Agronomic Benefits and Risks of Using Roundup Ready Wheat in Western Canada

R. Van Acker and M. Entz
Dept. of Plant Science, University of Manitoba, Winnipeg, MB R3T 2N2

Introduction
The pending registration and introduction of Roundup Ready wheat into Canada is controversial. While the technology will simplify, and in some cases improve in-crop weed control in wheat, there are a number of concerns surrounding the release of this crop. The benefits could include reductions in herbicide injury to wheat, improved control of herbicide-resistant weed biotypes, elimination of off-type wheat within a crop, and increased in-crop opportunities for the control or suppression of perennial weeds. The risks could include difficulty and cost of control of volunteer wheat, the risk of developing glyphosate resistant weeds in glyphosate dependant direct-seeding systems, the loss of farmer saved seed options for wheat and the contamination of wheat segregated for sale as non-GMO for significant customers in a single-desk marketing system.

Benefits
The primary benefit that has been touted for Roundup Ready wheat is improvement and simplification of in-crop weed control (Anonymous 2001). Certainly with Roundup ready canola growers experienced a much simpler weed control system and the efficacy and ease of use of Roundup are well recognized (Devine and Buth 2001). The increased prevalence of species such as sowthistle (Sonchus arvensis), Canada thistle (Cirsium arvense), flixweed (Descurainia sophia) and dandelion (Taraxacum officinale) across western Canada over the past decade is a concern to those practicing direct-seeding (Thomas et al. 1998). There is some speculation that an in-crop application of Roundup at a rate of 1 L product/acre could provide a useful tool for the control of many problem perennials and winter annuals in direct seeding systems (Froese 2001). With Roundup Ready wheat it will also be possible to eliminate off type wheat and other cereals from wheat. This will aid seed producers in maintaining purity of seedlot and it may help producers to reduce dockage and increase grade levels for their crop (Ogg and Jackson 2001).

There is some suggestion that the engineered herbicide tolerance of Roundup Ready wheat would reduce the level of herbicide injury in wheat that presently occurs with the use of group 1 wild oat herbicides (Acetyl CoEnzym A Carboxylase inhibitors) and group 2 wild oat herbicides (Acetyl Lactate Synthase Inhibitors) (Holzman et al. 2001). This benefit may be true in some cases where weather conditions increase crop injury but it must be recognized that in Manitoba between 1992 and 1997, on average for more than 35% of spring wheat fields, no wild oat herbicides were applied at all (Thomas et al. 1999).

Risks - Market Issue
Market acceptance
At the moment Canada sells wheat through a single desk system (the Canadian Wheat Board). Within this system all wheat within a class and grade may be pooled for shipment to meet customer needs. On average the CBW has about 20 per cent of the world market share for wheat, and 65 per cent for durum wheat (source: www.cwb.ca). The CBW sells some wheat to customers that are concerned about the presence of genetically modified wheat (GMO wheat) in their deliveries. Because we have single desks selling and a pooling of wheat within class and grade customers are concerned about the release of Roundup Ready wheat if there is not a segregation system in place of sufficient rigour as to provide assurance to customers that require it the absence of GMO wheat within a given shipment of Canadian wheat. If this market issue did not exist we would be left with management issues around the release of Roundup Ready wheat and these will be discussed later in the paper. However, at present the market issue does exist and if there is to be a system in place whereby the Canadian wheat production, collection and transport system can meet the non-GMO standards of the customers we must consider the challenges to meeting the requirements of such a system. The market issue may also be confounded with concerns over threats to biodiversity in the centres of origin for key world crops such as wheat. Recently there has
been evidence of transgenes escaping from corn to teosente in Mexico (Ellstrand 2001). Within the scope of this paper we will deal only with the agronomic and biological challenges around the segregation issue.

Segregation and Gene Escape

The segregation issue will eventually be defined by the limits on GMO contamination which will be allowed in shipments to customers requiring such tolerances. The level of these tolerances will determine whether they are achievable. Prior to the release of Roundup Ready wheat we have the fortune of having a broad release of Roundup Ready canola which we can use as a comparator case to aid us in evaluating the possibility of achieving and maintaining segregation systems in wheat.

In general, wheat is as persistent as canola both in terms of quantity (density) and frequency (% of fields) and it can persist to a measurable level for at least five years (Fig. 1). Persistence of canola cultivars is linked to dormancy characteristics which vary by cultivar (Gulden et al. 2000). The same is likely true for wheat cultivars.

Wheat can outcross to a significant extent under test conditions with a relatively small pollen source (Fig. 2). This outcrossing rate is cultivar dependant. Cultivars that have a greater level of male sterility are forced to greater outcrossing levels. The level of outcrossing can be similar to that seen with canola under similar study conditions (Staniland et al. 2000; Hucl and Matus-Cadiz, 2001).
Figure 2. Outcrossing rates of wheat (cv. Oslo vs cv. Katepwa) versus outcrossing rate of canola (mix of cultivars) up to distance of approximately 27 m from pollen source. Adapted from Staniland et al. 2000 and Hucl and Matus-Cadiz, 2001.

Figure 3. Outcrossing frequency for *Brassica napus* in paired field trials conducted at 11 sites across Saskatchewan in 2000. Fields were ¼ section pairs with one field seeded to Liberty tolerant canola and the other seeded to Roundup Ready canola. Outcrossing frequency was determined from samples taken at crop maturity out to distances of 800 m from shared border. Frequency at 800 m = 0.07%. Adapted from Beckie et al. (2001).

The studies on pollen flow in wheat in western Canada to-date have only been conducted over a limited area and included only a relatively small pollen source, and they have included only a very limited number of cultivars. In canola Beckie et al. (2001) have conducted a much larger field trial using paired entire ¼ section fields where the pollen source is large and the scenario resembles common practice after the release of Roundup Ready canola. The results show that outcrossing continues to a consistently measurable extent (measure at 11 field sites) to at least 800 m (Fig. 3). This study helps to explain why...
there have been so many reported cases of farmers finding Roundup Ready volunteer canola in fields in which no Roundup Ready canola has been seeded (Hall et al. 2000). There is also informed speculation that certified seedlots of canola are contaminated with genes from GMO canola and that this is leading to a general and uncontrolled spread of genes, such as those conferring Roundup resistance, throughout the canola genome in western Canada. The type of study conducted by Beckie et al. (2001) for canola has not been completed for wheat but it is required if we are to adequately plan for the confinement of Roundup Ready genes when Roundup Ready wheat is commercially released. It would be particularly important to investigate the outcrossing and persistence characteristics of cultivars which may potentially become available as Roundup Ready.

To complete our consideration of the challenges in segregating Roundup Ready wheat, and preventing gene spread from Roundup Ready wheat we must also consider the frequency of spring wheat in rotations in western Canada. In Manitoba, between 1992 and 1997 canola, on average, was included in rotations 23% of the time (approximately 1 in 5 years). Spring wheat, however, was included in rotations 43% of the time (approximately 2 in 5 years) (Thomas et al. 1999). Given the evidence of similarity in persistence of spring wheat and canola (Fig. 1) and the experience with canola with regard to the spread of the herbicide tolerance genes within the canola genome, it is likely that a release of Roundup Ready wheat with only the confinement regulations that existed with the release of Roundup Ready canola, would lead to perhaps an even more rapid and extensive uncontrolled spread of the Roundup Ready gene in the wheat genome of western Canada.

**Risks - Management Issues**

**Control of Volunteers**
If Roundup Ready wheat becomes commercially available the Roundup Ready wheat volunteer control will become an issue for farmers. Given the experience with gene escape in canola in Canada the issue of volunteer Roundup Ready wheat control may extend to producers who do not choose to grow this product. The control of Roundup Ready volunteer wheat will require the use of a non-glyphosate herbicide in the common pre-seeding herbicide “burnoff” for those producers who use a direct seeding system. Farmers who are dealing with Roundup Ready canola volunteers are concerned about costs and efficacy. They will have the same concerns with Roundup Ready wheat volunteers. Trials are being conducted to test the efficacy and reliability of control of wheat volunteers with various rates of group 1 herbicide (the aryloxyphenoxypropionates). Initial results look promising (Rainbolt et al. 2001) but there remains insufficient broad group 1 rate range efficacy data on real volunteers (those emerging from fall seed very early in the spring) in areas of western Canada where spring nights can be very cold. It is also true that nothing has been published on the biology and ecology of volunteer spring wheat to provide information on time of emergence and length of emergence period for this species (Ogg and Jackson 2001); two factors which can greatly influence pre-seeding and in-crop efficacy (Martin et al. 2001).

**Dependence on Glyphosate**
The refinement and adoption of direct seeding has been of tremendous value to farmers in western Canada in terms of savings in fuel, conserving soil organic matter, conserving soil moisture (allowing for continuous cropping with less fallow) and allowing producers to maintain economic viability by capturing economy of scale value (Derksen et al. 1996). In much of Saskatchewan, Manitoba and Alberta, farmers rely on direct seeding preceded by a glyphosate only burnoff. Many of these producers even use low glyphosate rates (0.3 L product/acre) to achieve sufficient burnoff at low herbicide cost (approximately $3.00 – $3.50/acre). Burnoff is used on many acres per farm (commonly over 1500 acres/farm) and any increased cost in burnoff, even a minor $2.00-5.00 increase could be a significant economic burden for these farmers. If there is gene escape of the Roundup Ready gene into the general wheat genome, then this cost will be incurred both by producers who chose to grow Roundup Ready canola and those who do not. Some farmers comment that although Roundup Ready wheat may bring simplicity to in-crop weed control in wheat, the control of volunteer Roundup Ready wheat will add to the cost and complexity of the now simple pre-seeding burnoff.
Resistance to Glyphosate

The evolution of glyphosate resistance within populations of weed species in western Canada is of great concern to producers who rely on direct seeding. To-date there has been confirmation of weed-resistance to glyphosate for 3 species; rigid ryegrass (Lolium rigidum) in Australia and northern California, goosegrass (Elusine indica) in Malaysia and horseweed (Conyza canadensis) in Delaware (Ogg and Jackson 2001). The latter is known as Canada fleabane in western Canada (Erigeron canadensis), a wind-dispersed winter annual considered common in zero-till fields (Watson et al. 2001). Some argue that the small number of resistant biotypes worldwide after glyphosate has been used for such a long time confirms that it is a herbicide to which resistance will rarely evolve (Bradshaw et al. 1997). Bradshaw and her colleagues (1997) published their review prior to the confirmed reports of glyphosate-resistant ryegrass in Australia. If glyphosate is always mixed with herbicides with other modes of action this may help to slow the evolution of resistance for common annual weed species, but the additional herbicides would have to offer efficacy and spectrum similar to that of Roundup, and the cost would have to be equivalent to that of Roundup alone or the farmers would be paying directly to slow the evolution of resistance to glyphosate.

No review has considered the change in use pattern of glyphosate towards extensive in-crop use in addition to its traditional role in pre-seeding weed-control and for the specific control of problem perennials. Perennials such as Canada thistle rely heavily on vegetative propagation and have limited gene pools (Heimann and Cussans 1996). Selection for resistance is often a numbers game and the likelihood for the existence of and selection for resistant biotypes increases for outcrossing annual species which have large and transient populations. In western Canada wild oat fits these criteria and many herbicide resistant and cross-resistant biotypes of wild oat have been selected for (Beckie et al. 1999). An increase in use of glyphosate in-crop will greatly increase the selection pressure for glyphosate-resistant
annual weeds. Even the movement to in-crop use in addition to pre-seeding use of glyphosate greatly increases the selection pressure because the in-crop control tends to include a much greater proportion of the annual weed population in any given field (Fig 4.)

Farm-saved seed

In Manitoba almost half of spring wheat seed is home-grown (Thomas et al. 1999). This is in contrast to canola where 100% of the seed used by farmers is purchased certified seed. The restriction in Roundup Ready canola to not use farm-saved seed would cause a significant change in practice and cost for many spring wheat producers if the same restriction applied in Roundup Ready wheat.

Summary
Roundup Ready wheat will bring simplicity and high efficacy and crop safety to spring wheat production in western Canada. There is, however, growing evidence of the problems of gene escape with Roundup Ready canola in western Canada. Given the strong similarities between wheat and canola with respect to field persistence and outcrossing rate to 27 m from pollen source, and the fact that spring wheat appears much more frequently in rotation than does canola it is apparent that there is a broad gene-bridge in spring wheat production in western Canada providing high risk for gene escape from Roundup Ready wheat. Gene escape will lead to both marketing and management problems with spring wheat and it may limit the sustainability of the valuable practice of direct-seeding in western Canada by increasing the cost and complexity of pre-seeding weed control and increasing the risk of glyphosate-resistant weed evolution.

Acknowledgments
The authors would like to thank Mike Grenier, Lyle Friesen, Gary Martens and Anita Brule-Babel for helping us to form the ideas in this paper.
References


Holzman, J. 2001. The economics of herbicide tolerant wheat in western Canadian crop rotations. MSc thesis, University of Saskatchewan, Saskatoon. SK.


