Technology Platform for Next Generation Plant Breeding

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Contents

• Global seed industry
• Next generation plant breeding
• High throughput platform
• Seed industry promotion center
Global Seed Market

2013 Global Proprietary Seed Market Value : 51 B USD

- Grain 56%
- Oilseed 18%
- Veg and Flower 13%
- Other Field 7%
- Forage and Turf 6%

Source : Sigma Seed 2014 (GFK and Context)
Global Seed Industry Megatrends

- Global proprietary crop seed market, $15B (’03) → $51B (’13)
- Seed price: GM crop, hybrid conversion, value-added
- Top 10 companies, over 75% MS (from 25% in 1995)
- New technology development, IP protection

$36B in decade  Climate ready  Monsanto R&D $1.7B
Can we feed 9 billion people?

2000-2010 Global Crop Consumption¹
- Corn +37%
- Soybean +47%
- Canola +53%

Food Production Goals²
- Sunflower +35%
- Rice +14%
- Increase food production by 70% by 2050 to feed estimated 9 billion people

World Stock to Use Ratio³
- Flat to down 2009-2010: Corn, Soy, Wheat and Rice

Source: DuPont Pioneer
GM Seed Market Growth

(in billions of dollars)

Yearly evolution over 5 years

Conventional seeds
GM* seeds
Total seeds

US Drought in 2012
Drought Tolerant Corn
Drought Tolerant Corn

Source: DuPont Pioneer, Syngenta, Monsanto
Novozymes Contributes
- Existing Microbial Products
- Microbial Discovery & Sourcing
- Application Development
- Strain Optimization
- Fermentation, Formulation, and Manufacturing
- Regulatory
- Intellectual Property

Monsanto Contributes
- Microbial Discovery and Sourcing
- Field Testing
- Commercial Organization
- Enabling Technologies
- Formulations
- Regulatory
- Intellectual Property

Discovery R&D
- Discovery activities not co-funded
- May include 3rd-party collaborations to identify and nominate microbes into the alliance
- IP is owned by inventing party, licensed to Alliance
- All discovery output is committed to the Alliance

Execution: Enable Better Outcomes

CLIMATE PRO™

Seed & Planting
- Planting Advisor
- FieldScripts®

Fertility
- Nitrogen Advisor

In-Season Management
- Pest & Disease Advisor
- Harvest Advisor
- Field Health Advisor
- Revenue Advisor

Source: Monsanto, the climate corporation update
Next Generation Plant Breeding

**BREEDING COMPETITIVE ADVANTAGES**

- **SCALE AND DIVERSITY**
  - Monsanto has the largest and most diverse global germplasm library of its kind

- **BREEDING CAPABILITY**
  - Monsanto has 10 years of mapping data, and 40 million marker-trait associations

**BIOTECH COMPETITIVE ADVANTAGES**

- **BIOTECH PIPELINE**
  - Monsanto has the deepest and broadest biotech pipeline in the industry

- **BIOTECH EXPERIENCE**
  - Monsanto has the most regulatory experience, and the most success launching the most traits

**TECHNOLOGY FOUNDATION**

- **INTEGRATED IT SYSTEMS**
  - Monsanto uses state-of-the-art Informatics like Genome sequencing, QTL information, and expression data to more efficiently manage data analysis and interpretation

- **TECHNOLOGY ENGINE**
  - Monsanto uses the most advanced tools of genomics, robotics, molecular markers, automated phenotyping, seed chippers to more efficiently select the best products

- **COLLABORATIONS/NETWORKS**
  - Monsanto has over 4,000 active technology agreements ranging from the best in class BASF collaboration to consulting and field research trials

Source: R Fraley, Monsanto Biennial Investor Event 2011
Next Generation Plant Breeding

Molecular Breeding
High throughput genotyping, genetic associations, doubled haploids

Trait Enhancement
Increased genetic diversity from native genes and transgenes

Phenotypic Evaluation
Surrogate assays, molecular phenotyping, single seed NIR, EnClass®

Biological Information
Statistical evaluations, modeling, computational biology and bioinformatics

Increased Rate of Genetic Gain in Desired Crops

Source: B Mazur (DuPont), G&LT Forum 2012
Technology Platform for NGPB

- Technology tools:
  - Molecular markers/high throughput genotyping
  - Automated phenotype analysis
  - Metabolic profiling
  - Automated seed clipping (clipping)
  - Doubled haploids

- Integrated IT system

- Collaborations/networks
Monsanto Corn Breeding

**Selection in the Lab Enhances Selection in the Field**

- Superior Genetics Advanced
- Hybrid Grain Yield and Agronomic Performance
- Automated Seed Chipping
- Phenotypic and Disease Evaluations
- DNA analysis and Selection of Superior Kernels

**Deploying the Technology Tool Kit**

1. **Analyze** – Global Database of 10 Years of Mapping
   - High-resolution trait knowledge enhances phenotypic selection
   - Over 40 million marker-trait associations
   - Derived from over 630,000 hybrids from more than 3,400 breeding pedigrees

2. **Select** – High-Density SNPs and Seed Chipping
   - DNA selection identifies superior seeds based on genotype
   - 10s of millions marker data points every year
   - 10s of millions of samples every year
   - Whole genome SNP knowledge
   - 75,000 SNP assays

3. **Accelerate** – Accelerate Breeding with DH
   - Doubled haploid (DH) inbreds enhance rate of genetic gain
   - 2nd generation of DH derived commercial products
   - All global breeding programs
   - Over 500,000 doubled haploid inbreds produced every year

**Technology Leadership**

**Competitive Advantage: Technology Engine**

*Monsanto has the tools and the experience in place to position it best to unlock the next wave of yield improvement on-farm*

Source: R Fraley, Monsanto Biennial Investor Event 2011
Seed Chipping Technology

Source: Monsanto
Seed Cutting Technology

Source: DuPont Pioneer, Monsanto

LASS (Pioneer)

Seed clipping (Monsanto)

Seeds precisely positioned
High Throughput Genotyping

Source: DY Sung (Monsanto)
Applying New Platform to Vegetable

Industry added two resistance genes in past 20 years. Monsanto plans to add 1 trait a year over the next 5 years.

Products from breeding launch:
- Virus1, Fungus1
- Virus2, Fungus2, 3, & 4
- Virus 2 & 3

Traits mapped:
- Virus1 & 3, Fungus3
- Fungus2, Virus2
- Fungus1, Fungus3

Marker Platform Developed

Source: Monsanto, WST Vegetable Poster 2012
Automated Phenotype Analysis

1. RGB visible light
2. NIR near infrared light
3. FLUOR fluorescent light
4. IR infrared light
5. ROOT NIR / RGB

Source: LemnaTec, Monsanto
<table>
<thead>
<tr>
<th>Area of application</th>
<th>References or examples</th>
</tr>
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<tbody>
<tr>
<td>basic plant science</td>
<td>Weidenbach D et al. (2015) Shoot and root phenotyping of the barley mutant kcs6 (3-ketoacyl-CoA synthase6) depleted in epicuticular waxes under water limitation. Plant Sig &amp; Behav</td>
</tr>
<tr>
<td>ecotoxicology</td>
<td>Hayes JE et al. (2013) Germanium as a tool to dissect boron toxicity effects in barley and wheat. FPB 40: 618</td>
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<td>All major plant breeders and agribusiness companies use phenotyping technology</td>
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<td>climate change research</td>
<td>Chen D et al. (2014) Dissecting the Phenotypic Components of Crop Plant Growth and Drought Responses Based on High-Throughput Image Analysis. Plant Cell Online 26: 4636-4655</td>
</tr>
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Monsanto Biotechnology Plant Physiology Center

- Functional Discovery
  - Arabidopsis

- Crop Physiology
  - Corn
  - Soy
  - Cotton

- Imaging and Automation

- Data Systems

Source: M H Malone, PhenoDays 2012
High Throughput Phenotyping Combines with Field Testing to Identify Yield Genes

Source: M H Malone, PhenoDays 2012
High Throughput Screening in R&D Pipeline

Source: M H Malone, PhenoDays 2012
High Throughput Genotyping & Phenotyping

- Allow breeders to unlock specific, targeted breeding opportunities
- Increase germplasm screening significantly in size
- Enable yield testing in the lab

**Number of New Hybrids Tested**

- Field Baseline
- 2010 Lab
- 2014 Lab
- 2018 Lab Projection

- 6X increase

**Predictive Analytics Optimizing Breeding Decisions**

- Germplasm Potential: High, Low
  - Germplasm Potential: High, 90% of Commercial Hybrids
  - Germplasm Potential: Low, 10% of Commercial Hybrids

- 15 years of marker to phenotype associations enables “yield testing” in the lab, in addition to field testing
- Significant increase in size of germplasm screening
- Optimize breeding cycle to enable complex trait stacks with newest genetics at the same pace

Source: Monsanto Annual R&D Pipeline Review 2015
K-Seed Valley Project
Seed Industry Promotion Center

• Promoting molecular breeding
  ▪ Services for advanced technology
  ▪ Facility & equipment
  ▪ Manpower
  ▪ Collaboration network
• Promoting seed export
• Promoting HRD for seed industry
Advanced Technology Services

- Genotyping (SNP marker)
- Functional component analysis
- Collaboration network
Syngenta APAC Genotyping Lab

- Freeze drying & grinding of samples
- DNA extraction & robotic grippers
- Liquid handling
- Data scanning
- PCR thermal cycler
- Array tape platform

Source: Syngenta, BC Kang (SNU)
Collaboration Network

Company A

Company B

Company C

Seed Industry Promotion Center

University

Public Research Institute

Service Company

Request

Service

License

Source: BC Kang, RDA 50 Years Symposium 2012
High Throughput Genotyping Platform

Source: Fluidigm, Life Technology, LGC Genomics, Douglas Scientific
Thank You