
ECOLOGY AND MANAGEMENT OF VOLUNTEER CANOLA

Introduction

Canola (*Brassica napus* L.) acreage has increased dramatically over the past decade. The seeded acreage in Canada has doubled from about 6 million acres in 1990 to over 12 million acres in 2004. This has contributed to volunteer canola becoming a more prominent weed issue in Western Canada.

Canola has a number of characteristics that are similar to weeds. It has a greater ability to respond to environmental fluctuations than most crops, and it produces a large number of seeds per plant. Under stressful conditions, some canola varieties have the ability to develop secondary dormancy (that is, shed seeds that are unable to germinate even when conditions are favourable), allowing for persistence in the soil seed bank. However, canola does not possess other common weed properties such as: sporadic germination; long seed life in the soil; mechanisms for long distance seed movement; or specialized competitive traits.

The abundance of volunteer canola in prairie fields has increased over the past fifteen years with the largest increases occurring in Saskatchewan and Manitoba (Table 1). While volunteer canola abundance has increased, the abundance of other volunteer crops has also increased. For example, volunteer wheat was ranked the 6th most abundant weed in Saskatchewan in 2003, an increase of 12 rankings since the 1980's.

Canola varieties with resistance to specific herbicides were introduced in the mid-1990's. Canola that is resistant to Roundup or other glyphosate products (Group 9), Liberty (Group 10), or imidazolinone (Clearfield) herbicides such as Odyssey and Pursuit (Group 2) have

become very popular choices for producers. It is estimated that over 90% of the canola acreage seeded on the prairies are varieties with these novel herbicide-resistant traits. Bromoxynil-resistant canola was also developed but is no longer commercially available. Roundup Ready and Liberty Link canola were developed through genetic transformation while Clearfield canola was developed by chemical mutagenesis.

Table 1: Relative abundance ranking of volunteer canola in weed surveys of the Prairie Provinces conducted in 2001-2003 and 1986-1989.

| Province | Abundance Ranking of Volunteer canola in: | |
|--------------|---|---------|
| | 2001-2003 | 1986-89 |
| Alberta | 12 | 19 |
| Saskatchewan | 13 | 21 |
| Manitoba | 9 | 28 |

With the introduction of herbicide-resistant traits, a number of concerns have arisen: gene transfer to wild relatives, "stacking" of multiple herbicide-resistant traits (e.g. canola plants with resistance to both Roundup and Liberty), and the control of volunteer canola prior to seeding broadleaf crops. In addition, the introduction of specialty canola with unique fatty acid profiles has raised concerns over identity preservation. To address these issues, a number of studies have been conducted at both Agriculture and Agri-Food Canada (AAFC) and universities to investigate the ecology and management of volunteer canola.

Issues

Harvest losses

Research conducted by the University of Saskatchewan on a number of producer's fields indicated high amounts of seed return to the soil from swathing and combining. On average, approximately 325 canola seeds/sq ft were returned to the soil surface from harvesting operations. Of this, about 80% of the seed was viable. This equates to 95 lbs/acre or about 15 times the normal seeding rate. In some cases, seed return was as high as 1300 seeds/sq ft.

Persistence / Secondary dormancy

Canola seed has been shown to persist in the field for at least four years after planted; however, it was not determined whether the persistence was due to reseeding of volunteers. More recent research has shown that about 0.1 to 0.2% of an original canola seed bank addition was present three years after seeding. In these studies, volunteers were controlled. Therefore, the vast majority of the canola seed bank is eliminated in the first two years after canola is grown. As mentioned above, seed bank additions from harvest operations can be relatively large. If the harvest operation contributed 300 seeds/sq ft to the seed bank, 1 seed every 2 sq. ft. could be present three years later.

Under certain environmental conditions (predominately warm, dry conditions after the seed has taken up some water), canola seed may develop secondary dormancy resulting in prolonged soil persistence. Some canola varieties have a higher potential for secondary dormancy than others. Unfortunately, varieties are not normally evaluated for this characteristic nor do breeding programs attempt to screen out this trait.

Outcrossing / Gene flow

The concern of outcrossing to weedy relatives has arisen with the introduction of canola types that have been bred to be resistant to specific herbicide groups. The other concern is the movement of the herbicide resistance genes between canola types, resulting in "stacking" of herbicide resistance traits.

The frequency of pollen-mediated gene flow and subsequent cross-fertilization of Argentine canola with wild relatives such as wild mustard, wild radish, and dog mustard is extremely low. In extensive greenhouse and field studies, only one Argentine canola/wild radish hybrid was detected among 33,000 plants tested in one field experiment, while no hybrids were detected in three other field experiments (26,000 samples tested). No Argentine canola/wild mustard or Argentine canola/dog mustard hybrids were detected among 43,000 and 22,000 seedlings tested, respectively. On the other hand, Argentine canola can cross-pollinate with *Brassica rapa* L. (Polish canola, bird's rape). The degree to which hybrids will form will depend on the varieties and the distance between the two species. In field studies conducted in Saskatchewan where Polish canola was grown beside an herbicide-resistant Argentine canola field, hybrids were detected at frequencies of 0.11% at 40 m and dropped below 0.01% at distances of 60 to 250 m from the edge of the Argentine canola field. The weedy bird's rape occurs in Eastern Canada and is not found in the canola growing areas of Western Canada. Also, Polish canola acreage is low in Western Canada (< 5% of canola grown) so the risk of gene transfer between these two species is currently low.

Pollen flow between varieties is quite common and there are reports of volunteer canola with resistance to two or three herbicide groups. The risk of multiple herbicide resistance developing depends on a number of factors: the distance between and the relative size of the pollen donor and recipient fields; environmental conditions such as wind speed and direction, relative humidity and temperature; and the presence of insect pollinators. Studies conducted at eleven commercial fields in Saskatchewan where Roundup Ready and Liberty Link canola were grown side by side found that gene transfer between these two canola types occurred at distances of up to 800 m (limit of the study area). Outcrossing dropped rapidly as the distance between the two canola types increased. For example, outcrossing frequency

of 1.4% occurred at the field borders but fell to 0.04% at 400 m. While multiple herbicide-resistant canola volunteers can occur, these volunteers have the same susceptibility to herbicides with other modes of action (2,4-D, MCPA, Buctril-M and Sencor) as conventional canola or canola with single resistance traits.

In some cases, canola with a particular herbicide resistance trait has shown up in fields where that type of canola has never been seeded. This may be due to gene transfer or seed contamination. Research in Saskatchewan and Manitoba has found the presence of off-type herbicide-resistant seed in certified seedlots. The percent of off-type seed ranged from 0 to as high as 2% in some cases. Even a small percentage of off-type seed in a seedlot can result in many unwanted off-type plants per acre. For example, 0.25% of off-type seed in a seedlot can result in over 1,500 off-type plants/acre. Efforts are underway by various organizations to minimize the presence of off-type seed in certified seedlots.

Cultural Management of Volunteer Canola

In order to minimize swathing losses, producers should start swathing their canola at the 30 to 40% seed colour change so that the majority of the crop is swathed at the optimum stage of 60% seed colour change. The Canola Council of Canada has a publication entitled *Canola Time of Swathing Guide* that producers can consult to determine optimum time of swathing. Delayed swathing will increase shatter loss and also appears to increase the potential for some canola varieties to develop secondary dormancy. In addition, the combine should be set to minimize harvest losses.

Research in Europe found that secondary dormancy and canola persistence were reduced in zero-tillage systems. Canadian studies have not shown tillage system to be as important a factor in determining the persistence of volunteer canola. In a study conducted across eight locations on the Prairies, canola persistence was similar in a crop-fallow and a continuous cropping rotation and level of soil disturbance (zero or conventional till) had little effect on persistence. However, secondary

dormancy does tend to be reduced if canola remains near the soil surface. Over-winter and early spring mortality of seed placed near the soil surface was found to be greater than for seed buried deep. Thus, producers should avoid fall or early spring tillage to allow the seed to remain on or near the soil surface.

There are a number of cultural methods that producers should integrate with chemical control to maximize economic benefits and minimize environmental concerns. These include high seeding rates, crop rotation, herbicide rotation, and early weed removal. For more information on cultural weed management, see the Saskatchewan Agriculture, Food and Rural Revitalization website (www.agr.gov.sk.ca) for the factsheet *Integrated Weed Management – Making it Work on Your Farm*.

Chemical Control

To effectively control volunteer canola with herbicides, application must be done early. Although volunteer canola develops a somewhat increased hardiness from exposure to cold temperatures in the spring, this increased hardiness does not increase its tolerance to herbicides. The main factor affecting herbicide performance is the canola growth stage. Fig. 1 illustrates the importance of controlling volunteer canola at early growth stages.

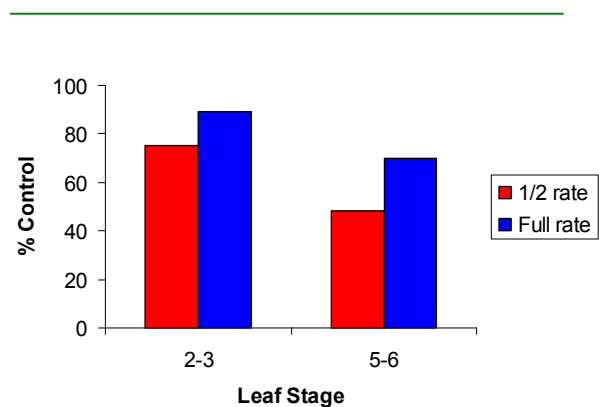


Figure 1: Effect of growth stage and phenoxy herbicide rate (2,4-D or MCPA) on % control of volunteer canola. Full rate equates to 0.45 L/acre of a 500 g/L formulation.

Pre-seed Burnoff

Pre-seeding glyphosate (various formulations) applications will control conventional canola volunteers as well as Liberty Link and Clearfield volunteers. A number of options exist for control of volunteer Roundup Ready canola prior to seeding cereals. The challenge exists for the control of Roundup Ready canola prior to seeding broadleaf crops such as field pea, lentil, sunflower, dry bean and chickpea.

To control volunteer Roundup Ready canola prior to cereals, most glyphosate formulations can be tank-mixed with 2,4-D, MCPA, Pardner, Buctril-M, or Express. Consult the current provincial Guide to Crop Protection for registered formulations or rates. The Pardner-glyphosate tank-mix must be applied very early (1-2 leaf stage) in order to provide effective control. PrePass, a formulation of glyphosate with a Group 2 broadleaf herbicide (florasulam) will also control all types of volunteer canola prior to seeding cereals. The glyphosate/Express tank-mix or the PrePass formulation may not control double-resistant Roundup Ready and Clearfield volunteers; however, these are rarely present.

For canaryseed, some glyphosate formulations can be tank-mixed with Buctril-M for control of all volunteer herbicide-resistant canola. Some glyphosate formulations can be tank-mixed with either Buctril-M or MCPA and applied prior to seeding flax.

Burnoff options prior to broadleaf crops are limited. Many of the broadleaf herbicides registered for pre-seed burnoff in cereals have a short-term soil residue that may damage emerging broadleaf crops. MCPA amine is registered as a tank-mix with glyphosate prior to seeding field pea. The rate of MCPA is quite low to minimize residue and application should be made early to maximize control. Research is ongoing to identify potential tank-mix candidates that can be safely applied prior to seeding broadleaf crops.

In-Crop Weed Control

As shown in Table 2, there are numerous in-crop herbicide options for controlling volunteer canola in cereals, but not in broadleaf crops. This reinforces the importance of crop rotation, specifically growing a cereal crop the year following canola.

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Table 2: Herbicides for controlling volunteer canola in field crops.

| Herbicide | Group | Cost/acre | Non-HR | Roundup Ready | Liberty Link | Clearfield | | Wheat | Durum | Barley | Oat | Rye | Canaryseed | Field com | Triticale | Flax | Soybean | Soybean | Bean | Chickpea | Lentil | Pea | Sunflower | Soybean | Fababean | Potatob |
|---------------------------|-------|-----------|--------|---------------|--------------|------------|----------|-------|-------|--------|-----|-----|------------|-----------|-----------|------|---------|---------|------|----------|--------|-----|-----------|---------|----------|---------|
| | | | | | | Group 9 | Group 10 | | | | | | | | | | | | | | | | | | | |
| PRE-SEEDING | | | | | | | | | | | | | | | | | | | | | | | | | | |
| glyphosate | 9 | 3.65-4.90 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Glamoxone | 22 | 29.06 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Senor | 5 | 5.91 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Altrinal | 1 | 7.50 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Mix 2,4-D or MCPA | 2,4 | 7.50 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Attain | 4 | 8.90 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Barvel II + MCPA or 2,4-D | 4 | 6.07 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Basaran | 6 | 17.82 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Basaran + 2,4-D | 6,4 | 10.90 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Buctri MMextrol/ Badge | 4,6 | 6.71 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Curtail M | 4 | 10.90 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Dichlorprop + 2,4-D | 4 | 5.75 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| DWel | 4 | 5.54 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| DWel DS | 4 | 4.68 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| FlexMax | 1,4 | 26.03 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Frontline | 2,4 | 7.40 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Glyphosate | 9 | 5.92 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Glamoxone | 1 | 7.50 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Herbimex | 1,6 | 23.18 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Herbimex BT MI | 1,6 | 23.18 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| K2 + 2,4-D | 2,4 | 23.01 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| MCPA* | 4 | 2.51 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| MCPA + MCPB | 4 | 21.95 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Odyssey | 2 | 24.43 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Pea Pack | 4,5 | 5.95 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Prestige | 4 | 14.45 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Prevail | 1,4 | 25.75 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Pursuit | 2 | 22.40 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Pursuit Ultra | 1,2 | 26.07 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Refine Extra | 2 | 6.09 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Senor | 5 | 5.31 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Spectrum | 2,4 | 19.60 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Stance | 4 | 6.70 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Target | 4 | 6.70 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Thump | 4,6 | 6.42 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Triumph | 1,2,4 | 20.96 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Trophy | 4 | 10.05 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Unity/SK only | 2,6 | 7.25 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| CHEM-FALLOW | | | | | | | | | | | | | | | | | | | | | | | | | | |
| DWel DS | 4 | 7.94 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| glyphosate | 9 | 3.65-4.90 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| glyphosate + 2,4-D | 9,4 | 5.00-8.00 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| glyphosate + Barvel II | 9,4 | 7.95 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| glyphosate + Partner | 9,6 | 13.52* | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| glyphosate + Target/Sword | 4,6 | 6.70 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |

Information compiled from 2004 Saskatchewan / Manitoba Guide to Crop Protection – follow the information in the Guide if any discrepancy with information in this table; Cost / acre based on 2003 suggested retail prices.
 Abbreviations: Non-HR: non-herbicide resistant; NA: not available.