Future Trends in Corn Genetics and Biotechnology

California Alfalfa & Forage Symposium

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Plant Breeding

The art and science of genetic improvement of plants
Knowledge Rich Library

- Proprietary genetics library
- 75 years of documented performance data
- Genomic descriptions of best lines
- Unique advantage – can’t be duplicated
Increasingly Erect Leaves

Left 1930s

Right 1990s
Smaller Tassels

Left 1930s

Right 1990s
Increased Flowering Synchrony

1930s

1990s
Improvements in Corn Productivity under Drought Stress

**Pioneer Hi-Bred Int'l. Hybrids**

![Historical Progress Chart]

- Bushels produced/inch of water in drought environment
- Decade of Release:
  - 20's
  - 30's
  - 40's
  - 50's
  - 60's
  - 70's
  - 80's
  - 90's

**Legend:**
- Historical Progress
- UCD Alfalfa Workgroup
Traditional Breeding

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Traditional Corn Breeding

- Germplasm Pool – The collection of inbreds and genes available for making new products
- Breeding Population – A cross between two or more inbreds to create variability
- Inbreeding & Selection – The process of selecting the best individual in a breeding cross
- Recycle elite germplasm – Once a new inbred is created it is added to our germplasm pool and serves a base of improved performance
Advance the inbred based on its hybrids performance in multi-location, multi-year field trials.
Doubled Haploids
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Doubled Haploids – Instant Inbreds

Traditional Inbreeding:
- 7 generations

Doubled Haploids:
- 2 generations

Advantages:
- Increases precision of molecular markers
- Reduces hybrid development cycle time 1-2 years
- Increases options for per se selection (parent traits, disease, maturity)
- Breeding impact – more complex pedigree selection away from home nursery
Doubled Haploid Lines

• 100% fixed, genetically uniform lines

• Improves breeding by...
  • Increasing genetic differences between lines
  • Increasing uniformity
    – easier to measure traits
    – increases repeatability
  • Testing final product immediately
  • Reduces product development time
Molecular Breeding

Genetic mapping
Map-based cloning

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Molecular Breeding

- **Identify parents**
  - Load breeding pipeline with known genotypes
  - More predictive of performance

- **Select superior progeny**
  - Identify progeny with traits not expressed in testing environment (e.g. select for GLS where disease does not occur)

- **Test final products**
  - Predict performance in non-stress environments
  - Predict favorable new combinations of inbred parents based on complementary molecular profiles
Molecular Breeding

- Enhance diversity of germplasm pool
  - Move small segment of exotic chromosome into elite background without “drag”
    - Ex) move genes from teosinte or landrace into elite corn without having to do extensive backcrossing and repeated phenotyping to eliminate yield, maturity and adaptation drag
  - Scan corn genome for sequences of interest identified in other species
  - Move gene from other species into corn (transgenes)
Inbred Selection Using Molecular Markers

- Molecular markers "tag" valuable chromosome segments
- Quickly determine if inbreds and hybrids possess a gene for a target trait
- Aggressively profiling eight decades of germplasm to create a master genetic map

Drives agronomic performance gains (e.g., anthracnose, SCN)
Molecular Marker Based Selection

- Phenotype = Genotype + Env + (Geno*Env)
  - Not all genotypes are observed in all environments!
- Markers allow for selection of genomic sections with known phenotypic effects in environments not conducive to phenotypic expression.
- Starting point of finding the underlying genes responsible for phenotype
Current Uses

- Understanding of Genetic Relationships

- Conversion Quality

- Corn Product Development
  - Targeting “Key” Traits
  - Important tool in inbred/hybrid development

- Germplasm protection
Other biotechnology applications

- **Transgenes**
  - European corn borer resistance ("bt")
  - Corn rootworm resistance
  - Herbicide tolerance

- **Future potential**
  - Yield
  - Drought tolerance
  - N-use efficiency
  - Nutritional and industrial traits

- **Intellectual property**
  - DNA fingerprints
  - Protect investment to insure plant breeding future research

- **Gene discovery**
  - Genome sequencing
  - Gene expression
  - Understanding gene function
Gene Shuffling

- Parental genes
- Derived gene variants
- Trait assays
  - Selected progeny genes
  - Assay
  - Selection
  - Shuffling

- Single Genes
- Gene Families
- Gene Pathways
- Whole Genomes
  - In vitro
  - In vivo
  - In silico

Repeat (Optional)
Ultimate Goal of Breeding is:
- Selecting for measurable improvements in traits

- Trade-off
- Test for measured improvement
- Stay focused

Corn Hybrid Variation

Is range broad enough to make meaningful progress?
Growing Value From Agronomic Traits

- **Drought tolerance**
  - Proprietary testing environments
  - Numerous early stage leads validated in multiple model crops
  - Average annual drought loss $8 billion globally

- **Nitrogen responsiveness**
  - Maintain yields using less nitrogen
  - Increase yields at current nitrogen levels
  - Industry-leading testing environments
  - Average nitrogen cost = $40/acre

- **Yield enhancement**
  - Farmers’ No. 1 priority
  - Six soybean biotech events in advanced testing
  - Numerous corn leads undergoing inbred evaluation

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Average Soybean Yield Advantage Over Control Varieties During Past Two Years

- **Drought Tolerance**
  - Check Hybrid
  - Pioneer Experimental Hybrid

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## 2008 Crop Genetics Pipeline

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<td>Proof of Concept</td>
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- Anthracnose Stalk Rot Resistance
- Fungal Disease Resistance
- Optimum® GA™
- Optimum® AcreMax™ 1
- Optimum® AcreMax™ 2
- Optimum® AcreMax™ 3
- Triple-Mode Herbicide Tolerance
- Drought Tolerance I
- Drought Tolerance II
- Nitrogen Use Efficiency
- Increased Yield I
- Increased Yield II
- Increased Ethanol Production II
- Increased Ethanol Production III
- Improved Feed II
- Improved Feed III
- Seed Production Technology
- Asian Soybean Rust Resistance
- Optimum® GAT™
- Triple-Mode Herbicide Tolerance
- Lepidopteran Resistance
- Hemiptera Resistance
- Aphid Resistance
- Cyst Nematode Resistance
- Increased Yield II
- Increased Yield III
- Improved Feed I
- Improved Feed II
- High Oleic + High Stearic Acid Oil
- High Oleic Acid Oil
- Omega-3 Oil
- Improved Flavor
- Improved Functionality
- Rice - Insect Resistance
- Canola - Glyphosate Tolerance
- Alfa - Glyphosate Tolerance

*Proprietary Pioneer Glyphosate + ALS Tolerance trait*
Questions?