USDA DROUGHT TOLERANCE RESEARCH OVERVIEW

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Drought Research in ARS
An Overview: soybeans and maize

AgForum

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Average Percentage of Indemnities by Hazard, all crops, 1948-1996*

- Drought
- Ex. Precip./Poor Drainage
- Frost & Freeze Damage
- Hail
- Flood
- Tornado & Hot Wind
- Insects
- Disease
- Others

43% {ABIOTIC 95%}

(*USDA Agricultural Statistics (1998))
Soy Production affected by drought

YEAR 1900 - 2005

%
Breeding for Improved Drought Tolerance

- Screening for drought tolerance using laboratory or glasshouse-based assays is notoriously difficult and not always correlated to observed tolerance in the field.
Drought Tolerance: Complex Phenotype

- Field Performance!
- Plant Architecture
- Morphology
- Cellular
- Sub-cellular
- Genetic
Integrated Program

New Sources of Drought Tolerance

Crop and Whole Plant Physiology

Genetics, ‘Omics’ and Molecular Biology (Biotechnology)

Field Breeding

Better Varieties
Soybean: *Glycine max*

Germplasm to Genes
Slow Wilting Trait

Fast wilting

Slow wilting
Searching the Globe for drought tolerance

30,000 Strains Of Soy
Slow Wilting Discovery

- Carolina: 6 Asian types
- Minnesota: 6 (more) Asian types
- Nebraska: 10 (more) Asian types
- Arkansas: 2 U.S. types
DNA MARKER RESULTS

4 Slow Wilting Genes identified thus far

More expected soon

OTHER ADVANCES

Slow wilting related to yield under stress
QTL’s for Yield under Drought: From PI 471938

Mean yield (kg) from 5 rain-fed environments

<table>
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<th>Year</th>
<th>1545</th>
<th>1613</th>
<th>1680</th>
<th>1747</th>
<th>1814</th>
<th>1881</th>
<th>1949</th>
<th>2016</th>
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<td>Yield</td>
<td>0</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>40</td>
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Hutcheson (1734)

PI 471938 (1747)

LOD = 2.5

LOD = 3.0

R² = 9%

Satt458
Satt397
Satt669
Satt389
Satt311
Sat_362
Satt226
Sat_365
Satt301
Sat_354
Sat_086
Satt256
Maize

Zea mays

Genes to Germplasm
Water Stress Cycle

Progression of “stress”

“Recovers” each night

Physiological Damage (yield reduced)

Plant death

Not full “Recovery”
Drought and Desiccation Tolerance

**Drought tolerance** = tolerance of sub-optimal water availability

**Desiccation tolerance** = tolerance of complete drying to equilibrium with the air

Drought tolerance mechanisms include ways of maintaining cell water content, such as osmotic regulation and stomatal closure, whereas desiccation tolerance consists of ways to survive the complete loss of water.
Sporobolus stapfianus

Craterostigma plantagineum
Induction by water stress vs Desiccation

Water Stress Cp 60%
- transport
- organic acid metabolism
- macromolecule binding

Drought - At
- oxidoreductase activity
- hydrolase activity
- nucleic acid binding

Drying Cp 5%
- metal ion binding
- nuclease activity
- macromolecule binding

transport
Genes Ascribed to Drought Tolerance
Domestication and plant breeding reduced maize genetic diversity

Selection Screens: Another way to identify genes that have contributed to agronomic traits

Very low sequence diversity

Slide courtesy of Masanori Yamasaki
Linkage Association

vs. B73
Syntenic Relationships
Sorghum - Rice - Maize
Drought Tolerance in Sorghum

- Two forms of drought tolerance have been observed in sorghum:
  - Pre-flowering
  - Post-flowering (the ‘Stay-Green’ trait)
- Each is identified by the lack of specific symptoms of water-deficit stress imposed at a particular plant growth phase
Integrated Approach

The Key for Crop Improvement in Drought Tolerance