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Genetic Engineering and Pollen Flow

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Pollen grains are the vehicles that transport a plant's male gametes. For plants that produce pollen, it is transported by wind and insects. Also, many species can pollinate some of their own flowers. Typically, the majority of the pollen grains produced by an individual plant move a very short distance. But if hundreds, thousands, or millions of plants are all creating pollen, the tiny fraction that goes a relatively long distance is multiplied accordingly. In the case of wind-pollinated plants that pollinate other plants (outcross), it is not unusual for viable pollen grains to be found more than ½ mile (800 m) from their source (Ellstrand 2003a).

Long-distance gene flow occasionally occurs in many plant species, including cultivated plants (Kelly and George 1998). For traditionally improved plants, most cases of gene flow have been of little consequence. Rarely, gene flow can provide benefits; a few spontaneous hybrids have been adopted as new cultivars. In some cases, gene flow has lead to problems (see Ellstrand 2003a). Therefore, concerns have been raised about the possibility of pollen flow from genetically engineered (GE) crops into plant populations for which they are not intended. As stated in a recent National Research Council (2004) report, engineered gene flow "is not expected to be a problem, in and of itself, unless it leads to undesirable consequences." Let's take a look at what those consequences might be.

A great deal of attention has been focused on engineered crop genes in natural populations. For guidance about future problems with GE crops, we can ask whether traditionally improved crops have hybridized with wild relatives, and if so, whether those hybrids have caused any problems. Most cultivated species naturally hybridize with some wild relative or relatives somewhere in the world (Ellstrand 2003a). In some cases, such as coffee, those wild relatives are geographically restricted. On the other hand, one or more wild relatives of rice are usually found where rice is cultivated worldwide. Most cases of natural hybridization between cultivated plants and their wild relatives have been of little consequence. On occasion, such hybridization has created two classes of problems:

- **The evolution of new or more difficult-to-control weeds.** In particular, the evolution of a new weed beet in Europe, a hybrid of sugar beet and an innocuous wild species, has resulted in well over a billion dollars' damage to Europe's sugar industry in terms of reduced yields and increased management costs (Ellstrand 2003a).
- **Increased extinction risks for wild relatives.** In Taiwan, gene flow from cultivated rice has played an important role in the extinction of a wild relative (Kiang et al. 1979).

Are there examples of gene flow from GE crops to wild relatives?

Among the current commercialized GE crops that are or could be grown in California, only canola has cross-compatible wild relatives. GE herbicide-resistant canola has already naturally hybridized with a weedy relative in Quebec (Warwick et al. 2003). In fact, it is as yet the only case known in which engineered genes from a commercial

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crop have been found in natural populations. Whether or not these hybrid populations are becoming a problem is currently under study by the group that discovered them.

Dozens of other GE species have been the object of field trials in California. Some of these have wild relatives in the state, including feral populations, and others do not. Plants grown under field trial conditions should be managed in such a way as to prevent their pollen from fertilizing other plants. However, pollen from GE herbicide-resistant creeping bentgrass grown in field trials in Oregon successfully fertilized plants in wild populations of the same species, as well as those of a weedy relative, several miles from the test plots (Watrud et al. 2004). This event represents the only known case to date of the movement of engineered genes from a field test into natural populations.

Much less discussed, but much more likely, is unintended pollen flow from GE plants into other fields of the same crop. Likewise, many crops have "gone wild," occurring as feral populations (see Gressel 2005 for many examples); these too could serve as repositories for engineered genes. In this case, the pollen source and pollen recipient are usually highly sexually compatible. Strict guidelines have been developed and followed for the last century to spatially and temporally isolate different stands of the same crop (see CCIA 2003). These have been created with the goal of obtaining a certain level of genetic purity for breeding and commercial purposes with the recognition that 0% adventitious presence (AP) is often impossible under field conditions.

What are the possible consequences of gene flow from GE crops to other cultivars?

The problems voiced about unintended gene flow from a GE crop to another crop of the same species include

- loss of security of intellectual property.
- nontarget effects on organisms in natural or agricultural ecosystems.
- evolution of new weeds, such as the case of multiple-herbicide-resistant canola (Hall et al. 2000). In that case, the new weed is still controllable, but requires a different herbicide than what is usually used on canola volunteers.
- "Genetic pollution" of crops intended to have a level of purity with regard to market demands, such as crops intended to be organic or intended to be sold to a foreign market that does not tolerate the presence of materials from GE plants.
- Possible health effects from genes engineered to produce pharmaceutical or industrial compounds if these plants enter the food or feed supply (see Ellstrand 2003b). Such plants are grown only under stringent field test regulations or in contained facilities such as greenhouses. However, lack of compliance can create opportunities for such genes to move.

The possibility of these and other potential problems has focused attention on creating new methods (Genetic Use Restriction Technologies, or GURTs) for containing pollen and seed from GE organisms. Many of these methods involve genetic alterations with the goal of reducing or preventing the unintended transmission of transgenes from one generation to the next. Most of these novel techniques are in the early stages of development (NRC 2004).

PERSPECTIVE

The successful prevention of problems due to flow of pollen or seed requires a mindful approach to consideration of the organism to be engineered, the specific trait to be engineered, whether the engineered organism should be grown outside, and, if so, the distribution of its wild and cultivated relatives. Guidelines have been developed to aid in decisions about whether and how to field-release GE plants (e.g., Christensen et al.

2005; Colorado Institute of Public Policy 2004; NRC 2004; Rissler and Mellon 1996; Scientists' Working Group on Biosafety 1998; Strayer 2002). Furthermore, the agencies that regulate GE plants take a case-by-case approach with their decisions; the consideration of the likelihood of gene flow and its potential consequences are generally given a high priority. For example, while certain engineered crops have been fully deregulated, others, such as those that produce industrial compounds (e.g., pharmaceuticals) currently must be grown under permit (Federal Register 2005).

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