Shaping Wheat for the Future: Leveraging the Wheat genome in Crop Efficiency Research and Breeding

John Jacobs
January 12, 2016
Agenda

- Why is Bayer investing in Wheat
- Pillars of Bayer’s Wheat strategy
- Examples from R&D
- Bayer and the IWGSC
- New era for the wheat genome
Wheat Yield Frontiers

- Based on Bio-Physical limits
- Potential Yield (Plot Trials)
- Top Quartile Farmers

<table>
<thead>
<tr>
<th>Country</th>
<th>Ave. Yield t/ha</th>
<th>Potential Yield t/ha</th>
<th>% Gap</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yaqui valley, Mexico</td>
<td>6</td>
<td>9</td>
<td>50%</td>
</tr>
<tr>
<td>Punjab, India</td>
<td>4.3</td>
<td>6.25</td>
<td>45%</td>
</tr>
<tr>
<td>Haryana, India</td>
<td>4.2</td>
<td>5.75</td>
<td>35%</td>
</tr>
<tr>
<td>Western Australia</td>
<td>1.8</td>
<td>2.6</td>
<td>45%</td>
</tr>
<tr>
<td>N Dakota, USA</td>
<td>2.5</td>
<td>3.7</td>
<td>50%</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>8.2</td>
<td>10.4</td>
<td>25%</td>
</tr>
<tr>
<td>Eastern China</td>
<td>4.7</td>
<td>7.0</td>
<td>50%</td>
</tr>
<tr>
<td>Kansas, USA</td>
<td>2.6</td>
<td>3.9</td>
<td>45%</td>
</tr>
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Source: FAO Expert Meeting on How to Feed the World in 2050 (Rome, 24-26 June 2009)
Potential of Wheat Seed/Trait market

![Graph showing the potential of wheat seed/trait market with data from Sigma Seed Gfk (data 2013).]
Why is **Bayer** investing in the Wheat Seeds & Traits market?

**No. 1**
WHEAT = key part of our business today

**No. 2**
NEW technology in breeding and traits can expand the yield frontier

**No. 3**
Integrating research, breeding and agronomy can deliver new solutions
Bayer CropScience investing EUR 1.5 billion in new solutions in cereals from 2010 to 2020
Bayer’s Seeds and Traits strategy

Traits and technology
Build competitive GM and non-GM trait platform via:
- In-house expertise
- Strategic partnerships

Germplasm and breeding
- Access global germplasm for synthesis into a regional breeding efforts
- Working to bring enhanced yield and yield stability through hybrids

Enabling Technologies
Build competitive enabling technologies to rapidly process candidate traits through pipeline

Unique technology offerings within Bayer CropScience
The hybrid wheat challenge…
How to produce economically at scale

**Todays “line” varieties**

- **Self pollinating:**
  - 100% seed recovery from area

**Todays hybrid system**

- **Strip planting:**
  - Harvest females: 60%–70% seed recovery
  - Chemical gametocide timing critical

**We test hybrid crosses**
Plan to address the challenges of earlier hybrid wheat production approaches by deploying new technology
Crop Efficiency: The use of a broad range of technologies to improve plant characteristics with the primary intention of increasing yield.

Target: Crop Efficiency

Expanding the yield frontier

Exploiting today's potential

Breeding

Chemistry

Biologicals

Traits
Crop Efficiency Research Strategy: focus on yield components

- Phenotypic trait
- Biological process
- Modified plants
- Biological expertise
- Crop & Breeding Expertise
- Omics
- Data mining
- Native
- GM
- Non-GM
- Tools to enable idea
- Idea to improve crop
- Consistent
- Focussed
- Stringent

Product concept
So where does the wheat genome fit in???

Everywhere!!!
SNP mining and QTL anchorage on sequence scaffolds
From map-based cloning to QTL Causal Gene mining

Original QTL region, few and highly fragmented sequence anchor points

Long and tedious process of map-based cloning for each locis of interest to arrive at small set of likely candidates

Original QTL region, immediate understanding of full gene content in reference line

Computational overlay with other omics data allows extraction of candidate gene list for evaluation and for experimental validation

Map-based cloning process becomes cheaper and faster

Requires complete and well-annotated (reference) genome
Translational biology

- **Translational biology**
  - Is that gene available in my crop?
  - Does it have the same expression pattern?
  - Which is the functional/structural ortholog?
  - Has it been selected for in domestication or breeding?

- **Annotation**
  - What is the function of my “new” wheat gene?

- **Sequence assembly**
  - How should I assemble these contigs? Are they part of the same gene or paralogous?
Orthology inference

- Best-Recip. BLAST/OrthoMCL perform poorly when high redundancy
- Orthologous Matrix is a better alternative
- Collaboration to develop OMA for Bayer crops
  - Christophe Dessimoz project lead
  - Henning Redestig Bayer lead
  - Natasha Glover Post-doc
  - Ivana Pilizota, Alex Warwick-Vesztrocy PhD

Requires complete and well-annotated (reference) genome
Translational genetics: circadian clock and wheat yield

Hypothesis: The circadian clock co-determines yield and yield associated traits in wheat

- PhD Student: Lukas Wittern
- Supervisors: Alex Webb (Cambridge), Andy Greenland (NIAB) & Matthew Hannah (Bayer)
Positioning clock gene orthologs on the draft wheat genome

- 2015: Arabidopsis gene -> wheat ortholog -> CSS contig -> SNP -> genetic map
- 2016: Arabidopsis gene -> wheat ortholog -> Draft genome assembly

**Requires complete and well-annotated (reference) genome**
Linking clock gene orthologs to phenotypic traits…

An Eight-Parent Multiparent Advanced Generation Inter-Cross Population for Winter-Sown Wheat: Creation, Properties, and Validation

Ian J. Mackay,* Pauline Bansept-Basler,* Toby Barber,* Alison R. Bentley,* James Cockram,* Nick Gosman,* Andy J. Greenland,* Richard Horsnell,* Rhian Howells,* Donal M. O’Sullivan,* Gemma A. Rose,* and Phil J. Howell*
*The John Bingham Laboratory, National Institute of Agricultural Botany (NIAB), Cambridge, CB3 0LE, United Kingdom
ORCID ID: 0000-0002-2605-2314 (I.J.M.)

Multiple Quantitative Trait Analysis Using Bayesian Networks

Marco Scutari,* Phil Howell,* David J. Balding,* and Ian Mackay*
*Genetics Institute, University College London (UCL), London WC1E 6BT, United Kingdom
and ¹National Institute of Agricultural Botany (NIAB), Cambridge CB3 0LE, United Kingdom

Bayer CropScience
Bayer and IWGSC

November 2011
• Bayer joined IWGSC

December 2013
• Bayer-sponsored project (€1 mio)
  “Whole Genome Profiling BAC libraries and physical map construction 8 chromosome arms

November 2015
• Bayer-sponsored project (€420K)
  “Whole Genome Profiling of BAC minimal tiling paths for 14 chromosomes

Jointly with: CNRGV, INRA, KeyGene and Abraham Korel
A new era for the wheat genome!

- Whole wheat genomes can be delivered in large scaffolds within a few months at a fraction of the cost
- One reference genome is not enough to capture all larger-scale variation (SV, introgressions, ...)
- There will be multiple wheat genomes before the end of this year!
- Consistency and high-quality must be assured
Proposed future role of IWGSC in partnering with Industry & Academia

IWGSC can continue to serve the wheat community
- Provide core set high resolution, high-quality reference genomes
- Coordinate annotation and additional data layers on core reference genomes
- Nurture community, ensure quality and standards

Wheat community and Industry can leverage the information of public reference genomes in “private” and collaborative wheat genome projects
Wouldn’t it be great if the largest crop genome had the best platform!?
Thank you
Bayer’s focus on Integrated Solutions

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<thead>
<tr>
<th></th>
<th>Chemicals</th>
<th>Biologicals</th>
<th>Traits</th>
<th>Seeds</th>
<th>Target focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Weed Management Systems for grass &amp; broad-leaved weeds</td>
<td>✔</td>
<td></td>
<td>✔</td>
<td></td>
<td>EXPLOIT</td>
</tr>
<tr>
<td>2. Disease management which meets regulatory demands, provides excellent disease control, &amp; yield benefits beyond disease control</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
<td>EXPLOIT</td>
</tr>
<tr>
<td>3. Deliver Yield gains</td>
<td>✔</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>EXPAND</td>
</tr>
</tbody>
</table>
Wheat Seed Investments since 2010

7 wheat breeding stations across main wheat-growing areas now operating

- Fargo, USA*
- Saskatoon, Canada*
- Lincoln, USA*
- Milly-la-Forêt, France
- Innovation Center in Ghent, Belgium
- Gatersleben, Germany
- Mironovka, Ukraine
- Horsham, Australia

Major alliances with world-class players in wheat breeding & technology

- 2010 Strategic decision to build global wheat seeds business
- 2015 Launch of first Bayer wheat varieties
- >2020 Hybrid seed varieties, locally-adapted with higher yield potential