated with GE varieties designed for human food markets. In Europe, consumers are now boycotting animal products from GE crop-fed animals, demand for non-GE feed is growing rapidly,¹⁰⁵ and all this could affect GE wheat markets down the road. RR wheat is targeted to varieties that dominate human food markets, so if approved, sales in feed grain markets would likely be small in the near term. However, with subsequent GE wheat developments, international consumer resistance to GE crop-fed animals could affect markets. In Canada, wheat is the basic grain used in poultry rations, starter rations for pig feeds, and in combination with barley or other grains, other pig rations. Barley, not wheat, is the major feed grain with livestock, except in corn growing regions (Quebec and Ontario). In the U.S., wheat is used in a wider range of rations.

4.2 Inadequate segregation infrastructure

Given experiences with GE corn, soybeans and canola, there are significant fears of contamination of non-GE wheat with GE varieties, raising the possibility that affordable segregation at a tolerance level acceptable to markets will be impossible. For farmers’ stories of contamination and its impact on their operations and finances, see the Greenpeace video *Grains of Truth*, as well as other Greenpeace documentation (see endnote for further information).¹⁰⁶

There are both biological and physical aspects to contamination. GE wheat can potentially pollinate non-GE wheat. Since wheat is primarily a selfer (self-fertilizing; outcrossing occurs at relatively low rates) the likelihood of such events is relatively low, especially in comparison to canola;

however, given the planted acreages of wheat, low rates of significant pollen movement and outcrossing still mean major movement in absolute terms because of the volume of pollen on the landscape.¹⁰⁷ Although wheat pollen is viable for a short period of time and does not travel great distances, those characteristics describe other crops as well and pollen has been found at low levels at significant distances from sources. Extreme weather events could increase the likelihood of biological contamination from GE wheat.

Just the threat of pollen movement is already having an impact on researchers who are producing non-GE wheat seed at research plots where GE wheat field trials are underway. Some researchers are reporting that farmer co-operators will only participate in trials involving seed from GE-free research centers.¹⁰⁸ In the U.S. two research centers have refused to allow GE wheat trials, to ensure the purity of the foundation wheat seed they produce.¹⁰⁹ To some degree the threat of pollen contamination has been recognized by the CFIA, as they increased for 2001 the buffer zones required of confined release trials;¹¹⁰ however, buffer zones create a false sense of security. For example, they are designed to allow for a small failure rate. Required planting distances can change as new information is acquired (as in the above example), and in commercial production, they rely on strict compliance on the part of all producers, an impractical expectation.

Organic farmers have already suffered the contamination of organic canola from GE canola and the resulting loss of their organic canola markets. They fear the same thing happening to organic wheat if GE wheat is introduced, in what could be a fatal blow. This has prompted organic farmers in Saskatchewan to launch a lawsuit against Monsanto and Aventis. The lawsuit seeks to collect damages for the loss of the organic canola market and to obtain an injunction against the introduction of GE wheat (For more information, visit www.saskorganic.com).

On the farm, contamination can occur during planting and harvesting operations when equipment is not properly cleaned, or from spills. Trucking harvested grain off the farm is also a source of contamination. With canola, truck-

ing from the farm has already been identified as a likely source of contamination of neighboring roadside canola fields. The same process is likely to occur with wheat (although perhaps at a lower rate given wheat biology), where GE wheat would end up in roadside ditches or even fields, leading to contamination of non-GE fields. A natural disaster, however, would cause major spreading. One Manitoba farmer was cited in press reports as saying, “One good flood [in the Red River Valley] and it’s got it everywhere.”¹¹¹

The greatest contamination is likely to arise in the grain handling system. It’s clear from the flow chart in Figure 1 illustrating the various possible players in the U.S. wheat production and distribution system from seed to table, that there are many opportunities for contamination to occur.

The current approach to segregation in the Canadian wheat trade is varietal control (see Section 4.3) and Kernel Visual Distinguishability (KVD). For several years, the private sector has pressured the wheat industry to develop a different IP system because it feels constrained in its varietal development by rules requiring that varieties be visually distinguishable. The development of GE wheats is also part of the rationale for overhauling the segregation system. According to the Canadian Grains Commission, “Most GEO varieties of grain will be visually indistinguishable from non-GEO varieties and would therefore be co-mingled when they enter into the bulk handling system, making all the product unacceptable to those markets. This translates into lost sales and profits to the Canadian farmer.”¹¹²

The Canadian Grain Commission, working with the CFIA, the CWB and the Canadian Seed Growers Association, is now suggesting KVD should be eliminated in favor of a declaration system. In their proposal, all wheat classes except hard red spring would be shifted to declarations by 2003, with that class shifted as well a few years later. Their hope is that DNA testing will be viable within three to five years. This kind of shift puts more onus and liability on farmers to authenticate what they bring to the elevators.¹¹³

In Canada, with 14 classes of wheat and up to five grades in each class and various other segregating factors such as

protein, moisture, ergot and fusarium, there are around 70 possible wheat segregations required for the handling system.¹¹⁴ Adding GE varieties could result in a doubling of the number of required segregations over time.

The U.S. does not employ a KVD system. Wheat buyers test at unload to ensure that the shipment meets the contracted quality. Quality standards are set by the United States Department of Agriculture (USDA), but government inspection (a limited one) is generally only required for exported grain, not for domestic commerce. Buyers and sellers can hire the USDA for quality assurance services on contract.¹¹⁵ There is no central system of evaluation to ensure new varieties meet specific end use quality requirements. Many varieties within a particular class with different end use quality characteristics can be sold to a customer with a resulting loss in consistency.

However, the USDA recognizes that GE crops provide new challenges, especially as interest in IP systems grows. Consequently, it has solicited ideas from the agricultural sector, including the wheat trade, on what role it should play in the future in helping to assure segregation. Comments from some wheat industry organizations suggest that there is little interest in moving closer to a Canadian style system and a more regulated role for government in setting IP system standards.¹¹⁶

Neither the U.S. nor Canadian handling and transportation systems are well set up to segregate GE from non-GE wheat. Major and expensive changes would be needed to accommodate GE wheat.¹¹⁷

First, purity targets for segregation would have to be established. Recent media reports highlight international customer demands for 100 percent purity of non-GE wheat. Many, however, in the biotechnology industry and wheat trade are hoping that some level of contamination would be acceptable. For example, a Monsanto official has been quoted as saying, “Our proposal is to launch [RR wheat] initially with a controlled marketing program, with some form of traceability in place to ensure that buyers who express a preference for a minimum GM content can get that.”¹¹⁸

The National Association of Wheat Growers (NAWG), Wheat Export Trade Education Committee (WETEC), and U.S. Wheat Associates (USWA) joint committee on biotechnology has established an advisory committee to work with Monsanto on the development of a closed-loop system to prevent commingling of GE wheat with conventional wheat. They also want a “reasonable” tolerance for accidental commingling of GE and non-GE grain.¹¹⁹

Interestingly, 100 percent purity targets have been set for other wheat IP systems, so there is a precedent that could be applied to GE wheat. One farm organization, Keystone Agricultural Producers, has called for a zero contamination policy at least until customers adopt a “reasonable” tolerance.¹²⁰ However, few in the trade believe that 100 percent purity is possible if RR wheat represents a significant percentage of production, since segregation systems historically have worked when attempting to keep small volumes separate from the general pool. Monsanto has repeatedly acknowledged that 100 percent purity will be impossible once GE wheat is commercialized.¹²¹ Even the current 1 percent standard for importation in the EU is believed by some in the wheat trade to be unattainable.¹²²

Second, KVD will have to be replaced with biochemical sampling all along the handling and transportation chain.¹²³ The grain industry already has some experience of this with specialty IP systems. Canadian Grain Commission staff are working on tests to identify GE wheat and believe that each company wishing to register a GE variety should be required to have a test developed; otherwise registration should be denied.¹²⁴ In the U.S., major food makers have called for requirements for such tests before new GE crops are brought to market,¹²⁵ though regulators have never indicated they would add such requirements. Even with such tests, seed certification and dual handling systems will be critical.¹²⁶

Third, a massive education effort directed at grain handlers would be required to minimize errors that have characterized earlier IP systems. The grain handling system is enormously complex (see Figure 1), particularly in the U.S., and significant contamination already occurs amongst conventional wheat varieties, much of it from handler ignorance or

basic human errors.¹²⁷

Fourth, a considerable investment in storage and handling infrastructure would be required of all players, from farmers to terminal operators. Recent capital investments in larger scale handling facilities, at the expense of smaller and more flexible ones, will likely reduce handler capacity to accommodate additional segregation requirements. One recent study has concluded that none of the low-cost segregation strategies in each of three different handling scenarios — in-terminal segregation, designated high-throughput terminals and designated small wooden elevators — would likely be economically feasible or optimal strategies.¹²⁸

Fifth, financial accountability and penalty systems would need to be in place to identify the appropriate liability in the case of contamination. A related question is ensuring enforcement of liability claims should they occur.

Sixth, audit trails would need to be in place, from the farm to the buyer, with inspections required at certain points in the chain and sampling at every exchange point.

Seventh, systems of sample retention will need to be more sophisticated so that if problems arise, they can be checked back through the chain.

A further potential source of contamination is the use of wheat screenings¹²⁹ in export shipments to make shipments up to export dockage allowances.¹³⁰ For example, feed peas destined for European markets frequently have wheat and canola screenings added to them because the regulations allow almost 8 percent dockage. Since the harvesting combine usually only has 1 to 2 percent dockage in it, screenings are mixed in at the export terminal which adds to the exporter’s profits, but spreads GE canola seed, and could spread GE wheat seed if the dockage rules and practices are not changed.¹³¹

Since the Canadian Grain Commission has responsibility for inspection and weighing in the Canadian grain industry, it will likely have to administer and enforce a system that permits GE wheat segregation. CGC officials are confident at this point they can develop a system that has tolerances

greater than 1 percent, with 5 percent being preferred¹³² (limits that may not be acceptable to importers). However, one study suggests that identifying a segregation system, at any tolerance, that optimally balances the financial interests of all the players in the wheat trade will be very difficult, and would likely require policy interventions on the part of the federal government.¹³³

Given weaker segregation systems in the U.S., legislatures in Montana and North Dakota have debated (and to this point rejected¹³⁴) imposing moratoria on GE wheat planting. In North Dakota's case, the moratorium would have been imposed at least until Canada approved RR wheat. North Dakota also considered how to establish a segregation program. Given the potential scale and complexity of wheat IP, there are big questions about the price of such systems and who bears the cost. In other GE commodities, based on premiums paid to growers and received from end users, segregation has not proven to be a significant overall expense. This may not hold true for wheat. Canada Wheat Board officials have been cited in media reports stating that a wheat segregation system will cost millions to operate.¹³⁵ An internal government memo obtained through access to information requests concluded that: "If transgenic wheat is registered, it will be difficult and costly to keep it segregated from non-transgenic wheat through the production, handling and transportation chain."¹³⁶

Moreover, a study by a University of Saskatchewan team concluded that segregation would be critical to producers because without it, the market price would drop for all producers. At a 1 percent tolerance, segregation of GE wheats would cost over \$1/bu (bushel). Only at a 5 percent tolerance might the segregation costs be manageable for the industry. They also concluded that only at this level of tolerance might a registration decision make financial sense for producers.¹³⁷ Yet it's clear from buyer rejection trends (see Section 4.1), that this would likely be an unacceptable threshold for GE wheat contamination.

One U.S. analyst predicts, based on wheat trade surveys, that segregation costs will fall between 0.15 and 0.50 cents/bushel.¹³⁸ An Australian study of the global wheat trade has concluded that the costs of segregation, if borne

by farmers, will negate any agronomic advantages of RR wheat.¹³⁹ Even Monsanto acknowledges that RR wheat will need to generate a premium because of the increased segregation, testing and liability, and they believe it will.¹⁴⁰ Their assumption, of course, is that farmers and handlers will have to pay the segregation costs, not the developer of the technology, and that's why a premium will be required. In commodities like corn, manufacturers, brokers and traders have attempted to force non-GE producers to bear the costs of segregation by positioning non-GE production as a specialty market. Wheat industry organizations like the Wheat Expert Trade Education Committee and the U.S. Wheat Associates also believe that those demanding and benefitting from segregation should bear all the costs.¹⁴¹

The StarLink episode shows that the costs of failure are extremely high. Low but far-reaching levels of contamination have cost U.S. corn growers hundreds of millions of dollars in export sales. Aventis, the developer of StarLink corn, has also paid compensation to farmers in the order of hundreds of millions of dollars,¹⁴² as well as up to \$9 million to settle consumer lawsuits.¹⁴³ The first failure of the GE wheat segregation system could trigger even more significant market losses, farm financial problems and lawsuits.¹⁴⁴

Perhaps summing it up best was Jim Stitzlein, market development manager for Consolidated Grain and Barge, who was quoted earlier in this report (see p. 15) predicting contamination will inevitably occur and acknowledging that the current commodity-based system hasn't responded well in the past.¹⁴⁵

Ironically, Canadian grain systems generally have an advantage for segregation purposes because of higher seed purity standards, lower risks of contamination in the handling system and better quality regulations and enforcement. This provides Canada better opportunities for non-GE crop production¹⁴⁶ which could have an interesting impact on the marketplace. Some believe at least one of the big exporters — the United States, Argentina, Canada and Australia who all support transgenic crops — will delay approval to capture market share on non-GE wheat. This has already happened with canola (Australia) and soybeans (Brazil). Canada is thought to be in a good position to

delay approval, with attendant economic opportunities. An agricultural economist at North Dakota State University has concluded that whoever of Canada and the U.S. first approves RR wheat for widespread release will suffer market losses.¹⁴⁷

4.3 Compromising the Canadian wheat varietal registration system

Most Canadian wheat requires varietal registration to be sold under a varietal name. The only exceptions to this are wheats sold under a speciality contract in a closed loop system, and wheats sold as feed grains in the domestic market. All other sales go through the Canadian Wheat Board and therefore, varietal registration is required.

Varietal registration is administered by the Canadian Food Inspection Agency (CFIA) and carried out by regional committees. In the case of wheat, it is primarily the Prairie Registration Recommending Committee for Grain (PRRCG), but there are also regional cereal committees in Ontario, Quebec and Atlantic Canada. Monsanto has to take its RR wheat to the PRRCG for Varietal approval and one of the key issues will be how to distinguish it from its non-GE analog. It is currently impossible to register new varieties that look like those of one class but have properties of another, or ones that have market desired properties within the same class and are visually indistinguishable from another variety in that same class.¹⁴⁸ It is unlikely most GE wheats could pass the visual distinguishability test.

Another avenue for rejection of a GE wheat varietal registration is the lack of market desire for the variety. Many Canadian farmers and farm organizations have expressed their desire to see registration committees take possible market losses into account, something they normally do not do, before approving a GE wheat variety.¹⁴⁹ A recently dropped provision available to the wheat, rye and triticale subcommittee of the PRRCG would have allowed rejection of varieties for reasons other than merit criteria. The provision read, "Candidates which introduce production or marketing risks for their own or for other classes may be rejected regardless of their merits in other traits." No other PRRCG subcommittees had this provision.¹⁵⁰ Prior to the

clause being dropped, the Chairman of the PRRCG had stated that the CFIA would back up a decision based on the clause.¹⁵¹

However, with questionable timing and motivation, the CFIA asked for it to be dropped because it was, in their interpretation, beyond the legal provisions of the Seeds Act and Regulations. Regarding continued demands for market acceptability to be considered in varietal registration, a senior CFIA official was cited in press reports as saying: "The PRRCG may make a recommendation to that effect, but because it is outside our legal mandate, we can't consider that recommendation." In response, the CWB continues to press for market acceptability to have a place somewhere in the approval system,¹⁵² although the federal Minister responsible for the CWB is not in agreement with their position.¹⁵³

There is a precedent in the Canadian agricultural regulatory system for socio-economic criteria. The Pest Management Regulatory Agency requires that pesticides be evaluated for their "economic value."¹⁵⁴ The provision is not well applied by the agency, but it exists, and it's reasonable to argue that if pesticide companies must demonstrate prior to approval that their product has value, then GE crop varieties should also be subject to the same test.

Denying a RR wheat varietal registration based on this provision or distinguishability criteria would prevent widespread legal movement of RR wheat into the human food chain (and international animal feed markets since those sales are organized by the Canadian Wheat Board). If, however, it was sold under provisions of a specialty contract to a processor in a closed loop system, it could still appear on a small scale in human food markets.

Registration denial would not necessarily prevent the RR wheat variety from being sold as a feed grain in the domestic market. The feed grain market, although sizeable, is not a lucrative target for Monsanto since the seed could not command the prices often paid for high quality wheat varieties sold into the human food market. But the company might sell there to recoup some of its development costs. Linking registration decisions to the earlier discussion about segre-

gation problems, the current handling system does not have the capacity to prevent intentional or accidental mixing of human and feed grains. There are weekly reports of Grandin, a non-registered feed wheat, being found in hopper cars in Vancouver and Thunder Bay destined for human consumption markets.¹⁵⁵ Inevitably, then, RR wheat would either find its way into human consumption channels or, if caught by testing for the presence of GE varieties, significant percentages of shipments would have to be turned back — as has happened with StarLink corn — with significant economic costs.

Although the use of marketing risk provisions remains uncertain, it would appear that RR wheat could only be registered with a complete overhaul of the registration system, an action that would considerably weaken Canada's reputation for quality varieties. There are changes afoot in the varietal registration process. Proposals from the CFIA, with a 2003 adoption schedule, would result in varietal performance being removed from the merit evaluation of milling wheat.¹⁵⁶ One year of performance data would still be required to help farmers make purchasing decisions, but could not be considered by the varietal registration process.¹⁵⁷ Presumably this would help GE wheat varieties that have acceptable disease and quality characteristics, but do not perform as well as their conventional analogs. These changes are not as dramatic as replacing Canada's current system with a U.S. style, with no central varietal evaluation and registration process. However, some worry that the varietal system is on a slippery downward slope, with compromised varietal quality the result. At a minimum, such changes shift responsibility to growers to assess performance, a problematic scenario when so many varieties of marginal difference are already on the market.

4.4 Problems for farmers

4.4.1 Contamination of conventional and organic wheat

A major problem for farmers — **contamination of conventional and organic wheat from GE wheat if environmental release is allowed** — has been outlined in Section 4.2 and will not be addressed further in this section. Other

problems relate to the false promises made to farmers by the biotech industry. The current GE crop applications (including wheat) have been presented to growers as solutions to their pest control problems. Monsanto is promoting RR wheat as delivering “benefits to farmers through better weed control, slightly higher yields, less dockage and lower production costs. It also offers another tool in managing Group 1 and Group 2 herbicide resistance.... Then there's the simple convenience factor of being able to use one product, with no tank mixing, for complete weed control. If you farm a lot of acres and things happen rapidly in the spring, sometimes that is a convenience and it does bring the producer a benefit.”¹⁵⁸ In press reports, Monsanto has claimed financial benefits due to yield increases of \$USD 6-11/acre.¹⁵⁹

4.4.2 Reliance on herbicides is not declining

The story so far on herbicide tolerant (HT) crops shows that reliance on herbicides is not, on average, declining. There appear to be two main parts to this phenomenon: changed herbicide use patterns actually produce total increases in the number of treatments, and volunteer plants¹⁶⁰ become harder to manage requiring increased herbicide use to manage them. Recently a third contributor to this problem appears to be emerging: overuse of Roundup may be creating glyphosate resistant weeds.

Herbicide reliance is up in RR canola and RR soybeans relative to conventional systems.¹⁶¹ In transgenic canola systems, for reasons not entirely apparent, farmers are spraying more acres, more frequently relative to conventional canola growers.¹⁶² Although use of some products has declined, use of glyphosate has risen substantially, resulting in greater acre-treatments. A detailed analysis of herbicide use on conventional and RR soybean acres shows that RR soybean systems (and the associated herbicide price wars triggered by the technology's introduction) are encouraging farmers to move away from low-input sustainable soybean systems in favor of those more dependent on herbicides.¹⁶³ One analyst calculates that pesticide use in RR soybeans is 5 to 10 times higher than in advanced IPM (Integrated Pest Management)¹⁶⁴ systems.¹⁶⁵

4.4.3 Management challenges controlling GE crop volunteers

GE wheat will enter farm rotations already built around RR canola and RR soybeans.¹⁶⁶ Almost all Canadian canola growers (about 33,000 of them according to the 2001 Census of Agriculture) grow wheat, usually preceding canola in the rotation, and RR canola is planted on about 40 percent of canola acreage.¹⁶⁷ With glyphosate-tolerant wheat in the rotation, some farmers and researchers believe there is an even greater likelihood that pesticide use will rise,¹⁶⁸ at least some of that increase due to difficulties controlling volunteers.

Volunteer wheat (and barley) is very competitive in canola, even more so than wild oats on a per plant basis. It can sprout up to six years after planting, and may cause serious yield losses.¹⁶⁹ Volunteer RR wheat will not be controllable in canola with Roundup, an herbicide that is very effective against conventional volunteer wheat. Other, generally more expensive and sometimes more toxic, herbicides will be required in the tank mix, the same ones that are already causing weed resistance problems.¹⁷⁰ All together, this will make weed management more complicated and may result in increased herbicide spraying, a result that would contradict the expressed purpose for developing the technology.

A team at the University of Saskatchewan, funded by the Western Grains Research Foundation, has carried out four studies on the farm economics of HT wheat. Their work suggests that any weed control benefits of RR canola could be lost when it is followed by RR wheat. "Then you're going to have to use a more complex herbicide cocktail... There will be increased costs in the second crop, which reduces the total benefits."¹⁷¹ Using Monsanto estimates, they concluded that although in-season herbicide costs for RR wheat would be lower than conventional herbicides (assuming no Technology Use Agreement fee), the cost of controlling RR wheat volunteers in another RR crop would take away most of the savings.¹⁷² Unless the Technology Use Agreement was under \$4/acre, which seems unlikely, the RR wheat would likely result in increased weed control costs relative to conventional systems.¹⁷³

Because of these kinds of problems, both current and projected, many canola growers are already avoiding RR canola¹⁷⁴ and will likely avoid glyphosate-tolerant wheat applications because they don't know how they will reduce pesticide use and manage both volunteer glyphosate-tolerant wheat and volunteer glyphosate-tolerant canola.¹⁷⁵

But even growers who avoid RR wheat may be affected. Monsanto promotes the environmental benefits of farmers using conservation tillage with its RR crops, but a recent agronomic assessment by the CWB notes that RR wheat could adversely effect wheat farmers who currently use conservation tillage. These farmers may see cost increases if they have to mix other herbicides to control glyphosate-tolerant volunteers from neighbors' fields. The Manitoba-North Dakota Zero Tillage Farmers Association and the Saskatchewan Soil Conservation Association say that weed control costs could increase from the adoption of RR wheat.¹⁷⁶

Monsanto acknowledges that RR wheat should not go forward without effective management of volunteer wheat.¹⁷⁷ Their research efforts to date on volunteer RR wheat management are not seen as promising by some who believe that the Group 1 herbicides being used in experiments are not designed for spring burndown, the most problematic control period; will not work effectively; and will prove to be too expensive.¹⁷⁸ There is no requirement in the regulatory system to fully examine such agronomic and environmental management challenges when evaluating an application for unconfined release (see Section 4.6).

4.4.4 Glyphosate resistance and RR™ crops

Even as they were first widely grown, scientists warned that RR crops could lead to overuse of Roundup that could be quickly followed by glyphosate-resistant weeds.¹⁷⁹ In early 2001, scientists began seeing signs that marestalk (horsegrass), a winter annual weed, was resistant to even 10 times the recommended application rate of Roundup.¹⁸⁰ Questioned about the findings, Monsanto seemed unconvinced. Referring to findings of glyphosate resistant ryegrass (in Australia) and goosegrass (in Malaysia) weeds in the early 1990s, Monsanto's John Goette boasted, "We have

only two resistant plants after one-quarter century of use.”¹⁸¹ Later, a Monsanto weed specialist derided the notion that RR crops were leading to resistant weeds, saying, “I would challenge anybody who says they’re going to predict weed resistance to herbicides.”¹⁸²

But the early reports of resistance were soon confirmed. Three fields in Delaware were infested with resistant marestail, and resistance was suspected in fields in New Jersey and Maryland.¹⁸³ University of Tennessee scientists also found glyphosate resistant marestail in 200,000 acres each of soybean and cotton fields in that state, and glyphosate-resistant marestail was also confirmed in Kentucky.¹⁸⁴ Taking up Monsanto’s challenge, one biotechnology industry scientist stated that “The overuse of glyphosate [on RR crops] allows the relatively few weeds that are naturally tolerant to it to escape treatment and multiply. If we keep subjecting a recurring population of weeds to glyphosate, then we will select for plants carrying traits which allow them to survive the glyphosate treatment generation after generation.”¹⁸⁵ As with RR volunteers, emerging resistant weeds will force farmers to use additional applications of potentially more toxic chemicals.

Marestail may not be the only weed developing glyphosate resistance. A University of Missouri-Columbia weed scientist discovered waterhemp that was tolerant to glyphosate in 2001. Even earlier RR soy farmers in Missouri and Illinois, who treated their fields with glyphosate season after season, reported waterhemp that survived applications of Roundup.¹⁸⁶ In 2002, Iowa State University scientists found a variable response to Roundup in waterhemp on an Iowa farm.¹⁸⁷ After just five years of widespread planting, RR crops may have doubled the number of glyphosate resistant weeds that developed in the previous 25 years.

4.4.5 Questions about performance and overall financial benefits

There is also considerable debate about the economic performance of different GE crops. An emerging interpretation is that the attraction for farmers is more short term managerial flexibility and convenience than input cost reductions and improved financial performance. These conveniences

result from the use of fewer kinds of pesticides, ease of harvest, flexibility, and less time carrying out certain field operations. Yet such conveniences do not necessarily result in greater financial returns to labor and management. In fact, these returns can be decidedly lower for GE varieties.¹⁸⁸ Those farmers using RR technology may find that their herbicide bill goes down, not because they’re spraying less frequently but because glyphosate is one of the cheaper herbicides at the moment,¹⁸⁹ and is likely to become cheaper in the near term now that the patent on glyphosate has expired and copycat versions are beginning to appear on the market at an even lower price.¹⁹⁰

This flexibility may also produce indirect financial benefits but these are difficult to quantify. As well, this short-term flexibility may fade as gene flow and other associated ecological disruptions become more apparent on farms. As noted above, some weeds are already tolerant of glyphosate, and this phenomenon is expected to increase as the range of RR crops expands. Weed tolerance will drive up total pesticide use and increase farmer costs. These ecological disruptions are essentially irreversible costs that in the case of RR wheat are likely to be borne by producers, rather than the biotechnology industry.¹⁹¹ Further, the increased weed management problems associated with GE crops may soon eliminate any short term flexibility and convenience some farmers have experienced.

An economic factor particular to wheat is its status as one of the few major crops in North America yet to be hybridized in a significantly commercial way.¹⁹² Consequently, growers are able to save seeds and plant them in subsequent years. Wheat is also the last remaining significant public sector crop, one where new varietal development is done by public sector scientists, the public owns the germplasm, and public varieties are important.¹⁹³ Assuming that GE wheat varieties will be subject to the same technology use agreements applied to other GE crops,¹⁹⁴ then annual seed saving will be lost as an option. Even growers who don’t use RR wheat will be affected because the need for segregation will require that all growers use certified seed every year (not bin run), something that only 20 percent do currently.¹⁹⁵ This will have significant seed cost implications. When added to the potential increased costs for chemical inputs

and segregation, farmers may appear to gain convenience in the short term but lose net income.

At this point, few are examining the larger picture. If Monsanto's yield claims are realized,¹⁹⁶ what impact will that have on prices farmers receive? With wheat prices at very low levels relative to adjusted historical levels, farmers are rightly concerned that any yield increases will just drive prices down further, especially in the absence of market acceptance. Such questions are notoriously difficult to study but at least two studies have found depressed wheat prices and revenues in a number of modeled scenarios,¹⁹⁷ particularly when GE and non-GE wheats are co-mingled.¹⁹⁸ The best that can likely be said at this point is that RR wheat may be beneficial to a limited number of growers, with benefits highly dependent on the management practices employed by the grower.¹⁹⁹ A University of Saskatchewan team concluded that GE wheat registration is unlikely to occur under conditions that generate positive economic benefits to farmers and society as a whole (as opposed to the biotechnology industry).²⁰⁰

In the final analysis, a key question is whether RR wheat will meet its own claims, and whether farmers can do other things to achieve what RR wheat is billed to deliver. Weed control in wheat is not generally a pressing problem. The CWB's assessment of RR wheat notes that currently wheat farmers have nearly 50 herbicide options for weed control.²⁰¹ Wheat does not present the kinds of management or environmental health challenges associated with pests like late blight in potatoes, scab in apples or flea beetles in canola. RR wheat may initially appear to offer managerial flexibility, but even without herbicides there are many strategies available for weed control in wheat, most notably rotational design, timing of operations and different tillage scenarios. Organic wheat production is successfully practiced by thousands of organic farmers in Canada and the U.S. Wheat is already one of the least sprayed crops (although herbicides are the major application), so there aren't even major social benefits that result from RR wheat if it does prove to reduce herbicide use.

Similarly, many of the emerging GE wheat applications (see Appendix 4) address management problems that can also

be solved in other ways. Fusarium Head Blight (FHB) is a significant problem, infecting 8.5 percent of the Saskatchewan wheat crop in 2000.²⁰² Farmers can follow classic IPM strategies (and research on them is on-going): e.g., use certified clean seed, remove infected trash, select more resistant varieties, rotate with other field crops like peas and brassica, rotate wheat varieties, stagger planting dates so the entire crop is not subject to high rainfall events at susceptible developmental stages, and use fungicides if these other practices don't look promising.²⁰³ Ontario is developing a fusarium monitoring and forecasting system.²⁰⁴ Concurrent to Agriculture and Agri-food Canada's (AAFC) GE work, researchers are also identifying biological control agents that are antagonistic to FHB.²⁰⁵ As well, a considerable amount of research is underway to develop marker-assisted breeding programs²⁰⁶ that will speed up the process of identifying and developing resistant varieties using non-rDNA technology.

4.5 Ecological disruption

The environmental hazards posed by GE wheats are likely to be more complex to characterize, monitor and mitigate than the significant problems posed by other GE crops such as canola. This reality is a function of wheat biology, the number of GE wheat applications in development (see Section 4.6.3 and Appendix 4), and wheat's place in rotations with other herbicide tolerant crops, discussed above. Given the agronomic problems facing farmers (see Section 4.4) and the weaknesses of the regulatory system (see Section 4.6), ecological disruption will inevitably result from RR wheat introduction. Although little study of RR wheat has yet been carried out, the emerging evidence of disruptions with other RR crops suggests that problems caused by RR wheat will follow both direct and indirect pathways. In fact, it is the failure of regulators and industry to understand the indirect pathways of ecological processes that makes ecological disruption virtually inevitable following release. The possibilities for RR to outcross are real, and its use will shift pesticide use patterns, likely resulting in changes in plant populations and crop rotation that will in turn reduce biodiversity by shifting food sources and habitat for insects, soil organisms and birds.

4.5.1 Altered weediness potential

The common view is that wheat has been domesticated for so long, with such extensive manipulation and loss of characteristics that make it vital in a natural ecosystem, that its ability to be invasive is minimal. Wheat is not generally considered to be invasive in wild culture because of the manipulation to eliminate shattering. Although wheat does survive sometimes in roadside ditches, regulators believe this is more often a result of trucking than distribution from fields and is easily controlled with mowing, cultivation or herbicides. According to the CFIA, there are no reports from anywhere in the world of wheat becoming an invasive weed.²⁰⁷ Although they acknowledge how trucking can spread GE wheat, they do not pursue any of the broader implications regarding contamination. For example, as discussed in Section 4.2, it is highly likely that seed will be contaminated with GE varieties through the handling system and this may turn out to be the greatest source of movement of GE wheat across the landscape.

A recent study in *Nature* concluded after 10 years of investigation, the studied GE crops could not survive in natural ecosystems in the UK.²⁰⁸ The study has been held up by proponents of GE crops as confirming evidence that these crops do not have greater weediness potential; however, the study only examined four GE crops in a limited number of ecosystems and did not examine whether the GE crops could pass genes onto wild relatives, increasing progeny survival rates. No studies have ever been carried out that project how millions of seeds dispersed into ditches and field borders will behave, the scenario presented by commercialization of GE wheat. The jury is still out, then, on the altered weediness potential of GE wheats.

4.5.2 Outcrossing to wild relatives

Since wheat is selfing²⁰⁹ (self-fertilizing), then gene flow probabilities are lower than for a crop like canola which is an outcrosser and has many closely related weedy relatives. A survey of 10 spring wheats found outcrossing rates of up to 9 percent.²¹⁰ Compared to some canola varieties that outcross at 30 percent,²¹¹ these are lower rates, but a selfer like wheat is still very subject to genetic contamina-

tion and gene flow to wild relatives because of the number of plants that populate the landscape.

Although there are no known wild triticum species in North America,²¹² gene flow to more distant wheat relatives is a distinct possibility. The closest wild relative is jointed goatgrass (*Aegilops cylindrica*) which survives as far north as the northern parts of Washington, Montana, and Idaho. It is a weed problem in winter wheat. It does not appear in Canada, although it is listed as a noxious weed in British Columbia, perhaps in anticipation of it spreading across the border at some point.

Regulators initially believed there were no credible reports of outcrossing of wheat with jointed goatgrass, and that the likelihood was low because of sterility in the progeny. Recent studies call this conclusion into question. Critics point out, that not all progeny are sterile, and should they backcross with jointed goatgrass, herbicide-resistant genes could readily spread through its population.²¹³ Based on experiments examining hybridization of imazamox-resistant wheat (a product of mutagenesis, not transgenic technology) and jointed goatgrass in both greenhouse and natural settings, scientists have concluded that management plans will be required to minimize the potential for gene flow.²¹⁴ In experiments, these researchers have found viable seed from these hybridizations, and a restoration of self-fertility following backcrossing²¹⁵ with jointed goatgrass. Consequently, the hybrids are being viewed as a bridge in the movement of HT resistance traits from HT wheat to jointed goatgrass.

A survey of Oregon wheat fields in 1998, 1999, and 2000, identified wheat/goatgrass hybrids in over 50 percent of the cultivated fields examined and 20 percent of non-field sites²¹⁶ and these are thought to be becoming more common in the Northwestern U.S.²¹⁷ Although the fertility of hybrids produced is low, in the order of 2 to 7 percent viable seed produced, self-fertility increases in subsequent generations.²¹⁸ Because the area over which wheat is grown and where jointed goatgrass also occurs is vast, low frequency events will inevitably arise. Swiss researchers concluded in relation to GE wheat that “the possibility of gene transfer from wheat to jointed goatgrass under natural con-

ditions (e.g. agroecosystems)...is likely” and that “even a small number of plants receiving an herbicide resistance gene could have important consequences on wheat cultivation in regions where both species grow intermixed.”²¹⁹ It is quite easy to see how the acquisition of a herbicide tolerant gene could lead to the evolution of weeds which are more difficult to manage. If herbicide tolerance genes were transferred from GE wheat into goatgrass which, in turn, made it more difficult to manage, economic losses could be great.

Whether the same process will occur in RR wheat is currently under investigation (see Appendix 4), but clearly there is sufficient concern about a similar process for gene flow to warrant the allocation of research dollars, some of them from Monsanto, an indication that they believe this to be a potential problem. The results will likely depend on which of the three wheat genomes the resistance trait is and the backcrossing opportunities. Even if the resistance trait is not located in the commonly shared genome,²²⁰ the imazamox-resistant wheat studies concluded that transfer was still possible, though less likely.

In Canada the most common weedy relative is *Agropyron repens*, quackgrass. There have been reports of outcrossing with quackgrass, but the CFIA does not consider these reports credible because they view them as outdated. There are reports of artificial outcrossing with other *Agropyron* species, but these have not been found to occur in natural settings. The CFIA concludes somewhat vaguely in their instructions to applicants on this subject: “...the numerous reports of hybridizations with wheat should be considered when evaluating the potential for the introgression of ‘novel traits’ from transgenic wheat into wild relatives.”²²¹

Unfortunately, there appears to be little research in Canada underway about this potential problem, and if industry applications are not made public we will never know if quality studies on the subject have been undertaken (see discussion of data quality in Section 4.6). This deficiency may be due to the belief on the part of regulators and the industry that quackgrass is relatively easy to control with herbicides in crops other than wheat. However, some farmers find quackgrass a very difficult weed to control because

of its spreading habits, so this is an overly optimistic assessment of quackgrass management. Also, similar conclusions of manageability (e.g., management of GE canola volunteers) by regulators have proven to be wrong (see discussion in sections 4.4.2 and 4.6).

A number of other plant species related to wheat have been cited as producing hybrids when artificially crossed with wheat (see Appendix 5). According to regulators, it is improbable that hybrids between wheat and these relatives would occur in nature, but these possibilities have received little research attention.

4.5.3 Changes to weed populations and biodiversity impacts

Herbicide use patterns in Roundup Ready™ soybeans and canola are shifting²²² and changes in weed populations are one of the results as substitution of Roundup for other products shifts what weed species survive. These changes could ripple through the larger ecosystem as food sources for insects or birds change or are eliminated through more complete weed control. A recent modeling study examining the impacts of HT sugar beets on one weed population and a bird species predicted a decrease in songbird populations in the UK associated with loss of weed seed food sources due to an increase in weed control associated with this HT crop.²²³ Although criticized for extending its conclusions beyond the available data in the model,²²⁴ the study highlights the potential direct, indirect and multilayered ecosystem effects that can result from changes in cropping and herbicide use patterns. At this point, from examinations of research databases, it does not appear that any research of this kind is being carried out. Whether Monsanto or any other applicant will have performed such studies will only become apparent if their application to regulators is made publicly available.

Given the exponential rise in Roundup use associated with RR crops, there are other potentially significant impacts on biodiversity. Glyphosate is generally believed to be immobile in soil as it readily binds to soil particles; however, at least one study found that glyphosate can be readily released from soil particles, and therefore may leach into

water.²²⁵ According to Dr. Sue Mayer, glyphosate has “...relatively low acute toxicity to mammals as it acts on an enzyme system in plants which is not present in animals. However, preparations of glyphosate often include a surfactant which not only increases toxicity to fish and other aquatic species but can cause serious eye irritation and allergic reactions. There are some indications that chronic exposure to glyphosate can be harmful if administered at high doses over prolonged periods.”²²⁶

Roundup can be toxic to fish depending on several factors including the hardness of the water, the age of the fish and water temperature. In some situations, concentrations as low as 10 parts per million of glyphosate can kill fish.²²⁷ Spray drift to borders and neighboring native vegetation can cause damage to wild plants and flowers. In turn the death of plants can have indirectly harmful effects on insects, birds and mammals which depend on the vegetation for food or shelter.²²⁸ Unfortunately, few of these potential impacts will be investigated by industry and demanded by regulators as part of a RR wheat application (see Section 4.6.1).

4.5.4 Impacts on soil biota

There may also be soil biota impacts due to increased reliance on one herbicide, glyphosate. Two examples from RR soybeans are instructive about what might happen. First, researchers in Arkansas have shown that glyphosate has a negative effect on a nitrogen-fixing bacteria (*Bradyrhizobium japonicum*) that lives in association with soybeans. As soybeans depend on the nitrogen provided by this bacterium, some downward effects on yields have been demonstrated in conditions where available soil water was limited.²²⁹ A second recent study showed a higher incidence of a fungal disease (*Fusarium* sp.) on soybeans treated with glyphosate,²³⁰ suggesting again that increased glyphosate use may disrupt soil organism population dynamics. Although such effects appear limited to agronomic performance, in fact they often have large ecosystem effects because reduced crop performance associated with changing soil dynamics usually triggers changes in crop management — more fertilizers, changes in crop rotation, more or different pesticide applications — which in turn

have larger impacts on soil, terrestrial and aquatic ecosystems.

Glyphosate use in RR wheat systems will not likely have impacts on the same soil organisms identified in these RR soybean studies. However, changes in soil biota are likely, since consistent application of any particular herbicide always causes disruptions of some kind. For example, negative effects of glyphosate on earthworms²³¹ and beneficial mycorrhiza fungi²³² have been reported. Research along the lines of that described above for soybeans should be done to investigate the specific impacts of increased herbicide use associated with RR wheat. Again, there is little evidence such work is being carried out by Monsanto and other applicants, or that regulators will require it.

4.6 Deep flaws in GE regulatory systems

There are many problems with Canadian and U.S. GE regulatory systems. Although the mechanics of regulation differ between the two nations, the basic assumptions that frame them are largely the same, based on work carried out under the aegis of the Organization for Economic Co-operation and Development (OECD).²³³ There are really four levels of the problem:

- the absence of a legislative framework for genetically engineered organisms and the use instead of a patchwork of existing legislation and regulation (with some modifications),
- the flawed ideological, regulatory and scientific assumptions of the regulations, directives, protocols, guidelines and data requirements,
- the limited knowledge base of the regulators,
- the culture and organization of the regulatory agencies, i.e., their human resource strategies, their decision making lines of authority, which create myopic decision making.²³⁴

All these elements contribute to a lack of knowledge of ecological and human health impacts that is central to concerns about the regulatory apparatus. This complexity will challenge a system that is poorly equipped to assess the interplay between GE crops and the host of organisms that interact with them, including humans.

Numerous reports have been published outlining the health and environmental risks associated with genetic engineering, and criticizing the agricultural/food biotechnology regulatory systems in Canada and the United States. Some of the organizations responsible for those reports are: Canadian Environmental Law Association, Canadian Institute for Environmental Law and Policy, Farmers' Legal Action Group, Inc., Food Policy Institute of the Consumer Federation of America, Greenpeace, National Academy of Sciences (U.S.), National Farmers Union, Ontario Public Health Association, Option consommateurs, Polaris Institute, Conseil de la science et de la technologie (Québec), Institut national de santé publique du Québec, Soil Association, Royal Society of Canada, Toronto Board of Health, and World Wildlife Fund Canada. For a bibliography of these reports and information about where to obtain copies, see the Greenpeace Canada backgrounder entitled "Resources Critical of Food and Agricultural Biotechnology and its Regulation" at www.greenpeace.ca (click on the genetic engineering section).

4.6.1 Problems with ecological impact assessment

Since no GE wheat applications appear to have been submitted to regulators in Canada and the United States,²³⁵ the validity of the assessment process can only be deduced from GE wheat regulatory documents and GE crop applications other than wheat. It is especially important to have access to such applications to understand whether U.S. and Canadian regulatory systems are truly effective. In both countries assessments are carried out without public access, on a case by case basis, for which guidelines are flexible and companies and regulators have considerable latitude in what data can be submitted and how they are interpreted. Many exclusions to data requirements can be granted if a "sound scientific rationale" can be demonstrated to regulators.

The best current indicator of the regulatory view of GE wheat is contained in a document produced by the Canadian Food Inspection Agency (CFIA) on the biology of wheat that serves as a reference document for all assessments in Canada of GE wheat applications.²³⁶ At this point,

no comparable documents explaining the views on GE wheat of U.S. regulators exist, although EPA and USDA regulations ask generally for data on the same themes identified in the CFIA wheat biology document. For each Plant with Novel Traits (PNTs), the CFIA develops a reference document that acts as the comparison for determining substantial equivalence.²³⁷ The wheat document serves as an indicator that the CFIA is prepared for GE wheat applications. It was prepared with assistance from Cyanamid Crop Protection.

Consistent with regulatory directives for applicants, the document examines five areas of ecological assessment: altered weediness potential, gene flow to related species, altered plant pest potential, potential impact on non-target organisms, and potential impact on biodiversity. The overall conclusion of the document is that no significant environmental impacts are expected, and any that do occur should readily be manageable by farmers. However, only the first two areas of environmental impact receive any significant discussion and the use of data to support their positive conclusions is selective at best (see discussion in Section 4.5). There is no significant discussion of altered pest potential, nor non-target organism and biodiversity impacts.

Indicative of a low level of ecological knowledge, the CFIA lists a series of agronomic pests that they want applicants to look at, but when it comes to non-pest species, the example list becomes very vague (e.g., soil organisms, beneficials, etc). Clearly, regulators do not know what potential problems might arise; therefore, do not know what to request of applicants, who consequently either do not know, or will choose to ignore, what to look for when doing their experiments.

The limited ecological assessment contained in the wheat biology document is consistent with the problems identified in assessments of other GE crops. It now appears that, even within the limited framework required by the regulatory system, some of the data submitted to U.S. and Canadian regulators to demonstrate environmental and health safety is of a very low quality and would not pass an independent peer review. This raises serious questions about the competence of industry scientists and the regula-

tors who assess the applications.

One of the most thoroughly analyzed applications is Monsanto's Roundup Ready™ Canola (GT73) submission to Canadian regulators.²³⁸ Most of the application was obtained through an Access To Information request²³⁹ by independent investigators. It was the second transgenic crop to be approved for sale in Canada, as a crop, for foods and for animal feed. The final hurdle was passed in April 1996.

In general, Monsanto supplied data using side by side comparisons with the untransformed parent canola variety in order to establish substantial equivalence. It appears from the evidence made available in the access to information request that the applicant supplied regulators with the required information and that the regulators determined substantial equivalence based on submitted data. In cases where some divergence from the parent plant was observed, the regulators concluded that these differences were manageable. Consequently, no full safety assessment was required by the regulators.

However, Drs. Katherine Barrett and Elizabeth Abergel,²⁴⁰ independently examining the Monsanto data, have described major deficiencies with them and their treatment by regulators. According to them:

- Many of the tests were poorly performed, with a lack of duplicate measurements, small sample sizes, uneven comparative scales, inappropriate data pooling, comparison of the parent with varieties other than the subject to the application, a lack of statistical consistency, indiscriminate use of data from trials to support the applicant's claim of substantial equivalence, and conclusions that are not supported by the actual data.
- Industry failed to adequately explain variability in the results when in fact the variability could result from the insertion of the gene expressing the herbicide tolerant trait. There was a strong tendency to treat variability as natural and to ascribe unusual results to "outlier effects."²⁴¹

- Monsanto selectively used literature reports to support the conclusions drawn in the studies.

The regulators, according to Barrett and Abergel, did recognize some of the potential ecological risks of Roundup Ready™ canola, including the problems of resistance to herbicides from canola volunteer weeds²⁴² and genetic pollution. However, they framed these risks as management-related problems, thereby shifting responsibility for managing the risks from the company to farmers. Regulators did not provide empirical data to support their conclusions that such risks are manageable for farmers.

All these problems with protocols and data led Barrett and Abergel to doubt their usefulness for determining risk. Oddly, the statistical treatment of the data by Monsanto appears not to meet the standard imposed by the CFIA in its 1996 revisions to field trial guidelines: that the designs be sufficiently statistically valid to be acceptable for inclusion in peer reviewed journals.

Similar problems with the quality of data submitted by industry to United States (U.S.) and European Union (EU) regulators, and the conclusions drawn from them, have been identified by Hilbeck et al (2000), the National Academy of Sciences (2000), Benbrook (2000), Purrington and Bergelson (1995), and Wrubel et al (1992).²⁴³ Purrington and Bergelson concluded, after examining some of the early petitions for unregulated status in the U.S., that the data was not of a quality normally required by ecologists for environmental assessments.

Particularly problematic in many of the studies submitted is the lack of basic ecological understanding of the behavior of soil biota and beneficial organisms. For example, both Hilbeck et al (2000) and the NAS (2000) found that industry scientists appeared to lack the basic information about the feeding behavior of the test organisms, making it unlikely that they actually consumed a diet containing GE components. It appears that industry scientists and regulators have very poor understanding of how disruptions in non-target populations can produce multiple unanticipated consequences for other organisms in the food web. Disturbances in soil biota populations, for example, can

lead to reduced organic matter decomposition rates, and reduced nutrient cycling which could ultimately produce yield declines.²⁴⁴

In their review of GE crop regulation in the U.S., the Consumers Federation of America concluded, “It is not at all clear that the information that USDA receives from the field tests and in petitions for nonregulated status under the FPPA [Federal Plant Protection Act] includes all or even very much of the data necessary to draw reasonable conclusions about the potential of the tested plants to cause ecological damage.”²⁴⁵

In a way, the ultimate indicator of the regulatory system’s ecological incompetence is that the studies determining problems are not coming from either industry or government, but rather independent researchers, usually ecologists or evolutionary biologists. Neither the Canadian nor U.S. government is funding much work on ecological impacts.²⁴⁶ The Royal Society of Canada concluded, “The sparse knowledge base available concerning the ecology and genetics of GM crops is a major hurdle for sound risk assessment, with important regulatory implications. We recommend that before GM crops are released they should be subjected to a more thorough ecological risk assessment than has been conducted to date.”²⁴⁷ Even some EPA scientists have stated that the agency should be requiring more data from industry on potentially adverse effects of GE plants on wildlife and soil biota.²⁴⁸

4.6.2 Problems with health impact assessment

There are numerous potential health risks associated with genetically engineered food. The process of genetic engineering is imprecise and random. Inserted genes may disrupt native genes, be unstable in their new environment, or function differently than expected. As a result, genetic engineering can have unexpected and unintended effects, leading to the following food safety concerns:²⁴⁹

- **Allergenicity:** New proteins produced by the effect of the foreign gene inserted into a genetically modified organism may cause allergies.

- **Toxicity:** The new proteins may also lead to the production of toxins.

- **Nutritional Changes:** The GE process could lead to nutritional changes.

- **Antibiotic Resistance:** Current transgenic plants may contain antibiotic resistant marker genes (a technique often used to show that the gene transfer has been successfully completed). It is feared this could contribute to the growing problem of antibiotic resistance, causing authorities such as the European Union, the British Medical Association, the Royal Society of Canada and the Ontario Public Health Association to call for a ban on the use of antibiotic resistance marker genes in GMOs.

Many are concerned that health risks associated with genetically engineered organisms might be exacerbated with the introduction of GE wheat into the food supply, since wheat is so widely consumed, often in a minimally processed form.

As with ecological assessment, the mechanics of food safety assessment differ between Canada and the U.S., but are based on the same concepts. No full industry pre-market notification submissions are currently publicly available in Canada and the U.S.,²⁵⁰ so it is difficult to assess in more detail the strengths and weaknesses of novel food assessment. Canadian and U.S. regulators have not produced a human health document equivalent to the CFIA’s wheat biology document, but generally, on the human health side, both U.S. and Canadian regulators are concerned primarily with changes to nutritional and anti-nutritional factors and allergens relative to their conventional analog.

How regulators might assess GE wheat products is speculative, especially since such limited information is available on how other assessments have been carried out. In both countries, the conditions for full safety assessments have rarely, if ever, been triggered since GE food products are almost always deemed substantially equivalent or generally recognized as safe (GRAS). Furthermore, until 1999, pre-market assessments in Canada were voluntary, and it appears they will remain so in the U.S.: the most recent

Federal Department of Agriculture (FDA) proposal only requires biotechnology companies to notify the agency when bringing a new GE crop to market. Pre-market assessments will continue to be voluntary.²⁵¹

Health Canada does post Novel Food Information Decisions on its web site, essentially summaries of the government's rationale for allowing commercialization. These decisions have been analyzed by Dr. Ann Clark of the University of Guelph.²⁵² Her conclusions suggest problems — similar to the environmental submissions — with the review process and the quality of the data, although in the absence of the full notification submissions, it is possible, though highly irregular, that Health Canada chose not to report on their web site on critical components of these industry submissions.

Clark's (and others') analysis of Canadian, U.S. and European data suggests that:

There is no evidence of whole grain product testing, so there appears to be no assessment of the possibility of unintended secondary metabolites with potential negative health impacts. Whole food testing is important, rather than simply testing the inserted transgene or bacterially derived versions, since there is some evidence that the gene insertion process can produce effects that alter the structure and function of the inserted gene sequence (post-translational processing), and this in turn can affect its behavior in humans.²⁵³ No chronic risk studies appear to have been undertaken. The trials that have been done only look at acute toxicity and are not predictive of chronic risks.

The data sets are very inconsistent. Doses, durations and other aspects of experimental design appear to be at the discretion of the applicant, not determined by the regulatory protocols. This raises questions again about whether the data are of peer-review quality. Such questions have been raised in other jurisdictions as well. In the UK, an Aventis feeding trial involving GE corn and chickens was reviewed by researchers working on studies for the Ministry of Agriculture, Fisheries and Food and was found to be "inadequate in terms of providing any evidence or conclusions. It is not of a standard that would be acceptable for publication

in a scientific journal."²⁵⁴ Concerns were also raised about what appeared to be higher death rates among chickens that ate the GE corn during the study, results that Aventis scientists did not further investigate or adequately explain. Significant study design flaws included a lack of control and insufficient replication.

The Public Health Association of Australia has leveled similar criticisms of some industry applications to the Australian and New Zealand Food Authority, their regulatory agency responsible for GE food approvals.²⁵⁵ Calgene's Flavr Savr tomato application to the U.S. FDA also contained significant data anomalies that the company did not explain and that some FDA staff questioned,²⁵⁶ yet regulators approved it for sale. Nutritional composition studies funded or carried out by industry and used to establish substantial equivalence, frequently have statistically significant variability in some nutritional parameters that are not explained, are identified as outliers, or deemed biologically insignificant in the face of competing evidence that suggests otherwise.²⁵⁷

Post-market, long-term health testing has never been done for any GE food currently on the market. The fact that both the Canadian and U.S. governments oppose mandatory labeling of GE food exacerbates the problem. While the authors of this report continue to advocate rigorous long-term *pre-release* health testing, in the present situation mandatory labeling would at least allow consumers and epidemiologists to correlate symptoms with the type of food, GE or non-GE, being consumed.

Since GE wheat will be assessed using the same regulatory systems that have produced these problems, there is no reason to be confident that it will not generate any environmental and human safety problems. In addition, the potential for conflict of interest is high in Canada with Monsanto's RR wheat, since the first one commercialized will come from a collaboration with Agriculture and Agri-food Canada (AAFC). An AAFC internal memo suggests that the ministry will have to play a significant role in developing public acceptance of the crop.²⁵⁸ It raises questions about the independent capacity of the CFIA to turn down an application from another arm of the government. In the U.S., movement of senior staff between federal agencies and the biotech-

nology industry leave its regulatory process open to conflict of interest allegations.

4.6.3 Problems assessing future GE wheat developments

The biotechnology industry is aggressively developing GE wheats, carrying out trials globally on a variety of GE wheat applications. While an application for unconfined release (Canadian terminology) or unregulated status (U.S. terminology) has not yet been confirmed by regulators or industry, field trials have been going on in both Canada and the United States (see Appendix 2) since 1994, and approval filings are imminent. Monsanto has also formed an industry committee and launched a lobby initiative in the hope of favorably influencing 17 major importers to accept GE wheat.²⁵⁹ Despite soothing talk from Monsanto about waiting to commercialize until market acceptance and segregation is in place, GE wheat development seems to be moving ahead.

As outlined in sections 3.1 and 3.2, the first GE wheat being brought forward uses approaches consistent with what are called first wave applications. Ninety-two percent of GE crop introductions to date have been in a small number of crops (primarily corn, soybeans, cotton, potatoes, canola and squash) for herbicide resistance, virus protection, or Bt expression, involving the insertion, deletion or altered regulation of one to three gene sequences; however, the next series of rDNA technologies are being applied to a wider range of crops, including wheat: for example, stacking traits together in first wave crops (e.g., herbicide resistance, yield characteristics); and more consumer and processor oriented modifications (flavor, color, texture, enhanced nutrition) (see Section 3.3).

Further behind are applications with large gene combinations: pharmaceuticals and vaccines; industrial enzymes; and enhanced animal nutrition. The applications are likely to become more complex, both in traits but also the processes for insertion, gene marking, gene promotion, and location of expression (see discussion in sections 3.3 and 3.4).

Many experts have questioned the safety of first wave applications. As discussed in Section 3.4, many of the current applications are producing unstable, imprecise and unpredictable GE constructs with potentially significant health and environmental risks. Some of these problems occur specifically in GE wheat because of the large size of the wheat genome, making the genetic engineering process more difficult to control reliably and resulting in common problems such as transgene silencing, instability and rearrangement.

These unforeseen events have the potential to cause significant ecosystem problems, particularly considering the varying environmental conditions to which the plants will be subjected, with varying weather and soil conditions, interactions with diverse plant and soil biota, not to mention, exposure to humans.

There is nothing in the current landscape to imbue confidence either in the ability of biotechnology companies to produce “safe” GEOs with future applications — if anything, the complexity of the new technologies has the potential to increase rather than decrease risks — nor in the ability of government to regulate with health and environmental safety as a top priority. Consider, the scale of problems that have already occurred with the first wave of GE crops (e.g., StarLink corn contamination; the development of triple-resistant canola in farmers’ fields; the destruction of the organic canola market due to contamination from GE crops;²⁶⁰ the illegal contamination of conventional seed with GE seed in Europe; the GE contamination of traditional maize in Mexico, a centre of origin and diversity of maize; to name a few). Consider the archaic ideology displayed by the biotechnology industry and governments toward a simplistic and mechanistic approach to genetic engineering that reveals a profound lack of ecological knowledge; and consider the weaknesses in the Canadian and U.S. regulatory systems.

As previously mentioned, a panel of the Royal Society of Canada (RSC) was convened at the request of the Canadian government expressly to examine the capacity of the Canadian regulatory system (a similar regulatory model is used in the U.S.) to oversee food biotechnology, with a par-

ticular focus on new technologies coming down the pipe. The RSC issued their report in January 2001, entitled *Elements of Precaution: Recommendations for the Regulation of Food Biotechnology in Canada*.²⁶¹ The report is an indictment of the food biotechnology regulatory system and the many ideologically-driven principles that underlie it. The RSC made 53 concrete recommendations that reflect a call for a complete overhaul of the current food biotechnology regulatory system. Some key findings of the RSC report are:

- The concept of substantial equivalence should be replaced with a rigorous scientific evaluation of GEOs and adoption of the precautionary principle.
- A transparent and public evaluation system should be established for experimental protocols, and the data and scientific bases used to give regulatory approval for GEOs.
- Rigorous and exhaustive scientific studies should be undertaken on the health and environmental safety of GEOs.
- A system of tracking and segregating GEOs should be established.

To eliminate the government's conflict of interest as both a regulator and promoter of agricultural biotechnology, steps should be taken for the government to maintain an objective and neutral stance.²⁶²

As the science changes, the regulatory apparatus continues to rely on narrow assessment protocols and very limited measures for post release monitoring. If the real risks associated with GE crops remain, and if regulators do not improve their capacity to assess ecological, health, agronomic and economic hazards, opposition to future GE applications — including GE wheat — will likely remain high.

5. Conclusions

The introduction of GE wheat is an unnecessary and dangerous risk. GE wheat would bring little or no benefit to farmers and would close existing export markets for wheat exports from the U.S. and Canada. With the economic and ecological disruption that could result from the introduction of GE wheat, it would be dangerous to permit its approval and commercialization. Given the current regulatory structure and capacities in the U.S. and Canada, there is every reason to fear that a thorough economic, environmental or health assessment of RR or other GE wheats will not be undertaken. **The environmental release and commercial production of GE wheat, and its use in food, should be prevented.**

Acronyms and Abbreviations

Alberta province (AB)	Herbicide tolerant (HT)
Agriculture and Agri-food Canada (AAFC)	Information Systems for Biotechnology (ISB)
Agricultural Producers Association of Saskatchewan (APAS)	Identity Preserved (IP)
Animal and Plant Health Inspection Service (APHIS) U.S.	Intergrated Pest Management (IPM)
Barley yellow dwarf virus (BYDV)	Inventory of Canadian Agricultural Research (ICAR)
Bialophos (BAR)	Japan Flour Millers Association (JFMA)
Canada Eastern Amber Durum wheat (CEAD)	Kernel Visual Distinguishability (KVD)
Canada Eastern Red wheat (CER)	Keystone Agricultural Producers (KAP)
Canada Eastern Hard Red Winter wheat (CEHRW)	Manitoba (MN)
Canada Eastern Soft Red Winter wheat (CESRW)	National Association of Wheat Growers (NAWG)
Canada Eastern Soft White Spring wheat (CESWS)	National Farmers Union (NFU)
Canada Eastern White Winter wheat (CEWW)	Nutritional qualities (nutr)
Canadian Food Inspection Agency (CFIA)	Organization for Economic Co-operation and Development (OECD)
Canadian Grain Commission (CGC)	Prince Edward Island (PEI)
Canadian Health Coalition (CHC)	Plant Biotechnology Institute of the National Research Council (PBINRC)
Canada Red Prairie Spring wheat (CPSR)	Plant with Novel Traits (PNTs)
Canada Western Amber Durum wheat (CWAD)	Prairie Registration Recommending Committee for Grain (PRRCG)
Canada Western Extra Strong wheat (CWES)	Recombinant DNA (rDNA)
Canada Western Red Spring wheat (CWRS)	Roundup Ready™ (RR)
Canada Western Red Winter wheat (CWRW)	Royal Society of Canada (RSC)
Canada Western Soft White Spring wheat (CWSWS)	Saskatchewan (SK)
Canadian Wheat Board (CWB)	Saskatchewan Association of Rural Municipalities (SARM)
Canada White Prairie Spring wheat (CPSW)	Saskatchewan Organic Directorate (SOD)
Confidential business information (CBI)	Selectable marker (SM)
Current Research Information Service (CRIS)	United States Department of Agriculture (USDA)
Dark Northern Spring wheat (DNS)	United States Wheat Associates (USWA)
Genetically engineered (GE)	Wheat Export Trade Education Committee (WETEC)
Environmental Protection Agency (EPA) U.S.	Wheat streak mosaic virus (WSMV)
European Union (EU)	
Federal Plant Protection Act (FPPA) U.S.	
Fungal resistance (FR)	
Fusarium Head Blight (FHB)	
Genetically engineered (GE)	
Genetically engineered organism (GEO)	
Genetic modification (GM)	
Genetically modified organism (GMO)	
Generally recognized as safe (GRAS)	
Green Fluorescence Protein (GFP)	
Grocery Manufacturers of America (GMA)	
Hard Red Spring wheat (HRS)	

Glossary

A number of terms have been used, often interchangeably despite technical and political differences, in the genetic engineering debate. For the purposes of this report, genetic engineering (GE) refers to the direct transfer or modification of genetic material using recombinant DNA (rDNA) techniques. It is used interchangeably in this report with a narrow definition of genetic modification (GM), although the latter term is sometimes used for political purposes by biotechnology proponents to denote a wider range of breeding techniques beyond recombinant DNA technology (a broad definition). The acronym GEO refers to the term "genetically engineered organism." It is used interchangeably in this report with the acronym GMO which refers to the term "genetically modified organism." Other terms with similar meanings used in this report are biotechnology and transgenic. The Canadian Food Inspection Agency uses the terminology "Plants With Novel Traits (PNTs)" to refer to plants produced using a wide range of breeding techniques including, but not exclusively, rDNA technology. Critics of biotechnology believe that the process by which a product is developed is as important to examine as the end product itself, and see unique problems with rDNA technology. This is not to say that some are not also critical of crops that result from other breeding techniques such as mutagenesis or "traditional" plant breeding. Critics recognize that plant breeding techniques represent a spectrum of interventions, but believe rDNA technology is a significant departure from other approaches with specific health and environmental risks.

Backcrossing: the crossing of a hybrid plant with one of its parents.

Bt: A bacterium that produces a protein called Bt toxin, a biological insecticide. When ingested, Bt toxin kills certain insect larvae, but is regarded as mostly harmless to humans, pets and most beneficial insects such as bees. Inserting a copy of the Bt gene into plants enables them to produce Bt toxin protein. Such plants can resist some insect pests.

Confined field trials: The release of a Plant with Novel Traits (PNT), for research purposes, under terms and conditions of confinement designed to minimize any impact the PNT may have on the environment. These terms and conditions include reproductive isolation, site monitoring, and post-harvest land use restrictions.

Dockage: the percentage of contamination with other seeds and detritus permitted by importers in a commodity shipment.

Gene: The smallest portion of a chromosome that contains the hereditary information for the production of a protein.

Genetic Engineering (GE): the direct transfer or modification of genetic material using recombinant DNA (rDNA) techniques. It is used interchangeably in this report with a narrow definition of genetic modification (GM).

Genetic Modification (GM): the direct transfer or modification of genetic material using rDNA techniques. This term is used interchangeably in this report with the term GE. It is sometimes used for political purposes by biotechnology proponents to denote a wider range of breeding techniques beyond recombinant DNA technology (a broad definition).

Genetically Engineered Organism (GEO): term used interchangeably in this report with the acronym GMO which refers to the term "genetically modified organism." Other terms with similar meanings used in this report are biotechnology and transgenic.

Integrated Pest Management (IPM): a systems approach to farming employing a host of preventive pest management practices. Because of this focus on preventing pest attack, pesticide use is minimized.

Marker gene: an active gene used to demonstrate that the introduced genes, or transgenes, have been integrated successfully into the host organism.

Marker-assisted breeding programs: programs that use genetic engineering technology to identify genes of importance, but instead of then using that information to recombine genes using rDNA technology, they use the information to complement traditional plant breeding strategies.

Mutagenesis: the process of changing the DNA base sequence at a specific site through an agent that causes biological mutation. Examples include chemicals, radioactive elements and ultraviolet light.

Novel food: a food derived from a plant, animal or microorganism that has been genetically modified so that: (i) the plant, animal or microorganism exhibits characteristics that were not previously observed in that plant, animal or microorganism, (ii) the plant, animal or microorganism no longer exhibits characteristics that were previously observed in that plant, animal or microorganism, or (iii) one or more characteristics of the plant, animal or microorganism no longer fall within the anticipated range for that plant, animal or microorganism.

Outcrossing: mating between different individuals.

Outliers: data points that appear to be inconsistent with most of the other data.

Pesticide: any poison, organic or inorganic, that is used to destroy organisms characterized as “pests” of any sort, including insecticides, fungicides, rodenticides and herbicides.

Plant with Novel Traits (PNT): a plant variety/genotype possessing characteristics that demonstrate neither familiarity nor substantial equivalence to those present in a distinct, stable population of a cultivated species and that have been intentionally selected, created or introduced into a population of that species through a specific genetic change.

Precautionary principle: asserts that parties should take measures to protect public health and the environment, even in the absence of clear scientific evidence of harm.

Promoter: a DNA sequence whose purpose is to “switch on” the introduced gene, or transgene, once it’s been integrated into the host organism.

Recombinant DNA (rDNA): technique of isolating DNA molecules and inserting them into the DNA of a cell. This technique includes taking copies of genes from one organism and inserting them in another organism. The two organisms can be totally unrelated.

Screenings: what is left over on the refuse side after a grain is cleaned.

Selfing: (self-fertilization) mating by a single hermaphrodite individual. Occurs commonly in plants.

Substantial Equivalence: a conceptual tool, not a scientific formulation, used as a decision threshold for further safety testing by government regulators. It is based on a determination of “equivalence” according to several arbitrarily chosen characteristics of a plant with a novel trait to a traditional counterpart in the same species that is in use and generally considered safe.

Transgene: a gene from one organism inserted into another, using rDNA technology.

Transgenic: carrying one or more genes introduced using recombinant DNA technology.

Vector: a portion of the DNA of an organism (often from an infectious organism, with the ability to integrate into foreign DNA) that is used as a vehicle to move a target gene (the introduced gene or transgene), into a “host” organism.

Virus: microscopic particle that contains genetic information, but must invade a cell to reproduce.

Volunteers: plants that grow up, unintentionally, in subsequent crops in the rotation. They are effectively weeds in the next crop.

Appendix 1

Main classes of wheat in Canada and the U.S. and their primary uses

Wheat classes are determined by the time of year they are planted and harvested, their hardness, color and the shape of their kernels. Each class has its own similar family characteristics (protein content, hardness characteristics, gluten quality), especially those related to food uses (primarily milling and baking). Wheat classes are regulated and monitored, more so in Canada than the U.S., and have a large impact on wheat varietal breeding programs.

Wheat Class	Primary uses	Notes
CANADA Canada Western Red Spring (CWRS) (hard red spring)	tin bread, flat bread, hearth bread, crackers, some noodles	Largest production class (70 percent of total), most exported; main markets: U.S., China, Indonesia, Iran.
Canada Western Amber Durum (CWAD)	semolina (pasta), bulgar, couscous	About 18 to 20 percent of total wheat production, mostly from SK; 80 percent exported, main export markets: Algeria, U.S., Italy, Morocco.
Canada Western Red Winter (CWRW)	flat bread, hearth bread, baguettes, crackers, some noodles; some blended with CWRS for pizza, doughnuts, bread, crackers	Not much winter wheat produced in Western Canada; except some soft in AB and SK and hard in AB; mostly for export (winter wheat is about 7 percent of total Canadian production); some grown in Ontario.
Canada Western Soft White Spring (CWSWS)	cookies, cakes	small production acreage
Canada Red Prairie Spring (CPSR)	flat breads, hearth breads, baguettes, crackers, some noodles	small production acreage
Canada White Prairie Spring (CPSW)	flat breads, hearth breads, crackers, some noodles	small production acreage
Canada Western Extra Strong (CWES)	crackers, some noodles, usually in blends	small production acreage
Canada Eastern Red (CER)	cake, cookies and biscuits	Eastern wheats generally seen to be of lower quality and less desirable in export markets. Used domestically and in the U.S. A lot of eastern wheat is feed grade.
Canada Eastern Red Spring (CERS)		
Canada Eastern Hard Red Winter (CEHRW)		Winter wheats produced in the East, particularly SW Ontario (85 percent of total winter wheat production).
Canada Eastern Soft Red Winter (CESRW)		
Canada Eastern Amber Durum (CEAD)	semolina	Very low production levels.

Wheat Class	Primary uses	Notes
Canada Eastern White Winter (CEWW)	cookies, cakes, biscuits, cereals, unleavened breads	Preferred by U.S. and Canadian cereal manufacturers because of its bran; exports for unleavened breads to Africa, middle East.
Canada Eastern Soft White Spring (CESWS)		
U.S. Hard red winter	bread, rolls and, to a lesser extent, sweet goods and all-purpose flour	Biggest class, major foreign buyers include Russia, China, Japan, Morocco and Poland. Kansas the largest producing state.
Hard red spring (Dark Northern Spring wheat, mentioned in press reports as the first RR wheat to be commercialized by Monsanto, is a sub-class)	bread	Grown in North Dakota (50 percent), Montana, South Dakota and Minnesota. Exported to Japan, the Philippines, Taiwan, Italy, South Korea and Venezuela (60 percent of exports).
Soft red winter	flat breads, cakes, pastries, and crackers	Grown primarily east of the Mississippi River. Largest customers are China, Egypt and Morocco.
Durum	semolina	North Dakota largest producer, lowest export volume (<5 percent), largest importer is Algeria.
Hard white wheat	yeast breads, hard rolls, bulgur, tortillas and oriental noodles	Used primarily in domestic markets.
Soft white wheat	bakery products other than bread	Grown mainly in the Pacific Northwest, exported to East Asia.
Unclassed wheat	feed	
Mixed wheat	feed	

Sources: CEREALS SECTOR PROFILE April 1999 Grains and Oilseeds Division, International Markets Bureau, Market and Industries Services Branch, Agriculture and Agri-Food Canada URL: <http://atssea.agr.ca/public/htmldocs/e2207.htm>; Canadian Grain Commission URL: www.cgc.com; The Wheat Grower/September-October 1994 Sponsored by Chicago Board of Trade <http://www.smallgrains.org/WHFACTS/6classwh.htm>. USDA: <http://www.usda.gov/gipsa/reference-library/standard/810wheat.pdf>

Appendix 2

Information on field trials in the U.S., Canada and globally

Analysis of Canadian field trials

From the Canadian Food Inspection Agency (CFIA) web site,²⁶³ some limited information on field trials is available:²⁶⁴

Year	No. of wheat field trials	Companies and traits ²⁶⁵	Provinces where trials take place
2002	53 (out of 241)	Monsanto 45 (HT) Syngenta 6 (disease resistance) Dow 2 (yield)	17 AB, 13 SK, 23 MN RR wheat trials at 33 Western Canada locations, 13-14 on AAFC research sites ²⁶⁶
2001	59 (out of 289)	Monsanto 56 (HT) BASF 2 (HT) Syngenta 1 (disease resistance)	21 SK, 19 AB, 19 MN
2000	72 (out of 178 total trials)	BASF 2 (HT) Monsanto 61 (HT) Novartis 7 (2HT, 5FR) PBINRC 2 (HT, nutr)	6 PEI, 22 MN, 25 SK, 19 AB
1999	123	BASF 16 (HT) Monsanto 106 (HT) PBINRC 1 (HT)	49 MN, 39 SK, 35 AB
1998	13		8 MN, 5 SK
1997	19		3 MN, 12 SK, 4 AB
1996	2		SK
1995	3 or 5 (record contradictory)		SK
1994	21		5 MN, 11 SK, 5 AB

Abbreviations: PBINRC - Plant Biotechnology Institute of the National Research Council; HT - herbicide tolerance; FR- fungal resistance; SM - selectable marker; nutr - nutritional qualities; PEI - Prince Edward Island; MN - Manitoba; SK - Saskatchewan; AB - Alberta

Field trials are normally restricted to 1 ha per site and 5 sites per province per applicant.

Analysis of U.S. Field Trials²⁶⁷

Similarly, in the U.S., no GE wheats have been approved, but there have been extensive field trials (see below). The USDA (Animal and Plant Health Inspection Service-APHIS) reviews all GE crop applications to ensure they are safe to grow, and then the EPA also has to approve those that involve new uses of pes-

ticides. USDA has approved field trials of GE wheat since 1994. In 2002, there were 35 field trial permit applications, 20 of them for glyphosate-tolerance, and most of these from Monsanto, but others from the USDA itself, some universities, and some other smaller biotechnology firms. Generally, permit applications are for herbicide tolerant and fungal resistant wheats, with some applications for food quality expressions and pharmaceuticals, and marker genes. In addition to permits, the regulatory system also provides for notifications. Notifications are a less rigorous form of permitting, presumably for confined releases of material for which permits have already been approved and therefore the USDA doesn't consider the GE application problematic. Certain GE wheat applications apparently became eligible for this notification process following amendments to the regulations in 1997. In this listing are more firms (including Novartis and Syngenta) and it appears somewhat wider applications,

including more agronomic characteristics such as yield improvements and drought resistance. Six applications in this series were denied, for reasons that are not revealed on the web site.

In total then, there are some 239 field tests (as of Aug. 30, 2002). How many applications for unregulated status all these will produce is unclear since many of the field trials may be for the same applications.

Main categories of U.S. field tests:

Novel trait	No. of approved field tests	Year started/year with most applications (where a trend)	Notes
Herbicide tolerance	142	94/00	Most applications from Monsanto for RR ²⁶⁸
Fungus resistance	27	96	Most applications from Novartis; fusarium, septoria
Virus resistance	24	95	Most applications from the U. Idaho; most are for barley yellow dwarf virus (BYDV) or Wheat Streak Mosaic Virus (WSMV)
Altered protein (drought tolerant, carbohydrate metabolism altered, nitrogen metabolism altered, yield increased, etc)	22	97/99	Majority are Monsanto and Montana State U. (Drought tolerance)
Product quality (storage protein altered, yield increased, more digestible, etc)	19		
Marker gene	4	95	
Pharmaceutical proteins	1	00	

Monsanto applications account for 174 of 246 permits or notifications, or 70 percent of the total. Monsanto officials have stated, “Trials are taking place in North and South Dakota, Montana and Minnesota. We’re working with existing U.S. wheat breeders, particularly the universities in those states. We need a certain number of trials to achieve registration from the U.S. Department of Agriculture and the Environmental Protection Agency. We are looking at yield, disease susceptibility and weed control. We are also looking at environmental impact, which is an important part of getting registration.”²⁶⁹ Apparently, Oregon State University is on the verge of signing a research and development deal with Monsanto for RR wheat. No money has changed hands at this point, but could later with commercialization.²⁷⁰ In fact, universities in these regions are working with Monsanto to develop RR wheats that are well adapted to their regional conditions, so it’s likely that RR spring wheat will be the first roll-out, followed by a number of other more regionally adapted varieties.

The next most significant institutional applicants²⁷¹ are the University of Idaho (16), Agricultural Research Service of USDA (14), Montana State University (14), and Novartis (7). It appears that different players are focusing on different applications. The HT field has largely been left to Monsanto, the University of Idaho is a major player in virus resistance. Novartis seems to be focusing on fungal resistance, Montana State University on drought and yield.

Note that there is currently no evidence from searching APHIS or EPA site that any genetically modified bacteria with relevance to wheat production have been approved for field testing (see below for research projects employing genetically modified bacteria).

Field trials with GE wheat globally²⁷²

Country	Company/Institution	Trait
U.S.	AgrEvo	• Herbicide tolerance – glufosinate
	Applied Phytologics	• Altered composition – improved digestibility
	ARS	• Fungal resistance (powdery mildew) • Herbicide tolerance – glufosinate • Altered composition – protein
	Cargill	• Altered composition – protein
	Kansas State University	• Fungal resistance (fusarium)
	Monsanto	• Altered composition – starch/sugar • Altered nitrogen metabolism • Enhanced photosynthesis • Increased yield • Fungal resistance – fusarium • Herbicide tolerance – glyphosate • Virus resistance – BYDV and WSMV
	Montana State University	• Drought tolerance • Altered composition – starch/sugar • Yield increase • Virus resistance – WSMV
	Novartis Seeds (now part of Syngenta)	• Fungal resistance – fusarium • Fungal resistance – powdery mildew • Fungal resistance – septoria • Fungal resistance – fusarium • Fungal resistance – powdery mildew

Country	Company/Institution	Trait
Canada	University of Idaho	<ul style="list-style-type: none"> • Virus resistance – BYDV • Virus resistance – WSMV
	BASF	<ul style="list-style-type: none"> • Herbicide tolerance
	Monsanto	<ul style="list-style-type: none"> • Herbicide tolerance – glyphosate
	Syngenta	<ul style="list-style-type: none"> • Fungal resistance
	Novartis Seeds (now part of Syngenta)	<ul style="list-style-type: none"> • Marker genes • Fungal resistance
Australia	Plant Biotechnology Institute (NRC)	<ul style="list-style-type: none"> • Herbicide tolerance • Altered composition
	CSIRO Plant industry	<ul style="list-style-type: none"> • Marker gene – GUS • Altered composition – starch • Altered composition – glutenin increased • Herbicide tolerance – glufosinate
Spain	University of Adelaide & Victoria Institute for Dryland Agriculture	<ul style="list-style-type: none"> • Herbicide tolerance
	Compañía Navarra Productora de Semillas SA Senasa	<ul style="list-style-type: none"> • Altered composition – starch + herbicide tolerance – glufosinate • Altered composition – starch
	Consejo Superior de Investigaciones Científicas	<ul style="list-style-type: none"> • Altered composition – glutenin increased
	Instituto de Agricultura Sostenible Consejo Superior de Investigaciones Científicas	<ul style="list-style-type: none"> • Altered composition – glutenin increased + herbicide tolerance – glufosinate
	Instituto Nacional de Investigaciones Agrarias y Alimentarias INIA (MAPA)	<ul style="list-style-type: none"> • Dalapon tolerance
UK	Institute of Arable Crop Research (IACR)/John Innes Institute	<ul style="list-style-type: none"> • Altered composition – improved baking quality + herbicide tolerance – glufosinate • Altered composition – starch/sugar + herbicide tolerance – sulfonyleurea
	Syngenta	<ul style="list-style-type: none"> • Fungal resistance – fusarium

Key: BYDV – barley yellow dwarf virus; WSMV – wheat streak mosaic virus

Appendix 3

Leading export destinations for Canadian and U.S. wheat

Canada — bulk wheat (including durum) ranking by weight, 10 year average 1990/91-1999/2000 (source: Canadian Grains Commission)

Rank

1. China (15 percent)
2. Iran (9 percent)
3. United States (8 percent)
4. Japan (8 percent)
5. Algeria (6 percent)
6. European Union (6 percent)
7. South Korea (5 percent)
8. Brazil (5 percent)
9. Indonesia (4 percent)
10. Mexico (3 percent)
11. Venezuela (3 percent)
12. Columbia (2 percent)
13. Chile (2 percent)
14. Peru (1 percent)
15. Philippines (1 percent)
16. Malaysia (1 percent)
17. Morocco (1 percent)
18. South Africa (1 percent)
19. Bangladesh (1 percent)
20. Pakistan (1 percent)

Total top 20: ~83 percent of 19.4 million tons

U.S. - unmilled wheat ranking by weight, 1999 and 2000 (source: USDA ERS)

<u>Rank</u>	<u>1999</u>	<u>2000</u>	<u>Hard Red Spring Wheat (1990 - 00)</u>
1	Egypt (16 percent of total)	Egypt (16 percent)	Japan
2	Japan (11 percent)	Japan (11 percent)	Philippines
3	Mexico (6 percent)	Philippines (8 percent)	Taiwan
4	Philippines (6 percent)	Mexico (6 percent)	Italy
5	South Korea (6 percent)	South Korea (6 percent)	South Korea
6	European Union (5 percent)	European Union (5 percent)	Spain
7	Newly Independent States (5 percent)	Nigeria (4 percent)	Dominican Republic
8	Nigeria (4 percent)	Taiwan (4 percent)	Venezuela
9	Russia (4 percent)	Algeria (3 percent)	Belgium
10	Israel (3 percent)	Israel (3 percent)	Thailand
11	Columbia (3 percent)	Yemen (2 percent)	
12	Peru (2 percent)	Columbia (2 percent)	
13	Algeria (2 percent)	Ethiopia (2 percent)	
14	Bangladesh (2 percent)	Venezuela (2 percent)	
15	Yemen (2 percent)	Morocco (2 percent)	
16	Pakistan (2 percent)	Indonesia (2 percent)	
17	Sri Lanka (2 percent)	Jordan (2 percent)	
18	Venezuela (2 percent)	Sri Lanka (2 percent)	
19	Indonesia (1 percent)	Newly Independent States (1 percent)	
20	Morocco (1 percent)	Thailand (1 percent)	

Total of top 20 ~ 85 percent of 28.3 million tons ~84 percent of 27.6 million tons

Appendix 4

A review of research on GE wheat in Canada and the U.S.

Canada — the ICAR database²⁷³

A search of the ICAR database produced only nine records of research on GE wheat. By far the two largest researchers in Canada are the National Research Council's Plant Biotechnology Institute (NRC PBI) in Saskatoon and AAFC through various research branches. The NRC PBI has been funded since at least 1989 to do GE wheat research and currently devotes 22 Person Years (PY) to this work, a huge research commitment. The description of their work is very vague, but suggests they are involved in direct development of commercial GE varieties. Monsanto, the University of Saskatchewan and AAFC are co-

operators and funding comes from the NRC and from the Saskatchewan Department of Agriculture and Food. AAFC is currently devoting an additional 15.1 PYs in four locations to the research effort and current projects date back from 1992 with some currently funded until 2009. Given the difficulty getting funding for research, this expresses a very strong commitment to GE wheat research. Presumably, their money is coming from internal allocations, usually matched with industry money. Much of the AAFC research focuses on basic information about transformation processes, finding significant traits, gene mapping and molecular markers, work that is a precursor to more market-oriented research and development.

Institution	Research	Project period	Person years of research	Funders
National Research Council, Plant Biotechnology Institute	Gene transformations; development of GE wheat	1989 -	22.0	NRC Sask Ag and Food
AAFC, Winnipeg	Marker assisted breeding; find significant traits, markers; gene transformation (durum? ²⁷⁴)	1992 - 2002	9.3	AAFC, Monsanto, and Western Grains Research Foundation?
AAFC, Ottawa	Molecular markers ²⁷⁵ for significant traits; identify genetic basis for desirable traits	1999-2009	3.8	AAFC and industry?
AAFC, Summerland, BC	Developing root zone pathogen resistance to increase host defenses	1999-2004	2.0	AAFC and industry?
AAFC, Ste-Foy, QC	Molecular markers for root rot and BYDV resistance in conventional breeding	1992-2003	2.0	AAFC and industry?
University of Guelph	Gene transfer	1999-2002	1.42	OMAFRA
McGill	Gene mapping fusarium	1999-2004	0.90	MAPAQ
Centre de recherche sur les grains	Gene mapping fusarium resistance and molecular markers	2000-2002	0.20	
University of Manitoba	Locate tan spot resistance and molecular markers	1992 -	0.50	NSERC

SA - the CRIS database

The U.S. research database generally provides more detailed information (except person-years) on trials, although records are inconsistent in their reporting of certain data. Compared to Canada, there is a much fuller range of research projects, and a greater diversity of institutional actors. It appears that the HT field has largely been abandoned as only three records address it. The vast majority (at least 69 of roughly 100 when overlaps are counted) are focused on agronomic applications (disease, insect, herbicide, yield, or environmental conditions related). These are primarily of interest to farmers, although some of these applications are also relevant to handlers, brokers and traders (storage pests) and processors (diseases reduce wheat quality). Approximately 19 records are more directly relevant to

processors. Most applications appear to be 5 to 10 years away from commercialization, although researchers have reported that some wheats resistant to Barley Yellow Dwarf Virus (BYDV) and some genetically modified bacteria designed to reduce root zone diseases in wheat may be on a commercialization track similar to RR wheat. Field trials have been going on for several years in the U.S. for some genetically organisms with such applications.

Some of the future applications may pose more significant problems for campaigning than does RR wheat. Some of these are highlighted in the table below and discussed more fully in the rest of the paper.

Analysis of U.S. research projects currently underway, just completed or recently terminated²⁷⁶

Type of research	Number of records	Final project years	On the market by?	Challenges for campaigning
Disease related	26			
a. Disease resistance in wheat	20	from 1999-2004		Huge economic burden for growers
• Fusarium Head Blight (scab)	13		10 years	Can cause health problems in human
• Rust	4			
b. Manipulation of microbes either the pathogen or its competitors)	6 (root system diseases, take-all disease the most prevalent)	from 1997-2002	2 estimates: within 3 years 5-10 years	Researchers using classical biocontrol strategies, except for GE manipulation
Insect applications	16			
a. expression of biopesticide	9	1999-2005		
- chitinase (to control fall army worm, storage beetles) ²⁷⁷	8			High storage losses in the U.S., and high pesticide use; lower in Canada due to colder weather
- parasitoid	1			
b. Insect resistance	5 (mostly Russian wheat aphid and hessian fly)	2000, 2003, 2005		
c. GE manipulation of insect pest	2 (for storage pests)	2001, 2004		

Type of research	Number of records	Final project years	On the market by?	Challenges for campaigning
Virus resistance	10	1999-2003	1-2 years for Barley Yellow Dwarf Virus resistance; 5-10 years for Wheat Streak Mosaic Virus ²⁷⁸	
Herbicide tolerance	3			
- dicamba tolerance	1	2004		
- evaluating HT effectiveness	1 (presumably RR)	2005		
Improved agronomic and processor traits	19			Industry believes these are more friendly consumer
a. yield	3	2001, 2003, 2005		
b. Durum pasta quality	2	2002		Some genes from related plants
c. dough strength	2	1999, 2003	5 years	
d. hardness (milling quality)	2	2001		
e. gluten modification to reduce celiac disease	1	2001		Apparent health benefit
f. Sprouting resistance	1	2002		
g. improved pollination	1	2000		
Nutritional improvements	4			
a. for humans	3			
- increase micronutrients	2	2001		
- improve protein	1	1999		
b. for animals - low phytic acid	1	2001		
Environmental conditions	10			
a. aluminum tolerance	4	1999, 2001		
b. drought tolerance	4	2003, 2005		
c. salt tolerance	2	2003, 2005		

Type of research	Number of records	Final project years	On the market by?	Challenges for campaigning
Evaluating gene flow to jointed goat grass	2	2003, 2004		
Bioremediation	1	2001		
Industrial fibres or films	1	1999		
Gene transformation, promoters or constructs	10	1999 - 2004		
Selectable markers	2	2005		

Appendix 5

Other plants related to wheat that have been reported to create hybrids with wheat in an artificial setting²⁷⁹

- *Elymus dahuricus* Turcz. ex Griseb. in Ledeb **Dahurian Wild Rye** (introduced/cultivated)
- *Elymus junceus* Fisch. **Russian Wild Rye** (cultivated/naturalized)
- *Leymus arenarius* (L.) Hochst (*Elymus arenarius* L.) **Sea Lyme Grass, Strand-Wheat** (naturalized)
- *Leymus mollis* Trin (*Elymus mollis* Trin) **Sea Lyme Grass, Strand-Wheat** (native)
- *Agropyron intermedium* (Host) Beauv. **Intermediate Wheatgrass** (naturalized/cultivated)
- *Agropyron trichophorum* (cultivated naturalized)
- *Agropyron elongatum* (Host) Beauv. **Tall Wheatgrass** (cultivated/naturalized)
- *Agropyron cristatum* **Crested Wheatgrass** (cultivated/naturalized)

These occur in Canada as naturalized and cultivated plants (specialized forage crops or for soil stabilization). These grass species are known to colonize disturbed habitats such as uncultivated fields and roadside areas.

Endnotes

¹ Barbara Fairchild, "Release Date for GM Wheat is 2005," *Farm Journal*, April 2002.

² Cited in Freeze, C., "Buyers Distrust Modified Wheat," *Globe and Mail*, 21 May 2001.

³ "Japanese Millers State Opposition to GM Wheat," *Reuters*, Feb. 22, 2001; Marc Kaufman, "Gene Spliced Wheat Stirs Global Fears," *The Washington Post*, 27 February 2001.

⁴ Roberta Rampton, "Roundup Use May Jeopardize Wheat Premiums," *Western Producer*, 8 February 2001; Greg Frost, "European buyers warn U.S. over gene wheat plans," *Reuters*, 2 February 2001; Philip Brasher, "Nervous farmers want curbs on biotech wheat," *Associated Press*, 17 February 2001.

⁵ USWA press release, "European and American Millers Tell U.S. Wheat Associates Board to Go Slow on GM Wheat," 28 August 2002.

⁶ Report on the 2001 AGROGENE Seminar quoted in *PRNewswire*, Paris, 26 February 2001.

⁷ Philip Brasher, note 3; "Nervous farmers want curbs on biotech wheat," *Associated Press*, 17 February 2001; "Monsanto Threatens North Dakota," *CropChoice News*, 12 March 2001, www.cropchoice.com; "Dear Senator Wanzek," *CropChoice News*, 9 July 2002, www.cropchoice.com

⁸ Anonymous, "S. Korea Regulations On Biotechnology Products," *Dow Jones Newswires*, 5 August 2002.

⁹ King, C.A. et al. 2001. Plant growth and nitrogenase activity of glyphosatetolerant soybean in response to foliar glyphosate applications. *Agronomy Journal* 93:179186; Kremer, R.J. et al. 2000. Herbicide impact on *Fusarium* spp. and soybean cyst nematode in glyphosate-tolerant soybean. Abstract presented at Agronomy Society of America meetings.

¹⁰ Piccolo, A. et al. 1994. Adsorption and desorption of glyphosate in some European soils. *J. Environ. Sci. Health B29(6)*:1105-1115; World Health Organization, United Nations Environment Programme, International Labour Organization. 1994. Glyphosate. Environmental Health Criteria 159. Geneva, Switzerland.

¹¹ Cox, C. 1995. Glyphosate, Part 2: human exposure and ecological effects, Herbicide Factsheet, *Journal of Pesticide Reform*, Winter 1995 15(4).

¹² In North America, wheat and wheat products are estimated to comprise 10 percent of the average person's diet, the largest plant component (Pest Management Regulatory Agency. 1998. Residue Chemistry Guidelines. Regulatory Directive Dir9802. PMRA, Ottawa).

¹³ Furtan, W.H. et al. 2002. The Optimal Time to Register Genetically Modified Wheat in Canada. Department of Agricultural Economics, University of Saskatchewan, Saskatoon. Feb. 2002.

¹⁴ For example, on 13 July 2001, an unprecedented Canadian collaboration of nine organizations representing farmers, wheat marketers, rural municipalities, environmentalists and consumers, participated in a press conference and wrote to Prime Minister Chrétien. Their initiative was supported by over 300 other organizations and experts. The July 31 letter said, "Genetically-modified (GM) wheat raises concerns in many sectors, both domestically and abroad. Farmers and grain industry participants are concerned about market loss and risks to Canada's distinguished reputation for quality wheat varieties. In addition, farmers are concerned about agronomic impacts. Consumers are concerned about food safety and regulatory adequacy. Citizens are concerned about environmental damage. Organic farmers are concerned about negative effects on Canada's successful organic sector." The collaboration, comprised of Agricultural Producers Association of Saskatchewan (APAS), Canadian Health Coalition (CHC),

Canadian Wheat Board (CWB), Greenpeace Canada, Keystone Agricultural Producers (KAP), National Farmers Union (NFU), Saskatchewan Association of Rural Municipalities (SARM), Saskatchewan Organic Directorate (SOD) and The Council of Canadians, are asking the government to “act immediately to prevent the introduction of GM [genetically modified] wheat into Canadian food and fields unless the concerns of Canadian farmers, industry, and consumers are adequately addressed.” and to make market acceptance a requirement in the regulatory approval process for GM crops. The above-named organizations also testified and made submissions to the Canadian Standing Senate Committee on Agriculture and Forestry, 8 November 2001.

¹⁵ Cereal Outlook April 1999.

¹⁶ Prairie Grain Crop Facts 2000-2001.

¹⁷ International Grains Council. 2001. World Grain Statistics. London, UK.

¹⁸ Carter, C.A. 2001. Current and Future Trends in the Global Wheat Market. CGIAR, CIMMYT. Mexico.

¹⁹ McMillan, D. 2002. “Former importers become major wheat exporters.” *The Western Producer*, 19 September 2002, P. 14; McMillan, D. “Wheat exporters jockey for position in changing marketplace.” *The Western Producer*, 26 September 2002, P. 14; White, Ed 2002. “New kids on the block will cap wheat increase.” *The Western Producer*, 19 September 2002, P. 16.

²⁰ CFIA Plant Biosafety Office. 1999. Regulatory Directive Dir1999-01: The Biology of *Triticum aestivum* L. (Wheat): A companion document to the Assessment Criteria for Determining Environmental Safety of Plant with Novel Traits. Available at: <http://www.inspection.gc.ca/english/plaveg/pbo/dir/dir9901e.shtml>

²¹ 2001 Canadian Agricultural Census and 1997 U.S. Agricultural Census.

²² A quick overview of the most common methods of genetic engineering can be found at <http://www.ucsus.org/agriculture/index.html>.

²³ A vector is a portion of the DNA of an organism (often from an infectious organism, with the ability to integrate into foreign DNA) that is used as a vehicle to move a target gene (the introduced gene or transgene), into a “host” organism.

²⁴ An Expert Panel Report on the Future of Food Biotechnology Prepared by the Royal Society of Canada at the request of Health Canada, Canadian Food Inspection Agency and Environment Canada. 2001. Elements of Precaution: recommendations for the regulation of food biotechnology in Canada. January 2001. www.rsc.ca/food-biotechnology/indexEN.html

²⁵ A promoter is a DNA sequence whose purpose is to “switch on” the introduced gene, or transgene, once it’s been integrated into the host organism.

²⁶ For more on the controversy surrounding this promoter, see the web site of the Institute of Science in Society, www.i-sis.org

²⁷ A marker gene is an active gene used to demonstrate that the introduced genes, or transgenes, have been integrated successfully into the host organism.

²⁸ For more on this controversy, see articles posted at <http://www.biotech-info.org>. Note that the new EU directive on biotechnology requires elimination of antibiotic resistance markers in GMOs destined for market by 2004, and by 2008 for research purposes. Other experts have called for a ban on the use of antibiotic resistant markers such as the British Medical Association, the Royal Society of Canada and the Ontario Public Health Association.

²⁹ Typically, the milestones in the development of any GE crop include:

- a) basic research on gene transformations,
- b) the application in the laboratory of that research to specific crops,

- c) regulatory approval for field trials (or confined release in Canada) and then the carrying out of these field trials,
- d) collection of data on environmental, human and animal safety, and then
- e) regulatory approval for unconfined release (Canada) or unregulated status (U.S.), and use as a human or animal feed.
- f) In Canada, for a wheat variety to be sold under a variety name and used legally in milling, it must be approved by the Prairie Registration Recommending Committee for Grain (PRRCG), acting under the authority of the Canadian Food Inspection Agency (CFIA), which generally involves 3 years of co-operative varietal trials.

³⁰ For more on this, see Mayer, S. 2002. Genetically Engineered Wheat — Changing our Daily Bread. Greenpeace International, Amsterdam.

³¹ Only imidazolinone-tolerant wheat, a product of chemical mutagenesis, has been approved in Canada (1998). A Canadian hard red spring variety (BW755) originally was denied varietal registration in February 2001 due to quality concerns, but was accepted following appeal to the PRRCG executive committee (Rance, L. 2001. Wheat wins appeal against PRRCG. *The Manitoba Co-operator*, 19 April 2001). BASF has commercialized spring and winter wheat in 2002 in the U.S. under the Clearfield brand. Since mutagenesis is not an rDNA technology it is not further considered here.

³² One of the RR spring wheats in Canadian field trials has BW 252, a high yielding, high protein hard red spring wheat developed by the Agriculture and Agri-food Canada (AAFC) Cereal Research Centre in Winnipeg, as its conventional analog (Rance, L. 2001. Roundup Ready™ wheat: will it bring bounty to farmers or just another weed? *The Manitoba Co-operator*, 19 July 2001, P. 7). AAFC has been working closely with Monsanto on development of RR wheat since 1997 according to press reports (Spears, T. with files from the Canadian Press. 2001. Federal memo warns against GM wheat: Canada still working with Monsanto to create country's first modified seed. *The Ottawa Citizen*, 1 August 2001. <http://www.ottawacitizen.com/>). This has prompted many to question the government's role in developing a GE crop

to which there is so much opposition, and to criticize the perceived conflict of interest created by the government's dual role in both developing and regulating RR wheat.

³³ In the U.S., it appears that a number of university plant breeders have been working with Monsanto and it is unclear at this point which conventional analogs in the U.S. are being used for the first wave of introductions, although a number of press reports have identified RR hard red spring wheats in the Dark Northern Spring subclass as the first to be commercialized.

³⁴ Rance, L. 2001. Marketability now on Ottawa's radar screen. *The Manitoba Co-operator*, 31 May 2001, P. 7.

³⁵ Paulson, J. 2001. Monsanto Vows to be Cautious with GM Wheat. *The Leader-Post* (Regina), 12 July 2001.

³⁶ Gillam, C. 2002. Monsanto says it's shifting strategy on GM wheat. *Reuters*, 29 July 2002; Pollack, A. 2002. Delay Is Seen for Genetically Modified Wheat. *The New York Times*, 31 July 2002. In fact, this idea was put forward in early 2001 by Darrell Hanavan, the chair of the joint biotechnology committee of the North American Wheat Growers and U.S. Wheat Associates. Hanavan said that introducing a "consumer-driven" GE wheat variety would be preferable to the wheat industry, and noted that Monsanto was one company with such products in development – see Gillam, C. 2001. Monsanto GM Wheat. *Reuters*, 1 February 2001.

³⁷ Ewins, A. 2002. GM wheat benefits probed. *The Western Producer*, 11 July 2002.

³⁸ Binkley, A. 2002. Monsanto: No change in RR approval process. *Food Chemical News*, Volume 44, Number 27, 19 August 2002; an August 22 USDA report says that Monsanto will apply for approval of RR wheat in the U.S., Canada and Japan "this year," at <http://www.fas.usda.gov/scripts/gd.asp?ID=145783635>

³⁹ Paulson, J. 2001. Monsanto vows to be cautious with GM wheat: won't commercialize RRW without controls. *The Leader-Post*, 12 July 2001.

⁴⁰ Dr. Stephen Yarrow, National Manager, Plant Biosafety Office, CFIA, Personal Communications to Holly Penfound, Greenpeace Canada, 4 September and 3 October 2002. Dr. William Yan, Chief, Evaluation Division, Bureau of Microbial Hazards, Food Directorate, Health Canada, Personal Communications with Holly Penfound, Greenpeace Canada, 8 November 2002.

⁴¹ See Part B - Foods Division 15, Table II (Agricultural Chemicals), Food and Drugs Act and Regulations, <http://laws.justice.gc.ca/en/index.html>

⁴² Note that it usually takes up to three years to achieve commercial volumes of certified seed.

⁴³ Given concerns about RR wheat and the locations of confined release trials that have been covered extensively in the Canadian farm press, it is not a given that sufficient numbers of co-operating farms can be found to run public trials.

⁴⁴ Dr. Stephen Fox, Secretary, PRRCG Subcommittee on Wheat, Rye and Triticale, personal communication to Dr. Rod MacRae, 9 August 2001.

⁴⁵ For more on this, see the documents posted on the CFIA's varietal registration office web site.

⁴⁶ Dr. Stephen Yarrow, National Manager, Plant Biosafety Office, CFIA, Personal Communication to Holly Penfound, Greenpeace Canada, 4 September 2002.

⁴⁷ Paulson, J. 2001. Monsanto vows to be cautious with GM wheat: won't commercialize RRW without controls. *The Leader-Post*, 12 July 2001.

⁴⁸ Binkley, A. 2002. Monsanto: No change in RR approval process. *Food Chemical News*, Volume 44, Number 27, 19 August 2002; an August 22 USDA report says that Monsanto will apply for approval of RR wheat in the U.S., Canada and Japan "this year," at <http://www.fas.usda.gov/scripts/gd.asp?ID=145783635>

⁴⁹ Canadian Wheat Board. Current State of Market

Acceptance and Non-acceptance of GM Wheat. Updated: 26 Sept. 2002.

⁵⁰ As the largest importer of U.S. wheat, Egypt will be largely influenced by safety, price and certain characteristics such as the nutritional value, Dr. Ahmed Khorshid, agricultural counselor at the Egyptian Embassy in Washington, told Lisa Kallal BridgeNews. www.checkbiotech.org (9 Feb. 2001).

⁵¹ Rampton, R. 2001. Roundup use may jeopardize wheat premiums. *The Western Producer*, 8 February 2001.

⁵² Gillam, C. 2001. Monsanto GM wheat. *Reuters*, 1 Feb 2001.

⁵³ An Expert Panel Report on the Future of Food Biotechnology Prepared by the Royal Society of Canada at the request of Health Canada, Canadian Food Inspection Agency and Environment Canada. 2001. Elements of Precaution: recommendations for the regulation of food biotechnology in Canada. January 2001. www.rsc.ca/food-biotechnology/indexEN.html

⁵⁴ An Expert Panel Report on the Future of Food Biotechnology Prepared by the Royal Society of Canada at the request of Health Canada, Canadian Food Inspection Agency and Environment Canada. 2001. Elements of Precaution: recommendations for the regulation of food biotechnology in Canada. January 2001. www.rsc.ca/food-biotechnology/indexEN.html

⁵⁵ Commoner, B. 2002. Unraveling the DNA Myth: The spurious foundation of genetic engineering, *Harper's Magazine*, February, www.mindfully.org/GE/GE4/DNA-Myth-CommonerFeb02.htm

⁵⁶ Ibid.

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⁶⁵ USWA press release, 2002. European and American Millers Tell U.S. Wheat Associates Board to Go Slow on GM Wheat. 28 August 2002.

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⁷⁴ Schubert, R. 2002. Farmer wants ND to ensure protection of foundation wheat seed stocks. *CropChoice News*, 13 June 2002. www.cropchoice.com

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⁹⁰ Freeze, C. 2001. Buyers Distrust Modified Wheat. *Globe and Mail*, 21 May 2001.

⁹¹ From a transcript of the CBC TV show Country Canada, 21 March 2002.

⁹² U.S. Wheat Association. 2002. European and American Millers Tell U.S. Wheat Associates Board to Go Slow on GM Wheat. Press Release. 28 Aug. 2002; Gillam, C. 2002. Asian opposition to biotech spring wheat steadfast. *Reuters*, 9 October 2002.

⁹³ From a letter from Greg S. Arason, President and Chief Executive Officer, The Canadian Wheat Board (CWB), dated 8 November 2000, addressed to Mr. Peter Pepneck, President, Alberta Soft Wheat Producers Commission, and submitted to the 18,19 Dec. 2000 meeting of the Canadian Committee on the Voluntary Labeling of Foods Obtained or Not Obtained Through Genetic Modification.

⁹⁴ Cited in Freeze, C. 2001. Buyers distrust modified wheat. *Globe and Mail*. 21 May 2001; and Canadian Wheat Board. Current State of Market Acceptance and Non-acceptance of GM Wheat. Updated: 26 Sept. 2002.

⁹⁵ Kuntz, G.M. 2001. Transgenic Wheat: potential price impacts for Canada's wheat export market. M.Sc. Thesis, University of Saskatchewan, Saskatoon. Sept. 2001.

⁹⁶ Canadian Wheat Board. Current State of Market

Acceptance and Non-acceptance of GM Wheat. Updated: 26 Sept. 2002.

⁹⁷ For a graphic summary, see <http://www.isb.vt.edu/news/images/hrsexports.gif>

⁹⁸ Cited in Freeze, C. 2001. Buyers distrust modified wheat. *Globe and Mail*, 21 May 2001.

⁹⁹ Human domestic use of durum production is even lower - about 3 percent.

¹⁰⁰ Cereal Outlook April 1999.

¹⁰¹ Canadian Wheat Board, 2001. Statement to the Standing Senate Committee on Agriculture and Forestry, Genetically Engineered Wheat, 8 November 2001.

¹⁰² The North American Millers Association is concerned primarily about segregation and skeptical that it is possible (President Betsy Faga, cited in Gillam, C. 2001. Monsanto GM wheat. *Reuters*, 1 Feb 2001).

¹⁰³ USWA press release, 2002. European and American Millers Tell U.S. Wheat Associates Board to Go Slow on GM Wheat. 28 August 2002.

¹⁰⁴ Wilson, B. 2001. *The Western Producer*, 8 November 2001 P. 10.

¹⁰⁵ Onstad, E. 2001. Demand surges for non-gmo animal feed in Europe. *Reuters*, 8 October 2001.

¹⁰⁶ Greenpeace U.S. 2001. Grains of Truth: video, GP U.S., Washington. To obtain a copy of the Greenpeace Grains of Truth video, or for other background information and testimonials about farmers' contamination problems, see the Farmers Speak Out section at www.greenpeaceusa.org/ge or click on the genetic engineering campaign at www.greenpeace.org or www.greenpeace.ca

¹⁰⁷ With tens of millions of acres planted to wheat in North America, generating quadrillions of pollen grains, low percentage events can still be triggered at high rates due to

the sheer volume of opportunities.

¹⁰⁸ Personal communication between Dr. Patrick Carr, Agronomist, North Dakota State University and Sharon Rempel, Curator, The Garden Institute of Alberta, 3 April 2001.

¹⁰⁹ Anonymous, 2002. Two Research Centers Decide Not to Plant Biotech Wheat Test Plots. Associated Press. 7 May 2002; Schubert, R. 2002. ND research extension centers say 'No' to transgenic wheat trials. *CropChoice News*, 6 May 2002, www.cropchoice.com.

¹¹⁰ GM wheat must be isolated from other species by 30 meters (up from 10 meters in previous years) and no cereal crops can be grown on the trial site during the two-year post-harvest period, according to an amendment to the CFIA Regulatory Directive 2000-07: Guidelines for the Environmental Release of Plants with Novel Traits within Confined Field Trials in Canada.

¹¹¹ Rampton, R. 2001. Farmers want brakes on GM wheat. *The Western Producer*, 8 February 2001.

¹¹² Canadian Grain Commission. 1998:6. Identity Preservation in the Canadian Grain System: a discussion paper. CGC, Winnipeg. Dec.

¹¹³ Dawson, A. 2002. "Declaration" proposed: KVD going. *The Manitoba Co-operator*, 7 March 2002. P. 1-3.

¹¹⁴ There are actually 14 main wheat classes in Canada, but they are divided regionally, half Western wheats and half Eastern wheats, so to some extent there is already regional segregation.

¹¹⁵ <http://www.usda.gov/gipsa/programsfgis/services.htm>

¹¹⁶ See, for example, the submissions by the North Dakota Wheat Commission and the Wheat Export Trade Education Committee, U.S. Wheat Associates, National Association of Wheat Growers. <http://www.usda.gov/gipsa/biotech/anpr/anpr.htm>

¹¹⁷ Much of this is based on information contained in the following report: Canadian Grain Commission. 1998:6. Identity Preservation in the Canadian Grain System: a discussion paper. CGC, Winnipeg. Dec.

¹¹⁸ Connor, S. 2001. Monsanto to launch the first GM loaf. *The Independent* (London), 15 January 2001.

¹¹⁹ Saylor, T. 2001. The StarLink incident: changing the face of the U.S. grain industry. *ISB News Report*, March 2001.

¹²⁰ Bell, I. 2001. Farm lobby takes tough stand on risk of GM contamination. *The Western Producer*, May 10, P.17.

¹²¹ Morrison, S. and Tait, N. 2001. Concern in Canada over biotech wheat. *Financial Times*, 26 April 2001; Schubert, R. 2002, note 73.

¹²² Off-the-record conversations between the authors and various major participants in the global wheat trade.

¹²³ Key links in the chain (though not required in every exchange) include: plant breeders, seed sellers, farmers, primary elevator/delivery agent, railway or trucker, transfer elevator, terminal, terminal shipper (ocean vessel, railway, trucker or container).

¹²⁴ Rance, L. 2001. The race is on for GM wheat test. *Ontario Farmer*, 3 April 2001, P. 47.

¹²⁵ Kraft press release, 2000. Kraft Foods Announces Voluntary Recall of All Taco Bell Taco Shell Products From Grocery Stores. 22 September 2000. <http://www.kraft.com/newsroom/09222000.html>; Grocery Manufacturers of America press release, 2000. GMA Statement on Kraft Foods Voluntary Taco Shell Recall. 22 September 2000. <http://www.gmabrands.com>.

¹²⁶ Rance, L. 2001. The race is on for GM wheat test. *Ontario Farmer*, 3 April 2001, P. 47.

¹²⁷ This was confirmed to Dr. Rod MacRae by an official of a North American rail company handling conventional and GE grains.

- ¹²⁸ Gosnell, D.C. 2001. Non-GM Wheat Segregation Strategies: comparing the costs. M.Sc. Thesis, University of Saskatchewan, Saskatoon.
- ¹²⁹ Screenings are what is left over on the refuse side after a grain is cleaned.
- ¹³⁰ In a commodity shipment, importers permit some percentage of contamination with other seeds and detritus. This level of contamination is known as dockage.
- ¹³¹ Pratt, S. 2001. Customers demand cleaner peas. *The Western Producer*, 14 June 2001.
- ¹³² White, E. 2001. CGC says GM wheat can be segregated. *The Western Producer*, 7 June 2001.
- ¹³³ Gosnell, D.C. 2001. Non-GM Wheat Segregation Strategies: comparing the costs. M.Sc. Thesis, University of Saskatchewan, Saskatoon.
- ¹³⁴ North Dakota weakened its bill in the face of threats from Monsanto to withdraw research funding in the state. See Dawson, A. 2001. North Dakota drops proposed moratorium on GM wheat. *The Manitoba Co-operator*, 17 May 2001, P.8. However, the North Dakota legislature has reopened discussion on the subject in July 2002 (Boldt, M. 2002. Legislators grapple with biotech wheat issue. *Associated Press*, 10 July 2002.
- ¹³⁵ Ewins, A. 2001 Customers throw cold water on GM wheat. *The Western Producer*, Jan. 2001.
- ¹³⁶ Spears, T. with files from the Canadian Press. 2001. Federal memo warns against GM wheat: Canada still working with Monsanto to create country's first modified seed. *The Ottawa Citizen*, 1 August 2001 <http://www.ottawacitizen.com/>
- ¹³⁷ Furtan, W.H. et al. 2002. The Optimal Time to Register Genetically Modified Wheat in Canada. Department of Agricultural Economics, University of Saskatchewan, Saskatoon. Feb. 2002.
- ¹³⁸ Saylor, T. 2001. U.S., Canada face biotech wheat showdown. *ISB News Report*, June 2001. <http://www.isb.vt.edu/news/2001/jun01.pdf>
- ¹³⁹ Reuters/Dow Jones. 2001. Australia: GM grains likely to dominate _ ABARE. 9 August 2001.
- ¹⁴⁰ Rance, L. 2001. Farmers want protection from Roundup Ready™ wheat. *The Manitoba Co-operator*, 1 March 2001, P. 17.
- ¹⁴¹ Letter to the USDA dated April 16, 2001 in response to ANPR Docket Number FGIS-2000-001a, on How USDA Can Best Facilitate the Marketing of Grain, Oilseeds, Fruits, Vegetables, and Nuts in Today's Evolving Marketplace. <http://www.usda.gov/gipsa/biotech/anpr/anpr.htm>
- ¹⁴² A range of figures are cited in press reports, from a few hundred million to \$1 billion dollars for total losses.
- ¹⁴³ Barbara Murray, "StarLink to Cost Companies \$9 Million," *Supermarket News*, 11 March 2002.
- ¹⁴⁴ The Keystone Agricultural Producers (KAP) in Manitoba have already passed a resolution that they'll consider a class action lawsuit against the CFIA if Canada's status as an exporter is harmed by genetically modified wheat. See Gilmour, G. 2001. KAP says GMO contamination legal issue. *The Manitoba Co-operator* May 3. P.8; and Bell, I. 2001. Farm lobby takes tough stand on risk of GM contamination. *The Western Producer*, May 10, P. 17.
- ¹⁴⁵ Bechman, T.J. 2002. Grain handler on biotech: 'We must listen better' — Next wave of high-tech grain traits will leave even less room for error. *Farm Futures Daily*, 18 September 2002.
- ¹⁴⁶ Rance, L. 2001. Traceability to continue: will Canada cash in? *The Manitoba Co-operator*, 19 April 2001, P. 1-2.
- ¹⁴⁷ Bill Wilson, North Dakota State University cited in Rance, L. 2001. Who dares take the first plunge with GMO wheat? *The Manitoba Co-operator*, 19 July 2001, P. 8.

¹⁴⁸ Unregistered varieties can still be used for IP contracts where total segregation is assured, and for animal feed. Consequently, there remains the potential for unregistered varieties to end up in the general human food system.

¹⁴⁹ White, E. 2001. GM wheat could be costly, say farmers. *The Western Producer*, 1 March 2001.

¹⁵⁰ Note, however, that under new regulatory proposals to be adopted by summer 2002, merit criteria are being narrowed to disease and quality characteristics for wheat from broader agronomic merit considerations. The devolution of the varietal registration process has begun. For the CFIA's proposal, see <http://www.inspection.gc.ca/english/plaveg/pbo/dir/dir9901e.shtml>

¹⁵¹ Rance, L. and Binkley, A. 2001. GM wheat can be kept out. *The Manitoba Co-operator*, April 12, P1, 3.

¹⁵² Dawson, A. 2001. Registration system doesn't take market impact into account. *The Manitoba Co-operator*, 9 August 2001, P. 7.

¹⁵³ Wilson, B. 2002. Don't reject science-based variety registration: Goodale. *The Western Producer*, 16 May 2002.

¹⁵⁴ Agriculture and Agri-food Canada (AAFC). 1993. Assessment of the Economic Benefits of Pesticides. Regulatory Directive 93-17. AAFC, Ottawa. Available on the web site of the Pest Management Regulatory Agency. <http://www.hc-sc.gc.ca/pmra-arla/english/index-e.html>

¹⁵⁵ Darrin Qualman, Executive Secretary, National Farmers Union, personal communication to Holly Penfound, Greenpeace Canada, May 2001.

¹⁵⁶ Three years of quality assessment are likely to remain standard, but disease evaluation requirements will likely vary. The worry is that the longer the time for evaluation, the more fully a variety's behavior can be characterized (Personal communication, Dr. Stephen Fox, Secretary, PRRCG wheat, ye and triticale subcommittee, October 2001).

¹⁵⁷ Rance, L. 2001. Variety registration system faces changes. *The Manitoba Co-operator*, 27 September 2001, P. 12.

¹⁵⁸ Rance, L. 2001. Farmers want protection from Roundup Ready™ wheat. *The Manitoba Co-operator*, 1 March 2001, P. 17.

¹⁵⁹ Kaufman, M. 2001. Gene-spliced wheat stirs global fears. *The Washington Post*, 27 February 2001, sec. A, p1.

¹⁶⁰ Volunteers are plants that grow up, unintentionally, in subsequent crops in the rotation. They are effectively weeds in the next crop.

¹⁶¹ We use the term reliance here because a cursory examination of herbicide costs and weight of active ingredient applied suggests that herbicide use is down. This is because products like glyphosate do not require as high a dose as some of the products they are replacing. Glyphosate is also generally a cheaper product. But price and weight of active ingredient are not seen to be reliable indicators of how reliant farmers are on herbicides for weed control. Other measures, such as acre-treatments help provide a more complete understanding. For more on this, see Benbrook, C. et al. 1996. Pest Management at the Crossroads. Consumers Union, Yonkers, NY.

¹⁶² Serecon Management Consulting Inc. and Koch Paul Associates. 2001. An Agronomic and Economic Assessment of Transgenic Canola. Prepared for the Canola Council of Canada. January.

¹⁶³ Benbrook, C. 2001. Troubled Times Amid Commercial Success for Roundup Ready™ Soybeans: Glyphosate Efficacy is Slipping and Unstable Transgene Expression Erodes Plant Defenses and Yields. Northwest Science and Environmental Policy Center, Sandpoint Idaho. 3 May 2001.

¹⁶⁴ IPM or Integrated Pest Management is a systems approach to farming employing a host of preventive pest management practices. Because of this focus on *preventing* pest attack, pesticide use is minimized.

¹⁶⁵ Benbrook, C. 1999. Evidence of the magnitude and consequences of the Roundup Ready™ yield drag from University-based varietal trials in 1998. AgBiotech InfoNet Technical Paper #1. 13 July 1999.

¹⁶⁶ Some U.S. soybean growers are saying RR wheat won't be necessary in RR soybean systems because they feel weed control is sufficient following the RR soybean crop (ISB news report by Tracy Saylor, Aug 2001).

¹⁶⁷ JoAnne Buth, Vice President - Production, Canola Council of Canada, Personal communication to Dr. Rod MacRae, 18 May 2001.

¹⁶⁸ Rampton, R. 2001. Farmers want brakes on GM wheat. *The Western Producer*, 8 February 2001.

¹⁶⁹ From The Growers Manual, Canola Council of Canada. <http://www.canola-council.org>

¹⁷⁰ Scott Day, Manitoba Agriculture, personal communication to Dr. Rod MacRae, April 2001.

¹⁷¹ Ewins, A. 2001. Study will help farmers with economics of GM production. *The Western Producer*, 18 January 2001, P. 10.

¹⁷² Furtan, W.H. et al. 2002. The Optimal Time to Register Genetically Modified Wheat in Canada. Dept. Agricultural Economics, University of Saskatchewan, Saskatoon. Feb. 2002.

¹⁷³ This study contained a number of assumptions about herbicide prices and wild oat infestations on the average farm that likely inflate the benefits of the RR wheat system. RR wheat systems were not compared to wheat managed under Integrated Pest Management systems. For more on these assumptions, see the See Canadian Wheat Board. 2002. Agronomic Assessment of Roundup Ready™ Wheat. CWB, Regina.

¹⁷⁴ For more on why, see Serecon Management Consulting Inc. and Koch Paul Associates. 2001. An Agronomic and Economic Assessment of Transgenic Canola. Prepared for

the Canola Council of Canada. January 2001.

¹⁷⁵ See 2001 stories by Laura Rance in *The Manitoba Co-operator*.

¹⁷⁶ Canadian Wheat Board, 2002. A Discussion Paper on Agronomic Assessment of RR Wheat. July 2002, pp 9-10.

¹⁷⁷ Rance, L. 2001. Farmers want protection from Roundup Ready™ wheat. *The Manitoba Co-operator*, 1 March 2001, P. 17.

¹⁷⁸ Rance, L. 2001. Roundup Ready™ wheat: will it bring bounty to farming, or just another weed? *The Manitoba Co-operator*, 19 July 2001, P. 7.

¹⁷⁹ Owen, M. 1997. North American developments in herbicide tolerant crops. Presentation at the 1997 British Crop Protection Conference. Weed Science (Online) at <http://www.weeds.iastate.edu/weednews/Brighton.htm>; Smeda, R.J., et al, 1998. Herbicide Resistant Weed Update for Missouri. Presentation at the 1998 University of Missouri Ag Chem Short Course, at <http://www.psu.missouri.edu/agronx/weeds/newsletterarticles/98agchemshortcourse.html>.

¹⁸⁰ Holmberg, M. 2001. Maverick marestail won't be rounded up. *Successful Farming*, 15 February 2001.

¹⁸¹ Heikens, N. 2001. Weed develops Roundup resistance East Coast find will affect farmers' strategies nationwide. *The Star* (Indianapolis), 20 February 2001.

¹⁸² Canon, S. 2001. Weeds Developing Resistance to Widely Used Herbicide, Some Say. *The Star* (Kansas City), 21 August 2001.

¹⁸³ VanGessel, M. 2001. Determining Presence of Glyphosate-Resistant Horseweed Under Field Conditions. Weed Facts. University of Delaware, College of Agriculture and Natural Resources, 13 March 2001. http://www.rec.udel.edu/weed_sci/WeedFacts/Marestail-resistance.htm.

- ¹⁸⁴ Boerboom, C. 2001. Horseweed Resistance to Glyphosate. University of Wisconsin. August 2001.
- ¹⁸⁵ Syngenta Announces Guidelines To Prevent Weed Resistance To Glyphosate Herbicides. Syngenta press release. Greensboro, N.C., 25 February 2002. http://www.syngentacropprotectionus.com/media/article.asp?article_id=199
- ¹⁸⁶ Canon, S. 2001. Weeds Developing Resistance to Widely Used Herbicide, Some Say. *The Star* (Kansas City), 21 August 2001.
- ¹⁸⁷ Holmberg, M. 2002. Weed resistance is the Achilles' heel of effective herbicides. *Successful Farming*, April 2002 <http://www.agriculture.com/sfonline/sf/2002/april/0206production.html>
- ¹⁸⁸ Duffy, M. 2001. Who benefits from biotechnology? American Seed Trade Association Meeting, 5-7 Dec. 2001. Chicago.
- ¹⁸⁹ Serecon Management Consulting Inc. and Koch Paul Associates. 2001. An Agronomic and Economic Assessment of Transgenic Canola. Prepared for the Canola Council of Canada. January 2001; also Benbrook, C. 2001. Troubled Times Amid Commercial Success for Roundup Ready™ Soybeans: Glyphosate Efficacy is Slipping and Unstable Transgene Expression Erodes Plant Defenses and Yields. Northwest Science and Environmental Policy Center, Sandpoint Idaho. 3 May 2001.
- ¹⁹⁰ Coffman, B. 2001. Industry feature: off-patent herbicide options. *AgWeb*, 8 March 2001.
- ¹⁹¹ Furtan, W. H. et al. 2002. The Optimal Time to Register Genetically Engineered Wheat in Canada. Dept. Agricultural Economics, University of Saskatchewan, Saskatoon. Feb. 2002.
- ¹⁹² A limited number of winter wheat hybrids are available in the U.S. on limited acreage. No hybrid spring wheats have been commercialized (CFIA Plant Biosafety Office. 1999. Regulatory Directive Dir1999-01: The Biology of *Triticum aestivum* L. (Wheat): A companion document to the Assessment Criteria for Determining Environmental Safety of Plant with Novel Traits. Available at: <http://www.inspection.gc.ca/english/plaveg/pbo/dir/dir9901e.shtml>
- ¹⁹³ Note that the partnership between Monsanto and AAFC to develop the first RR wheat is seen by some to compromise this benefit. As well, Monsanto now claims to control the best wheat breeding material in the world (Abel, C. 2000. Wheat future in in Bio-Tech not GM. *Farmer's Weekly*, 25 February 2000).
- ¹⁹⁴ Monsanto has yet to decide whether it will use technology use agreements to recoup its investment (Rance, L. 2001. Roundup Ready™ wheat: will it bring bounty to farming, or just another weed? *The Manitoba Co-operator*, 19 July 2001, P. 7), but clearly they will need to restrict seed saving in some form to generate profit.
- ¹⁹⁵ Rance, L. 2001. High-tech wheat coming, whether we like it or not. *Winnipeg Free Press*, 13 Jan. 2001. <http://www.winnipegfreepress.com/business/index.html>
- ¹⁹⁶ Since only Monsanto data is currently available, and reporting of it has been quite general, it is difficult to determine the validity of their claims. See Canadian Wheat Board. 2002. Agronomic Assessment of Roundup Ready™ Wheat. CWB, Regina. Given the disparity between claims and reality in other crops, it is unlikely farmers will see the yield benefits Monsanto presents. For a review, see CIELAP. 2002. Citizens' Guide to Biotechnology. CIELAP, Toronto <http://www.cielap.org>
- ¹⁹⁷ DeVuyst, E.A. et al. 2001. Modeling international trade impacts of genetically modified wheat introductions. *Agribusiness & Applied Economics Report #463*, North Dakota State University, Fargo. <http://agecon.lib.umn.edu/>
- ¹⁹⁸ Kuntz, G.M. 2001. Transgenic Wheat: potential price impacts for Canada's wheat export market. M.Sc. Thesis, University of Saskatchewan, Saskatoon. Sept. 2001.

¹⁹⁹ See, for example, Holzman, J. 2001. The Economics of Herbicide Tolerant Wheat in Western Canadian Crop Rotations. M.Sc. Thesis, University of Saskatchewan, Saskatoon.

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²⁰² Western Grains Research Foundation Press Release. 2001. Pioneering study aims for biological control of fusarium head blight. 8 March 2001. <http://www.westerngrains.com>

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²⁰⁶ Marker-assisted breeding programs use genetic engineering technology to identify genes of importance, but instead of then using that information to recombine genes using rDNA technology, they instead use the information to complement traditional plant breeding strategies.

²⁰⁷ CFIA Plant Biosafety Office. 1999. Regulatory Directive Dir1999-01: The Biology of *Triticum aestivum* L. (Wheat): A companion document to the Assessment Criteria for Determining Environmental Safety of Plants with Novel Traits. Available at: <http://www.inspection.gc.ca/english/plaveg/pbo/dir/dir9901e.shtml>

²⁰⁸ Crawley, M.J. et al. 2001. GM plants make weedy weeds. *Nature* 409 (8 Feb. 2001):682-683.

²⁰⁹ Selfing (self-fertilization) is mating by a single hermaphrodite individual. Occurs commonly in plants.

²¹⁰ CFIA Plant Biosafety Office. 1999. Regulatory Directive Dir1999-01: The Biology of *Triticum aestivum* L. (Wheat): A companion document to the Assessment Criteria for Determining Environmental Safety of Plants with Novel Traits. Available at: <http://www.inspection.gc.ca/english/plaveg/pbo/dir/dir9901e.shtml>

²¹¹ Abergel, E. 2000. Growing Uncertainty: the environmental risk assessment of genetically engineered herbicide tolerant canola in Canada. Ph.D. Dissertation. York University, Toronto.

²¹² There are wild triticum species in the middle East, the biological home of wheat. Just as in the case of corn and Mexico, the biological home of corn, there is significant potential for gene flow associated with exported North American wheat to the Middle East.

²¹³ Scientist points out possibility of Roundup Ready™ wheat crossing with goatgrass weed. *CropChoice News*, 5 February 2001 <http://www.cropchoice.com/leadstry.asp?recid=231>

²¹⁴ Seefeldt, S.S. et al. 1999. The production of herbicide-resistant jointed goatgrass (*Aegilops cylindrica*) x wheat (*Triticum aestivum*) hybrids in the field by natural hybridization and management strategies to reduce their occurrence. 1999 BCPC Symposium Proceedings No. 72: Gene flow and agriculture: relevance for transgenic crops. Pp. 159-163; Mallory-Smith, C.A. et al. 1999. Potential for gene flow between wheat (*Triticum aestivum*) and jointed goatgrass (*Aegilops cylindrica*) in the field. 1999 BCPC Symposium Proceedings No. 72: Gene flow and agriculture: relevance for transgenic crops. Pp. 165-169.

²¹⁵ Backcrossing refers to the crossing of a hybrid plant with one of its parents.

- ²¹⁶ Survey of Oregon wheat fields to identify hybrids between wheat and jointed goatgrass. Oregon Wheat, March 2001. <http://jgg.unl.edu>
- ²¹⁷ Weed scientists tracking wheat pollen flow. <http://jgg.unl.edu/articles/0801m.smith.reviewed.htm>
- ²¹⁸ Mallory-Smith, C.A., Snyder, J., Hansen, J.L., Wang, Z. & Zemetra, R.S. (1999) Potential for gene flow between wheat (*Triticum aestivum*) and jointed goatgrass (*Aegilops cylindrica*) in the field. BCPC Symposium Proceedings No 72: Gene Flow and Agriculture: Relevance for Transgenic Crops. British Crop Protection Council: Farnham, Surrey.
- ²¹⁹ Guadagnuolo, R., Savova-Bianchi, D. & Felber, F. (2001) Gene flow from wheat (*Triticum aestivum* L.) to jointed goatgrass (*Aegilops cylindrica* Host.) as revealed by RAPD and microsatellite markers. *Theoretical and Applied Genetics* 102: 1-8.
- ²²⁰ Wheat and jointed goatgrass share one genome.
- ²²¹ CFIA Plant Biosafety Office. 1999. Regulatory Directive Dir1999-01: The Biology of *Triticum aestivum* L. (Wheat): A companion document to the Assessment Criteria for Determining Environmental Safety of Plants with Novel Traits. Available at: <http://www.inspection.gc.ca/english/plaveg/pbo/dir/dir9901e.shtml>
- ²²² Serecon Management Consulting Inc. and Koch Paul Associates, 2001. An Agronomic and Economic Assessment of Transgenic Canola. Prepared for the Canola Council of Canada. January 2001; also Benbrook, C. 2001. Troubled Times Amid Commercial Success for Roundup Ready™ Soybeans: Glyphosate Efficacy is Slipping and Unstable Transgene Expression Erodes Plant Defenses and Yields. Northwest Science and Environmental Policy Center, Sandpoint Idaho. 3 May 2001.
- ²²³ Watkinson, A.R. et al. 2000. Predictions of biodiversity response to genetically modified Herbicide Tolerant crops. *Science* 289(5484, 1 Sep 2000):1481-1482.
- ²²⁴ Firbank, L.G. and Forcella, F. 2000. Genetically modified crops and farmland biodiversity. *Science* 289 (5484, 1 Sept. 2000):1481-1482.
- ²²⁵ Piccolo, A. et al. 1994. Adsorption and desorption of glyphosate in some European soils. *J. Environ. Sci. Health B29(6):1105-1115.*
- ²²⁶ From information produced by the Pesticide Action Network (1996) cited in Mayer, S. 2002. Genetically Engineered Wheat — Changing our Daily Bread. Greenpeace International, Amsterdam.
- ²²⁷ World Health Organization, United Nations Environment Program, International Labor Organization. 1994. Glyphosate. Environmental Health Criteria 159. Geneva, Switzerland.
- ²²⁸ Cox, C. 1995. Glyphosate, Part 2: human exposure and ecological effects, Herbicide Factsheet, *Journal of Pesticide Reform*, Winter 1995 15(4).
- ²²⁹ King, C.A. et al. 2001. Plant growth and nitrogenase activity of glyphosate-olerant soybean in response to foliar glyphosate applications. *Agronomy Journal* 93:179-186.
- ²³⁰ Kremer, R.J. et al. 2000. Herbicide impact on *Fusarium* spp. and soybean cyst nematode in glyphosate-tolerant soybean. Abstract presented at Agronomy Society of America meetings. http://www.asa-cssa-sssa.org/cgi-bin/abstract_database_search.cgi?objective=Kremer.
- ²³¹ Springett, J.A. and Gray, R.A.J. 1992. Effect of repeated low doses of biocides on the earthworm *Aporrectodea caliginosa* in laboratory culture. *Soil Biol. Biochem.* 24(12):1739-1744.
- ²³² Chakravarty, P. and Chatarpaul, L. 1990. Non-target effect of herbicides: I. Effect of glyphosate and hexazinone on soil microbial activity. Microbial population, and in-vitro growth of ectomycorrhizal fungi. *Pestic. Sci.* 28:233-241.

²³³ For an overview, see McGarity, T.O. and Hansen, P.I. 2001. *Breeding Distrust: an assessment and recommendations for improving the regulation of plant derived genetically modified foods*. A Report prepared for the Food Policy Institute of the Consumer Federation of America, Washington. 11 January 2001.

²³⁴ For a review of some of these problems in Canada, see Abergel, E. 2000. *Growing Uncertainty: the environmental risk assessment of genetically engineered herbicide tolerant canola in Canada*. Ph.D. Dissertation. York University, Toronto; and *An Expert Panel Report on the Future of Food Biotechnology Prepared by the Royal Society of Canada at the request of Health Canada, Canadian Food Inspection Agency and Environment Canada*. 2001:131. *Elements of Precaution: Recommendations for the Regulation of Food Biotechnology in Canada*. January 2001. (www.rsc.ca/food-biotechnology/indexEN.html). For the U.S., see McGarity, T.O. and Hansen, P.I. 2001. *Breeding Distrust: an assessment and recommendations for improving the regulation of plant derived genetically modified foods*. A Report prepared for the Food Policy Institute of the Consumer Federation of America, Washington. 11 January 2001.

²³⁵ For Canada, this information is up-to-date as of October 3, 2002 (Dr. Stephen Yarrow, National Manager, Plant Biosafety Office, CFIA, Personal Communications to Holly Penfound, Greenpeace Canada, 4 Sept. and 3 October 2002.)

²³⁶ CFIA Plant Biosafety Office. 1999. *Regulatory Directive Dir1999-01: The Biology of Triticum aestivum L. (Wheat): A companion document to the Assessment Criteria for Determining Environmental Safety of Plants with Novel Traits*. Available at: <http://www.inspection.gc.ca/english/plaveg/pbo/dir/dir9901e.shtml>

²³⁷ The policy concept of substantial equivalence embodies the idea that existing organisms used as foods, or as a source of food, can be used as the basis for comparison with their GE version when assessing the human or environmental safety of that GE crop or food. The concept of substantial equivalence has been criticized by many

experts, including the Royal Society of Canada in their report *Elements of Precaution: Recommendations for the Regulation of Food Biotechnology in Canada*, January 2001: pp. 177-193. www.rsc.ca/foodbiotechnology/indexEN.html

²³⁸ Barrett, K. 1999. *Canadian Agricultural Biotechnology: risk assessment and the precautionary principle*. Ph.D. Dissertation, Department of Botany, University of British Columbia; Abergel, E. 2000. *Growing Uncertainty: the environmental risk assessment of genetically engineered herbicide tolerant canola in Canada*. Ph.D. Dissertation. York University, Toronto.

²³⁹ Note that some information on every approved GE crop has now been obtained through ATI requests and is currently being analyzed to assess whether the patterns found in the Roundup Ready™ canola application run through all applications.

²⁴⁰ Barrett, K. 1999. *Canadian Agricultural Biotechnology: risk assessment and the precautionary principle*. Ph.D. Dissertation, Department of Botany, University of British Columbia.

²⁴¹ Outliers are data points that appear to be inconsistent with most of the other data.

²⁴² Note that triple resistance has now been found in volunteer canola (weeds) in Alberta. The volunteer canola was resistant to all the main herbicides found in herbicide tolerant varieties: Roundup, Liberty and Pursuit. See MacArthur, M. 2000. *Triple-resistant canola weeds found in Alta*. *The Western Producer*, 10 February 2000.

²⁴³ Hilbeck, A. et al. 2000. *Review of Non-target Organisms and Bt Plants*. Report to Greenpeace International, Amsterdam. EcoStrat GmbH (Available at www.greenpeaceusa.org); National Research Council. 2000. *Genetically Modified Pest-Protected Plants: science and regulation*. National Academy Press, Washington, DC; Benbrook, C. 2000. Comments submitted to Docket Number OPP-30487a: registration application for Cry3Bb transgenic corn modified to control the corn rootworm. Submitted to the Environmental Protection Agency, 20

March 2000; Purrington, C.B. and Bergelson, J. 1995. Assessing weediness of transgenic crops: industry plays plant ecologist. *Trends in Ecology and Evolution* 10(8):340-342; Wrubel, R.P. et al. 1992. Field testing transgenic plants. *BioScience* 42:280-289.

²⁴⁴ Wolfenbarger, L.L. and P.R. Phifer, 2000. The ecological risks and benefits of genetically engineered crops. *Science* 290:2088-2093 (15 Dec. 2000).

²⁴⁵ McGarity, T.O. and Hansen, P.I. 2001:112. *Breeding Distrust: an assessment and recommendations for improving the regulation of plants derived genetically modified foods*. A Report prepared for the Food Policy Institute of the Consumer Federation of America, Washington. 11 January 2001.

²⁴⁶ The U.S. is providing a minuscule 1 percent of its biotechnology research budget to ecological impacts. The \$1.5 million provides support for about 10 projects. No Canadian estimates are publicly available, although it is known that the CFIA has funded some studies of Bt corn impacts on monarch butterflies. It is highly unlikely that Canadian funding exceeds that of the U.S. as a percentage of total research efforts.

²⁴⁷ An Expert Panel Report on the Future of Food Biotechnology Prepared by the Royal Society of Canada at the request of Health Canada, Canadian Food Inspection Agency and Environment Canada. 2001:131. *Elements of Precaution: Recommendations for the Regulation of Food Biotechnology in Canada*. January 2001. www.rsc.ca/food-biotechnology/indexEN.html

²⁴⁸ McGarity, T.O. and Hansen, P.I. 2001. *Breeding Distrust: an assessment and recommendations for improving the regulation of plant derived genetically modified foods*. A Report prepared for the Food Policy Institute of the Consumer Federation of America, Washington. 11 January 2001.

²⁴⁹ For an overview of the health issues related to genetically engineered food, see the Greenpeace fact sheet entitled "GE food: Safe to eat?" (May 2002) available at

www.greenpeace.ca (click on the genetic engineering campaign). As well, many of the reports referenced in footnote 218 address health risks associated with GE and the food biotechnology regulatory system.

²⁵⁰ In fact, in the U.S., since such submissions are voluntary and it is up to the manufacturer to determine whether a pre-market submission is actually required, very few submissions have been made. Calgene's Flavr Savr tomato application was the only one submitted to substantial public consultation, so there is a fair bit of information available on it.

²⁵¹ FDA policy proposal, <http://www.cfsan.fda.gov/~lrd/fr010118.html>

²⁵² Clark, E.A. 2000. Food Safety of GM Crops in Canada: toxicity and allergenicity. Genetic Engineering Alert Canada. Available at: www.canadians.org

²⁵³ Hansen, M. 2000. Comments on the human health and product characterization sections of EPA's Bt Plant-Pesticides Biopesticides Registration Action Document. Consumer Policy Institute/Consumers Union. Presented to the EPA Science Advisory Panel Arlington, VA. 20 October 2000.

²⁵⁴ Friends of the Earth. 2000. Scientists Slam GM Research Key Industry Study Unfit for Publication. FOE Press Release. 3 November 2000.

²⁵⁵ Strong, G. 2000. GM-food tests 'inadequate'. *The Age*, 29 Oct. 2000.

²⁵⁶ Fred A. Hines, "FLAVR SAVR Tomato (Pathology Review PR-152; FDA Number FMF-000526): Pathology Branch's Evaluation of Rats with Stomach Lesions from Three Four-Week Oral (Gavage) Toxicity Studies (IRDC Study Nos. 677-002, 677-004, and 677-005) and an Expert Panel's Report." Memo to Linda Kahl, Biotechnology Policy Branch, 16 June 1993. Available at: <http://www.bio-integrity.org/FDAdocs/17/fhlkp.pdf>.

²⁵⁷ For a review of this with soybean data, see Benbrook, C. 2001. Troubled Times Amid Commercial Success for Roundup Ready™ Soybeans: glyphosate efficacy is slipping and unstable transgene expression erodes plant defenses and yields. Northwest Science and Environmental Policy Center, Sandpoint Idaho. 3 May 2001.

²⁵⁸ Spears, T. with files from the Canadian Press. 2001. Federal memo warns against GM wheat: Canada still working with Monsanto to create country's first modified seed. *The Ottawa Citizen*, 1 August 2001. <http://www.ottawacitizen.com/>

²⁵⁹ Gillam, C. 2001. U.S. wheat leaders head to Canada, Japan on GM Wheat, *Reuters*, 1 February 2001.

²⁶⁰ For further information about legal action that has been launched against Monsanto and Aventis by organic farmers in Saskatchewan, Canada, see www.saskorganic.com/ The lawsuit seeks to collect damages for the loss of the organic canola market and to obtain an injunction against the introduction of GE wheat.

²⁶¹ www.rsc.ca/foodbiotechnology/indexEN.html

²⁶² A triple conflict of interest arises with the decision of Agriculture and Agri-Food Canada to enter into a partnership with Monsanto by providing publicly-owned wheat germplasm to develop the company's RR wheat (see footnote 32). Thus, the Canadian government has assumed the additional third role of "developer" of a GE crop to its already conflicted roles as a promoter and regulator of genetically engineered organisms.

²⁶³ CFIA web site, field trials. www.inspection.gc.ca/english/plaveg/pbo/triesse.shtml

²⁶⁴ From the data provided it is unclear how many of these trials are for the same applications, by the same applicants, or are continuations from year to year of essentially the same inquiry. Consequently, we cannot at this point say anything about how many products are likely coming down the pipeline.

²⁶⁵ From news reports and data provided by Dr. Stephen Yarrow, CFIA.

²⁶⁶ Pratt, S. 2002. Farmers reveal GE wheat test sites. *The Western Producer*, 16 May 2002.

²⁶⁷ Based on a review of the ISB field trials database (www.isb.vt.edu/cfdocs/fieldtests1.cfm), with updating by Norm Kaethler of the Pesticide Action Network-North America (PANNA).

²⁶⁸ Monsanto has one application involving an HT/ FR stack. Permits were issued in 94 and 96, on four applications, the other 90 are all notifications.

²⁶⁹ Connor, S. 2001. Monsanto to launch the first GM loaf. *The Independent* (London), 15 January 2001.

²⁷⁰ Martinez Starke, A. 2000. Biotech wheat goes under the microscope in pacific northwest. *Knight-Ridder Tribune*, 11 December 2000.

²⁷¹ Note that the data sets do not provide information on all the partners that might be involved in the field trials.

²⁷² GeneWatch UK (2001) Genetic Engineering: a review of developments in 2000 Briefing No 13 cited in Mayer, S. 2002. Genetically Engineered Wheat — Changing our Daily Bread. Greenpeace International, Amsterdam.

²⁷³ Inventory of Canadian Agricultural Research (ICAR). All research carried out at universities or within federal and provincial government systems, or receiving public funding report to this inventory (<http://res2.agr.ca/icar/english/searche.htm/>). A search of all wheat records was carried out in the spring of 2001, revealing 9 on or related to GE wheat.

²⁷⁴ There are some media reports that federal research on GE durum wheat has been abandoned (GMO folks have a little surprise from Alberta. *The Toronto Star Editorial*, Thomas Walkom 2 May 2000.)

²⁷⁵ Molecular markers are used in some disease-resistance, yield and other agronomic characteristics, and milling quality plant breeding programs in Canada and the U.S.. Genetic technology is used to help identify the suitable traits, and then this information is used to speed up traditional plant breeding. Marker-assisted plant breeding is seen by many to be the way of the future, because it appears to limit the controversies surrounding transgenic modifications. There remains debate, however, about how extensively the technique can be used (Gene Research Finds New Use in Agricultural Breeding. 7 March 2001. *The New York Times*, Andrew Pollack. <http://www.nytimes.com/2001/03/07/business/07BREE.html>). Another non-transgenic approach is to making functional changes to the native DNA that do not require insertion of genetic material from other sources. These techniques are not further considered here since the focus of the report is rDNA technology and transgenic wheat.

²⁷⁶ A search was done in the spring of 2001 of the Current Research Information Service (CRIS) at <http://cris.csrees.usda.gov/> which contains records of current or recently completed research projects in agriculture, food and nutrition, and forestry. Projects are conducted or sponsored by USDA research agencies, state agricultural experiment stations, the state land-grant university system, other co-operating state institutions, and participants in a number of USDA research grant programs. A search was carried out using the key words: transgenic; genetically modified; genetically engineered; and wheat. Of the records retrieved (239), 95 were found to be relevant (most of these were not about GE wheat or were replicates of other records, or were GE wheat projects terminated in 1997 or earlier). These 95 records can not be assumed to represent 95 distinct research projects, since some may be continuations, revisions or relatives of other projects.

²⁷⁷ Pioneer, Dekalb, Mycogen, Prodigene are companies identified in commercialization of chitinase expressing wheats.

²⁷⁸ Note that some researchers believe that WSMV would make a good vector for introducing gene sequences to wheat. (Wheat streak mosaic virus as a gene expression

vector. *ISB News Report*, March 2001.)

²⁷⁹ Source: CFIA Plant Biosafety Office. 1999. Regulatory Directive Dir1999-01: The Biology of *Triticum aestivum* L. (Wheat): A companion document to the Assessment Criteria for Determining Environmental Safety of Plant with Novel Traits. Available at: <http://www.inspection.gc.ca/english/plaveg/pbo/dir/dir9901e.shtml>



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