DEVELOPING A SUPERIOR MAIZE HYBRID

PIONEER HI-BRED INTERNATIONAL, INC.

A HISTORY OF INNOVATION

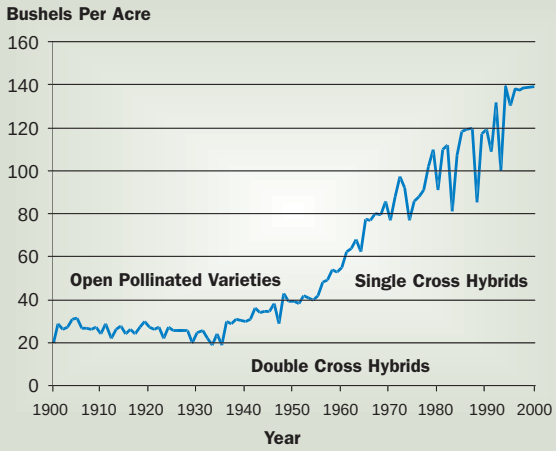
When commercial hybrid maize was first introduced, few people realized its potential to increase the world's agricultural productivity. Hybrid maize breeding originated in 1909, primarily through the innovative research of Dr. G.H. Shull, a scientist at the Carnegie Institute in Washington, D.C. A few years later, a young central Iowan named Henry A. Wallace studied the work of Shull and others, and began his own experiments. In 1926, Wallace's backyard maize breeding experiments led to the birth of the Hi-Bred Corn Company, the first company to develop, produce and market hybrid maize. The company eventually became known as Pioneer Hi-Bred International, Inc. Now a DuPont subsidiary, Pioneer is the world's leading developer and supplier of advanced plant genetics to farmers worldwide.

The very phenomenon that captured Henry Wallace's attention is what makes hybrid maize valuable to growers today. Hybrid maize development improves farmers' productivity and helps ensure a reliable, sustainable food supply. Pioneer researchers have been making innovative breakthroughs in hybrid maize improvement throughout the company's history.

Trends for maize yields in much of the U.S. Corn Belt show yield increases of 1.5 to 2 bushels per acre, per year since the 1950s. Much of the increase can be attributed to improved genetics through innovative plant breeding, and Pioneer researchers have played a key role in this progress.

During the 75-year history of the company, researchers at Pioneer have developed the largest, most diverse and highest quality collection of maize ermplasm, or corn genetics, in the industry. Pioneer researchers also were the first in the industry to apply genomics to crop improvement. Genomics is a science that helps researchers better understand the function of maize genes.

U.S. Average Maize Yields 1900 - 2000



Yield trends in the United States have steadily increased since hybrids were first commercialized.

WHY HYBRID MAIZE?

Hybrid maize generates high yields, increased value and reduced production costs. The plants are bigger, stronger and more vigorous. This hybrid vigor, or heterosis, occurs when crossing two genetically unrelated inbred parents to create a hybrid.

Plants grown from hybrid seed are bigger, stronger and more vigorous than either of the parent plants. This hybrid vigor contributes greatly to the high productivity of today's maize growers.

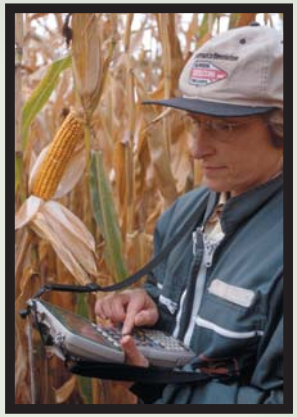
INDUSTRY-LEADING RESEARCH

At Pioneer, innovative research begins with listening to the customer. Maize growers, processors, livestock producers and commodity grain users identify specific qualities they want in a hybrid. In addition to this input, researchers rely on several other sources for information, including sales and marketing staffs, marketing surveys, university researchers, and industry and government data.

It is clear from all this information that customer needs vary greatly from one region to another, from one farmer to another, and from one field to the next. However, the one thing that is consistent around the world is the expectation that products yield in the customers' environments. This means yield in a variety of measures. While researchers once pursued yield only in terms of bushels per acre, today yield means much more. It means farmer profitability per acre. It means pounds of pork, beef or poultry produced per acre. It means pounds of extractable starch, amino acids or oil harvested per acre. Researchers at Pioneer concentrate on a vast array of input traits, such as stalk or root strength, and output traits, such as feed and food attributes, to help maximize customer productivity and profitability.

The strengths that Pioneer has in plant genetics and information technology, as well as its worldwide research network, play vital roles in meeting customer needs. This network makes it possible for local researchers familiar with area practices and conditions to share crop performance data quickly and reliably. To aid in this effort, hand-held computers are used in field trials. In addition, Pioneer has worked with experts to design combines that capture trait data during harvest. This helps researchers collect and share information around the world. Wide-area testing practices and computational biology help Pioneer offer its customers products with superior performance stability backed by multiple years of data.

A Pioneer sales professional checks in with a customer at harvest time in Brazil.



Researcher Maryse Lafouasse uses a hand-held computer to record data in the field.

Lisa Howland looks through the germplasm library at a maize research center.

Pioneer possesses superior germplasm – the collection of maize genes used to develop hybrids – which provides an incredible resource for researchers doing work in such areas as gene discovery for the improvement of specific traits, and molecular breeding. Understanding a plant's genetics is important for customers, because a single gene can have a significant impact on product performance. It is the combination of many genes that ultimately determines how a hybrid will perform in a farmer's field.

RESEARCH BY THE NUMBERS

In many ways, Pioneer research sets the pace for the industry. Each year, about 10-15 percent of Pioneer® brand seed products are new, which means customers are always offered improved crop genetics. This progress is the direct result of a significant investment in research. The following numbers demonstrate our commitment to genetic improvement:

- 120 research locations in 30 countries
- More than 1,300 research employees
- More than 3 million breeding/selection plots
- More than 11,000 research trials and on-farm strip tests for product evaluation and characterization
- More than 1,400 collaborations with external researchers
- More than 2,500 patents granted worldwide

PRODUCT DEVELOPMENT PROGRESS THROUGH BIOTECHNOLOGY

The science of biotechnology provides researchers with new tools to better understand plants and develop better hybrids. A deeper understanding of a plant's genetic structure is vitally important because understanding how plants work can help us address issues facing the human race. Genes are made of sections of DNA in which the chemical bases are arranged in a specific order or sequence. The sequence provides the instructions for a leaf to be a leaf, or a plant to resist a particular disease.

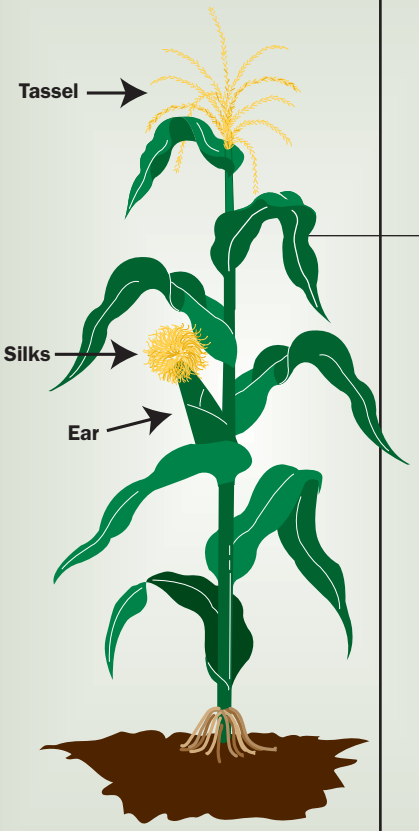
Researcher Richard McCardell examines grain.

One biotechnology tool, transformation, gives scientists the ability to improve products in ways not possible through conventional breeding. If genes for a valuable trait are available from other sources, researchers are able to integrate those genes into the maize germplasm, and thus offer improved products. An example is maize with improved resistance to insects. *Bacillus thuringiensis* (Bt) is a naturally occurring soil bacterium containing a gene that gives protection against certain insects. Researchers have been able to insert this Bt gene into the maize germplasm and create hybrids with the added trait of resistance to European corn borer and other pests. As with all Pioneer® brand products, hybrids developed through transformation are thoroughly tested and approved by appropriate regulatory agencies that determine their effectiveness and safety.

Genomics also is an important biotechnology tool. Genomics is the study of the genetic material in a chromosome set. The information gathered through genomic tools, when used in conjunction with other technologies, helps researchers better understand which genes determine important traits, and how genes work together.

Another biotechnology tool is a molecular marker. A molecular marker is a piece of DNA that is closely associated with a gene (or genes) responsible for a certain trait. Molecular markers help identify traits like maturity or height along the DNA trail. Using molecular markers, Pioneer researchers can better predict which plants have beneficial traits. This saves time because the first selection is made in the lab even before field trials begin. As a result, breeders begin field trials with an improved pool of candidate hybrids that are more likely to succeed in customers' fields.

Biotechnology tools have led to the development of maize with improved disease resistance, improved grain qualities and other traits beneficial to producers and consumers. These tools also have helped researchers develop tomatoes with greater amounts of cancer-fighting antioxidants, and identify a plant gene that could keep fruits and vegetables fresher longer.



THE ANATOMY OF A MAIZE PLANT AND DEVELOPMENT OF A HYBRID

A mature maize plant has three visible reproductive system components:
- the tassel at the top of the plant,
- the ear containing the embryo, and
- the silks on the top of the ear.

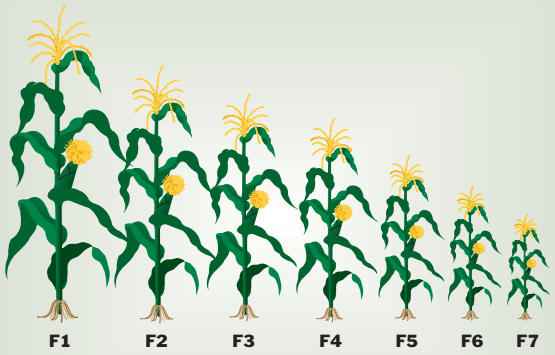
A maize plant has both male and female reproductive components. It can fertilize itself and nearby maize plants.

The tassels, the male part, produce the pollen needed to produce seed. Ears, the female part, have silks. Pollen travels along the silks to fertilize seed embryos on the ear. Under ideal growing conditions, each fertilized embryo will produce a new seed. There is one silk for each embryo on the ear. When the pollen from a maize plant fertilizes its own ear, the plant is referred to as being self-pollinated.

An inbred is a plant that possesses only the traits of the self-pollinated plant. Developing inbreds, the parents of hybrids, which exhibit desirable characteristics, is the researcher's first step of field breeding.

Proper selection of inbreds for parent lines is critical to developing consistent, top-performing products. Development of new inbreds involves crossing elite inbreds, self-pollinating the progeny and studying several generations of the plant. During early parent line development, each plant possesses different combinations of genes, resulting in various combinations of traits that respond differently to environmental stresses. At this point, the inbreds sort themselves into unique patterns as the offspring plants segregate from the parent lines. During the phases of inbred line development, researchers select the seed from the best plants in the best rows, and plant those seeds for the next generation of testing. At Pioneer, this happens around the globe as researchers evaluate multiple generations of inbreds, using computer networks and other technologies to help them select the best-performing plants. This development phase takes about five generations.

Once they have identified excellent inbreds for parents, scientists begin the second major challenge of hybrid development – identifying combinations of parent lines that produce the highest-yielding hybrids. To create hybrids for testing, unrelated parents are crossed to produce experimental hybrids and their performance is tested year after year.



Breeders evaluate the characteristics of large numbers of inbreds each year. Seeds from plants with the best combination of specific traits are saved for further development.

TESTING, TESTING, TESTING

Pioneer has a strong commitment to thorough testing, which begins at the product concept stage and carries through to product commercialization. Pioneer scientists worldwide begin with roughly 130,000 new experimental hybrids each year. To determine which of these new hybrids will perform most consistently in various conditions, researchers use a rigorous Wide Area Testing program.

Between the fifth and 10th generations of product development, experimental hybrids go through a series of increasingly extensive yield tests. One might think of this program as the way a student progresses through college. The experimental hybrids enter as "freshmen." In this case, only the top 10 percent from the first season of testing are advanced to make up the "sophomore" class.

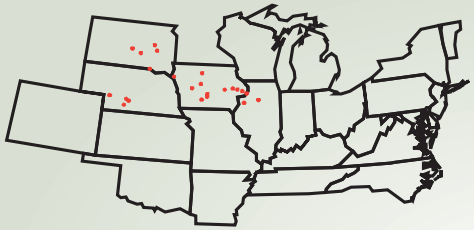
During the next two years (the sophomore and junior years), hybrids are tested at more and more locations and are challenged with a range of soil types, climate conditions and other pressures, such as insects and disease. At each stage of testing, researchers look for high and stable yields, standability, tolerance to stresses and other traits important to our customers. Only the hybrids that meet strict standards are advanced to the next class until graduation to a commercial product.

More than 100 experimental hybrids advance to the "senior" level, but only about 15 to 20 hybrids "graduate" and are commercialized. By the time a Pioneer® brand hybrid is offered for sale, it has been tested at more than 1,500 locations and in more than 200 customer fields. This thorough testing system helps develop leading-edge genetics with a total package of traits that customers require.

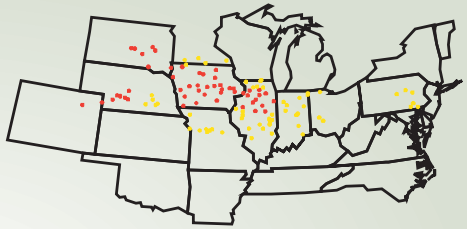
MANY SEASONS, MANY LOCATIONS

Researchers at Pioneer use a unique system of testing hybrids in a wide variety of environments worldwide. These graphs are typical of the way a hybrid is tested before commercialization.

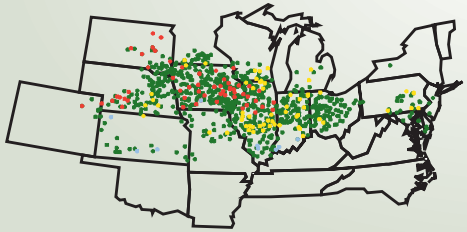
Year 1. 23 Unique Locations



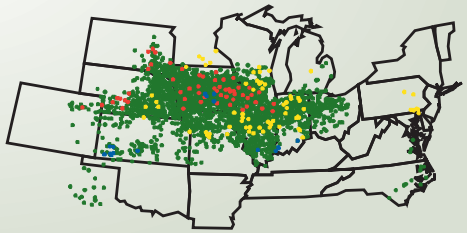
Year 2. 118 Unique Locations, Including Italy



Year 3. 140 Unique Locations, Including Greece, Italy, Portugal and Spain



Year 4. 1,470 Unique Locations, Including Australia, Greece, Italy, Spain and Turkey



Plant breeding is, in part, a numbers game: The more genetic combinations that are tested, the greater the odds of developing improved products faster. Researchers can maximize genetic progress throughout the development process by making breeding selections based on *genotype*, the combination of genes that make up a hybrid, and *phenotype*, the observed measurement of those genes in a given environment.

To advance new products to customers more quickly, researchers use specialized equipment to plant, harvest and evaluate more test rows at once. Also, Pioneer uses a global network of off-season nurseries to shave years off the product development process. These facilities are in warm climates where multiple generations of maize can be grown and evaluated each year. This helps get new, high performing, thoroughly tested products into customers' hands faster.

Furthermore, since product performance varies in different environments, researchers also are working with technologies to help them better predict product performance in various environments. These technologies, combined with superior genetics, will aid researchers in "custom-building" hybrids for customers' environments.

DELIVERING BETTER PRODUCTS

Creating new and improved products is a continual process at Pioneer, where researchers are devoted to the following efforts to help customers:

Herbicide Resistance – Researchers are working on projects based on effectiveness, compatibility, flexibility, crop safety, environmental safety and price. Herbicide-resistant hybrids offer farmers environmentally friendly options for weed control.

Insect Resistance – Work in this area is focused on developing hybrids with increased protection against European corn borer, corn rootworm, armyworm and earworm.

Disease Resistance – Pioneer researchers have developed hybrids with enhanced resistance to diseases such as gray leaf spot, and are working to reduce damage from other diseases.

Drought Tolerance – Researchers are working on hybrids with greater ability to withstand drought conditions. This will be particularly important as stress on the world's water resources continues to increase.

Quality Traits – Research efforts concentrate on characteristics such as whole plant digestibility for livestock production, energy content and others. Along with testing maize hybrid characteristics, researchers also gauge animal production performance. Because most of the grain grown is fed to livestock, Pioneer researchers are investing a great deal of effort to make our seed produce better feed for animal consumption.

Maize for Human Consumption – Researchers are developing yellow and white maize hybrids for human consumption to meet the growing demand in South Africa, Mexico and the United States. Pioneer® brand products have captured roughly 80 percent of the North American market share for white maize hybrids, and 50-60 percent of the North American yellow dent maize market for human consumption.

LIVING WALLACE'S VISION

Henry Wallace was so certain of the value of hybrid maize in 1926 that he began to envision how hybrids could be efficiently developed and produced. That vision led to Pioneer Hi-Bred International, Inc., the world's first commercial business with the sole purpose to develop, produce and sell hybrid maize. Today, Pioneer researchers are building on the progress made in maize hybrid development to create better soybean, canola, sunflower, sorghum, pearl millet, rice, wheat and alfalfa products for customers around the world.

Through continual research advances and crop improvements, Pioneer will continue to live Wallace's vision and build better products for customers everywhere.

A Hybrid Maize Story

Chapter 1:
Growers in central Illinois are in the heart of the U.S. Corn Belt. They need a high-yielding hybrid that performs well in moderate temperatures and on non-irrigated land. They also need hybrids with insect tolerance and strong roots. With those needs in mind, Pioneer researchers begin the hybrid development process. The first step is to develop inbreds and evaluate them for characteristics sought by customers.

Chapter 2:
The researchers at the Illinois research center spot a promising inbred. Because it consistently delivers high yield, it is identified as a potential female parent. The researchers begin using this female to develop experimental hybrids across the Pioneer global network. A hybrid exhibits traits from both parents, so researchers carefully evaluate the experimental hybrids to see which has the best combination of traits. But, the story doesn't end here.

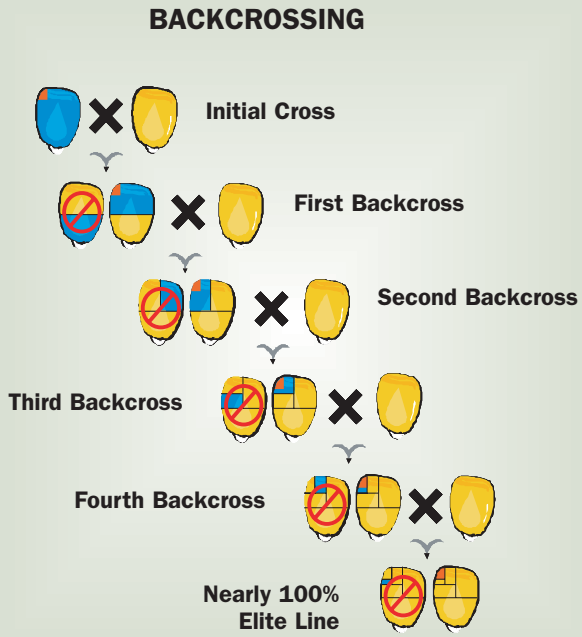
Chapter 3:
Researchers at a station in central Nebraska have their eyes on another high-performing inbred. Nebraska is on the western edge of the U.S. Corn Belt, and is generally a dryer environment than environments like central Illinois. Therefore, growers need hybrids with tolerance to heat and drought. The inbred selected at Nebraska has consistently performed at the top of each generation. Because it sheds large quantities of pollen during an extended period of time, it is identified as a male inbred.

Chapter 4:
The crucial point in the story: the inbreds from Illinois and Nebraska are crossed, and researchers immediately take notice. The experimental hybrid is high yielding and has a stable package of agronomic traits. It is advanced to the next round of testing. This is no small feat, because every year thousands of new experimental hybrids are tested, and only the very best are eventually commercialized as Pioneer® brand hybrids.

Researcher Shifu Zhen examines plants in the greenhouses.

Chapter 5:

Researchers are working on the added option of insect resistance for the new product. To accomplish this, a gene that produces the resistance trait is inserted into an inbred. This "donor" inbred for the resistance trait is the female parent of the Illinois inbred. Through backcrossing, the trait is integrated into the Illinois inbred, and the converted inbred is crossed with the Nebraska male. The resulting conversion has the same qualities as the first experimental, with the added trait of resistance to European corn borer and other insects. Once the conversion is made, researchers focus on the quality of the conversions, ensuring that the resistance trait is reliably expressed and all the desirable traits of the elite parent are also expressed. Researchers perform extensive field testing to ensure that the only performance difference between the two products is the added trait.



Chapter 6:
During the third year of hybrid testing, the parent seed team begins producing larger quantities of both the male and female seed to ensure that enough seed is available for commercial testing.

Chapter 7:
In each year of testing, the experimental hybrids are tested at more unique locations. In the final year of testing, more than 300 locations are used, including several locations in southern Europe. After years of thorough testing and appropriate regulatory approvals, both products are commercialized. The two parent lines are produced, conditioned and stored to meet the anticipated demand.

A Parent Seed worker walks through a detasseled field. The tassels are left on the male plants only. They produce the pollen needed to fertilize the ear silks of the female, or detasseled, plants in the field.

Chapter 8:
The two hybrids are commercialized as 33P66 and 33P67 – the latter is the conversion with added insect resistance. Once the new hybrids are sold, the seed is shipped to Pioneer sales representatives and distributors, who deliver it to customers.

In the first year of commercialization, both products have high yields in customer fields. They placed in the top level in U.S. National Corn Growers Association (NCGA) yield trials in Iowa, Missouri and Illinois. Additionally, the genetics from both the western and eastern parts of the U.S. Corn Belt prove to be an advantage, as the hybrids win NCGA yield trials all across the United States. Hybrid 33P66 also is sold to growers in southern Europe.

Epilogue
This story never ends. Even as new products graduate to market, researchers continuously evaluate new products and changing conditions to incorporate new genetics and technological advances for even better products.