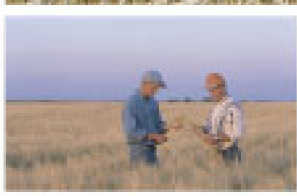
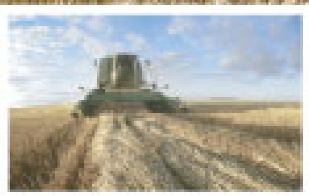
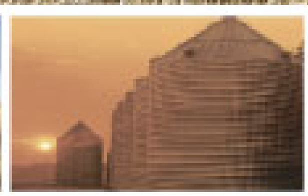
CWB

A Discussion Paper on

Agronomic Assessment of Roundup Ready® Wheat







Executive Summary

Wheat is an important part of crop rotations in Western Canada with seeded acreage averaging about 21 million acres in recent years. The herbicide Roundup® (active ingredient – glyphosate) is used extensively in Western Canada and is an important weed control tool for farmers. Roundup Ready® canola, as well as other herbicide tolerant canola varieties, have been widely adopted by farmers across Western Canada.

These, and other intersecting factors, mean that the possible introduction into Western Canada of Roundup Ready wheat (RRW) - a genetically modified (GM) herbicide tolerant variety - requires careful deliberation. In fact, the agronomic management questions are as important as, and in many ways connected to, the market impact questions that have been widely discussed among farmers and others in the grain industry. For example, any problems with control of volunteer RRW could have an impact on the adventitious (unintentional) presence of RRW in non-GM wheat shipments.

As the date nears when RRW could become available for commercial production, it is critical that adequate information be made available to decision makers, including farmers, government, grain handlers, marketers and technology developers. Where knowledge gaps exist, the work necessary to close them must be done.

This paper assembles information and professional opinions about the agronomic benefits and risks associated with the potential introduction of RRW. It should be made clear that no claim is being made that this discussion paper is the final word on RRW agronomics. There is no firm conclusion at this point as to whether the potential agronomic benefits of RRW outweigh the costs and risks. The purpose of this document is to disseminate known information and encourage discussion. The next stage will be to use the results of industry discussions to further advance knowledge of potential agronomic impacts in preparation for the decision about the introduction and adoption of Roundup Ready wheat in Western Canada.

Based on Monsanto's research reports, the potential direct benefits of RRW include a reduction in input costs, a simplified weed control program and a resulting yield benefit due to improved weed control. Further, the use of Roundup herbicide as an in-crop treatment in wheat would potentially offer a new mode of action for controlling herbicide resistant weed biotypes.

Research and extension agronomists expressed a number of concerns about the potential impact of RRW, and these are summarized in the main paper within six areas identified as requiring continued research and evaluation. Three main concerns that are common and evident throughout the discussion relate to:

1. Control of volunteer RRW

The cost and availability of control options for managing herbicide tolerant wheat would make for increasing complexity and risk in managing crop rotations. Studies conducted by the University of Saskatchewan Department of Agricultural Economics demonstrate that the potential returns that herbicide tolerant wheat offer farmers are highly sensitive to farmer's individual management practices and cropping systems. Increasing costs of managing volunteer RRW, especially under conservation tillage systems, could negate potential returns from the introduction of this technology. Furthermore, including more than one Roundup Ready crop in rotation would require careful management of volunteers, and could lead to increased herbicide costs if tank mixtures are required for control.

2. Gene Spread
Field surveys demonstrate that volunteer wheat may persist in rotations for up to five years. Given the frequency of wheat in crop rotations and the length of volunteer persistence, gene spread by contamination through co-mingling of seed, or through pollen flow, is of primary concern for farmers who choose not to adopt the technology.

More research is required on the risk of gene spread if RRW were to be granted environmental release and grown on commercial scale. The factors of large-scale pollen sources and herbicide selection pressure must be further investigated. The persistence and dormancy characteristics of volunteer wheat in crop rotations must be better understood to ensure cost-effective control options and stewardship practices are in place prior to introduction of RRW.

3. Herbicide Resistance
While RRW offers a new control option for resistant weed management, there is concern that the in-crop use of Roundup will increase the selection pressure and risk for developing weed resistance to glyphosate. Conservation tillage systems are highly reliant on the use of glyphosate for pre-seed weed control, and any increase in herbicide costs due to glyphosate resistant weeds could put conservation farming systems at risk.

As well as these three common concerns, three additional concerns were identified. These relate to quantifying the crop tolerance and yield benefit, grain quality enhancement and potential benefits as compared to the introduction of other Roundup Ready cropping systems.

Introduction

A thorough understanding of the agronomic issues related to Roundup Ready® wheat (RRW) is one of the necessary conditions to make good decisions on the potential introduction of this product into Canada. The purpose of this paper is to review and evaluate the main arguments being made regarding the potential benefits, costs and risks of RRW.

This paper, prepared by the Canadian Wheat Board (CWB), draws upon a variety of written material, public presentations and comments made by a variety of industry experts. Given the complexity of these agronomic issues, the CWB cannot accept responsibility for the veracity of all of this information nor the arguments being made. The purpose of this work is to consolidate the main issues within one discussion paper in order to contribute to a rigorous evaluation of RRW prior to final decisions being made on its potential commercial production.

The paper is divided into two main sections. The first section summarizes and evaluates the main points on RRW agronomics that have been made in various publications, presentations and discussions with research and extension agronomists. The second section then consolidates the main issues identified in Section One with comments regarding each issue's importance, information gaps and the main points of disagreement aired in any discussions to date.

Comments or questions regarding this paper should be sent to:

Mike Grenier
Agronomist
Canadian Wheat Board
Box 816, Stn. M.
Winnipeg MB R3C 2P5
Tel: 204-983-2996 Fax: 204-984-1699
Email: mike_grenier@cwb.ca

Section One: Existing Publications, Presentations and Discussion Feedback

A. Information Provided by Monsanto

Monsanto is the owner of Roundup Ready technology and the developer of RRW. In various publications and presentations, they have articulated the following potential benefits of RRW:

1. Potential Benefits of RRW

Potential Direct Benefits
The ability to use Roundup herbicide, as an in-crop treatment would reduce management risk associated with post-emergent herbicide programs. Some of the direct and easily identifiable benefits are:

More efficient weed control due to increased flexibility and effectiveness:

- Crop tolerance - The nature of the transgenic event confers a high level of crop safety with very low risk for crop injury or setback due to herbicide stress. It allows for increased flexibility with no crop tolerance concerns due to environment and/or application overlap. This is an advantage compared to conventional wild oat herbicides that rely on natural crop selectivity, are more environmentally sensitive in their crop response and have label restrictions relative to application timing.

Simple effective weed control with the benefits of:

- Broad spectrum annual and perennial weed control with a single application;
- Highly efficacious, achieving stable results across varying environmental conditions and locations;
- Wide window of application;
- Saves time as no tank mixes are required, and it is easy to mix and clean; and
- Control of volunteer cereals, especially volunteer barley, resulting in high varietal purity levels.

Weed resistance management:

- Control of current known resistant weed biotypes; and
- Offers new in-crop mode of action as a rotational management tool for delaying the development of herbicide resistance.

Potential Indirect Benefits

Monsanto states that combining elite germplasm with the in-crop use of Roundup® herbicide will result in superior agronomic and quality benefits over conventional wheat. Information from Monsanto indicates that the following potential indirect benefits should result from the introduction of Roundup Ready technology in wheat:

- Superior crop safety and early weed control should result in extra yield and reduced dockage;
- Early seeding benefits for pest and disease management such as midge, Fusarium head blight and other leaf diseases;
- Roundup herbicide offers a high level of environmental safety, relative to environmental footprint and toxicity of glyphosate;
- Overall reduction in amount of herbicide used;
- No re-cropping restrictions compared to the use of some current residual herbicides;
- Increased adoption of minimum till and/or zero till practices resulting in improvements in soil quality and reduction in erosion potential; and
- Future developmental benefits from the technology, including stacking of both agronomic performance (yield, disease resistance) and end-use quality traits.

There is no doubt that farmers would welcome new weed control options in wheat production. However, the positive benefits from the introduction of new technology must be clearly understood and communicated. Since this is new technology yet to be released and proven in commercial wheat production, the perceived benefits must be weighed and considered against the implications and potential negative attributes resulting in increased management risk arising from the technology adoption.

2. Remaining Questions

Crop Tolerance and Yield Response

Limited data presented to date reports only average crop injury and yield response for nine Canadian studies. It would be more useful to present the data in terms of demonstrating specifically when RRW rewards farmers with more agronomic return and reduced management risk. In other words, when and for what type of farming operation is RRW the optimal production system to use?

Stewardship Principles
The use of glyphosate for control of current resistant weed biotypes and as a new in-crop mode of action for managing and preventing the onset of weed resistance, are the most compelling advantages of RRW.

Minimal discussion has been held as to the risk of developing weed resistance to glyphosate. There is no argument that the unique mode of action for glyphosate, combined with the lack of residual activity, leads to low risk for developing weed resistance. However, it is known that for Group 4 auxinic-type herbicides, while the risk for developing resistance is low, with continued selection pressure over time resistance does eventually evolve, and has in fact occurred on the Prairies. The question with Roundup is at what point does frequency of use substitute for lack of residual control in determining and assessing the risk of developing weed resistance to glyphosate. Current marketing strategies by Monsanto continue to promote and demonstrate the power of Roundup for pre-seed, pre-harvest, post-harvest and chem-fallow use. At some point, the discussion needs to include how an in-crop treatment with RRW reduces the agronomic risk for farmers' overall cropping systems while recognizing how they are using glyphosate in their current production strategies.

Monsanto indicates that studies are underway to assess the risk of contamination and spread of the Roundup Ready gene through pollen flow. In addition, they discuss the importance of a strict and robust system of production to ensure control of RRW in the grain handling system. There have been instances with other genetically modified (GM) crops where unexpected events have occurred. In Canada, such an unexpected event resulted in the voluntary withdrawal of the GM canola variety, Quest, by the respective seed companies in order to protect the integrity of Canada's exports. This, along with the example of Starlink™ corn, demonstrates how far and wide trace contamination or larger percentages of GM varieties can unexpectedly turn up. Some people question the ability to prevent the gene spread from GM crops.

Improved Crop Quality
Monsanto concludes that the combination of improved crop safety, early weed removal and earlier seeding will result in improved quality primarily in increased protein levels and protein quality. The premise for these potential improvements in crop quality is that there will be more available soil nitrogen especially during the early stages of crop development. This should lead to more uniform and early maturing crop kernel development resulting in higher test weight and flour extraction.

Discussions with crop physiologists and soil fertility experts indicate a high level of skepticism as to the validity of this claim. Certainly where both the wheat crop and weeds have equal access to N supply then there may be an advantage with the RRW system. However current tillage, fertilizer placement and seeding practices strive to maximize competitiveness of the wheat crop, including preferential access to fertilizer. Comparisons with RRW against AC Superb (the non-GM wheat variety from which RRW was derived from) using current production practices would demonstrate any benefit in crop quality.

An improvement in crop quality will be achieved through control of volunteer cereals resulting in high purity levels. However the loss of glyphosate as a pre-harvest management tool may negate any improvements in quality by increasing the risk of downgrading through weathering, green kernels or frost damage.

3. Gene Flow in Wheat – Monsanto Technical Bulletin

Monsanto issued a technical bulletin in response to questions about gene flow from RRW confined field trials. In this bulletin, Monsanto outlines the steps they have taken in their research program to "mitigate the likelihood of adventitious presence of Roundup Ready trait in commercially grown wheat".

A key component of the regulations involving confined field trials for Plants with Novel Traits (PNTs) is the use of isolation distances or buffer zones. Monsanto's bulletin reports on the scientific published data to evaluate the risk of outcrossing in wheat, and how the data was used in determining a sufficient isolation distance for confined field-testing of RRW. The bulletin also describes other components of the regulations and precautions that Monsanto has taken with respect to compliance and auditing, and for seed and grain accounting programs.

This technical bulletin summarizes Monsanto's confined field testing research program and provides details with respect to minimizing gene flow from confined RRW trials. However, it does not address the larger issue of gene flow once RRW is in commercial production and grown on a large scale. The research data available on outcrossing levels in varieties of wheat is based on small plot research trials.

Strict field testing regulations associated with assessing environmental safety of PNTs are being followed during this product development phase for RRW. These regulations make it difficult to design and conduct trials to assess potential impact once in RRW is in large-scale commercial production. There have been reported cases with both Roundup Ready canola and corn where unexpected gene spread through possible outcrossing or contaminated seed has occurred.

B. University of Saskatchewan Studies

1. The Economics of Herbicide Tolerant Wheat in Western Canadian Crop Rotation

Recent thesis work by a University of Saskatchewan Agricultural Economics graduate student examining "The Economics of Herbicide Tolerant Wheat in Western Canadian Crop Rotations" predicts a net average producer benefit in the order of $6.67 per acre from adopting the RRW technology.

A number of assumptions were made during the development of the model used to estimate and compare producer returns under various crop management scenarios. Two major variables important to the comparison of GM wheat to conventional wheat were the assumed yield benefit from GM wheat and the cost of production set for conventional wheat. For purposes of the thesis, the base scenario assumed a six per cent yield increase from herbicide tolerant (HT) wheat, and the herbicide costs for conventional wheat were set at $20.75 per acre for both grass and broad-leaved weeds. Additionally, the cost of production for RRW was based on a technology use agreement (TUA) charge similar to Roundup Ready canola and set at $15 per acre.

The author concludes that while the producer benefits from adopting RRW are positive, they are highly dependent upon management practices used by individual farmers. The agronomic cost of controlling volunteer HT wheat was factored into crop rotation scenarios, but the author recommends additional research on the market impact of volunteer GM wheat in rotational crops. Environmental costs and benefits were identified. The author recommended that additional research be done in the areas of the development of herbicide resistant weeds, contamination and spread of GM wheat onto other farms and the potential to reduce overall herbicide usage.

The study was Prairie-wide, and it was emphasized the sensitivity to individual management practices and their impact on net realized return from adopting HT wheat. However, it is interesting to note that on a regional, or especially on an individual farm basis, this margin of benefit can easily be reduced or negated dependent upon local management practices and risks.

In evaluating the magnitude of a $6.67 per acre net return and understanding the profitability of RRW from an agronomic benefit standpoint, the influence of management practices on the input variable costs:

- **Cost of Roundup herbicide and the requirement for a sequential treatment**
  A major assumption in determining the profitability of RRW system is the use of single application of 0.5 litres per acre of Roundup at $4.30 per acre. Monsanto is quite strong in promoting the benefits that may accrue from an early in-crop application, and realizes that in cases of later emerging weed flushes, a second application may be warranted. They further state that they are pursuing a registration that allows for sequential applications. In Roundup Ready canola, it is common for producers to use two applications of 0.5 litres per acre. In this study, any requirement for a second application will reduce the increase in grower revenue by the cost of that application ($4.30 per acre using the cost noted above);

- **Crop injury response and yield benefit**
  The author readily admits the limitations of the data used to estimate the yield benefit. Monsanto indicates studies are underway to assess the yield advantage of the RRW system as compared to current available herbicides. In evaluating system comparisons, it will be important to understand the agronomic factors that contribute to a yield, or lack of yield, advantage when using RRW. Knowledge of weed spectrum and density will be important in assessing performance of RRW as compared to various standard herbicide use patterns. Studies comparing RRW system to superior new wheat varieties such as AC Superb, with current herbicide options, will be beneficial in determining when and where farmers could optimize their production by using the RRW system;

- **Comparative costs of conventional herbicides**
  In this study, it was assumed that a wild oat herbicide would be necessary in conventional wheat production. In the cost assumption of $20.75 per acre for conventional wheat, the wild oat component comprises over two-thirds of the costs of the tank mix. Various market surveys, as well as field crop records, indicate many acres across the Prairies do not receive a wild oat herbicide. Therefore in this study, a producer receive a net benefit of return from adopting RRW only if a wild oat herbicide is normally required.

  Most cost analysis comparisons of RRW utilize suggested retail prices for conventional herbicides. In understanding the cost-benefit of the RRW system, it is important to consider the whole system of crop protection inputs and not look at individual posted suggested retail prices. Many programs are targeted at farmers based on their purchasing profile of acreage use, volume and brand loyalty. Farmers can leverage their buying power to reduce their total herbicide or overall crop input expenses. For example, by utilizing certain brands of herbicides, farmers can realize substantial reduction in cereal fungicide costs from the brand manufacturer, which can be significant if Fusarium Head Blight or other leaf diseases are a problem. Also, based on herbicides used, farmers may be able to reduce seed costs and/or input costs for their non-cereal crops depending on individual manufacturer's customer loyalty programs.

  Differences in seed costs must also be taken into account. Farmers who adopt RRW will be required to purchase certified seed for each year of production.

  In addition, any cost comparison of RRW with current wheat production cost needs to factor in a TUA fee (the University of Saskatchewan study assumes $15 per acre). No estimates by Monsanto have been provided as to the form or level of TUA that will be required by farmers adopting RRW, but some attempt will need to be made to recoup development costs, as well as fund future biotech products.

- **Crop rotations and tillage system**
  The study does discuss the requirement for and cost of a secondary herbicide when a second Roundup Ready crop is grown in rotation with RRW, or where a secondary herbicide will have to be tank mixed with glyphosate to control volunteer RRW under zero tillage. This requirement for a secondary herbicide to be tank mixed with glyphosate could easily negate the $6.67 per acre benefit realized in the RRW production year.

2. The Optimal Time to Register Genetically Modified Wheat in Canada

The University of Saskatchewan's Department of Agricultural Economics undertook three studies with each one looking at the effect of GM wheat on agronomics, segregation and market impact. A fourth paper uses the findings from the three previous studies, plus the concept of option value to evaluate the optimal time to register GM wheat. For the purpose of this paper, the authors focus on two agronomic factors when comparing the cost-benefit of GM wheat versus conventional wheat varieties and the effects on profitability of succeeding rotational crops. The first factor simply compares the estimated yield and cost of production of GM wheat versus average cost of production for conventional wheat varieties. The second factor examines the effects of GM wheat on the additional management costs during rotational crop production. The main effect on rotational flexibility is the control of volunteer RRW in succeeding years. Here the economic impact will be dependent upon the tillage system and type of crops grown in rotation. The authors acknowledge that the spread of RRW, through contamination, onto neighboring farms will increase the cost of production for non-adopters.

The cost-benefit comparison rests primarily on the assumptions that there will be both an irreversible market cost and an irreversible environmental cost. These irreversible costs arise from the assumption that it will be impossible to reclaim all the RRW genes once they are introduced.

The paper also demonstrates the requirement for a credible, cost-effective segregation system if farmers are to realize any net benefit from RRW technology.

The paper demonstrates, from an agronomic cost-benefit standpoint, that the benefits that GM wheat offers farmers are highly dependent upon farmers' individual management practices and cropping systems. The paper suggests the benefit of simple weed control could be more than offset by the increased risk in management practices due to the complexities and cost of managing volunteer GM crops in rotation, especially under conservation tillage systems.

Comparing the cost of production for GM wheat and conventional varieties, the study indicates a difference of $10.20 per acre, which is a lower cost than the one reported in the previous study described above. This reduction is due to revising the herbicide costs for conventional wheat down from $20.75 to $14.50 per acre, based on reports of average herbicide costs in Alberta and Saskatchewan. Ignoring any costs for a TUA or environmental costs, the authors estimate the potential economic benefit of GM wheat as being between $8.72 and $14.93 per acre. This benefit is achieved though improved crop yields and reduced production costs as compared with yields and costs for conventional wheat varieties. The actual benefit that farmers will realize is dependent upon the pricing level that the developer decides to charge for the GM wheat technology. Within this realized benefit, farmers adopting the technology will need to factor in their rotational costs for controlling volunteer RRW and any other Roundup Ready crops such as volunteer Roundup Ready canola. Unless an individual farmer realizes additional benefits, the potential economic benefit does not offer much in terms of reducing management risk compared to potential increased rotational costs.

Equally important to measuring the benefits realized by technology adopters is the impact on non-adopters. Among their conclusions, the authors emphasize the concern that all farmers will be affected by the decisions of those who adopt the technology, and that this cannot be accounted for in the current marketplace. Within the paper, the issue of gene spread through contamination and pollen flow is accepted as both an irreversible market and environmental cost, whereby it is assumed that all the genes cannot be reclaimed once introduced into the environment. The authors assume the most likely source of gene spread will be contamination through harvest losses. In estimating environmental costs to non-adopters, they assume it will take ten years before the spread of volunteer GM wheat reaches economic thresholds. Based on current experiences with GM canola, it would seem this assumption does not accurately reflect the risk of GM wheat gene spread through pollen flow to neighboring fields. Nonetheless, the study does demonstrate that any discussion involving potential segregation of GM crops must account for the risk of gene spread beyond the farms that adopt the technology. This risk must be assumed from the time of introduction, and well into the foreseeable future.

C. Feedback, Reactions and Response to RRW

In consultation with numerous research scientists and extension agronomists throughout Western Canada, the CWB has received extensive feedback on the introduction of RRW.

There is general agreement with Monsanto's stewardship initiative in stressing the importance of providing best management recommendations for the new technology prior to commercialization. Many agree that the lack of an agronomic stewardship program was a deficiency of the introduction of Roundup Ready canola, resulting in some of the problems farmers are facing with GM canola today.

However in general, the majority of the feedback is cautiously neutral to negative towards the introduction of RRW. Many do not feel that the benefit of introducing RRW outweighs the agronomic costs and increased management risk. All agree on the importance of assessing the impact of the technology on agricultural practices, as well as factoring in alternative cost controls to replace or augment current glyphosate use patterns. Those include:

1. Gene Spread and Volunteer RRW Control

The control of volunteer RRW is likely the single biggest issue of concern, and is believed by many to outweigh any potential benefits in agronomic performance and weed control.

The introduction of RRW into a rotation would require management of volunteers directly in the fields where the RRW is grown, but also in fields where introduction of RRW during transport or through pollen flow may occur. Many of the scientists believe that, with the number of field inquires related to problems with volunteer GM canola control, and the suspected levels of GM contamination in canola seed lots, a cautious and prudent approach should be taken with RRW. Despite the reduced risk of pollen transfer with wheat as compared to canola, results from previous and ongoing canola studies clearly demonstrated the under-estimation of movement and spread of GM canola once in commercial production. As previously mentioned, the examples of Quest canola and Starlink corn clearly show what could happen in wheat given the scale of production in Western Canada. In assessing the agronomic cost-benefit of RRW it must be assumed that there will be spread by seed stock contamination at some level. The question becomes, "Can RRW be agronomically managed and controlled in commercial wheat production?".

Gene Spread through Pollen Flow

Regulations on the introduction of PNTs are most concerned with the potential for gene spread and the risk of cross-pollination to related weedy species. This is a concern expressed by the Saskatchewan Soil Conservation Association (SSCA) as outlined in their RRW position paper. However, what concerns most researchers and farmers is not only the risk for developing super weeds, but the ability for gene flow to occur among existing wheat varieties, creating volunteer herbicide tolerant crop problems.

As outlined in Monsanto's bulletin on gene flow in wheat, outcrossing is a normal plant process occurring in most crop species such as wheat. Studies conducted by Hucl and Matus-Cadiz (2001) confirm low levels of outcrossing rates among varieties of spring wheat. Outcrossing levels varied by variety, ranging from 0.2 per cent to a maximum of 3.8 per cent. Outcrossing rates were also shown to decrease with increasing distance from the pollen source, with a maximum outcrossing distance of 27 meters observed. While these levels of outcrossing are considered to be low, they do indicate that for a strong self-pollinator like wheat, even with a small pollen source, gene flow does occur.

Research has shown that the level of gene spread will be dependent on the size of pollen sources, environmental factors and the outcrossing characteristics of the recipient plant population. What has not been demonstrated in Western Canada is what levels of gene spread can be expected through pollen flow into Canadian varieties of wheat once RRW is grown on commercial scale production. A recent review by Van Acker and Entz (2001) emphasizes the concern for pollen flow in RRW by comparing what has been observed with GM canola in Western Canada. They demonstrate that, even with levels of outcrossing of less than one per cent, there is considerable risk for gene spread into neighboring fields. Field scale studies with GM canola observe appreciable outcrossing occurring at long distances when measured from field-sized pollen sources.

Assessments of the risk of gene spread by RRW into neighboring fields must also account for the selection pressure of glyphosate herbicides used on these fields. In the absence of selection pressure, the introgression of a GM wheat trait would be considered to be stable and remain at low levels. However in the case of RRW, if the selection pressure of glyphosate herbicide is applied, this will allow for the rapid increase in individuals expressing the RRW trait. This is similar to the development of herbicide tolerant weed populations that farmers must adopt different control strategies to manage.

The persistence and dormancy characteristics of volunteer wheat will also influence the risk of RRW gene spread once in production. Weed survey studies conducted by Thomas and Leeson (1999) report that volunteer wheat can persist for up to five years. These surveys emphasize the importance of considering both the frequency of wheat in crop rotation, and the volunteer persistence and dormancy characteristics of volunteer RRW. Even with strict isolation distances for commercial production, without effective control and proper management of volunteer RRW, there will be sufficient pollen sources to act as contamination sources of pollen flow year in and year out. There is evidence that this is occurring, and causing problems due to gene spread and contamination from GM canola varieties.

The implications for gene spread through pollen flow will be dependent upon the acreage of RRW involved, the proximity to neighboring non-GM wheat fields and herbicide use patterns on these fields. Even at low outcrossing levels, such as less than one per cent, the implications for gene flow of RRW would have considerable agronomic effects on the management practices of all farmers, and especially for those utilizing conservation tillage systems.

Gene Spread through Contamination

The issue of gene spread will not only be confined to spread by pollen flow. Other contamination sources through physical seed transport must be considered. The main source of contamination would be from harvest losses in RRW fields being combined. Other transport losses may occur during trucking or seeding and harvest equipment movement between fields. Examples of herbicide resistant weed spread through equipment movement between fields have been documented in Western Canada.

Co-mingling sources of contamination exist during on-farm storage and through slippage in the grain handling system. This co-mingling may result in potential sources of contaminated seed stocks. Even at low frequencies within allowable purity standards, these co-mingling seed stocks could then act as sources of pollen flow contamination.

During harvesting, small numbers of plants along field margins can be missed. Under conservation tillage systems, these plants would remain undisturbed and be prone to spread through seed stripping by wildlife, wind and water.

Other severe weather events such as flooding, hail storms or tornadoes could act as vectors for seed movement. In Manitoba, the recent occurrence and spread of the weed, curled dock, in the Red River Valley region is thought to have been influenced by water movement during the 1997 flooding of the Red River.

Cost and Management of Volunteer RRW

The level of complexity for managing RRW in rotation is currently being studied, and will weigh heavily into the cost-benefit calculation for introduction of the technology. Looking back at GM canola, many are quick to point out the benefits of the technology in terms of reduction in management risk in producing canola. However compared to wheat, given the differences in management practices, and the fact that there is little demand from farmers for help with improved weed control (close to 50 herbicide options are currently available for use on wheat), some feel the risk of contamination alone warrants keeping RRW out of the Canadian wheat system.

Some of the factors affecting the cost of volunteer RRW control include:

> **Rotational considerations**
> Increased management considerations for including RRW into rotations where pulse or special crops are included. Pulse and special crop growers have limited effective weed control tools, and rely on glyphosate for both pre-seed and pre-harvest operations. As previously mentioned in the University of Saskatchewan study discussion, there are management considerations for introducing RRW with other Roundup Ready crops that will necessitate tank mixing to control volunteers;
>
> Some believe that the introduction of glyphosate as an in-crop treatment for RRW, as a means to simplify the agronomic production system, is a poor choice. Ongoing crop rotational studies demonstrate the benefits of increasing biological diversity and long- term sustainability in terms of reducing management risk and increasing net returns.
>
> Additionally, other issues mentioned include disposal and handling of dockage screenings and control of volunteers from a disease standpoint (e.g. the potential for RRW volunteers to act as a green bridge for wheat streak mosaic and subsequent implications for winter wheat production);
>
> **Conservation tillage management**
> For farmers who do not accept the RRW technology, the risk of introduction by contamination is significant. Glyphosate is the predominant tool under minimum or no-till regimes for weed control, and its effectiveness would be reduced by the impact of having to control volunteer plants. The requirement for tank mixing glyphosate with an additional herbicide to control

volunteers would reduce the overall economic benefit by the cost of the additional herbicide. The Saskatchewan Soil Conservation Association's position paper on RRW outlines their concerns for increased cost and complexity in managing volunteers, especially when more that one Roundup Ready crop is grown in rotation.

As previously mentioned under rotational considerations, over-reliance on glyphosate for in-crop use resulting in increased selection pressure puts at risk other conservation practices relative to water conservation farming and direct seeded forages;

Chem fallow
In the more arid regions of the Prairies where chem fallow is used as an effective soil and moisture management practice, glyphosate is one of the most cost-effective tools widely used in weed control programs. The lack of alternate cost effective control strategies would require mixing glyphosate with a secondary herbicide partner.

Increased costs
All of the comments made above relate to the additional cost of controlling and managing volunteers, which negates any net realized benefit for farmers deciding to grow RRW. Non-adopters risk increased management costs from the introduction of RRW volunteers onto their farms.

Monsanto indicates they are developing cost-effective and environmentally responsible ways to control volunteer Roundup Ready plants. This involves the development of pre-formulated mixtures of other herbicides with glyphosate, and including built-in designer adjuvants to enhance efficacy. They do not yet indicate what the price will be for these new herbicide products or the implications for RRW farmers versus non-adopters. They have, however, applied for patent protection in the development of these tank mixtures for controlling volunteers of any Roundup Ready crop. In any case, the ability for farmers to choose a formulation and supplier of glyphosate will be restricted, dependent upon the presence of volunteer Roundup Ready plants in their rotation and tillage regime. Both the Saskatchewan Soil Conservation Association and the Manitoba North Dakota Zero Tillage Farmers Association have expressed concern about the agronomic impact and rising cost of weed control due to the introduction of RRW.

Many are concerned about Monsanto's reliance on mixing glyphosate with Group 1 chemistry given the poor efficacy of Group 1 under cooler temperatures, dense weed populations and/or adverse environmental conditions.

2. Weed Resistance Management

While the use of an in-crop treatment of glyphosate may be viewed as a positive weed resistance management tool, there is debate that this movement to an in-crop use pattern will result in increased risk for developing glyphosate resistance. The spectrum and abundance of weeds present at time of in-crop application will be different compared to those for a pre-seed or pre-harvest application. Increased widespread use of glyphosate on weeds that would not normally be present at time of application would result in increasing the selection pressure on these populations. The end result would be an actual increase in risk for developing weed populations resistant to glyphosate. Van Acker and Entz (2001) illustrate how the change in use pattern for Roundup herbicide could lead to the evolution of glyphosate resistance in Western Canada, which is a concern for farmers who rely on direct seeding.

Some have commented that regardless of risk for developing resistance, the increased selection pressure would result in weed population shifts to species having natural tolerance to glyphosate.

3. Environmental Risk Management

The use of an in-crop treatment of a non-selective herbicide such as Roundup would increase the management risk associated with drift to sensitive crops and/or habitat buffer zones.

D. Comparison of Roundup Ready Wheat and Canola Systems

There have been many references to the rapid adoption of GM canola, the benefits associated with these technologies and why the introduction of RRW would benefit farmers. In comparing and evaluating the agronomic benefits of the RRW system to GM canola, it must be clear what the agronomic differences are between growing canola and wheat and the relative concerns farmers have when they are assessing their production risks.

The Canola Council of Canada recently conducted a study evaluating the impact of transgenic canola on growers, industry and environment. It is worthwhile to look at some of the key agronomic findings from this study, and see how they might compare in the RRW system.

1. Benefit in Weed Management

One of the key benefits identified by farmers' adoption of GM canola was improved weed control and weed resistance management. Compared to wheat farmers, prior to the introduction of GM technology, canola farmers had limited cost-effective weed control options, especially for managing broadleaf weeds. Weed control programs relied heavily on pre-emergent herbicides and careful field selection. The introduction of RR canola simplified the system so that farmers could select any field regardless of weed spectrum. Wheat farmers currently have many more highly effective herbicides to choose from, and the ability to use them in tank mixtures for achieving broad-spectrum post-emergent weed control.

The option to use Roundup in-crop provided an additional mode of action for farmers to take to delay weed resistance in particular to Group 1 resistant wild oats. Wheat farmers concerned about delaying wild oat resistance are currently rotating to a Group 2 wild oat herbicide, keeping Group 1 use available for flax, pulse and special crop production. The development of multiple group resistance in wild oats will limit this control strategy. The benefit of a RRW system for delaying weed resistance would still likely be viewed as a positive attribute for most farmers.

2. Yield, Dockage and Grade

In GM canola, there was an average ten per cent yield increase that was attributed in part to higher yielding varieties (mainly through advances in hybrid varieties), improved weed control and earlier seeding. Differences in breeding programs likely will not result in significantly higher yielding varieties of GM wheat being introduced as compared to non-GM varieties. Currently, farmers have access to the wheat variety AC Superb, which is the non-GM variety from which one of the first varieties of RRW is derived. As previously discussed, wheat farmers already have access to a much wider range of herbicides than did canola growers, so will likely not see the same change in weed control that GM canola offered them. Early seeding in wheat is not as significant a management issue as it is for canola, as farmers do not have the problems associated with limited herbicide options and having to rely on pre-emergent herbicide programs. One of the biggest benefits of early seeding with canola was the avoidance of high summer temperatures during the critical flowering period, which is also not as significant a concern in wheat production.

Reduction in dockage was observed and also attributed to more effective weed control. Again due to differences in available herbicide options, dockage is generally not a management issue for wheat farmers.

No differences in grade were noticed following the introduction of GM canola. However as already discussed, Monsanto does feel there will be benefits in wheat quality with RRW due to more uniform kernel development, although experts question the reality of this assertion.

3. Tillage and Summerfallow

Farmers used extensive tillage for seedbed preparation for canola, including pre-emergent herbicide incorporation. The introduction of GM canola allowed more farmers to adopt minimum or no tillage practices. This reduction in tillage allowed for improved soil conservation, reduction in summerfallow and a reduction in fuel consumption. Direct seeding and minimum till systems are already common practices in wheat production, therefore the same benefit is not likely to be realized under introduction of RRW.

4. Less Herbicide Used

The introduction of GM canola allowed farmers to replace high-use rate pre-emergent herbicides, with much more effective lower use rate post-emergent herbicides. This difference in rate of active ingredients allowed for significant reduction in overall amounts of pesticides used, despite an actual increase in the average number of herbicide applications on GM canola. Wheat farmers have many more options in effective post-emergent herbicides at low-use rates, so it is unlikely the same reduction in overall pesticide use would be observed, although there would still likely be an improvement in terms of environmental footprint.

5. Increased Grower Revenue

In the canola study, a net revenue benefit of $5.80 per acre was reported. This higher revenue was attributed in large part to higher yield, less dockage and reduction in tillage. Given the differences between canola and wheat production already noted, it is questionable how much benefit farmers adopting RRW technology would accrue as compared to the introduction of GM canola.

Section Two: Main Issues and Information Gaps

1. Control of Volunteer RRW

There is wide agreement that the issue of volunteer control requires that management practices need to be in place prior to introduction of the technology. This is often commented on as the major deficiency in introducing GM canola to Western Canada.

The studies conducted by the University of Saskatchewan Department of Agricultural Economics demonstrate that the potential returns herbicide tolerant wheat offers farmers are highly sensitive to their individual management practices and cropping systems. Increasing costs of managing volunteer RRW, especially under conservation tillage systems, could negate potential returns from the introduction of RRW. Further, including more than one Roundup Ready crop in rotation would require careful management of volunteers and could lead to increased herbicide costs if tank mixtures are required for control. The cost of control and complexity of managing volunteer RRW in rotation remains to be determined and would have a large impact on the net revenue benefit a farmer adopting the technology would realize.

2. Gene Spread

Among researcher scientists and agronomists, there is overwhelming agreement as to the potential risk for contamination of non-GM wheat through spread of the RRW gene. The persistence of volunteer RRW in crop rotations will be a potential source of genetic contamination for both adopters and non-adopters of the technology. It remains for Monsanto to assess and communicate the magnitude of this risk, and the consequences for current agronomic management practices. The ability to control the spread of a gene from a GM crop has not been demonstrated with Roundup Ready canola in Western Canada.

Field surveys demonstrate that volunteer wheat may persist in rotations for up to five years. Given the frequency of wheat in crop rotations and the length of volunteer persistence, gene spread by contamination through co-mingling of seed, or through pollen flow, is of primary concern for farmers who choose not to adopt the technology.

More research is required on the risk of gene spread if RRW were to be granted environmental release and grown on commercial scale. The factors of large-scale pollen sources and herbicide selection pressure must be further investigated. The persistence and dormancy characteristics of volunteer wheat in crop rotations must be better understood to ensure cost-effective control options and stewardship practices are in place prior to introduction of RRW.

3. Herbicide Resistance

While RRW offers a new control option for resistant weed management, there is concern that the in-crop use of Roundup will increase the selection pressure and risk for developing weed resistance to glyphosate. The development of glyphosate weed resistance could pose a major threat to soil conservation advances made through the adoption of zero-till and minimum till direct seeding systems which are both highly reliant upon the use of glyphosate for pre-seed weed control

4. Crop Tolerance and Yield Benefit

The profitability of RRW is highly sensitive to individual farm management practices. There is currently a lack of information as to where and when RRW would be the optimal production system for a farmer to adopt.

5. Quality Enhancement Claims

A large gap exists in the information on end-use quality enhancement.

6. Comparison to Other Roundup Ready Systems

Comparing RRW to other Roundup Ready systems requires careful consideration of the differences between cropping systems. In canola, soybeans or corn, the introduction of Roundup Ready technology reduced agronomic management risk by offering improved weed control and environmental benefits in terms of soil conservation and ground water quality. It is unclear as to whether or not these same benefits would be realized in spring wheat production through the introduction of RRW.

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