

Rotations with Herbicide Tolerant Crops

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Introduction

Herbicide tolerant (HT) canola now occupies 85% of the canola acreage in Canada. This is a rapid increase since its introduction in 1995. Farmers have adopted it due to the greater number of options it provides for weed control. Not only do they use the more effective herbicides available in-crop for these HT types, but they also use that control to clean up weeds from the previous crop. Their choice of canola and herbicide system subsequently affects their choice of crop and weed control in the following year. If introducing herbicide tolerance to canola, our 3rd most planted crop, has changed our rotations, consider what may happen when we introduce herbicide tolerance into our most widely grown crop: wheat. Herbicide tolerant wheat is coming to the prairies in 2004. This talk will discuss the interaction of herbicides with conventional rotations, and in HT canola and HT wheat.

Herbicide Groups

Herbicides are grouped according to mode of action, and herbicides within a group have many properties in common. Throughout this talk, herbicide groups will often be mentioned, rather than individual herbicide products, so the following table is offered as examples of common herbicides in each group

Group	Description	Examples of herbicides
1	Grassy control	Achieve, Puma, Horizon, Assure, Fusion, Select, Venture, Poast
2	Growth inhibitors, often with residual activity	Odyssey, Refine Extra, Sundance, Everest, Assert. Muster, Ally, Express Pack
3	Mitotic inhibitors	Treflan, Edge, Advance, Rival
4	Growth regulators	2,4-D, MCPA, Lontrel, Attain
6	Photosynthetic inhibitors	Pardner, Basagran, Buctril M (with MCPA),
9	Glyphosate	Roundup, Touchdown, Vantage, Credit, etc
10	Glufosinate	Liberty
11	Photosynthetic inhibitor	Amitrol
22	Desiccants	Gramoxone, Reglone

Typical rotations

Let's look at a typical 4-year rotation: Barley, Peas, Wheat and Canola. We'll see how the herbicide use changes with different HTC canola types, and later we'll look at HT wheat types.

Barley is typically seeded later, once the other crops are in the ground (see [http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/crop5757](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/crop5757)). Thus there may be an opportunity or need to apply a preseed herbicide as winter annuals are getting larger, spring annuals have emerged, or perennials have resumed growth. In-crop, a broad-spectrum combination is often applied, including a wild oat Group 1 product, and broadleaf control such as

a Group 6 and 4 product like Buctril M, or a Group 2 such as Refine Extra. Pre-harvest applications of glyphosate are often used in feed barley fields with significant perennial weed infestations, especially when the following crop is peas. Post-harvest applications are unusual, as barley is very competitive once established, thereby causing low fall stubble weed populations.

Peas are a good follow crop after barley. Although peas are seeded early, glyphosate applied preseed, or prior to crop emergence is fairly common since peas are not as competitive as cereals and canola. Odyssey (Group 2) or Pursuit (Group 2) and a Group 1 product are the most commonly used in-crop choices. The Group 2's are effective herbicides, but their persistence in the soil does limit the choices of subsequent crops, particularly in low organic matter soils and dry areas. Since peas are poor competitors and in-crop options lack perennial broadleaf weed control, producers should use pre-harvest glyphosate in the preceding crop in fields with perennial weed infestations. However, pre-harvest glyphosate is sometimes used in field pea to help dry down green annual weeds and late maturing peas, and for control of perennial weeds.

Wheat following peas allows for a good herbicide rotation, and wheat is tolerant to Odyssey residues. Wheat is normally seeded fairly early similar to canola, and preseeding herbicide application may be needed depending upon the weed spectrum present. As for barley, typical in-crop control includes a combination of wild oat control with a Group 1 product, and broadleaf control with Group 4 (Attain or MCPA for example) or Group 2 products like Refine Extra. Pre-harvest or post harvest control with glyphosate is a possibility to control perennials or emerging winter annuals.

Herbicide tolerant canola varieties have changed canola from a crop with few in-crop herbicide options, to several. Roundup Ready canola is most popular, occupying just over half of the canola acreage in Alberta (M. Hartman, personal communication). Liberty Link and Clearfield Canola have approximately 19 and 14% of the acreage, respectively.

A farmer's choice of herbicide tolerant canola system is dependent upon the weeds present, cost, presence of resistant weeds, soil type, and personal preference. If the Roundup Ready system is chosen, a preseeding burndown may not be done, as an early and later application of glyphosate in-crop will control both early germinators, and later annual and perennials. Post-harvest applications are least used following this herbicide system, due to good perennial control or suppression. Some producers will withhold a post-harvest glyphosate application in the year preceding Roundup Ready Canola, as they rely on early seeding and an early in-crop glyphosate application to control winter annuals.

In Liberty Link and Clearfield systems, early seeding means a preseeding herbicide application may not be needed. Preseeding burnoff options are limited to glyphosate and Amitrol. In Liberty Link systems, Group 3 products are sometimes used in the prior fall or before seeding (DF trifluralin) in areas with heavy flushing weeds such as chickweed and green foxtail. Odyssey is most commonly used in-crop in Clearfield Canola, and it has fewer recropping restrictions and better grassy control than Pursuit. Only one application is made in-crop, as it offers residual control of weeds. Liberty, the only choice in Liberty Link canola, offers good non-selective control primarily to young weeds. A single application is typical, often in a tank mix with a

Group 1, and the vigorous hybrid canola varieties in this system offer some competition to later emerging weeds.

Control of herbicide tolerant canola volunteers

Control of HT canola volunteers has required some adaptations to weed control in other crops. Any HT or conventional canola can be controlled by the Group 4 products 2,4-D or MCPA, Group 6 bromoxynil (Pardner), Group 11 (Amitrol) or Group 22 (Gramoxone PDQ). While the Group 4 or 6 herbicides are not registered alone for preseeding control, there are effective preseeding combinations as glyphosate tank mixes for most crops. In-crop, Clearfield canola volunteers will not be effectively controlled by Group 2 herbicides, therefore another Group must be used, typically Group 4 or 6 herbicides. In peas, Clearfield volunteers can only be controlled in-crop with Tropotox or Clovitox (Group 4) or Basagran (Group 6).

Effective canola volunteer control necessitates that we do not assume volunteers have only one type of herbicide tolerance. Pollen flow between adjacent canola fields occurs, and the outcrossing produces volunteers with additional herbicide resistance. This is usually first noted when some canola volunteers are unexpectedly not controlled by glyphosate or Group 2 products. Multiple herbicide tolerance in volunteers is not uncommon, for example if Roundup Ready (Group 9 resistant) and Clearfield (Group 2 resistant) canola have been grown close together, some volunteers would have resistance to both herbicide groups. In this example, preseeding mixtures like PrePass or Express+glyphosate (Groups 2 and 9) would be much less effective, particularly at the adjoining edges of the two fields where most of the cross-pollination would occur.

Multiple or additional unlabeled herbicide tolerance in canola can also occur in certified seed, and this is officially referred to as adventitious presence. While it is not a concern for a canola crop destined for crush, it is a concern for seed producers, organic growers, and those that do not wish to deal with herbicide tolerant crops and their volunteers. Even a low level of contamination, say 0.25%, may result in 1000 plants per acre with the unwanted herbicide trait. Producers can also ensure control of these types by using Group 4 and 6 products, as above.

Build-up of herbicide resistant weeds in a rotation

Repetitive herbicide use can eventually result in a build-up of resistant weed populations; therefore the groups of herbicides to be used should be factored into rotational decisions.

All weed species have genetic diversity, and each plant's genes determine its susceptibility to a herbicide. For example, all stinkweed seems tolerant of Lontrel, and susceptible to most Group 2 products. Yet there is a small percentage of stinkweed, perhaps 1 in a million with tolerance to those Group 2 products, and application of such a herbicide will kill all stinkweed except the one or 2 in the field with a resistant biotype. Thus the resistant plant sets seed, and the field has more of them the following year. Repeated use of the same herbicide, or even the same group, selects for such resistant plants until they have increased to form sizeable patches in a field.

It is more common to find biotypes with resistance to Group 1 and 2 herbicides than it is to find those resistant to Group 9 (glyphosate) or Group 4. Thus we refer to Groups 1 and 2 as high-risk herbicides. Many fields across the prairies have wild oat or one of 8 other weed species with

resistance to Group 1 or 2 herbicides. By comparison, there are very few weeds in the world with resistance to either glyphosate or 2,4-D.

Farmers on the Prairies frequently use these high-risk products. For example, 47% of the cropland in Alberta has Group 1's applied to them, and 35% receive Group 2 herbicides.

Group 1 products are used frequently for selective grassy control in crops as there are few herbicide options that offer lower risk of developing herbicide resistance. Group 2 (Everest, Sundance) and 3 (trifluralin, ethalfluralin) herbicides are an alternative to Group 1's for control of some grassy weeds, but they too are prone to development of resistant types. The wild oat Group 8 (Avenge, Avadex) and 25 (Mataven) products were discontinued, as long-term usage resulted in resistant populations building up in many fields. Grassy control can be achieved in canola and peas with other herbicide groups, thus the greatest risk of developing herbicide resistance to Group 1's appears to be in short cereal rotations.

While Group 2 products are also considered high risk for developing resistance, farmers use them less than 25% of the time for broadleaf control in cereals or canola (2003 data), so there appear to be decent herbicide rotations in most fields. However, producers should include the following year(s) as active Group 2 weed resistance selection when residual products (such as Pursuit) are used in low organic matter / dry soil situations. Weeds controlled only by Group 2 products in a producer's herbicide rotation would be the ones at highest risk for developing resistance. Chickweed and hemp nettle are examples of weeds with limited control options in cereals, other than using Group 2 products. Group 2 resistance has been reported on the prairies on both of these weeds, and is widespread in chickweed.

Avoiding build-up of herbicide resistant weeds in a rotation

Combining and rotating various weed control strategies will minimize the build-up of herbicide resistant weeds. Rotating to competitive crops, utilizing spring tillage, and maximizing crop growth by using management practices such as high seeding rate, early seeding, narrow row spacing, and silaging will effectively reduce the presence of resistant weeds.

Chemical control will remain most effective if combined with those agronomic practices, and:

- 1) Two or more herbicides effective against the weed are tank mixed. Recent research has shown that such tank mixes greatly reduce the build-up of resistant weeds.
- 2) Effective single herbicides are rotated, using the same group as infrequently as possible. Each time a single herbicide is used, realize that you may have selected a few resistant plants, and you will need to control them with other means next year. This may also necessitate a change in crop rotation. Save your best herbicide for your least competitive crop. For example, peas are poorly competitive, and Odyssey is the best herbicide for them. Once that Group 2 product has been used on peas, use other groups in the following crops as much as possible.

For grassy weed control, increasing the number of broadleaf crops such as peas and HT canola in the rotation allows a greater number of herbicide groups to be used.

Adding Herbicide Tolerant Wheat to a Rotation

This talk will discuss only rotations and weed control options in HT wheat, and not economic, market, or other issues. Herbicide tolerant wheat varieties can increase the options for weed control in-crop, but some adjustments will be required to control wheat volunteers in the following crop.

Spread of herbicide tolerance traits by pollen flow from one wheat field to another are expected to be much less than occurs with HT canola.

a) Clearfield Wheat

Clearfield wheat will be available in western Canada on a limited basis in 2004. The recommended herbicide for weed control in-crop with Clearfield (CF) wheat is Adrenalin, which contains 2,4-D and one component of Odyssey: the Group 2 product imazamox (AC299,263). If a field is to be sown to Clearfield wheat, a pre-seeding herbicide will be recommended, typically glyphosate, as Adrenalin cannot be applied until the wheat is at the 4-leaf stage. If Clearfield canola volunteers are in sufficient number, glyphosate alone, or glyphosate with a Group 4 or 6 product may be applied pre-seed. Adrenalin will control many weed species including all types of HT canola volunteers, and non-Clearfield cereals in-crop.

Rotations following Clearfield wheat

General observations suggest that volunteer wheat can be a problem in crops the year following a wheat crop, but seldom are they a concern two years after seeding wheat. Clearfield wheat volunteers cannot be controlled in-crop in cereals, so malt or seed barley, or durum wheat would be poor choices the following year. The only option for control in these cereals would be pre-seed, however glyphosate will be effective at this time.

Most crops including peas and all canola types may be seeded following CF wheat, however if you use Clearfield canola or peas, you will be stacking Group 2 herbicides, and encouraging the build-up of Group 2 resistant weeds. Clearfield wheat volunteers in Clearfield Canola may necessitate a Group 1 product in-crop (Assure, Fusion, Select, Venture, Poast), or preseed control with glyphosate.

Liberty Link or Roundup Ready canola, or silage barley would be good options following Clearfield wheat.

b) Roundup Ready Wheat

Roundup Ready wheat is not currently registered, but may become available in a year or two. If a field is to be sown to Roundup Ready wheat, a pre-seeding herbicide will usually not be applied. However, if Roundup Ready canola volunteers are in sufficient number, a Group 2, 4, or 6 product must be applied, either pre-seed, or in-crop. Good control of perennials in-crop may mean a pre-harvest or post-harvest glyphosate application may not be required.

Rotations following Roundup Ready wheat

Most crops seeded the year following Roundup Ready Wheat may require a pre-seed tillage or herbicide such as a Group 1, 10 (Liberty), 11 (Amitrol) or 22 (Gramoxone PDQ) to eliminate potentially high levels of wheat volunteers. The inexpensive, effective pre-seed option of

glyphosate alone will only be suitable two years or more after Roundup Ready wheat. Currently, only Gramoxone PDQ and Amitrol are registered for a general pre-seed burndown that would control Roundup Ready wheat, but Gramoxone PDQ cost is high. The pre-seeding rate Amitrol has a short residual that forces delayed seeding for crops other than wheat, barley and canola. However, Monsanto is testing Group 1 products for such use. In barley seed production, malt barley or durum wheat, the pre-seeding window is the only opportunity to control the wheat volunteers, and thus a registered, cost-effective herbicide is essential unless tillage is to be applied. If a Group 1 product is chosen, it should be one with good efficacy under cool conditions to be used at that time of year. The extra applications of Group 1 products to control Roundup Ready Wheat volunteers may mean there will not be a reduction in usage of high-risk products if this technology is adopted.

In Liberty Link and Clearfield canola, the in-crop Liberty and Odyssey treatments will control wheat volunteers. For Roundup Ready Canola, an additional Group 1 product may be required for the Roundup Ready wheat volunteers.

Summary

Crop and herbicide rotations are necessarily linked together, and a change in one can necessitate a shift in the other. Herbicide tolerant crops allow a greater number of herbicide groups to be rotated, thus controlling a greater number of weeds, and retarding the development of herbicide resistant weed populations. Herbicide tolerant canola has been widely adopted across the prairies, and herbicide tolerant wheat will be available in 2004. Control of HT volunteers requires adjustments to pre-seeding and in-crop applications, and additional herbicides may be required.