Improving California Wheat for Grain & Forage

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Work funded by:
- California Wheat Commission / CCIA
- USDA-NIFA
- HHMI-GBMF
The wheat breeding program

- **Common wheat**
  - Increase yield (1,182 lb/ac since 1995)
  - Improve disease resistance
  - Improve drought tolerance
  - Improve nutritional value

- **Durum wheat**
  - Increase yield: 450 lb/ac since 1995
  - Reduce cadmium content in the grain
  - Increase pasta quality
  - Increase percent of resistant starch
Post-2000 wheat stripe rust epidemics

New races detected in CA in 1999
Sequencing their genomes we now know that these new races came from Asia

The post-2000 stripe rust races resulted in large economic losses

In 2003 25% of the wheat crop was lost to stripe rust

We lost most of the CA varieties

- Dirkwin
- Summit
- Blanca Grande
- Yecora Rojo
- Dirkwin
- Express
- Bonus
- Brooks
- Stander
Recovering CA varieties by MAS

<table>
<thead>
<tr>
<th>% of Dirkwin</th>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% + 50% +</td>
<td>Dirkwin   X Madsen Yr17</td>
</tr>
<tr>
<td>50% + 75% +</td>
<td>Dirkwin   X F1 hybrid</td>
</tr>
<tr>
<td>75% + 87% +</td>
<td>Dirkwin   X Back Cross 1</td>
</tr>
<tr>
<td>87% + 94% +</td>
<td>Dirkwin   X Back Cross 2</td>
</tr>
<tr>
<td>94% + 97% +</td>
<td>Dirkwin   X Back Cross 3</td>
</tr>
<tr>
<td>97% + 98% +</td>
<td>Dirkwin   X Back Cross 4</td>
</tr>
<tr>
<td>98% + 99% +</td>
<td>Dirkwin   X Back Cross 5</td>
</tr>
<tr>
<td>99% + 99% +</td>
<td>Back Cross 6 Self pollination</td>
</tr>
</tbody>
</table>

Selection for Yr5 Dirkwin/Avoet-Yr5
* Dirkwin BC2
* Dirkwin BC3
* Dirkwin BC4
* Dirkwin BC5
* Dirkwin BC6

Selection for Yr15 Dirkwin/Avoet-Yr15
* Dirkwin BC2
* Dirkwin BC3
* Dirkwin BC4
* Dirkwin BC5
* Dirkwin BC6

Selection for Yr17 Madsen/Dirkwin
* Dirkwin BC2
* Dirkwin BC3
* Dirkwin BC4
* Dirkwin BC5
* Dirkwin BC6

NEW Dirkwin Yr5 Yr15 Yr17
Recovered CA varieties by MAS

- Dirkwin: Converted into **New Dirkwin** \((Yr5 + Yr15 + Yr17)\)
- Anza: converted into **Lassik**: with HP and gluten strength genes
- Expresso: converted into **Expresso** \((Yr5 + Yr15)\)
- Summit: converted into **Summit 515** \((Yr5 + Yr15)\)
- Blanca Grande: converted into **Blanca Grande 515** \((Yr5 + Yr15)\)
- Patwin: converted into **Patwin 515** \((Yr5 + Yr15 + Yr17)\)
- Kern: converted into **Kern 515** \((Yr5 + Yr15 + GPC)\)

**UCD & industry wheat varieties developed in collaboration with UC covered** **151,000 acres** **in 2014** *(27% of CA wheat acreage)*
Association Mapping: linking genotype and phenotype

- 1000 bread wheat accessions
- 9000 markers
- Evaluations 3 locations x 2 years

Comparison of 7 subpopulations showed Increased resistance in south Asia

Phenotype 875 accession 6 loc.
Association Mapping: linking genotype and resistance phenotype

• We identified 10 major *Pst* resistance genes (+87 minor resistance genes!)
• We initiated validation and deployment in CA varieties
Sr35: identifications of the 1st gene conferring immunity to Ug99

- Expression of this gene in transgenic wheat plants result in resistance to Ug99
- Cassettes with multiple resistance genes can be incorporated in transgenic wheat
- We are also incorporating the natural allele using non-transgenic approaches
Molecular markers for drought tolerance

The distal 1RS segment is associated with significant increases in yield under normal and limited irrigation (~2000 lb/acre!). (consistent in 5 year experiments, isogenic lines)

The distal 1RS segment is associated with:
- Improved canopy water status
- Higher stomatal conductance.

The plants with the distal 1RS segment have increased access to water!

Theoretical and Applied Genetics 2014
1st UC Low Cd Durum Wheat MIWOK:

**2013 Imperial Cadmium levels**

- Miwok: 200 ppb
- Desert King: 400 ppb
- Kronos: 200 ppb

**Marker for low Cd**

- 1kb Not digested
- Kofa
- MIWOK
- Commander
- Strongfield
- UC1308
- LDN

**Yield 2013 Regional Durum Imperial**

- Miwok: 6500 lb/acre
- ORITA: 5500 lb/acre
- PLATINUM: 5000 lb/acre
- TOPPER: 4500 lb/acre
- DESERT KING: 4500 lb/acre
- FORTISSIMO: 4500 lb/acre
- VOLANTE: 4500 lb/acre
- HAVASU: 4500 lb/acre
- WESTMORE: 4500 lb/acre
- MAESTRALE: 4500 lb/acre
- SARAGOLLA: 4500 lb/acre
- WB-MOHAVE: 4500 lb/acre

**Yield 2013 Regional Durum Fresno**

- Miwok: 6500 lb/acre
- PLATINUM: 5500 lb/acre
- TOPPER: 5500 lb/acre
- DESERT KING: 5500 lb/acre
- FORTISSIMO: 5500 lb/acre
- VOLANTE: 5500 lb/acre
- WESTMORE: 5500 lb/acre
- MAESTRALE: 5500 lb/acre
- SARAGOLLA: 5500 lb/acre

Miwok is the top yielding line in SJ Valley 2011-2013
Improving resistant starch (RS) in wheat

- Wheat has 75% amylopectin and 25% amylose

- Amylose generate resistant starch that works as dietary fiber

- RS consumption has benefits in the large intestine as well as systemic health benefits (reduced risk of diabetes, obesity, heart disease, and cancers of the colon and rectum)

- Breads and cooked cereals/pastas contribute ~40% of RS intake, but they have very little RS

- An improvement in the amount of RS in wheat can satisfy the recommended intake of RS
Engineering the starch biosynthetic pathway

We have sequence 90,000 genes in 1500 line and identified 3,000,000 mutations. We can knock out any gene of wheat!

Example: Knock out all SbeII

- Found mutations in SbeIIb genes
- Backcrossed 2 generations
- Combined the 4 mutations

Effect of sbeIIa + sbeIIb quadruple mutant on amylose and RS

MUT: Davis 40% / Tulelake 54.4 % amylose

MUT: Davis 2.9%/ Tulelake 3.7% RS
Small Grains Regional Trials

2014. 13 locations
Phil Mayo, Diane Prato-Mayo and Sam Fraser

Comparison of public and private varieties performance in
- Irrigated
- Rain Fed

Agronomy Progress Report 318 (2014)
http://smallgrains.ucdavis.edu/
Small Grains website

http://smallgrains.ucdavis.edu/ Agronomy Progress Report 318

• Cultivar performance
  – 13 locations

• Disease resistance notes
  – Stripe rust
  – Leaf rust
  – Septoria
  – BYDV

• Quality evaluations (CWC)
  – Bread quality
  – Pasta quality

• 2014 results available
  – 46 Tables organized by crop & location

Small Grains
University of California

Summary of yield performances (2012-2014)
Wheat & triticale (Sacramento, San Joaquin, Imperial Valley & rainfed)
Durum wheat (Sacramento, San Joaquin, & Imperial Valley)
Barley (Sacramento and San Joaquin Valley & rainfed)

Agronomy Progress Reports (all crops, all locations)
2014 (No. 318) (for a complete PDF click here)
2013 (No. 316) (for a complete PDF click here)
2012 (No. 314) (for a complete PDF click here)
2011 (No. 304) 2006 (No. 293) 2001 (No. 276)
2010 (No. 303) 2005 (No. 290) 2000 (No. 272)
2009 (No. 301) 2004 (No. 288) 1999 (No. 265)
2008 (No. 296) 2003 (No. 286) 1998 (No. 262)
2007 (No. 295) 2002 (No. 279)
California grows 200,000 to 230,000 acres of Oat (2\textsuperscript{nd} only to TX)

Oat is a crop of multiple uses but in CA is predominantly grown as forage, silage, hay or green chop

**Objectives:**

1) incorporate additional resistance to CYDV and BYDV
2) transfer the early flowering of Montezuma
3) develop a healthier, more productive UC cultivar
4) develop grain oat cultivars. There is interest by millers in organic oats
Disease Resistance to:

Aphid (virus) damage

Methods:
Conventional Breeding
New crosses and Introductions
Modified bulk in early generations
Pedigree selection in advanced generations
Replicated Experiment to evaluate grain yield

With some help:
we can incorporate marker assisted selection and replicate the success story from wheat!
Training the new breeders

10 PhD trained, 6 more in progress!

THANK YOU!
A public resource to modify most wheat genes

- We sequenced 90,000 genes from 1500 tetraploid wheat mutant lines
- We identified 3,000,000 mutations in genes regions
- We generated a searchable public database (available mid 2015)
- We can knock out most wheat genes (non GMO)
- We generated a huge amount of new variability.

Gene of interest

Request seed