Challenges and progress in wheat improvement

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With contributions from other CIMMYT colleagues

CIMMYT, India (a.k.joshi@cgiar.org)
Consumption Kg/person/year
Most wheat production will be in Asia – India and China
Wheat yields have stagnated in NW Europe, but still increasing in China and India.

Source: Cassman, 2014, WFP Iowa
Too many challenges..
How many traits?
Any core trait?
Yield, yield, yield...
We develop new wheat lines and test through out the world
Advanced lines tested in different Es and Ms

- Flat-5 irrigations
- Raised bed-5 irrigations
- Raised bed-2 irrigations
- Flat- drip irrigation
- Raised bed-Late (Feb sown)
- Raised bed-5 irrigations- Early (October Sown)
Grain yield enhancement in new wheat cohorts
under optimum irrigation management

- 1% annual genetic gain continues

Bread wheat variety Borlaug 100 released in 2014 in Mexico with 9% grain yield superiority over Roelfs released in 2007 in Mexico & DPW621-50 released in India

Source: Ravi Singh, CIMMYT-Mexico
Specific examples
A case study of breeding for Biofortified Wheat
“Wheat with high Zinc”
HarvestPlus initiative in wheat

2004-2009 Phase I
Discover genes & sources of variation

2009-14 Phase II
Develop varieties

2015+ Phase III
Deliver to clients

Frequently asked questions in Phase I
• Will it be possible to breed nutrient rich varieties?
• Will such varieties will meet farmers expectations?
• Will these be bioavailable?

Map source: Dave Hodson, CIMMYT
Initial Target Country / Areas for Zinc Wheat

Baseline Micronutrient Level in Commercial Crop: 25 µgg⁻¹

Target Increment to be added: 12 µgg⁻¹

ME1: Temperate Irrigated High Production NWPZ

ME5: Irrigated High Temperate Stress EGPZ

In Phase III, this was expanded to Nepal and Bangladesh

Source: HarvestPlus
Wild relative species are best Zn sources

Wheat Wild Relative Species

- Dicoccoides
- Dicoccum
- Monococcum
- T. spelta
- Wide Crosses

Zinc $\mu g g^{-1}$ vs. Iron $\mu g g^{-1}$
A number of well known steps

**Genetic Variation for Zinc & Iron in Wheat**

- Best Zn sources crossed to elite wheat adapted to target areas

- 3500 lines in 2009

- 1400 Selected

- Zn/Fe determined & advanced in Summer Cycle

_Cd. Obregon, March 2009_
From genetic resources to High zinc wheat in farmers’ fields of South Asia in less than 10 years

Progenitors

2017: Biofortified wheat released

T. dicoccon

India (NWPZ)
WB 2 and HPBW01
Two sister Mayil lines (+6 ppm Zn)

T. durum based Synthetic

India (private sector)
Zinc Shakti; Extra-early, +14 ppm Zn (40% increase)

T. spelta

Pakistan
Zincol 2016; +6 ppm Zn
2000 tons of seed sown in 2016-17

Source: Ravi Singh and Govindan Velu
Another example
The Ug99 experience

stem (black) rust fungus

• 13 races now known
• Presence in 13 countries confirmed
• Localized epidemics in Ethiopia, Kenya & other east African countries
There are too many genes. What will work?

Source: www.publish.csiro.au/
Shuttle breeding with Kenya was the key

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

- **Toluca 2640 masl**
  - Leaf rust, Fusarium

- **El Batán 2249 masl**
  - Leaf rust, Fusarium
  - Tan spot

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

- Mexico-Kenya Shuttle breeding initiated in 2006
- About 2000 F3/F4 populations undergo shuttled annually
- High yielding, resistant lines distributed worldwide since 2011
Ug99 was blocked by resistant varieties
A new challenge?
Wheat blast: a new challenge in south Asia
Wheat Blast vulnerable areas in South Asia
Best yielding lines are now evaluated against wheat blast at Bolivia & B’desh
Bari Gom 33 (KACHU/SOLALA)
Resistant to wheat blast; also Biofortified
Grain Zn 50-55 ppm; TGW 45-52 g

First blast resistant variety of wheat released in Bangladesh in 2017
Resistance obtained through 2NS translocation from *Aegilops ventricosa*

- Line with 2NS segment show 85% reduced infection
- This segment also has rust (*Lr37, Sr38, Yr17*) and nematode resistance
- Molecular marker already available (*Helguera et al. 2003*)

*Cruz et al, 2016, Crop Science*
International collaboration for wheat blast

Bolivia: Identified in 1996

Argentina: At Chaco in 2007

Paraguay: First time observed in 2002

Brazil: Identified for the first time in the state of Parana 1985

Bangladesh: First report 2016
How we top up knowledge?
70,000 wheat genetic resources screened under heat stress at Mexico

~0.8m wheat genetic resources exist in collections worldwide

Source: M. Reynolds
Impact of Temperature on Wheat Yaqui Valley, Sonora, Mexico

$Y=11.55 - 0.65X$

$R^2=0.75$

4.4 $^\circ$C variation in 30 years

January-April Average Minimum Temperature $^\circ$C

1°C increase = 700 kg lower yield

New variety: CIRNO C2008

Old varieties

Source: H.-J. Braun and I. Ortiz-Monasterio, CIMMYT
Very late sown trials with different moisture regimes
Genomic selection has been introduced
Grain yield up to 8.67 t/ha

### Pusa
- **Sup 152** (6.51 t/ha; **19**)
- **Sup/Baj#1** (4.80 t/ha; **160**)
- **Sup/Baj#1** (5.02 t/ha; **152**)
- **NADI** (7.20 t/ha; **70**)

### Ludhiana
- **Kachu#1** (6.6 t/ha; **85**)
- **MISR#1 = NARC 2011** (6.02 t/ha; **87**)
- **Munal#1** (7.03 t/ha; **07**)
- **MUCUY** (7.51 t/ha; **65**)

### Jabalpur
- **Seher #06** (7.58 t/ha; **61**)
- **MISR#1 = NARC 2011** (7.52 t/ha; **21**)
- **Sup/Baj#1** (7.53 t/ha; **153**)
- **KEDEA** (8.67 t/ha; **78**)

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**Yield (t/ha)**

**2013-14 (540 lines)**

**2014-15 (660 lines)**

**2015-16 (660 lines)**

**2016-17 (660 lines)**
12.4 t/ha

Iran
(Spring wheat)

Source: Jalal Kamali, CIMMYT-Iran
The CGIAR provides 80% of seed distributed annually.

Half of it is Maize and Wheat seeds.

Source: GCDT; online database collections, publications and communications between GCDT and responsible banks, 2008-2010.

Source: Tom Payne, CIMMYT-Mexico
Conclusion

There is substantial progress in breeding high yielding, stress tolerance in wheat varieties. However, challenges are equally threatening. Much more effort is required.
“Only breeding improved varieties is not enough; there must be a combination of strategies – almost everything ......”
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