A Few Thoughts on the Future of Plant Breeding

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VP Global Plant Breeding
Monsanto Distinguished Science Fellow
There are about 2,200 plant breeders in the USA. Most of them are working on food or feed crops.

A ratio of 150k:1 is pretty efficient..... not bad for a few farm kids.
The Conundrum of Breeding
this year’s answers to last year’s questions
There is no data on the future…

But there is one!
Germplasm
Technology
People

To be successful in Breeding one must be at least trilingual
The uncomfortable fact is that progress is not possible without change.
Multiple career tracks are essential in plant breeding
Teaching is not.....just do it like I do....

Back-flip
This Ski Trick is a backward somersault in the air.
As you take off, shift your weight backwards by leaning back.
This will make your spin.
New breeders will find themselves working in a highly technical environment.
Breeding and Biotech Provide Integrated R&D Paths to Commercial Products

Development Pathways

Germplasm

DISCOVERY

PHASE I

PHASE II

PHASE III

PHASE IV

BREEDING

GENOMICS

MARKERS

ELITE GERMPLASM

IT PLATFORM

ANALYTICS

COMMERCIAL

BIOTECHNOLOGY

Seed Sold To Farmers
Advice to New Corn Breeders

Good breeders are most successful in one heterotic pool than in others
Better breeders understand 1 ½ heterotic pools...i.e., choose better testers
Rare breeders master both sides of the pedigree and have walked miles looking for new and useful genetic variation. Their plants talk to them.
Most new lines do not achieve their greatest commercial success with the original tester
Plant Breeding is a Complex Global Business

- Increased Yield
- Disease Resistance
- Stress Tolerance
- Grain Quality / Added Value
- Build on strength of current germplasm as well as Molecular Breeding and Crop Analytics Capabilities

Magnetic Resonance (MRI) and Near Infrared (NIR) Hyperspectral Imaging for Composition analysis
Markers Allow Breeders to Get Best Combinations of Germplasm Faster With Greater Predictability

Marker-Assisted Breeding Rate of Gain is a 2X to 3X Improvement vs. Conventional

- Corn plant has 40,000 genes spanning 10 chromosomes.
- Characteristics (traits) are built from different pieces on different chromosomes. Markers indicate where particular genes are located.
- Using markers to make better selections, breeders can improve the probability of success:

<table>
<thead>
<tr>
<th>Probability of finding 1 trait that is controlled by 20 genes</th>
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<tbody>
<tr>
<td>“Random” crosses: 1 per trillion</td>
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</table>

After application of markers and breeding technology
The technology is changing rapidly even within “molecular breeding”

Marker-Assisted Breeding
Rate of Gain is a 2X Improvement vs. Conventional Methods

**CYCLE 1:**
INTEGRATION OF GLOBAL GERmplasm
- ASSEMBLED 36 MAJOR CORN BREEDING PROGRAMS IN 12 COUNTRIES
- FIRST INTRA-COMPANY CROSSES; BY CYCLE 3, >50% OF HYBRIDS IN THE U.S. PORTFOLIO MADE THROUGH INTRA-COMPANY CROSSES

**CYCLE 2:**
APPLICATION OF MOLECULAR BREEDING TO SELECTION
- PREDICTIVE COMBINATIONS ALLOW MORE EFFICIENT BREEDING
- MOLECULAR BREEDING ACCELERATES TRAIT INTEGRATION BY SHORTENING ‘BACKCROSSING’ CYCLES

**CYCLE 3:**
SELECTION POWER OF MOLECULAR BREEDING
- MOLECULAR BREEDING IMPROVES GENETIC RATE OF GAIN BY 2X VERSUS CONVENTIONAL BREEDING
- LAST YEAR, FIRST MOLECULAR BREEDING HYBRIDS ENTERED COMMERCIAL PORTFOLIO
New traits raise old questions

Soil Probe Analysis of Water Use by Similar Genetics in Colorado

<table>
<thead>
<tr>
<th>Water Use Key</th>
<th>Soil Insecticide</th>
<th>YieldGard® Rootworm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Water Absorption</td>
<td>DKC 61-72 with Force®</td>
<td>DKC 61-68</td>
</tr>
<tr>
<td>Moderate Water Absorption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Water Absorption</td>
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</tbody>
</table>

Water Use Key:
- Low Water Absorption
- Moderate Water Absorption
- High Water Absorption

August 9, 2006

August 15, 2006

August 25, 2006
Our world of plant breeding has changed

Advances Assisting in Protecting and Boosting Yields

<table>
<thead>
<tr>
<th>Commercialized Products</th>
<th>Future Products</th>
<th>Higher Yielding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulate farmers from extreme weather and insect infestations</td>
<td>Boost yield while maximizing the seed for use in feed, food and fuel</td>
<td></td>
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Molecular Breeding Forms the Solid Base to Build in Seed Enhancement

- Commercialized
- Early Next Decade
- Mid Next Decade
- ...and Beyond
We will need a bunch of smart, hot, sweaty breeders to do this!

Step-Changes in Grain Potential

- Corn Stover to Ethanol
- Biotech Yield Increases
- Drought Trait on Dryland Acres
- Molecular Breeding
- Increase to 90 Million Acres
- 30 Year Trend Line

Ethanol Output (in billions of gallons)

2005 2010 2015 2020 2025 2030
Plant Breeders Play a Central Role in Monsanto

The Art and Science of Breeding Contributes Greatly to Improving Plants

Today's plant breeders require:
• Several skills, significant knowledge and a variety of abilities to function in diverse scientific teams.
• A passion for working closely with plants in field environments.
• Understanding complex interactions of genotypes with environment.
• A strong ability to apply the sciences toward the directed goal of marketable products

Breeders connect science and product development process to business channels.
We need more breeders…after all…some of us are going to “retire” in 10-20 years

- Our success in seeds and traits has created a need for more plant breeders at Monsanto
- Created a team to work toward partnering with universities in education, mentoring and development of new plant breeders
- Our hope is that greater involvement in the process of training new plant breeders will ensure a viable pipeline of top talent to supply future staffing needs
Who will educate the breeders in the future?

A WAY TO ENSURE CONTINUED BREEDING INTEREST IS TO CREATE PLANT BREEDING CENTERS
Survey of More Than 100 Monsanto Breeders on Plant Breeding Education

<table>
<thead>
<tr>
<th>January 2007</th>
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<tbody>
<tr>
<td><strong>Future Difference</strong></td>
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<tr>
<td>Genomics; Bioinformatics; Proteomics; Metabolomics</td>
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<tr>
<td><strong>IMPORTANT</strong></td>
</tr>
<tr>
<td>Population Genetics; Plant Pathology; Management; Ethical, Legal, and Social Issues; Intellectual Property; Reproductive Biology; Bioinformatics; Mechanization/Automation; Physiology/Whole Plant Biochemistry; Transformation/Transgenes; Physiological Genetics; Entomology</td>
</tr>
<tr>
<td><strong>ESSENTIAL</strong></td>
</tr>
<tr>
<td>Breeding Methods/Principles of Plant Breeding; Mendelian Genetics; Quantitative Genetics/Selection Theory; Data Management; Molecular Breeding; Statistics/Experiment Design</td>
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THE RULES OF THE EDUCATION GAME ARE CHANGING IN BREEDING
Have you ever been really good at something you didn’t like?

Jack Nicholas
At a minimum we need....

Professors who know how to teach
Professors who conduct relevant research
Inquisitive minds who don’t mind getting hot, sweaty, and dirty to find out the answer
A graduate education that enables individual excellence on cross functional teams
Breeders who understand theory and can implement it on an industrial scale.
Love what you do….do what you love

Successfully Delivering Better Products to Growers Requires:

- Cutting-Edge Scientific Innovation
- The collaboration of breeding, biotechnology and other disciplines to deliver tomorrow’s improved plants
- Capitalizing on Breeding to Deliver What the Market Needs
Breeding for a better future