Reflections on Past and Future

INDIA-CIMMYT Collaboration on Wheat Improvement

Hans-Joachim Braun

CIMMYT, Global Wheat Program, Mexico

ICAR-IIWBR
September 8, 2020
Wheat Production 1961 to 2015: Global, in developing and developed countries (000 tons)

Data Source: FAO, USDA. Compiled by H.-J. Braun
India Wheat Yield and Production continues to grow at linear rates

Source: FAO, USDA
Average National Wheat Yield of Major Wheat Producers

Source: Compiled by H.J.Braun  Data: USDA
10 year average global wheat yield and average yield increase during a decade

Mean Yield kg/ha
3500
3000
2500
2000
1500
1000

Global

India

10yr yield increase kg/ha
700
600
500
400
300
200
100
0

Mean Yield
Global Yield gains
India Yield gains

Data: FAO, USDA Compiled by H.-J.Braun
Concentration trends in the seed industry, 1985–2016

Market share of the five biggest companies

Source: Bonny 2017.
Private and Public Sector Partners in International Wheat Improvement Network (IWIN): Key to Delivering Impacts

Locations receiving CIMMYT nurseries

Source: K. Sonders CIMMYT
Benefits from IWIN - Key points from survey

• No other crop where one central breeding program has been so dominating
• Model had impact far beyond wheat since it served as model for other crops
  IRRI first International Center but Wheat first international program
• Has united and standardized the global wheat community to a unique language –
  we understand each other
• Brings together the global genetic diversity – melting pot for alleles. Increasingly
  important as free germplasm exchange becomes more and more difficult
• Only publicly available source for improved and genetically diverse germplasm –
  paramount since IP laws have shut down much of germplasm exchange
Impact of CGIAR Wheat Breeding Germplasm

Percent of Spring bread wheat releases derived from CIMMYT and ICARDA by region and origin 1994-2014

Note: Percent release roughly represents area sown to CIMMYT derived wheat varieties

Our germplasm goes to about 50 locations

Map source: Prasun Gangopadhyay, BISA
The size of the font indicates the relative size of the distribution

Source: T. Payne, CIMMYT
If you desire peace, cultivate justice, but at the same time cultivate the fields to produce more bread; otherwise there will be no peace.”

“The first essential component of social justice is adequate food for all mankind. Food is the moral right of all who are born into this world.”

Dr. Norman E. Borlaug (1914-2009)
Results are based replicated yield trials of 600 genotypes
One possible region of nearly linear increase is testing of more lines per year
in Mexico
1. For the first time in South Asia, 10 t/ha grain yield achieved (location: BISA, India)
2. To see the potential of CIMMYT lines, DG ICAR desired first coordinated high yield trial for fast track varietal release which is in place now

<table>
<thead>
<tr>
<th>Yield (t/ha)</th>
<th>No. of Lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0</td>
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<td>4.2</td>
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<td>4.4</td>
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<td>5.8</td>
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<td>6.0</td>
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<td>7.0</td>
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<td>7.2</td>
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<td>7.4</td>
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<td>9.4</td>
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<td>9.8</td>
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<td>10.0</td>
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<td>10.2</td>
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<tr>
<td>10.4</td>
<td></td>
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<tr>
<td>10.6</td>
<td></td>
</tr>
</tbody>
</table>

Additional: 1st biofortified wheat released in India
EAT–Lancet Commission report on healthy diets from sustainable food systems

- Food production today already unsustainable
- Cereals will remain important in future diets (1/3 calories & protein contribution)
- Investments to increase cereal systems productivity / efficiency paramount

*Figure 5: Environmental effects in 2010 and 2050 by food groups on various Earth systems based on business-as-usual projections for consumption and production*
We estimate the cost of three diets

- **Cost of Calorie Adequacy (CoCA)**
  - minimum cost to meet energy requirements using the least cost available starchy staple food in each country

- **Cost of Nutrient Adequacy (CoNA)**
  - minimum cost to meet energy and nutrient requirements (23 macro and micro-nutrients, with upper as well as lower bounds)

- **Cost of Recommended Diet (CoRD)**
  - Minimum cost to meet food-based dietary guidelines, based on food group classifications

Anna Herforth et al., 2020
Main results: Global average costs

- $0.79 per day to meet daily energy needs using the most affordable starchy staple
- $2.34 per day to meet all essential nutrient requirements
  - no requirement for proportionality/palatability
- $3.75 per day (range $3.29 to $4.58) to meet dietary recommendations
  - we use 10 different definitions of a healthy diet published by UN member states (no single definition of a healthy diet)
The future of Wheat – Wheat Berries

908 g Hard Red Spring = Wheat Berries

103 MPesos = 5.5. US$ / kg

6046 US$ / ton of wheat

Farm Wheat Price: 202 $/ ton

30 x what a farmer gets
A healthy diet is unaffordable for the poor in every region of the world.

a) Cost of an energy sufficient diet compared with the international poverty line.

b) Cost of a healthy diet compared with the international poverty line.

NOTES: Maps show the affordability of each of the three reference diets (energy sufficient, nutrient adequate and healthy diet) by comparing the cost of each of them with the international poverty line (USD 1.90 PPP a day) in 155 countries in year 2011, converted to local currency.
Peer-reviewed research shows that micronutrient deficiency is “likely to remain problematic under all modelled scenarios” through 2050...

*Source: World Bank, Nutrition at a Glance country briefs
** Source: Nelson et al., Nature Sustainability (2018)
Zinc enriched wheat varieties in South Asia

India Released: WB-02, PBWZn-01 (2017)

Pakistan: Zincol 2016; Pipeline variety: NR443

India PVS variety: Zn-Shakti, Chitra (2015)
Pipeline: BHU 31 & BHU 35

India private sector Ankur Shiva (2017)

Nepal: Pipeline variety
NL 1327 & 1328 (expected release 2019-20)

Bangladesh
BARI Gom 33 (2017)
Blast resistant

From genetic resources to High zinc wheat in farmers’ fields of South Asia in less than 10 years with 20-40% more zinc
<table>
<thead>
<tr>
<th>Indicator</th>
<th>High Zinc Wheat Subjects</th>
<th>Low Zinc Wheat Subjects</th>
<th>Days of Sickness Averted For ~1300 Subjects Over 180 Days</th>
<th>Difference Significant at 5% Level of Confidence?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Children 4-6 Years</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Days With Pneumonia</td>
<td>203</td>
<td>244</td>
<td>41</td>
<td>YES</td>
</tr>
<tr>
<td>Days With Vomiting</td>
<td>60</td>
<td>99</td>
<td>39</td>
<td>YES</td>
</tr>
<tr>
<td><strong>Women 15-49 Years</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Days With Fever</td>
<td>999</td>
<td>1092</td>
<td>93</td>
<td>YES</td>
</tr>
</tbody>
</table>

Sazawal et al. 2018
Wheat contribution to daily intake

- Micronutrients
- Vitamins B
- Fibers
- Carbohydrates
- Proteins
- Energy

Source: The UK National Diet and Nutrition Survey 2014
<table>
<thead>
<tr>
<th>Crop/Scenario</th>
<th>Asia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereal Grains</td>
<td></td>
</tr>
<tr>
<td>Barley</td>
<td>9</td>
</tr>
<tr>
<td>Maize</td>
<td>3</td>
</tr>
<tr>
<td>Millet</td>
<td>4</td>
</tr>
<tr>
<td>Rice</td>
<td>2</td>
</tr>
<tr>
<td>Sorghum</td>
<td>6</td>
</tr>
<tr>
<td>Wheat</td>
<td>1</td>
</tr>
<tr>
<td>Roots, Tubers &amp; Bananas</td>
<td></td>
</tr>
<tr>
<td>Banana</td>
<td>16</td>
</tr>
<tr>
<td>Cassava</td>
<td>12</td>
</tr>
<tr>
<td>Plantain</td>
<td>19</td>
</tr>
<tr>
<td>Potato</td>
<td>5</td>
</tr>
<tr>
<td>Sweet potato</td>
<td>11</td>
</tr>
<tr>
<td>Yam</td>
<td>15</td>
</tr>
<tr>
<td>Oilseeds &amp; Pulses</td>
<td></td>
</tr>
<tr>
<td>Beans</td>
<td>14</td>
</tr>
<tr>
<td>Chickpea</td>
<td>20</td>
</tr>
<tr>
<td>Cowpea</td>
<td>17</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>7</td>
</tr>
<tr>
<td>Lentils</td>
<td>18</td>
</tr>
<tr>
<td>Other pulses</td>
<td>13</td>
</tr>
<tr>
<td>Pigeonpea</td>
<td>8</td>
</tr>
<tr>
<td>Soybean</td>
<td>10</td>
</tr>
</tbody>
</table>

**NIPI**

The Nutrient Investment Productivity Index (NIPI) ranks crop-specific productivity growth for its contributions across multiple deficit nutrients.

NIPI sums the rank order values for each nutrient and then ranks the results. The result is an index from 1 - most number of deficient adequacy ratios improved.

Source: Wiebe et al., 2018: Modeling Impacts of Faster Productivity Growth: Inputs to the Multi-Donor Initiative on Crops to End Hunger IFPRI/USDA/Commissioned paper by USAID.

Data Source: FAO / USDA
Slide Source: W.H. Pfeiffer, H+
Wheat and heat and irrigation
Adapting to Climate Change: Heat Tolerant Wheats prove their Value in Farmers’ Fields in Mexico

**Equation:**

\[ Y = 11.55 - 0.65X \]

\[ R^2 = 0.75 \]

**Graph Description:**

- **Y=11.55 – 0.65 X**
- **R²=0.75**
- **1°C increase = 700 Kg lower yield**
- **4.4°C variation from 1981 to 2017**
- **January-April Average min. Temperature °C**
- **Yield increase through breeding**
- **New variety**
- **Old varieties**

Source: H.-J. Braun and I. Ortiz-Monasterio, CIMMYT
WUE! in GxExM context

Yield of CIRNO2008 in Yaqui Valley farmers fields (bed irrigation) and surface drip irrigation on CENEB during 2013 - 2017

Data: S. Mondal et al., paper submitted
Continuous drip irrigation Side study on Irrigation

- Same seed rate, irrigation water and fertilizer given two sets of experiments
  - Difference: one receives water every 7 days (continuous) the other every 25-27 days (interval)

Visible differences observed, High biomass and tillering in both bread wheat and durum wheat.
Trait differences

Differences in other traits under continuous (CI) vs interval irrigation

- Heading: 3-4 days longer in CI
- Maturity: 7 days in BW and 10 days in DW longer in CI
- Biomass: 10% higher in CI, 1t/ha difference
- Grain number & tiller number: 8-10% higher in CI

No difference in Thousand grain weight
Effect of residue mulch, and drip spacing and flood irrigation system on irrigation water productivity ($WP_i$) during two rice and wheat growing seasons (BISA station, Ludhiana) (Jat et al. submitted)
Water (liter) needed to produce 1 kg wheat with various irrigation systems

Source: Compiled by H.J. Braun from various sources
Wheat (kg) produced with annual per capita water consumption of one person

- USA: 295 l / capita / day
- Germany: 130 l / capita / day
- India: 30 l / capita / day

Investments needed to upgrade irrigation systems: 1 tn $ (FAO 2011)
### Summary of case studies on Wheat Yield Progress

<table>
<thead>
<tr>
<th>Region (Wheat MegaEnvironment)</th>
<th>Estimated farm or potential yield (t/ha) and yield gap (%) in 2010</th>
<th>FY</th>
<th>PY</th>
<th>Yield gap (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spring wheat regions</strong> (some examples)</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Yaqui Valley, Mexico (WME1)</td>
<td>6.4</td>
<td>9.0</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td>Punjab, India (WME1)</td>
<td>4.5</td>
<td>7.0</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>Western Australia (^b) (WME4)</td>
<td>1.8</td>
<td>2.6</td>
<td>44</td>
<td></td>
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<tr>
<td>North Dakota, (^b) USA (WME6)</td>
<td>2.5</td>
<td>4.0</td>
<td>60</td>
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</tr>
<tr>
<td><strong>Winter wheat regions</strong> (some examples)</td>
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<td></td>
</tr>
<tr>
<td>Shandong and Henan (WME10)</td>
<td>5.8</td>
<td>8.8</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>United Kingdom (WME11)</td>
<td>8.0</td>
<td>10.7</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>Kansas, (^b) USA (WME12)</td>
<td>2.8</td>
<td>3.8</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td><strong>Average all cases (n = 12)</strong></td>
<td>4.43</td>
<td>(^b)na</td>
<td>48 ± 4</td>
<td></td>
</tr>
<tr>
<td><strong>After weighting for WME production (WME 1 = 23%, WME 6 = 13%, WME 11 = 38%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>World</td>
<td>3.0</td>
<td>4.5</td>
<td>50</td>
<td></td>
</tr>
</tbody>
</table>

**Yield Gap Closure with Genotype, Agronomy, Policy**

Wheat Yield Gap Small in LDC compared to Rice and Maize

Source: Fischer et al (2014)
GAP - Productivity has consistently grown for major cereals

Trends in productivity (q/ha) of major cereals in Ethiopia

- Maize: 212%
- Wheat: 175%
GAP - Productivity has consistently grown for major cereals

Trends in productivity (q/ha) of major cereals in Ethiopia

Productivity (q/ha)

Maize
Wheat
Tef
Barley
Sorghum


8.43 15.0 12.62 15.75 17.48

20.54 29.54 30.59 34.21 39.44

18.60 25.35 27.36
My personal key example for Genotype x Agronomy x Policy

Early sowing in Punjab and Haryana due to new varieties and Happy Seeder result in higher yields – and option for dual purpose wheat – extra fodder

Green dots: Wheat fields
Slide: Amit Srivastava and Prasun Gangopadhyay, CIMMYT India
Data source: NASA
Fast track release for early (Oct) sown in NW India

- Fields are vacated by middle of October
- Early sowing gives higher yield – up to 9 ton/ha
- Early sowing can use residual moisture of monsoon and can escape terminal heat
- There are machines available that can plant under rice residue and can avoid straw burning

3 varieties identified for release this year in India – DBW 303, DBW 187, WH 1270
Green Revolutions – all based on N

1st Green Revolution – 1840 Guano NPK from Chile/Peru

2nd Green Revolution – 1910 Haber Bosch – N – synthesis

3rd Green Revolution – 1967 semi-dwarfs utilize more N

4th Green N Revolution needed
to feed 9.5 billion, with how little N can this be done

Agronomy x Fertilizer Formulation x Genetics x Microbes
Root Research


Global N application and crop yield – 1961 – 2013

1961 11 mln t
2013 115 mln t of which 75% in developing countries - mainly Asia

NUE in wheat has not changed since 1999
1999: 33%  2015 35%
Omara, et al., 2019

N-application increased 10 times
Crop yield increased 3 times

Global N application and crop yield – 1961 – 2013

1961 11 mlln t
2013 115 mlln t of which 75% in developing countries -mainly Asia

N-application increased 10 times
Crop yield increased 3 times

N application to maize in China and USA

Yield increase at stagnant N
=> Increased NUE

Diminishing Yield increases
Typical fertilizer response

Zhang et al., 2015. Nature. 15743
New Approaches to Breeding

- Accelerating Genetic Gains in Maize and Wheat – BMGF, FCDO, USAID, USDA – target regions S-Asia and E-Africa
- Focus on reducing cycle time
- Breeding decisions based on Genomic Estimated Breeding Values
- Rapid Bulk Generation Advancement – Speed Breeding – 3 or 4 years
- Rapid Cycle Recurrent Selection – Parents selected from F5
- Selection Index for yield and Zn
- Requires input from many disciplines quantitative genetics, bioinformatics
- CMMYT plans to base a scientist in India to work closely with Indian colleagues to fully exploit the potential of this approach
- Will continue shuttle and compare in a few years costs, selection efficiency and most important performance of germplasm
Expanding India-CIMMYT/BISA collaboration in Wheat Breeding to benefit smallholder farmers

- Piloting of rapid cycling, quantitative genetics and molecular breeding to enhance genetic gain for grain yield and grain Zn
- Earlier and increased phenotyping in target population of environments (TPEs-S-Asia) beyond selection environments (SE) in Obregon. *GS trials currently grown at 3 BISA sites in India, 3 in Pakistan, 2 in Nepal and 1 in Bangladesh*
- Early access of elite lines & data to participating partners for use as parents, or variety release for faster delivery of genetic gain

In both the AGG & Zn-mainstreaming projects we seek partnerships with 3-4 institutions in each TPEs for phenotyping of Stage 2 trials (180-200 entries)
Breeding Cycle time reduction from current 2-generations/year field-based selection

`Rapid Bulk Generation Advancement` (RBGA) & `Rapid Cycle Recurrent Selection` (RCRS) Schemes

Piloting & optimization to initiate in January 2021

1-year saved from the current 2 generation/year field-based shuttle breeding

1-2 years saved from the current yield testing protocol

Shuttle Breeding operates in parallel
So all methods can be Compared re Costs and Germplasm Perform.
Relative grain yield performance of the highest yielding Elite Spring Wheat Yield Trial (ESWYT) line in each year over the grain yield of the local check in that year across 12 sites in the 24th to the 37th ESWYT

- There was a clear superiority of the highest yielding ESWYT lines over the local check in 144 out of the 152 (94.7%) site-year combinations.
- The mean increase in grain yield of the highest yielding ESWYT line over the local check in the 144 site-year combinations was 1.1 + 0.7 t/ha (29.5 + 28.6% increase) and it ranged from 0.03 to 3.54 t/ha (0.6 to 237.2% increase).
Response to selection in Obregon and genetic gain in TPEs of India (ESWYT 2003-04 to 2017-18)

Note: ESWYT is TPE1 targeted yield trial

<table>
<thead>
<tr>
<th>Grain yield progress Kg/ha/year</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>TPE1</td>
<td>119</td>
</tr>
<tr>
<td>TPE2</td>
<td>46</td>
</tr>
<tr>
<td>TPE3</td>
<td>125</td>
</tr>
<tr>
<td>Across</td>
<td>109</td>
</tr>
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</table>
Molecular tracking of favorable allele frequencies and the effect of selection in 15 years of wheat breeding at CIMMYT

The favorable alleles for several grain yield associated markers have reached fixation indicating the effective impact of grain yield selection at CIMMYT, and also emphasize:

(i) the need for a continued effort of the breeders in introducing novel sources of favorable alleles and

(ii) the importance of integrating genomic tools in achieving accelerated fav. allele enrichment.

Trends in the 2NS translocation frequencies in CIMMYT’s yield trial germplasm (<9,000 lines each year)

Trends in the grain yield favorable allele frequencies in the globally distributed Elite Spring Wheat Yield Trials
Main points

• Physiological pre-breeding is an effective method to incorporate complex traits from exotic germplasm into elite lines

• Molecular markers will increase the efficiency to fix favorable alleles and genes in later generations
## Selection Traits in Spring Bread Wheat Product Profiles

<table>
<thead>
<tr>
<th>Trait</th>
<th>Breeding Program 1</th>
<th>Breeding Program 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Product Profile</td>
<td>Market Segment</td>
</tr>
<tr>
<td></td>
<td>1. Hard White-</td>
<td>2. Hard White-</td>
</tr>
<tr>
<td></td>
<td>Optimum Environment</td>
<td>Heat Tolerant</td>
</tr>
<tr>
<td></td>
<td>HW-OE</td>
<td>Early Maturity</td>
</tr>
<tr>
<td>High and stable yield potential</td>
<td>2x</td>
<td>1x</td>
</tr>
<tr>
<td>Water use efficiency/Drought tolerance</td>
<td>X</td>
<td>XXX</td>
</tr>
<tr>
<td>Heat tolerance</td>
<td>XX</td>
<td>XXX</td>
</tr>
<tr>
<td>End-use quality</td>
<td>XXX</td>
<td>XXX</td>
</tr>
<tr>
<td>Enhanced grain Zn (and Fe) content</td>
<td>XXX</td>
<td>XXX</td>
</tr>
<tr>
<td>(new mainstreaming trait)</td>
<td>XXX</td>
<td>XXX</td>
</tr>
<tr>
<td>Stem rust (Ug99 &amp; other)</td>
<td>XX</td>
<td>XX</td>
</tr>
<tr>
<td>Stripe rust</td>
<td>XXX</td>
<td>XXX</td>
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<tr>
<td>Leaf rust</td>
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<td>XX</td>
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<tr>
<td>Septoria tritici blotch</td>
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<td>XXX</td>
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<tr>
<td>Spot blotch</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Fusarium – head scab and myco-toxins</td>
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<td>-</td>
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<tr>
<td>Wheat blast- new threat in South Asia</td>
<td>X</td>
<td>XX</td>
</tr>
<tr>
<td>Maturity</td>
<td>Normal-late</td>
<td>Normal</td>
</tr>
</tbody>
</table>

**Importance:** X= low, XX= moderate, XXX= high

### Common agronomic traits:
- plant height
- stem strength
- leaf health
- spike fertility
- grain size & plumpness, etc.
Selection Traits in Spring Bread Wheat Product Profiles

<table>
<thead>
<tr>
<th>Trait</th>
<th>Breeding Program 1</th>
<th>Breeding Program 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trait 1</td>
<td>X</td>
<td>X</td>
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<tr>
<td>High and stable yield potential</td>
<td>XXX</td>
<td>XXX</td>
</tr>
<tr>
<td>Water use efficiency / Drought tolerance</td>
<td>XX</td>
<td>XX</td>
</tr>
<tr>
<td>Heat tolerance</td>
<td>X</td>
<td>XXX</td>
</tr>
<tr>
<td>End use quality</td>
<td>XXX</td>
<td>XXX</td>
</tr>
<tr>
<td>Enhanced grain Zn (and Fe) content (new mainstreaming trait)</td>
<td>XXX</td>
<td>XXX</td>
</tr>
<tr>
<td>Stem rust (Ug99 &amp; other)</td>
<td>XX</td>
<td>XX</td>
</tr>
<tr>
<td>Stripe rust</td>
<td>XXX</td>
<td>XX</td>
</tr>
<tr>
<td>Leaf rust</td>
<td>XXX</td>
<td>XXX</td>
</tr>
<tr>
<td>Septoria tritici blotch</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Spot blotch</td>
<td>X</td>
<td>XXX</td>
</tr>
<tr>
<td>Fusarium - head scab and myco-toxins</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wheat blast</td>
<td>X</td>
<td>XXX</td>
</tr>
</tbody>
</table>

**Importance:** X= low, XX= moderate, XXX= high

1. These product profiles need to be verified with our NARS partners and updated as required in the future

2. Gender intentionality (traits preferred by women farmers) need to be explored and integrated

**Common agronomic traits:** plant height, stem strength, leaf health, spike fertility, grain size & plumpness, etc.
Happy Gene Package
Wide Adaptation – Yield Stability – Disease Resistance – Tolerance to abiotic stresses – Quality
Countries that often release same line or sister lines

Need to keep desirables alleles as block
Wheat as a Global Crop requires Global Co-ordinated Responses
Private and Public Sector Partners in International Wheat Improvement Network (IWIN): Key to Delivering Impacts
Locations receiving CIMMYT nurseries

Source: K. Sonders CIMMYT
Global network of precision field-based wheat phenotyping platforms developed with co-investing national agricultural research institutes (http://wheat.org)
# INTERNATIONAL WHEAT YIELD PARTNERSHIP

IWYP's goal is to increase the genetic yield potential of wheat by 50% in 20 years.

## Public Members
- **Australia**: GRDC
- **Canada**: AAFC
- **France**: INRAE
- **India**: DBT
- **Mexico**: CIMMYT, SADER
- **Syngenta Foundation Wheat Initiative**

## Private Companies
- **BASF**
- **KWS**
- **Limagrain**
- **LongReach**
- **Mahyco**
- **Pioneer**
- **RAGT**
- **SeedCo**
- **Syngenta**
Ethiopia and Afghanistan
Wheat Impact studies using DNA Fingerprinting

Afghanistan:
• 75% of samples CIMMYT derived varieties
• 58% of farmers had correct variety name

Ethiopia
• 89% of samples from all provinces CIMMYT derived varieties
• 55% of sampled households growing rust resistant varieties
• 45% of samples varieties released in last 10 years
  61% released since 2005
Wheat accessions phenotyped during 2005-2020 for Ug99 resistance at Njoro (Kenya) and participating countries, in partnership with KALRO

>610,000 accessions screened since 2005
50,000 annual capacity (2 Seasons)
20-25 countries/institutions
2570 wheat lines from India (across 10 seasons)
Rust control in India

Leaf Rust: Last epidemics around 1980 – Sonalika epidemic
Stem Rust: Last major epidemics in late 70s – ca 200 mlln $ loss
Today, 7 mlln ha rust prone area sown with resistant varieties

Leaf rust and stem rust are basically controlled in India through resistant varieties which are maturing earlier and consequent low inoculum built up

Use of rust genes with pleiotropic effects (Lr 34, 46, 67, 68, Sr2 etc)

– no complacency permitted – rust never sleeps!!!

Yellow rust remains an issue
rapid replacement of susceptible varieties and support for continuous resistance breeding
Wheat varieties released during 2005-2016 showing high to adequate resistance to Ug99 race group
Regions with similar climate to location where Wheat Blast is reported from in Zambia

Climate analogues to outbreak sites
Temperature
- High climate similarity
- Medium climate similarity

Source: Kai Sonder, CIMMYT-SEP
WB in Bangladesh

2015-16: 1st report of WB occurrence in eight districts. 25-30% loss

2016-17: WB spread to four more districts. 5-10% loss

2017-18: Unfavorable conditions for development of WB. Spread to additional five districts. 3-5% loss

2018-19: WB limited due to unfavorable conditions. Spread to four more districts. 1-2% loss

2019-20: WB limited due to unfavorable conditions. Spread to one more district. 1-2% loss
Wheat breeding in India 2013-2018

- >50 CIMMYT derived wheat varieties released
  22 direct CIMMYT introduction
  30 derived from crosses between Indian and CIMMYT parents
- 4 biofortified (high Zn) wheat varieties released (2 public, 1 private, 1 PVS)
- ~35 centers got new germplasm (~600 lines) each year
- Indian germplasm tested for Ug99 (in Kenya) and wheat blast (in Bolivia and USA)
- >300 scientists attended international events and training courses
- 6 of 8 released varieties in 2019 CIMMYT derived
Shifting Global Shares of Public Food & Ag R&D, 1960-2011

Source: Pardey, Chan-Kang, Beddow and Dehmer (2016, in process)
1600 wheat scientists from >90 countries have been trained at CIMMYT.

Many visiting scientists

10 International Recruited Indian Scientists

Program Director Dr. S. Rajaram
Breeding Lead Dr. R. Singh
The partnership between ICAR and CIMMYT in agricultural research is one of the longest and most productive in the world with a history of over five decades. The collaboration started with the visit of Nobel laureate Dr Norman E. Borlaug to India in 1963 for help in paving the way for “Green Revolution” in active partnership with the national agricultural research system (NARS), farmers and the Government of India.

CIMMYT germplasm goes to the right place in South Asia – to farmers, scientists, students, industry and other stakeholders.
Conclusion

The partnership between ICAR and CIMMYT in agricultural research began in 1966, with a focus on helping to pave the way for “Green Revolution” in active partnership with the national agricultural research system (NARS), farmers and the Government of India. Whatever matters for wheat in India, Matters for CIMMYT’s Global Wheat Program To the next decade of a Fruitful and Productive co-operation
Thank You very much for your attention