International Seed Federation
Seed is Life

NAVIGATING THE EVOLUTION OF PLANT BREEDING INNOVATION

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A statement prepared by the International Seed Federation

> "The breeding of plants for food has resulted in the greatest advance in human civilization"
>
> Norman Borlaug, Winner of the Nobel Peace Prize, 1970.

As the International Seed Federation (ISF) celebrates its 100-year anniversary in 2024, we reflect on the success of a century of plant breeding innovation and its impact on society and call on all stakeholders to ensure that the next 100 years are just as fruitful. Providing farmers with access to quality seeds to feed a growing population is fundamental to enhancing agricultural productivity and fostering a more sustainable food system worldwide. This necessitates establishing clear and timely pathways to market for products developed using all plant breeding methods.

Plant breeding drives constant improvement using and generating genetic diversity and selecting for the most useful characteristics. Over time, the expanding plant breeder's toolbox has enhanced the ability to access a wider range of genetic diversity. This continuous improvement of plants is one of the pillars of agriculture and in turn, essential for society. Over the last century, plant breeding has been steadily advancing, transforming agricultural production, and providing societies with a range and volume of nutritious food not previously available.

To meet growing demands for food, feed, fiber and fuel, plant breeders have focused on enhancing plant characteristics, for example: improving yield, flavor, quality and nutrition; and developing varieties that are resilient to changing climate, and environmental stress (e.g. water scarcity), pests and disease. In the upcoming century, production challenges are expected to worsen. According to the Food and Agriculture Organization of the United Nations (FAO), 828 million people (or 10 percent of the world's population) go to bed hungry each night (FAO, 2022). Addressing these and other unforeseen challenges will require an enabling, harmonized global policy environment and sustained agricultural investment with continued innovation in plant breeding.

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Crop improvement is driven by advancing plant breeding methods

Plant breeding's pivotal role in advancing agriculture over the past century evolved from connecting the power of genetics and understanding hybridization to use of advanced biotechnological and precision plant breeding methods. Since the 1850's, when Gregor Mendel (known as the "father of modern genetics") first studied genetic variation and heredity of plant characteristics, a range of plant breeding methods have been developed and adopted. This has improved the quality and reduced the cost of food for consumers, by making the plant breeding process more efficient, cost-effective, and predictable. Advancements have allowed plant breeders to access the genetic diversity of related species, through a range of methods that have allowed for wider crosses.

More recently, plant breeding methods like genetic modification and genome editing, in conjunction with advanced selection tools such as marker-assisted and genomic selection, together with high-throughput screening, have complemented the development of new plant varieties with desired characteristics. In the hands of farmers, these improved varieties have facilitated the adoption of production practices that support soil health and decrease input resources; enabling farmers to produce more with less. While more people than ever now have access to safe, nutritious, and affordable food, there are still millions of people suffering from hunger.

Each advancement in plant breeding innovation has not occurred in isolation; rather, they have evolved in a complementary manner. Today, plant breeders utilize a combination of methods when developing a new plant variety. The methods highlighted below are invaluable in modern plant breeding programs and will continue to be used and optimized further.

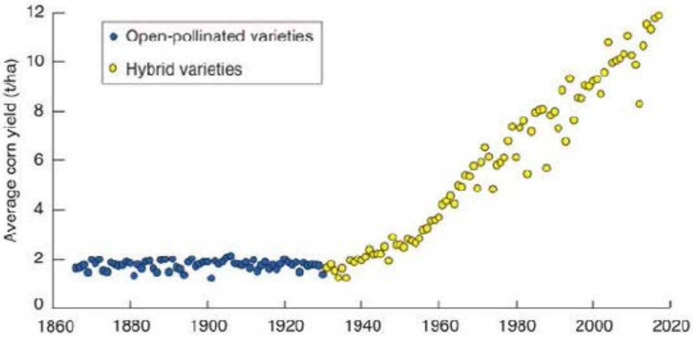
Transformative Plant Breeding Methods of the last 100 Years

HYBRIDIZATION

In the early 20th century, plant breeders began using hybridization methods to develop cultivars with improved characteristics. By crossing diverse germplasm within the same plant species, hybrids exhibit superior qualities and vigor, such as higher and more stable crop yields, disease resistance, and improved nutritional profiles. This breakthrough method laid the foundation for subsequent advancements and enhanced farmers' choice for superior seed varieties each season.

HYBRID CORN DRAMATICALLY INCREASES PRODUCTIVITY

Farmers in the US primarily cultivated "open-pollinated" corn varieties until the 1930s after which they rapidly transitioned to planting hybrid corn. In 1935, only 1 percent of the corn crop was seeded with hybrids, but by 1940 the total was over 30 percent. By 1960, hybrid seed accounted for 96 percent of corn acres [(NASS USDA, 2018)](). According to the [Corn Farmers Coalition](): "Farmers today produce five times as much corn as they did in the 1930s – on 20 percent less land. That is 13 million acres (5.3 million hectares). The yield per acre has skyrocketed by a six-fold gain from 1.6 to 10.4 tons/ha."



Average grain yield in tons per hectare for corn varieties in the United States. Yield of Open-pollinated varieties (blue) from 1866 to 1930 and hybrid varieties (yellow) from 1931 to 2017. Data Source: United States Department of Agriculture. National Agricultural Statistics Service, 2018. (www.nass.usda.gov)

MUTATION BREEDING

Starting in the 1940s, plant scientists began utilizing radiation or chemicals to induce mutations and enhance the level of genetic variation in plants. These methods increased genetic variation from 1000 to 1 million-fold over the background mutation rate. The resulting mutagenized plants are then screened to identify plants with the desired improved characteristics. Mutation breeding accelerated the development of unique plant varieties and has resulted in more than 3,200 new commercial varieties.

Midribs of brown midrib (left) and conventional (right) forage sorghum leaves. Data Source: Marsalis Mark., 2011 – University of New Mexico.

FEED QUALITY OF FORAGE SORGHUM IMPROVED VIA MUTAGENESIS

Sorghum is a relatively drought-tolerant grain and forage crop grown in many countries around the world. Sorghum can be grown to produce forage used as animal feed or as bioenergy feedstock. Starting in the late 1970s, plant breeders have been improving the feed quality of sorghum forage by first identifying and then incorporating a number of chemically induced mutations that reduce lignin production (Porter et al., 1978). These mutations, resulting in hybrid lines with a "brown midrib" or BMR phenotype, make the sorghum forage more digestible to ruminant animals and thus have increased relative feed value over non-BMR sorghum.

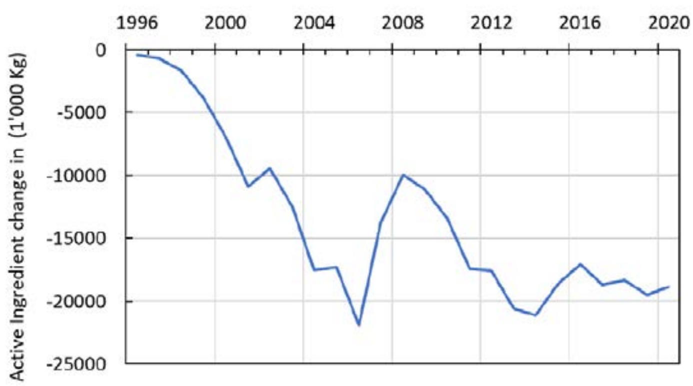
GENETIC MODIFICATION

By the 1980s, the use of new genetic modification methods enabled the insertion of specific desirable genes into plants, providing plant breeders with new levels of precision over the introduction of desired characteristics beyond hybridization and mutation breeding. Genetically modified crops have since been developed with attributes like improved composition, herbicide tolerance, insect resistance, and improved tolerance to stress conditions. While these genetically modified crops have significantly enhanced the productivity, safety (through a reduction in grain mycotoxin contamination) and sustainability of agricultural cropping systems, their use has been mostly limited to major row crops. Unlike crops developed using other plant breeding methods, genetically modified crops are subject to additional specific regulatory oversight in most countries.

GENETICALLY MODIFIED INSECT-RESISTANT COTTON REDUCES PESTICIDE USE

The introduction of insect-resistant cotton developed using genetic modification, in the mid-1990s was credited with a significant reduction in the use of insecticides to control caterpillar pests. Between 1996 and 2020, "the technology has been responsible for a 339 million kg reduction in use of insecticide active ingredient on cotton crops around the world, equal to about a 30% reduction in total insecticide usage (by volume)" (Brookes, 2022)

Reduction in insecticide Active ingredient



Insecticide use in cotton declined in most years following genetically modified insect-resistant cotton adoption in nine major cotton growing markets. Data source: Brookes, 2022.

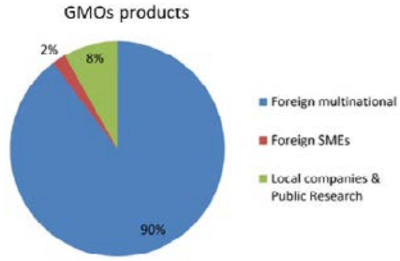
GENOME EDITING

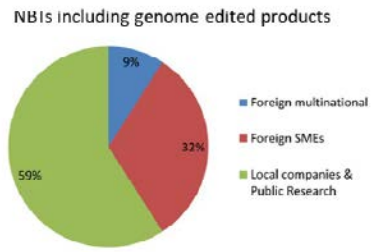
The past decade has witnessed the evolution of genome editing as a method for precise and targeted changes to the plant's genome. This method allows plant breeders more precision and control over the modification of desirable characteristics and can unlock genetic variability that was previously inaccessible. The adoption of genome editing as part of the plant breeding process can lead to accelerated development of desired characteristics. As more countries formalize policies that view certain genome edited plants outside the GMO regulatory scope, genome editing is now being used by small to large, and public enterprises in wide range of different plant species. The ISF has consistently advocated that plant varieties developed through the latest plant breeding methods, such as genome editing, should not be regulated differently if they are similar to varieties that could have been produced through earlier plant breeding methods.

GENOME EDITING HELPS DIVERSIFICATION OF DEVELOPERS AND CHARACTERISTICS PROFILES

The studies by Whelan and colleagues (2020; 2022) showed that since implementing a review process to confirm the non-GMO status of genome edited organisms, the development of products using new breeding techniques (NBTs) including genome editing methods, as compared to genetically modified products, is driven by a more diverse group of developers and led mostly by small and medium enterprises (SMEs) and public research institutions.

Developer Profiles





Comparative analysis of products (including at design stage) of new breeding techniques (NBTs), including genome editing versus genetically modified organisms (GMOs) reviewed through the Argentine regulatory system. Data source: Whelan et al., 2020.

Advances in Plant Selection Methods

Plant breeders are always looking for the proverbial 'needle in a haystack'. In the 1990s, marker assisted selection (MAS) accelerated the plant breeding process by allowing more efficient identification of desirable genetic combinations, resulting in the development of superior plant varieties. Through genetic markers, plant breeders can identify and select for desired characteristics, such as disease resistance or quality attributes, without having to physically observe them.

In recent years, advancements in DNA sequencing and bioinformatics have fueled the use of genomic selection as a plant breeding tool. By sequencing and analyzing the entire genome of a plant, plant breeders can make predictions about the performance of characteristics in a specific environment and select plants with the highest genetic potential for trials. This data-driven approach speeds up the plant breeding process by enabling the targeted development of crops with optimized characteristics for specific regions and growing conditions.

Past, Present and Future of Plant Breeding Innovations

The past century has realized remarkable strides in plant breeding innovation, revolutionizing agriculture, and advancing global food security. Plant breeders are the cornerstone of a more resilient and productive agricultural sector.

In modern plant breeding, advancements in genetic technologies and precision breeding methods have dynamized the field. Today, plant breeders leverage cutting-edge tools to enhance plant characteristics, creating varieties that are more resilient, productive, and adaptable to evolving environmental challenges. The intersection of conventional plant breeding programs with innovative genetic methods holds great promise for addressing global food security and sustainability challenges.

Through time, plant breeders continue to be conservators of genetic diversity, and catalysts in translating this diversity to improve plant varieties. As we embark on the next century of plant breeding, the continued collaboration between scientists, plant breeders, farmers, policy makers and consumers will be pivotal in addressing the challenges of an ever-changing world and ensuring a more sustainable future for generations to come. The ISF stands together with all plant breeders, current and future, to build on this incredible legacy of innovation over the next century and beyond.

Plant breeding existed long before 1924,
the year our organization started its work.
The journey of plant breeding continues, and the ISF
will continue to be a part of it.

A Call to Action

Plant breeders have a long and consistent track record, relying on science, creativity, and new methods to develop plant varieties that are more productive, hardier, and more nutritious. For plant breeders to continue to keep pace with a changing world to bring solutions to farmers and consumers, national and global agricultural policies must facilitate the use of future plant breeding innovation and ensure farmers' access to quality seeds.

The International Seed Federation calls on governments to adopt harmonized global policies on plant breeding innovation, to enable and embrace sustained investment in agricultural research, and to develop the agricultural workforce. It is critical that regulations applicable to plant breeding innovation are risk proportionate, science-based, and adaptable to reflect evolving scientific knowledge as well as the application of that knowledge.

Future-proof regulatory policies will motivate continued advancements in plant breeding so that breeders can successfully integrate innovation into their plant breeding programs and deliver the best plant varieties to farmers and society at large; ultimately, contributing to the fulfillment of the United Nations Sustainable Development Goals.

"Nature is the world's best inventor,
and so we're finding ways to use what nature has discovered
and turn it into a technology"

Jennifer Doudna, Nobel Laureate 2020