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Gene Flow in Alfalfa:

Biology, Mitigation, and Potential Impact on Production

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Executive Summary

U.S. alfalfa (*Medicago sativa* L.) hay and seed growers produce for various markets and should continue to have the choice to do so. Growers also need the ability to adopt new technologies that enable them to address changing global market situations and remain competitive. These technologies can be production, agronomic, or quality related. At the same time, it is essential that growers work together to ensure that differing market requirements can be met. As in all biological systems, 100% purity (or 0% impurities) of any constituent is very difficult to achieve and may not be possible economically. This is especially true for field-scale agriculture. As a result, growers and agricultural societies have adopted process-based strategies such as the Certified Seed and National Organic Programs that tolerate a low and acceptable threshold of impurities in the final product, whether pesticide, weed seed, or varietal seed. These systems have been recognized and adopted worldwide.

This paper describes the biology and agronomic practices in alfalfa that should be considered in developing coexistence strategies to allow growers to have choices, specifically between *genetically engineered*[1] (GE), conventional, and GE-sensitive markets in the United States. These strategies are based on science and are a direct extension of well-established coexistence principles routinely used by seed growers. The management practices currently being used by growers of Roundup Ready alfalfa (RRA) seed are presented as an example of strategies developed by the alfalfa seed industry that allow coexistence of different production systems.

The majority of the domestic market is not sensitive to GE alfalfa, but portions of the domestic hay and seed markets and much of the export hay and seed markets are sensitive to the *adventitious presence* (AP) of GE traits. A successful coexistence strategy for GE, conventional, and organic alfalfa recognizes and addresses potential *gene flow* between hay and seed.

Gene flow is described as the exchange of genes from one population to another. There are various modes of opportunity for pollen- and seed-mediated gene flow in alfalfa. Understanding the relative magnitude of risk associated with each mode can help in the development of rational mitigation strategies that minimize potential gene flow from GE alfalfa to conventional alfalfa hay and seed production. In terms of acres and value, hay-to-hay is the most prevalent interface, yet scientific evidence shows that this situation is manageable and provides the least opportunity for gene flow. Alfalfa is not sexually compatible with any other wild or cultivated plant species in the United States (McGregor 1976).

Unlike the majority of biotech[2] crops grown today, the primary commodity for alfalfa is forage hay, not seed. The fact that the production of viable seed is required for gene flow has large implications for potential gene flow in alfalfa. Although the potential for seed-mediated gene flow does exist, best management practices in the cleaning and management of seed harvesting and processing equipment are effective in managing *admixtures* between GE and conventional alfalfa seed. Coupled with cultural and rotational practices to manage volunteer seedlings, seed-mediated gene flow in alfalfa likely will be very low.

Pollen-mediated gene flow requires the presence of pollinators, proximity, and synchrony in flowering of source and recipient fields/plants, and viable seed production in the recipient fields/plants. Routine cutting management schedules in hay production limit flowering synchrony and nearly eliminate the potential for viable seed production, both of which are required for effective pollen-mediated gene flow. These factors, when combined with the other biological barriers described in this paper, decrease the likelihood of gene flow in hay to near zero.

There are fewer barriers to gene flow into alfalfa seed production fields because the seed fields flower for an extended time, introduced pollinators are used to maximize seed production, and the harvest of viable

[1] Italicized terms (except genus and species names) are defined in Appendix B: Glossary.

[2] For purposes of this paper, the term biotechnology-derived (also termed genetically modified [GM] or genetically engineered [GE]) is shortened to "biotech."

seed is the desired outcome. Although the potential for pollen-mediated gene flow from *feral* alfalfa or hay-to-seed production exists, it commonly is controlled through various management practices and is limited by the low relative pollen abundance of the source versus recipient seed production fields during flowering. The primary mechanism for pollen-mediated gene flow in alfalfa is from one seed field to another.

Gene flow is managed proactively in conventional commercial seed production to optimize *varietal genetic purity*. The key mitigation strategy used to manage gene flow commercially is the planned spatial isolation of one seed production field from another. Results from several gene flow experiments have provided pollinator-specific, science-based isolation guidelines designed to minimize gene flow from GE alfalfa to conventional varieties. These isolation distances have been adopted by the industry for RRA seed production and serve as a model for future biotech crops in alfalfa. The National Alfalfa and Forage Alliance (NAFA) Best Management Practices protocol also calls for regular testing of AP in conventional seed lots using publicly available test kits to assess the adequacy of stewardship standards (NAFA 2008). This testing ensures a dynamic process to monitor and, if necessary, to adjust the isolation requirements for GE alfalfa seed production.

Understanding potential gene flow in alfalfa hay and seed production is an important first step in developing management strategies designed to mitigate gene flow. The authors conclude that sufficient scientific data are available to design these strategies and, as outlined in this document, those strategies will be successful in managing gene flow from GE to conventional alfalfa hay and seed production. Regular testing will be needed, however, to monitor the effectiveness of these strategies, and adjustments should be made if and when appropriate.