SEED PRODUCTION ISSUES FOR GENETICALLY ENHANCED ALFALFA

Shannon Mueller[1]

ABSTRACT

Advances in biotechnology offer great opportunities for improvement of alfalfa varieties. The industry must develop new protocols for seed production and establish stewardship programs to preserve the value of this technology. The greatest concern is with gene flow from biotech varieties to conventional varieties. Increasing isolation distances and pollination control are strategies being reviewed to maintain seed purity and limit adventitious presence. The economics of seed production are expected to improve with the introduction of biotech alfalfa varieties, but liability issues are yet to be resolved.

Keywords: alfalfa seed production, GMO, genetically engineered, biotechnology, isolation, gene flow, pollen flow, pollination, seed purity, adventitious presence, trait stewardship

INTRODUCTION

Alfalfa seed is produced in the Western United States where the climate is conducive to the production of high yields of high quality alfalfa seed. Public and proprietary seed is produced for markets throughout the US and for export worldwide. Major producing states include California, Idaho, Nevada, Oregon, and Washington. Non-dormant alfalfa production is centered in California while production of dormant and semi-dormant varieties is located primarily in the Pacific Northwest.

Alfalfa seed has always been produced with a focus on the quality of the final product. State crop improvement associations guarantee certified varieties meet the standards set by the industry by evaluating crop history, inspecting fields, and testing seed samples. Seed that does not meet the established standards for purity, germination, or weed seeds cannot be sold as certified.

Advances in biotechnology offer great opportunities for improvement of alfalfa varieties. Genetic engineering is widely used in many crops to incorporate genes for improved agronomic performance, such as herbicide tolerance and pest resistance. Other developments, including improved nutrition or pharmaceutical use, will be commercialized in the near future. In the United States, regulatory agencies (USDA/APHIS, EPA, FDA) require the developer to show that the introduction of the new variety presents no risk to human health or the environment, and that the safety of food and/or feed is not jeopardized prior to releasing a variety containing a biotech trait. After deregulation (release) there are no regulatory restrictions on planting and use of genetically engineered varieties, but companies have developed stewardship programs to safeguard their varieties and surrounding crops.

---

[1] Shannon Mueller, UC Cooperative Extension Farm Advisor, Fresno County, 1720 S. Maple Avenue, Fresno CA 93702. Email: scmueller@ucdavis.edu. ***In:*** Proceedings, National Alfalfa Symposium, 14-15 December, 2004, San Diego, CA, UC Cooperative Extension, University of California, Davis 95616. (See http://alfalfa.ucdavis.edu for this and other proceedings).

Although genetically engineered crops offer many benefits to growers and the environment, there are concerns that must be addressed. The level of concern seems to be associated with the trait itself and the commodity that carries it. For example, crops developed to “produce” pharmaceuticals will be of greater concern than varieties carrying a gene for herbicide tolerance. Commodities that have the potential to enter the human food chain, such as canola and corn, have raised more questions than the introduction of biotech cotton did. It is also true that people’s comfort level with the technology increases with time and experience.

Most of the experience in California has been with genetically engineered corn and cotton. With these crops, there appeared to be little, if any, concern about biotech genes “escaping” into the environment. However, the introduction of genetically engineered alfalfa stimulates new discussions because, unlike corn and cotton, alfalfa seed production requires pollination by insects to produce a viable crop. The potential for the gene to move from a biotech field into the environment is of concern to the people who have the gene and want to keep it and also of concern to those that don’t have the biotech trait and don’t want it.

Although the objective of this paper is to discuss issues related to seed production of genetically engineered alfalfa in general, it is difficult to avoid using Roundup Ready Alfalfa as the example since it will be the first variety to enter the marketplace. Developers of this technology are in the somewhat unenviable position of establishing new protocols for seed production and stewardship programs. However, growers, conditioners, seed companies, and beekeepers *all* recognize that biotechnology is the future and they better participate in the process.

ISOLATION

Isolating fields from one another is a standard practice in alfalfa seed production to limit gene flow. Isolation standards were set in the 1980’s, using pest resistance genes as pollen flow markers between seed production fields. Established standards require that fields producing foundation seed be no closer than 900 feet from an adjacent alfalfa field. For certified seed production, the isolation distance is 165 feet. Isolation requirements for certified seed production also take into consideration the percentage of the field within 165 feet of another variety of alfalfa. Currently, if 10 percent or less of the certified field is within the 165-foot isolation zone, no isolation is required. If more than 10% of the field is within the isolation zone, that part of the field must not be harvested as certified seed. This requirement is based on the assumption that seed from the entire field will be mechanically mixed during harvest and cleaning operations, and this process will dilute the small percentage of off-type seed which may be produced in the area closest to adjacent fields of different varieties. Now technology exists to more accurately evaluate the movement of genes from one field to the next. With the release of biotech varieties, isolation distance requirements and the “10% Rule” will need to be reviewed.

Forage Genetics and Monsanto are working with state crop improvement associations to establish a system where every acre of biotech seed will be “registered”. The crop improvement association would be the clearinghouse for information and growers could call to check isolation prior to planting. Seed companies may take greater responsibility to place acres in such a way to meet isolation requirements. Opportunities may exist for growers in a region to concentrate biotech alfalfa seed production in a specific area to help manage isolation requirements. To aid in this process, an internet program to locate and track seed production fields is being considered for alfalfa as for other California crops (http://ccia.ucdavis.edu/Mapmockuplogin.htm).

POLLEN FLOW AND GENE FLOW

Pollen flow is not equivalent to gene flow, although the terms are often used interchangeably. *Pollen flow* is the movement of pollen from one location to another. *Gene flow* requires that the pollen move to a new location and result in the transfer of a gene between plants. As with conventional alfalfa varieties, *pollen flow* from biotech fields to other sites is quite likely, especially considering the large populations of pollinating insects placed in seed fields during bloom. However, when considering *gene flow*, the likelihood that off-site movement of pollen containing the specific gene will result in transfer of the gene between plants is much lower. Gene flow is affected by sexual compatibility, flower characteristics, pollen viability and quantity, proximity of neighboring plants, pollinator activity and environmental conditions. In the US, there are no sexually compatible relatives to alfalfa, so feral alfalfa is the only concern with respect to gene flow outside of alfalfa production fields (seed and hay). The influence of pollinator activity and environment will vary with location.

Pollinator Influence on Gene Flow and Isolation

In California, most alfalfa seed growers use honeybees to pollinate seed fields. In the Pacific Northwest, seed growers use either leafcutter bees or alkali bees to pollinate the crop. Forage Genetics and Monsanto have been diligent in getting information on pollen-mediated gene flow with various pollinator species. New isolation standards can’t be established until gene flow data is available.

Three years of pollen flow studies conducted with leafcutter bees in the Pacific Northwest showed that although gene flow could be detected over 1500 feet from the pollen source, it is reduced to less than 0.5% at 1000 feet and less than 0.2% at distances greater than 1500 feet (St. Amand et al., 2000; Forage Genetics, 2001). Honey bee studies conducted in 2003 evaluated movement of the Roundup Ready gene into herbicide susceptible alfalfa trap plots aligned at specific distances (up to 2.5 miles) from a herbicide-resistant alfalfa source plot (Teuber et al, 2004). A significant decrease in gene flow with increasing distance from the source plot was observed. At 900 feet, pollen-mediated gene flow was less than 1.5% and it decreased to less than 0.2% near 5000 feet. Gene flow continued to decline out to 2.5 miles where it was detected at a very low frequency (<0.03%). Initial range-finding tests with honey bees must be expanded, and studies with alkali bees must be initiated once the trait is deregulated if they are to be used for seed production. Until those studies are complete, alfalfa seed will only be produced with leafcutter bees.

It is clear that pollen-mediated gene flow decreases exponentially with distance, and the safe distance will vary depending on the pollinator. Although specific requirements have not been established, greater isolation distances will most likely be required to meet the more stringent seed quality standards that may be required to address specific markets for biotech varieties.

Pollen Movement in the Hive

Where honey bees are used for pollination, they will definitely contribute to pollen-mediated gene flow. Since alfalfa is not a preferred pollen source, bees typically only collect and eat alfalfa pollen when other pollens aren't available. When they are restricted to alfalfa as a pollen source, once it has been packed away as "bee bread" it will never get back into the field in a state that it can pollinate anything, so it is of no real concern in terms of gene flow. However, pollen *will* adhere to the bodies of honey bees visiting flowers in alfalfa fields to collect nectar (or pollen) and this pollen can be moved to other flowers or between bees inside and outside of the hive. Pollen can be moved great distances as a result of bee-to-bee contact and redeposition in fields. It is virtually impossible to guarantee that loose pollen won't be around and possibly moved out of the hive again at some future time. The extent to which this occurs combined with the viability of the pollen over time in both feral and managed colonies needs to be evaluated before the risk can be assessed.

Furthermore, hives of honey bees are moved throughout the country for pollination and honey production. Movement of GE pollens to crops that are supposed to remain GE-free is a legitimate concern when colonies are moved around during the year. The safest practice would be *not* to use bees to pollinate non-biotech crops that have been in biotech crops. This will necessitate planning with the beekeeper to be sure that bees are kept away from specific crops and locations. Until there are biotech genes in almonds, there should be enough colonies of honey bees in California that GE-free bees should be readily available.

BRIDGES FOR POLLEN MOVEMENT

Although standards can be revised to modify isolation and control pollination, movement of pollen beyond the borders of an individual field cannot be prevented entirely.

Feral and Volunteer Alfalfa

Feral or volunteer alfalfa grows rampant along roads and ditch banks, in fallow fields, and as a weed in cropland throughout the state. As it blooms, it can provide a bridge for pollen movement from production fields to other fields. In the case of biotech alfalfa, regulatory agencies require that developers of new varieties demonstrate that "fitness" does not change such that weediness would become an issue. In other words, they must show that plants carrying the biotech trait would not be more likely to survive than any other alfalfa plant.

If the biotech trait doesn't provide any competitive advantage, one feral alfalfa plant would have no greater advantage than another in terms of survival. In the case of RR alfalfa, feral plants carrying this gene could eventually predominate if the only control strategy available was Roundup herbicide. Fortunately, that is not the case. A good stewardship program includes grower education concerning control of volunteer plants using mechanical or chemical alternatives and preventing viable seed set in volunteers.

Forage Production Fields

In general, gene flow to or from hay fields is not of great concern because under typical management, hay fields rarely bloom or produce viable seed. However, with the introduction of

GMO varieties, stewardship programs should focus attention on the importance of timely and thorough harvest of hay fields to prevent gene flow.

It is also important to consider the effect changes in forage management practices have on pollen flow potential. For example, research has been conducted since the 1960's to demonstrate the benefits of leaving strips of uncut alfalfa in hay fields during harvest as a reserve for insect pests and beneficials. This practice is currently undergoing a renaissance as a lygus management strategy. When the strips are left during mid-summer, they easily bloom and may even produce seed. Wide adoption of this pest management strategy in hay fields would certainly have an impact on potential gene flow.

SEED PURITY

Seed purity is controlled in the field as well as during post-harvest handling. Purity indicates how "uniform" the seed is for a specific trait. For example, Forage Genetics and Monsanto have set a standard of >90% purity for RR varieties - more than 90% of the seeds must contain the desired gene. The industry currently accepts low levels of contamination because of the 10% Rule in determining isolation, but standards may change with the introduction of biotech traits.

Adventitious presence (AP) is another factor in seed purity. AP is defined as the unintended presence of an unwanted trait in seed or forage. AP is controlled in the field through isolation and pollinator selection. During harvest and when the seed is transported, cleaned and bagged, AP is controlled through proper sanitation. These practices will maintain purity of biotech varieties and prevent AP in conventional varieties. The industry must set limits as to the percent AP they are willing to tolerate. Different markets may have different thresholds for AP. Once a trait is deregulated, there are no federal or state mandates on seed production, but as part of a stewardship program, companies must define standards that will be acceptable throughout the industry.

Many in the industry believe that existing procedures that prevent mixing or contamination of seed lots will provide adequate safeguards for transgenic crops. Some suggest that, depending on the market destination of the seed, a more thorough cleaning, such as that which occurs between classes of seed (certified to foundation) might be required, complete with outside inspections by the Ag Commissioner. Although it has been proposed that the industry establish biotech-designated conditioning facilities, this is probably not feasible because of the limited number of existing facilities.

Seed can be tested after harvest to make sure it meets accepted standards and tested again after conditioning to guarantee the same. For cotton, the industry is using a strip test to detect the presence of biotech. Testing at each stage may be required to allow identification of the source of the problem if contamination is identified. Multi-stage testing would be necessary to determine whether contamination occurred in the field, the combine, the truck, or during conditioning. Along with testing considerations come sampling issues. Proper sampling will improve the chances of finding something if it is there, but unfortunately can never guarantee that it is not.

The need for “process certification” and testing leads to a discussion of the need to establish a trace back system. Seed can lose its identity very quickly as it moves through marketing channels. This becomes more evident with each report of food safety problems in the media. In the case of seed, a trace back system would identify where the seed was grown, how it was processed, and its ultimate market destination.

Once the seed is conditioned, application of a unique seed colorant will help avoid accidental physical contamination between seed lots. Forage Genetics and Monsanto have made this a trait requirement. All RR alfalfa seed will be coated and given a purple colorant. Inadvertent mixtures will be obvious and the seed should not find its way to unintended markets. (For a review of identity preservation, see Sundstrom et al. 2002).

MARKETING

The vast majority of alfalfa seed produced in California is exported to other countries. In the Pacific Northwest, more of the seed is grown for domestic use, although some is exported. If countries restrict biotech crops, alfalfa seed production in California will be significantly affected. In the case of RR alfalfa, applications to deregulate the trait were submitted to Japan, Taiwan, South Korea, Mexico and Canada as well as to US regulatory agencies. US commercial releases will be coordinated with Japanese approval to protect export markets. In the Imperial Valley, RR alfalfa won’t be grown as a forage crop to protect the seed growers’ existing markets for export seed. Non-biotech seed needs to be safeguarded so that it can continue to move freely in the marketplace.

Food Use

Currently, seed produced in much of California and the Pacific Northwest is prohibited from entering the sprout market because of pesticides and desiccants used during production. However, if new technologies eliminate the need for pesticide applications, new alfalfa varieties should be required to get approval for both feed and food use to eliminate food safety concerns. Although there are no restrictions preventing RR alfalfa seed from entering the food chain, there is no intention that the seed be marketed to sprouters.

ORGANIC PRODUCTION

Acreage and demand for organically grown alfalfa hay and seed is relatively small, but organic growers have big concerns about GE crops. Hedgerows, buffers, large isolation distances, and utilization of non-GE bees will minimize pollen flow, but it is recognized that pollen from wind or bee pollinated crops cannot be absolutely controlled. Testing and process certification will be especially important to insure the integrity of these crops.

ECONOMICS

Most seed companies and growers anticipate lower production costs for biotech varieties. For example, RR alfalfa should result in lower weed control costs as compared to conventional varieties. However, the ability of genetically engineered varieties to produce seed at levels comparable to or better than the best conventional varieties will also have a major impact on the economics of seed production. A premium will need to be paid to the grower if the variety is a poor seed producer or if it requires extraordinary efforts to manage (e.g. requiring leafcutter bee pollination).

On the other hand, there may be bonuses in terms of greater flexibility in production systems. Moving to a shorter production season improves flexibility and also lowers cost of production. An added benefit of the RR trait in alfalfa seed production may be in dodder control. Dodder is a prohibited noxious weed, and if a single dodder seed is discovered in an alfalfa sample tested for certification, the entire lot will be refused. In commercial seed production of RR alfalfa in the Pacific Northwest (2004), growers were getting nearly 100% weed control, including dodder.

A very real advantage of biotech improvements to alfalfa variety development is the opportunity to differentiate alfalfa and lift it from its current "commodity" status. Growers have a difficult time improving their margins now because frankly, alfalfa is alfalfa. Enhanced traits may allow for special pricing. On the flip side, many growers expressed concerns about supply and demand issues affecting the production economics. If an improved variety floods the market, as we saw when Capture insecticide was first introduced, the economics of seed production change immediately and dramatically. Over the long term, with improved efficiencies, acreage will decline, but profits should increase for those who remain seed growers.

TRAIT STEWARDSHIP

On-line stewardship courses, similar to the ones Monsanto supports for corn and cotton, are useful in providing detailed information on the requirements and benefits of good stewardship. Growers must be aware of and agree to the use restrictions and stewardship responsibilities before signing any agreements. For example, they must understand how to incorporate different pest management strategies to prevent or delay resistance to maintain the effectiveness of the biotech crop and preserve the value of the patented seed technology. The industry must practice good stewardship to maintain export markets. Loss of markets would mean a loss of revenue and a seed surplus.

Traits must be managed so they remain available in the marketplace. Growers adhering to stewardship requirements and growing crops under state certification programs will provide some assurance to buyers that seed was produced and handled in such a way to guarantee seed purity and AP. Non-certified varieties have always carried some risk in terms of reliability of performance, and the risk in some marketplaces may be even greater with the advent of biotech.

Most growers and seed companies desire a system of self-regulation over systems imposed by regulatory agencies. Established prudently, these programs can effectively maintain consumer confidence in the product and protect the trait. Many growers cited the stewardship program established by the seed industry when Capture insecticide was introduced. Grower participation was excellent and control of seed and by-products from the field was outstanding.

LIABILITY ISSUES

In today's world, seed growers assume the responsibility and receive the benefit for ensuring that their crop meets mutually agreed upon contract specifications for purity. But in the new world of genetically engineered crops, it has yet to be determined what will happen if they don't succeed. Liability questions are a big issue for each participant in the seed industry – grower, seed company, conditioner, and beekeeper. "Off market" seed will no longer move to VNS or "branded" products. What will happen to the seed that doesn't meet the established standards? Whose fault is it if a neighboring field has adventitious presence or doesn't meet purity standards? Contracting will need to be very clear in assigning liability and seed companies may find they must participate more fully in all aspects of seed production. These issues are currently being debated for other outcrossing biotech crops such as corn and canola.

SUMMARY

Roundup Ready alfalfa is the first in what the industry hopes will be a long line of genetically enhanced alfalfa varieties in need of seed production. With its introduction, all existing seed production practices must be carefully reviewed. New or modified protocols should be established for seed production and handling since the product may be required to meet a higher standard of purity. Safeguards must protect conventional varieties from adventitious presence and maintain existing domestic and export markets. Rigorous monitoring and evaluation of new standards must take place to ensure the industry is doing all it can to guarantee the safety and reliability of the new technology. Ultimately, the decision will be up to an individual grower as to whether they want to produce seed or hay of biotech varieties. They must be confident in their understanding of the use restrictions and stewardship requirements and accept the long-term ramifications of producing biotech seed on their farm.

REFERENCES

Forage Genetics, 2001. Alfalfa pollen-mediated gene flow studies 2000-2001. **http://www.foragegenetics.com/news.htm**

McCaslin, M., 2003. Managing Seed Quality in Biotech Alfalfa Seed Production. Pp.41-42. In: Proceedings Alfalfa Seed Production Symposium, March 4 & 5, 2003, Five Points and El Centro CA.

St. Amand , P.C., D.Z. Skinner, and R.N. Peaden, 2000. Risk of alfalfa transgene dissemination and scale dependent effects. TAG 101: 107-114.

Sundstrom, F.J., J. Williams, A.E. Van Deynze, and K.J. Bradford, 2002. Identity preservation of agricultural commodities. University of California Division of Agriculture and Natural Resources Publication 8078. ANR Communication Services Web Site, http://anrcatalog.ucdavis.edu

Teuber, L.R., A. VanDeynze, S. Mueller, M. McCaslin, S. Fitzpatrick and G. Rogan, 2004. Gene flow in alfalfa under honey bee (*Apis mellifera*) pollination.

Van Deynze, A., K.F. Bradford, and A. VanEenennaam, 2004. Crop Biotechnology: Feeds for Livestock. University of California Division of Agriculture and Natural Resources, **http://anrcatalog.ucdavis.edu**.