Reflections

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Genetic Engineering

Horticulture is a diverse, eclectic field. Our research ranges from applied, readily applicable studies to genomics, sometimes within the same faculty program. Need to know the best watermelon variety for Texas, Pennsylvania, or Indiana? Ask any of the horticulture specialists in those states. Need to know about transcriptional regulation of carotenoid biosynthesis genes in watermelon? Check the recently published article in the Journal of ASHS. A research study in horticulture could easily touch on a half dozen other fields, including soils, nutrition (both plant and human!), entomology, plant pathology, ag engineering, and ag economics.

We support industries that commercially produce hundreds, even thousands, of plant species, and those industries range from small backyard growers to large, multinational businesses. Our extension faculty might discuss the basics of using compost in the morning to master gardeners, new food safety regulations over lunch to commercial growers, and the advantages of large-scale phenotyping in the afternoon at a departmental seminar. Add consumer horticulture to the mix, and who knows what kind of questions we will address in a typical day.

The diversity of horticultural science leads to a diversity of opinions within horticulture. I think our diversity of opinions means that we can look at an issue and understand it from all sides, and be open to discussing ideas openly, honestly, and without excessive bias. With that in mind, I think we are particularly well-suited to addressing one of the most contentious issues of the day—genetic engineering. Our field includes many scientists developing products using genetic engineering techniques, and many others working with organic growers that do not use these techniques. Horticulturalists have the potential to be both positively and negatively affected by genetic engineering.

To be honest, genetic engineering (GE) is one of the most well-known and argued, but least understood, issues of our time. The public is most familiar with the term GMO (genetically
modified organisms). Organisms containing genetic material from other organisms are known as transgenic. A variety of technologies are used to create genetically engineered (GE) crops, either through the introduction of additional genetic material or manipulation of existing genes. A recently developed set of processes known as the CRISPR/Cas9 system is faster, more flexible, and less expensive than previous processes. These new processes may speed the introduction of new products and allow genetic engineering to be commercially viable on crops with limited production acreages. The CRISPR/Cas9 system also provides the option of being able to alter genomes of plants and animals without the introduction of foreign DNA but with genetic editing, and thus, the products produced may not be considered GMO.

While the attention is mostly on GE crops such as cotton, corn, and soybean with herbicide tolerance and/or the Bt insecticide gene, many GE plants have been produced, focusing on a wide range of production and human health issues. Examples include virus resistance, insect resistance (in addition to Bt), stress resistance (i.e., drought), toxin reduction, browning reduction, vitamin enrichment, edible oils, biofuels, production of drugs and other compounds, and bioremediation. Proponents note that GE technology is in its infancy, and has the potential to address important problems, such as diseases in banana and cassava; drought, heat, and cold resistance; and allergens in peanut and wheat. Opponents of GE technology are more conservative in their assessments and do not believe that the risks of GE crop technology have been determined to be safe for a sufficient period of time. Also, many opponents note that more holistic and accessible approaches to improving crop systems and human nutrition exist that do not require the use of GE technology.

Science

There are three frequent questions regarding GE crops. Is the technology itself safe to people and the environment (focusing on the process, not on the genes being manipulated or any secondary effects)? Is the movement of genes from one species to another safe? Is the process of creating and commercializing GE crops having unintended consequences?

On the first question, after 20 years of use, the science appears to be settled. A recent and comprehensive report said that the technology is safe (National Academies of Sciences, Engineering, and Medicine, 2016), and the overwhelming majority of scientists agree (Plumer, 2015). The report went further to address the second question regarding the movement of genes and stated that the genetically engineered plant products created to date are also safe. We should add the caveat that this discussion is based on current regulations and currently available GE
plants, including those with the \textit{Bt-} and glyphosate-resistance genes. However, one can certainly imagine all sorts of situations in an unregulated environment where the movement of genes would result in an unsafe product. Indeed, early in the development of GE crops, Brazil nut genes introduced into soybeans could have caused an allergic reaction in people sensitive to Brazil nuts (Nordlee et al., 1996). We should note, however, that these products were intended for animal feed and were never commercialized due to the potential human health issues.

The report also noted that GE crops are valuable to agriculture and society in general. For example, the use of the Bt has cut insecticide use in conventional agriculture drastically, and the commercialization of GE disease resistant papaya has allowed that industry to rebound in Hawaii.

The question of unintended consequences is very broad, difficult to anticipate, hard to research, and dependent on the product being examined. Numerous consequences of GE crops have been documented or proposed, and are listed in the Politics section below. This column is not intended to be a review article, but I will discuss two consequences of genetically engineered plants below and will note that the science on most of these issues has not been settled.

One potential consequence of the widespread use of GE Bt crops is the occurrence of insect resistance (Tabashnik et al., 2013). Bt resistance has now been documented in five of 13 major pest species from many locations around the world. Some insect populations have more than 50\% of individuals resistant to at least one of the Bt toxins (Tabashnik, 2015). The companies providing the GE crops and farmers have been employing many strategies to prevent or delay resistance, but failures in implementation and/or gaps in the strategies exist, and resistance is occurring. The long-standing practice and knowledge of rotating and minimizing product applications to decrease the risk of building up resistance to pests and diseases is not being addressed with many GE systems. The immediate problem is especially concerning to organic and sustainable farmers, as they depend on spot applications of Bt products to manage a number of insects and are fearful that this effective tool will disappear.

In the second example, a consequence of the widespread use of Roundup Ready varieties is the heavy use of glyphosate, which has increased from 12.5 million kg in 1995 to 113.4 kg in 2014, using conservative numbers (Benbrook, 2016). Roundup Ready soybean, cotton, and corn varieties were first introduced in 1996. In 1995, glyphosate was the 7th most heavily used pesticide in U.S. agriculture and has since moved into the number-one spot. It should also be noted that, while the introduction of herbicide resistance crops resulted in greatly increased glyphosate use, it has largely been at the expense of other herbicide classes (Osteen and
Overall herbicide use has also increased since 2002 due to increasing crop acreage, which has, in turn, increased use of herbicide-resistant varieties and the resulting glyphosate sprayed on them.

The impact of glyphosate use is widely debated, with studies evaluating both human health and environmental impacts. Glyphosate is considered to have a low toxicity to mammals, and typical human exposure is present within acceptable levels according to government agencies. Farm workers and their surrounding communities (e.g., the midwest and the cotton belt) may have higher exposure levels than the general public and should be mindful of the EPA lifetime health advisory (HA) limits. However, some literature shows possible negative effects from the chemical, which led to the IARC (World Health Organization’s International Agency for Research on Cancer) decision to classify it as a “probable human carcinogen”. Environmental effects of glyphosate are similarly being researched, and there is clear data that show an increase in weed resistance, which is causing significant problems in some areas. Glyphosate-resistant Palmer amaranth is now widespread and glyphosate resistance has been identified in dozens of other weed species. The effects of glyphosate on fish and water insect/microbe communities have been also described. These findings indicate that glyphosate can have negative ecological impacts, as with any herbicide, and must be used with vision and care. Thus, while heavy use of glyphosate is not a direct product of GMOs, it is being used in such high amounts due to the widespread use of GE herbicide-tolerant crops. The approval of GE crops with resistance to other herbicides may lessen the impact of glyphosate, but, of course, these herbicides may have their own consequences.

**Politics**

One of the more complex political situations is heavily based on emotion and politics rather than scientifically confirmed facts. A large swath of the general public is against GMOs. A recent survey also confirmed that a large number of people are also against having DNA in their food, indicating a limited understanding of science in general. Educating the public about agriculture and science is paramount to helping them make more informed decisions. I use a computer and cell phone every day and get the basic idea of how they work, but I am clueless regarding the actual details of how they function. We need to add to this discussion the fact that the major benefits from the first widely commercialized GE crops were for farmers and were not readily apparent to the consumers. Only now are products, such as ‘Arctic’ non-browning apples, appearing that the average consumer can understand and relate to. Is it any wonder that
the average consumer knows and understands little about GMOs? To be honest, the same statement could be made regarding the general public’s understanding of horticulture and agriculture—or science in general.

More specifically, many in the organic and alternative agriculture communities have come out against GE crops for both scientific and philosophical concerns. A new “non-GMO label” has also been created. Considering the potential benefit of using plants with genetically engineered insect and disease resistance, one might think that this community would be strong advocates for GE crops. However, one needs to note that the core values and practices of organic agriculture include an emphasis on naturally derived inputs, utilizing preventative actions to decrease pest and disease pressure, physical means of weed control, supporting biodiversity across the farm scale, and lastly using approved pesticides after a problem is present. Many of these core elements are not incorporated in GE production systems.

Several other actions resulted in the organic agriculture community at first being wary and then opposed to GMOs. At the beginning, GMOs were widely touted as the next green revolution and the answer to many problems. While the much-vaulted golden rice, intended to ease malnutrition, was the altruistic case example, the most widely commercialized GE crops were Roundup Ready corn, cotton, and soybeans, which had the effect of increasing glyphosate sales. To many people this felt like a bait and switch.
Second, genes from GE crops can move to non-GE fields through pollen movement, weather, and accidental seed contamination. A number of lawsuits were launched to protect the proprietary technology, some of which were against smaller farmers in the organic community. The fact that the company releasing these products is one of the largest companies in the United States only added to the feeling of David versus Goliath. The potential loss of control of one’s land, organic certification, and livelihood from genetic contamination concerns many organic producers. There have also been cases of non-approved GE crops contaminating farm fields, leading to concern about regulation efforts and company practices.

Third, there is the overall concern that the highly successful GE varieties will crowd out non-GE varieties, resulting in the potential extinction or functional disappearance of unique genes found within those varieties. We may need these genes someday if another major pest problem becomes prevalent or to broaden adaptability of commercial crops in the face of climate change. It should be noted that loss of genetic diversity is an issue not limited to GE crops, but can be accentuated by their extensive use.

Fourth, there are concerns about the effects of large monocultures. The process of growing large amounts of a crop in contiguous space has resulted in fence-to-fence farming, eliminating edge habitat for many native plants and animals. While this is not an issue specific to GE crop production, the negative effects of monocultures are accentuated by GE production. For example, most recently, concerns about the iconic Monarch butterflies are due to the loss of their milkweed hosts from large scale glyphosate spraying in Roundup Ready corn and soybean fields (Hartzler, 2010). Non-Roundup Ready corn and soybean fields are not as clean of “weeds” as Roundup Ready types, allowing some milkweeds to grow, hosting the Monarchs. In addition, experimentally Bt-contaminated pollen from Bt corn has been shown to negatively affect Monarch caterpillars growing on pollen-contaminated milkweed. It should be noted, however, that most studies show that the real risk in the field to Monarchs is quite low, approaching zero (Sears et al., 2001).

Finally, many people are concerned about the increased use of glyphosate on human health and the environment as discussed in the Science section. Whether the risks are real or not, however, has become almost secondary as most people have little ability to weigh risks from various factors and advocate accordingly.
The Future

Based on the science, there is much agreement that currently produced genetic engineering processes and products are safe and provide benefits to farmers and to the general public. It is my feeling that GE crops should not be banned, and the science of genetic engineering should be further researched to advance the technology. Indeed, genetic engineering may be the only practical way to combat some pathogens, such as those causing citrus greening, which is devastating citrus producers of all sizes. Looking further into the future, the use GE technology might become a critical strategy due to the increasing need for food production and increasing pressure from diseases, insects, drought, and heat. In addition, the development of CRISPR and related techniques may greatly refine the process of manipulating the genome, so much so that the resulting products may not be considered true GMOs and equivalent to those obtained through traditional breeding.

However, it is also clear that a product-by-product risk analysis must be done to continue to prevent unsafe products from reaching markets. Indeed, the National Academies report stated that evaluations should include more comprehensive “–omics level” analysis, which examines a plant’s DNA sequence, gene expression, and molecular composition for all products before being marketed (National Academies of Sciences, Engineering, and Medicine, 2016).

There are downsides to the widespread commercialization and use of GE crops. Continued scientific studies may bear out a host of other negative consequences from various GE crops. Thus, we should continue regulation of GE crops and continue efforts to minimize the negative effects of GE crops, both direct and indirect, on human health and on the environment. We should continue to support efforts by the sustainable and organic community and various agencies to preserve a broad array of varieties, especially heritage varieties with their unique genes, and regionally adapted hybrids and landraces. The effect of accidental GMO gene flow on the organic businesses is not trivial, and we must encourage industry and government to be proactive in addressing these issues.

We sometimes forget that all technologies have downsides and that it is impossible to produce a new technology with no negative side effects. Electricity is dangerous, especially so when it was first being widely distributed throughout the United States. We have learned to make it much safer and use it carefully to harness the advantages while minimizing the dangers. Similarly, we will need to review and address the side effects of GE crops as they occur.

In closing, the diversity of opinions in horticulture can allow us to view genetic engineering with hope towards the future, but with a healthy dose of concern as well. Horticultural science is
well-suited to extracting the benefits of genetic engineering while minimizing the negative effects. We may well see horticulturists leading the way in carefully integrating genetically engineered crops into sustainable and organic farms for the benefit of all. This can only be done with thoughtful discussions, good science, critical thinking, and active listening by all involved.

Resources


