THE CANADIAN GMO CANOLA EXPERIENCE

K. Neil HARKER and George W. CLAYTON
Agriculture & Agri-Food Canada, Lacombe Research Centre, Lacombe, Alberta

R. Keith DOWNEY
Agriculture & Agri-Food Canada, Saskatoon Research Centre, Saskatoon, Saskatchewan

Abstract

Canadian canola producers have four different herbicide tolerant (HT) systems to choose from. About 40% of the canola acreage is sown to transgenic Roundup (glyphosate) HT varieties, while the transgenic Liberty (glufosinate) and the mutant Pursuit or Clearfield (imidazolinone) systems each make up about 15-16% of the crop. To date, the newly introduced transgenic bromoxynil system has occupied minimal acreage. According to the Canola Council=s 2000 producer survey, the technology has been rapidly adopted because it is effective, economic, environmentally friendly and holds promise for the fall seeding of spring cultivars. Given alternative herbicide modes of action available with HT systems, some growers utilize HT canola (particularly glufosinate tolerant) to delay the development of herbicide resistance in weed populations. Pollen flow, resulting in gene stacking, has occurred in commercial fields where different systems have been grown side by side or in close proximity. However, all volunteer canola plants, transgenic, mutated and conventional are readily controlled in pre-seed burn-off treatments, in cereal crops and in chemical fallow land with standard phenoxy herbicides. Diligent control of volunteer canola, as well as careful choice of crop rotations, is required to effectively manage these herbicide systems. How unprecedented levels of weed control in herbicide-tolerant GMO canola will impact ecosystem diversity is an important and unanswered question.

Introduction

Genetically modified organisms (GMOs) have received exceptional attention over the last few years. Some fear that the introduction of GMOs have brought considerable, negative short- and long-term environmental and health consequences. Others feel that GMOs have resulted in production efficiencies and increased environmental sustainability, i.e. less tillage, less pesticide use, and continued increases in crop productivity. In Canada GMO canola has been on the market since 1995 (Figure 1) and has increased to more than 50% of the entire canola market (Figure 2 B Note: imidazolinone tolerant canola is not transgenic). Therefore, in Canada we are in a unique position to report on experiences with and short-term consequences of GMO canola.

Herbicide Tolerance

The first marketed GMO trait in Canadian canola was herbicide tolerance (HT). The weed management benefits in GMO canola have been considerable in areas where weeds such as false cleavers (*Galium spurium*) and stork=sbill (*Erodium cicutarium*) are present. Some GMO canolas also provide weed management advantages for control of perennial species such as quackgrass (*Elytrigia repens*) and Canada thistle (*Cirsium arvense*). Where relatively Aeasy-to-control@ weed populations predominate [e.g. wild oat (*Avena fatua*) or wild buckwheat (*Polygonum convolvulus*)], there appears to be no advantage in using HT canolas. Canola yields are higher with HT canola treatments at some locations (Figure 3) and similar to standard treatments of sethoxydim plus ethametuslfuron at other locations (Figure 4, Derksen et al. 1999, Harker et al. 2000). Therefore, GMO herbicide tolerant canolas are more useful in some areas than others. Indeed, since the introduction of HT canolas, farmers have been able to grow canola in fields with weed infestations that previously would have been prohibitive. The question remains, ADo we really need GMO herbicide-tolerant canola?@

Survey

In 2000, the Canola Council of Canada commissioned a survey to answer some questions regarding GMO canola (See Canola Council of Canada 2001 reference for more details). The survey included 650 canola growers, half of which grew transgenics and half of which grew standard varieties. The main reason growers chose the transgenic route was superior weed control. The main reason growers chose the standard route over transgenics was the cost of the technology use agreement (TUA B only applicable for Roundup Ready canola). The cost of seed ($16.21/acre versus $11.69 acre) and fertilizer (increase of $1.72 acre) were slightly higher for transgenic growers. On the other hand, the use of herbicides, tillage, and fuel were all reduced for transgenic growers. There was a 40% reduction in herbicide costs for transgenic growers, 15% more transgenic growers employed direct seeding (direct drilling), and the lower tillage required substantially reduced fuel costs for transgenic growers. Transgenic growers also had 10% higher yields and lower dockage (3.8% versus 5.1%). Returns for transgenic growers were $5.80/acre higher. Overall, the survey indicates that GMO canola provides opportunities for enhanced production and profits as well as environmental benefits (soil conservation and reduced fossil fuel and pesticide use).

Weed Resistance

In western Canada, there are two monocot [wild oat (*Avena fatua*) and green foxtail (*Setaria viridis*)] and nine dicot weed species that are resistant to herbicides. The probability of finding ACCase resistant wild oat in random samples of any treated annual crop field in western Canada is approximately 50% (personal correspondence: Hugh Beckie). If current herbicide use trends continue, the rate of appearance of new resistant weed biotypes will remain the same or accelerate. Of the three herbicide-tolerant canolas, glufosinate-tolerant canola provides the best management option to avoid development of herbicide resistant weeds. Glufosinate is mostly employed in glufosinate-tolerant canola in western Canada; therefore selection pressure for resistance is minimal. The same cannot be said for glyphosate- and imidazolinone-tolerant canolas. Glyphosate and imidazolinone (as well as related sulfonylurea herbicides) are used in many situations other than canola. Weed resistance to imidazolinone and sulfonylurea herbicides is already considerable. Weed resistance to glyphosate has not been reported in Canada thus far, but resistance to glyphosate is probably also inevitable in Canada. Therefore, increased usages of glyphosate and imidazolinones in tolerant canolas will increase the risk of selecting tolerant weed biotypes.

Pollen Flow

Canola pollen is relatively Asticky@ and heavy and does not move readily on its own. However, wind, bees and other insects can effect considerable pollen transfer to other canola plants and plants of other species. In addition, small amounts of pollen may also be transferred via fur and clothing. Careful management of breeders plots and the prevention of admixtures is important to contain GMO canola traits. Because there are so many agents and opportunities for pollen flow, outcrossing, although erratic and limited, is inevitable (Figure 5). The important question is AHow much outcrossing will be acceptable?@ The following factors can all influence outcrossing: distance between donor and recipient fields, relative size of donor and recipient fields, synchrony of flowering, rainfall, wind direction, temperature, and pollinators. Optimal outcrossing occurs when small (low pollen supply) recipient fields are beginning or ending flowering (low pollen supply) and adjacent large donor fields (high pollen supply) are in full flower. Therefore, flowering synchrony is not necessarily optimal for outcrossing. Two large fields in synchronous flower would have limited outcrossing except at field margins.

In western Canada the risk of outcrossing and gene transfer to related weedy relatives of *B. napus* is extremely low (Bing et al. 1991, Lefol et al. 1997). Although interspecific crossing among *B. napus, Brassica rapa* and *Brassica juncea* has long been known to occur in nature, all three species are grown in western Canada as commercial crops and therefore are not present in the weedy form. On the other hand, wild mustard (*Sinapis arvensis*) is a widespread and persistent weed. Studies have shown that the cross *B. napus* by *S. arvensis* is a difficult cross to make and where hybrids have been obtained they were weak and largely sterile. Given the data to date there appears to be general agreement that no natural gene flow would occur between these two species. A hybrid plant has also been obtained from the interspecific cross *B. napus* x dog mustard (*Erucastrum gallicum*), a minor weed in western Canada (Lefol et al.1997). Although the hybrid was weak and would not likely survive in the wild it did set seed when pollinated by *E. gallicum*. Visual and cytological examination of the backcross progeny indicated they were poor competitors and apparently had reverted to the *E. gallicum* genotype. Fortunately other weedy relatives are not present (hoary mustard, *Hirschfelfdia incona*) or are rarely seen (wild radish, *Raphanus raphanistrum* and black mustard, *Brassica nigra*) in western Canada.

GMOs and Diversity

Despite all of the positives in this paper, there are questions that should be considered with the adoption of any new technology. Should we learn that GMO canola does not cause unmanageable outcrossing problems, or that GMO transgenes are not incorporated into non-target organisms, or that there are no significant health or environmental risks to GMO canola, what are the consequences of unprecedented levels of weed control? If repeated applications of herbicides such as glyphosate allow the removal of almost every weed in a canola field, and canola represents 99.9% of the plant species in a given field, will other organisms in the ecosystem be affected? What about interdependent bird, insect, soil macro fauna, and soil microbe food chains (Taylor and Maxwell 2001)? Are there weeds that some of these organisms require as a food substrate (see Figure 6 for a simplified representation of several plant species with diverse morphology, rooting patterns and constituents)? How many of these organisms will remain when the only plant food substrate in large fields is canola? These questions are interesting, important, and, as yet, unanswered.

However, it is important to note that cropping practices in western Canada are constantly changing. Canola has never been the only crop grown. In addition to the dominant cereal production, pulse crops such as peas, lentils and chickpeas have been introduced and widely adopted in the rotation. These legumes have provided a new and valuable food source for birds, insects and wild life. In addition, these extensive legume plantings have resulted in desirable modifications to the soil micro flora. Recent shifts to more livestock-pasture, minimum or zero till cultivation and continuous cropping have provided greater refuge and diversity in ground cover for insects and wild life. Thus although relatively weed-free canola may reduce the spectrum of plant species in a HT canola field, the adjoining field may be an even more desirable and sustaining source of food and shelter. It should be remembered that the change over from rapeseed to canola quality varieties in Europe resulted in a more palatable and extended winter pasture for wild life (deer, rabbits, birds etc.) than was previously the case. It should be further kept in mind that the UK did not grow *B. napus* until the 70's and it=s introduction greatly expanded the diversity of plant cover and food sources for UK insect and wild life. Thus although there may be questions as to the ecological impact of HT canola, these must be answered in the context of the total cropping system. To date the ecosystem has proved to be very resilient.

Literature Cited

Bing, D.J., R.K. Downey and G.F.W. Rakow. 1991. Potential of gene transfer among oilseed *Brassica* and their weedy relatives. Proc. 8th Interm. Rapeseed Cong. Saskatoon pp. 1022-1027.

Canola Council of Canada. 2001. Impact of transgenic canola on growers, industry and environment. [Online] Available: http://www.canola-council.org/manual/GMO/gmo_main.htm [21 June 2001].

Derksen, D. A., K. N. Harker, and R. E. Blackshaw. 1999. Herbicide tolerant crops and weed population dynamics in western Canada. Proc. of 1999 Brighton Conference on Weeds. Brighton, UK. Vol. 2:417-424.

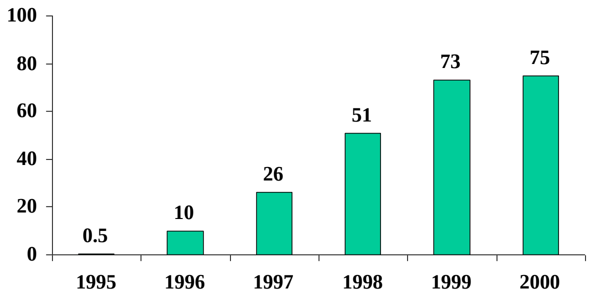
Harker, K. N., R. E. Blackshaw, K. J. Kirkland, D. A. Derksen, and D. Wall. 2000. Herbicide-tolerant canola: weed control and yield comparisons in western Canada. Can J. Plant Sci. 80:647-654.

Lefol, E., G. Seguin-Swartz and R.K. Downey. 1997. Sexual hybridization in crosses of cultivated *Brassica* species with *Erucastrum gallicum* and *Raphanus raphanistrum*: potential for gene introgression. Euphytica 95: 127-139.

Taylor, R. L. and B. D. Maxwell. 2001. Indirect effect of herbicides on avian food resources and beneficial arthropods. Proc. West. Soc. of Weed Sci. Paper #71, Coeur d= Alene, Idaho, March 13-15.

Figure 1

HT Canola in Canada - % of total ha



Average Canola Production area – 5 Million ha (1995-2000)

Figure 2

HT Canola Groups - % of total ha

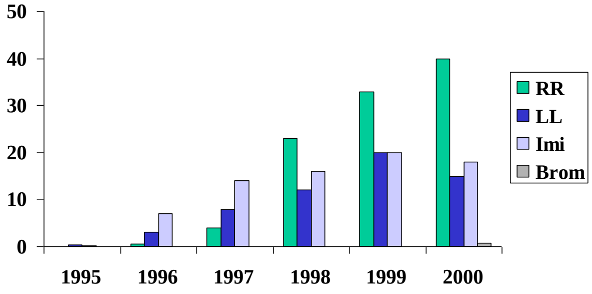
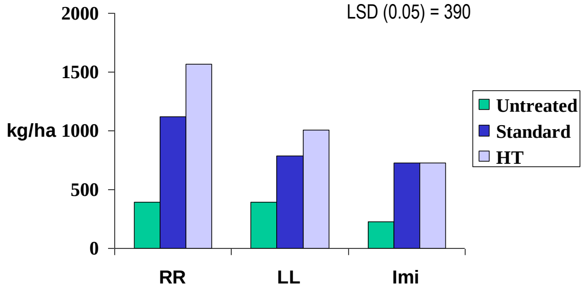


Figure 3

Scott, Saskatchewan Yields - 1995

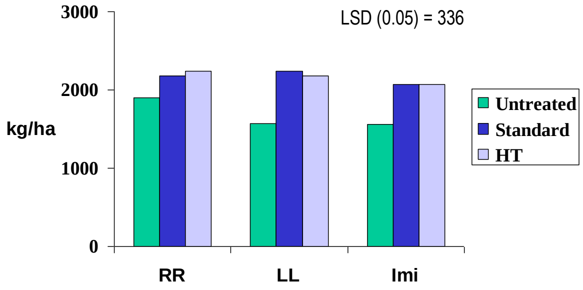


LSD (0.05) = 390

* Standard = postemergence sethoxydim + ethametsulfuron

Figure 4

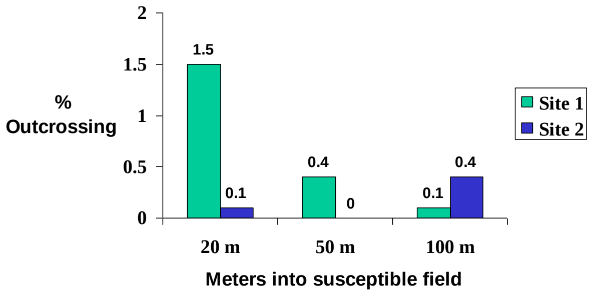
Brandon, Manitoba Yields - 1996



LSD (0.05) = 336

* Standard = postemergence sethoxydim + ethametsulfuron

Figure 5
Outcrossing - Inevitable & Erratic



At distances of 366 m, outcrossing has been detected at 0.6% (*B. napus*) and 3.7% (*B. rapa*)

Figure 6
GMO Effects on Diversity