GENE EDITING FACTS

To achieve our vision of "a world where the best quality seed is accessible to all, supporting sustainable agriculture and food security", ISF believes that science and innovation must continue to flourish. The latest plant breeding methods can accelerate the improvement of seed varieties for the benefit of agriculture and consumers globally.

Gene editing is a new tool in the plant breeding toolbox

Plant breeding is a collection of scientific disciplines. It involves many different tools all used to develop plants that meet the needs of farmers and the needs of a changing world. These tools provide solutions to global challenges by developing improved varieties that are better adapted to withstand diseases, pests, climate change, and other threats and offering better quality.[1] Gene editing is one tool that plant breeders and scientists use to develop new varieties more efficiently.

A HISTORY OF INNOVATION

Since the first seed was planted, farmers have continued to selectively breed and grow the best and heartiest crops. As the world and science progresses, so does breeders' understanding about plants and the breeding process. They have continued to be more efficient in choosing which crops to breed and in identifying beneficial characteristics to grow heartier, tastier, and more pest-resistant varieties. This was evident in the mid-20th century when Norman Borlaug led the first Green Revolution, leveraging humanity's knowledge of plant breeding to double wheat yields, feeding billions globally.[2]

CONTINUING THE TRADITION

Now, in the early-21st century, we're witnessing another leap in plant breeding innovation. The tools may be different, but the goal remains: Grow what the world demands with the least resources possible, while adapting to a changing world. Gene editing is a natural addition in the continued improvement of plant breeding. Because of its increased precision, gene editing can allow breeders to adapt more quickly to address the new and emerging global challenges of today and tomorrow.

UNDERSTANDING PLANT BREEDING

Plant breeding is the science of developing new or improved characteristics in plants. Whether breeders use traditional crossing and selection or gene editing, these tools allow the development of characteristics from within the plant's own gene pool. Gene editing is built on the foundation of conventional plant breeding tools and their long and safe history of beneficial use.

> **"Gene editing is built on the foundation of conventional plant breeding tools and their long and safe history of beneficial use."**

While gene editing is a new plant breeding tool, it does differ from classical genetic engineering. In agriculture, classical genetic engineering is most often used to introduce desired characteristics that are outside of the plant's gene pool. These plants are commonly called GMOs (genetically modified organisms). While gene editing can be used to develop GMOs, plant breeders more often use gene editing within the existing genetic diversity they normally use, also known as the breeders' gene pool, to develop improved characteristics..[3]

THE BOTTOM LINE

Gene editing is plant breeding

Gene editing is part of plant breeding innovation. It builds on years of tradition and is the result of advanced science and understanding of plant genetics. Gene editing allows breeders to work within a plant's own gene pool to try to reach the same endpoint as they would through more traditional breeding methods–but with greater precision and efficiency. With reasonable and differentiated regulation, the contribution that gene editing can make will only increase, creating a better future for the environment and global food security.

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Gene editing improves the precision of plant breeding

Genetic variation is the foundation for plant breeding. Compared to other plant breeding methods that are used to increase genetic variation, gene editing stands out as a tool that allows the introduction of targeted variation. Because of the precise way genetic variation can be introduced through gene editing, it results in far fewer "unintended" genetic changes.[1] When undesired changes do occur, there are proven and tested processes in place to remove them. In any breeding program, regardless of the breeding methods used, plant breeders discard plants with unintended characteristics; breeding with gene editing is no different.

You probably have noticed the uniform-looking fields of corn, soybeans, or other crops while in the countryside. However, within these fields there is significant genetic diversity among individual plants. Take corn for example. Each new generation of a corn plant may have anywhere from 17-120 new genetic changes across its genome – the blueprint for its DNA.[1] These natural and spontaneous changes are the foundation of plant diversity and drive evolution, as they continue to provide opportunities for adaptation to new environments and changing climates.

These changes can occur before any human breeding innovation is introduced to the corn crop. Counter arguments often emphasize the possibility, even small, of unintended consequences, but this is nothing new to plant breeders. Plant breeders are constantly monitoring these changes in order to preserve the important characteristics of their varieties.

HAVE CONFIDENCE IN THE PLANT BREEDING PROCESS

As with most new innovations, there is understandable concern about what impacts gene editing could have on the world. It is reassuring to know that plant breeding involves long-established safeguards and processes to effectively handle unintended changes. Only plants that have the desired characteristics are further developed into new varieties that are multiplied in the field and marketed commercially. Whether the breeding process has only used crossing and selection or has also used gene editing, plant breeders identify and remove plants showing an unintended characteristic.[2] Scientific advances are making it easier to identify those plants with these unintended attributes.[3]

> **"Plant breeding involves long-established safeguards and processes."**

All methods of plant breeding have the possibility of new and unknown genetic changes. Gene editing tools, like CRISPR-cas9, herald a level of precision never before seen in plant breeding programs because unintended genetic changes are rarer in frequency, while still being mitigated before the crops are planted in the ground.[4]

THE BOTTOM LINE

Gene editing delivers more predictable food quality and security

Consider the genetic diversity present in a corn field. Now consider how we can maintain the tradition and necessity of growing food, while reducing resources, and creating more resilient crops. Gene editing allows us to do both–with increased precision.

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Gene editing is built on scientific advances and a better understanding of natural processes

Over the years, scientists and breeders have continued to learn more about innovations in plant breeding to help solve global challenges. Evolving breeding methods offer plant breeders more precision and efficiency than ever before. Newer methods like gene editing are built on the mechanisms used in more traditional plant breeding methods, or those found in nature, often making the results similar to traditionally bred plants.

THE NATURE OF GENETICS

All plants and animals are comprised of cells with genes made from DNA—the blueprint for life. Changes to these genes can come about in a variety of ways—both spontaneously and targeted. Evolution, a fundamental feature of life, is dependent on the creation of genetic variation driven by genetic changes. These changes are a constant process that allow organisms, like plants, to adapt to changing environments. Leveraging the ever-increasing knowledge about the genetic makeup of plants, scientists and breeders make this process more efficient by using more precise gene editing methods.

"Evolving breeding methods offer plant breeders more precision and efficiency than ever before."

When plant breeding first started millennia ago, farmers and plant breeders knew little about genetics. And while we still don't know all the functions of genes, our understanding continues to increase. Today, we have a vast and continuously growing amount of information available that allows scientists and breeders to make more informed choices in the breeding and selection of plants to address global issues, including climate change and hunger.[1]

THE LIMITATIONS OF DETECTION

Gene editing is not a single tool but a versatile set of tools that allows scientists and breeders to work within the existing genetic diversity, also known as the breeders' gene pool. This is what differentiates plants developed with the use of gene editing from GMOs (genetically modified organisms).

Detection methods look for specific DNA sequences, called genetic signatures, which are added to the genome when developing a GMO. Given that the breeding results obtained by most gene editing methods could be replicated by nature or achieved by earlier breeding methods, these genetic signatures are not present in most gene edited plants.

"Gene editing is not a single tool but a versatile set of tools that allows scientists and breeders to work within the existing genetic diversity..."

THE BOTTOM LINE

Leveraging science for a better agriculture

The use of gene editing to develop new plant varieties is a promising and growing field. Of most interest are those gene editing applications that lead to DNA changes that could also occur in nature or from more traditional breeding methods. Because of this, genetic changes resulting from gene editing cannot reliably be differentiated from the same changes that can occur by traditional breeding or spontaneously in nature.[2]

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Plant breeding is safe by design[1]

Plant breeders and farmers strive to produce safe and sustainable food while protecting, or even enhancing, the environment. With these shared values, plant breeders ensure that new varieties, including those that were developed with the use of gene editing, meet safety, quality, and environmental standards. The history of plant breeding is built on the foundation of the long-established quality management practices, which include multiple field trials, screening for unwanted plant characteristics, and selecting only those plants with the desired attributes.

SHARING OUR VALUES

Just as we value safety as consumers, all partners in the agricultural food chain have a shared responsibility to produce safe food that has minimal impact on the environment. This chain starts with plant breeders, developing the seeds farmers will use to grow crops for food, feed, fiber, and fuel, and to develop new, better-tasting, and more nutritious plant varieties for consumers.

Plant breeders use recent advancements such as gene editing to develop improved crops that are important to the agriculture food chain and the consumer, all while using well-documented and thorough quality management processes. As much as plant breeding is a process of selecting beneficial plant characteristics, it's also a process of eliminating undesired characteristics.

"Just as we value safety as consumers, all partners in the agricultural food chain have a shared responsibility to produce safe food that has minimal impact on the environment."

A SERIES OF CHECKS AND BALANCES

In the same way researchers develop other complex products like vehicles or medicine, plant breeders spend time understanding how a gene edited crop will be used, taking into account any safety and risk considerations.[2]

Before any new plant variety, including those developed using gene-editing, is made commercially available, it undergoes a series of tests. This includes geographic adaptation trials—ensuring the gene edited plant can grow in different areas and climates without adversely affecting the crop's performance. Plant breeders also evaluate how the gene edited crop needs to be safely processed and stored, addressing any negative consequences during processing.

If at any point during these tests, a new plant variety fails to meet expectations, those plants are discarded until the plant breeding process produces a safe and more adapted variety. This same process is applied when gene editing is one of the breeding methods used and therefore these products are as safe as any other products on the market.

"Before any new plant variety is made commercially available, it undergoes a series of tests."

THE BOTTOM LINE

Plant breeding is built upon a long history of safety

Plant breeders work to produce crops, including those developed with the use of gene editing, that are safe for humans, animals, and the environment—while demonstrating the positive characteristics farmers and consumers want. Using the proven tools of the breeding and selection, this process enables a more diverse, resilient, and efficient food system that will continue to benefit generations to come.

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Gene editing research is diverse and global

Gene editing is revolutionizing plant sciences and its applications in agriculture. In the last decade alone, crop-focused gene editing research projects have grown exponentially. As the field of gene editing expands, so is access to the gene editing methods and the ability for a wide variety of public and private organizations across the globe to develop their own crops using gene editing techniques.

"In the last decade alone, crop-focused gene editing research projects have grown exponentially."

EFFORTS TO EXPAND ACCESS

Organizations of all sizes have the opportunity to create innovative solutions using gene editing and to benefit from the results. While the discovery and development of the CRISPR Cas-9 gene editing method is most well-known and notable due to its efficiency, there are additional gene editing tools available.

Academic institutions generally do not need a license to use CRISPR Cas-9 if used to conduct basic research. Production of a commercial product by either public or private developers would be subject to license requirements. In recent years, many academic researchers have leveraged shared gene editing tools to conduct safety and environmental studies, which have further demonstrated the benefits of gene editing.[1]

"Organizations of all sizes have the opportunity to create innovative solutions using gene editing and to benefit from the results."

DIVERSE AND GLOBAL RESEARCH

Gene edited products are developed by companies of all different sizes. In fact, the first commercialized gene edited plants, high oleic soybeans in the United States and high GABA tomatoes in Japan, were developed by two smaller companies.

In addition to commercial development, gene editing research across the globe has expanded to cover a wide array of crops, including many smaller crops. Since the mid-1990s, plant breeders have published thousands of peer-reviewed research publications, conducted primarily by public institutions.[1] Likewise, studies focused specifically on bringing gene edited products into the marketplace have well surpassed 200 peer-reviewed publications. That number continues to grow—largely due to research at public institutions, representing 25 different countries.[2,3,4]

"One of the key benefits of gene editing tools like CRISPR is its ease of implementation."

THE BOTTOM LINE

Gene editing promotes expanded involvement and more choices

One of the key benefits of gene editing tools like CRISPR is its ease of implementation. This means that up-front investment costs are not a barrier to small entities to develop innovative products. This enables public sector institutions, smaller companies, and start-ups to leverage these tools to conduct research and develop improved crops. There's no question that gene editing methods are widely accessible, evident by the number and diversity of gene edited crops under development. These efforts are accelerating global research and crop development which benefits farmers, consumers, and the world.

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Gene editing is a vital tool for global advancement in crop production

Plant breeders are working to address the need for affordable food and develop solutions for a changing climate by applying gene editing as an additional, and critical, plant breeding tool. Gene editing's improved efficiency compared to more traditional breeding methods allows plant breeders to more rapidly and efficiently develop and deliver new varieties adapted to changes in climate and to contribute to a healthy, safe, and secure food supply.

DRIVING MORE EFFICIENT PROGRESS

Plant breeders are foundational to progress in agriculture, developing new plant varieties that feed and fuel the world. Delivering on this goal is a challenge because of the pace of global change. Plant breeding requires foresight and innovation because the breeding process, no matter the method used, can take years of a selection and performance evaluation before a new variety is ready for the market.

Gene editing offers improved precision and efficiency when incorporated into the breeding process.[1] This doesn't mean plant breeders spend less time evaluating gene edited plants. Gene editing is also a research tool that helps us to learn more about genetics and gene interactions which, in turn, decreases the cost and time of initial research and development. With these efficiencies, plant breeders can develop more choices for farmers.[2]

To offer the right choices that farmers need to drive progress, plant breeders must predict demand for certain types of crops years in advance.[3] Whether it's the need for drought tolerance or a resistance to a specific pest, plant breeders can address these issues faster than ever before by using gene editing to develop these improved crops.[4]

HELPING FARMERS DELIVER SOCIETAL BENEFITS

Agriculture involves a series of choices and trade-offs, which are necessary to balance environmental impacts, farmers' livelihoods, and the need to grow food for the world in a more sustainable way. When farmers can choose the right seeds for their land, it improves the likelihood of better yields. Diversity of seed choices also helps farmers fight pests and disease and allows them to adjust to changing climate patterns.

Access to improved seeds ensures farmers can participate in agriculture innovation and take advantage of progress in agricultural productivity. Gene edited crops can play an important role in enhancing the sustainability of many different agricultural systems-- regenerative practices, precision technology, and even organic farming practices can all leverage advancements in gene edited crops.

THE BOTTOM LINE

Gene editing is an important tool

Crops developed with the help of gene editing are expected to contribute to many important societal objectives – the reduction of the environmental footprint of agricultural production, the reduction of food waste, and the improvement of the nutritional value of food, especially for at-risk populations.[5] Through current and future applications, gene editing has the potential to be a key contributor in driving global progress, including helping to accomplish the United Nation's Sustainable Development Goals, and reaching the ambitious goal of achieving net-zero emissions by 2050.

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