Perspectives on Applied Aspects of Breeding for Rust Resistance

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Panelists:

- Vinod Prabhu, Indian Agricultural Research Institute (India)
- Goodarz Najafian, Seed and Plant Improvement Institute (Iran)
- Peter Njau, Kenya Agricultural Research Institute (Kenya)
- Francois Koekemoer, Sensako (South Africa)
- Jim Anderson, University of Minnesota (USA)
- Yuchun Zou, Sichuan Academy of Agricultural Sciences (China)
A successful variety is the sum of various traits-integrating simultaneous improvement for multiple traits is the only way forward

Core traits (ideally should be present in all CIMMYT wheats)

- High and stable yield potential
- Durable resistance to Rusts-Stem (Ug99), Stripe and Leaf
- Water use efficiency/ Drought tolerance
- Heat tolerance
- Appropriate end-use quality

Additional traits for specific mega-environments

- Durable resistance to diseases and pests
  - Septoria leaf blight (ME2)
  - Spot Blotch (ME5)
  - Tan Spot (ME4)
  - Fusarium – head scab and myco-toxins (ME2/4/5)
  - Karnal bunt (ME1)
  - Root rots and nematodes (ME2)
- Enhanced Zn and Fe concentration (ME1/5)
Challenges to wheat breeding

- Under resourced programs—financially and human—(some other crops more remunerative than wheat)
- High expectations for making fast progress with complex traits such as grain yield, stress tolerance, end-use quality, durable disease resistance
- Inadequate phenotyping facilities to detect smaller differences (often high CVs in trials, disease nurseries)
- Poor training in universities for field based research

**Stronger collaboration and partnerships essential**
Breeding for rust resistance

- Longer-term objective versus short-term emergency response to handle situations such as Ug99, aggressive yellow rust race
- Only few investing on the search for new resistance genes but many programs worldwide depend on this—potentially leading to limited genetic diversity at a given time
- Many publications on linked markers for resistance genes but only few useful when tried by breeding programs—cost and logistics remains a major issue
- Understanding the genetic basis of resistance in varieties is often post analysis—a reality unlikely to change unless diagnostic markers for effective resistance genes are developed
Race-specific resistance to stem rust on 6DS

- Race-specific gene for Ug99 resistance mapped on 6DS in several CIMMYT/US wheats
- Similar effects as *SrTmp* or *SrCad*
- Close to *Sr42*
- Resistance enhanced with other APR genes

Lopez-Vera et al. 2013 (manuscript under review)
Utilizing and deploying resistance more responsibly - gene stewardship

- Evergreen debate however unlikely to happen unless
  - ?
  - ?
- Importance of larger genetic diversity for resistance genes versus few genes used more responsibly
- Using race-specific vs. quantitative adult plant resistance
- Role of multi-pathogen resistance genes such as ABC transporter Lr34/Yr18/Sr57/Pm38/Sb1/Bdv1 in conferring resistance durability
- Scientists of various disciplines working together

Resistance breeding need to remain simple for adoption by large number of breeding programs
Building complex adult plant resistance to stem rust for durability

Diversity for slow rusting, minor \( S_r \) genes: 13 genomic regions identified in CIMMYT wheat through bi-parental and association mapping studies

Four genes with pleiotropic genetic effects on multiple diseases now known:

\( S_r 2/Y_r 30/L_r 27/P_m, L_r 34/Y_r 18/P_m 38/S_r 57, L_r 46/Y_r 29/S_r 58/P_m 39, L_r 67/Y_r 46/P_m 46/S_r 55 \)
Integrating resistance to Ug99 race of stem rust fungus in CIMMYT wheats

Mexico (Cd. Obregon-Toluca/El Batan) - Kenya International Shuttle Breeding: a five-year breeding cycle

- Cd. Obregón 39 masl
  High yield (irrigated), Water-use efficiency, Heat tolerance, Leaf rust, stem rust (not Ug99)

- El Batán 2249 masl
  Leaf rust, Fusarium

- Toluca 2640 masl
  Yellow rust
  Septoria tritici
  Fusarium

- Njoro, Kenya 2185 masl
  Stem rust (Ug99 group)
  Yellow rust

- Targeted crosses for shuttle breeding made in 2006 and 1st group of populations planted in Kenya in 2008
- 2000 F3/F4 populations undergo Mexico-Kenya shuttle
- High yielding, resistant lines derived from 1st group of Mexico-Kenya shuttle distributed worldwide in 2011, 2012 and 2013
Progress in grain-yield potential of new bread wheat lines developed since the launch of Borlaug Global Rust Initiative (1st year yield data from: Ciudad Obregon, Mexico 2005, 2010 and 2013)

Several fold increases in new breeding lines derived from crosses made progressively over years with higher yields than the checks.
Ug99 stem rust resistance in 604 wheat entries included in various international trials for distribution in 2013/2014

<table>
<thead>
<tr>
<th>Adult plant resistance category</th>
<th>Stem rust severity (%)</th>
<th>Entries No.</th>
<th>%</th>
<th>Race-specific genes</th>
<th>Entries No.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Near-Immune Resistant</td>
<td>1</td>
<td>19</td>
<td>3</td>
<td>Sr13</td>
<td>27</td>
<td>4</td>
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<tr>
<td>Resistant</td>
<td>5-10</td>
<td>52</td>
<td>9</td>
<td>Sr22</td>
<td>7</td>
<td>1</td>
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<tr>
<td>Resistant- Mod. Res.</td>
<td>15-20</td>
<td>133</td>
<td>22</td>
<td>Sr25</td>
<td>54</td>
<td>9</td>
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<tr>
<td>Moderately Resistant</td>
<td>30</td>
<td>71</td>
<td>12</td>
<td>Sr26</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sr1A.1R</td>
<td>9</td>
<td>1</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sr42: 6DS gene</td>
<td>88</td>
<td>15</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SrHuw234</td>
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<td></td>
<td>SrND643</td>
<td>74</td>
<td>12</td>
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<td></td>
<td></td>
<td></td>
<td>Sr?</td>
<td>12</td>
<td>2</td>
</tr>
</tbody>
</table>

46% entries possess high to adequate adult-plant resistance & another 46% carry diverse race-specific resistance genes often in combination with Sr2 and other minor APR genes
Increased yield potential of new wheat varieties contributes to enhance productivity in farmers’ fields and fast adoption.

Average wheat grain yield trends in farmers fields in Yaqui Valley, Mexico from 1951-2013 despite a reduction in number of irrigations from six to four.

**Graph: Grain Yield (kg/ha) vs Year of Harvest**

**Equation:**

\[ \text{Yield} = -1.52 \times 10^{-5} + 78.7 \text{ kg/ha/year} \]

\[ r^2 = 0.887 \]

**Yield Increase/year = 2.13%**

**Table: Yield Increase per Year**

<table>
<thead>
<tr>
<th>Time period</th>
<th>Yield increase per year (%)</th>
<th>Yield increase per year (kg/ha)</th>
<th>R2 Year vs Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>1951-2012</td>
<td>2.15</td>
<td>78</td>
<td>0.882</td>
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<td>1951-1960</td>
<td>4.98</td>
<td>88</td>
<td>0.664</td>
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<td>1961-1970</td>
<td>3.51</td>
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<td>0.410</td>
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<td>1971-1980</td>
<td>1.69</td>
<td>72</td>
<td>0.220</td>
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<td>1981-1990</td>
<td>1.08</td>
<td>54</td>
<td>0.207</td>
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<td>1991-2000</td>
<td>1.59</td>
<td>84</td>
<td>0.449</td>
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<td>2001-2010</td>
<td>1.15</td>
<td>62</td>
<td>0.567</td>
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<tr>
<td>2001-2013</td>
<td>1.63</td>
<td>114</td>
<td>0.553</td>
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**Source:** K. Sayre