Modern Technologies to Access Common Bean Responses to Environmental Stress

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The Changing Face of Climate

Average Temperatures (10 year average)

1884
Cooler in our past

1949
Baseline year

Warmer since mid-1900s

2014

Data from: climate.nasa.gov
The Changing Face of Climate

Our History!!!

Data from: climate.nasa.gov

How are the biological process being retuned as the environment changes???

Our Future (2100)???

Change relative to 1950-1980 average.
Environment Affects The Four Biological Processes Necessary for An Organisms To Be Successful

**Growth and Development**

- Flower
- Leaf
- Seed pod
- Seedling
- Stem
- Root

**Reproduction**

- Bush bean (dicot) life cycle
- Fertilization
- Pollen tube
- Zygote

**Biotic Stress Tolerance**

- Image of a leaf showing biotic stress tolerance

**Abiotic Stress Tolerance**

- Image of a field showing abiotic stress tolerance

Processes are interconnected!!!

All processes compete for a limited supply of energy!!!

Processes are prioritized!!!
These Biological Processes Intersect At the Gene Level To Control Resource Allocation

Climate Change

Manifested differently

• Drought and heat
  • Often coupled effects
• But
  • Some areas experience extreme rainfall
  • Flooding
How To Discover the Genetic Factors Controlling the Current and Future Pathways???

Accurate phenotyping

- Assess the subcomponents of a phenotype
- The subcomponents collectively define the multiple facets of a phenotype

Genome-wide genotyping

- 100,000s SNPs to Millions of SNPs

Goal

- Integrate functional phenotyping and genotyping to develop crops that are successful in a climate change world
Goal: Phenotype at the Level of a Single Gene

How: Appropriate Is Phene Phenotyping??

Bean Rust: *Ur-3* resistance
- Phvul.011G192600
  - 46.9216 - 46.919 Mb
  - Missense mutation
  - H929R

Bean Rust: *Ur-11* resistance
- Pv11
  - 47.94 – 48.48 Mb
  - 8 NBS-LRR genes

Collaborators
Phil Miklas
Talo-Pastor Corrales
GLOBAL PHOTOSYNQ Project
(http://photosynq.org)

Hand-held Photosynthesis Monitor

Important Photosynthetic Traits Measured

**Phi2**
- Efficiency of Photosystem II
  - % of incoming light available for photochemistry

**NPQt**
- Non-photo chemical quenching
  - Amount of light dissipated as heat

**LEF**
- Linear electron flow
  - Number of micromoles of electrons flowing out of photosystem II per second

**SPAD**
- Chlorophyll content

Developers
David Kramer’s Group
Michigan State Univ
## PHOTOSYNQ Results

### Variables Correlated with Phenotypes Among Market Classes

<table>
<thead>
<tr>
<th>Comparison (r value)</th>
<th>Black (n=18)</th>
<th>Pinto (n=33)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHI2 vs maturity</td>
<td>-0.68**</td>
<td>0.56*</td>
</tr>
<tr>
<td>NPQT vs maturity</td>
<td>0.54*</td>
<td>-0.55*</td>
</tr>
<tr>
<td>LEF vs maturity</td>
<td>-0.74**</td>
<td>0.51*</td>
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</table>

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<tr>
<td>PHI2 vs plant height</td>
<td>ns</td>
<td>0.53*</td>
</tr>
<tr>
<td>NPQT vs plant height</td>
<td>ns</td>
<td>-0.57*</td>
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<td>LEF vs plant height</td>
<td>ns</td>
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</table>

### Collaborators
- Juan Osorno
- Ali Soltani (NDSU)
- David Kramer’s Group (MSU)
- Phil Miklas
  USDA/ARS, Prosser, WA

### Durango Diversity Panel
- n=192
- Fargo, North Dakota: 2015
PHOTOSYNQ Results

Genome-Wide Association Studies

NPQT

Phi2

IPH

SPAD
Mobile Data Collection Cart

**USDA/ARS, Mayaguez, Puerto Rico**

*Based on design of: White and Conley. 2013. Low cost cart for proximal sensing. Photo: Isabela, PR (R. Goenaga)*

**Designer/Operator:** Jesus Linares

**Collaborators**

Tim Porch, USDA/Mayaguez, leader
Jesus Linares
Mobile Data Collection Cart

Improvement on Original Design

Location Sensor
(GPS-RTK)

NDVI, Biomass Sensor
(Plant canopy reflectance)

Canopy temperature sensor
(Infrared radiometers)

Plant height sensor
(Ultrasonic Distance Sensor)
Validation

Plant Height QTL on Pv07

INB 841 x RCB 593 RIL population

<table>
<thead>
<tr>
<th>Date</th>
<th>Marker</th>
<th>Position</th>
<th>LOD</th>
<th>Other Pop.</th>
</tr>
</thead>
<tbody>
<tr>
<td>36 DAP</td>
<td>S7_50,538,695</td>
<td>Pv07: 50,538,695</td>
<td>6.88</td>
<td>BeanCAP, AM100</td>
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<tr>
<td>57 DAP</td>
<td>S7_47,147,541</td>
<td>Pv07: 47,147,541</td>
<td>5.24</td>
<td>BeanCAP, AM100</td>
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<tr>
<td>63 DAP</td>
<td>S7_47,387,581</td>
<td>Pv07: 47,387,581</td>
<td>6.04</td>
<td>BeanCAP, AM100</td>
</tr>
</tbody>
</table>

Cart functioning properly!!!
Canopy Temperature: Drought Stress

**Evaluation of Base120 Common Bean Panel**

<table>
<thead>
<tr>
<th>Phvul gene model</th>
<th>Chrom.</th>
<th>Start</th>
<th>End</th>
<th>At symbol</th>
<th>At description</th>
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</thead>
<tbody>
<tr>
<td>Phvul.004G166400</td>
<td>4</td>
<td>44,862,449</td>
<td>44,865,654</td>
<td>AT4G29080.1</td>
<td>Phytochrome-associated protein 2</td>
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<tr>
<td>Phvul.011G173200</td>
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<td>44,624,028</td>
<td>44,627,578</td>
<td>AT4G31940.1</td>
<td>Cytochrome P450, family 82, subfamily C, polypeptide 4</td>
</tr>
</tbody>
</table>
Bean Plant Architecture

Durango Bean Growth Habit

**Type III Growth Habit**

*First:* Dry, cut and windrow beans

*And then:* Thresh and harvest beans

**Type II Growth Habit**

*One step direct harvest*

- What **genomic regions/genes** control the trait?
- How might the trait be scored?
  - **Stem strength**
Shear Strength

Variable Stem Strength in Common Bean

Collaborators

Sreekala Bajwa Group (NDSU)

Juan Osorno, Ali Soltani (NDSU)

Maximum force to break stem

Area under curve (normalized)
Shear Strength

Shear Strength and Growth Habit QTL Correlated

Shear Test QTL = Growth Habit QTL
- Pleiotropic effect of the same gene(s)!!!
  - RING/U-Box or RLK???

Maximum Load

Area Under Curve, Normalized

Growth Habit (previous trial)
Review

Low-altitude, high-resolution aerial imaging systems for row and field crop phenotyping: A review

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UAV Sensing

Unmanned Aircraft Vehicles

Drone Technology in Action

Collaborators

Phil Miklas
USDA/ARS
Prosser, WA

Sindhuja Sankaran
Wash St Univ

Drone Imagery
UAV Sensing

Unmanned Aircraft Vehicles

Figure 3. Correlation between NDVI measured at the R3 growth stage and seed yield (kg ha\(^{-1}\)) for the 20 most drought susceptible lines under terminal drought stress (DS), Othello, WA, 2014. **, represents significance at 0.01 level of probability.

NDVI Difference Vegetation Index
- Normalized
- Measure of greenness
- Photosynthesis trait
  - Affected by drought
  - NDVI lower under drought
  - Correlated with yield
NDVI correlated with:

- Flowering and maturity date
- Under stress and non-stress conditions
- Response different for drought tolerant/susceptible genotypes
Acknowledgements

McClean Lab

Samira Mafi Moghaddam
GWAS, Candidate gene discovery

Sujan Mamidi
Read mapping, SNP discovery

Rian Lee
Lab Management