Listicle

Developments in Agrigenomics

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The global population is expected to grow to 9 billion by 2050. The energy and nutrition required to feed this growing population will require a significant increase in our agricultural output and processes.

The adoption of high-throughput genomics platforms by each sector of agriculture has steadily contributed to a growing collection of knowledge and innovative techniques. Agrigenomics is the application of modern genomics tools throughout agriculture. These tools offer food producers and researchers with whole-genome insights that can increase productivity, reduce losses and improve sustainability. Such improvements also help address the persistent threats presented by climate change and food insecurity.[1] In this listicle, we further explore modern genomics techniques used by commercial farmers, breeders and researchers.

Next-generation sequencing

Genome sequencing provides deep insights into the genetic potential of plants and animals

Next-generation sequencing (NGS) is one of the fundamental technologies responsible for genomics revolutionizing the biological sciences, especially for agrigenomics. NGS is a high-throughput form of genome sequencing that processes massive (i.e., deep) amounts of data in parallel.

Common wheat is one of the most widely grown crops globally. While its nutritional value is well understood, our understanding of its genome was severely limited due to its complexity until NGS advancements arrived. For comparison, the complete human genome contains approximately 3.1 billion nucleotides while the common wheat genome has *17 billion* base pairs organized amongst multiple sub-genomes.[2] The efforts behind sequencing the common wheat genome took 13 years of extensive collaboration and high-speed computing.

After successfully sequencing the wheat genome in 2018, researchers began performing comparative genomics with relative plant species to better understand its history and potential for adaptation to emergent threats like disease and climate change. Prior to this development, it was extremely difficult to obtain function insights into genetic markers of common wheat and similar crops.

Genomic selection

Genotyping by sequencing methods help breeders and ranchers increase their agricultural productivity

The improved scalability, speed and affordability of NGS enables the agriculture community to better understand the links between genes and phenotypic traits of interest. This knowledge is essential for the improvement of selective breeding programs created by academic and commercial producers.

Conventionally, selective breeding is primarily driven by phenotypic traits such as size or color.[3] One historical example of selective breeding is the intervention of mankind with wheat over thousands of years: by repeatedly choosing wheat plants that produce more wheat after each life cycle, we artificially bred today's wheat to share a collection of genes that contribute to its overall productivity and nutritional value.

However, the selection of desired offspring from parent plants or animals over millennia has led to a reduction of genetic diversity with our agricultural products.[4] Consequentially, this reduction in genetic diversity has made some diseases more dangerous for these same crops and animals. Challenges like this inspired the agricultural community to adopt NGS techniques that expanded our understanding of crop and livestock genomes and their respective relationships with environmental stresses.

Marker-assisted breeding is another agricultural development that uses genomics to identify desirable organisms within a population for breeding. Once a reference genome is generated for a population, targeted sequencing can identify molecular markers that may be linked to phenotypes of interest such as increased yield or disease resistance.

Today, the application of NGS technologies in agriculture allows researchers to better understand the whole genome of crops and animals without having to solely depend on visible observations. This development improves how selective breeding programs are designed so that desirable traits such as increased drought resistance or bigger seed size are brought to market more quickly and efficiently.

Genetic engineering

Gene-editing tools like CRISPR provide new alternatives to conventional methods of agriculture

In parallel with NGS and targeted genotyping by sequencing, the adoption of genetic engineering techniques has significantly contributed to the advancement of modern agriculture.[5] Genetic engineering involves the modification of an organism's genome through artificial selection. While conventional methods of breeding are considered forms of genetic engineering, the advancements of biotechnology have made it possible to manipulate the genetic makeup of crops and animals with accurate precision.

The core technology behind the current revolution of gene editing is the CRISPR-Cas9 system. After the discovery of CRISPR gene-editing technology in 2012, precise genome modifications quickly became affordable and scalable for the biological sciences. Naturally, CRISPR applications have already begun for scientists and researchers focused on agricultural issues such as food security and food availability. Unlike traditional methods of genome editing, CRISPR can make gene modifications without the use of foreign DNA sequences. This feature allows geneticists to natively edit the genomes of crops so that they obtain desirable qualities like increased drought tolerance or expanded herbicide resistance.[6]

Tomatoes and other readily studied fruit crops became some of the earliest model systems to broadly apply CRISPR technologies. For example, CRISPR has been used to inactivate the tomato gene *DMR6*, which confers increased resistance against downy mildew. When this same approach was used to target genes *DCL2* and *CP*, tomatoes became more susceptible to viral infections. Beyond the development of disease-resistant fruits, CRISPR can also be used to improve the nutritional quality and domestication of crops. These types of applications include gene edits linked to external characteristics like fruit coloring or internal traits such as overall shelf life.

Due to the speed, affordability, and relative easiness of CRISPR, plant breeders have also adopted this revolutionary technology to enhance the yields and efficiencies of staple crops like rice, wheat and maize. These CRISPR-related applications are some of the necessary efforts behind our attempts to feed a growing population in a sustainable manner.

Regulation of genetically modified food

Government agencies are updating regulatory frameworks due to emerging gene-editing technologies

In the United States, at least three different agencies play a role in the regulation of genetically modified crops: The Environmental Protection Agency (EPA), the Food and Drug Administration (FDA) and the Department of Agriculture (USDA). Before CRISPR technologies were understood, these agencies loosely regulated genetically modified (GM) foods available to the public if they were safe to consume by humans and animals. The advent of CRISPR forced these agencies to update their respective policies to accommodate its emergence throughout agriculture.

The Animal and Plant Health Inspection Service (APHIS) is a collaborative branch of the USDA involved in the regulation of GM plants. A lot of their work requires input from plant breeders and researchers to ensure that GM crops do not harm non-GM crops in the field. These inputs also guide the ongoing development of regulatory policies focused on genetic engineering practices that are being applied to key plants and animals today. The FDA currently regulates GM animals as animal drugs. Yet, they rely upon a voluntary Plant Biotechnology Consultation Program and APHIS for guidance when it comes to the safety of GM crops. To address such misaligned challenges, APHIS recently submitted a proposal that would further establish safety assessments and regulations for GM crops and animals under the USDA's purview.

It will take a global effort to educate and inform the public about the benefits and safety of GM crops while ensuring GM technologies are safe and useful for agricultural purposes. Nonetheless, the global adoption of CRISPR and other GM technologies could forever change how we feed a growing population that continues to battle forces of climate change and food security.

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