



The miracles of science

**Food, Feed, Fuel and Fiber:
Meeting the Challenge for Increased Grain Production**

**Pioneer Hi-Bred International, Inc.
January 2007**

Food, Feed, Fuel and Fiber

Meeting the Challenge for Increased Grain Production

Summary

- Crop yields have kept pace with rapidly expanding global population and production demands during the past half century as a result of genetic research, new technologies and improved farming practices.
- Advanced plant breeding, biotechnology and other innovations hold potential to continue the impressive productivity gains that farmers have demonstrated by delivering more bushels per acres with reduced water and fertilizer resources per unit of production.
- Improvements in technology and breeding hold promise to improve grain quality as well as quantity. By producing wholesome, disease-resistant grain, farmers experience reduced levels of grain damage and waste in the harvesting, handling, transportation and storage processes used in modern grain production.
- A critical component of continued yield increases is to maximize the productivity of each acre (i.e. choosing products and practices to match varying soil conditions within individual fields.)
- High quality grain, when combined with new, more efficient biofuels production technologies can maximize the energy output per acre and provide valuable feed co products to support a healthy livestock industry.

Introduction

With every generation, the world's demand for food, feed, fuel and fiber changes and grows. Increasing populations, evolving diets, and most recently, soaring demand for biofuel production, have posed challenges to farmers to increase grain production. With each challenge, U.S. agriculture has risen to meet the demand.

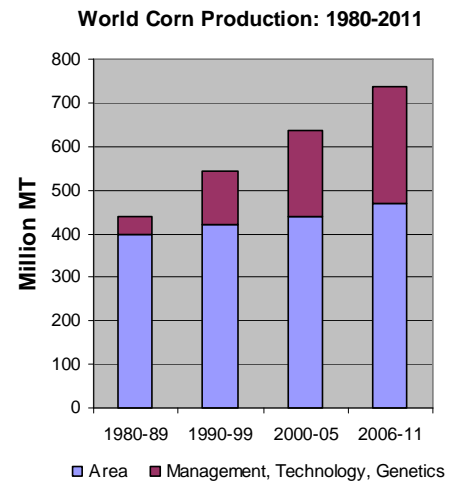
Eighty years ago, the development of hybrid corn sparked an agricultural revolution helping us to more efficiently produce quality food and feed for our country and the world. We are on the leading edge of a similar revolution that is challenging farmers to also deliver a stable, sustainable fuel supply through ethanol, biodiesel and other biofuel production.

Global population has more than doubled since 1945 to reach 6.5 billion today, and one billion inhabitants are added every 12 to 15 years¹. In addition, incomes are improving in the developing world, which is expected to increase demand in those countries for grain-fed meat. At the same time, developed countries have increased interest in using crops to produce biofuels such as ethanol, biobutanol and soy diesel to offset demand for costly petroleum-based fuels. This increased demand comes while land available for agriculture is being lost to urban expansion. If agriculture is to meet this growing demand, it is essential that producers increase yields on currently available acreage. This too, will prevent marginal or protected land from being placed into production.

In the last half century, agriculture has kept pace with growing population. For example, in 1945, the average corn yield in the United States was about 33 bushels per acre. Today, the average U.S. yield is about 150 bushels, but many farmers have achieved yields much higher, even up to a record of 440 bushels per acre². This demonstrates that available land can be much more productive with innovative management techniques and superior hybrids.

Globally, there were 329 million corn acres in 1981. Today, 361 million acres are harvested worldwide, a mere 9.8 percent increase. However, production increased from 17 to 27 billion bushels over that time, a monumental 56 percent increase. In other words, our advances in technology and agricultural practices have created 150 million “virtual acres” in the past quarter century³.

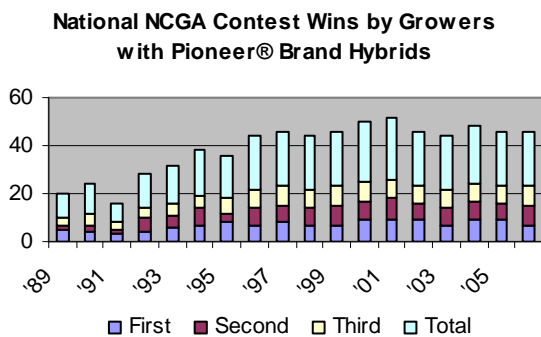
Agriculture is a highly sophisticated field, in which scientific research, new technologies and improved management practices help to maximize the yield potential of every available acre. Continued research and a robust pipeline of products and technologies promise to help farmers worldwide meet the increased demand for food, feed and fuel in the 21st century.



Advanced Technologies Boost Yields

Recent statistics demonstrate that corn and soybean yield potential has not nearly been reached.

For example, the 2002 U.S. average corn yield was 129 bushels per acre. However, an individual corn grower established the single-farm yield record that year with a Pioneer® brand hybrid yielding 442 bushels per acre. Pioneer brand corn hybrids are consistently at the top of the annual National Corn Growers Association yield contest.



Similarly, Pioneer brand soybean varieties yielded more than 100 bushels per acre (field average) in locations in Nebraska in 2005, compared with the 2005 U.S. average yield of 43.3 bushels per acre. In 2006, Kip Cullers of Purdy, Mo., established a new world record in soybean production at 139 bushels per acre. Cullers achieved the record yield with Pioneer® brand soybean variety 94M80 in his Missouri Soybean Association yield contest plot.

The performance of these products demonstrates the potential of modern crops to break traditionally perceived yield barriers. Pioneer is aggressively working to maximize the genetic potential of crops through advanced plant breeding, biotechnology and other innovative technologies.

- **Molecular Breeding.** Pioneer has the largest collection of corn breeding germplasm – more than 40,000 lines – as a result of 80 years of continuous corn breeding. Advances in plant breeding techniques enable plant scientists to analyze this vast collection on the molecular level. Through molecular analysis, researchers identify the specific genes or sections of genetic material that contribute to higher yields. Once identified, this genetic material can be marked and moved into the genetic construct of hybrids to improve yield potential of those plants.

Researchers also use molecular breeding, also known as marker-assisted selection, to identify traits for benefits such as drought tolerance, disease resistance or stalk and root strength. In this way, plant breeders are able to produce hybrids with selected traits to boost and protect yield potential.

Pioneer has invested heavily in this exciting new technology and growers are seeing the benefits with industry-leading corn and soybean yields, and new technologies that will deliver stronger products to growers.

- **Biotechnology.** Yield-boosting genes do not always come from the corn germplasm. Sometimes genes from other plant species can be introduced into the corn genome to impart a trait that boosts or protects yield. The transgenic improvement of crops has been generically referred to as biotechnology. Since 1996, genes from naturally-occurring bacteria and other micro-organisms have been added to corn, soybeans, cotton, canola and other crops to improve farmers' productivity.

Biotechnology helps corn farmers preserve the yield potential contained in the seeds they plant by warding off the major corn insect pests – European corn borer and corn rootworm. Herbicide tolerant corn and soybeans enable growers to improve their control of yield-robbing weeds.

Yields have increased as the technology has been widely adopted. USDA figures indicate that average U.S. corn yields, which increased about 1.65 bushels per acre during each of the 25 years prior to 1996, have increased about 2.71 bushels per acre each year since the introduction of insect resistant corn traits that year. In other words, biotechnology in tandem with improved germplasm has contributed to an average yield that is 27.1 bushels per acre greater than yields just 10 years ago⁴.

- **Gene Shuffling.** This novel, proprietary approach optimizes desired traits by multiplying the effectiveness of beneficial genes. Gene shuffling technology is highly sophisticated, yet based on traditional breeding principles that use genetic diversity to select for improved genes with high value. Think of it as physical training for genes. If you can improve the gene's ability to perform, you can improve the plant's ability to function even in less than ideal conditions.

The Optimum™ GAT™ trait, which provides tolerance to both glyphosate and a broad range of ALS herbicides, is a product of gene shuffling. Pioneer researchers are using this technology to develop a number of next generation solutions for herbicide, insect and disease resistance, yield enhancement and nutritional improvement.

A Promising Pipeline

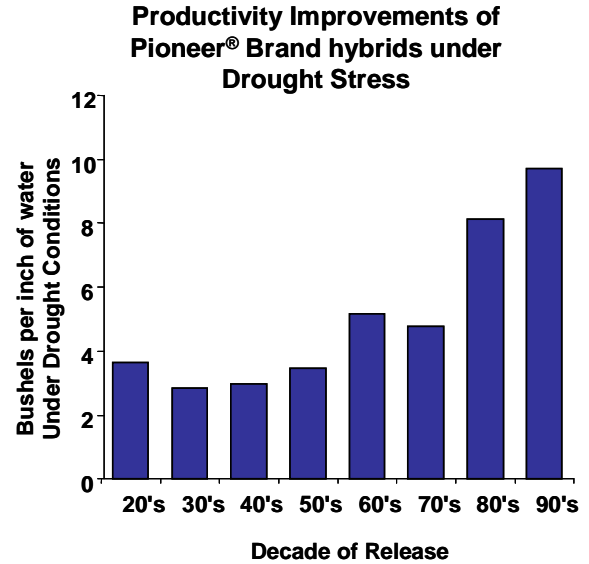
During the past half century, improvements in corn hybrids and soybean varieties have boosted yield. In the past 10 years, biotechnology has helped prevent yield loss to insects, weeds and disease. The next decade promises to add additional agronomic traits that will boost and preserve yield. These include:

- **Anthraxnose Stalk Rot Resistance.** Anthracnose is the most common stalk rot disease faced by corn growers worldwide. Yield losses due to stalk rot can reach as high as 40 percent as a result of reduced ear size and stalk lodging. The estimated value of yield loss is more than \$1 billion in North and South America alone.

Pioneer has identified a rare native corn gene that provides resistance to the fungus that causes Anthracnose stalk rot and premature plant death. We are rapidly incorporating this gene into elite corn hybrids. The trait should be commercially available in North America sometime in 2008.

- **Drought Tolerance.** Drought causes losses for growers in excess of \$8 billion annually across the globe. Maintaining yields during water stress will help preserve grower incomes and yield more grain for the food and energy value chain. In addition, the ability to produce crops with limited amounts of water holds great potential to increase yields in traditional corn growing regions and in regions where corn is not grown because of limited rainfall.

Conventional Pioneer brand hybrids have been developed to be more tolerant of drought and periodic water deficits. Pioneer hybrids have increasingly delivered higher yields per inch of water under drought conditions as outlined in the accompanying chart.



During the next decade, Pioneer will use its molecular breeding capabilities to isolate drought-resistance genes in its vast corn germplasm collection to develop more drought-tolerant hybrids. Researchers also will seek transgenic solutions that will further improve drought tolerance.

No plant can survive without water. Our goal is to maintain yields and productivity when plants water is withheld during critical growth periods and help them better endure drought overall.

- **Nitrogen Responsiveness.** Nitrogen fertilizer is one of the key reasons why corn yields have increased steadily during the past half century. Proper use of fertilizer can double or even triple corn yields. Each year, U.S. farmers apply an average of 136 pounds of nitrogen per acre of corn at a cost of about \$40 per acre. However, not all the fertilizer that is applied is taken up through roots to be utilized by the plant.

Pioneer is aggressively pursuing enhanced efficiency in nitrogen use – applying both transgenic and traditional research methods to future hybrid improvement. Pioneer is in the discovery phase of developing its high nitrogen efficiency hybrids and anticipates having a product ready for the commercial market in the next 10 years. Our ultimate goal is to deliver a product to our customers that requires reduced quantities of nitrogen while maintaining overall yield or, alternatively, increases overall yield at existing levels of nitrogen usage.

Rapid Scale-up Possible with New Techniques

In the past, it has taken plant breeders several years to produce new inbred lines of seed. Recent advancements in plant breeding now make it possible to cut the development time dramatically once the desired traits have been identified in parental lines.

- **Doubled Haploids.** This technology improves plant breeding efficiency and effectiveness by generating inbred lines with 100 percent purity in just one generation. In more traditional breeding, it takes seven generations to do this.
- **FAST Corn Technology.** Functional Analysis System for Traits or FAST allows plant breeders to grow corn to maturity in a fraction of the time of traditional corn. Using FAST corn

technology, scientists can quickly assess how specific genes affect a plant and exponentially increase the number of genes tested each year. Automated digital imaging speeds up the process by precisely measuring the physical traits of plants such as growth, healthiness, and durability to determine how or if the gene in question influences these characteristics.

Improved Grain Quality for the Biofuels Demand

When insects attack corn plants, they can damage the roots or stalks to prevent grain production. They also can attack the grain within the ears. When insects feed on corn grain, they create a habitat for fungus to form. This can lead to the formation of harmful mycotoxins, such as fumonisin, which renders the grain unfit for use as food or feed. Research has shown that biotech corn protected against European corn borer can reduce fumonisin levels by as much as 90 percent.⁵ However, the gene that controls corn borer is not effective against all insect species that attack the ear. Pioneer is seeking to expand the spectrum of insect control to maximize grain yields.

Combining unique Pioneer genetics with Herculex insect protection traits already offers additional control of western bean cutworm, which initially was a threat primarily to dry beans but now has spread to corn in some major corn-producing states. Western bean cutworm larvae damage corn primarily by feeding on developing kernels. This causes direct yield losses and also allows secondary insects and diseases to invade the ear. By broadening the spectrum of insect protection contained in the seed, Pioneer researchers are helping to protect yields and improve the quality of grain.

Leading the Way in Biofuels

Pioneer is committed to enhancing the productivity of the biofuels industry. We are taking a holistic approach that focuses on increasing yield and co-product value per bushel and increasing overall corn grain yield per acre. By developing hybrids that produce grain ideally suited for ethanol production, it is possible to produce more ethanol from a bushel of grain.

Pioneer developed the first grain assay to accurately predict ethanol yield in corn. We have found a 7 percent variation in ethanol yield potential among corn hybrids. For 2007, more than 180 Pioneer ethanol hybrids have been identified as part of our overall Pioneer IndustrySelect® program to match our seed products with the grain end use.

In addition to improving the ethanol potential of grain, Pioneer also is researching ways to enhance the value of feed co-products, since nearly one-third of grain used to produce ethanol enters the feed stream as a co-product, Pioneer researchers are targeting discovery research efforts to increase the amount of fermentable starch in corn, as well as increase the feed value of distillers grain. We are working with ethanol processors and input suppliers (enzyme companies) to better understand ways to improve overall process efficiency by matching our product development targets with processing technologies of the future.

Pioneer is also developing crops that have added value in the growing biodiesel industry. Canola hybrids have been developed that have substantially higher levels of oil, the primary ingredient in biodiesel production. Pioneer has characterized high-yielding soybean products for higher oil and protein levels, ideal for meeting the needs of the soy biodiesel market.

DuPont has a significant effort to deliver new technologies to the growing biofuels market. Through corn yield increases, cellulosic production and ethanol production efficiencies we will be able to double our per-acre ethanol output in ten years. In addition to improving corn for ethanol production, DuPont is developing and supplying new technologies to allow conversion of cellulose to biofuels. The company also is developing biobutanol, the likely next generation of biofuels with improved performance characteristics, including enhanced fuel efficiency.

Maximizing the Productivity of Each Acre

The tremendous advancements in traditional breeding, biotechnology and other processes give growers a wide range of seeds with the potential for much higher yields and overall value. The challenge does not stop there, however. Growers must choose the right seed for their soil and climatic conditions. They must also ensure that their soil is as productive as it can be. Maximizing production on every acre through product positioning and management practices is a critical component of meeting the global demand for grain. Pioneer provides industry-leading services and employs innovative technologies to assist farmers in planting the right products on the right acres to maximize their return on investment.

- **EnClass® System Technology.** This system developed by Pioneer helps researchers place corn hybrids into environments where they are most likely to perform well. The EnClass system looks at a number of different environmental factors (weather, soils, insect pressure, etc.) and categorizes them into groupings of conditions called environmental classes. These classes are based on specific factors that drive many of the variations in product performance that can occur from one environment to another. Pioneer researchers then document the performance of products within each environment class using a database of hundreds of thousands of product comparisons from side-by-side customer trials and research locations.

Coupling this with the knowledge of individual hybrid performance in each class creates a powerful tool to help select and position products on a field-by-field basis that improves the likelihood that a product will perform well locally over time.

- **Yield Mapping.** The use of GPS systems and new types of equipment enable growers to get the maximum output from the various soil types and terrains within a single mapped field. Not only can growers tailor their fertilizer applications to match the soil conditions, they can vary the types of hybrid seeds they plant within a field. Yield mapping provides farmers with an opportunity to analyze their results based on the products they used and the management practices they employed.
- **Corn-After-Corn Expertise.** With the anticipated growth of corn-after-corn acres due to growing ethanol demand, Pioneer has aggressively provided information and expertise to its customers to help them manage this special production challenge. The national network of Pioneer agronomists have communicated production messages and field information to help growers manage corn growing in corn residue; this includes information on hybrid selection, disease and insect management, field preparation and season-long management. Communications have been sent directly to customers with this information as well. In addition, each Pioneer corn hybrid has a high residue suitability rating, providing growers with additional tools to evaluate which products to plant in fields with corn residue.

Conclusion

Throughout the past half century, advances in seed quality and improvements in farming practices have enabled the agricultural community to keep pace with burgeoning global population growth. As demand for grain continues to expand, agricultural research is developing new techniques, products and practices that hold great potential to continue to meet global demand for grain for food, feed and biofuels. An essential element in sourcing this demand is to create new types of grain ideally suited for fuel with feed co-products. It also is essential to solve yield-robbing problems such as drought, disease and insect and weed pressure. Through plant genetic research and development, growers are provided the tools to maximize the productivity of each crop production acre in a way that respects the environment and sustains the grower's livelihood well into the future.

¹ U.S. Census Bureau, Global Population Profile, 2002

² National Corn Growers Association, "World of Corn," 2006

³ Background data - USDA, Jan 2007. Calculations of "virtual acres" by Pioneer Hi-Bred, Global Marketing.

⁴ USDA National Agricultural Statistics Service,

http://www.nass.usda.gov/Charts_and_Maps/Field_Crops/cornprod.asp

⁵ "100 Years of Bacillus Thuringiensis: A Critical Scientific Assessment," American Academy of Microbiology, 2002, p. 12, <[http://www.asm.org/ASM/files/CCPAGECONTENT/docfilename/0000003782/Btreport\[1\].pdf](http://www.asm.org/ASM/files/CCPAGECONTENT/docfilename/0000003782/Btreport[1].pdf)>.

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For additional information contact: Pat Arthur
Public Affairs Manager
Pioneer Hi-Bred International
515-334-6515
Pat.Arthur@Pioneer.com

Additional Resources:

To learn more about meeting the challenge for increased grain production, visit the websites listed below. Pioneer assumes no responsibility for information provided on these sites.

[Biotechnology Industry Organization \(BIO\)](#)

[Ethanol Promotion and Information Council: Concerns about High Corn Prices Unfounded](#)

[International Food Policy Research Institute: The Promises and Challenges of Biofuels for the Poor in Developing Countries](#)

[National Corn Growers Association: The Food Versus Fuel Debate](#)

[Renewable Fuels Association](#)