The Movement of Genetically Modified (GM) Material and Containing or Confining GM Material

A Report by Rene Van Acker Ph.D., P.Ag., in relation to the Supreme Court of Western Australia
Proceeding no. CIV 1561/2012 Marsh vs. Baxter.
November 6, 2012.

Foreword

To produce this report I have relied upon my own expertise and experience relevant to the topic and gained in terms of formal training over the past 20 plus years and work, study and research experience over the past 16 plus years. I have also reviewed the statement of claim for this case and the consolidated statement of agreed and not agreed facts. In addition I have consulted published reports, studies and documents from around the world that are relevant to this topic and pertinent to the purposes of this report (see list of references cited at the end of this report). In these respects I consider that I have made all inquiries which I believe are desirable and appropriate and that no matters of significance which I regard as relevant have to my knowledge been withheld or not considered for the creation of this report within its intended scope.

Qualifications

My name is Dr. Rene Van Acker and I am Associate Dean of the Ontario Agricultural College, and Professor in the Department of Plant Agriculture at The University of Guelph (Since September 2009), Canada. I was previously (July 2006 - September 2009) Professor and Chair of the Department of Plant Agriculture and from1996 to 2006 was Professor of weed science and crop management at the University of Manitoba, Winnipeg, Canada. My research areas include weed seedling recruitment biology and ecology, robust cropping systems, and the coexistence of genetically modified (GM) and non-GM crops. I conduct field-based research, supervise graduate students and teach courses at the undergraduate and graduate levels. I have published over 100 peer-reviewed works to date and have made over 300 other non-peer reviewed contributions. My work on the coexistence of GM and non-GM crops and the movement of GM traits from crop to crop has lead to international collaborations, presentations, and consulting work with governments and organizations in Denmark, Australia, Austria, Switzerland, the United States (U.S.) and Canada, including membership on the scientific advisory committees for the International conferences on the coexistence of GM and non-GM crops in agricultural supply chains (GMCC) which has hosted conferences in Denmark (2003), Montpellier (2005), Seville (2007), Melbourne (2009) and Vancouver (2011), with the next conference scheduled for Lisbon in 2013. I have also conducted contained trials of regulated GM crops (from 1999 to 2003) while at The University of Manitoba. I have previously been retained and appeared on the stand as an expert witness on the topic of the movement and containment of GM material in Canada in the case of Monsanto v. Percy Schmeiser, in Canada (Federal Court of Canada 2001) and in the U.S. in the Genetically Modified Rice Litigation (United States District Court 2012). I grew up on a farm in southwest Ontario, Canada. I hold BSc and MSc degrees in crop science and weed management, respectively, from the University of Guelph, Canada and a PhD in crop-weed ecology from the University of Reading in the UK. I am a member in good standing of the Ontario Institute of Professional Agrologists (P.Ag.).

I have provided a complete CV along with this report and below are listed my peer reviewed publications relevant to the topic of this report (and two government commissioned reports; 1 U.S. and 1 Canadian). In addition, I have made over 45 invited presentations on this topic over the past decade.

Peer reviewed publications by Rene Van Acker related to the movement of GM material from crop to crop and the coexistence of GM and non-GM crops.

Bagavathiannan, M.V., G. S. Begg, R. H. Gulden, and R. C. Van Acker. 2012. Modelling the Dynamics of Feral Alfalfa Populations and Its Management Implications. PLoS ONE 7(6): e39440. doi:10.1371/journal.pone.0039440.

Van Acker, R.C. 2012. Understanding Agricultural Species Metapopulation Biology and Ecology and the Implications for Coexistence in Low Level of Presence Scenarios. AgBioForum 15:54-60.

Bagavathiannan, M.V., R. H. Gulden, and R.C. Van Acker. 2011. The ability of alfalfa (*Medicago sativa*) to establish in a semi-natural habitat under different seed dispersal times and disturbance. Weed Sci. 59:314-320.

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Bagavathiannan, M.V., Julier, B., Barre, P. Gulden, R.H., and Van Acker, R.C. 2010. Genetic diversity of feral alfalfa (Medicago sativa L.) populations occurring in Manitoba, Canada and comparison with alfalfa cultivars: an analysis using SSR markers and phenotypic traits. Euphytica 171:419-432.

Willenborg, C.J., A. L. Brûlé-Babel, and R.C. Van Acker. 2010. Identification of a hybridization window that facilitates sizable reductions of pollen-mediated gene flow in spring wheat. Transgenic Research 19: 449-460.

Bagavanthiannan, M.V. and R. C. Van Acker. 2009. Transgenes and national boundaries – the need for international regulation. Environmental Biosafety Research 8:141-148.

Mauro I.J. S.M. McLachlan, and R. C. Van Acker. 2009. Farmer knowledge and *a priori* risk analysis: Pre-release evaluation of genetically modified Roundup Ready wheat across the Canadian prairies. Environ. Sci. Pollution Res. 16: 689-701.

Willenborg, C.J., A.L. Brûlé-Babel, and R.C. Van Acker. 2009. Low crop densities promote pollen-mediated gene flow in spring wheat (*Triticum aestivum* L.). Transgenic Research 18:841-854. Willenborg, C.J., E.C. Luschei, A.L. Brûlé-Babel, and R.C. Van Acker. 2009. Crop genotype and plant population density impact flowering phenology and synchrony between cropped and volunteer spring wheat. Agron. J. 101:1311-1321.

Willenborg C. J., E. C. Luschei, A. L. Brûlé-Bable, and R. C. Van Acker. 2009. Flowering phenology and synchrony between volunteer and cropped spring wheat (Triticum aestivum L.): identification of a hybridization window and its implications for pollen-mediated gene flow. Crop Sci. 49:1029-1039.

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Bagavanthiannan, M.V., and R.C. Van Acker. 2007. Feral nature of alfalfa (*Medicago sativa* L.): potential barrier for the coexistence of genetically modified and conventional alfalfa in diverse production systems. In. A.J. Stein and E. Rodriguez-Cerezo Eds. Proceedings of the Third International Conference on Coexistence between Genetically Modified (GM) and non-GM based Agricultural Supply Chains. Seville, Spain, Nov 20-21, 2007. Pp. 225-226.

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The Movement of Genetically Modified (GM) Material and Containing or Confining GM Material

The following report is intended to provide information pertaining to the questions below submitted to me by Mr. Mark Walter of Slater and Gordon to direct my report in relation to the case of Marsh vs. Baxter (Supreme Court of Western Australia Proceeding no. CIV 1561/2012).

1. Please provide a high-level description of what genetic modification or engineering of crops and canola in particular involves.
2. Please describe the kinds of measures that have been adopted internationally (whether regulated or not) to:
    a. contain or confine GM material within geographic regions, particular environments or agricultural systems or otherwise to isolate or insulate non-GM crops from GM crops (including GM canola crops);
    b. protect the integrity of non-GM industries from incursion by GM;
    c. otherwise to manage co-existence of non-GM crops and GM crops, including GM canola crops.
3. In your answer to 2, please comment on the relevance, if any, of isolation distances, buffers and methods of harvesting.

Genetic Engineering (GE) or Genetic Modification (GM)

Genetic engineering (GE) and genetic modification (GM) both refer to the techniques that allow for specific pieces of DNA to be moved from one organism and inserted into another. The intention of GM is that the piece or pieces of DNA that are transferred between organisms are a specific gene (or genes - the transferred genes are referred to as transgenes) that encode for a desired trait (i.e. herbicide tolerance) that is then expressed in the receiving organism. The novelty of GM is; 1) that very specific pieces of DNA can be moved between organisms (i.e. a single gene) and 2) that the technique allows DNA to be moved between any organisms (i.e. DNA movement is not limited by species boundaries and/or sexual compatibility requirements). GM allows DNA transfer between organisms that could not occur in nature and would not be possible via traditional plant or animal breeding techniques. As such, the possibilities in terms of what genes (or DNA) may be transferred into an organism are almost endless and profoundly beyond what would be possible naturally (Glick and Pasternak 1998). Roundup Ready® canola is an example of a GM crop where the trait of herbicide tolerance (tolerance to the herbicide glyphosate) is achieved in canola by transferring two new genes into canola using GM techniques. One gene produces a version of the target enzyme of the glyphosate herbicide (EPSP synthase) that is insensitive to the herbicide (does not bind the herbicide and so is not affected by it) and a second gene which expresses a protein that metabolizes (breaks down) the glyphosate herbicide into constituent chemicals that do not have any herbicidal effect. The action of these two genes makes the GM Roundup Ready® canola tolerant to the glyphosate herbicide.

The Movement of GM Material

In North America, there is more than a decade of experience with the commercial production of GM crops. This experience has provided two key lessons: 1) when GM crops are grown outside at a commercial scale, the movement of GM traits beyond their intended destinations can be expected and the risk of escape increases with the scale of production, and 2) full retraction of escaped GM traits is very difficult and may be impossible if escape is into a broader agricultural supply chain (Marvier and Van Acker 2005; Lamb and Booker 2011).

These points support the need for caution, serious consideration and systematic efforts where there is a hope, expectation or requirement of co-existence between GM and non-GM crops and commercial segregation of GM from non-GM crops, especially for situations where a GM trait is regulated or other situations where there is zero threshold for the adventitious presence (AP) of GM material. Ellstrand (2012) has noted that since the first GM crops were commercialized in the mid 1990s, reports of GM material appearing where it was not intended, expected or wanted have steadily increased. This reflects both the increase in production acres of GM crops, and the number of GM crops commercialized; and perhaps an underestimation of the challenge of containing GM traits. GM trait movement is especially complex within large agricultural supply chains that involve many actors and living elements across an active landscape (Van Acker et al. 2007). Traits may persist and move among living populations of plants, including feral and volunteer plants, and among latent populations in seed that may exist in a myriad of places within the production and supply chain, and which may persist in the environment. In any case, the role of volunteer and feral populations and latent seed populations in trait persistence and movement can be substantive. As such, this needs to be well recognized and understood for trait risk assessment purposes and for the consideration of commercial co-existence or segregation schemes and for the containment of GM material.

The potential for the movement of GM material depends in part on the nature of the crop species. Crop species range in terms of their biology and ecology in relation to intraspecific trait movement (including the movement of GM traits) and the challenges of trait containment. Wheat (*Triticum aestivum* L.) may represent the least challenging scenario whereas species such as alfalfa (*Medicago sativa* L) and canola (*Brassica napus* L) may be the most challenging (Tolstrup et al. 2003). Placement along this continuum depends very much on the biology and ecology of these species in the context of agronomy and farming practices and the nature of the supply chains they move through.

Canola and GM Material Movement

GM canola has been grown in western Canada since 1995 (Demeke et al. 2006). Currently well over 90% of the canola grown in western Canada is GM (Beckie et al. 2011). By the year 1998 (4 years after the start of cultivation) GM traits were already stacking within volunteer canola plants (Hall et al. 2000) and by 2007 the stacking of GM traits in escaped (and possibly feral) roadside populations of canola had also been documented (Knispel et al. 2008). This was very strong empirical evidence of the effectiveness of the complete dynamic of the GM traits within the canola metapopulation and through the agricultural supply chain. Recently there was evidence of GM canola having moved through broad areas within the United States (Schafer et al. 2011) primarily along the Canada-U.S. boarder and along grain transportation routes. In addition, GM canola has been found commonly in shipping ports in both exporting and receiving countries (Yoshimura et al. 2006).

The movement of GM traits within the canola metapopulation is a function of its biology and ecology as well as the way in which canola is farmed, the farming systems it is part of and also the way in which canola is handled in the supply chain including the production of seed. There has been so much intra-specific GM trait movement in canola in western Canada that farmers in this region have come to expect the appearance of unintended traits in their canola in all cases (Friesen et al. 2003).

At the time of unconfined commercial release of Roundup Ready® (glyphosate-tolerant) canola in Canada, it was known that there was significant potential for out-crossing within the canola (*Brassica napus* L.) genome given that canola is a known outcrossing species (Cuthbert and McVetty 2001) and that transgene movement from canola crop to canola crop would occur (CFIA 1995). The eventual appearance of the transgenes conferring glyphosate tolerance in non-Roundup Ready (RR) canola certified seed lots (Friesen et al. 2003) showed that there was an effective means of transgene movement in operation but the exact mechanisms of movement were not known. Some of the non-RR canola seed lots had RR transgenes present at very high levels (approaching 5%). Given current knowledge of pollen-mediated gene flow (PMGF) in *B. napus*, it is unlikely that pollen flow would cause greater than 0.1% presence in a single generation of pedigreed seed given the strict seed production and isolation protocols. Adventitious presence in these seed lots above 0.25% were likely the result of inadvertent mechanical mixing of certified seed during harvest or handling, or contamination occurring in earlier generations of pedigreed seed production (i.e., Breeder or Foundation seed) (Friesen et al.

2003). In Denmark, an analysis of the possibility of achieving coexistence of GM and organic canola concluded that " a threshold for an organic crop of approximately 0.1% will be virtually impossible to achieve." (Tolstrup et al. 2003). Danish experts made this conclusion on the basis, in part, of the out-crossing nature of canola along with its ability to persist in fields and recur as a volunteer for many years after sowing.

Pollen Mediated GM Material Movement

The two vectors of GM material movement are pollen and seed. Gene flow via pollen tends to occur over shorter distances, generally, but pollen can be carried long distances by wind or pollinators (for some species) and Rieger et al. (2002) have shown in Australia, that the potential for very long distance (over 2 km) pollen mediated gene flow is possible in canola. The distance for effective pollen-mediated gene flow (PMGF) depends on many factors including; to what extent the species will outcross, the size and weight of its pollen, the size of the pollen source, and the weather (in relation to movement of the pollen as well as effects on receptivity of the female).

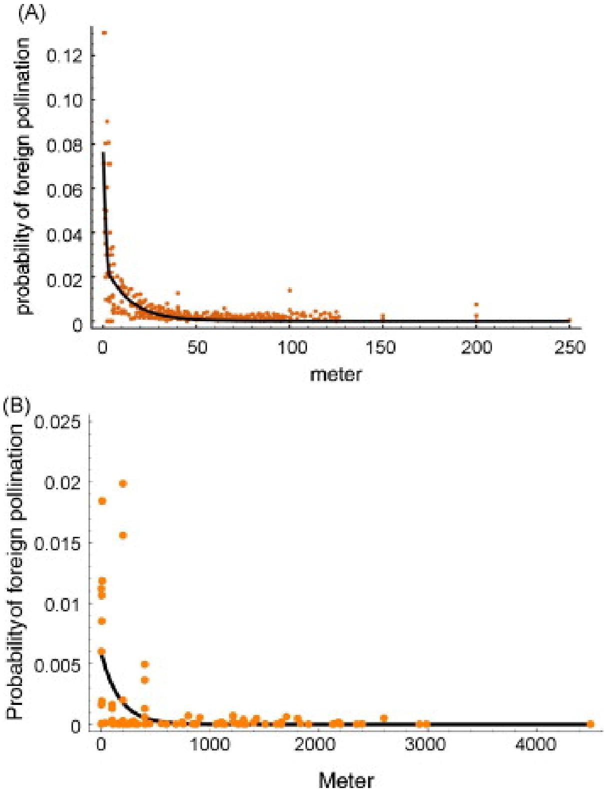

Figure 1. Modelling pollen flow from GM oilseed rape to (A) adjacent fields of non-GM (conventional) oilseed rape and (B) non-adjacent fields of conventional oilseed rape using data from Europe, North America, and Australia (as published in Beckie and Hall 2008 who reproduced this figure with permission from the authors: Damgaard C. and Kjellsson G. 2005. Gene flow of oilseed rape (*Brassica napus*) according to isolation distance and buffer zone Agric. Ecosyst. Environ.108: 291-301).

There is relatively good empirical modeling of PMGF for a variety of crops (Beckie and Hall 2008; Figure 1) including in some cases (as with canola in western Canada) for GM and non-GM crops grown at commercial scale (Beckie et al. 2003). However, those establishing protocols to prevent GM material from escaping have relied on traditional isolation distances for given crops taken from certified seed production standards which may or may not be suited to the confinement task depending on the required threshold of adventitious presence. If the threshold is very low (0.1% or lower for example) then the seed production standards are not likely to be adequate. Certified seed production isolation distances were established to prevent PMGF to an extent sufficient to protect varietal purity in seed production scenarios but not to prevent the AP of GM material necessarily (Tolstrup et al. 2003; Friesen et al. 2003). Within this context there was a requirement to keep PMGF levels very low, but perhaps only below 0.1%, and it was sufficient, in terms of protecting varietal integrity with respect to complex polygenic traits to only keep PMGF levels below 5%, for example. However, to maintain stringent confinement of GM crops, traditional isolation distances may not be sufficient because PMGF can result in low levels of AP even at great distances (Claessen et al. 2005).

Seed Mediated GM Material Movement

Seed movement is another means of GM material movement and admixture of seed can occur at many points within farming and grain handling systems (Le Bail 2003). Genes (GM material) may travel great distances when crop seeds are transported by humans either knowingly or unknowingly (Marvier and Van Acker 2005) and with the assistance of the seed and grain movement infrastructure, transgene movement can potentially occur at a global scale (Colbach et al. 2001; Lamb and Booker 2011). In addition, because seeds may be persistent, seed movement can facilitate GM material movement and gene flow over time (Hall et al. 2000).

Relatively little research has been done on the nature of seed mediated GM material movement. What has been acknowledged in relation to seed mediated GM material movement is that it is often related to human involvement or human error in regard to handling or managing crops or seeds (Ellstrand 2012). In terms of seed movement, certainly complete separation of operations (e.g. farming and grain handling) is acknowledged as a prudent means of working towards successful coexistence between GM and non-GM crop production and towards the goal of preventing GM material from ending up where it is not intended, expected or wanted (Van Acker 2012). Starting with absolutely clean seed (seed free from GM material) is critical (Van Acker et al. 2007) and the stringent separation of GM-free seed production from any sort of GM crop farming or handling, and frequent testing is required in this regard.

In western Canada, my own research group (Friesen et al. 2003) tested certified canola seed lots for the adventitious presence (AP) of unintended GM traits (transgenes) and found that AP levels varied significantly among the companies whose seed lots we tested. The seed lots from some companies had consistently low (and in some cases zero) AP levels, while for one company in particular the AP levels were high, in one case reaching almost 5%. Our study suggested that approaches and protocols likely differed among companies with respect to preventing AP and some companies demonstrated an ability to maintain AP of unintended transgenes at very low levels (zero or near zero levels in certified seed lots of canola). It was obvious to us that some companies made a systematic effort to achieve consistently low AP levels. I know, for example, that the canola breeder at University of Manitoba (Dr. Peter McVetty) actively and constantly tests the seed lots in his canola breeding program with an aim to keeping unintended transgenes out of his breeder seed lots and that he employs a range of means (a system) for keeping his breeder seed clean including training of staff, dedicated equipment, isolation of production fields, stringent record keeping and separation of storage and processing from any GM crop or seed production.

The persistence of seeds of GM crops is an important consideration for transgene escape and movement. After a crop has been harvested, volunteer and feral GM crop populations can appear in subsequent years and act as a place for the transgenes to come from or escape to. In this sense, for crop species which have large and robust volunteer and feral populations, and especially for crops that produce very persistent seed (or propagule) banks (like canola), a metapopulation for a given transgene may arise within a given region. Depending on the extent and robustness of the subpopulations within such a metapopulation (especially the volunteer and feral populations) and the frequency of the given crop species in rotations in time and space within a region, the containment of a transgene, once it has entered a metapopulation, may become impossible unless some drastic action is taken such as exclusion of all cultivation of a given crop in a region for a given time (i.e. the duration of its seedbank persistence) and the eradication of all volunteer and feral individuals of that species within the same region. This would be impractical but it is what would be required. If nothing is done to try to eradicate the populations of plants containing unwanted transgenes, and if the transgene is selectively neutral in both agricultural and natural settings (which would be the case for RR canola in an organic farming system), then the frequency of that transgene in the system it has escaped into will remain static and the transgene will not disappear from that system on its own. The ability of GM material to entrench itself in a system is seen in western Canada where there is evidence that a very high proportion of feral (non-field) populations of canola are GM, and some of these populations are accumulating multiple GM traits (Knispel et al. 2008) which shows that these feral populations of canola have the ability to persist even in places where they are not being cultivated and in less than ideal growing conditions for canola (roadsides) (Knispel and McLachlan 2010). The persistence of volunteer canola has been studied extensively. Canola is known to be an effective and persistence volunteer in part because it's seed has the ability to enter into secondary dormancy (Gulden et al. 2003 a, b, 2004). In western Canada, the average persistence of volunteer canola is 2-5 years (Harker et al. 2006; Lawson et al. 2006) and volunteer canola persistence in famers fields has been shown to decline rapidly after the first one or two years (Harker et al. 2006; Baker and Preston 2008). However, many researchers have measured longer persistence of canola at low levels. Beckie and Warwick (2010) have measured canola persistence of up to 7 years even when canola has not been grown on a field again. In Europe, canola has commonly been reported to persist for 5-8 years (Begg et al. 2006) while D'Hertefeldt et al. (2008) have recorded field persistence of up to 10 years and P.J. W. Lutman (personal communication) has witnessed persistence in his field experiments of more than 12 years. The implication here is that even if one controls all volunteer plants and prevents any further seed entry it could take many years (and possibly more than a decade) to eliminate an escaped canola population if it has had a chance to establish a seedbank (Begg et al. 2006).

Protecting The Integrity Of Non-GM Industries From Incursion By GM Material

The segregation of GM and non-GM crops occurs throughout the world in both scenarios where coexistence is regulated (e.g. European Union) and where it is not (e.g. Canada). In the former, coexistence is guided by directives (EU 2001) and effective coexistence is ensured by law (DMFAF 2004). One example in this respect is Denmark, the first EU nation state to establish coexistence law. The Danish coexistence law includes a system of measures to facilitate and ensure coexistence. There are for example, requirements that the GM crops being grown are identified publicly and that their location is available to be viewed by neighbours including neighbours who could be negatively affected by the movement of GM material from these sites (e.g. organic farmers). The legislation also allows the Danish government to set rules to facilitate segregation of GM from non-GM include in the following areas:

"i) The registration of anyone who handles or transports genetically modified material.
ii) An obligation to notify owners and users of nearby fields, purchasers, partners etc. in connection with: a) Growing.
  b) Use of vehicles, machines, equipment, storage rooms etc.
  c) Transfer of the right to use or the ownership of fields, vehicles, machines, equipment, storage rooms etc.
iii) Reporting of fields with genetically modified crops.
iv) Growing, including also rules on the distance to other fields with the same crop etc. and on growing

intervals.

v) Storage and transport.

vi) Cleaning of vehicles, machines, equipment, storage rooms etc." (DMFAF 2004).

The legislation also includes formal mechanisms for recourse and compensation in cases where there is GM escape and concomitant harm.

The EU has updated its directive on coexistence recently and within this update they recognize the need for flexibility in regulation between nation states and in addition they recognize that in some cases in order to achieve coexistence it may be necessary to exclude GM cultivation altogether from large areas where it is deemed that systems for preventing unintended presence would not be effective (EU 2010). Section 5 of this directive update states "(5) In some cases, depending on economic and natural conditions, it may be necessary to exclude GMO cultivation from large areas. This possibility should rest on the demonstration by the Member States that, for those areas, other measures are not sufficient to prevent the unintended presence of GMOs in conventional or organic crops. Moreover the restriction measures needs to be proportionate to the objective (i.e. protection of particular needs of conventional or organic farmers)."

In the case of jurisdictions where coexistence is not ensured by law (e.g. Canada), the default is for the onus to be on the farmer or business operator who wishes to remain free from GM and this is something I highlight in Van Acker et al. 2007; a chapter written as guidance to organic growers in terms of maintaining their operations free from GM material. In Canada, for example, when a GM crop is deregulated it is assigned unconfined release status. This removes any requirements for containment or confinement of that GM crop or GM material coming from that crop (i.e. GM traits and transgenes). In this case, those who wish to remain GM-free are recommended to employ a range of means (a system) to prevent incursion of GM material (Riddle 2004). This system may include a range of efforts for example; isolation distances, physical barriers or buffers, sanitation (control of volunteer and feral populations), use of clean seed, stringent record keeping and testing to ensure freedom from GM material. The overall intent behind segregation systems is to keep the GM and non-GM operations apart in as many ways as possible including separate locations, separate storage, separate equipment, separate supply and delivery chains. This is possible if the operator trying to maintain their operation free from GM is aware of others who are growing GM and where and how they are operating. This knowledge is critical as it goes a long way to preventing surprise incursions which may then be very difficult to eradicate (Van Acker et al. 2007). This is likely why the Danish coexistence legislation includes a substantive amount of language on open communication of GM growing sites and operations.

Assessing some of the approaches to preventing incursion of GM reveals opportunities and challenges, but it is acknowledged that one single approach, or technique to prevent GM crop incursion is not sufficient. A system of means, with redundancy must be used to effectively prevent the incursion of GM crops into operations where they are not intended or wanted (Van Acker 2012).

Isolation distances

Most of the research that has been conducted regarding the movement of GM material and isolation distances has been concerning pollen mediated movement of GM material (Pollen Mediated Gene Flow -PMGF). Certainly the work of Rieger et al. (2002) demonstrated the great distance of PMGF possible in canola in Australia and Beckie et al. (2003) demonstrated the significant extent of PMGF possible in the case of commercial scale production of GM canola in a region where the vast majority of canola grown is GM. In relation to PMGF research, it is possible to estimate the isolation distance required to minimize PMGF and the distances required to have a high probability of meeting given adventitious presence threshold requirements (Tolstrup et al. 2003). This is practical if one is working to threshold levels of perhaps 0.1% or higher. But there are problems when thresholds are very low, or zero. The evidence and research to-date shows that very low levels of PMGF can occur at very long distances, sometimes thousands of meters (Beckie and Hall 2008; Figure 1). The evidence shows that very large isolation distances (thousands of meters) would be required to achieve high confidence of very low probabilities of PMGF, and even then the probability would not be zero (Figure 1).

Another method to minimize transfer of GM material between crops is to create isolation in time by growing like crops asynchronously in adjacent fields or farms. Temporal isolation is a well known method for helping to segregate crops and has been used for a long time by plant breeders and seed growers to facilitate the maintenance of varietal purity (CSGA 2012). A long and diverse crop rotation allows reduction in seed banks for volunteer species before that same species is cropped again within a given field. A diverse crop rotation facilitates the detection of volunteers in subsequent crops and allows for effective roguing or control with herbicides. It also helps to limit PMGF by not have like crops grown next to one another.

Isolation distances are most commonly used in seed production to meet regular seed (variety) purity standards (not necessarily absolute genetic purity standards) (Van Acker et al. 2004). Isolation distances in the case of seed production are maintained by the seed grower who is looking to prevent incursion of off types and the isolation distance is not the only measure taken to manage purity. Seed growers also use other means including inspecting and roguing seed fields to remove off types, using dedicated harvesting and seed cleaning and handling equipment, controlling volunteer and feral populations near seed fields, using long rotations and testing to maintain the variety purity of the seed (CSGA 2012).

Buffers

Buffers, like isolation distances, are intended primarily to limit PMGF. Pollen barriers are specifically intended to limit PMGF by providing a physical obstacle that hinders the movement of pollen from a GM crop. Pollen barriers may be hedges, trees or other tall annuals or perennial plants intended to physically limit pollen movement. In some cases a non-GM strip of the same crop species is planted around the GM crop to act as an isolation distance (a buffer zone) that also produces competing pollen which can help to limit PMGF. Buffer zones are considered more effective than isolation distances alone (Beckie and Hall 2008). However, it is important to note that these types of barriers have not been studied or employed to achieve absolute prevention of PMGF and on their own and without combinations of other measures as part of a segregation system including other isolation mechanisms etc..buffers will not absolutely prevent PMGF. As far as I know, there have been no peer-reviewed studies of the use of physical barriers in fields to prevent the movement of GM material via seed. Canola swaths can be moved by wind (Western Producer 2012) and some harvesting techniques (see below) can help to reduce the chances of this happening.

Method of Harvest

Canola can be either swathed and then combine harvested or directly combine harvested. Canola is more typically swathed rather than direct combined because it is prone to shattering. Seed pods (siliques) can shatter open during direct combining when they are very dry and seed is then lost to the ground. When canola is swathed before all of the seed is fully ripe and dry, the seed pods are much less likely to shatter and when the swaths are picked up by the combine later (after the seeds have ripened and dried in the seed pods) there is less shatter of pods because the canola is bound within a swath and the swath pickup head on the combine is gentler than the cutting head used for direct combining. The Canola Council of Canada recommends swathing over direct combining in order to maximize harvested yield and to limit the seed that can volunteer in subsequent years (Canola Council of Canada 2012). For farmers wishing to limit the size of their volunteer canola population swathing is recommended because it results in much less canola seed on the ground at harvest (Gulden et al. 2003a). For managing volunteers, it is best if they are controlled before they ever set viable seed. This will limit, to the extent possible, the size of the volunteer seed bank but it does not necessarily mean that the canola seed bank will disappear quickly (Begg et al. 2006).

In the case of containing GM canola, swathing facilitates the potential movement of GM canola to where it is not intended, expected or wanted. The movement of canola swaths by wind is common and known by canola farmers to occur regularly (MAFRI 2012; Western Producer 2012). Growers wishing to prevent such movement will roll their swaths as the canola is being cut. The roller, pulled behind a swather, pushes the swath into the canola stubble helping to hold it there in the wind. This does not guarantee that swaths won't move in the wind but it can help reduce the chance of swath moving in the wind. In cases where GM canola needs to be contained, direct combining of the canola would be considered a better and more responsible practice, but alone, it may not necessarily prevent movement of GM material from a given field.

Systematic Approaches to Preventing GM Crop Incursion

Containing GM crops (or preventing their incursion into non-GM fields, farms and supply chains) is challenging and requires a very dedicated, multi-faceted and redundant approach. I have a few examples of the type of efforts required to contain GM material.

I have experience growing regulated GM crops in field trials under contract for Monsanto. In 1999, I conducted 3 field trials in one location to look at weed control efficacy. These trials were not taken to harvest because the variety was not locally adapted (season was too short) but we were required to log all seed (for planting) in and out of the trials, we returned all unplanted seed to Monsanto. We monitored these trials monthly for two years afterwards to ensure no volunteers. In 2001, we conducted a Roundup Ready (RR) wheat field trial at one location. For this trial the RR wheat variety we were using was locally adapted and we could take it to yield. We did not want the trials on our University of Manitoba research farm sites because we had a wheat breeder in the department who had breeding plots on these sites. My department head at the time would not allow us to put this trial on those sites because of the risk of admixture and AP. We co-operated with a grain company who had a research farm just south of Winnipeg and they allowed us to site the trial there on a field that was in alfalfa and would not be returned to annual crops for at least 5 years. The trial we conducted for Monsanto ran for three years (2001, 2002 and 2003) and we monitored the sites every two weeks for two years after that (2004 and 2005) to ensure no volunteers. For this trial we had a third party auditor present on-site when we were harvesting the Roundup Ready wheat and when we were cleaning the harvesting equipment and we ensured that the harvesting equipment we used was never used by the wheat breeding program. All harvest equipment cleaning had to be done at the trial site. The third party auditor was hired by Monsanto and the auditor’s presence at the site was arranged by Monsanto. All seed in and out of the trials was traced by log and all seed was returned to Monsanto. While conducting the RR wheat field trials, we had occasional unannounced visits by the Canadian Food Inspection Agency (CFIA) or Monsanto employees in order to check our documentation and to inspect the sites and our facilities for storage and seed processing and handling. We also used storage and processing locations that were separate from the wheat breeding program and the field site we used was never and would never be used by the wheat breeding program.

In Canada there is a significant identity preserved (IP) business for non-GM soybeans for customers primarily in Southeast Asia and Europe. This business is an example of GM and non-GM segregation. The aim of the business is to deliver non-GM soybeans to customers with a guarantee of AP levels below 0.5% to 2% (the exact level depending on the customer’s own tolerance level) but the requirement is not zero. The IP is to exclude deregulated GM soybeans grown in the region and as such the business is self-regulated by an industry group called the Canadian Soybean Export Association (CSEA). Even though the end-customer tolerance for GM material in their product is not zero, the CSEA still demands for its associated members involved in the IP non-GM soybean business that all planting, harvesting and transporting equipment as well as elevator legs, conveyors, augers and storage bins must be either dedicated to non-GM or thoroughly cleaned and inspected before being used for non-GM loads (Anderson 2005). They also employ regular testing to ensure that they are meeting the customers’ non-GM standards. Their protocols and actions are audited by Canadian Grain Commission accredited third party auditors. This effort is a good example of businesses making a stringent effort to meet standards in order to do good business, and the example emphasizes the systems approach required to prevent the incursion of GM material into an agricultural operation.

Summary and Conclusions

Genetic modification (GM), or genetic engineering (GE) allows DNA transfer between organisms that could not occur in nature and would not be possible via traditional plant or animal breeding techniques. After more than a decade of GM crop cultivation and decades of study of GM crops it is now generally acknowledged that when GM crops are grown outside at a commercial scale, the movement of GE traits beyond their intended destinations can be expected and the risk of escape increases with the scale of production, and 2) full retraction of escaped GM traits is very difficult and may be impossible if escape is into a broader agricultural supply chain. Since GM crops were first commercialized in the mid-1990s, reports of GM material appearing where it is not intended, expected or wanted has steadily increased. With respect to GM canola, the nature of canola, including its out-crossing ability and its ability to persist in the environment make it particularly difficult to contain (or retract after escape) and there is an abundance of evidence from around the world that GM canola has the ability to escape, and in many cases has escaped cultivation and ended up where it was not intended, expected or wanted. GM canola moves in one of two ways, by pollen mediated gene flow (PMGF) or by seed. PMGF in canola has been substantively studied and the results of these studies show that it is common and that it can occur at low levels to long distances (up to thousands of metres). There has been much less study of seed mediated GM canola movement but experts acknowledge that it occurs and that human error often plays a role in GM crop escape via seed. After escape, GM canola seed can persist for a long time in the environment, even without new seed additions. Studies have shown persistence at low levels of 10 years or greater. The potential long term persistence of canola escapes makes eradication of escapes and clean up after escapes very challenging and requiring sustained and substantive effort. Preventing GM crops from appearing where they are not expected or wanted is regulated in some jurisdictions (e.g. EU nation states). In these cases, segregation rights are protected in law and there are formal recourse and compensation mechanisms. There are also requirements for communication and full transparency in terms of where GM crops are being grown so that neighbours growing or not growing GM crops can prepare and work to prevent adventitious presence of GM material. In areas where there is no regulated coexistence and deregulated GM crops have unconfined release the onus is on the non-GM farmer of business operator to protect their farm or business from GM material incursion. These farmers and business operators use a variety of means in a systems approach in order to prevent the incursion of GM material or to confine GM material. Methods within such a system could include; isolation (in time and space), buffers and particular harvest methods. It is understood by experts that GM containment and preventing incursion by GM material is challenging and no single means of segregation or containment is sufficient to effectively contain GM material especially in cases where low levels of escape can cause harm.

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