The Feral Nature of Alfalfa and Implications for The Co-Existence of Genetically Modified (GM) and Non-GM Alfalfa

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Roundup Ready (RR) alfalfa@has been approved for unconfined release in Canada allowing for its commercialization. RR alfalfa is genetically modified (GM), therefore organic and conventional alfalfa growers in Canada have concerns regarding adventitious presence (AP) ofGM alfalfa (or GM traits) in their crops and the agronomic issues and potential market loss associated with such GM AP. Co-existence strategies are proposed by some stake holders as the solution for these concerns however feral (persisting outside of cultivation) alfalfa populations occur in natural and semi-natural habitats and will act as barriers to co-existence. This report summarizes the potential role of feral populations in novel trait movement and the implications for the establishment of co-existence among GM and non-GM alfalfa production fields.

Understanding the nature of gene flow and contamination

Management of gene escape requires recognition of the various routes of gene escape from cultivated fields. Potential routes include: a) pollen escape through outcrossing including insect mediated pollination [pollen mediated gene flow (pMGF)]; b) seed escape during transport, harvesting and other farming activities; and c) seed escape via rodents, arthropods, birds and other seed predators. Pollen mediated gene escape is the major concern for hay producers while both pollen and seed mediated gene escape are concerns for seed producers.

Pollen mediated gene flow (pMGF) from alfalfa fields

Alfalfa is a cross-pollinated crop where pollination is facilitated by insects including leaf cutter, alkali, honey and bumble bees. In Canada, producers typically place leaf cutter bees in seed production fields to increase pollination and seed set, however wild populations of both leaf cutter and bumble bees are common. Honey bee mediated long distance dispersal of pollen from alfalfa seed and hay production fields has been confirmed for distances up to 1000m (Arnand et al., 2000). The proportion of outcrossed seeds was about 22% for seed production fields and 15% for hay fields at 1 km from the pollen source. In a similar study with leaf cutter bees, Teuber et al. (2004) found outcrossing levels of 1.5% at 270m and 0.2% at 1.5 km and were able to detect very low levels of outcrossing «0.03%) at 4 km. Fitzpatrick et al. (2003) observed outcrossing levels of 1.4% at 152m and only 0.28% at 274m with no outcrossing at 61Om. In the same study, a single outcrossing event was detected at 804m, although at a very low frequency. However, it is vital to note that the sizes of the pollen source fields employed in this particular study were only between I and 1.6 acres. However, in reality, the production fields are much larger and that practical levels of long distance gene flow could be much higher, as discovered by Watrud et al. (2004) in creeping bentgrass.

Feral alfalfa and PMGF

Feral alfalfa plants are commonly observed in road sides, field shoulders and other natural and semi-natural habitats in Canada. We have been conducting experiments since 2006 in selected rural municipalities in Southern Manitoba (Hanover, MacDonald and Springfield) designed to investigate the nature and dynamics of feral alfalfa populations and their role in long distance PMGF. A detailed road side survey was initially carried out to record the extent of occurrence of feral alfalfa populations in these municipalities. The survey revealed widespread occurrence of feral populations in alfalfa growing regions. The mean number of populations recorded per Ian respectively in Hanover, MacDonald and Springfield were 1.68, 1.32 and 0.21. On average, feral alfalfa populations were located within 87m (MacDonald), 210m (Hanover) and 328m

(Springfield) of cultivated alfalfa fields, a distance sufficient to effect cross pollination in alfalfa. Arnand et al. (2000) investigated GM trait movement among widely dispersed, individual feral plants on road sides and confirmed PMGF at a distance of 230m with an outcrossing frequency of 92%. Feral alfalfa plants therefore can act as bridges for medium and long-distance GM trait dispersal out of cultivated fields.

Unlike other GM crops, alfalfa is perennial, outcrossing and indeterminate flowering crop where pollination is facilitated by insects. It is a very hardy species that is highly adapted to resource poor environment such as road verges. In Manitoba, some roadside alfalfa populations have been shown to be self-sustaining and therefore truly feral (Bagavathiannan and VanAcker, 2008b) (Fig. 1, Fig.2, Fig.3). Road verge management including mowing and herbicide application has considerable influence on the dynamics of these populations. Mowing can substantially reduce seed output and plants that escape mowing in June continue can grow to produce a large mature seed crop. Applications of 2, 4-D herbicide may kill alfalfa seedlings and established alfalfa plants, but dormant seeds in the soil seed bank can re-establish feral populations.

Feral alfalfa and seed mediated gene escape

Seed escape from transgenic varieties followed by successful establishment outside of cultivation will directly result in the adventitious presence of trans genes in the environment. Farming activities serve as the main source of seed escape from cultivated fields. Additionally alfalfa seeds are rich in protein and serve as a nutritious food source for the seed predators. Seed dispersal can be facilitated by seed predators, including birds (FigA). Seed predator mediated seed dispersal is possible both from alfalfa seed production fields and from feral populations.

Implications for the co-existence of GM and non-GM alfalfa

The establishment, presence and persistence of feral alfalfa populations will have implications for the release of GM alfalfa as these populations make the complete confmement of GM traits very difficult and once a given GM trait escapes into the environment, retraction of the trait will be unlikely. As such, feral alfalfa is a barrier for the successful co-existence of GM and non-GM alfalfa In addition, PMGF can operate over long distances for alfalfa and growers who wish to maintain their alfalfa GM-free will need to be aware of GM-alfalfa production within a relatively large area around their farm. Strict adherence to purpose designed stewardship practices can help minimize the potential of GM trait escape into feral and non-GM alfalfa and increase the chances of successfully achieving coexistence between GM and non-GM alfalfa.

Stewardship approaches for reducing adventitious presence of GM traits in non-GM alfalfa

Minimizing pollen mediated gene flow

i) Seed production fields: Because feral alfalfa plants growing in road verges and other unmanaged areas will facilitate GM trait movement, management of these populations is necessary. In Canada, current isolation distance required for certified alfalfa seed production is 50 meters and for foundation seed it is 200 meters (for fields exceeding 5 acres) or 300 meters (for fields that are 5 acres or less) (CSGA, 2003). These isolation distances are designed to achieve variety purity (within limits) but not necessarily genetic purity (or the prevention of GM trait entry). As such, and given the evidence of long distance PMGF in alfalfa, the commercial production of GM alfalfa will require non-GM alfalfa growers to greatly increase these isolation distances if they want to assure GM free seed sources. Frequent testing of seed sources will also be required to provide assurance of the effectiveness of isolation approaches.

ii) Hay production fields: Hay fields are required to be managed properly and cut regularly before flowering. However, bad weather conditions can delay haying operations, resulting in flowering within hay crops and opportunities for PMGF and GM trait entry. This may mean that producers who have neighbors growing GM alfalfa may also need to consider isolation distances in relation to their hay fields.

b) Minimizing seed mediated gene flow

Seeding, spraying and harvesting equipment must be cleaned prior to and after use in any GM alfalfa fields (preferably at the field's edge). Alfalfa seed (especially GM alfalfa seed) should be transported in spill proof containers to avoid seed escape and reduce the establishment of feral GM alfalfa populations in road verges. The effective control of escaped and feral alfalfa populations can also help to prevent predator mediated seed movement.

c) Sustained stewardship practices

Establishing region-wide stewardship practices will be necessary to reduce the potential for gene flow between GM and non-GM alfalfa (VanAcker et aI., 2007). If GM alfalfa is commercialized, all GM alfalfa growers should be required to inform neighbors that they are growing GM alfalfa. A public registry would facilitate such announcements and allow non-GM growers the opportunity to maintain GM-free alfalfa if they wish. In addition, all alfalfa growers (both GM and non-GM) should work to identify and control escaped and feral alfalfa populations both on their farm sites and along roadsides. Special collaborative programs with municipalities, including weed supervisors would be required in order to facilitate the management of these populations. Individual growers may want to monitor volunteer alfalfa populations to ensure that populations from one stand do not persist to flower in subsequent stands.

Challenges to co-existence

Although stringent regulatory procedures and good stewardship practices will help reduce the level of gene flow between GM and non-GM alfalfa, the total containment of GM traits in commercial systems across a broad region is perhaps impossible (Marvier and VanAcker, 2005). Unfavorable weather conditions, human error and other random events are unavoidable and after unconfmed commercial release of GM crops, the adventitious presence of GM traits in the environment is a reality. Once GM traits escape into the environment, it will be impossible to recall them. Producers who wish to maintain crops GM-free will need to make conscientious efforts to do so and need an understanding of the routes and mechanisms of GM trait movement. In addition, cooperative efforts from GM growers would greatly facilitate the coexistence of GM and non-GM crops, with the neighbourly declaration of GM crop cultivation by GM crop growers being particularly helpful. Currently such cooperation is voluntary.

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