HARVEST AT RISK

IMPACTS OF ROUNDUP READY WHEAT IN THE NORTHERN GREAT PLAINS

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Executive Summary

By the end of 2002, a significant number of foreign buyers of hard red spring wheat grown in the Northern Great Plains had told the grain trade and farm organizations that the planting of Roundup Ready (RR) wheat would lead them to look elsewhere for grain that was not genetically engineered. In March 2004, a delegation from Japan delivered to wheat industry leaders in North Dakota a petition signed by 414 organizations urging the rejection of RR wheat (Reuters News Service 2004). Japan would turn to Canada and Australia for non-GE wheat if RR varieties were planted in the U.S., according to the delegation.

Fear of market rejection and lower prices mobilized many in the wheat industry first to raise questions, and then to openly oppose commercial release of Roundup Ready (RR) hard red spring wheat. The questions slowed the pace of regulatory reviews and delayed final approval. This gave scientists, farmers, and environmentalists more time to develop, compile and analyze information on the potential problems and consequences of commercial release of RR wheat. New information led to more questions and deeper concerns, and as a result, more and more individuals, and wheat industry organizations spoke out against the technology.

On May 10, 2004, the technology developer, Monsanto Company, suspended further efforts to gain government approval and market RR spring wheat. Carl Casale, a Monsanto executive vice president, stated that–

> "*As a result of our [R+D] portfolio review and dialogue with wheat industry leaders, we recognize the business opportunities with Roundup Ready spring wheat are less attractive relative to Monsanto's other commercial priorities.*"
>
> (Monsanto Company 2004)

Some wheat industry leaders and organizations appear ready to make another push for approval of genetically engineered wheat. Sherman Reese, Vice President of the National Association of Wheat Growers, said at an industry meeting in February 2005 that –

> "*The hope and promise of biotechnology is so compelling…the faster we can do it, the better off we'll be.*"
>
> (Gillam 2005)

An estimate by Iowa State University economist Dr. Robert Wisner that approval of RR wheat would trigger a loss of up to one-half of today's export sales and a 33% decline in average market prices clearly played a role in solidifying opposition in the wheat industry to approval of the technology under the current circumstances. It remains unlikely that the technology will be adopted until these projected impacts are substantially reduced.

If these circumstances change, however, and the industry reverses its united opposition to Roundup Ready wheat, Monsanto will almost certainly move quickly to push the technology through the remainder of the government approval process. As farmers across the Northern Great Plains plant the first crop of RR spring wheat, a high-stakes experiment will unfold. Will farmers who grow RR wheat be rewarded with lower operating costs, or higher yields? What are the potential costs of adoption? On balance, would farmers who adopt the technology benefit? What would be the impact on farmers who choose not to adopt the technology?

This report strives to describe the probable consequences of RR wheat adoption and to project economic impacts on growers and across the industry.

Potential Need

The popularity of Roundup Ready soybean, corn, and cotton varieties stems from three factors – simplicity, robustness, and effectiveness. RR weed management systems require little management attention and only basic proficiency in the operation of spray equipment.

It is a robust and forgiving system, in that over- or under-application of glyphosate (Roundup) herbicide will not spell disaster, nor will an equipment breakdown or bad weather that delays spray operations. It will work in conjunction with any tillage and planting system, and requires only the most basic spray equipment.

Because the herbicide mixing, loading, and application processes are simpler, it takes less time to cover a given field and all the fields managed by a farmer. As a result, RR technology helps producers cover more ground and expand farm size, while still achieving good weed control.

Roundup Ready wheat, if commercialized, would deliver the same sort of benefits to spring wheat growers, at roughly the same percentage increase in seed costs. To get a complete picture of the costs and benefits of RR wheat, it is important to look at whether RR wheat might solve other problems faced by wheat farmers, or perhaps set the stage for some new ones to emerge or existing problems to worsen.

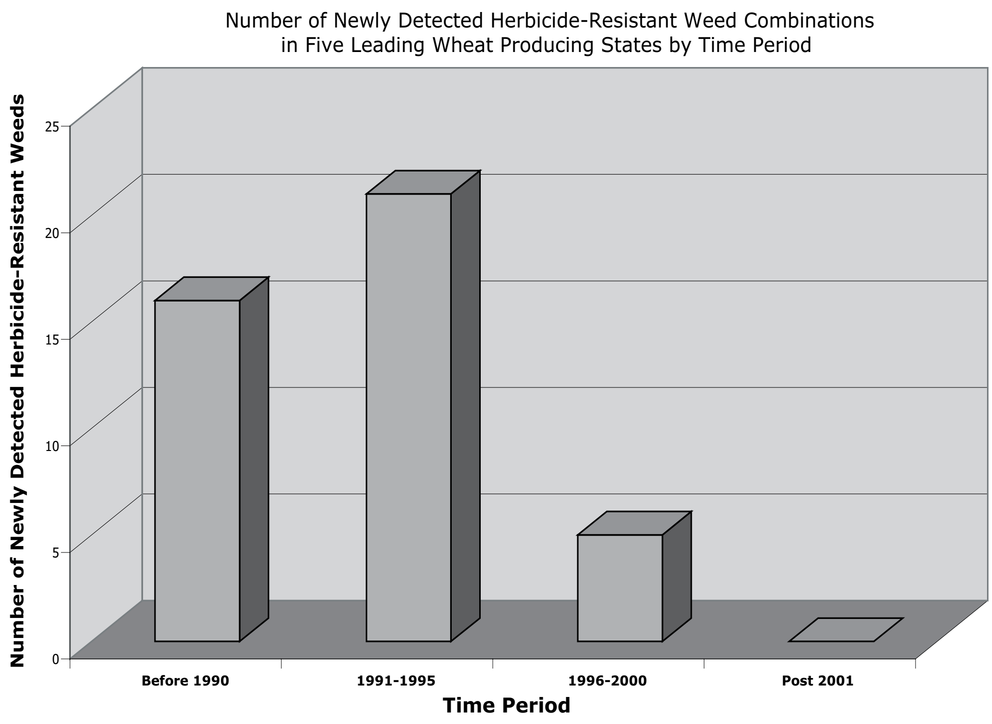
There is no evidence that wheat herbicide efficacy is slipping in the Northern Great Plains. A detailed examination of the herbicides applied over the last decade supports the conclusion that growers have largely stuck with products that both work and are priced competitively. Over most of the last 10 years, between 83% and 93% of wheat acres have been treated with the top two products – MCPA and 2,4-D.

In addition, herbicide alternatives abound. In 1992 and 1995, USDA reported the use of 13 herbicides on one percent or more of national hard red spring wheat acreage. By 2000, the number had risen to 18. Ten more herbicides were registered for use on wheat but were not used widely enough for USDA to include them in its survey results. Since 2000, several new products have entered the market. In addition, the 30-plus herbicide active ingredients now on the market are formulated into well over a dozen premixes containing two to four active ingredients.

The emergence of weed biotypes resistant to wheat herbicides emerged as a significant problem in the late 1980s and grew worse for about 10 years. Thirty-seven resistant weeds were documented by scientists from 1985 through 1994. The spread of resistance markedly slowed in the second half of the 1990s, a period during which only five new resistant biotypes were documented. Not a single additional resistant weed has emerged since, as evident in Figure 1.

The absence of any new cases of resistant weeds in the last five years is evidence that spring wheat growers are now doing a good job managing weed

Figure 1.



resistance. They have diversified their selection and use of herbicides. Equally important, herbicides bear only a portion of the weed management burden in spring wheat production. Crop rotations and tillage are integral weed management practices on the majority of the farms growing spring wheat.

The costs of weed control are not rising. Indeed, USDA data show that average herbicide costs have fallen modestly over the last several years, largely as a result of lower prices for many widely used products that have gone off patent. In addition, the low cost of many older but still effective herbicides caps the prices that herbicide manufacturers can charge for new chemistry.

Roundup Ready Crops and No-Till

Roundup Ready technology is highly compatible with no-till planting systems. Only about 9% of hard red spring wheat acres were planted using no-till in 1998 in the Northern Great Plains region (Ali 2002). Such systems are used with success throughout the region, and in years with limited moisture, no-till yields are often higher than in nearby fields that were tilled and planted with conventional equipment. Still, many farmers are hesitant to adopt no-till because it slows down the warming of the soil in the spring, can lead to uneven germination, and sacrifices yield in years with ample or more than ample rainfall. No-till fields are also more susceptible to certain pest problems.

Roundup Ready wheat technology will not significantly enhance the ease, efficacy, or profitability of no-till systems in the Northern Great Plains. One new disadvantage will also emerge. Once RR wheat is widely planted, volunteer RR wheat will be harder to control along roads, rights of way, and in public places, where glyphosate is often the herbicide of choice. Farmers planting Roundup Ready soybeans, corn, or canola will also have problems when RR wheat volunteers germinate. For these reasons, it is unlikely that the commercial release of RR wheat will greatly change the number of farmers utilizing no-till planting systems.

Monsanto and other promoters of RR wheat have claimed that a switch to RR technology and wider use of glyphosate will reduce the public health and environmental impacts of herbicide use in wheat production areas. This claim rests on the often-repeated assertion that glyphosate is relatively non-toxic compared to other herbicides, and quickly breaks down to benign chemicals. Recent research, however, has raised troubling questions about the safety of glyphosate and formulated Roundup herbicides. A study published in the June 2005 issue of *Environmental Health Perspectives*, a publication of the National Institute of Environmental Health Sciences, found that glyphosate is toxic to human placental cells at concentrations below those found with agricultural use (Richard et al., 2005). According to the French scientists who carried out the work –

> *"…glyphosate acts as a disruptor of mammalian cytochrome P450 aromatase activity from concentrations 100 times lower than recommended use in agriculture."*
> (Richard et al., 2005)

Moreover, formulated Roundup herbicides were nearly twice as toxic as glyphosate alone in one assay used by the French team. The authors speculate that formulated Roundup products are more toxic because the adjuvant and stabilizers in Roundup formulated herbicides alter the cellular uptake of glyphosate, enhance potency, or promote bioaccumulation.

Fortunately, herbicide use in spring wheat production virtually never results in residues in harvested wheat because most herbicides are applied early in the season, long before kernels of grain have started to form. If and as RR wheat is adopted, more mid-season glyphosate applications will be made, in some cases, after wheat kernels have formed. As a result, Roundup residues might start appearing in harvested wheat. Still, because of the environmental properties and low mammalian toxicity of glyphosate, it is premature to conclude that residues in wheat will emerge as a serious concern.

Because of the climate in the Northern Great Plains, herbicide runoff is not a common cause of serious damage in aquatic ecosystems. Acute risks to applicators and other non-target organisms are also modest, based on contemporary herbicide use patterns.

Given that ample herbicide alternatives are available, weed management costs are stable or falling, and resistance is in check, there is no compelling need driving the commercial adoption of RR wheat in the Northern Great Plains region, beyond Monsanto's understandable desire to recover its development costs.

Potential Impacts

Nine areas of mostly negative consequences would likely to follow the planting of Roundup Ready spring. These include –

- ❑ Emergence of Resistance
- ❑ Gene Flow
- ❑ Disease Pressure and Related Problems
- ❑ Impacts on Seed Plus Herbicide Expenditures
- ❑ Market Rejection
- ❑ Dockage
- ❑ Yields
- ❑ Grain Quality
- ❑ Wheat Prices

Possible economic impacts following the widespread adoption of Roundup Ready hard red spring wheat are estimated for two scenarios. "Widespread" adoption means that 30% of hard red spring wheat acreage is planted in a given year to RR wheat. The impacts of RR wheat adoption under each scenario are estimated relative to a hard red spring wheat baseline that does not include the planting of genetically engineered wheat. The baseline scenario is based on the projections of prices, yields, and acreage contained in USDA's recent Wheat Outlook report (Vocke et al., 2004). Data on production costs is derived from statistics compiled and analyzed by the USDA's Economic Research Service (ERS) (Ali 2002).

The "Optimistic" scenario reflects a series of assumptions that are generally positive in terms of the performance of RR wheat technology and problems triggered by its adoption. It is unlikely that the economic impacts of adoption of RR will be more favorable than projected under this scenario, at least not until RR wheat is fully embraced in export markets.

The second, "Pessimistic" scenario combines a series of assumptions and consequences that collectively reflect "worst case" but still plausible outcomes from the perspective of wheat farmers and the industry. It is not likely that adoption of the technology will impose costs on the industry higher than those estimated in this scenario.

Under the "Optimistic" scenario following widespread adoption of RR spring wheat –

- ❑ The 70% of farmers not planting RR spring wheat would lose $5.60 per acre in income as a result of a decline in average market prices not likely to be less than 4%.
- ❑ On the 30% of acres planted to RR varieties, gross income would fall $3.95 per acre. But after taking into account the higher cost of RR seed and herbicides, net cash returns would drop $11.03 per acre.
- ❑ Industry-wide on average, hard red spring wheat net farm income (after subtracting seed and herbicide costs, but no other costs) is projected to be $110.21 per acre, or $7.23 less than in the no-RR wheat baseline.

Markedly more severe economic impacts would occur if the "Pessimistic" scenario proves closer to actual outcomes –

- ❑ The 70% of farmers not planting RR wheat would lose $14.00 per acre from the projected 10% drop in market prices.
- ❑ Income over operating costs on farms planting RR wheat seed would decline to $80.13 per acre, taking into account the higher prices paid for seed and herbicides and the drop in market prices. They would earn $37 less per acre than farmers under the no-RR wheat baseline.
- ❑ Net farm income averaged across the whole industry drops to $96.50 per acre, $20.94 below the no-RR wheat baseline, or an 18% decline.

Across the whole industry, the "Optimistic" scenario would translate into a loss of $94,000,000 annually based on USDA's recent estimate of 13 million acres planted to hard red spring wheat varieties in 2004 (Vocke et al., 2004). The annual loss would grow to $272,000,000 if the "Pessimistic" scenario proves to accurately reflect actual impacts.

Both scenarios are based on the assumption that foreign buyers will not reject U.S. durum wheat if RR hard red spring wheat is commercialized, and that there will be no negative price impacts on durum wheat shipments from the Pacific Northwest.

The two scenarios combine many assumptions about inherently uncertain events, but each represents a plausible combination of outcomes. The actual economic impact of adoption of RR hard red spring wheat will likely fall somewhere between the "Optimistic" and "Pessimistic" scenarios.

This prediction will give little comfort to wheat farmers in the Northern Great Plains, or to the region's milling industry and grain exporters. The findings in this report support the conclusion that Roundup Ready hard red spring wheat is a technology that is not necessary and likely to cause more problems than it solves. For this reason, farmers, university specialists, and the industry should cooperate in carrying out a fresh, more in-depth and independent appraisal of the consequences following adoption of Roundup Ready wheat. This reassessment should ideally be completed before further steps are taken toward the approval and commercial release of this technology.

There is another reason for caution. A bad experience with Roundup Ready wheat will surely delay and could jeopardize grower and market acceptance of ongoing and future applications of biotechnology in the development of new wheat varieties, including applications that raise few if any food safety concerns. For example, both university and private sector wheat breeders are working hard to develop spring wheat varieties that are resistant to *Fusarium* head blight, the number one disease across the wheat industry and by far the major cause of mycotoxin contamination in wheat.

Tools with their roots in biotechnology are accelerating progress toward blight-resistant wheat and include genomics and marker-assisted breeding. Blanket rejection of any breeding tool with roots in biotechnology might raise the hurdles faced by new *Fusarium* resistant varieties developed using conventional breeding techniques, augmented with biotech-based gene mapping and gene-marker tools.

Setting the Stage for Roundup Ready Wheat

In response to the unexpected success of Roundup Ready soybeans in 1997-1998, Monsanto Corporation accelerated the research and breeding work necessary to introduce Roundup Ready (RR) herbicide-tolerant technology in additional crop markets. RR cotton, canola, and corn varieties reached the U.S. market a few years after soybeans. Since the late 1990s, no new crop engineered to tolerate glyphosate herbicide has been approved and commercialized, although several seem close to reaching the market.

RR wheat and alfalfa are the two major crops that have been most aggressively pursued by Monsanto. In the absence of considerable industry and consumer resistance to RR wheat, this technology would likely already be on the market. But by the time the technology reached the final stages of regulatory review in 2003, potentially significant problems had surfaced. New questions stimulated new research. In both the U.S. and Canada, government scientists and risk assessment experts, independent scientists, farmers, the grain trade, GE activists, and the media are now involved in the review of this technology and the debate over its future.

Concerns first arose in response to the documentation of canola phenotypes in Canada that had attained resistance to multiple herbicides. Through the normal flow of genes in and across farm fields, some canola had gained resistance genes against herbicides in four different families of chemistry.

The first peer reviewed paper in a U.S. scientific journal documenting the flow of genes from wheat to its closely related weedy relative, jointed goatgrass, appeared in 1998 in *Weed Science* (Zemetra 1998). Both weed scientists and wheat breeders at the time recognized it was possible, and indeed perhaps likely, that the RR resistance gene would move from RR spring wheat varieties into jointed goatgrass. Once in jointed goatgrass, further movement into other types of wheat also loomed as a distinct possibility.

In September 2000 the StarLink Bt-corn episode began to unfold. StarLink was a variety of Bt-transgenic corn engineered to control the European corn borer. Because of concerns over allergenicity, StarLink corn was only approved for animal consumption; StarLink was not supposed to reach the human food supply. But it did. Over the next year, issues arising from the detection of StarLink DNA in human foods became a major national and international story. Extensive coverage of how and why the problem occurred in the first place, and the U.S. government response to it, eroded confidence in the depth and quality of U.S. regulatory reviews of genetically engineered crop varieties.

In part because of concerns triggered by StarLink, many overseas buyers of spring wheat produced in the Northern Great Plains let grain traders and the industry know that the introduction of transgenic wheat would lead them to take their business elsewhere.

Other problems began to attract the attention of farmers, the wheat industry, and environmental and consumer organizations. In the late 1990s, troubling science had documented the buildup of *Fusarium* species in the soil on farms producing RR soybeans in the Midwest (Kremer et al., 2002). Given the already devastating impact of *Fusarium* head blight on the Minnesota spring wheat industry (Holden 2005), the possibility that *Fusarium*-related diseases might grow more frequent and/or severe in the wake of RR wheat adoption was chilling and of considerable economic importance, given the impact of fungal infections on the potential for mycotoxin contamination in wheat.

These are among the reasons that has made the RR wheat approval process contentious and protracted, and ultimately led Monsanto to suspend efforts to win approval of RR wheat technology.

In this section, the reasons why Monsanto invested so heavily in the development of RR wheat are explained, along with the nuts and bolts of weed management in spring wheat. Reasons why some farmers remain eager to have access to RR wheat technology are also discussed.

Reasons Driving Monsanto Investments in RR Wheat

Developing RR wheat was a logical next step for Monsanto in its efforts to expand the market reach of its transgenic seeds and herbicide-tolerant technology. The reasons are simple and obvious -- a chance to expand Roundup herbicide sales, and increase income from RR wheat seed sales and technology fees.

RR wheat was seen by Monsanto as its ticket to gain a foothold in another important sector of agriculture in which the company had only a limited presence. Monsanto seeds and herbicides accounted for a tiny share of total use in wheat production. Gaining a bigger presence in the hard red spring wheat industry would, Monsanto hoped, open the door to other types of wheat, as well as barley, oats, and other small grains.

The strong appeal to Monsanto of gaining entry to the wheat market via RR technology stemmed from the fact that RR wheat would simultaneously expand the company's market share in wheat herbicides and wheat seed sales.

Overview of Spring Wheat Weed Management Practices

Hard red spring wheat (HRSW) is planted in late March through mid May in most of the Northern Great Plains. This region encompasses the four states accounting for the majority of national HRSW acres – Minnesota, Montana, North and South Dakota.

Seeding rates vary between 1.0 and 1.3 million seeds per acre (Holden 2005). South Dakota Cooperative Extension experts recommend a rate of 28 seeds per square foot, or 1.2 to 1.5 bushels per acre (Wrage 2005). Air-seeding systems are increasingly common and can accomplish tillage, planting and fertilization operations in a single pass.

Advances in equipment now allow many farmers to complete planting operations over a three-week period when soil moisture conditions are optimal, assuming the weather cooperates. Timely and early planting helps minimize yield losses. There is a general rule of thumb in the region – every day that planting is delayed after May 10, yields will typically drop by one bushel per acre per day of delay (Wrage 2005). While the planting date after which yields start to decline varies across the region, the daily loss of yield when planting is delayed is generally on the order of one bushel per acre.

Spring wheat is typically grown in a two or three year rotations, and in Minnesota, four year rotations are sometimes used to help reduce losses to *Fusarium* head blight (Holden 2005). Most growers plant wheat following soybeans, another small grain crop, or a fallow season. Wheat is not often planted into a field that produced corn the year before, because corn stubble can harbor the *Fusarium* fungus that causes head blight.

Rotations also play a key role in insect and weed suppression, and especially in helping to keep wild oats in check. Continuous wheat tends to fare poorly and hence almost all farmers adhere to some sort of crop rotation pattern.

The Appeal of RR Wheat to Farmers

The popularity of the Roundup Ready weed management system among nearly all soybean corn, and cotton farmers that have adopted it stems from three factors – simplicity, robustness, and effectiveness.

Especially in the first few years of use, farmers typically achieve good to excellent weed control with one or two applications of a single, easy-to-handle herbicide, glyphosate. There are no complicated tank mixes to manage, nor major worries about equipment calibration. The rate of Roundup application can range from 0.5 pounds per acre to 2.0 pounds or more, achieving both acceptable results and posing little or no risk of wheat crop injury (as long as RR wheat varieties are planted, of course).

The system is forgiving in other ways. If bad weather or an equipment breakdown delays the application of Roundup, it is typically still possible to make a later application that will bring weeds under control and avoid serious yield penalties. If a spray applicator double covers some areas in a field, there will be no serious consequences. If an untimely rain washes the applied glyphosate off weeds prior to translocation into plant tissues, another application can be made a few days later, often at Monsanto's expense.

But perhaps most important, the system requires little management attention and only rudimentary applicator skills. Spray equipment operators can proceed at a faster average rate than previously feasible. As a result, RR technology removes or loosens weed management as an often-binding constraint on the number of acres an operator or farm manager can realistically cover in a day, and hence manage in a given year.

Claims that the RR system reduces weed management costs contradict nearly every independent study of the economics of RR technology. Several government and university studies have concluded that farmers spend more money for seed and less money on herbicides in the RR system, resulting at the end of the day in only a modest change in total costs (for multiple studies, see the "Farmer Costs and Returns" section of Ag BioTech InfoNet at *www.biotech-info.net/costs.html#cost_returns*).

Farmers who have struggled with weed management, and have routinely sprayed more with less satisfying results than nearby neighbors, often do benefit economically from adoption of the RR system. Other farmers who have found effective ways to keep weed management costs down, while still achieving good control, will probably sacrifice some net return per acre for the simplicity they gain from adoption of RR technology. Some farmers find this to be an acceptable tradeoff, while others do not.

But across the agricultural sector, RR technology in soybeans, corn and cotton has been an economic wash for U.S. farmers. Growers abroad have benefited more substantially from RR technology largely because they have gained access to it with no, or only a modest technology premium, coupled with generally lower prices for glyphosate herbicides.

Impacts of Roundup Ready Spring Wheat on Weed Management System Performance and Costs

Economics and efficacy drive technology adoption on the farm. In soybeans, the rapid rate of adoption of Roundup Ready technology was caused by the problems farmers were having with low-dose soybean herbicide-based systems that were finicky and unforgiving, and often expensive. Carryover and crop injury problems periodically added insult to injury.

In corn, the adoption of RR technology has progressed much more slowly than in soybeans. This is because farmers have an easier time controlling weeds in corn than soybeans, and because the existing herbicide options in corn are more robust, reliable, and cheaper than was the case with soybeans when RR technology was first introduced.

Every new technology requires investments in research and development and in testing. The adoption of new technology requires farmers to gain new knowledge, and sometimes to change the equipment they use. For such investments to pay dividends, and for the technology to be a market success, it must either accomplish the same task as other technology more cheaply, or it must work better than other available technology.

Over the last five years proponents of RR wheat technology have advanced several arguments in support of their claim that the U.S. wheat industry needed, and would substantially benefit from, the introduction of RR technology. Here those arguments are assessed in light of university and government data and generally accepted facts about weed management in spring wheat production.

Herbicide Efficacy

Slipping efficacy in contemporary spring wheat weed management systems would surely heighten grower interest in new technology like Roundup Ready wheat. Table 1 provides an overview from 1992 through 2002 of spring wheat herbicide use in the four states that account for the majority of national acres. (South Dakota data for 2002 is missing because USDA did not survey spring wheat herbicide use in that state that year). Appendix Table 1 provides more detailed information on herbicide use state-by-state for 1992, 1995, 2000 and 2002. Both tables are based on official USDA National Agricultural Statistics Service (NASS) pesticide use surveys covering spring wheat production systems.

Nationally (see bottom of Table 1), there has been little change in the average pounds of herbicides applied per acre, as is clear in Figure 2. In 1992, growers applied on average 0.51 pounds of herbicides, and in 2002, the average acre was treated with 0.56 pounds. The modest 9.8% increase over the last decade is evidence of relative stability in herbicide use and reliance. Note in most states and nationwide in 2000, there was marked increase in herbicide use. Unusually wet and untimely rains triggered this spike in 2000 herbicide use in many spring wheat production areas.

A detailed examination of the products used during this time period also supports the conclusion that growers have largely stuck with herbicides that both work and are priced competitively. Table 2 reports the percent of acres treated and pounds applied of the seven leading herbicides in 1992, 1995, and 2002. The top two products – MCPA and 2,4-D – were applied on 83% to 93% of the hard red spring wheat acres in each of these three years.

Wheat farmers have increased the average number of herbicides applied per acre from 2.01 in 1992 to 2.7 in 2002, as shown in Table 1. Grain and row-crop farmers across the country have also gradually diversified their herbicide programs in step with the commercial introduction of more post-emergence herbicides targeted toward specific weed management needs – like early-season grass control or season-long broadleaf management. The gradual upward trend in the number of herbicide active ingredients applied is displayed graphically in Figure 3.

The increase in the number of products applied on spring wheat acreage has been accompanied by steady declines in average rates of application. The two market leaders – MCPA and 2,4-D – are each applied at about 0.3 pounds per acre. In 1992, five of the top 12 herbicides applied were applied at rates less than 0.1 pound per acre and three were applied at the very low rate of 0.01 pound, or less (see Appendix Table 1). By 2002, eight of the 12 most widely used herbicides

Table 1.

Overview of Herbicide Use in Spring Wheat Production
in Leading Production States and National Totals: 1992 to 2002

Montana	**1992**	**1995**	**2000**	**2002**	**Percent Change 1992 to 2002**
Acres Treated with Herbicide	2,385,000	3,555,000	3,015,000	3,375,000	41.5%
Average Number of Herbicides Applied per Acre Treated	1.39	2.04	3.39	2.65	90.6%
Average Pounds Applied per Acre Treated	0.33	0.54	0.95	0.55	66.7%
North Dakota					
Acres Treated with Herbicide	8,280,000	7,470,000	6,120,000	6,210,000	-25.0%
Average Number of Herbicides Applied per Acre Treated	1.84	2.23	2.87	2.48	34.8%
Average Pounds Applied per Acre Treated	0.39	0.49	0.6	0.53	35.9%
Minnesota					
Acres Treated with Herbicide	2,520,000	3,555,000	1,800,000	1,800,000	-28.6%
Average Number of Herbicides Applied per Acre Treated	2.02	3.32	2.23	1.88	-6.9%
Average Pounds Applied per Acre Treated	0.52	0.59	0.56	0.46	-11.5%
South Dakota					
Acres Treated with Herbicide	2,430,000	1,125,000	1,485,000		
Average Number of Herbicides Applied per Acre Treated	1.11	2.02	2		
Average Pounds Applied per Acre Treated	0.27	0.35	0.36		
National					
Acres Treated with Herbicide	15,660,000	14,220,000	12,420,000	11,430,000	-27.0%
Average Number of Herbicides Applied per Acre Treated	2.01	2.45	3.16	2.7	34.3%
Average Pounds Applied per Acre Treated	0.51	0.54	0.78	0.56	9.8%

Source: Data from Appendix Table 1, which is based on annual Agricultural Chemical Use surveys collected by the National Agricultural Statistics Service.

were applied at a rate less than 0.1 pounds per acre and four products were very-low-dose herbicides, each applied at 0.01 pound per acre or less.

This shift toward low-dose chemistry is why there has been little change in the total pounds of herbicides applied, despite the 34% increase in the average number of herbicides applied on each acre. This trend toward greater reliance on the low-dose imidazolinone and sulfonylurea herbicides in spring wheat production mirrors similar trends in corn, soybeans, and cotton.

This trend also explains why every acre planted to Roundup Ready wheat, if the technology is approved and marketed, will markedly increase herbicide use. While Monsanto never announced its final recommended Roundup application rates on RR wheat, the rates almost certainly will fall between 0.75 and 1.0 pounds per acre. As is now the case with soybeans, corn, and cotton, the average rate applied by wheat farmers will likely be marginally below the minimum rate recommended on glyphosate herbicide labels. Accordingly, glyphosate will likely be applied at about twice the rate of today's herbicide market leaders, and six-times or more the application rate of the low-dose products now in widespread use.

Based on the data reviewed on spring wheat herbicide use, there is little evidence of any significant problems in spring wheat weed management. Some growers have struggled with pigeon grass management in recent years, largely because of resistance to older herbicides. One of the relatively new sulfonylurea

Figure 2.

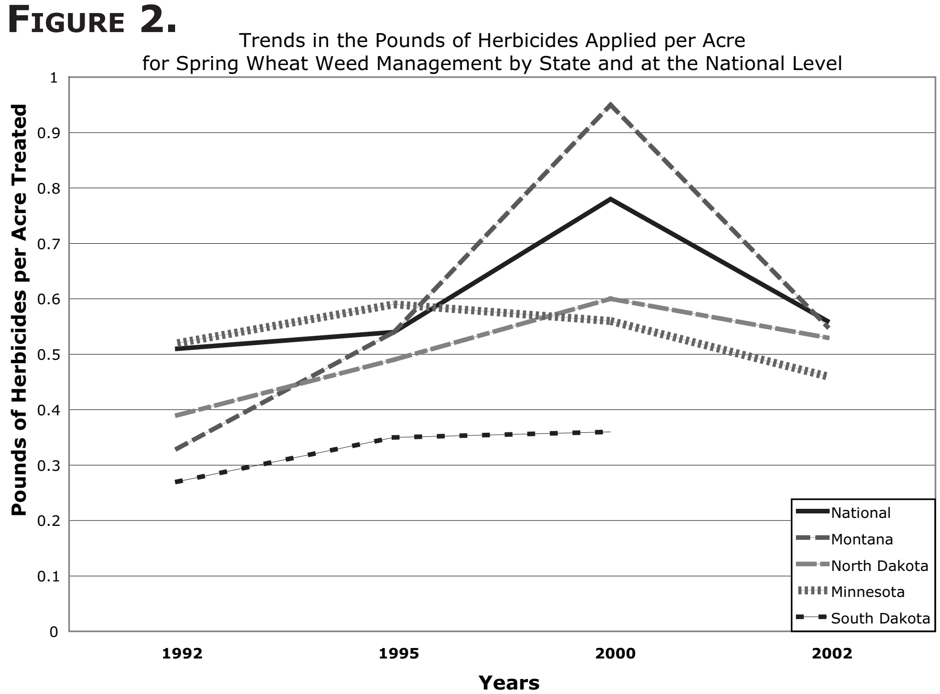


Table 2.

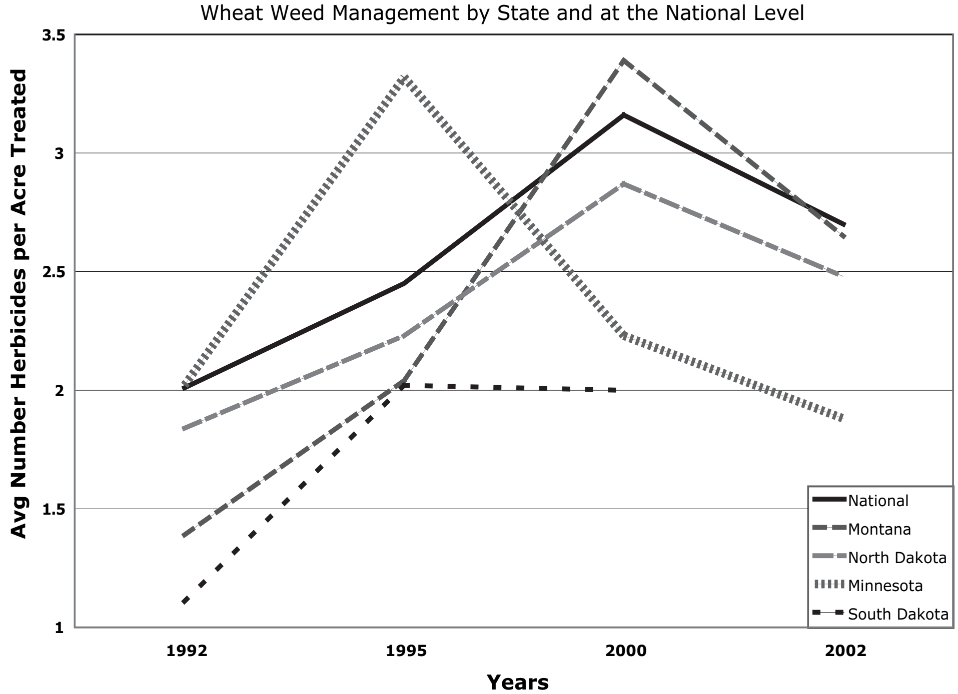
Percent of National Acres Treated and Pounds Applied
of the Five Leading Herbicides Applied to Spring Wheat, 1992-2002

	Common Trade Name	Percent Acres Treated 1992	1995	2002	Pounds Applied 1992	1995	2002
MCPA	MCPA	37%	39%	47%	2,198,000	2,288,000	1,808,000
2,4-D	2,4-D	52%	54%	36%	2,867,000	3,083,000	1,785,000
Fenoxaprop-P-ethyl	Puma	8%	15%	29%	85,000	203,000	239,000
Bromoxynil	Buctril	10%	9%	24%	399,000	372,000	716,000
Dicamba	Banvel	29%	30%	18%	372,000	309,000	120,000
Tribenuron-methyl	Express	13%	25%		17,000	25,000	
Thifensulf- uron-methyl	Harmony	7%	16%	12%	15,000	31,000	9,000
Glyphosate	Roundup			15%			1,235,000
Totals		**156%**	**188%**	**181%**	**5,953,000**	**6,311,000**	**5,912,000**

Source: Appendix Table 1. Herbicide use data is from National Agricultural Statistics Service, USDA, field crop pesticide use surveys.

herbicides (Express) apparently works well on pigeon grass and has largely solved the problem on affected farms.

Figure 3. Trends in the Average Number of Herbicides Applied for Spring Wheat Weed Management by State and at the National Level



Costs of Herbicide-Based Weed Management Systems

Another important indicator of weed management system stability is grower expenditures on herbicides. The USDA compiles and reports detailed wheat cost of production data for several regions and nationally. The "Northern Great Plains" region encompasses the four states producing most of the red spring wheat grown in the U.S. (Ali 2002). Moreover, spring wheat accounts for 81% of the wheat grown in this region (Ali 7005), so the expenditure data for this region largely reflects spring wheat production.

Expenditures on chemicals (mostly herbicides) were reported as $10.09 per acre in 2002 in the Northern Great Plains region, and $10.05 in 2003. USDA estimated costs four years earlier in 1998 at $10.61. Clearly, the lack of change in herbicide use or costs per acre is evidence of the stability and efficacy of weed management systems over the last decade or more.

Alternatives to Sustain Weed Management Efficacy

The number of herbicides registered and used in managing weeds in spring wheat has grown steadily over the last two decades. In 1992 and 1995, USDA reported the use of 13 herbicides nationally on one percent or more of national acreage. By 2000, the number had risen to 18, and by 2002 the USDA reported that 20 herbicides were applied. The USDA survey does not report use of another ten herbicide active ingredients that were marketed for weed management in spring wheat, according to the 2002 "Weed Control Manual" (Meister 2005).

The numbers of herbicide active ingredients accessible to growers in 2000 and 2002 does not include the growing number of premixes that include two, three, and even four active ingredients. Each premix is formulated to optimally meet a specific need in a given tillage and planting system. The "Weed Control Manual" for 2002 lists 12 premixes containing two active ingredients, three containing three actives, and one with four. The number of premixes on the market today far exceeds the number in 2002.

The ample number of active ingredients registered and sold for weed management in the Northern Great Plains has helped assure farmers access to effective herbicides, especially given the significant reliance in the region on cultural practices (especially rotations and tillage) to suppress weed populations. In addition, the number of products on the market has kept prices down and the market for herbicides competitive. Indeed, the modest decline in average herbicide expenditures over the last five years reflects competitive pricing, more so than reductions in acre treatments or pounds applied.

University crop profiles for spring wheat production in the region also demonstrate that farmers have a wide range of choices. For each weed or type of application (pre-emergence, at plant, post-emergence, burndown), university profiles identify a half-dozen to a dozen or more herbicide options (Holden 2005; Wrage 2005). Accordingly, the lack of alternatives is not a major factor driving the need for Roundup Ready technology.

Commercialization of RR wheat would add one additional management option to an already long list.

Weed Populations Resistant to Herbicides

Roundup Ready technology clearly has helped soybean and cotton farmers deal with the growing number of weeds resistant to widely used imidazolinone and sulfonylurea herbicides. Might spring wheat farmers comparably benefit from RR technology?

The Weed Science Society of America compiles and posts on the Internet the "International Survey of Herbicide Resistant Weeds" (Weed Science Society of America 2005). Detailed information on the first reported incidence of resistant weeds, by crop and location, is presented on this website. State-level reports are available and have been analyzed across the Northern Great Plains region. Appendix Table 2 provides a detailed overview of all resistant weeds by state, including the year that resistance was first documented. The information in this appendix table in summarized in Table 3, "Number of Weeds Resistant to Individual Herbicides by Time Period of First Documentation and State."

Clearly, resistance emerged as a significant problem in spring wheat growing areas in the late 1980s and early 1990s. Resistance to important ALS and ACCase inhibitors occurred during this period in kochia, wild oats, and Russian thistle across most of the Northern Great Plains region. (See *www.weedscience.org* for in-depth discussions of the resistance mechanisms in both the ALS and ACCase class of herbicides). This was roughly the same time period that resistance spread in soybean producing areas.

By the second half of the 1990s, however, the spread of resistance markedly slowed. Only five new resistant biotypes were documented during this period. Not a single additional resistant weed has emerged in the last four years.

This data provides strong evidence supporting the conclusion that spring wheat growers have learned to manage resistance through cultural practices and diversifying their choice of herbicides. The USDA's Economic Research Service (ERS) reports spring wheat herbicide use data across 12 families of chemistry through its web-based "Crop Production Practices" data series. Rotating herbicides across families of chemistry is one of the most important ways to delay the emergence of resistance. In 1996 spring wheat farmers applied only three different herbicide families of chemistry on 9% or more of treated acres. By 2000, the number had risen to six and the acreage treated with the most widely applied family of chemistry had declined compared to 1996.

In Montana, the state with the second highest number of resistant weeds (10), farmers almost doubled the average number of herbicides applied in a given year from 1.4 in 1992 to 2.7 in 2002. Moreover, most farmers selected products from two distinct families of chemistry, in this way spreading out the control burden across different modes of action.

In contrast, farmers in Minnesota producing spring wheat actually reduced the number of herbicide active ingredients applied on the average acre from 2.02 in 1992 to 1.88 in 2002. This reduction reflects a gradual movement toward broad-spectrum herbicides and the relative absence of resistant weeds. Only four resistant weeds have been reported in wheat growing areas of Minnesota, compared to 10 in Montana.

Equally important, herbicides bear only a portion of the burden in managing weeds in spring wheat fields across the region. As a result, farmers impose a lower level of selection pressure on weed populations, and for this reason resistance is more effectively managed.

Accordingly, the emergence of new and difficult to control resistant weeds is clearly not

Table 3.

Number of Weeds Resistant to Individual Herbicides by Time Period of First Documentation and State

	Number of Resistant Weeds				Total Number of Resistant Weeds
	Before 1990	1991-1995	1996-2000	Post 2001	
Montana	6	3	1		10
North Dakota	3	3	1		7
South Dakota	1	1			2
Minnesota		4			4
Washington	2	3	2		7
Idaho	4	7	1		12
Five State Total	16	21	5	0	42

Source: Compiled from Appendix Table 1.

among the factors that might interest farmers in adopting Roundup Ready wheat technology.

Adoption of No-Tillage Planting Systems

Roundup Ready technology is highly compatible with no-till planting systems and has accelerated the adoption of no-till in soybean production in Argentina and Brazil. The impact of RR plant varieties on no-till soybean, corn, and cotton acres in the U.S. has been modest, especially compared to the nearly universal embrace of no-till plus RR soybeans in South America.

Only about 9% of spring red wheat acres were planted using no-till in 1998 in the Northern Great Plains region (Ali 2002). While no-till systems are used with success throughout the region, at least in most years, the lack of tillage in the spring, coupled with residues from the previous crop year, can slow down the warming of the soil. This can lead to delayed and uneven germination and reduced yields (Wrage 2005). The crop residue in no-till fields also provides habitat and feed sources for a range of pests and can trigger problems with plant diseases.

Problems with no-till are exacerbated in years with above normal spring rainfall. The added moisture further slows the warming of the soil, can delay planting, and can increase soil-borne pathogen pressure. Both conventional and conservation tillage systems tend to work better than no-till in wet years because they promote drying and even seeding and germination.

No-till systems tend to work best and often produce yields higher than other tillage options in dry years. In making tillage and planting system choices, farmers have to weigh all these factors and select a system that will, over several years, maximize average per acre profits. The potential for yield losses in wet years in fields planted to no-till systems tends to be greater than the yield advantage of no-till in dry years. This no doubt is one of the reasons no-till has not been adopted as widely in spring wheat production as it has been in other crops.

The Roundup Ready system will not change the fundamental constraints limiting adoption of no-till wheat. It will, in fact, create a new disadvantage, as RR wheat volunteers spread across the landscape. Weed management along roads, power lines, right of ways, and in public parks will become more difficult, given that glyphosate herbicides are often the product of choice in managing weeds in these areas. Farmers will also face a new headache – RR wheat volunteers in fields planted to RR corn, soybeans, and canola.

Potential to Lessen Use of Unacceptably Risky Herbicides

Reducing reliance on high-risk pesticides is often encountered in the pro-GM literature as one of the generic benefits following adoption of transgenic crop cultivars. There is evidence backing up this claim only in the case of Bt-cotton (Benbrook 2004; Weed Science Society of America 2005). The planting of Bt-cotton has reduced use of a number of broad spectrum and disruptive organophosphate (OP) and carbamate insecticides. As a result, populations of beneficial insects have recovered in many cotton farming regions, further reducing reliance on insecticides. Evidence has emerged that some bird species are also recovering in cotton producing regions.

In the case of Bt-corn, there has been a modest reduction in insecticide use, and hence no appreciable change in the environmental or public impacts of corn insect pest management (Benbrook 2004; Weed Science Society of America 2005). The lack of pesticide-risk-reduction benefits from Bt-corn arises from three well-documented factors. First, a significant share of the acres planted to Bt-corn for management of the European corn borer (ECB) would not have been treated with an insecticide in the absence of Bt-corn technology. Chemical control options for the ECB are pricey and bring about at best 75% control.

Second, those farmers along the western and southern borders of the Corn Belt who do routinely spray for ECBs have moved almost exclusively to low-dose synthetic pyrethroid insecticides, many applied at rates below 0.01 pound per acre. These insecticides have highly favorable environmental fate and mammalian toxicity profiles. No regulatory authorities or public health organizations are actively working to restrict their use because of hazards to people, other mammals, or birds.

Synthetic pyrethroids are not without risks. They are among the most toxic pesticides in common use to a variety of aquatic invertebrates and can also be highly toxic to young fish. They also can decimate populations of beneficial insects, an important factor that can trigger

Table 4.

Relative Acute Avian Risks of Wheat Herbicides per Acre Treated, National Average Herbicide Use in 2002

Active Ingredient	Trade Name	Percent Acres Treated in 2002*	Probability of Kill	Relative Risk Category
Bromoxynil octanoate	Bronate	2%	4.3%	Modest
Bromoxynil	Buctril	24%	2.7%	Modest
2,4-D	2,4-D LV	36%	0.70%	Modest
Dicamba	AgriStar Dicamba	18%	0.2%	Low
Glyphsate (conventional)	Honcho	15%	0.25%	Low
Glyphosate (RR)**	Honcho	-	0.5%	Low
Fluroxypyr	Starane	5%	0.01%	Very Low
Fenoxaprop-P-ethyl	Puma	29%	0.01%	Very Low
MCPA	Rhonox MCPA	47%	0.02%	Very Low
Tribenuron-methyl	Express	12%	0.01%	Very Low
Thifensulfuron	Pinnacle	10%	0.01%	Very Low
Metsulfuron-methyl	Ally	7%	0.01%	Very Low

Source: Derived from Appendix Table 2.

* Herbicides applied on greater than 4.9% acres, except for bromoxynil octanoate and clodinafop-propargyl (avian risk data not available).

** Glyphosate foliar applications made on Roundup Ready wheat during the production season are estimated to increase avian exposure levels, on average, two-fold compared to pre-plant burndown applications. Hence, the two-fold difference in scaled avian risks between conventional and RR wheat applications of glyphosate.

outbreaks of secondary pests. But in corn country, runoff to surface waters tends to be minimal given the ways these low-dose insecticides are applied for management of the ECB. Likewise, the timing of most applications and the method of application minimize exposures to beneficial insects.

For these reasons, Bt-corn for ECB control has had a modest impact on the pounds of insecticides applied and an even more limited impact on risks. For essentially the same reasons, the just-introduced Monsanto MON 863 Bt-corn for management of corn rootworms will also have a modest impact on corn insecticide risks. In addition, MON 863 Bt-corn poses considerable ecological risks to certain soil-borne organisms, including earthworms.

To what extent might Roundup Ready wheat reduce public health and environmental risks?

Adoption of RR wheat would increase reliance on and use of glyphosate and reduce the use of the more costly imidazolinone and sulfonylurea herbicides currently in use, and would likely also reduce somewhat the acres treated with bromoxynil (Buctril).

Herbicide use in spring wheat production virtually never results in residues in harvested wheat because of the time when the herbicides are applied. If and as RR wheat is adopted and more mid-season applications are made, residues of glyphosate might start appearing occasionally in wheat. But because of the timing of most Roundup applications in RR wheat fields and the environmental fate of this herbicide, it is premature to conclude that residues in harvested wheat will emerge as a serious concern.

Because most of the Northern Great Plains region is typically dry and herbicide runoff is not nearly as serious as it can be in the Midwest and other regions with higher rainfall during the spring spraying season, spring wheat herbicide impacts on aquatic organisms are infrequent and typically not serious.

The two most worrisome pesticide-use related risks in spring wheat production arise from exposures to applicators and other people working in or near fields during the spray season, and second, the exposure to birds that fly through and use treated areas as a source of feed and habitat. Tables 4 and 5 provide an overview and ranking of the herbicide risks to birds and people.

These tables are based on relative risk indices produced using the Pesticide Environmental Assessment System, or PEAS. This system has been developed by Ecologic, Inc. and Benbrook Consulting Services as a tool for setting pesticide risk reduction goals and monitoring progress toward such goals. PEAS has evolved from the multiattribute pesticide risk ranking system developed as part of the World Wildlife Fund-Wisconsin Potato and Vegetable Growers Association-University of Wisconsin collaboration. The underlying methodology has been described elsewhere (Benbrook et al., 1996; Benbrook et al., 2002; Benbrook 2004; Weed Science Society of America 2005).

Table 5.

Relative Acute Mammalian (Worker) Risks of Wheat Herbicides per Acre Treated, National Average Herbicide Use in 2002

Active Ingredient	Trade Name	Percent Acres Treated in 2002*	Oral LD-50s	Scaled Worker Toxicity per Acre Treated	Relative Risk Category
Bromoxynil octanoate	Bronate	2%	190	100	Moderate
Bromoxynil	Buctril	24%	190	83	Modest
MCPA	Rhonox MCPA	47%	700	29	Modest
2,4-D	2,4-D LV	36%	700	59	Modest
Glyphosate (RR)**	Honcho	-	4,230	5.8	Low
Fenoxaprop-P-ethyl	Puma	29%		1.7	Very Low
Fluroxypyr	Starane	5%		1.7	Very Low
Dicamba	AgriStar Dicamba	18%	1,707	1.9	Very Low
Glyphsate (conventional)	Honcho	15%		1.15	Very Low
Metsulfuron-methyl	Aly	7%		1.2	Very Low
Clodinafop-propargyl	Discover	8%		1.1	Very Low
Tribenuron-methyl	Express	12%	5,000	0.13	Very Low
Thifensulfuron	Pinnacle	10%	5,000	0.13	Very Low

Soure: Derived from Appendix Table 3.

* Herbicides applied on greater than 4.9% acres, except for bromoxynil octanoate.

** Glyphosate foliar applications made on Roundup Ready wheat during the production season are estimated to increase worker exposure levels, on average, five-fold compared to pre-plant burndown applications. Hence, the five-fold difference in scaled worker risks between conventional and RR wheat applications of glyphosate.

The avian risks in Table 4 are based on the typical rate of application of each herbicide in spring wheat production. The fourth column reports the "probability of kill," a measure of avian risks derived from the sophisticated avian risk model developed by Dr. Pierre Mineau, an avian risk specialist working for the Canadian Fish and Wildlife Service (Mineau 2002). The only herbicide that poses an even modest level of risk is bromoxynil, with about a 3% probability of kill in treated fields. Given that Buctril is applied pre-plant or at planting time – a period when birds are not typically resident in fields – the risks are likely even less than suggested by Mineau's model.

Likewise, applicator and occupational exposure to people following spring wheat herbicide use poses modest to virtually no risk to humans, as shown in Table 5. The fourth column reports the oral LD-50s (dose killing 50% of the animals in an acute toxicity study) for spring wheat herbicides. According to the World Health Organization, pesticides with an oral LD-50 of 20 parts per million (ppm) or less are classified as "extremely toxic." Pesticides with oral LD-50s between 200 ppm and 2,000 ppm are regarded as "moderately toxic," and pesticides with LD-50s over 2,000 ppm are "slightly hazardous."

In addition, worker exposures to herbicides are modest because of the timing and way herbicides are applied in spring wheat production systems. Accordingly, a low priority can be placed on reducing worker risks from occupational exposure to herbicides in spring wheat production. Human and avian risks are several-fold greater from the insecticide applications that periodically are required to deal with summer insects. Adoption of Roundup Ready wheat would not impact the frequency or severity of insecticide-related risks.

Predictable and Potential Consequences Following Widespread Planting of Roundup Ready Spring Wheat

Nine areas of probable and potential impacts likely to follow widespread planting of Roundup Ready spring wheat are discussed in this section. "Widespread" planting would occur when 30% or more of the spring wheat acreage nationwide is planted to RR varieties. At this level of adoption, there will likely be county-size areas with over 50% adoption.

Some impacts of widespread adoption are predictable, if not certain to occur. Examples include some degree of market rejection, falling prices, and increased use of glyphosate herbicide. It is more difficult to project how quickly other problems will emerge, how serious and widespread they will become, how long new problems will persist, and whether they will gradually or quickly worsen, or fade away, as a result of management changes and corrective actions.

The enormous range in potential impacts following widespread adoption of RR wheat makes many people nervous and has caused government agencies to delve more deeply into the underlying issues than otherwise likely.

In estimating the economic impacts associated with the adoption of RR wheat in the next section, two estimates are provided for some impacts. One set of economic impact estimates reflects the optimistic assumptions that problems will be addressed and managed as they are recognized, studied, and understood, and that the agricultural community, technology providers, government agencies, and researchers will cooperate openly in seeking solutions.

A second, more pessimistic set of estimates is based on different assumptions. Several problems will emerge relatively quickly. Of these, a portion will worsen over time, in part because the source of the problems will prove difficult to prove, triggering protracted debates and delays in corrective actions.

Some of the nine potential areas of impact discussed below have been extensively studied and debated, while others have received relatively little attention. This report does not attempt to conduct a thorough review of the vast and still growing literature now available on the consequences of the adoption of the RR technology.

Declining Wheat Quality

Adverse impacts on wheat quality could trigger a degree of erosion in farm level wheat prices, if and as the milling industry recognizes that the baking quality and/or nutritional quality of RR spring wheat is not as high or consistent as conventional varieties. This problem could also complicate efforts to sustain the confidence of foreign buyers of U.S. hard red spring wheat.

Wheat quality impacts have received essentially no attention in the regulatory review process to date, despite evidence in the open scientific literature suggesting that problems with wheat quality could emerge as RR wheat acreage increases.

A study was published in March 2004 in the Journal of Agricultural and Food Chemistry by a team of Monsanto researchers and consultants. It asserts that the composition of grain and forage from RR wheat is equivalent to conventional wheat (Obert et al., 2004). Table 6 draws upon the data in the Obert study and shows that RR wheat is actually not equivalent to conventional wheat.

The study was well designed and compared the yield and composition of the MON 71800 line to a control variety, the unengineered parent of MON 71800. In addition, another variety was included in the study that was identified by farmers in each trial location as among the best-adapted conventional varieties. Results from this second conventional variety were used to identify ranges in the values of various indicators of grain and forage composition and quality.

In 1999 there were three tests sites and in 2000, there were five. There were four replicated blocks at each site. The results in Table 6 reflect the average of all the replicates at all the sites each year.

Grain harvested from RR wheat plants contained 0.24% less protein than the control wheat in both 1999 and 2000 trials. While this quarter-of-a-percent decline in protein levels might seem small and was regarded as of no biological significance by the study authors, such a difference could be significant to wheat farmers, millers, and the wheat market.

The farm-level price per bushel of hard red spring wheat is linked to protein content, which is particularly important with HRSW because of the impact of protein on gluten content and baking quality. When protein levels drop below 14 percent, the industry standard, the discount per one-quarter percent of protein ranges between $0.15 and $0.25 cents, depending on the year, amounts and quality of grain in storage, and market conditions. In 2005, unusually heavy rains occurred in late April and early May through much of the PNW wheat belt, increasing yield estimates but also stressing wheat plants in fields that were treated with typical rates of nitrogen fertilizer. Many fields with higher yields are likely to harvest grain with lower protein content. A story in the June 17, 2005 *Capital Press* reported that hard red spring wheat growers were likely to face a $0.22 discount for each quarter percent of protein below 14%.

Farmers are also sometimes paid a premium when protein content rises above 14%. This premium is typically less than the discount for low-protein wheat, and generally ranges between $0.05 and $0.15 per one-quarter percent increase in protein levels. The premium moves toward the upper value in years when market supplies of high-protein wheat are tight, and sticks around $0.05 to $0.07 when there are ample supplies relative to demand.

Accordingly, in a low-protein year like 2005, a 0.24% decline in protein levels below 14% in the wheat harvested off a RR field could cost the farmer almost $0.20 per bushel. In a higher-protein year, the average farmer might lose a premium of $0.10 to $0.15 when selling a RR hard red spring crop with 0.24% lower protein than in conventional varieties. In a crop that sells for $2.75 to $3.50 a bushel in most years, the price reduction between $0.10 and $0.20 a bushel would certainly be of concern to growers and the industry as a whole.

In 1999 trials, the Vitamin E content of MON 71800 wheat was 21% lower than conventional wheat (Obert et al., 2004). In the 2000 trials, the level of the antioxidant p-coumaric acid also was 21% lower in the RR wheat compared to the conventional varieties. There were modest reductions in several other food quality indicators. In nine out of the 10 cases reported in Table 6, levels were lower in the RR wheat than in the controls.

In the journal article, regulatory submissions, and all public statements on the question of nutritional and quality equivalence of RR crops compared to

TABLE 6.

Some Differences Observed in the Composition and Quality of Roundup Ready (MON 71800) and Conventional Wheat Varieties

	Crude Protein (% dry matter)	Niacin (mg/kg)	Thiamin (mg/kg)	Vitamin E (mg/kg)	Folic Acid (mg/kg)	p-coumaric acid (mg/kg)
1999 Trials						
MON 71800	16.71	49.57	4.93	48.71	NA	NA
Control	16.95	51.01	5.02	62.06	NA	NA
2000 Trials						
MON 71800	16.66	59.42	4.28	9.35	0.72	29.20
Control	16.9	58.59	4.62	9.99	0.77	37.10

Source: Based on published Monsanto research (Obert, J.C., et al. "The Composition of Grain and Forage from Glyphosate Tolerant Wheat MON 71800 Is Equivalent to That of Conventional Wheat (Triticum aestivum L.)," Journal of Agricultural and Food Chemistry, Volume 52, No. 5, March 10, 2004).

conventional varieties, Monsanto correctly points out that there is a high degree of variation in the levels of proteins, vitamins, minerals, and antioxidants in foods grown in different areas, and from one year to the next. This is why scientists are supposed to design these sorts of nutritional quality and equivalency studies "side-by-side" using the same cultural practices and planting methods. The goal is to eliminate all possible sources of variation, except for the genetic differences in the transformed variety compared to its untransformed parent.

Given that the 1999 and 2000 trials carried out by Monsanto were indeed "side-by-side," it is not appropriate to dismiss the observed differences through reference to the magnitude of variation observed in other varieties and in different years. In three cases the differences evident in the table are significant enough to be of concern – protein, Vitamin E, and p-coumaric acid – and should trigger more careful and extensive research. In addition, the article reports that several outlier values were omitted from the statistical analysis, with little explanation of why they were regarded as outliers. Given that the purpose of such a study is to determine whether there are any significant differences between the transgenic and parental varieties, dismissing outliers without reporting what the levels were, or adequately explaining why they were deemed outliers, lessens the scientific value of the research and raises new questions.

There is, moreover, other evidence suggesting that the genetic transformation that makes plants resistant to Roundup herbicide impacts plant physiology in ways that reduce average protein levels in harvested crops. A team of scientists carefully measured both the levels and quality of protein in soybeans and soybean meal from the five leading countries in the global soybean marketplace – the U.S., Brazil, Argentina, India, and China (Karr-Lilienthal et al., 2004). The results were striking and are summarized in Table 7.

The samples were collected in 2002. Roundup Ready soybeans accounted for about 98% of the soybeans grown in Argentina that year, and so the results for Argentina are almost certainly based on Roundup Ready beans. No RR soybeans were planted in India or China. That year, about one-half the soybeans in the U.S. were RR and somewhere around one-quarter of Brazilian beans were RR.

The soybeans from Argentina were clearly inferior in terms of protein quality compared to the soybeans grown in the other countries and the differences were large and highly significant (Karr-Lilienthal et al.,

Table 7.

Protein Quality Differences in Soybeans Produced in Five Countries in 2002
and in Soybean Meals Manufactured from Those Soybeans,
With Emphasis on the Quality Gap in Argentinean Soybeans and Meal
(see notes)

	Argentina	Brazil	China	India	U.S.	Average of Brazil, China, India, and U.S. Levels	Percent Difference: Argentina to Other Four Countries
Soybeans	- - - - - - - - - Percent on a Dry Matter Basis - - - - - - - -						
Crude Protein (% dry matter basis)	32.6	39.3	44.9	39.6	37.1	40.23	-23.4%
Phenylalanine	1.63	2.98	2.33	2.03	1.95	2.32	-42.5%
Methionine	0.48	0.54	0.64	0.54	0.53	0.56	-17.2%
Lysine	2.07	2.41	2.69	2.48	2.37	2.49	-20.2%
Soybean Meal							
Crude Protein (% dry matter basis)	47.4	57	58.5	57.8	53.2	56.63	-19.5%
Phenylalanine	2.39	2.91	2.93	3.03	2.8	2.92	-22.1%
Methionine	0.72	0.75	0.81	0.77	0.77	0.78	-7.6%
Lysine	2.97	3.38	3.39	3.55	3.25	3.39	-14.2%

Notes: The research team tested low and high quality soybeans and meal from India; the data reported here are for the high quality soybeans and meal.

Source: Karr-Lilienthall, L.K., Grieshop, C.M., Merchen, N.R., Mahan, D.C., and G.C. Fahey. "Chemical Composition and Protein Quality Comparisons of Soybeans and Soybean Meals from Five Leading Soybean-Producing Countries," Journal of Agricultural and Food Chemistry, Vol. 52, No. 20, October 6, 2004.

2004). Crude protein levels in the Argentina bean were 23% lower than the average levels in the other four countries. Compared to the high quality soybeans produced in China, the Argentinian RR soybeans contained 37% less crude protein – a remarkable difference in a basic measure of food composition and quality.

The research team did not explore or explain why the Argentinian soybeans were so inferior. There is no way to know for sure whether the deficiency in protein levels was linked in some way, in whole or part, to the genetic transformation that made the beans tolerant of Roundup herbicide. This is one plausible explanation for the decline. The Lilienthal et al. study has no doubt broadened interest in the grain trade and livestock industry on the connections between RR technology and protein levels and quality, since the feed value of soybean-based supplements rests largely on the protein content of the soybeans.

Given the importance of adequate wheat protein levels to the quality and reputation of the spring wheat industry in the U.S., any evidence suggesting that RR technology might trigger even a modest reduction in wheat protein levels must be taken seriously. Even if such an impact occurs only in some years under certain combinations of weather conditions and production practices, its overall impact on the industry deserves careful analysis.

Table 8.

Differences in the Shikimic Acid Content in Wheat Kernels, Flour, Crust, and Bread Made from Wheat Sprayed with Glyphosate and Other Common Herbicides

	Kernel	Flour	Crust	Bread
	- - - Parts per million dry matter basis - - -			
Glyphosate treated wheat	99	41	30	24
Metsulfuron + 2,4-D treated Wheat	40	17	12	10
Control Wheat	32	14	12	11
Glyphosate-treated Wheat as Percent of Control	**309%**	**293%**	**250%**	**218%**

Source: Derived from data published by Bresnahan, G.A. et al. "Glyphosate Applied Preharvest Induces Shikimic Acid Accumulation in Hard Red Spring Wheat (Triticum aestivum)," Journal of Agricultural and Food Chemistry, Volume 51, No. 14, June 2003.

Declining Baking Quality

There is also evidence in published scientific literature that the application of glyphosate herbicide on wheat plants during the later stages of the growing season increases the concentration of shikimic acid in the wheat plant's tissues and in the harvested grain. For years, some wheat farmers have sprayed their fields with a low rate of glyphosate late in the season to accelerate the pace of crop drying across a field, so that harvest operations can be started earlier and to reduce average grain moisture levels at harvest.

Scientists at North Dakota State University wondered what impact this late-season use of glyphosate might have on the levels of shikimic acid in the wheat kernels harvested off treated fields, and whether the differences at harvest would carry over as the wheat is processed into flour and baked into bread (Bresnahan et al., 2003). Key results of their experiment are summarized in Table 8.

As is obvious in Table 8, the differences were indeed substantial. Levels of shikimic acid were over three-times higher in the wheat kernels harvested from sprayed fields compared to unsprayed control fields. The levels declined by over half when the wheat was milled, but the levels in flour made from the sprayed fields were still almost three-times higher than in the flour made from unsprayed wheat. In the baked bread and crust from treated wheat, the shikimic acid levels remained more than two-times higher than when the flour was from an untreated field.

These findings are important and worrisome because shikimic acid levels are correlated with important baking characteristics of wheat. Dough made from glyphosate treated wheat appears to require more energy to properly develop. Glyphosate applied preharvest when the wheat contains 30% or more moisture content has been shown to alter gluten and dough properties (Bresnahan et al., 2003).

Spring wheat fields planted to RR varieties will be sprayed during the growing season, in most cases earlier than the typical time period when glyphosate is sprayed to accelerate drying and facilitate harvest operations. Still, this experiment raises questions that warrant more study. It might be possible to keep shikimic acid levels within an acceptable range by placing a minimum preharvest interval on the label of glyphosate herbicide products, but this course of action has never been proposed or discussed in any publicly available documents.

Emergence of Resistance

Reliance year after year on a single herbicide selects for phenotypes in weed populations that are less sensitive to the herbicide. The early stages of this process leads to the evolution of tolerant weeds. Farmers will notice a larger number of weed escapes at the end of the season, and more spotty control.

If and as farmers continue to spray the same herbicide more frequently and/or at higher doses, the selection pressure on weed populations will increase and accelerate the emergence of genetically resistant phenotypes. This natural selection process eventually leads to resistant weed populations. Resistance in a given weed biotype to one herbicide in a family of chemistry usually means that the same weed biotype will also be resistant to the other herbicides in the family of chemistry.

Widespread planting of Roundup Ready wheat in the Northern Great Plains will set in motion evolutionary change and adaptation within weed populations. These changes will impact both the composition of weed species and the effectiveness of glyphosate herbicide. An assessment of the impact of widespread planting of RR soybeans and corn in the Corn Belt provides a preview of what might happen in the Northern Great Plains if RR technology is widely adopted.

The February 2004 *Farm Journal* contains an article focusing on weed problems in the Midwest entitled "The Top 10 Weeds." The list is based on a ranking of the "worst" weeds by land grant university weed scientists. The article identifies the top 10 weeds, along with where and why these weeds have become so difficult to control. The list and some excerpts follow –

1. **Waterhemp** —*"….it's no surprise this weed got the most votes…[resistant to several common herbicides and]…Some say it is becoming resistant or tolerant to glyphosate herbicides…"*
2. **Common lambsquarter** — *"Post-applied herbicides, including glyphosate, don't always knock it down…"*
3. **Giant foxtail**
4. **Velevetleaf**
5. **Giant ragweed** —*"…it also has a knack for scoring over most herbicide defenses sooner or later…" (In the summer of 2004, a biotype of ragweed was found in Missouri that is resistant to glyphosate herbicide).*
6. **Morningglory species** —*"One weed scientist notes it can be 'controlled' with glyphosate but has thrived since Roundup ready soybeans became popular."*
7. **Kochia** — *Note: While the* Farm Journal *article does not mention resistance to Roundup in kochia, many reports have surfaced of tolerance, if not resistance in some locations.*
8. **Common cocklebur**
9. **Horseweed** —*"This weed got double votes cast in Eastern states – one as a weed and one as a glyphosate-resistant weed…resistant biotypes continue to roll out of Dellmarva into the eastern Corn Belt, Tennessee, Arkansas, and Mississippi."*
10. **Woolly cupgrass**

Out of the top 10 weeds plaguing farmers in the Midwest, six have emerged as major problems largely or partially in response to Roundup Ready technology. Millions of pounds of additional herbicides are applied each year now because these weeds have become tolerant of glyphosate or resistant to it.

Glyphosate resistant marestail is definitely the biggest problem where RR soybeans and RR cotton have been widely planted for several years in a row.

In the last four years glyphosate-resistant marestail has spread rapidly. It now infests millions of acres in about 20 states and is forcing many farmers to make rescue treatments with 2,4-D and/or dicamba.

Four years ago, promoters of RR crops dismissed concerns over the emergence of resistant weeds. It was often asserted that Roundup had been used for 25 years in the U.S. without any significant problems with resistance, and based on this record, why would anyone expect resistance to now become a problem?

Glyphosate herbicide is used in an RR system in fundamentally different ways than glyphosate is used in conventional cropping systems. Before RR technology, Roundup could only be applied early in the crop season as a burndown treatment before the crop had germinated, or post-harvest, to clean up any late maturing weeds. From planting time through harvest, weeds were never subjected to selection pressure from applications of Roundup, a limitation that proved for 25 years to be an effective resistance management plan.

In a RR cropping system, Roundup is typically applied twice, once early in the season and a second time prior to the crop canopy closing. In no-till systems, Roundup is often applied three times – a burndown application, followed by two in-season sprays. Clearly, the change in the timing and number of Roundup applications in a crop year has had a major impact on selection pressure, and hence on weed populations. It has shifted the composition of weeds toward those genetically equipped to survive glyphosate applications, and triggered the emergence of tolerant biotypes, some of which have recently evolved to resistant status.

Today, the efficacy of the RR system in soybeans and cotton is in serious jeopardy because of resistance to two or more common weeds in several major production areas. Resistant ragweed, a major weed across most of the Midwest, has recently been confirmed. A respected weed scientist at the University of Arkansas, Dr. Ford Baldwin, has spoken out forcefully on the imminent hazard posed by resistance to glyphosate –

> "*Very shortly, I think the impact of herbicide resistance is going to be huge. I've been saying so for a while, now. So have others...*"
> (*Delta Farm Press*, Feb. 10, 2005)

Dr. Steven Powles is an international expert on herbicide resistance and has worked in Australia for many tears on glyphosate resistant ryegrass, a very common and serious weed in Australia. He traveled to the U.S. in early 2005 and has given several lectures. In an interview with the Delta Farm Press, Powles explained that Australia is currently "number one" in the world in terms of resistant weed problems, but predicted that "…the United States is about to take the top spot away from us. My prediction is you will be crowned king of herbicide resistance within the next few years." After noting the strong selection pressure exerted on weeds across the U.S. because of RR technology, Powles made an important point –

> "*But relying too much on any one biological system will have repercussions. The massive adoption of Roundup Ready across vast slices of the United States – along with the persistent usage of glyphosate – is a very strong selection pressure. Increasingly, U.S. weeds are surviving glyphosate. And a weed that can survive glyphosate is in herbicide heaven. Its competitors are killed while it can grow and reproduce. This is slowly but surely, and inexorably, occurring.*"
> (*Delta Farm Press*, Feb. 10, 2005).

Widespread planting of RR wheat in the Northern Great Plains will be accompanied by a substantial increase in glyphosate use. The more widely and more frequently glyphosate is applied, the sooner resistant weeds will emerge. The fact that most spring wheat in the Northern Great Plains region is planted in rotations could prove important in slowing the emergence of resistance. But if some farmers rotate RR wheat with RR soybeans or RR canola, resistance will emerge even faster. Farmers will then have to find ways to deal with a new resistant "weed" – volunteer RR wheat.

The emergence of tolerant, and eventually resistant weeds in the Northern Great Plains will have many impacts. Herbicide use and costs will rise. The spread of resistant genes will accelerate, possible back into other varieties of wheat. Resistant weeds will spread onto rights-of-way, roadsides, public parks, and into farmyards, where they will thrive whenever Roundup is applied. Companies, farmers and universities producing certified seed for sale will face new weed management challenges, since most markets will want seed that is not genetically engineered and seed that is free of weed seeds, especially RR weeds.

Gene Flow

Gene flow will occur in the event of widespread planting of RR wheat. The Roundup resistant gene will, in all likelihood, move into jointed goatgrass within a few years, based on University of Idaho research published in 1998 (Zemetra 1998). The RR transgene, or portions of it, will also slowly gain a foothold in foundation hard red spring wheat seed stocks. Gene flow into the seed planted by organic farmers will be a periodic problem, especially for farmers selling into markets with strict purity requirements.

It is hard to know whether the gene will make its way into other types of wheat, although over time this too could happen. The Center of Science in the Public Interest carried out an analysis of spring and winter wheat acreage in counties across five major wheat-producing states. They found 11 counties in South Dakota and Washington with 20,000 or more acres of both winter and spring wheat. Idaho, Montana, and Oregon had another 18 counties with 20,000 or more acres of each type of wheat (Gurian-Sherman 2003).

Even the staunchest promoters of RR technology now admit that some degree of gene flow will occur if RR wheat is widely planted. But "so what?" they are quick to add. A certain degree of gene flow across varieties, and from cultivated plants to weedy relatives, has been occurring since the beginnings of agriculture and is virtually impossible to stop. Why should farmers, the government, or the grain trade worry about a modest and unavoidable degree of gene flow from RR wheat?

In the absence of ongoing selection pressure (i.e., use of glyphosate), plants or weeds that have picked up the RR gene would not have any ecological advantage over its competitors, and so the gene may in effect fade away through, for example, gene silencing.

If organic certifiers, parts of the food industry, and export markets adopt strict "no transgenic DNA in wheat" policies, the presence of detectable levels of transgenic DNA will impose economic losses on affected farmers. If this were to emerge as a common problem, it is hard to imagine that agricultural leaders and public institutions will fail to take strong actions to try to address the source of the problem and assure that those suffering losses through no fault of their own are compensated. The USDA stepped in aggressively in the wake of the StarLink episode and spent over $1 billion in an attempt to shield farmers from losses and get the corn sector through the crisis. The same sort of response by USDA would surely follow any substantial loss of wheat export market share triggered by the finding of transgenic DNA.

Uncertainty casts a long shadow over estimates of the longer-term consequences of gene flow. Experts have developed and analyzed a wide variety of scenarios. The most immediate and significant impacts will almost certainly stem from export market rejection and heightened costs associated with crop segregation, testing, and litigation.

The most worrisome scenarios entail some as yet unproven and undetected impact of the RR transgene on the physiology of plants that raises new food safety or grain quality questions. The RR transgene alters the shikimic pathway, one of the most important biosynthetic pathways in all plants. This pathway governs plant defense systems and how plants respond to biotic and abiotic stresses. It triggers the production of secondary plant metabolites and plant proteins that play many roles in plant defenses. Some may turn out to be new human allergens or toxins.

Evidence in the literature on GE crop risk assessment raises special concerns about unusual patterns of gene expression and protein production that can be triggered by extreme weather or pest related stresses. This is one reason why genetically engineered crops need to be tested not just under typical or ideal weather and agronomic conditions, but also under high-stress circumstances. Clearly, climatic extremes are part of what makes farming so challenging in much of the Northern Great Plains region.

Disease Pressure and Problems

Fusarium head blight is the number one wheat plant disease in the United States, impacting both yields and grain quality. The *Fusarium* pathogen also produces mycotoxins that are harmful to livestock and humans, especially deoxynivalenol (DON). In Canada, wheat that contains 0.25% *Fusarium* damaged kernels is downgraded from Canadian Red Class (CWRS) #1 to #2, and 1% *Fusarium* damaged kernels triggers downgrading to CWRS #3 (Fernandez et al., 2003).

From 1998 through 2000, Fusarium cost U.S. wheat growers an estimated $2.7 billion (Wood 2002). Disease severity is driven largely by environmental factors and can arise quickly, leaving growers few options. There are no effective fungicide treatments for head blight, nor commercially available varieties with more than intermediate levels of resistance, despite a concerted effort over many years by breeders to identify resistance genes (Wood 2002).

Researchers in Saskatchewan carried out an in-depth analysis of the factors triggering *Fusarium* head blight in spring wheat production systems over four seasons (Fernandez et al., 2003). Application of glyphosate herbicide was the most dominant production practice associated with the severity of *Fusarium* head blight. It was the only production practice in 1999 that was linked to heightened disease severity, and was one of only two practices in 2002. The team also concluded that –

> "*When wheat grown under minimum-till was analyzed separately, GF (glyphosate) application displayed an even greater effect on FHB (*Fusarium *head blight).*"

In addition, the team found that fields under minimum tillage systems had the highest levels of disease in years when disease pressure was medium to high (Fernandez et al., 2003).

The Saskatchewan team reported other ominous findings. Grain harvested off fields previously treated with glyphosate had 97% more *Fusarium*-damaged kernels than untreated fields (Fernandez et al., 2003). Grain harvested off fields previously treated with glyphosate and planted using minimum tillage had head blight disease severity values 122% higher on average than untreated fields. Accordingly, the risk of mycotoxin problems in fields previously treated with glyphosate would also be much higher.

In the two years with the highest disease pressure (2000 and 2001), the index used to measure the severity of *Fusarium* head blight was 75% higher in glyphosate treated fields compared to those not treated (Fernandez et al., 2003).

This research in Saskatchewan was done using conventional wheat varieties, so no fields were sprayed multiple times with glyphosate in a single growing season and none were sprayed during the growing season. It is possible, and perhaps even predictable, that the extended time period during which glyphosate will be applied in the wake of widespread planting of RR wheat will trigger more pronounced spikes in *Fusarium* levels, at least in some years and under some combinations of production practices and weather conditions. Accordingly, farmers adopting RR wheat will need guidance from researchers to project and monitor the frequency and severity of head blight, the degree of infection that can be attributed to the new way in which glyphosate is used, and the economic impacts of higher percentages of *Fusarium*-damaged kernels. This information is essential to carry out a thorough farm-level cost-benefit analysis of RR wheat technology.

A number of potential mechanisms leading to higher *Fusarium* head blight damage in wheat previously treated with glyphosate are noted by the Saskatchewan team. *Fusarium* species can act synergistically with other fungi in causing death and damage to glyphosate treated plants. Glyphosate treatment has been shown to increase soil-borne pathogen levels in many studies, sometimes leading to greater root colonization, damage, and higher disease losses. Some studies have shown that certain fungi can actually use glyphosate as an energy source, and other studies have found that glyphosate treatment can trigger pronounced shifts in soil microbial communities, possibly impacting phosphorous availability and root and plant health. And perhaps most worrisome, a few studies have shown that glyphosate can act directly on plant defense mechanisms and responses to stress, through impacts on core biosynthetic pathways and phenolic metabolism (Fernandez et al., 2003).

The buildup of *Fusarium* in Minnesota following the adoption of no-till planting systems and RR crops has triggered a drop in wheat production from 2.5 million acres in 1997 to under 2 million today (Holden 2005). Research in Minnesota has documented that applications of glyphosate on RR soybeans can lead to a buildup of *Fusarium* in the soil, heightening soybean plant susceptibility to soybean cyst nematode infection (Kremer et al., 2002; Kremer et al., 2001). Ongoing work in Minnesota is exploring the linkages between glyphosate use, RR crops, and soybean sudden death syndrome, another costly new soil disease problem that has emerged since the introduction of RR technology.

Agricultural Research Service (ARS) scientists in Pullman, Washington, have shown that applications of glyphosate on two common PNW weeds leads to a buildup of *Phytium* and *Fusarium* on the roots of the dying weeds (Kawate 1998). If a new crop is planted too soon after the application of glyphosate, the crop's developing root system can become infested with these root diseases, triggering sometimes-substantial yield losses. This capacity of soil borne pathogens to first spike following an application of glyphosate, and then move underground from the decaying root system of the weeds to the roots of a freshly planted crop, was labeled the "green bridge" by Dr. James Cook and colleagues at WSU in the early 1990s.

Scientists at Purdue University studied the impact of glyphosate applications on RR soybeans on "take all" disease in winter wheat planted into soybean stubble.

"Take all" is another periodically serious wheat disease and is caused by the pathogen *Gaeumannomyces graminis*. In 1999-2001, the team planted a variety of plots at an experiment station in northwestern Indiana. RR soybeans were sprayed with glyphosate in the same way as on farms in the area. The scientists found "increased disease severity in subsequent winter wheat crops" (Hickman et al., 2002).

The evidence pointing to possible linkages between RR spring wheat, increased glyphosate use, and plant disease problems is compelling. Given that even a modest change in plant diseases can have a significant impact on crop quality and income to farmers, this cluster of issues warrants a much more systematic research effort in the United States. No research team in the U.S. has received the funding needed to carry out a multiyear, multiple site field study on glyphosate-wheat disease and wheat quality interactions like the one carried out in Saskatchewan.

No scientific team anywhere has carried out such work using RR wheat cultivars. Given the quality and diversity of data suggesting that moderate to serious disease-related problems may in fact emerge following widespread planting of RR wheat, new research should be initiated in the United States on this potentially costly problem.

Market Rejection

Until consumer and grain trade attitudes toward Roundup Ready wheat change dramatically, the most immediate and costly consequences following the planting of RR wheat in the Northern Great Plains will be loss of export sales and lower prices. In all likelihood, even the planting of a few thousand acres could cost the industry some sales and raise doubts about grain quality and purity. It remains to be seen whether a system to segregate RR wheat, in order to keep it out of export channels, would temper market rejection.

In 2003, a report commissioned by the Western Organization of Resource Councils (WORC) addressed the market impacts following commercialization of RR wheat (Wisner, 2004b). In November 2004 an update of the Wisner report was released (Wisner, 2004a). The updated report concluded that –

- Adoption of RR wheat "risks the loss of one-third to one-half of U.S. hard red spring and durum wheat exports;
- The European market will be almost entirely lost;
- Market prices would fall 33% and approach feed-wheat levels; and
- Cross-contamination to organic wheat could jeopardize the approximate 50% premium now paid for certified organic supplies.

Wisner concluded that durum wheat export sales would also be at risk because of potential co-mingling, given that the crops are planted and harvested around the same time across much of the Northern Great Plains region and move through the same marketing system. The substantial projected market impacts of RR wheat, in contrast to RR soybeans and processed products from RR corn, is attributed to the fact that RR wheat would be the first transgenic human food grain to enter export market channels.

Most of the transgenic corn and soybeans grown in the U.S. are fed to animals, processed into oils or sugars, or used to make ethanol. Transgenic proteins from corn and soybean based processed products and animal products are hard to detect and in all likelihood, are rarely present (Wisner, 2004a). Still, the U.S. lost most of its corn grain exports to Europe several years ago. In the 2003-2004 marketing year, soybean exports from the U.S. to the European Union dropped 38% and soybean meal exports dropped 79% (Wisner, 2004a).

In his update report, Wisner summarizes several recent developments in the EU and other countries that reinforce his initial estimates of market rejection and price declines. If further research like the Canadian study on wheat quality and glyphosate use confirm the existence of an environment-driven linkage between glyphosate use, *Fusarium* kernel damage, and mycotoxin levels, Wisner's estimates of market loss will almost certainly prove conservative.

Impacts on Costs and Returns

Widespread planting of RR spring wheat will impact farmer expenditures on seed and herbicides. It may increase disease severity and losses and reduce dockage from weed seeds. It will decrease market prices because of export market rejection. Estimates of the magnitude of these costs are projected under two scenarios for the hard red spring wheat industry on a per acre basis and industry-wide.

The estimates are based on the assumption that RR wheat varieties are planted on 30% of total hard red spring wheat acres. The changes in costs, income, and returns are projected for the 70% of acres planted to conventional varieties, based on the latest USDA estimates of spring wheat yields and costs of production in the Northern Great Plains region.

Impacts on the 30% of the acres planted to RR wheat varieties are also estimated, based on percent changes in input use, prices, and returns compared to conventional spring wheat acres. Bottom line impacts on per acre returns are then compared for farmers planting conventional and RR varieties, and industry-wide under each scenario.

The first scenario combines a series of assumptions that are generally optimistic and favorable toward the technology – in short, the Roundup Ready wheat "rosy" scenario. It assumes that significant progress is made in gaining confidence in the technology so that market rejection is minimal; most farmers will be able to manage weeds with one application of glyphosate in the majority of fields planted to RR wheat, and that an additional herbicide is required on 40% of the RR wheat acres planted; Monsanto decides to price RR seeds with a lower premium then expected by some analysts; wheat weed diseases will only modestly worsen; there is no need to segregate the crop and policies are put in place to minimize the fear and consequences of gene flow; and, no unforeseen efficacy or wheat quality and safety issues will emerge.

The second scenario combines a series of pessimistic assumptions that collective comprise a "nightmare" scenario for the Northern Great Plains wheat industry, Monsanto, and in particular, wheat farmers. It assumes that market rejection will reduce prices by 10% -- less than one-third of Wisner's estimate, but still a serious drop. This reflects the reality that the U.S. wheat industry and grain trade are not likely to allow commercial use until there is evidence that at least some EU customers will continue sourcing hard red spring wheat from the U.S.

The "Pessimistic" scenario assumes that 65% of farmers planting RR wheat will need a second application of glyphosate and that 80% will apply a residual herbicide at planting, and that herbicide prices will rise marginally compared to the "Optimistic" scenario. The premium charged for RR wheat seed is placed toward the upper end of the range projected by wheat industry analysts.

Wheat diseases are projected in this scenario to reduce average yields 4% (a net 3% drop after the 1% increase based on improved weed control). The wheat price paid to farmers declines an additional 6% because of the increased incidence of *Fusarium* damaged kernels and the additional steps required to segregate the crop, prevent co-mingling, and determine GM-status. Last, this scenario assumes that the lessened dockage for weed seeds will reduce farm income only $0.80 per acre, or about $0.02 per bushel.

The total impact on per acre costs, income and profit or losses is presented for the two scenarios in Tables 12 and 13. First, the basis for the cost and income-related estimates in each of these areas is presented. To the fullest extent possible, official USDA cost, yield, and market price data are used in constructing the projections.

Seed

Seventy percent of spring wheat growers plant their own seed. As a result, the cash cost of seed for these farmers equals the market price of wheat, $3.50 per bushel, plus the cost of cleaning, which is about $0.75 per bushel. The typical seeding rate is assumed to be 1.5 bushels per acre, leading to a per acre seed cost of $6.38. The projected market price for wheat of $3.50 per bushel is used in all aspects of the projections and is based on the USDA's projections in recent *Wheat Outlook* report (see Figure 4) (Vocke et al., 2004).

Following adoption of RR wheat, it is assumed that 70% of acreage will continue to be planted to conventional varieties. Of this portion of total wheat industry acres, it is assumed that 70% will be planted to seed saved by farmers at an average cost of $6.38 per acre. The 30% of farmers planting conventional seeds that are purchased will spend an estimated $9.00 per bushel, or $13.50 per acre assuming a 1.5 bushel per acre seeding rate.

Farmers who adopt Roundup Ready wheat will be required to sign a technology agreement that prohibits both the planting of wheat harvested from a RR field and the selling or trading of the seed to another wheat farmer. For this reason, farmers growing RR wheat will face significantly higher seed costs.

Analyses, commentaries, and reports on the economics of RR wheat typically include estimates of the premium that will be charged for RR wheat seed. While Monsanto never announced officially what premium it would seek, most estimates fall in the $10.00 to $15.00 per acre range.

A story in the December 11, 2000 *Oregonian* newspaper quotes the then-chairman of U.S. Wheat Associates speculating that Monsanto will likely set the technology fee for RR wheat at about $10.00 per acre. Canadian farmers are charged a $15.00 technology fee per acre of RR canola.

A Monsanto brochure claims that field tests showed an average 10% yield increase worth about $10.00 per acre. Monsanto also projects that there will be reduced dockage with RR wheat worth up to $2.73 per acre. Accordingly, Monsanto has claimed direct economic benefits over $12.00 per acre.

In the "Optimistic" scenario, it is assumed that farmers will pay a $10.00 per acre premium for RR seed, above the costs of purchased conventional seed. In the "Pessimistic" scenario, a seed premium of $15.00 is projected. These premiums encompass the technology fee that Monsanto has been charging all farmers planting its GE plant varieties. Given the complex diversity of ways that Monsanto is now licensing its RR technology traits to seed companies, it has become difficult to sort out the magnitude of the technology fee in contrast to other premiums and incentive programs that impact the price of seed.

In general, Monsanto and other GE seed suppliers set the technology fee based on what the market will bear. Farmers' willingness to pay more for RR wheat seed rests, in turn, on the perceived benefits of the RR system compared to other alternative systems.

Table 9.

CLEARFIELD System Wheat Return on Investment Calculator:
Grower Break Even Analysis

Category	Conventional	CLEARFIELD*	Comments
Seed Cost ($/ac)	6.5	8.25	Avg. Central Plains price/acre
Herbicide Cost ($/ac)	5	20	Avg. Central Plains price/acre
Program Costs ($/ac)	11.5	28.25	Seed + herbicide cost ($/ac)
Less Certified Seed Bonus ($/ac)	0	2	Valid on CLEARFIELD* seed + Beyond™ treated acres
Adjusted Program Costs ($/ac)	11.5	26.25	
Net Difference ($/ac)		14.75	Difference in Conventional and CLEARFIELD* Program
Avg. Net Price for Wheat ($/bu)	3.88	3.88	Net $/bu on grower basis
Break Even Point (bu/ac)		3.801546392	Net difference in program costs ($/ac) /Avg. Net Price ($/bu)
Avg. Wheat Yield (bu/ac)	40	40	
Production Break Even (%)		0.095038659	Break even point (bu/ac)/Avg. wheat yield (bu/ac)

* Example assumes no yield loss if CL System is not used

Farmers looking for herbicide-tolerant wheat options can choose BASF's CLEARFIELD System – conventionally-bred spring wheat that is tolerant to the imidazolinone herbicide Beyond. The CLEARFIELD System technology agreement forbids the replanting of harvested wheat and also strongly encourages farmers to only use BASF's Beyond herbicide. While farmers can apply other imidazolinone herbicides on CLEARFIELD wheat, doing so nullifies the warranty and, according to BASF, "greatly increases the risk of outcrossing to, and subsequent imidazolinone resistance in jointed goatgrass." The terms of the "Wheat Stewardship Grower Agreement" go on to say, in fine print, that farmers who violate the terms of the agreement by selling seed or replanting it –

"…*agree that damages will include liquidated damages of $100 per acre for the acres of unauthorized CLEARFIELD seed involved.*"

CLEARFIELD wheat was introduced commercially in 2004, and too few seed dealers or farmers have used it to provide solid estimates of costs. Colorado State University specialists developed a "CLEARFIELD Wheat ROI (Return on Investment) Calculator" to allow growers to carry out break-even analyses. Table 9 presents the basic projected costs of the system and the "Break Even Point" – 3.8 additional bushels per acre, or about a 10 percent increase in average yields.

The CLEARFIELD System is projected to increase seed plus herbicide costs from $11.50 to $28.25 per acre, or by 2.5 fold. The increase of $16.75 per acre is significant and reflects 12% of the current revenue from a 40-bushel harvest per acre, based on the projected $3.50 per bushel market price (Vocke et al., 2004). The USDA's Economic Research Service projected total Northern Great Plains wheat farm operating costs (seed, fertilizer, chemicals, fuel, repairs, custom work) at $49.32 in 2002 and $60.33 in 2003, a wetter year with higher yields and higher rates of fertilization. Accordingly, the increase in costs associated with the CLEARFIELD System is one-quarter to one-third of cash operating costs.

When land and other overhead costs are taken into account, ERS estimated that wheat farmers lost $77.10 per acre in 2002 and $53.16 in 2003, before government payments. Government payments were made to wheat farmers on the order of $30.00 to $50.00 per planted acre in 2001-2003. Accordingly, adoption of the CLEARFIELD System, or other genetically modified herbicide tolerant technology with comparable added costs, will increase the cost of government price and income support programs by about one-third to one-half in order to assure farmers the same level of return per acre (or no greater loss per acre).

Herbicides

Cost of production data compiled by the USDA projected chemical costs in the Northern Great Plains region of $10.05 per acre in 2003. This cost estimate is used in both scenarios in calculating costs on farms planting conventional seeds.

TABLE 10.

Herbicide Use and Expenditures per Acre Under Two Scenarios Following Widespread Adoption of Roundup Ready Spring Wheat

	Percent of RR Wheat Acres Treated	Rate per Acre (lds a.i.)	Number of Applications	Pounds Applied	Price per Pound of A.I.	Cost per Acre
Pre-RR Wheat Baseline						
All herbicides			2.7	0.56	$ 17.95	$ 10.05
Optimistic Scenario						
Glyphosate	100%	0.6	1.1	0.66	$ 10.00	$ 6.60
Other herbicides	40%	0.3	1	0.3	$ 4.00	$ 1.20
Acres Treated With Two Herbicides			2.1	0.96		$ 7.80
Average all RR Acres			1.5	0.78		$ 7.13
Pessimistic Scenario						
Glyphosate	100%	0.75	1.65	1.24	$ 11.00	$ 13.61
Other herbicides	80%	0.3	1	0.3	$ 4.50	$ 1.35
Acres Treated With Two Herbicides			2.65	1.54		$ 14.96
Average all RR Acres			2.45	1.48		$ 14.48

Table 10 sets forth the herbicide use and expenditure assumptions used in the two scenarios. Under the "Optimistic" scenario, only 10% of farmers have to apply a second application of Roundup – about what happened in the early years of adoption of RR soybeans. The average rate applied is on the low end of expectations, at 0.6 pounds of active ingredient per acre. The price per pound edges downward from the average price of $10.83 per pound in 2003 (National Agricultural Statistics Service 2004).

A projected 40% of the acres planted to RR varieties will be treated with a second herbicide active ingredient applied, on average, at 0.3 pounds per acre. The cost of these other herbicide applications is placed at the average of today's market leaders – MCPA and 2,4-D. On this 40% of the acres planted to RR varieties, the average cost of herbicides per acre is estimated at $7.80.

The last step involves calculating an industry-wide, weighted average cost of herbicides per acre, based on the assumption that 60% of the acres entail herbicide expenditures of $6.60 and 40% require herbicide applications costing $7.80. This weighted average cost per acre under the "Optimistic" scenario is $7.13.

Accordingly, compared to the pre-RR wheat baseline, each acre planted to RR wheat under the "Optimistic" scenario will reduce herbicide expenditures by about $3.92 per acre, while the average pounds of herbicides per acre would increase by 0.22 pounds, or about 40%. The increase in pounds applied reflects the fact that glyphosate is a relatively high-dose herbicide compared to the current spring wheat market leaders, which are applied at about 0.3 pounds per acre.

Under the "Pessimistic" scenario, the average rate of glyphosate application rises to 0.75 pound per acre and 65% of the RR acres require two glyphosate applications. Accordingly, the amount of glyphosate applied increases to 1.24 pounds of active ingredient. In addition, a projected 80% of RR wheat acres are treated with another herbicide, at a marginally higher price per pound compared to the "Optimistic" scenario.

Compared to the baseline, the cost of herbicides would rise $4.43/acre, or by about 44%, under the "Pessimistic" scenario. The pounds of herbicides applied would increase 0.92 pounds per acre, or 1.6 times higher than in the baseline. These changes in herbicide use patterns under RR wheat are roughly similar to those that have occurred in conjunction with widespread planting of RR corn, soybeans, and cotton (Benbrook, 2004).

DOCKAGE AND YIELDS

Currently, dockage for weed seeds in harvested grain costs spring wheat growers about $4.00 per acre on average, or $0.10 per bushel based on a 40-bushel average yield. Some of Monsanto's promotional literature for RR wheat has claimed that the technology will reduce dockage triggered by the presence of weed seeds in harvested wheat enough to increase per acre returns by $2.73 (i.e., dockage would decline from $4.00 to $1.27 per acre). Under the "Optimistic" scenario, it is assumed that farmers planting RR wheat will reduce dockage charges by $2.00 per acre, increasing wheat prices by about $0.05 per bushel.

Under the "Pessimistic" scenario, the savings through reduced dockage declines to $0.02 cents per bushel, or by about $0.80 per acre.

While Monsanto has projected about a 10% yield increase with RR wheat, there is no evidence in the open scientific literature to support such a significant increase. Given the likely increase in RR wheat fields of *Fusarium* head blight and possibly other root diseases, such a sizable increase in yields seems even less plausible.

The impacts of RR wheat on yields will be a function of two impacts: the degree to which improved weed control increases yields, if at all, and second, the extent to which heightened disease pressure, or other factors, reduces yields, if at all.

Under the "Optimistic" scenario on acres planted to RR wheat, a 4% increase in yields from improved weed control is assumed, along with a 1% decline in yields linked to disease pressure, for a net increase of 3%. In the "Pessimistic" scenario, the percentages are reversed. The yield increase from improved weed control is placed at 1% and the decline from heightened disease is projected at 4%, for a net decline of 3% per acre.

Table 11.

Hard Red Spring Wheat Baseline Projections
Based on Average 40 Bushel Yields and
No Planting of Roundup Ready Wheat

	Average per Bushel	Average per Acre
Inputs		
Seed Costs	$ 0.21	$ 8.51
Herbicide Costs	$ 0.25	$ 10.05
Subtotal	**$ 0.46**	**$ 18.56**
Factors Impacting Income		
Market Price/Income	$ 3.50	$ 140.00
Dockage	$ (0.10)	$ (4.00)
Income to Farmer	**$ 3.40**	**$ 136.00**
Income Minus Seed Plus Herbicide Costs	**$ 2.94**	**$ 117.44**

Grain Quality and Price

The impact of RR wheat on the distribution of protein levels, quality grades, percent of *Fusarium* damaged kernels, mycotoxin levels, and market price is difficult to project, yet is potentially of considerable significance.

Under the "Optimistic" scenario, these grain-quality-related problems surface relatively infrequently and are well managed by farmers, the grain trade, and hence are accommodated by the market without significant disruption. Collectively, they account for just a 3% reduction in market price from the $3.50 baseline.

In the "Pessimistic" scenario, the *Fusarium*-related problems arise somewhat more frequently and are moderately more severe. In addition, the response to them is somewhat less successful and the market response is greater. As a result, market prices are projected to drop 6% compared to the $3.50 baseline.

Market Rejection

The estimate by Wisner that approval of RR wheat would trigger a loss of up to one-third to one-half of today's export sales and a 33% decline in average market prices clearly played a role in solidifying the opposition in the wheat industry to approval of the technology under the current circumstances. It remains unlikely that the technology will be adopted until these projected impacts are substantially reduced.

TABLE 12.

"Optimistic" Scenario Projections of Spring Wheat Input Use, Expenditures, Market Prices, Yields, and Net Income

	Percent of Total Spring Wheat Acres Planted	Average per Bushel	Average per Acre
Portion of Wheat Acres Not Planted to RR Varieties	70%		
Seed Costs		$ 0.21	$ 8.51
Herbicide Costs		$ 0.25	$ 10.05
Subtotal		**$ 0.46**	**$ 18.56**
Yield			**40**
Impact of Market Rejection on Price		-4%	
Market Price		$ 3.36	
Dockage Impact on Price		$ (0.10)	$ (4.00)
Net Income to Farmer		$ 3.26	$ 130.40
Net Income Minus Seed Plus Herbicide Costs		**$ 2.80**	**$ 111.84**
Portion of Wheat Acres Planted to RR Varieties	30%		
Seed Costs		$ 0.45	$ 18.51
Herbicide Costs		$ 0.17	$ 7.13
Subtotal		**$ 0.62**	**$ 25.64**
Yield (3% increase)			**41.2**
Impact of Grain Quality on Price		-3%	
Impact of Market Rejection on Price		-4%	
Market Price		$ 3.26	
Dockage		$ (0.05)	$ (2.00)
Net Income to Farmer		$ 3.21	$ 132.05
Net Income Minus Seed Plus Herbicide Costs		**$ 2.58**	**$ 106.41**
Weighted Averages Across All Wheat Acres			
Seed Costs		$ 0.28	$ 11.51
Herbicide Costs		$ 0.22	$ 9.17
Subtotal		**$ 0.51**	**$ 20.68**
Yield			**40.36**
Net Income to Farmer		$ 3.24	$ 130.89
Net Income Minus Seed Plus Herbicide Costs		**$ 2.74**	**$ 110.21**

If these projected impacts were substantially reduced, increasing the likelihood that the technology will gain regulatory approval and adoption by farmers, there would still likely be some price reduction due to market rejection. Under the "Optimistic" scenario, it is assumed that market rejection will trigger just a 4% decline in average prices below the $3.50 per bushel baseline level. Under the "Pessimistic" scenario, significantly more buyers would look elsewhere for GM-free wheat and prices would decline 10% in the United Sates.

IMPACTS OF SCENARIOS ON FARM INCOME

The economic impacts of widespread adoption of RR wheat are projected under two scenarios, each compared to a pre-RR wheat baseline.

Table 11 presents the pre-RR wheat baseline and projects yields of 40 bushels per acre, a market price of $3.40 per bushel after estimated dockage of $0.10 per bushel, and gross income to the farmer of $136.00 per acre. After subtracting seed and herbicides costs, the projected net income per acre is $117.44. This figure does not include any land costs, the costs associated with tillage, planting, and harvest, or other direct and indirect costs. All other "Net Income" estimates in the tables that follow also exclude these other significant direct and indirect costs.

The results of the "Optimistic" scenario are set forth in Table 12, assuming that 30% of total red spring wheat acreage is planted to RR varieties. Here costs and returns are estimated separately for the 70% of acreage planted to conventional varieties. These costs equal the baseline scenario, except for the impact of the planting of RR wheat on wheat prices. On average, farmers not planting RR varieties would lose $5.60 per acre in income as a result of the 4% decline in average market prices.

On the 30% of acres planted to RR varieties, the market price would drop from $3.26 to $3.21. Income per acre would fall $3.95 compared to farmers not planting RR wheat, because of the net impacts of the yield increase and the drop in market price and dockage. After taking into account the added cost of seed and herbicides, net cash returns to the 30% of farmers planting RR wheat decline $5.43 per acre compared to the 70% of farmers not planting RR wheat in the "Optimistic" scenario.

The bottom section of Table 12 calculates the industry-wide impact of the adoption of RR wheat. These estimates represent an average across the wheat acres planted and not planted to RR wheat varieties, weighted by the portion of total acres planted to conventional and RR varieties. The same weighted average impacts appear in the following two tables.

Industry-wide under the "Optimistic" scenario, net farm income (after subtracting seed and herbicide costs) is projected to be $110.21 per acre, $7.23 less than in the No-RR wheat baseline.

Individual farmers and the industry as a whole would fair markedly worse under the "Pessimistic" scenario, as shown in Table 13. In this scenario, market rejection lowers prices 10% for all growers.

On the 30% of acres planted to RR wheat, there is a net 3% decrease in average yields, reflecting the assumption that yields increase by only 1% because of improved weed control, but fall 4% because of increased disease pressure.

In the "Pessimistic" scenario, there is an average 6% drop in wheat price on the acres planted to RR wheat, triggered by a combination of lower levels of protein and higher levels of *Fusarium* damaged kernels

Table 13.

"Pessimistic" Scenario Projections of Spring Wheat Input Use, Expenditures, Market Prices, Yields, and Net Income

	Percent of Total Spring Wheat Acres Planted	Average per Bushel	Average per Acre
Portion of Wheat Acres Not Planted to RR Varieties	70%		
Seed Costs		$ 0.21	$ 8.51
Herbicide Costs		$ 0.25	$ 10.05
Subtotal		**$ 0.46**	**$ 18.56**
Yield			**40**
Impact of Market Rejection on Price		-10%	
Market Price		$ 3.15	
Dockage Impact on Price		$ (0.10)	$ (4.00)
Net Income to Farmer		$ 3.05	$ 122.00
Net Income Minus Seed Plus Herbicide Costs		**$ 2.59**	**$ 103.44**
Portion of Wheat Acres Planted to RR Varieties	30%		
Seed Costs		$ 0.48	$ 18.51
Herbicide Costs		$ 0.37	$ 14.48
Subtotal		**$ 0.85**	**$ 32.99**
Yield (3% decrease)			**38.8**
Impact of Grain Quality on Price		-6%	
Impact of Market Rejection on Price		-10%	
Market Price		$ 2.94	
Dockage		$ (0.02)	$ (0.80)
Net Income to Farmer		$ 2.92	$ 113.30
Net Income Minus Seed Plus Herbicide Costs		**$ 2.07**	**$ 80.31**
Weighted Averages Across All Wheat Acres			
Seed Costs		$ 0.29	$ 11.51
Herbicide Costs		$ 0.29	$ 11.38
Subtotal		**$ 0.58**	**$ 22.89**
Yield			**39.64**
Net Income to Farmer		$ 3.01	$ 119.39
Net Income Minus Seed Plus Herbicide Costs		**$ 2.43**	**$ 96.50**

Table 14.

Impacts of the Widespread Adoption of Roundup Ready Hard Red Spring Wheat on Per Acre and Industry-Wide Income from Wheat Sales Under Two Scenarios Compared to the No-RR Baseline

	Average per Bushel	Average per Acre
No-Roundup Ready Baseline		
Average Yield (bushels)		40
Seed plus Herbicides Costs	$ 0.46	$ 18.56
Net Income to Farmer	$ 3.40	$ 136.00
Net Income Minus Seed Plus Herbicide Costs	**$ 2.94**	**$ 117.44**
"Optimistic" Scenario: Industry Wide		
Average Yield (bushels)		40.4
Seed plus Herbicides Costs	$ 0.52	$ 20.68
Net Income to Farmer	$ 3.24	$ 130.89
Net Income Minus Seed Plus Herbicide Costs	**$ 2.74**	**$ 110.21**
"Pessimistic" Scenario: Industry Wide		
Average Yield (bushels)		39.64
Seed plus Herbicides Costs	$ 0.59	$ 22.89
Net Income to Farmer	$ 3.01	$ 119.39
Net Income Minus Seed Plus Herbicide Costs	**$ 2.44**	**$ 96.50**
Industry-Wide Impacts in the "Optimistic" Scenario Compared to No-RR Baseline		
Average Change in Yield (bushels)		0.4
Change in Seed plus Herbicides Costs	$ 0.06	$ 2.12
Change in Net Income to Farmer	$ (0.16)	$ (5.11)
Change in Net Income Minus Seed Plus Herbicide Costs	**$ (0.20)**	**$ (7.23)**
Industry-Wide Impacts in the "Pessimistic" Scenario Compared to No-RR Baseline		
Average Yield (bushels)		-0.36
Change in Seed plus Herbicides Costs	$ 0.13	$ 4.33
Change in Net Income to Farmer	$ (0.39)	$ (16.61)
Change in Net Income Minus Seed Plus Herbicide Costs	**$ (0.50)**	**$ (20.94)**

and mycotoxins, as well as new charges for segregation and testing. Savings from reduced dockage is projected to fall to $0.80 per acre, or $0.02 per bushel.

As a result of these developments, net farm income under the "Pessimistic" scenario drops to $96.50 per acre across the whole industry. This drop represents a $20.94 decline from the pre-RR wheat baseline, or 18%.

The farmers planting RR wheat under the "Pessimistic" scenario would lose $37.13 per acre compared to the No-RR wheat baseline, a 31% drop.

Table 14 summarizes the impacts of the two scenarios relative to the pre-RR wheat baseline. Across the whole industry, the "Optimistic" scenario loss of $7.23 per acre would translate into a total loss of $94,000,000 based on USDA's recent estimate of 13 million acres planted to hard red spring wheat varieties in 2004 (Vocke et al., 2004).

The impacts of the "Pessimistic" scenario are far greater, and could reach a projected $272,000,000 annual loss of income across 13 million acres planted. The prospect of losses of this magnitude lies behind the broad-based industry opposition to the commercialization of RR spring wheat.

The projections offered in these two scenarios are obviously only rough estimates, but the assumptions were selected with the goal of providing a sense of the possible economic impacts under two extreme, but plausible scenarios. In all likelihood, the actual economic impacts on the hard red spring wheat industry, following widespread adoption of RR wheat, would fall somewhere between the "Optimistic" and "Pessimistic" scenarios. For the average Northern Great Plains wheat grower, this prediction is likely of little comfort.

Appendix

Appendix Table 1.

Herbicides Applied to "Other Spring Wheat"
in 1992, 1995, 2000, and 2002: Totals by State and National

National

2002 Acres Planted = 12,700,000

2002 Acres Treated with Herbicides = 11,430,000

Active Ingredient	AI Type	Percent Acres Treated	Total Acres Treated	Number of Appls	Rate of Appl	Acre Treatments	Pounds Applied
MCPA	H	47	5,969,000	1.0	0.31	5,969,000	1,808,000
2,4-D	H	36	4,572,000	1.1	0.34	5,029,200	1,785,000
Fenoxaprop-P-ethyl	H	29	3,683,000	1.0	0.06	3,683,000	239,000
Bromoxynil	H	24	3,048,000	1.0	0.24	3,048,000	716,000
Dicamba	H	18	2,286,000	1.0	0.05	2,286,000	120,000
Glyphosate	H	15	1,905,000	1.4	0.44	2,667,000	1,235,000
Tribenuron-methyl	H	12	1,524,000	1.0	0.01	1,524,000	9,000
Thifensulfuron	H	10	1,270,000	1.0	0.01	1,270,000	14,000
Clodinafop-propargyl	H	8	1,016,000	1.0	0.04	1,016,000	46,000
Metsulfuron-methyl	H	7	889,000	1.0	0.00	889,000	3,000
Fluroxypyr	H	5	635,000	1.0	0.07	635,000	44,000
Triasulfuron	H	4	508,000	1.0	0.01	508,000	6,000
Fluroxypyr 1-methylheptyl	H	3	381,000	1.0	0.13	381,000	42,000
Acetic Acid	H	3	381,000	1.0	0.46	381,000	146,000
Tebuconazole	F	3	381,000	1.1	0.09	419,100	43,000
Bromoxynil octanoate	H	2	254,000	1.0	0.29	254,000	64,000
Propiconazole	F	2	254,000	1.0	0.09	254,000	25,000
Picloram	H	2	254,000	1.0	0.01	254,000	3,000
Clopyralid	H	2	254,000	1.0	0.08	254,000	21,000
Chlorsulfuron	H	1	127,000	1.0	0.01	127,000	1,000
					Totals	30,848,300	6,370,000

Average Acre Treatment	2.70	Average Pounds Applied per Acre	0.56

HERBICIDES APPLIED TO "OTHER SPRING WHEAT"
IN 1992, 1995, 2000, AND 2002: TOTALS BY STATE AND NATIONAL

Minnesota

2002 Acres Planted = 2,000,000

2002 Acres Treated with Herbicides = 1,800,000

Active Ingredient	AI Type	Percent Acres Treated	Total Acres Treated	Number of Appls	Rate of Appl	Acre Treatments	Pounds Applied
MCPA	H	53	1,060,000	1.0	0.33	1,060,000	351,000
Bromoxynil	H	35	700,000	1.0	0.24	700,000	170,000
Fenoxaprop-P-ethyl	H	30	600,000	1.0	0.07	600,000	42,000
2,4-D	H	20	400,000	1.0	0.43	400,000	171,000
Thifensulfuron	H	8	160,000	1.0	0.01	160,000	2,000
Tribenuron-methyl	H	7	140,000	1.0	0.01	140,000	1,000
Glyphosate	H	6	120,000	1.0	0.66	120,000	75,000
Clodinafop-propargyl	H	5	100,000	1.0	0.05	100,000	5,000
Propiconazole	F	5	100,000	1.0	0.08	100,000	7,000
					Totals	3,380,000	824,000

Average Acre Treatment	1.88	Average Pounds Applied per Acre	0.46

Montana

2002 Acres Planted = 3,750,000

2002 Acres Treated with Herbicides = 3,375,000

Active Ingredient	AI Type	Percent Acres Treated	Total Acres Treated	Number of Appls	Rate of Appl	Acre Treatments	Pounds Applied
2,4-D	H	65	2,437,500	1.2	0.34	2,925,000	997,000
Dicamba	H	32	1,200,000	1.1	0.05	1,320,000	66,000
Metsulfuron-methyl	H	22	825,000	1.0	0.00	825,000	3,000
Glyphosate	H	19	712,500	1.8	0.41	1,282,500	533,000
MCPA	H	15	562,500	1.0	0.28	562,500	155,000
Clodinafop-propargyl	H	13	487,500	1.0	0.05	487,500	22,000
Triasulfuron	H	13	487,500	1.0	0.01	487,500	6,000
Bromoxynil	H	8	300,000	1.0	0.22	300,000	66,000
Tribenuron-methyl	H	7	262,500	1.0	0.01	262,500	1,000
Thifensulfuron	H	5	187,500	1.0	0.01	187,500	1,000
Chlorsulfuron	H	4	150,000	1.0	0.01	150,000	1,000
Fenoxaprop-P-ethyl	H	4	150,000	1.0	0.05	150,000	9,000
					Totals	8,940,000	1,860,000

Average Acre Treatment	2.65	Average Pounds Applied per Acre	0.55

Appendix Table 1. *(continued)*

Herbicides Applied to "Other Spring Wheat"
in 1992, 1995, 2000, and 2002: Totals by State and National

North Dakota

2002 Acres Planted = 6,900,00

2002 Acres Treated with Herbicides = 6,210,000

Active Ingredient	AI Type	Percent Acres Treated	Total Acres Treated	Number of Appls	Rate of Appl	Acre Treatments	Pounds Applied
MCPA	H	62	4,278,000	1.0	0.30	4,278,000	1,302,000
Fenoxaprop-P-ethyl	H	42	2,898,000	1.0	0.06	2,898,000	189,000
Bromoxynil	H	30	2,070,000	1.0	0.23	2,070,000	480,000
2,4-D	H	26	1,794,000	1.0	0.34	1,794,000	617,000
Glyphosate	H	16	1,104,000	1.0	0.56	1,104,000	628,000
Tribenuron-methyl	H	16	1,104,000	1.0	0.01	1,104,000	7,000
Thifensulfuron	H	13	897,000	1.0	0.01	897,000	11,000
Fluroxypyr	H	7	483,000	1.0	0.07	483,000	31,000
Clodinafop-propargyl	H	7	483,000	1.0	0.04	483,000	19,000
Fluroxypyr 1-methylheptyl	H	4	276,000	1.0	0.13	276,000	37,000
					Totals	15,387,000	3,321,000

Average Acre Treatment	2.48	Average Pounds Applied per Acre	0.53

HERBICIDES APPLIED TO "OTHER SPRING WHEAT"
IN 1992, 1995, 2000, AND 2002: TOTALS BY STATE AND NATIONAL

National

2000 Acres Planted = 13,800,000

2000 Acres Treated with Herbicides = 12,420,000

Active Ingredient	AI Type	Percent Acres Treated	Total Acres Treated	Number of Appls	Rate of Appl	Acre Treatments	Pounds Applied
2,4-D	H	45	6,210,000	1.0	0.33	6,210,000	2,137,000
MCPA	H	44	6,072,000	1.0	0.34	6,072,000	2,072,000
Fenoxaprop-P-ethyl	H	27	3,726,000	1.0	0.08	3,726,000	302,000
Bromoxynil	H	26	3,588,000	1.0	0.24	3,588,000	871,000
Dicamba	H	25	3,450,000	1.2	0.09	4,140,000	383,000
Glyphosate	H	20	2,760,000	1.5	0.41	4,140,000	1,707,000
Tribenuron-methyl	H	15	2,070,000	1.0	0.01	2,070,000	23,000
Clopyralid	H	14	1,932,000	1.0	0.10	1,932,000	179,000
Tebuconazole	F	9	1,242,000	1.0	0.06	1,242,000	72,000
Triasulfuron	H	9	1,242,000	1.0	0.02	1,242,000	21,000
Tri-allate	H	9	1,242,000	1.0	1.08	1,242,000	1,301,000
Tralkoxydim	H	7	966,000	1.0	0.19	966,000	189,000
Trifluralin	H	6	828,000	1.0	0.34	828,000	287,000
Thifensulfuron	H	4	552,000	1.0	0.01	552,000	7,000
Fluroxypyr	H	3	414,000	1.0	0.15	414,000	62,000
Metsulfuron-methyl	H	3	414,000	1.0	0.00	414,000	1,000
Picloram	H	2	276,000	1.0	0.01	276,000	3,000
Imazamethabenz	H	1	138,000	1.0	0.37	138,000	69,000
					Totals	39,192,000	9,686,000

Average Acre Treatment	3.16	Average Pounds Applied per Acre	0.78

Appendix Table 1. (continued)

Herbicides Applied to "Other Spring Wheat"

in 1992, 1995, 2000, and 2002: Totals by State and National

Minnesota

2000 Acres Planted = 2,000,000

2000 Acres Treated with Herbicides = 1,800,000

Active Ingredient	AI Type	Percent Acres Treated	Total Acres Treated	Number of Appls	Rate of Appl	Acre Treatments	Pounds Applied
MCPA	H	75	1,500,000	1.0	0.45	1,500,000	676,000
Clopyralid	H	45	900,000	1.0	0.10	900,000	90,000
Fenoxaprop-P-ethyl	H	28	560,000	1.0	0.06	560,000	36,000
Bromoxynil	H	25	500,000	1.0	0.24	500,000	119,000
2,4-D	H	11	220,000	1.0	0.35	220,000	78,000
Thifensulfuron	H	7	140,000	1.0	0.01	140,000	2,000
Tribenuron-methyl	H	7	140,000	1.0	0.01	140,000	840
Dicamba	H	3	60,000	1.0	0.10	60,000	6,000
					Totals	4,020,000	1,007,840

Average Acre Treatment	2.23	Average Pounds Applied per Acre	0.56

Montana

2000 Acres Planted = 3,350,000

2000 Acres Treated with Herbicides = 3,015,000

Active Ingredient	AI Type	Percent Acres Treated	Total Acres Treated	Number of Appls	Rate of Appl	Acre Treatments	Pounds Applied
2,4-D	H	63	2,110,500	1.1	0.34	2,321,550	845,000
Glyphosate	H	42	1,407,000	1.9	0.29	2,673,300	807,000
Triasulfuron	H	39	1,306,500	1.0	0.02	1,306,500	21,000
Dicamba	H	38	1,273,000	1.7	0.11	2,164,100	245,000
Tri-allate	H	21	703,500	1.0	1.14	703,500	782,000
MCPA	H	13	435,500	1.0	0.26	435,500	114,000
Bromoxynil	H	8	268,000	1.0	0.23	268,000	63,000
Metsulfuron-methyl	H	6	201,000	1.0	0.01	201,000	1,000
Tribenuron-methyl	H	4	134,000	1.0	0.01	134,000	1,000
					Totals	10,207,450	2,879,000

Average Acre Treatment	3.39	Average Pounds Applied per Acre	0.95

HERBICIDES APPLIED TO "OTHER SPRING WHEAT"
IN 1992, 1995, 2000, AND 2002: TOTALS BY STATE AND NATIONAL

North Dakota

2000 Acres Planted = 6,800,000

2000 Acres Treated with Herbicides = 6,120,000

Active Ingredient	AI Type	Percent Acres Treated	Total Acres Treated	Number of Appls	Rate of Appl	Acre Treatments	Pounds Applied
MCPA	H	53	3,604,000	1.0	0.31	3,604,000	1,130,000
2,4-D	H	43	2,924,000	1.0	0.32	2,924,000	938,000
Bromoxynil	H	40	2,720,000	1.0	0.24	2,720,000	652,000
Fenoxaprop-P-ethyl	H	40	2,720,000	1.0	0.09	2,720,000	238,000
Tribenuron-methyl	H	25	1,700,000	1.0	0.01	1,700,000	20,000
Dicamba	H	21	1,428,000	1.0	0.06	1,428,000	86,000
Clopyralid	H	11	748,000	1.0	0.09	748,000	73,000
Trifluralin	H	11	748,000	1.0	0.34	748,000	248,000
Fluroxypyr	H	6	408,000	1.0	0.15	408,000	61,000
Glyphosate	H	5	340,000	1.1	0.53	374,000	182,000
Tralkoxydim	H	3	204,000	1.0	0.17	204,000	36,000
					Totals	17,578,000	3,664,000

Average Acre Treatment 2.87

Average Pounds Applied per Acre 0.60

South Dakota

2000 Acres Planted = 1,650,000

2000 Acres Treated with Herbicides = 1,485,000

Active Ingredient	AI Type	Percent Acres Treated	Total Acres Treated	Number of Appls	Rate of Appl	Acre Treatments	Pounds Applied
2,4-D	H	56	924,000	1.0	0.30	924,000	276,000
Dicamba	H	42	693,000	1.0	0.07	693,000	46,000
MCPA	H	30	495,000	1.0	0.31	495,000	152,000
Clopyralid	H	12	198,000	1.0	0.08	198,000	16,000
Thifensulfuron	H	11	181,500	1.0	0.01	181,500	2,000
Tribenuron-methyl	H	11	181,500	1.0	0.01	181,500	1,000
Metsulfuron-methyl	H	10	165,000	1.0	0.00	165,000	495
Bromoxynil	H	8	132,000	1.0	0.27	132,000	37,000
					Totals	2,970,000	530,495

Average Acre Treatment 2.00

Average Pounds Applied per Acre 0.36

Appendix Table 1. (continued)

Herbicides Applied to "Other Spring Wheat"
in 1992, 1995, 2000, and 2002: Totals by State and National

National

1995 Acres Planted = 15,800,000

1995 Acres Treated with Herbicides = 14,220,000

Active Ingredient	AI Type	Percent Acres Treated	Total Acres Treated	Number of Appls	Rate of Appl	Acre Treatments	Pounds Applied
2,4-D	H	54	8,532,000	1.0	0.35	8,532,000	3,083,000
MCPA	H	39	6,162,000	1.1	0.35	6,778,200	2,288,000
dicamba	H	30	4,740,000	1.0	0.07	4,740,000	309,000
tribenuron-methyl	H	25	3,950,000	1.0	0.01	3,950,000	25,000
thifensulfuron-methyl	H	16	2,528,000	1.0	0.01	2,528,000	31,000
fenoxaprop-P-ethyl	H	15	2,370,000	1.0	0.08	2,370,000	203,000
bromoxynil	H	9	1,422,000	1.0	0.27	1,422,000	372,000
triasulfuron	H	7	1,106,000	1.0	0.02	1,106,000	18,000
imazamethabenz	H	6	948,000	1.0	0.35	948,000	316,000
clopyralid	H	4	632,000	1.0	0.10	632,000	64,000
trifluralin	H	4	632,000	1.0	0.46	632,000	285,000
metsulfuron-methyl	H	4	632,000	1.0	0.00	632,000	3,000
tri-allate	H	4	632,000	1.0	0.90	632,000	630,000
					Totals	34,902,200	7,627,000

Average Acre Treatment	2.45	Average Pounds Applied per Acre	0.54

Appendix Table 1. (continued)

Herbicides Applied to "Other Spring Wheat"
in 1992, 1995, 2000, and 2002: Totals by State and National

Minnesota

1995 Acres Planted = 2,250,000

1995 Acres Treated with Herbicides = 2,025,000

Active Ingredient	AI Type	Percent Acres Treated	Total Acres Treated	Number of Appls	Rate of Appl	Acre Treatments	Pounds Applied
MCPA	H	62	1,395,000	1.1	0.31	1,534,500	469,000
tribenuron-methyl	H	46	1,035,000	1.1	0.01	1,138,500	6,000
thifensulfuron-methyl	H	44	990,000	1.1	0.01	1,089,000	12,000
2,4-D	H	35	787,500	1.1	0.34	866,250	288,000
fenoxaprop-P-ethyl	H	33	742,500	1.0	0.08	742,500	62,000
bromoxynil	H	24	540,000	1.0	0.25	540,000	136,000
imazamethabenz	H	22	495,000	1.0	0.38	495,000	191,000
clopyralid	H	14	315,000	1.0	0.10	315,000	31,000
					Totals	6,720,750	1,195,000

Average Acre Treatment	3.32	Average Pounds Applied per Acre	0.59

Montana

1995 Acres Planted = 3,950,000

1995 Acres Treated with Herbicides = 3,555,000

Active Ingredient	AI Type	Percent Acres Treated	Total Acres Treated	Number of Appls	Rate of Appl	Acre Treatments	Pounds Applied
2,4-D	H	76	3,002,000	1.0	0.39	3,002,000	1,223,000
dicamba	H	63	2,488,500	1.0	0.06	2,488,500	153,000
triasulfuron	H	18	711,000	1.0	0.01	711,000	10,000
tri-allate	H	11	434,500	1.0	0.99	434,500	423,000
metsulfuron-methyl	H	8	316,000	1.0	0.00	316,000	1,000
MCPA	H	8	316,000	1.0	0.32	316,000	108,000
					Totals	7,268,000	1,918,000

Average Acre Treatment	2.04	Average Pounds Applied per Acre	0.54

HERBICIDES APPLIED TO "OTHER SPRING WHEAT"
IN 1992, 1995, 2000, AND 2002: TOTALS BY STATE AND NATIONAL

North Dakota

1995 Acres Planted = 8,300,000

1995 Acres Treated with Herbicides = 7,470,000

Active Ingredient	AI Type	Percent Acres Treated	Total Acres Treated	Number of Appls	Rate of Appl	Acre Treatments	Pounds Applied
2,4-D	H	50	4,150,000	1.0	0.33	4,150,000	1,365,000
MCPA	H	49	4,067,000	1.1	0.36	4,473,700	1,576,000
tribenuron-methyl	H	30	2,490,000	1.0	0.01	2,490,000	17,000
dicamba	H	20	1,660,000	1.0	0.07	1,660,000	109,000
fenoxaprop-P-ethyl	H	17	1,411,000	1.0	0.08	1,411,000	116,000
thifensulfuron-methyl	H	14	1,162,000	1.0	0.01	1,162,000	15,000
bromoxynil	H	9	747,000	1.0	0.29	747,000	208,000
trifluralin	H	7	581,000	1.0	0.45	581,000	249,000
					Totals	16,674,700	3,655,000

Average Acre Treatment	2.23	Average Pounds Applied per Acre	0.49

South Dakota

1995 Acres Planted = 1,250,000

1995 Acres Treated with Herbicides = 1,125,000

Active Ingredient	AI Type	Percent Acres Treated	Total Acres Treated	Number of Appls	Rate of Appl	Acre Treatments	Pounds Applied
2,4-D	H	47	587,500	1.0	0.35	587,500	207,000
dicamba	H	31	387,500	1.0	0.08	387,500	29,000
MCPA	H	29	362,500	1.0	0.38	362,500	136,000
tribenuron-methyl	H	24	300,000	1.0	0.01	300,000	2,000
thifensulfuron-methyl	H	22	275,000	1.0	0.01	275,000	3,000
metsulfuron-methyl	H	15	187,500	1.0	0.00	187,500	1,000
fenoxaprop-P-ethyl	H	14	175,000	1.0	0.10	175,000	16,000
					Totals	2,275,000	394,000

Average Acre Treatment	2.02	Average Pounds Applied per Acre	0.35

APPENDIX TABLE 1. (CONTINUED)

HERBICIDES APPLIED TO "OTHER SPRING WHEAT" *IN 1992, 1995, 2000, AND 2002: TOTALS BY STATE AND NATIONAL*

National

1992 Acres Planted = 17,400,000

1992 Acres Treated with Herbicides = 15,660,000

Active Ingredient	AI Type	Percent Acres Treated	Total Acres Treated	Number of Appls	Rate of Appl	Acre Treatments	Pounds Applied
2,4-D	H	52	9,048,000	1.0	0.31	9,048,000	2,867,000
MCPA	H	37	6,438,000	1.1	0.33	7,081,800	2,198,000
dicamba	H	29	5,046,000	1.0	0.07	5,046,000	372,000
tribenuron-methyl	H	13	2,262,000	1.0	0.01	2,262,000	17,000
bromoxynil	H	10	1,740,000	1.0	0.23	1,740,000	399,000
fenoxaprop-P-ethyl	H	8	1,392,000	1.0	0.06	1,392,000	85,000
thifensulfuron	H	7	1,218,000	1.0	0.01	1,218,000	15,000
metsulfuron-methyl	H	6	1,044,000	1.0	0.00	1,044,000	4,000
trifluralin	H	4	696,000	1.0	0.39	696,000	249,000
tri-allate	H	4	696,000	1.0	0.98	696,000	632,000
mancozeb	F	3	522,000	1.2	1.32	626,400	706,000
imazamethabenz	H	2	348,000	1.0	0.31	348,000	103,000
diclofop-methyl	H	2	348,000	1.0	0.71	348,000	263,000
					Totals	31,546,200	7,910,000

Average Acre Treatment	2.01	Average Pounds Applied per Acre	0.51

Herbicides Applied to "Other Spring Wheat"
in 1992, 1995, 2000, and 2002: Totals by State and National

Minnesota

1992 Acres Planted = 2,800,000

1992 Acres Treated with Herbicides = 2,520,000

Active Ingredient	AI Type	Percent Acres Treated	Total Acres Treated	Number of Appls	Rate of Appl	Acre Treatments	Pounds Applied
MCPA	H	65	1,820,000	1.2	0.28	2,184,000	611,000
2,4-D	H	36	1,008,000	1.0	0.27	1,008,000	283,000
bromoxynil	H	33	924,000	1.0	0.23	924,000	212,000
fenoxaprop-P-ethyl	H	15	420,000	1.0	0.06	420,000	27,000
dicamba	H	11	308,000	1.1	0.07	338,800	25,000
diclofop-methyl	H	8	224,000	1.0	0.75	224,000	159,000
					Totals	5,098,800	1,317,000

Average Acre Treatment	2.02	Average Pounds Applied per Acre	0.52

Montana

1992 Acres Planted = 2,650,000

1992 Acres Treated with Herbicides = 2,385,000

Active Ingredient	AI Type	Percent Acres Treated	Total Acres Treated	Number of Appls	Rate of Appl	Acre Treatments	Pounds Applied
2,4-D	H	70	1,855,000	1.0	0.36	1,855,000	686,000
dicamba	H	55	1,457,500	1.0	0.06	1,457,500	95,000
					Totals	3,312,500	781,000

Average Acre Treatment	1.39	Average Pounds Applied per Acre	0.33

Appendix Table 1. (continued)

Herbicides Applied to "Other Spring Wheat"

in 1992, 1995, 2000, and 2002: Totals by State and National

North Dakota

1992 Acres Planted = 9,200,000

1992 Acres Treated with Herbicides = 8,280,000

Active Ingredient	AI Type	Percent Acres Treated	Total Acres Treated	Number of Appls	Rate of Appl	Acre Treatments	Pounds Applied
2,4-D	H	53	4,876,000	1.0	0.29	4,876,000	1,471,000
MCPA	H	43	3,956,000	1.0	0.35	3,956,000	1,392,000
dicamba	H	26	2,392,000	1.0	0.07	2,392,000	173,000
tribenuron-methyl	H	19	1,748,000	1.0	0.01	1,748,000	14,000
fenoxaprop-P-ethyl	H	9	828,000	1.0	0.06	828,000	54,000
thifensulfuron	H	9	828,000	1.0	0.01	828,000	9,000
bromoxynil	H	7	644,000	1.0	0.23	644,000	147,000
				Totals		15,272,000	3,260,000

Average Acre Treatment	1.84	Average Pounds Applied per Acre	0.39

South Dakota

1992 Acres Planted = 2,700,000

1992 Acres Treated with Herbicides = 2,430,000

Active Ingredient	AI Type	Percent Acres Treated	Total Acres Treated	Number of Appls	Rate of Appl	Acre Treatments	Pounds Applied
2,4-D	H	47	1,269,000	1.0	0.34	1,269,000	428,000
dicamba	H	36	972,000	1.0	0.08	972,000	79,000
MCPA	H	17	459,000	1.0	0.31	459,000	143,000
				Totals		2,700,000	650,000

Average Acre Treatment	1.11	Average Pounds Applied per Acre	0.27

Appendix Table 2.

Wheat in the Pacific Northwest

Year of First Documentation of Resistant Weeds by Family of Chemistry and State, and Total Number of Herbicides Resistant to a Given Weed and All Weeds

	Kochia	Russian Thistle	Wild oats	Italian Ryegrass	Persian Darnell	Green Foxtail	Prickly Lettuce	Spiny Sowthistle	Mayweed Chamomile	Sunflower	All Weeds
Montana											
ALS Inhibitors (B/2)	1989	1987	1996								
ACCase Inhibitors (A/1)			1990		1993						
Photosystem II Inhibitors (C1/5)											
Thiocarbamates (N/8)											
Pyrazoliums (Z/8)											
Synthetic Auxins (O/4)	1995										
Total Weed-Herbicide Combinations	**4**	**1**	**4**		**1**						**10**
North Dakota											
ALS Inhibitors (B/2)	1987		1996								
ACCase Inhibitors (A/1)			1991								
Photosystem II Inhibitors (C1/5)											
Thiocarbamates (N/8)											
Pyrazoliums (Z/8)											
Synthetic Auxins (O/4)	1995										
Dinitroanilines (K1/3)						1989					
Total Weed-Herbicide Combinations	**3**		**3**			**1**					**7**
Minnesota											
ALS Inhibitors (B/2)	1994										
ACCase Inhibitors (A/1)			1991								
Photosystem II Inhibitors (C1/5)											
Thiocarbamates (N/8)											
Pyrazoliums (Z/8)											
Synthetic Auxins (O/4)											
Total Weed-Herbicide Combinations	**3**		**1**								**4**
South Dakota											
ALS Inhibitors (B/2)	1988									1996	
ACCase Inhibitors (A/1)											
Photosystem II Inhibitors (C1/5)											
Thiocarbamates (N/8)											
Pyrazoliums (Z/8)											
Synthetic Auxins (O/4)											
Total Weed-Herbicide Combinations	**1**									**1**	**2**
Washington											
ALS Inhibitors (B/2)	1989	1987					1993	2000			
ACCase Inhibitors (A/1)			1991	1991							
Photosystem II Inhibitors (C1/5)											
Thiocarbamates (N/8)											
Pyrazoliums (Z/8)											
Synthetic Auxins (O/4)											
Total Weed-Herbicide Combinations	**1**	**1**	**1**	**1**			**1**	**2**			**7**
Idaho											
ALS Inhibitors (B/2)	1989	1990					1987		1997		
ACCase Inhibitors (A/1)			1992	1992							
Photosystem II Inhibitors (C1/5)											
Thiocarbamates (N/8)			1993								
Pyrazoliums (Z/8)			1993								
Synthetic Auxins (O/4)											
Total Weed-Herbicide Combinations	**1**	**1**	**6**	**1**			**2**		**1**		**12**

Notes: 1. In the first column listing herbicide families of chemistry, the letter-numbers in parentheses refer to the herbicide mode of action classifation system used by the Weed Science Society of America.
2. "Total Weed-Herbicide Combinations" reflect the total number of individual herbicides resistant to a given weed, and the sum across all weeds. In some cases, there are up to three herbicides in a family of chemistry resistant to a given weed.

Source: Data from the "International Survey of Resistant Weeds," an Internet-based database compiled by the Weed Science Society of America, accessible at http://www.weedscience.org

Appendix Table 3.

Hard Red Spring Wheat Herbicides

Avian (AV) Toxicity Values and Toxicity Units per Threated Acre for Currently Used (2002 - National NASS Survey) Active Ingredients

Active Ingredient	AI Type	Trade Name	Timing of Application	Target	Form Type	Other	UPAF	Avian Tox Value	UPAF Adj. Toxicity	Scaled Avian Value
Bromoxynil octonoate	H	Bronate	Post emergence	Foliar	Liquid	unspecified	1	0.0428	0.042800	100.00
Bromoxynil	H	Buctril	Post emergence	Foliar	Liquid	unspecified	1	0.0271	0.027100	63.32
2,4-D	H	2,4-D LV4	Post emergence	Foliar	Liquid	unspecified	1	0.0066	0.006600	15.42
Glyphosate (RR)	H	Honcho	Post emergence	Foliar	Liquid	unspecified	1	0.0049	0.004900	11.44
Glyphosate (conventional)	H	Honcho	Pre emergence	Soil	Liquid	unspecified	0.5	0.0049	0.002450	5.72
Dicamba	H	AgriStar Dicamba 5G	Post emergence	Foliar	Liquid	unspecified	1	0.0021	0.002100	4.91
Fluroxypyr 1-methylheptyl	H	Starane	Post emergence	Foliar	Liquid	unspecified	1	0.0017	0.001700	3.97
Clopyralid	H	Curtail	Post emergence	Foliar	Liquid	unspecified	1	0.0011	0.001100	2.57
Propiconazole	F	Tilit	Post emergence	Foliar	Liquid	unspecified	1	0.0008	0.000800	1.87
Tebuconazole	F	Folicur	Post emergence	Foliar	Liquid	unspecified	1	0.0007	0.000700	1.64
Fenoxaprop-P-ethyl	H	Puma	Post emergence	Foliar	Liquid	unspecified	1	0.0007	0.000700	1.64
MCPA	H	Rhonox MCPA	Post emergence	Foliar	Liquid	unspecified	1	0.0002	0.000200	0.47
Picloram	H	Tordon	Post emergence	Foliar	Liquid	unspecified	1	0.0001	0.000100	0.23
Chlorsulfuron	H	Glean	Post emergence	Foliar	Liquid	unspecified	1	0.0001	0.000100	0.23
Triasulfuron	H	Amber, Rave	Post emergence	Foliar	Liquid	unspecified	1	0.0001	0.000100	0.23
Thifensulfuron	H	Pinnacle	Post emergence	Foliar	Liquid	unspecified	1	0.0001	0.000100	0.23
Tribenuron-methyl	H	Express	Post emergence	Foliar	Liquid	unspecified	1	0.0001	0.000100	0.23
Chlorsulfuron	H	Glean	Pre emergence	Soil	Liquid	unspecified	0.5	0.0001	0.000050	0.12
Metsulfuron-methyl	H	Ally	Post emergence	Soil	Liquid	unspecified	0.5	0.0000	0.000020	0.05
clodinafop-propargyl	H	Discover	Post emergence	Foliar	Liquid	unspecified	1			
Acetic acid	H	Esteron	Post emergence	Foliar	Liquid	unspecified	1			

Appendix Table 4.

Hard Red Spring Wheat Herbicides

Worker Exposure (WE) Toxicity Values and Toxicity Units per Treatead Acre for Currently Used (2002 - National NASS Survey) Active Ingredients

Active Ingredient	AI Type	Trade Name	Timing of Application	Target	Form Type	Other	UPAF	LD50	Inverse LD50	Use Rate	Rate Adj. Toxicity	UPAF Adj. Toxicity	Scaled WE Toxicity Value
Bromoxynil octonoate	H	Bronate	Post emergence	Foliar	Liquid	unspecified	1	190	0.0053	0.29	0.001526	0.001526	100.00
Bromoxynil	H	Buctril	Post emergence	Foliar	Liquid	unspecified	1	190	0.0053	0.24	0.001263	0.001263	82.76
2,4-D	H	2,4-D LV4	Post emergence	Foliar	Liquid	unspecified	1	375	0.0027	0.34	0.000907	0.000907	59.40
MCPA	H	Rhonox MCPA	Post emergence	Foliar	Liquid	unspecified	1	700	0.0014	0.31	0.000443	0.000443	29.02
Acetic acid	H	Esteron	Post emergence	Foliar	Liquid	unspecified	1	1161	0.0009	0.46	0.000396	0.000396	25.96
Glyphosate (RR)	H	Honcho	Post emergence	Foliar	Liquid	unspecified	1	5000	0.0002	0.44	0.000088	0.000088	5.77
Propiconazole	F	Tilit	Post emergence	Foliar	Liquid	unspecified	1	1520	0.0007	0.09	0.000059	0.000059	3.88
Dicamba	H	AgriStar Dicamba 5G	Post emergence	Foliar	Liquid	unspecified	1	1707	0.0006	0.05	0.000029	0.000029	1.92
Fluroxypyr 1-methylheptyl	H	Starane	Post emergence	Foliar	Liquid	unspecified	1	5000	0.0002	0.13	0.000026	0.000026	1.70
Fenoxaprop-P-ethyl	H	Puma	Post emergence	Foliar	Liquid	unspecified	1	2357	0.0004	0.06	0.000025	0.000025	1.67
Tebuconazole	F	Folicur	Post emergence	Foliar	Liquid	unspecified	1	4000	0.0003	0.09	0.000023	0.000023	1.47
Clopyralid	H	Curtail	Post emergence	Foliar	Liquid	unspecified	1	4300	0.0002	0.08	0.000019	0.000019	1.22
Glyphosate	H	Honcho	Pre emergence	Soil	Liquid	unspecified	0.2	5000	0.0002	0.44	0.000018	0.000018	1.15
clodinafop-propargyl	H	Discover	Post emergence	Foliar	Liquid	unspecified	1	2276	0.0004	0.04	0.000018	0.000018	1.15
Picloram	H	Tordon	Post emergence	Foliar	Liquid	unspecified	1	5000	0.0002	0.01	0.000002	0.000002	0.13
Thifensulfuron	H	Pinnacle	Post emergence	Foliar	Liquid	unspecified	1	5000	0.0002	0.01	0.000002	0.000002	0.13
Chlorsulfuron	H	Glean	Post emergence	Foliar	Liquid	unspecified	1	5000	0.0002	0.01	0.000002	0.000002	0.13
Triasulfuron	H	Amber, Rave	Post emergence	Foliar	Liquid	unspecified	1	5000	0.0002	0.01	0.000002	0.000002	0.13
Tribenuron-methyl	H	Express	Post emergence	Foliar	Liquid	unspecified	1	5000	0.0002	0.006	0.000001	0.000001	0.08
Metsulfuron-methyl	H	Ally	Post emergence	Soil	Liquid	unspecified	0.6	5000	0.0002	0.004	0.000000	0.000000	0.03
Chlorsulfuron	H	Glean	Pre emergence	Soil	Liquid	unspecified	0.2	5000	0.0002	0.01	0.000000	0.000000	0.03

Appendix Table 5.

Acute Worker and Avian Risks with Herbicides
Used in Spring Wheat Production in 1992, 1995, 2000, and 2002; Totals by State and National

National 2002 Acres Planted = 12,700,000
2002 Acres treated with herbicides = 11,430,000 (90%)

Active Ingredient	Acre Treatments	Avian Tox Units per Acre Treated	Avian Tox Units per Acre Treated (Scaled*)	Total Avian Tox Units	Acute Tox Units per Acre Treated	Acute Tox Units per Acre Treated (Scaled*)	Total Acute Tox Units
MCPA	5,969,000	0.00020	0.5	1,194	0.00044	29.0	2,643.4
2,4-D	5,029,200	0.00660	15.4	33,193	0.00091	59.4	4,559.8
Fenoxaprop-P-ethyl	3,683,000	0.00070	1.6	2,578	0.00003	1.7	93.8
Bromoxynil	3,048,000	0.02710	63.3	82,601	0.00126	82.8	3,850.1
Dicamba	2,286,000	0.00210	4.9	4,801	0.00003	1.9	67.0
Glyphosate	2,667,000	0.00245	5.7	6,534	0.00002	1.2	46.9
Tribenuron-methyl	1,524,000	0.00010	0.2	152	0.00000	0.1	1.8
Thifensulfuron	1,270,000	0.00010	0.2	127	0.00000	0.1	2.5
Clodinafop-propargyl	1,016,000				0.00002	1.2	17.9
Metsulfuron-methyl	889,000	0.00002	0.0	18	0.00000	0.0	0.4
Fluroxypyr	635,000	0.00170	4.0	1,080	0.00003	1.7	16.5
Triasulfuron	508,000	0.00010	0.2	51	0.00000	0.1	1.0
Fluroxypyr 1-methylheptyl	381,000	0.00170	4.0	648	0.00003	1.7	9.9
Tebuconazole	419,100	0.00070	1.6	293	0.00002	1.5	9.4
Acetic Acid	381,000				0.00040	26.0	151.0
Picloram	254,000	0.00010	0.2	25	0.00000	0.1	0.5
Clopyralid	254,000	0.00110	2.6	279	0.00002	1.2	4.7
Propiconazole	254,000	0.00080	1.9	203	0.00006	3.9	15.0
Bromoxynil octanoate	254,000	0.04280	100.0	10,871	0.00153	100.0	387.6
Chlorsulfuron	127,000	0.00010	0.2	13	0.00000	0.1	0.3
			Totals	144,661			11,880
		Average per Acre Treatment		0.013			0.001

* Max value = 100

Appendix Table 5. *(continued)*

Acute Worker and Avian Risks with Herbicides
Used in Spring Wheat Production in 1992, 1995, 2000, and 2002; Totals by State and National

Minnesota

2002 Acres Planted = 2,000,000

2002 Acres treated with herbicides = 1,800,000 (90%)

Active Ingredient	Acre Treatments	Avian Tox Units per Acre Treated	Avian Tox Units per Acre Treated (Scaled*)	Total Avian Tox Units	Acute Tox Units per Acre Treated	Acute Tox Units per Acre Treated (Scaled*)	Total Acute Tox Units
MCPA	1,060,000	0.00020	0.5	212	0.00044	29.0	469.4
Bromoxynil	700,000	0.02710	63.3	18,970	0.00126	82.8	884.2
Fenoxaprop-P-ethyl	600,000	0.00070	1.6	420	0.00003	1.7	15.3
2,4-D	400,000	0.00660	15.4	2,640	0.00091	59.4	362.7
Thifensulfuron	160,000	0.00010	0.2	16	0.00000	0.1	0.3
Tribenuron-methyl	140,000	0.00010	0.2	14	0.00000	0.1	0.2
Glyphosate	120,000	0.00245	5.7	294	0.00002	1.2	2.1
Clodinafop-propargyl	100,000				0.00002	1.2	1.8
Propiconazole	100,000	0.00080	1.9	80	0.00006	3.9	5.9
			Totals	22,646			1,742
			Average per Acre Treatment	0.013			0.001

* Max value = 100

Appendix Table 5. *(continued)*

Acute Worker and Avian Risks with Herbicides
Used in Spring Wheat Production in 1992, 1995, 2000, and 2002;
Totals by State and National

Montana 2002 Acres Planted = 3,750,000
2002 Acres treated with herbicides = 3,375,000 (90%)

Active Ingredient	Acre Treatments	Avian Tox Units per Acre Treated	Avian Tox Units per Acre Treated (Scaled*)	Total Avian Tox Units	Acute Tox Units per Acre Treated	Acute Tox Units per Acre Treated (Scaled*)	Total Acute Tox Units
2,4-D	2,925,000	0.00660	15.4	19,305	0.00091	59.4	2,652.0
Dicamba	1,320,000	0.00210	4.9	2,772	0.00003	1.9	38.7
Metsulfuron-methyl	825,000	0.00002	0.0	17	0.00000	0.0	0.4
Glyphosate	1,282,500	0.00245	5.7	3,142	0.00002	1.2	22.6
MCPA	562,500	0.00020	0.5	113	0.00044	29.0	249.1
Triasulfuron	487,500	0.00010	0.2	49	0.00000	0.1	1.0
Clodinafop-propargyl	487,500				0.00002	1.2	8.6
Bromoxynil	300,000	0.02710	63.3	8,130	0.00126	82.8	378.9
Tribenuron-methyl	262,500	0.00010	0.2	26	0.00000	0.1	0.3
Thifensulfuron	187,500	0.00010	0.2	19	0.00000	0.1	0.4
Fenoxaprop-P-ethyl	150,000	0.00070	1.6	105	0.00003	1.7	3.8
Chlorsulfuron	150,000	0.00005	0.1	8	0.00000	0.1	0.3
			Totals	33,684			3,356
		Average per Acre Treatment		0.010			0.001

* Max value = 100

APPENDIX TABLE 5. *(CONTINUED)*

ACUTE WORKER AND AVIAN RISKS WITH HERBICIDES
USED IN SPRING WHEAT PRODUCTION IN 1992, 1995, 2000, AND 2002;
TOTALS BY STATE AND NATIONAL

North Dakota 2002 Acres Planted = 6,900,000

2002 Acres treated with herbicides = 6,210,000 (90%)

Active Ingredient	Acre Treatments	Avian Tox Units per Acre Treated	Avian Tox Units per Acre Treated (Scaled*)	Total Avian Tox Units	Acute Tox Units per Acre Treated	Acute Tox Units per Acre Treated (Scaled*)	Total Acute Tox Units
MCPA	4,278,000	0.00020	0.5	856	0.00044	29.0	1,894.5
Fenoxaprop-P-ethyl	2,898,000	0.00070	1.6	2,029	0.00003	1.7	73.8
Bromoxynil	2,070,000	0.02710	63.3	56,097	0.00126	82.8	2,614.7
2,4-D	1,794,000	0.00660	15.4	11,840	0.00091	59.4	1,626.6
Tribenuron-methyl	1,104,000	0.00010	0.2	110	0.00000	0.1	1.3
Glyphosate	1,104,000	0.00245	5.7	2,705	0.00002	1.2	19.4
Thifensulfuron	897,000	0.00010	0.2	90	0.00000	0.1	1.8
Clodinafop-propargyl	483,000				0.00002	1.2	8.5
Fluroxypyr	483,000	0.00170	4.0	821	0.00003	1.7	12.6
Fluroxypyr 1-methylheptyl	276,000	0.00170	4.0	469	0.00003	1.7	7.2
			Totals	75,017			6,260
		Average per Acre Treatment		0.012			0.001

* Max value = 100

Appendix Table 5. *(continued)*

Acute Worker and Avian Risks with Herbicides
Used in Spring Wheat Production in 1992, 1995, 2000, and 2002;
Totals by State and National

National — 2000 Acres Planted = 13,800,000
2000 Acres treated with herbicides = 12,420,000 (90%)

Active Ingredient	Acre Treatments	Avian Tox Units per Acre Treated	Avian Tox Units per Acre Treated (Scaled*)	Total Avian Tox Units	Acute Tox Units per Acre Treated	Acute Tox Units per Acre Treated (Scaled*)	Total Acute Tox Units
2,4-D	6,210,000	0.00660	15.4	40,986	0.00091	59.4	5,630.4
MCPA	6,072,000	0.00020	0.5	1,214	0.00044	29.0	2,689.0
Fenoxaprop-P-ethyl	3,726,000	0.00070	1.6	2,608	0.00003	1.7	94.8
Bromoxynil	3,588,000	0.02710	63.3	97,235	0.00126	82.8	4,532.2
Dicamba	4,140,000	0.00210	4.9	8,694	0.00003	1.9	121.3
Glyphosate	4,140,000	0.00245	5.7	10,143	0.00002	1.2	72.9
Tribenuron-methyl	2,070,000	0.00010	0.2	207	0.00000	0.1	2.5
Clopyralid	1,932,000	0.00110	2.6	2,125	0.00002	1.2	35.9
Tebuconazole	1,242,000	0.00070	1.6	869	0.00002	1.5	27.9
Triasulfuron	1,242,000	0.00010	0.2	124	0.00000	0.1	2.5
Thifensulfuron	552,000	0.00010	0.2	55	0.00000	0.1	1.1
Fluroxypyr	414,000	0.00170	4.0	704	0.00003	1.7	10.8
Metsulfuron-methyl	414,000	0.00002	0.0	8	0.00000	0.0	0.2
Picloram	276,000	0.00010	0.2	28	0.00000	0.1	0.6
			Totals	165,001			13,222
		Average per Acre Treatment		0.013			0.001

* Max value = 100

Appendix Table 5. (continued)

Acute Worker and Avian Risks with Herbicides
Used in Spring Wheat Production in 1992, 1995, 2000, and 2002;
Totals by State and National

Minnesota

2000 Acres Planted = 2,000,000

2000 Acres treated with herbicides = 1,800,000 (90%)

Active Ingredient	Acre Treatments	Avian Tox Units per Acre Treated	Avian Tox Units per Acre Treated (Scaled*)	Total Avian Tox Units	Acute Tox Units per Acre Treated	Acute Tox Units per Acre Treated (Scaled*)	Total Acute Tox Units
MCPA	1,500,000	0.00020	0.5	300	0.00044	29.0	664.3
Clopyralid	900,000	0.00110	2.6	990	0.00002	1.2	16.7
Fenoxaprop-P-ethyl	560,000	0.00070	1.6	392	0.00003	1.7	14.3
Bromoxynil	500,000	0.02710	63.3	13,550	0.00126	82.8	631.6
2,4-D	220,000	0.00660	15.4	1,452	0.00091	59.4	199.5
Tribenuron-methyl	140,000	0.00010	0.2	14	0.00000	0.1	0.2
Thifensulfuron	140,000	0.00010	0.2	14	0.00000	0.1	0.3
Dicamba	60,000	0.00210	4.9	126	0.00003	1.9	1.8
			Totals	16,838			1,529
			Average per Acre Treatment	0.009			0.001

* Max value = 100

Appendix Table 5. *(continued)*

Acute Worker and Avian Risks with Herbicides
Used in Spring Wheat Production in 1992, 1995, 2000, and 2002;
Totals by State and National

Montana

2000 Acres Planted = 3,350,000

2000 Acres treated with herbicides = 3,015,000 (90%)

Active Ingredient	Acre Treatments	Avian Tox Units per Acre Treated	Avian Tox Units per Acre Treated (Scaled*)	Total Avian Tox Units	Acute Tox Units per Acre Treated	Acute Tox Units per Acre Treated (Scaled*)	Total Acute Tox Units
2,4-D	2,321,550	0.00660	15.4	15,322	0.00091	59.4	2,104.9
Glyphosate	2,673,300	0.00245	5.7	6,550	0.00002	1.2	47.1
Triasulfuron	1,306,500	0.00010	0.2	131	0.00000	0.1	2.6
Dicamba	2,164,100	0.00210	4.9	4,545	0.00003	1.9	63.4
MCPA	435,500	0.00020	0.5	87	0.00044	29.0	192.9
Bromoxynil	268,000	0.02710	63.3	7,263	0.00126	82.8	338.5
Metsulfuron-methyl	201,000	0.00002	0.0	4	0.00000	0.0	0.1
Tribenuron-methyl	134,000	0.00010	0.2	13	0.00000	0.1	0.2
			Totals	33,914			2,750
			Average per Acre Treatment	0.011			0.001

* Max value = 100

Appendix Table 5. (continued)

Acute Worker and Avian Risks with Herbicides
Used in Spring Wheat Production in 1992, 1995, 2000, and 2002;
Totals by State and National

North Dakota

2000 Acres Planted = 6,800,000
2000 Acres treated with herbicides = 6,120,000 (90%)

Active Ingredient	Acre Treatments	Avian Tox Units per Acre Treated	Avian Tox Units per Acre Treated (Scaled*)	Total Avian Tox Units	Acute Tox Units per Acre Treated	Acute Tox Units per Acre Treated (Scaled*)	Total Acute Tox Units
MCPA	3,604,000	0.00020	0.5	721	0.00044	29.0	1,596.1
2,4-D	2,924,000	0.00660	15.4	19,298	0.00091	59.4	2,651.1
Fenoxaprop-P-ethyl	2,720,000	0.00070	1.6	1,904	0.00003	1.7	69.2
Bromoxynil	2,720,000	0.02710	63.3	73,712	0.00126	82.8	3,435.8
Tribenuron-methyl	1,700,000	0.00010	0.2	170	0.00000	0.1	2.0
Dicamba	1,428,000	0.00210	4.9	2,999	0.00003	1.9	41.8
Clopyralid	748,000	0.00110	2.6	823	0.00002	1.2	13.9
Fluroxypyr	408,000	0.00170	4.0	694	0.00003	1.7	10.6
Glyphosate	374,000	0.00245	5.7	916	0.00002	1.2	6.6
			Totals	101,237			7,827
			Average per Acre Treatment	0.017			0.001

* Max value = 100

Appendix Table 5. *(continued)*

Acute Worker and Avian Risks with Herbicides
Used in Spring Wheat Production in 1992, 1995, 2000, and 2002;
Totals by State and National

South Dakota

2000 Acres Planted = 1,650,000

2000 Acres treated with herbicides = 1,485,000 (90%)

Active Ingredient	Acre Treatments	Avian Tox Units per Acre Treated	Avian Tox Units per Acre Treated (Scaled*)	Total Avian Tox Units	Acute Tox Units per Acre Treated	Acute Tox Units per Acre Treated (Scaled*)	Total Acute Tox Units
2,4-D	924,000	0.00660	15.4	6,098	0.00091	59.4	837.8
Dicamba	693,000	0.00210	4.9	1,455	0.00003	1.9	20.3
MCPA	495,000	0.00020	0.5	99	0.00044	29.0	219.2
Clopyralid	198,000	0.00110	2.6	218	0.00002	1.2	3.7
Thifensulfuron	181,500	0.00010	0.2	18	0.00000	0.1	0.4
Tribenuron-methyl	181,500	0.00010	0.2	18	0.00000	0.1	0.2
Metsulfuron-methyl	165,000	0.00002	0.0	3	0.00000	0.0	0.1
Bromoxynil	132,000	0.02710	63.3	3,577	0.00126	82.8	166.7
			Totals	11,487			1,248
			Average per Acre Treatment	0.008			0.001

* Max value = 100

Appendix Table 5. *(continued)*

Acute Worker and Avian Risks with Herbicides
Used in Spring Wheat Production in 1992 1995, 2000, and 2002;
Totals by State and National

National

1995 Acres Planted = 15,800,000

1995 Acres treated with herbicides = 14,220,000 (90%)

Active Ingredient	Acre Treatments	Avian Tox Units per Acre Treated	Avian Tox Units per Acre Treated (Scaled*)	Total Avian Tox Units	Acute Tox Units per Acre Treated	Acute Tox Units per Acre Treated (Scaled*)	Total Acute Tox Units
2,4-D	8,532,000	0.00660	15.4	56,311	0.00091	59.4	7,735.7
MCPA	6,778,200	0.00020	0.5	1,356	0.00044	29.0	3,001.8
dicamba	4,740,000	0.00210	4.9	9,954	0.00003	1.9	138.8
tribenuron-methyl	3,950,000	0.00010	0.2	395	0.00000	0.1	4.7
fenoxaprop-P-ethyl	2,370,000	0.00070	1.6	1,659	0.00003	1.7	60.3
bromoxynil	1,422,000	0.02710	63.3	38,536	0.00126	82.8	1,796.2
triasulfuron	1,106,000	0.00010	0.2	111	0.00000	0.1	2.2
metsulfuron-methyl	632,000	0.00002	0.0	13	0.00000	0.0	0.3
clopyralid	632,000	0.00110	2.6	695	0.00002	1.2	11.8
			Totals	109,029			12,752
			Average per Acre Treatment	0.008			0.001

* Max value = 100

Appendix Table 5. *(continued)*

Acute Worker and Avian Risks with Herbicides
Used in Spring Wheat Production in 1992, 1995, 2000, and 2002;
Totals by State and National

Minnesota

1995 Acres Planted = 2,250,000
1995 Acres treated with herbicides = 2,025,000 (90%)

Active Ingredient	Acre Treatments	Avian Tox Units per Acre Treated	Avian Tox Units per Acre Treated (Scaled*)	Total Avian Tox Units	Acute Tox Units per Acre Treated	Acute Tox Units per Acre Treated (Scaled*)	Total Acute Tox Units
MCPA	1,534,500	0.00020	0.5	307	0.00044	29.0	679.6
tribenuron-methyl	1,138,500	0.00010	0.2	114	0.00000	0.1	1.4
2,4-D	866,250	0.00660	15.4	5,717	0.00091	59.4	785.4
fenoxaprop-P-ethyl	742,500	0.00070	1.6	520	0.00003	1.7	18.9
bromoxynil	540,000	0.02710	63.3	14,634	0.00126	82.8	682.1
clopyralid	315,000	0.00110	2.6	347	0.00002	1.2	5.9
			Totals	21,638			2,173
		Average per Acre Treatment		0.011			0.001

Montana

1995 Acres Planted = 3,950,000
1995 Acres treated with herbicides = 3,555,000 (90%)

Active Ingredient	Acre Treatments	Avian Tox Units per Acre Treated	Avian Tox Units per Acre Treated (Scaled*)	Total Avian Tox Units	Acute Tox Units per Acre Treated	Acute Tox Units per Acre Treated (Scaled*)	Total Acute Tox Units
2,4-D	3,002,000	0.00660	15.4	19,813	0.00091	59.4	2,721.8
dicamba	2,488,500	0.00210	4.9	5,226	0.00003	1.9	72.9
triasulfuron	711,000	0.00010	0.2	71	0.00000	0.1	1.4
metsulfuron-methyl	316,000	0.00002	0.0	6	0.00000	0.0	0.2
MCPA	316,000	0.00020	0.5	63	0.00044	29.0	139.9
			Totals	25,180			2,936
		Average per Acre Treatment		0.007			0.001

* Max value = 100

Appendix Table 5. (continued)

Acute Worker and Avian Risks with Herbicides
Used in Spring Wheat Production in 1992, 1995, 2000, and 2002;
Totals by State and National

North Dakota

1995 Acres Planted = 8,300,000
1995 Acres treated with herbicides = 7,470,000 (90%)

Active Ingredient	Acre Treatments	Avian Tox Units per Acre Treated	Avian Tox Units per Acre Treated (Scaled*)	Total Avian Tox Units	Acute Tox Units per Acre Treated	Acute Tox Units per Acre Treated (Scaled*)	Total Acute Tox Units
2,4-D	4,150,000	0.00660	15.4	27,390	0.00091	59.4	3,762.7
MCPA	4,473,700	0.00020	0.5	895	0.00044	29.0	1,981.2
tribenuron-methyl	2,490,000	0.00010	0.2	249	0.00000	0.1	3.0
dicamba	1,660,000	0.00210	4.9	3,486	0.00003	1.9	48.6
fenoxaprop-P-ethyl	1,411,000	0.00070	1.6	988	0.00003	1.7	35.9
bromoxynil	747,000	0.02710	63.3	20,244	0.00126	82.8	943.6
			Totals	53,251			6,775
			Average per Acre Treatment	0.007			0.001

South Dakota

1995 Acres Planted = 1,250,000
1995 Acres treated with herbicides = 1,125,000 (90%)

Active Ingredient	Acre Treatments	Avian Tox Units per Acre Treated	Avian Tox Units per Acre Treated (Scaled*)	Total Avian Tox Units	Acute Tox Units per Acre Treated	Acute Tox Units per Acre Treated (Scaled*)	Total Acute Tox Units
2,4-D	587,500	0.00660	15.4	3,878	0.00091	59.4	532.7
dicamba	387,500	0.00210	4.9	814	0.00003	1.9	11.4
MCPA	362,500	0.00020	0.5	73	0.00044	29.0	160.5
tribenuron-methyl	300,000	0.00010	0.2	30	0.00000	0.1	0.4
metsulfuron-methyl	187,500	0.00002	0.0	4	0.00000	0.0	0.1
fenoxaprop-P-ethyl	175,000	0.00070	1.6	123	0.00003	1.7	4.5
			Totals	4,920			709
			Average per Acre Treatment	0.004			0.001

* Max value = 100

Appendix Table 5. *(continued)*

Acute Worker and Avian Risks with Herbicides
Used in Spring Wheat Production in 1992, 1995, 2000, and 2002;
Totals by State and National

National 1992 Acres Planted = 17,400,000
1992 Acres treated with herbicides = 15,660,000 (90%)

Active Ingredient	Acre Treatments	Avian Tox Units per Acre Treated	Avian Tox Units per Acre Treated (Scaled*)	Total Avian Tox Units	Acute Tox Units per Acre Treated	Acute Tox Units per Acre Treated (Scaled*)	Total Acute Tox Units
2,4-D	9,048,000	0.00660	15.4	59,717	0.00091	59.4	8,203.5
MCPA	7,081,800	0.00020	0.5	1,416	0.00044	29.0	3,136.2
dicamba	5,046,000	0.00210	4.9	10,597	0.00003	1.9	147.8
tribenuron-methyl	2,262,000	0.00010	0.2	226	0.00000	0.1	2.7
bromoxynil	1,740,000	0.02710	63.3	47,154	0.00126	82.8	2,197.9
fenoxaprop-P-ethyl	1,392,000	0.00070	1.6	974	0.00003	1.7	35.4
thifensulfuron	1,218,000	0.00010	0.2	122	0.00000	0.1	2.4
metsulfuron-methyl	1,044,000	0.00002	0.0	21	0.00000	0.0	0.5
			Totals	120,227			13,727
			Average per Acre Treatment	0.008			0.001

* Max value = 100

Appendix Table 5. *(continued)*

Acute Worker and Avian Risks with Herbicides
Used in Spring Wheat Production in 1992, 1995, 2000, and 2002;
Totals by State and National

Minnesota

1992 Acres Planted = 2,800,000
1992 Acres treated with herbicides = 2,520,000 (90%)

Active Ingredient	Acre Treatments	Avian Tox Units per Acre Treated	Avian Tox Units per Acre Treated (Scaled*)	Total Avian Tox Units	Acute Tox Units per Acre Treated	Acute Tox Units per Acre Treated (Scaled*)	Total Acute Tox Units
MCPA	2,184,000	0.00020	0.5	437	0.00044	29.0	967.2
2,4-D	1,008,000	0.00660	15.4	6,653	0.00091	59.4	913.9
bromoxynil	924,000	0.02710	63.3	25,040	0.00126	82.8	1,167.2
fenoxaprop-P-ethyl	420,000	0.00070	1.6	294	0.00003	1.7	10.7
dicamba	338,800	0.00210	4.9	711	0.00003	1.9	9.9
			Totals	33,135			3,069
		Average per Acre Treatment		0.013			0.001

Montana

1992 Acres Planted = 2,650,000
1992 Acres treated with herbicides = 2,385,000 (90%)

Active Ingredient	Acre Treatments	Avian Tox Units per Acre Treated	Avian Tox Units per Acre Treated (Scaled*)	Total Avian Tox Units	Acute Tox Units per Acre Treated	Acute Tox Units per Acre Treated (Scaled*)	Total Acute Tox Units
2,4-D	1,855,000	0.00660	15.4	12,243	0.00091	59.4	1,681.9
dicamba	1,457,500	0.00210	4.9	3,061	0.00003	1.9	42.7
			Totals	15,304			1,725
		Average per Acre Treatment		0.006			0.001

* Max value = 100

Appendix Table 5. *(continued)*

Acute Worker and Avian Risks with Herbicides
Used in Spring Wheat Production in 1992 , 1995, 2000, and 2002;
Totals by State and National

North Dakota

1992 Acres Planted = 9,200,000
1992 Acres treated with herbicides = 8,280,000 (90%)

Active Ingredient	Acre Treatments	Avian Tox Units per Acre Treated	Avian Tox Units per Acre Treated (Scaled*)	Total Avian Tox Units	Acute Tox Units per Acre Treated	Acute Tox Units per Acre Treated (Scaled*)	Total Acute Tox Units
2,4-D	4,876,000	0.00660	15.4	32,182	0.00091	59.4	4,420.9
MCPA	3,956,000	0.00020	0.5	791	0.00044	29.0	1,751.9
dicamba	2,392,000	0.00210	4.9	5,023	0.00003	1.9	70.1
tribenuron-methyl	1,748,000	0.00010	0.2	175	0.00000	0.1	2.1
fenoxaprop-P-ethyl	828,000	0.00070	1.6	580	0.00003	1.7	21.1
thifensulfuron	828,000	0.00010	0.2	83	0.00000	0.1	1.7
bromoxynil	644,000	0.02710	63.3	17,452	0.00126	82.8	813.5
			Totals	56,286			7,081
		Average per Acre Treatment		0.007			0.001

South Dakota

1992 Acres Planted = 2,700,000
1992 Acres treated with herbicides = 2,430,000 (90%)

Active Ingredient	Acre Treatments	Avian Tox Units per Acre Treated	Avian Tox Units per Acre Treated (Scaled*)	Total Avian Tox Units	Acute Tox Units per Acre Treated	Acute Tox Units per Acre Treated (Scaled*)	Total Acute Tox Units
2,4-D	1,269,000	0.00660	15.4	8,375	0.00091	59.4	1,150.6
dicamba	972,000	0.00210	4.9	2,041	0.00003	1.9	28.5
MCPA	459,000	0.00020	0.5	92	0.00044	29.0	203.3
			Totals	10,508			1,382
		Average per Acre Treatment		0.004			0.001

* Max value = 100

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