Nutrient and Water Use Efficiency as Key Targets for Sustainable Crop Production

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Monsanto Company
Agriculture is at the Center of Many of Society’s Most Important Debates

- **Global food security**
  - Enhanced productivity
  - Increased yield
  - Sustainable production

- **Water availability**
  - Drought-tolerant crops

- **Biofuels**
  - Yield technologies to help meet demand for both food and fuel

- **Climate Change**
  - CO₂ footprint
  - Fertilizer use
  - Drought-tolerant crops
A Global Commitment to Sustainable Agriculture

Supporting farmers is the heart of this effort as they work: to

Help farmers **DOUBLE YIELDS** in corn, cotton, soybeans & spring-planted canola by 2030

**REDUCE** inputs by 1/3 per unit of output

**IMPROVE THE LIVES** of farmers around the world
What Does it Mean to Double Yield in the U.S. by 2030?

**Corn**
- 2000 Baseline: 137 bu/ac
- 2030 Goal: 300 bu/ac

**Soybean**
- 2000 Baseline: 37 bu/ac
- 2030 Goal: 80 bu/ac

**Cotton**
- 2000 Baseline: 632 lbs/ac
- 2030 Goal: 1,300 lbs/ac

How Are We Going to Reach These Goals?

**Breeding**
- Creates new, more robust varieties that perform better in the field.

**Biotech**
- Adds special beneficial genes to the plant.

**Agronomic Practices**
- Agronomic practice improvements makes acres more productive.
Pesticide, Nitrogen, Rainfall Use Declining In Corn

As busheles/acre increase, inputs per bushel have decreased

Corn Input Levels Relative to 2000 Levels
(3 Year Running Averages)

Input Level Per Bushel Output
(2000 = 100)

1970 1990 2010 2030

Data Sources: USDA, NASS “Agricultural Chemical Usage Report”; dmrkynetec; NOAA; USDA ERS
Yield and Stress Pipeline

- **Multi-year Field and controlled environment testing platform**
- **Phase II**
  - Extensive Testing of potential commercial products
- **Phase III**
  - Transformation
  - Seed Increase and molecular characterization
  - Nominations
- **Phase IV**
  - Regulatory and Trait Integration
  - Regulatory submissions
  - Seed manufacturing
New Leads Validated As Robust Yield-and-Stress Pipeline Continues To Show Strong Progress

<table>
<thead>
<tr>
<th>FARMER BENEFIT</th>
<th>CONSTRUCT STATUS</th>
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<tbody>
<tr>
<td><strong>Drought Family</strong></td>
<td>• Mitigates environmental impact to maximize yield with reduced water</td>
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<tr>
<td><strong>Yield Family</strong></td>
<td>• Maximizes yield potential of germplasm</td>
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<tr>
<td><strong>Nitrogen Family</strong></td>
<td>• Allows plant to more effectively use nitrogen, potentially reduce key input cost</td>
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**Yield Difference (Bu/acre)**

- Significant at p-value ≤ 0.10
- p-value > 0.10

In collaboration with BASF
Avenues to increase Nitrogen Use Efficiency (NUE)

Nitrogen use efficiency (NutE)
How does the plant use the N it acquires to produce grain?

- No pollination
- Early kernel abortion
- Reduced kernel weight

Souce: HTTP://NITROGENES.CROPSCI.UIUC.EDU/NUE.CFM
Diverse Mechanisms for Nitrogen-Use Efficiency

<table>
<thead>
<tr>
<th>Processes</th>
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<tr>
<td>Enhanced Nitrogen Uptake/Transport</td>
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<tr>
<td>Improved Nitrogen Assimilation</td>
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<tr>
<td>Enhanced Protein Synthesis</td>
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<tr>
<td>Improved photosynthesis</td>
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<tr>
<td>Improved General Stress Response</td>
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<td>Unknown</td>
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</table>

Processes that Impact Nitrogen Use

- Storage and Remobilization
- C/N Balance
- Amino Acids
- Proteins
- Chlorophyll

Assimilation
Uptake
Sensing

Transport

NO$_3^-$
NH$_4^+$
Linking Genotype to Phenotype is Critical: Automated High Throughput Methods are used for phenotyping and measuring yield

Whole Plant Phenotypes

Metabolite Fingerprinting provides Information on how transgenes lead to alterations in biochemical pathways

• Monsanto’s Automated Greenhouse in USA for corn, soy, cotton and canola
• Collaboration with BASF provides access to Crop Design’s automated rice greenhouse platform
Automated Greenhouse Screens include nitrogen stress and water stress
Field Performance is the Bottom Line for Biotechnology Trait Product Development

Huge Diversity in Germplasm and Environments
- With 75-85 million acre crops, environmental and genetic diversity is the rule
- Germplasm types differ in maturity, adaptation to abiotic and biotic stress
- Yield and Stress traits require broad field testing over years to evaluate efficacy and potential interactions
Plant response to nitrogen apparent in aerial field images

2009 Field Trial
Several Generations of Drought-Tolerance Genes are in Testing

THE COMPLEXITY OF PLANT BIOLOGY...

- POLLEN SHED & GROWTH
- IMPROVED SILK EXPANSION
- IMPROVED EAR DEVELOPMENT, KERNEL NUMBER & FILL
- REDUCED WATER LOSS
- IMPROVED PHOTOSYNTHESIS
- PLANT GROWTH
- WATER UPTAKE BY ROOTS

REQUIRES ADVANCED R&D RESOURCES

Early screening for leads is conducted with automated greenhouse and extensive field testing

Followed by physiological & biochemical characterization

BUILDING A FAMILY OF TRAITS CONVEYING DROUGHT TOLERANCE IN CORN

IN COLLABORATION WITH BASF
First-Generation Drought Trait on Track for Launch in Western U.S. in 2012\(^1\)

- **CspB enhances the way the plant uses its genetics**
- **CspB plants adapt more effectively to deal with drought**
- **Under drought, CspB plants are less stressed leading to enhanced photosynthesis and development**
- **Better growth leads to increased kernel number**

**Increased Yield Under Water-Deficit Stress**

<table>
<thead>
<tr>
<th>Days</th>
<th>Control without gene</th>
<th>With gene</th>
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<tr>
<td>1</td>
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**Control Hybrid (76 BU/AC)**

**With Gene (94 BU/AC)**

1 Launch country represents the U.S. where Monsanto technology fits on its share base; 2020 value reflects gross sales opportunity in the country of launch.
First-Generation Drought Gene Performs in Elite Germplasm Combinations Despite Limited Drought Pressure

2009 FIELD TEST DATA

2010 FIELD TESTING (Garden City, KS)

Test Hybrids

Data from sites identified as having drought stress
All differences significant at .05 level

IN COLLABORATION WITH BASF
First-Generation Drought Trait in Pre-Launch Phase: Expanded Testing in 2010 To Isolate Best Gene by Germplasm Combinations

**DROUGHT I: 2010 FIELD TESTS**

- Over 200 testing locations across the U.S.
- Over 100 locations in target market of Colorado, South Dakota, Kansas and Nebraska
- Plans include simulated drought conditions in the event of excessive moisture
- Hot weather and adequate rainfall across much of the Corn Belt with isolated pockets of very dry conditions

IN COLLABORATION WITH BASF
Drought Tolerant Corn Products Target the Needs of Farmers in Different Regions

- **D1** Targets a Yield Advantage in Western Great Plains Dryland Production
- **D2** Adds a Yield Advantage in Drought “Insurance” Market When Drought Occurs
- **D2** Provides Opportunities in Irrigation Market

**Western US Dryland**
- KS, NE, TX, CO, SD, ND
- 10-13 M acres corn

**Drought “Insurance”**
- Central, E. and S. Corn Belt
- 30-50M acres

**Reduced Irrigation Cost**
- KS, NE, TX, CO, ID
- 12M acres

IN COLLABORATION WITH BASF
Average Sub-Saharan African Corn Yields are Among the Lowest Globally

2008/2009 CORN YIELDS BY COUNTRY

IMPROVED AGRONOMIC PRACTICES, BREEDING AND BIOTECH CAN ALL PLAY A ROLE

Source: USDA FAS Oct 2009
Delivering Water-Efficient Maize for Africa Requires Strong Partnership of Technology Providers

THE PARTNERS

• African Agricultural Technology Foundation (AATF) is leading the project
• CIMMYT and Monsanto will bring best in global maize germplasm, testing and breeding methods, and biotechnology
• National Ag. Research System (NARS) participation is a crucial part of testing products and bringing WEMA to Sub-Saharan African farmers

THE TECHNOLOGY

• Best global germplasm to combine new sources of drought tolerance and African adaptation
• More rapid gains in conventional drought tolerance through molecular breeding
• Additional drought tolerance obtained through state-of-the-art biotechnology
First WEMA Data from One Trial Set in South Africa

Yield and Test Weight

Pollen Shed and Silking

Kernels per ear

- Gene   + Gene
Genetics, Biotech Traits and Agronomics Work Together to Bring More Crop per Drop

![Bar chart showing the average bushel produced by inches of water from 1960 to 2009. The chart compares historic population (blue bars) and current population (red bars). Source: Monsanto data 2009, Water Utilization Gothenburg, Nebraska.](chart.png)
Breeding and Biotech Provide Parallel R&D Paths to Commercial Products
From the Genome to the Field

- Genetic Engine
  - Test populations
  - Breeding pipeline
  - Transgenics

- Validation
  - Characterization of germplasm diversity

- Prediction
  - Accurate, sophisticated genetic modeling tools

- Data Mining
  - WHOLE GENOME SEQUENCE
  - GEOGRAPHICAL INFORMATION SYSTEMS
  - CUSTOMIZED GENETIC INPUT & PRESCRIPTIVE HYBRID PLACEMENT IN THE FIELD
Agriculture will continue to be the biggest consumer of available water, but Monsanto, along with others, are working to “squeeze more food from a raindrop”
Thank You