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Gene Editing: A Potential Game Changer for Crop Agriculture

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Inside...

Key Points:

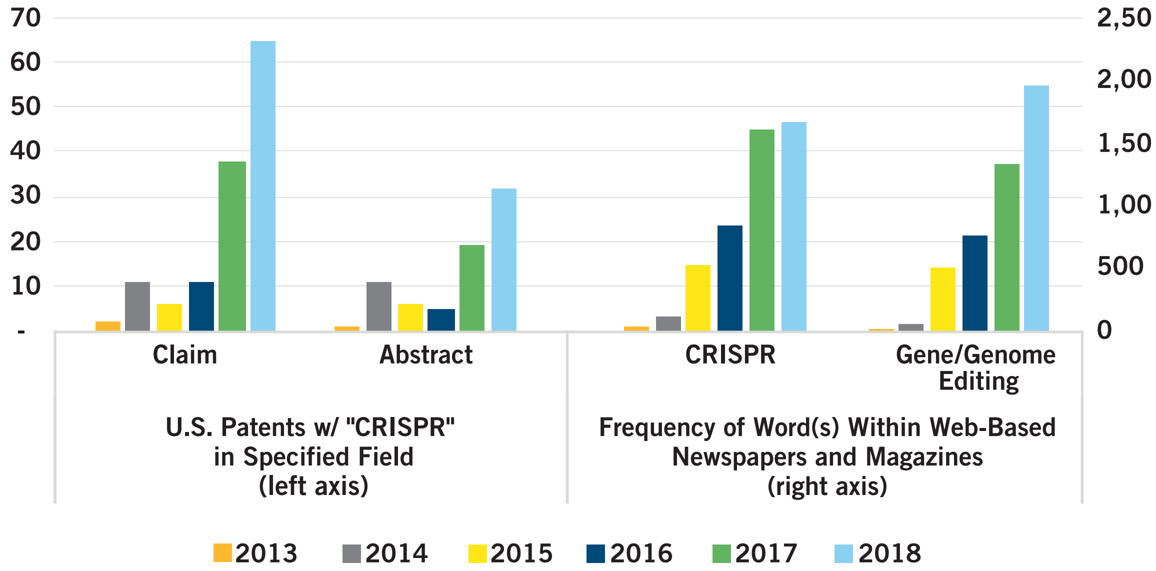
- Gene editing is a suite of technologies that make targeted changes to DNA quicker and more precisely than traditional genetically modified organism (GMO) technologies.
- Unlike GMO technologies, gene editing does not necessarily involve a transgene (i.e., gene from another species) and produces a genetic makeup that can be achieved in nature or via traditional non-GMO techniques.
- Development costs and time are significantly reduced using gene editing, which will increase the pace of innovation in crop agriculture.
- Gene-editing technologies offer solutions to critical food and agriculture challenges, including labor and water shortages, disease and chemical resistance, environmental sustainability, climate change, food waste, food security, taste, and nutrition.
- Consumer acceptance could impact the pace of adoption and innovation.
- Gene-edited crop commercialization is intensifying. Corn, soybeans, and other large-acreage crops will lead in commercialization. Specialty crops will lag behind, likely taking five or more years before widespread commercialization is achieved.

Introduction

Interest, innovation, and investment in gene editing tools like CRISPR (clustered regularly interspaced short palindromic repeats) and TALEN® (transcription activator-like effector nucleases) have heated up in recent years, and will only intensify in 2019. (*See Exhibit 1.*) The technology is being described as "game changing," "revolutionary," and "evolutionary." And it certainly has the potential to live up to the hype.

Gene editing within crops allows for economical nutritional improvements while enabling the production system to produce more with less. The low cost of gene-editing technologies offers solutions to agricultural labor and water shortages, disease and chemical resistance, climate change, food waste, food security, and nutrition.

EXHIBIT 1: Interest and Innovation in Gene Editing is Growing Fast



Note: The NOW Corpus covers many web-based newspapers and magazines; however, it is not comprehensive. Data is presented to provide an indication of magnitude and direction.

Sources: U.S. Patent Office; NOW Corpus, Brigham Young University

However, gene-editing technologies are relatively new and face a number of potential challenges, particularly with consumer acceptance. Barring widespread rejection by consumers, gene editing will be a boon to specialty crops producers, food and agriculture supply chains, and allied industries in the years ahead.

Defining Gene Editing

Gene editing is a suite of technologies that make precise and targeted changes to DNA. These technologies are frequently described as "molecular scissors."

Most current gene-editing applications turn on or off selected genes. Some can also insert DNA.

Gene editing differs from traditional genetically modified organism (GMO) technologies in these ways:

- **Does not necessarily involve a transgene** (a gene from another species). The resulting genetic makeup is one that could be achieved in nature or via traditional non-GMO techniques.
- **Quicker and more precise.** Varieties developed using gene editing typically take three to five years to develop versus 5 to 15 years for transgenic GMOs and more than ten years for mutagenesis and cross breeding. The reason: Traditional non-GMO techniques develop random combinations of genes, so it takes many years to create and identify the variety with the desired trait.
- **Costs significantly less.** Developing a variety using traditional GMO techniques typically costs more than $100 million. With gene editing, it can potentially cost less than $10 million, and in some cases much less.

Gene editing is not seen as a replacement to GMO techniques, but rather another tool in the toolbox. Given its low cost and shorter development timeframe, and with hopes of greater consumer acceptance, gene-editing is seeing a growing share of research dollars. Investments are being made by the large biotech companies as well as smaller companies and university researchers. Over time, gene-edited products will make up a growing share of the crop portfolio, but this does not mean that many of the GMO crops on the market today or future GMO developments will be eliminated.

Gene-Editing Technologies

- **Zinc Fingers** is the oldest of the gene-editing technologies.
- **TALEN®**. Calyxt holds the license to use TALEN® for commercial crop applications. The company's current focus is on its high oleic soybean, to which 17,000 acres were planted and harvested in 2018. The number of planted acres doubled to 34,000 in Q1 2019. Other crops in its pipeline include wheat, canola, potatoes, and alfalfa.
- **RTDS** (rapid trait development system) is patented by Cibus. The company released an herbicide-tolerant canola in 2016 and has flax, rice, and potato products in its pipeline.
- **CRISPR** is the latest technology. It is lower cost, quicker, simpler and easier to use, and has fewer intellectual property restrictions than other gene-editing technologies.

Benefits

The potential benefits of gene-editing technology are vast. Scientists are continually improving the technology and uncovering new applications to resolve some of agriculture's greatest challenges. (*See Exhibit 2.*)

Challenges

Trust and having the "right" benefits will be key in gaining consumer acceptance for gene editing, emphasizes the Coalition for Responsible Gene Editing in Agriculture. Developing a strategy to gain global understanding and acceptance of gene editing technology is the core mission of the coalition, a program of the Center for Food Integrity (CFI) formed by leaders throughout the agriculture supply chain, including food manufacturers, retailers, biotech companies, NGOs, and academics.

Challenges that are far less important but still notable involve regulatory and intellectual property issues.

1. Consumer Acceptance

The level of consumer acceptance is important to the future pace of innovation and adoption rates of gene-edited foods. However, it will not be a game stopper. Here's why:

1. Consumer acceptance is measured on a spectrum; it is not a 0 percent or 100 percent only issue.
2. Adoption rates of GMO corn and soy are above 90 percent in the U.S. despite its high cost of development and opposition by some consumers. Gene editing resolves one of the key issues with GMO by excluding the use of a transgene.

The level of consumer acceptance is more important for the pace of innovation and widespread adoption of foods produced for human consumption. The pace of innovation within food crops, including specialty crops, stand to be impacted more than crops used for animal feed or industrial inputs.

Education, transparency, and the "right" consumer benefits will be key in gaining consumer trust and acceptance.

- **Education:** A survey by CFI found that support for CRISPR increased from 49 to 62 percent after consumers watched a series of short educational videos.[1] However, while education is important, the information must come from a source they trust.

  Consumers' acceptance requires education on two key challenges:

  1. Concerns over the potential for unintended consequences.
  2. Gene editing sounds the same in consumers' minds as "GMO."

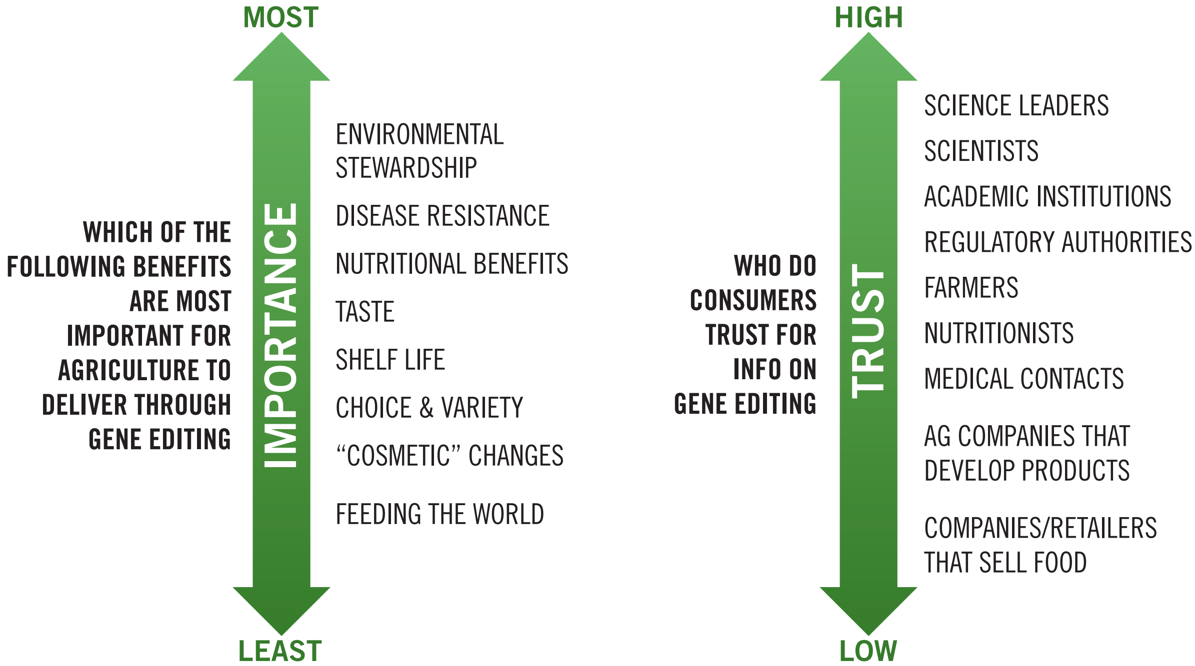
- **Transparency:** Mark Lynas, an environmental activist and opponent-turned-proponent of GMOs, summarized a key challenge to acceptance, saying: "People are getting increasingly scared of GMOs precisely because the industry is fighting a rearguard battle not to tell people which foodstuffs contain them." [2]

EXHIBIT 2: Benefits and Specialty Crop Application Examples of Gene-Editing Technology

BENEFIT CATEGORY	SPECIALTY CROP APPLICATION EXAMPLES	BENEFIT EXAMPLES
Nutrition and Food Safety	• **Peanuts** with reduced allergens • **Camelina** (oilseed) with boosted omega 3 content • **Cassava** with no cyanide • **Potato** that doesn't release acrylamide when processed after cold storage • Boosted beta carotene in **sweet potato**	• Vitamin enhanced • Reduced allergens • Omega 3s • Gluten free • Removes toxic/harmful attributes
Environmental Sustainability	• Powdery mildew-resistant **tomatoes** could save billions of dollars and eliminate spraying of fungicides. • Disease resistance reduces need for chemicals	• Less water • Reduced nutrient runoff • Fewer chemicals • Increased biodiversity
Food Waste	• Reduced browning mushroom and **potato** • **Tomato** with extended shelf life • **Blueberries** designed for mechanical harvest *(due to labor shortages and limited harvest window, this is a food that is frequently wasted because it is not harvested in time)*	• Extends shelf-life • Greater harvest efficiency • Extends production cycle
Food Security	• Disease resistance in: **grapes, oranges, grapefruit, apples, banana, cucumber, cocoa, sweet potato, tomato, potato** • Early harvest and extended harvest **tomatoes**	• Disease resistance • Higher yields • Drought tolerance • Climate change adaptation • Expanded geographical range
Development Time and Cost	• 3-5 years vs 5-15 years for traditional GMO, 10+ years faster than mutagenesis and traditional breeding. • $90+ million less than traditional GMO **Variation around these time and cost ranges will exist.*	• Greater innovation • More companies • More crops
Taste and Function	• Enhanced flavor of otherwise favorable **tomato** varieties • **Sugarcane** with higher biofuel conversion rates • Sweeter **strawberries** • Naturally decaffeinated **coffee**	• Greater innovation • More companies • More crops

Source: CoBank

EXHIBIT 3: Communicating the Benefits of Gene Editing



Source: Center for Food Integrity

The Benefits of Transparency

- In 2016, the Campbell Soup Company voluntarily decided to label all of its U.S. food products that contained GMO ingredients. They have seen favorable business results from this decision.
- In 2014, Vermont passed a law requiring GMO food labels. Research by Purdue University estimated that this policy led to a 19 percent reduction in the opposition to genetically engineered foods.[3]

It is from this standpoint that the National Bioengineered Food Disclosure Law requiring food manufacturers to disclose the presence of bioengineered foods and ingredients (NBFDL) was signed by President Obama in 2016. The rules to implement this law were finalized and released by the USDA in December 2018. The finalized labeling standard uses the term "bioengineered" in place of GMO, and essentially excludes foods derived from gene editing technologies that do not utilize foreign DNA (i.e., non-native to the edited species). On the surface, the rule appears favorable to gene editing technologies. However, there is concern that it could have a negative longer-term impact on trust if/as consumers become aware of the exclusion.

- **"Right" Benefits:** Gene editing proponents can learn from the GMO experience. Having the "right" benefits – environmental, disease resistance, or nutritional – will improve the chances of consumer acceptance, according to the CFI. (*See Exhibit 3.*)

2. Regulation

The primary regulation risk is for crops with significant exports to the European Union.

- **U.S.** – In March 2018, the USDA announced its ruling that certain gene-edited plants can be designed, cultivated, and sold free from regulation. The "certain" gene-edited plants include those that result in a genetic alteration that could have otherwise been developed through traditional breeding techniques and which are not transgenic.

- **Europe** – On July 25, 2018, the Court of Justice of the European Union ruled that gene-edited plants will be regulated in the same manner as traditional GMO.
- **Canada** – Canada regulates new plants based on a novelty determination rather than the method of development.
- **Argentina and China** – Similar to the U.S., these countries have adopted a light-touch regulatory approach to gene editing.

3. Technology and Intellectual Property
Efforts are ongoing to improve the technologies, but there are no major technical roadblocks preventing the commercialization of crops developed using gene editing.

The two key inventors of CRISPR, the Broad Institute and UC Berkeley, are in a legal battle over who owns the technology for plant use. Corteva has the rights to use and sublicense the technology. However, a license is not needed for research, except if the product moves to commercialization. In October 2017, the Broad Institute and Corteva agreed to provide non-exclusive sublicenses to any company wanting to use the technology for agricultural plant development. Still, getting a license for CRISPR can be burdensome. Some researchers have responded by developing workarounds that use different enzymes and systems not covered by the original CRISPR patents.

Conclusions

Gene editing has the potential to be a game-changer for the food system by making notable improvements in nutrition, food safety and security, the environment, and farm profitability.

Critical to its widespread success:

- Developing the technology in a responsible way.
- Accurate and transparent communication about the technology and the benefits that matter most to consumers.

The extent of consumer acceptance will drive the pace of innovation and the adoption rate across crops. Specialty crops and food crops will be the most at risk if consumer resistance is high.

Gene editing opens the door for historic crop improvements in the specialty crop sector. Costly and time-intensive, traditional GMO techniques have created barriers to entry for smaller companies and small-acreage crops. The sector has been largely reliant on cross breeding and mutagenesis techniques, and for some crops, including vegetatively propagated crops, there are challenges to the use of these non-GMO methods. As a result, the pace of improvement in the specialty crop sector has lagged behind that of many other crops.

An increasing number of gene-edited crops are expected to hit the market over the next several years. Jennifer Kuzma of the Genetic Engineering and Society Center at North Carolina State University estimates 20 commercialized gene-edited crops will become available in the U.S. in the next five years.

Specialty crops won't be among the front-runners in the race to commercialization. Corn, soybeans, wheat, and canola will be initial crops of focus since they demand more acres. While a few gene edited specialty crops could make it to grocery shelves in the next few years, it will likely take five or more years for gene-edited specialty crops to make it out of research and into commercialization in a meaningful way.

References

[1] 2018. The Coalition for Responsible Gene Editing in Agriculture. "Gene Editing Engage in the Conversation." Center for Food Integrity

[2] 2013. Mark Lynas. "Why we Need to Label GMOs". Speaking at the Center for Food Integrity Summit, Chicago, October 15, 2013. http://www.marklynas.org/2013/10/why-we-need-to-label-gmos/

[3] 2018. Kolodinsky and Lusk. "Mandatory Labels can Improve Attitudes toward Genetically Engineered Food." Science Advances.

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