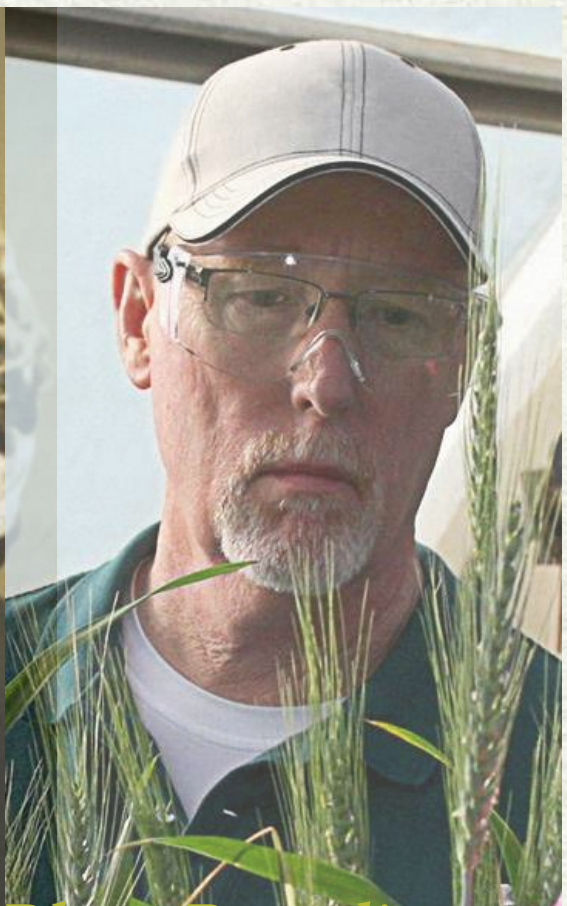


INNOVATIONS IN PLANT BREEDING



HISTORY OF *Plant Breeding*



MONSANTO



DO YOU KNOW **WHAT CROP THIS IS?**



Hint: It's one of the **most recognizable commodities in the world**. It's used in items such as toothpaste, soda pop, salad dressing and gasoline. It helps provide us with the milk we drink, the eggs we enjoy for breakfast and the hamburgers we eat at family cookouts.

So, what is this crop that makes significant contributions to not only our local communities, but also our global economy?



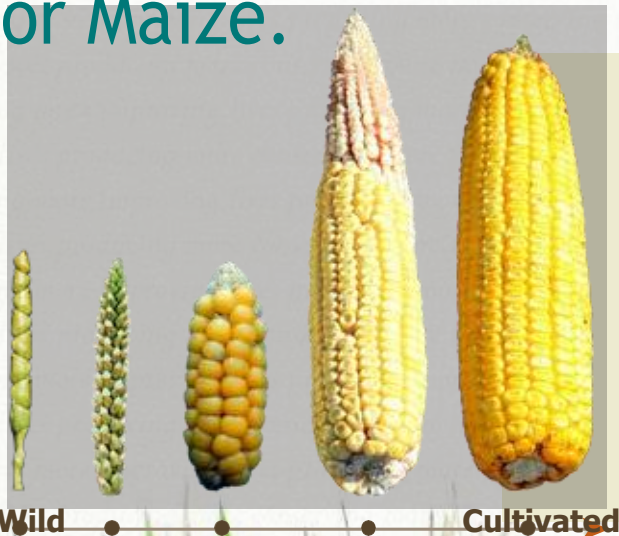
DO YOU KNOW **WHAT CROP THIS IS?**

CONTINUED



It's **Corn** or Maize.

More than 10,000 years ago, corn looked a lot different than the golden cobs we recognize today. **But, why is that?** How did wild maize evolve from a small grass to the modern-day, 800-kernels-per-ear corn hybrid? **The answer lies in the evolution of the science of plant breeding.**



Source: Doebley, John. Maize-teosinte.
Doebley Lab. Web. 11 Sept 2014.

Basic differences between **wild** plants and **cultivated** plants:

- Sustainability of production
- Rate of maturity
- Climate and regional adaptation
- Growth patterns
- Plant health

WHAT IS PLANT BREEDING?



Plant breeding is the **science, art** and **business** of improving plants for human benefit.



- **Plant Breeding as Science** - By understanding genes and heredity, scientists are able to select appropriate traits to more consistently express desired characteristics.



- **Plant Breeding as Business** - Consistency of those important characteristics can positively impact the environment, while also ensuring the availability of a safe and nutritious food supply.



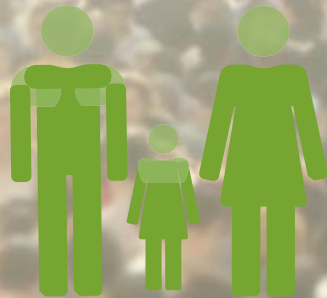
- **Plant Breeding as Art** - Breeders use their observational skills, experience, intuition and judgment to see plant differences.



WHAT IS PLANT BREEDING?

CONTINUED

At its core, plant breeding is about improving the genetic performance of plants - like corn, soybeans, wheat and other crops - to help make **peoples' lives better here** - and **better around the world.***



The world's population is expected to grow to **9.6 billion people** over the next few decades, which means farmers will need to grow as much food in the **next 50 years** as they did in the **past 10,000 years combined.**

*<http://www.nature.com/news/genetically-modified-cotton-gets-high-marks-in-india-1.10927>

THE BASICS OF **PLANT BREEDING**



Plant breeding innovation and technology advancements are helping farmers do what they've done for thousands of years even better, **ensuring that their crop makes it from their field to your family's table.**

Plant breeding plays a major role in work to **find sustainable agriculture solutions that help farmers:**

- i. Conserve natural resources**
- ii. Use data to improve farming practices**
- iii. Use water and other important resources more efficiently**
- iv. Protect their crops from pests and disease**

“We Need to Improve Plant Characteristics, Now What?”

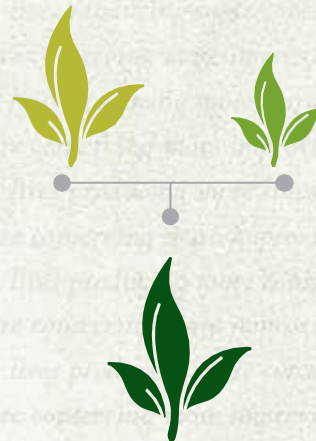
Finding that needle in the haystack, the one characteristic that can offer farmers an advantage, is incredibly difficult and time-consuming. Three steps **help scientists improve their chances:**



- **Testing** - Clear goals and objectives before a single seed is ever put into the ground.



- **Selecting** - Identify plants and the genetic markers in their DNA that are linked to the characteristics scientists would like to improve.



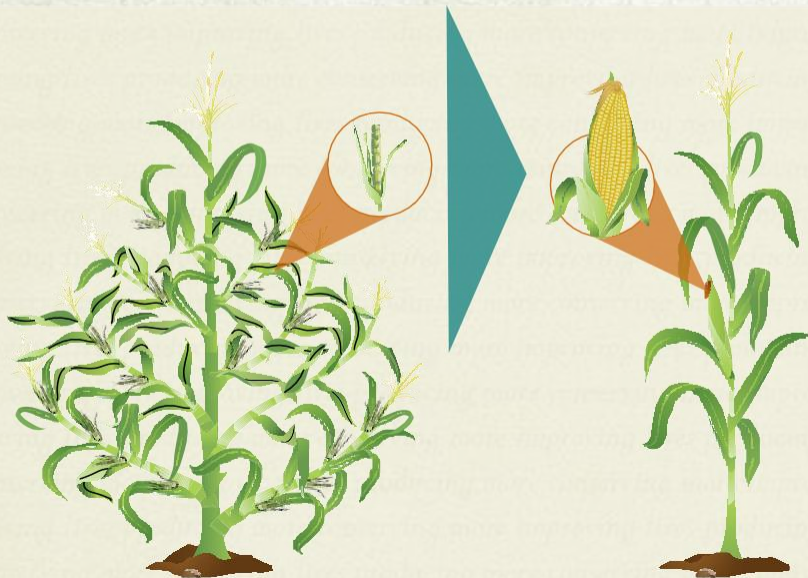
- **Crossing** - Breeders combine the best characteristics from both parents to create new varieties.

PLANT BREEDING IS ABOUT **CREATING SOLUTIONS**



Throughout the history of civilization, plant breeding innovations “were discovered” as a solution to a problem. Even indigenous farmers who worked the fields more than 10,000 years ago understood that,

in order to survive, they needed plant varieties specifically adapted to their conditions.



Hundreds of generations of selection were required to transition from wild maize to the corn we farm today.

PLANT BREEDING IS ABOUT CREATING SOLUTIONS

CONTINUED

Today's, plant breeding role in agriculture is no different. Focusing on **creating plant varieties that are better than the previous generation, with characteristics such as:**



Water-use efficiency



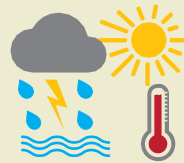
Nutrient-use efficiency



Insect and disease tolerance



Early maturity



Environmental stress tolerances



Yield potential

Modern scientific techniques make selecting for traits more **precise** and **efficient**, leading to **greater progress.**

THE IMPORTANCE OF GENETIC DIVERSITY: **SURVIVAL OF THE FITTEST**

Why can some crops survive changes to their environment, while others cannot? One reason is **genetic diversity**. Some plants better adapt to certain evolving challenges. **Plant diversity can improve the probability of survival in challenging circumstances**. Access to key characteristics through genetic diversity leads to a wider array of plant innovations.

Seen and Unseen:

Phenotype - A plant's observable or seen physical characteristics

Genotype - A plant's genetic makeup



THE HISTORY OF PLANT BREEDING: **STANDING ON THE SHOULDERS OF GIANTS**

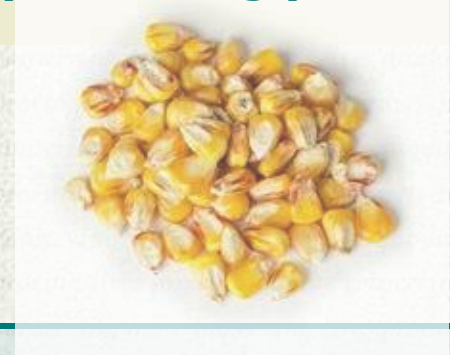


Maize Diversity, Source: Monsanto Monmouth, IL Learning Center

Through programs and partnerships, we collaborate with farmers, researchers, nonprofit organizations and universities to help tackle some of the world's biggest challenges. Today's plant breeders know this well, because they are able to make discoveries based on breeding milestones that came before them. Throughout history, certain individuals and events helped lay the **foundation for the modern principles of plant breeding.**



More than 10,000 years ago, even the earliest farmers selected seeds from their **best-performing plants.**



8000 B.C. - 5000 B.C. - Mesoamericans domesticate maize.



700 B.C. - Assyrians and Babylonians hand-pollinate palm.

Source: <http://cuke.hort.ncsu.edu/cucurbit/wehner/541/hs541hist.html>

THE HISTORY OF PLANT BREEDING: GREGOR MENDEL



<http://commons.wikimedia.org/wiki/Template:PD-US> - published in the US before 1923 and public domain in the US.

► **Gregor Mendel**, the father of modern genetics, is responsible for discovering and establishing many of the rules of **heredity**. Mendel conducted hybridization experiments with garden pea plants and discovered that specific traits are transmitted from parent to offspring through subsequent generations. To help explain his theory, Mendel used the terms “recessive” and “dominant” when referencing certain traits. **His work is the foundation of modern-day plant genetics**

1727 – Louis Leveque de Vilmorin founded the Vilmorin Breeding Institute. His work in sugar beets lays the foundation for improved size, shape and sugar content.



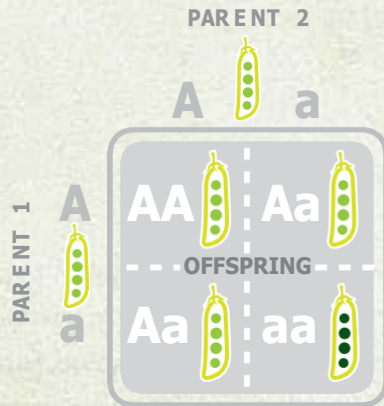
*Source: <http://cuke.hort.ncsu.edu/cucurbit/wehner/541/hs541hist.html>

1866 – Gregor Mendel demonstrates the role of invisible “factors” – now called genes.



THE HISTORY OF PLANT BREEDING: GREGOR MENDEL

CONTINUED



A **Punnett Square** is a chart that helps predict all of the possible gene combinations in a cross between parents. Gregor Mendel used this tool to **help predict the genotypes and phenotypes of the offspring of a cross**. Throughout his experimentation with pea plants, Mendel focused on characteristics: plant height, pod shape, pod color, seed shape, seed color, flower position and flower color.

If Mendel is the father of genetics, then **Charles Darwin** is the stepfather. Darwin's theory of evolution and concept of natural selection, combined with Mendel's work on heredity, became the **foundation of plant breeding and selective breeding**.

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THE HISTORY OF BREEDING: THE BEGINNINGS OF MODERN PLANT BREEDING



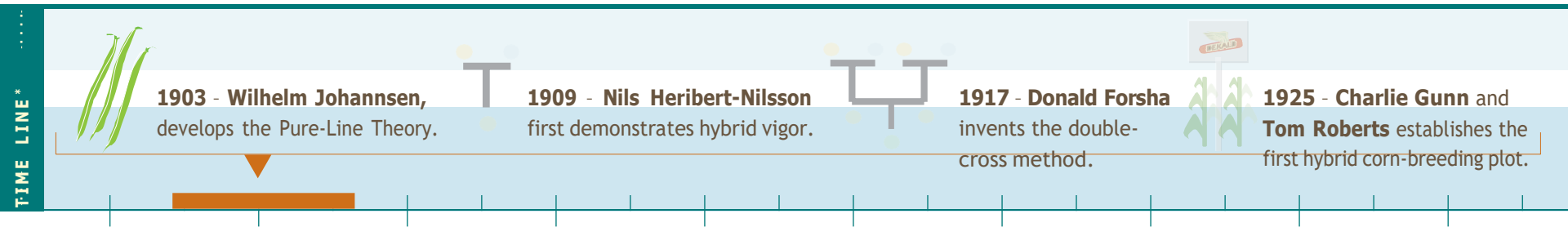
Prior to 1900, the study of genetics was still unknown. Plant breeders of this time based their selections on phenotypes, or visible plant characteristics. But that started to change. Many scientists began making landmark contributions

- whether domesticating certain crops or developing new varieties and hybrids - contributing to genetic improvement in plants.



► Wilhelm Johannsen

In 1903, using common beans, Wilhelm Johannsen **developed the Pure-Line Theory, confirming selection techniques could produce uniform cultivars, or true breeding.** He also coined the terms “genotype” and “phenotype.”



THE HISTORY OF BREEDING: THE BEGINNINGS OF MODERN PLANT BREEDING

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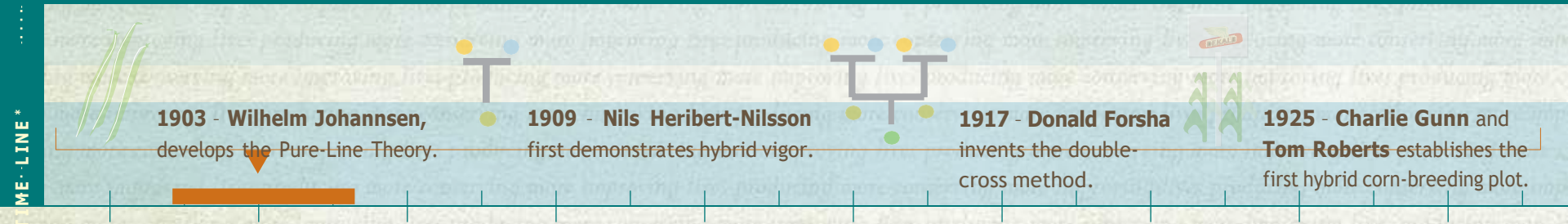


► Nils Heribert-Nilsson

In 1909, Nils Heribert-Nilsson published a paper demonstrating how **results between crosses, or hybrids, yielded plants that outperformed either parent.** This gave rise to what is known as hybrid vigor, which is the foundation of today's hybrid crop production programs.

► Donald Forsha Jones

In 1917, Donald Forsha Jones **invented the double-cross method of hybrid seed production,** which helped produce the first commercial hybrid corn in the 1920s.



*Source: <http://cuke.hort.ncsu.edu/cucurbit/wehner/541/hs541hist.html>

THE HISTORY OF BREEDING: THE BEGINNINGS OF MODERN PLANT BREEDING

CONTINUED



► Hybrid Corn Breeding Plot

In 1925, establish the first hybrid corn-breeding program. By 1933, they were developing hybridsthat were getting 35-percent yield boost.

Their research would eventually transform agriculture and the world economy.



TIME[®] magazine named hybrid corn as one of the **innovations** that most shaped our world in the **20th century**.



1903 - Wilhelm Johannsen, develops the Pure-Line Theory

1909 - Nils Heribert-Nilsson first demonstrates hybrid vigor.

1917 - Donald Forsha invents the double-cross method.



1925 - Charlie Gunn and Tom Roberts establishes the first hybrid corn-breeding plot.

*Source: <http://cuke.hort.ncsu.edu/cucurbit/wehner/541/hs541hist.html>

THE HISTORY OF PLANT BREEDING: THE GREEN REVOLUTION

► The Green Revolution: 1940s-1960s

The Green Revolution was a culmination of initiatives that lead to the increase in agricultural production worldwide, particularly in developing countries. Combining high-yielding varieties with modern agricultural production techniques - such as the expansion of irrigation infrastructure, greatly improved agricultural output throughout the world, saving billions of people from famine and starvation.



1940s-1960s

Norman Borlaug leads the Green Revolution



1953 - **James D. Watson** and **Francis Crick** discovers the structure of DNA.



1970 - **Norman Borlaug** is awarded the Nobel Peace Prize.



1983 - The first Biotech Plants are developed.

THE HISTORY OF PLANT BREEDING: **NORMAN BORLAUG**



► **Norman Borlaug**

Considered to be the **father of the Green**

Revolution, Norman Borlaug's groundbreaking research on wheat improvements helped combat world hunger. He is credited with **saving**

more than a billion lives through his introduction of high-yielding, disease-resistant wheat varieties into developing countries like Mexico, Pakistan and India. In 1970, Borlaug was awarded the Nobel Peace Prize for his contribution to world peace through increasing the food supply. In 1986, he created the World Food Prize to recognize leaders in food innovation and to promote further research.



“Food is the moral right of all who are born into this world”

--Norman Borlaug

1940s–1960s

– **Norman Borlaug** leads the Green Revolution



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THE HISTORY OF BREEDING: THE BEGINNINGS OF MODERN PLANT BREEDING

► James D. Watson and Francis Crick



In 1953, the duo discovered the structure of DNA - the double helix - which helped explain how hereditary information is coded and replicated. **This discovery was one of the most significant of the 20th century**, and has helped advance molecular biology to this day.

First Biotech Plants- plants that have a beneficial trait from nature, which are adapted to help them better survive in their environment.

1940s–1960s

– **Norman Borlaug** leads the Green Revolution



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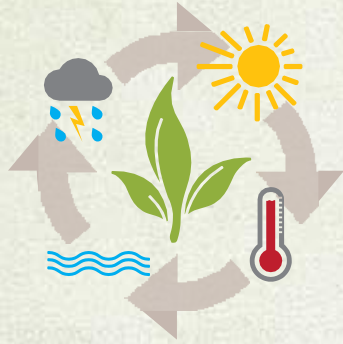
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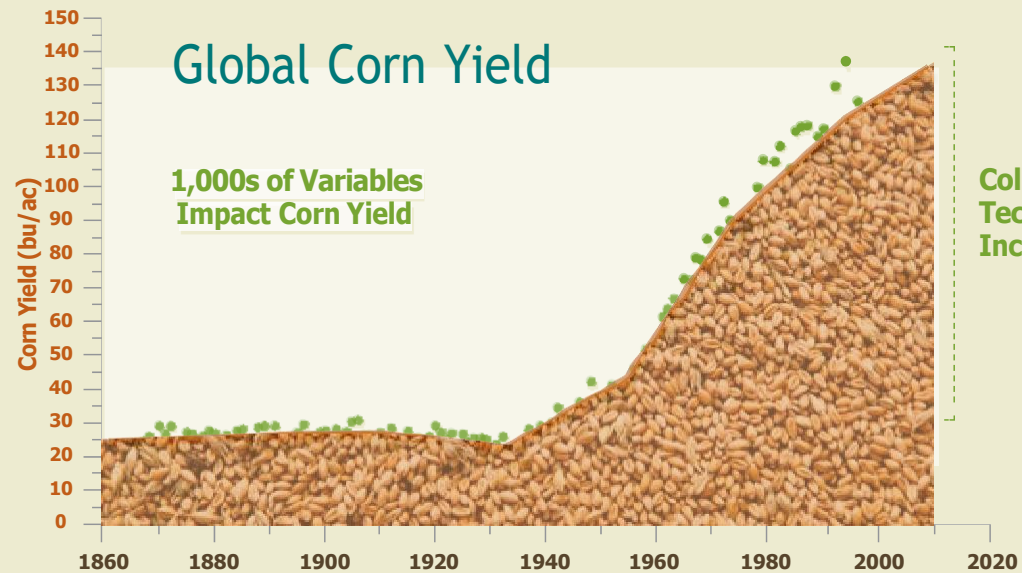
MODERN PLANT BREEDING



Today, plant breeders still rely on classic methodologies to develop top-performing products. Modern technologies help optimize the predictability of how certain plants will grow in a variety of environmental conditions. **It's this relationship between plant genotypes and the environment that will continue to drive genetic improvements for future generations.**

Breeding Works

Discoveries made by the greatest minds have contributed immensely to the improved yields we are benefiting from today.



Source: Crosbie and Lamkey, ASTA Proceedings, 1999

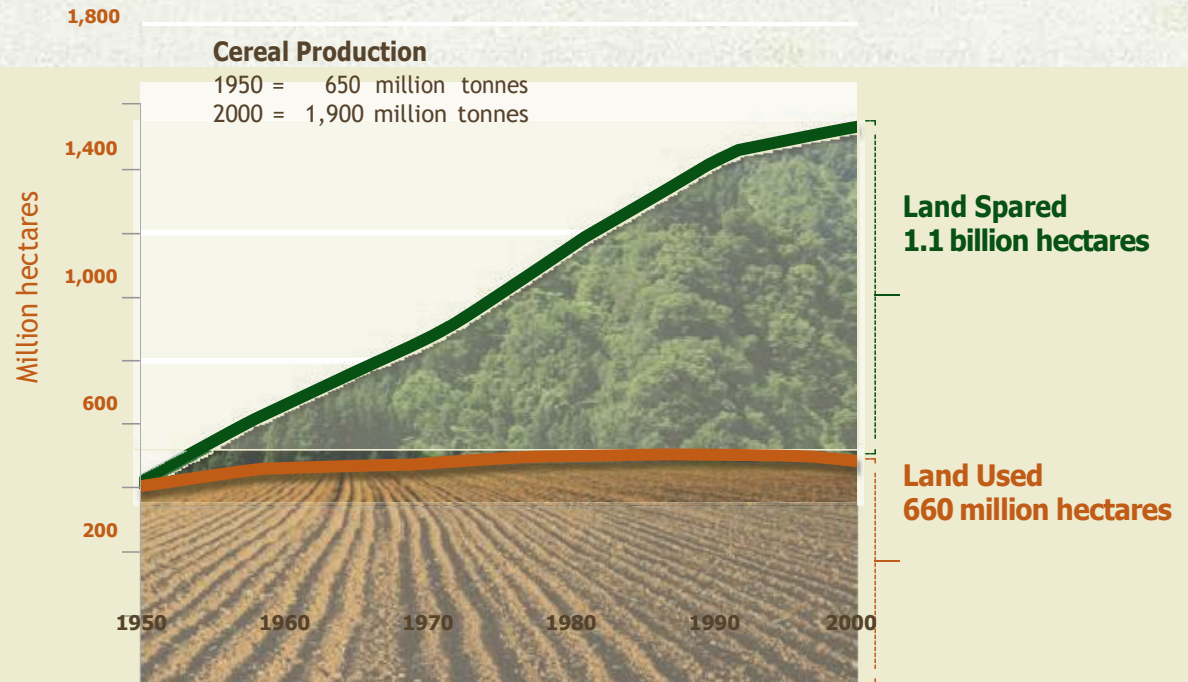


Evolving Crop Production Systems

In the future, sustainable production techniques will contribute to **more economically viable solutions.**

Land Area Saved Through Improved Technology

Plant breeding doesn't only help improve products. It also helps improve sustainability. Between 1950 and 2000, the amount of land spared has risen dramatically, as production has risen on roughly the same amount of land.



Source: FAO Production Yearbooks and AGROSTAT

MODERN PLANT BREEDING

CONTINUED



Cotton to Clothing

How Your Favorite Pair of Blue Jeans Are “Grown”



Seed company breeds seed for fiber quality and in-field performance ▶

Farmer plants seed and grows cotton ▶

Farmer harvests cotton, which is transported to the gin ▶



Cotton gin processes the cotton ▶

Clean, processed cotton is sent to a mill ▶

Mill creates fabric ▶

Manufacturer buys fabric and creates jeans ▶

Jeans are shipped to stores ▶

You kick back in your favorite pair of blue jeans

MODERN PLANT BREEDING

CONTINUED

Soybeans Are Healthy for People – And the Economy

Soybeans do more than just help lower cholesterol levels and improve hearthealth.

They are also making gains in areas that affect us on a daily basis.



- 82,368 crayons can be produced from one acre of soybeans. Source: FarmFlavor.com
- Soy ink is used to print newspapers and textbooks. Source: FarmFlavor.com
- Candles, hand sanitizers, lipstick, chocolate and soap are made with soybeans. Source: growingon.com
- The elevator system in the Statue of Liberty uses soybean-based hydraulic fluid. Source: AmericasFarmers.com
- Soybeans are used in plastics, wood adhesives and textiles. Source: tnsoybeanfestival.com
- Soybean oil provides an environmentally friendly fuel for diesel engines. Source: tnsoybeanfestival.com



HOW WILL FUTURE GENERATIONS **ADAPT CROPS TO MEET THEIR NEEDS?**



We don't know what the next 10,000 years have in store. But we do know one thing: **There are still plenty of advancements to be made.** Innovations in plant breeding remain at the forefront of our effort to provide better seed products that help **feed, fuel and clothe the world.**



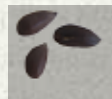
Corn

A popular ingredient in food, corn is also used to create valuable fuel alternatives.



Soybeans

Providing more than healthy oil options, soybeans are also used to create soy-based inks.



Cotton

A natural fiber, used to create fabric. Cotton seed can be used as cooking oil and a biodiesel fuel.



Wheat

A staple food used to make flour, bread and cereal, but today, wheat is also contributing to biofuel.



Plant Breeding