Genetic Engineering:

What it Means and Why You Should Pay Attention

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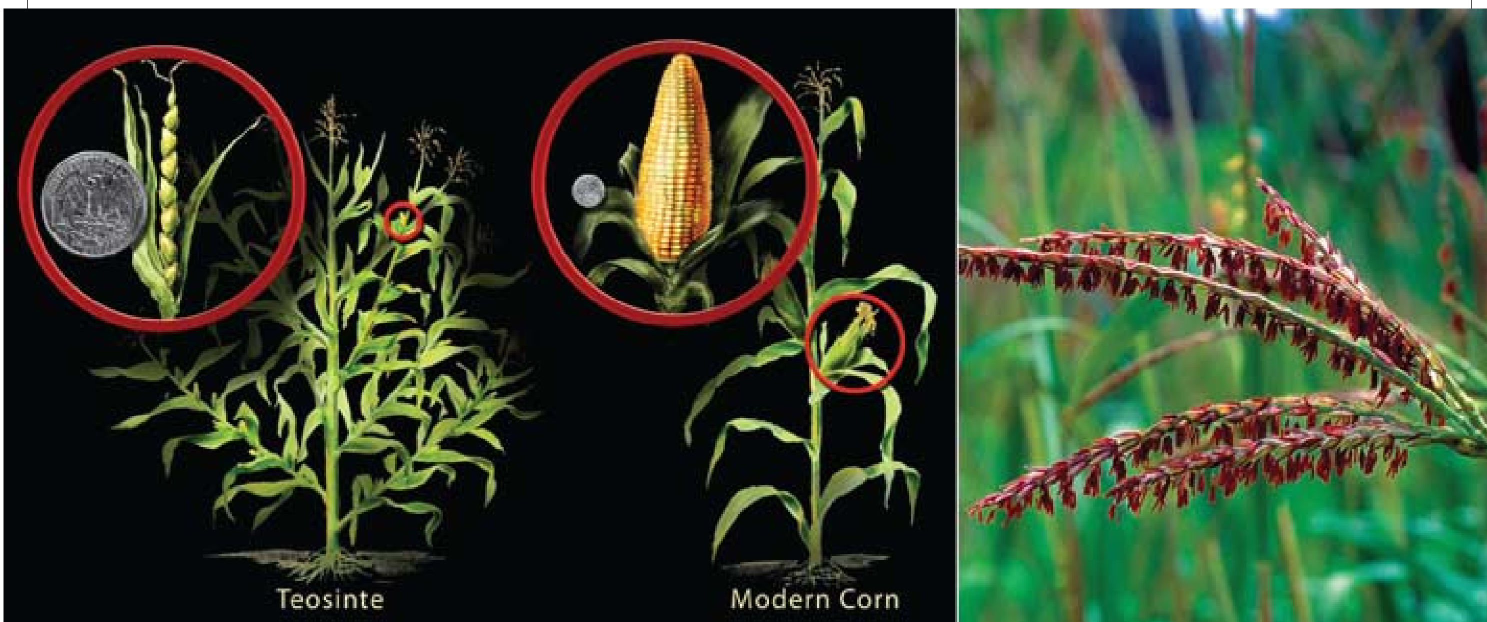


Modern corn (center) is the result of millennia of selective breeding that started with two grasses, Teosinte (left) and gamagrass (right), culminating in a new species that only exists because of human intervention. Credit: Nicolle Rager Fuller, National Science Foundation.

On June 13, 2017, the University of California, Davis, in cooperation with the Agribusiness Committee of the California State Bar Business Law Section, hosted a workshop entitled, "Genetic Engineering in Agriculture: Science, Policy and Law." Although there are currently no "genetically modified" avocados in existence, and there likely won't be for some time, the industry has been considering technologies such as marker-assisted breeding, so understanding the laws and public perceptions surrounding these technologies is important.

What Is "Genetic Modification"?

Perhaps no scientific concept is more hotly debated, or misunderstood, in the popular press today than that of "genetic modification," commonly referred to by the colloquialism "GMO" (genetically modified organism). Scientifically speaking, genetic modification is a very ambiguous term. Every sexual crossing (plant or animal) or random mutation results in a genetic modification. And man has been using this to our benefit ever since the agricultural revolution started 12,500 years ago. What is really being referred to by the moniker "GMO" is genetic engineering.

Genetic engineering "is adding, subtracting, or adjusting genes in the lab that change a trait in the resulting plant, animal or microbe. It satisfies the very definition of engineering—the application of science and mathematics to affect properties of matter or the sources of energy in nature to be made useful to people."

Perhaps no greater example of genetic modification exists than what we know as corn. The modern corn plant (*Zea mays*) does not exist in the wild, has no wild equivalent and cannot exist without being managed by man. Modern molecular analytical techniques have allowed us to understand that corn was developed through the selective breeding of two grasses: teosinte—a grain plant with very small vertical kernels—and gamagrass. To look at teosinte and gamagrass and think that these two plants can be crossed, back crossed and selected for over thousands of years to yield an entirely new, unrecognizable species seems like science fiction, but it is simply the result of genetic modification and time.

Modern genetic engineering technologies simply allow scientists to do what man has been doing for thousands of years on a much shorter time scale. A perfect example of this can be found in cattle. Angus beef cattle have been bred for optimal muscle production, and along the way they have lost the trait for horns (known as "polled"). Holstein dairy cattle have been bred for optimal milk production, and they still possess the trait for horns. Horns are not desirable in dairy cows since the cows can injure each other and workers with the horns, so veterinarians perform a procedure known as disbudding to kill the horn bud on calves. Although considered a humane practice, disbudding does cause discomfort to the calves.

Using modern genetic engineering technology, scientists can move the polled trait from Angus to Holstein cattle without altering all the other Holstein traits that breeders have worked for more than a century to develop. Although Angus and Holstein cattle are sexually compatible and can be crossed by traditional means to move the polled trait into Holsteins, traditional breeding would bring in many other undesirable traits from the Angus line. Breeders would then spend many years, likely decades, and a lot of money to remove the undesirable traits while trying to preserve the polled trait they want. Thus, genetic engineering could accomplish in a short time, and more cost effectively, what traditional breeding would take decades to do.

Why Is Genetic Engineering so Controversial?

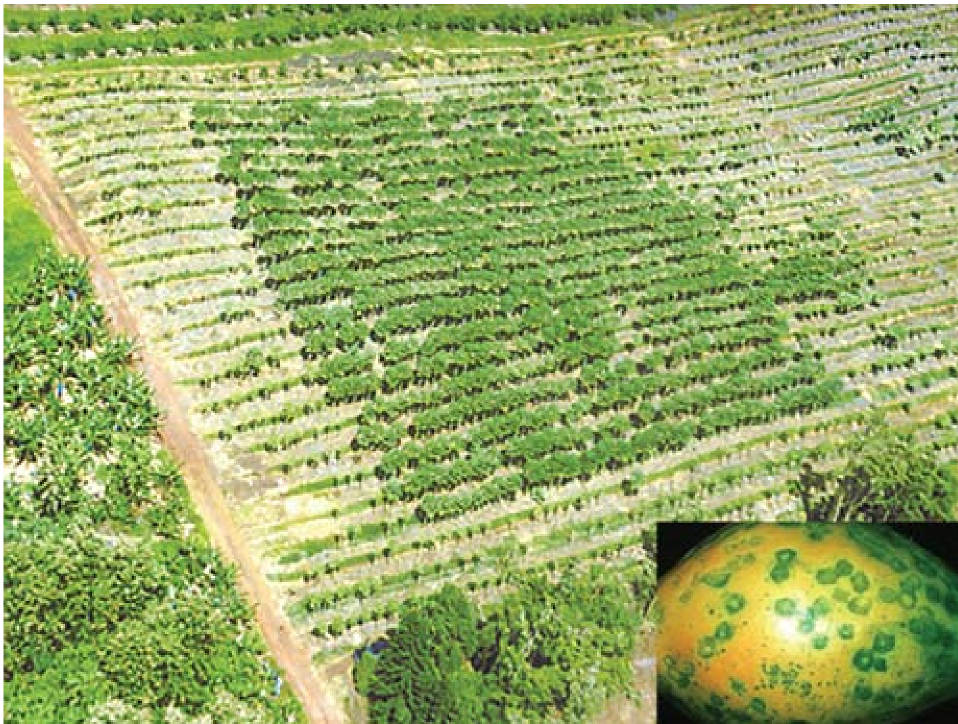
Although there is no easy answer to the question of why genetic engineering is so controversial, it is likely because the technology has unfortunately been closely linked to agrochemicals such as glyphosate (Round-Up®). One of the first uses of genetic engineering that gained wide-spread adoption was to genetically engineer crops to be resistant to herbicides. Agronomic crops such as corn, soybean and canola have all been engineered to be resistant to glyphosate and other common herbicides. This allows farmers to spray entire fields, resulting in better weed suppression and greater crop growth. However, it also means that the crop that is ultimately destined for human consumption or animal feed has been treated with the herbicide and it can lead to more rapid resistance to the herbicide among weed populations.

As a result, genetic engineering has become all but synonymous with Round-Up® resistance and is inextricably linked to Monsanto and other large agricultural biotech companies. This is unfortunate since most genetic engineering research is being done in the public sector—by universities and the United States Department of Agriculture (USDA) —and is targeted at issues that, if not for the dark cloud of herbicide resistance, would probably be viewed favorably by most people.

Genetic Engineering: Herd Immunity for Plants

One of the ideas that commonly comes up when discussing genetic engineering is that if genetically-engineered crops are grown, conventional crops will go away. In fact, the opposite is true and is exemplified by human immunization.

We commonly use vaccines to prevent debilitating diseases in humans, but for various reasons not everyone can receive a vaccine. However, by protecting a large enough portion of the population from a given disease, those who cannot be vaccinated also are protected. This is known as herd immunity—the resistance to the spread of a contagious disease within a population that results in a sufficiently high proportion of



A field trial from the Puna region of Hawaii showing a solid block of papaya ringspot virus-resistant 'Rainbow' growing well while the surrounding susceptible 'Sunrise' is severely infected with papaya ringspot virus. A papaya fruit affected by papaya ringspot virus (inset). Credit: Dennis Gonsalves, USDA U.S. Pacific Basin Agricultural Research Center.

individuals who are immune to the disease. Thus, planting a disease-resistant, genetically-engineered crop on a large scale can allow other farmers to continue to grow conventional varieties of the same crop disease free.

This concept has been proven in Hawaii where papaya ringspot virus had all but ended papaya production in the state by 1995. Dr. Dennis Gonsalves, USDA Agricultural Research Service, developed two varieties of papaya — 'Rainbow' and 'SunUp' — resistant to papaya ringspot virus using genetic engineering. These trees went into field trials in the Puna region of the Big Island starting in 1995 and have proven to maintain resistance for more than 20 years. Today, because of the high percentage of resistant papayas being grown on the Big Island, the disease pressure has diminished enough for farmers to once again grow the highly profitable Kapoho variety (non-genetically modified) for export to Japan. In addition, papaya production has been able to return to Oahu where it had previously vanished due to papaya ringspot virus.

A similar scenario may be the greatest hope for overcoming devastating diseases in other crops, such as Huanglongbing (HLB; citrus greening) in citrus and perhaps even laurel wilt in avocado.

Regulatory Issues

Perhaps even more difficult than overcoming public perception is overcoming the regulatory hurdles to get genetically-engineered products into production. Often regulations have not kept pace with technology and are outdated. For example, genetically-engineered animals are regulated by the Food and Drug Administration (FDA) because they fit the FDA's definition of a drug: "articles (other than food) intended to affect the structure of any function of the body of man or any other animals." Thus, the Holstein dairy cow would be regulated as a drug if the polled trait were moved from Angus beef cattle using genetic engineering, but not if it that same trait was moved by traditional breeding over many generations – even though the result is the same.

Plants are no less regulated than animals and are actually reviewed by three government agencies: USDA, FDA and the Environmental Protection Agency (EPA). The USDA determines if a plant is safe to grow based on its authority to

A bottle of salt with a misleading "non-GMO verified" label. Salt is a mineral containing no DNA and thus cannot be genetically modified since it has no genome.

regulate plant pests. For example, could the crop become a weed? Were any plant pests used in its development (for example, the coat protein from papaya ringspot virus)?

The FDA makes the determination whether a crop is safe to eat. That is, determining whether the genetically engineered crop is substantially equivalent to conventional varieties with respect to its nutritional value, allergenicity, etc.

The EPA regulates plants that have pesticidal properties. Are they safe for humans, non-target organisms and the environment?

All of this regulatory compliance comes at a significant cost. A 2007 study estimated the average costs for regulatory compliance reviews for a single crop ranged from $7-$15 million, and potentially took a decade or more to complete.

And new federal regulation will require all genetically-engineered foods to be labelled as such starting July 2018. The downside of this regulation is that it does nothing to curb the misleading non-GMO labelling that has become ubiquitous.

Virtually all of our foods, plants and animals, have been substantially genetically modified from their original form. In fact, many of our foods have no wild relatives. Modern genetic improvement techniques are extensions of breeding that make it more precise and more targeted, allowing us to achieve in a relatively short period of time what our ancestors achieved over thousands of years.

Our modern society allows for pests and diseases to spread among our world's agricultural systems faster than ever —HLB, laurel wilt, avian influenza, mad cow disease. Too fast for conventional breeding techniques to keep up and stay ahead of the threats. In fact, some of these diseases and pests are so devastating they could wipe out germplasm repositories —the very places we would go to look for traits to breed resistance —before we have time to assess the situation and react. We may not have a choice but to look to genetic engineering to solve some issues in the not too distant future.

Although there are currently no genetically engineered avocados, we must be mindful of new techniques and technologies that become available that could help us confront some of our industry's greatest challenges. Simultaneously, we must pay attention to regulatory issues and laws surrounding genetic engineering so that our ability to utilize these techniques and technologies is not compromised before we even start.