Impacts of CIMMYT Maize Breeding in Sub-Saharan Africa

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Maize in Sub-Saharan Africa

• Maize is life for most of Africa
• Grown on 36 million ha in SSA
• > 208 million farmers depend on maize
• Average yields in SSA are the lowest (<2 t/ha) in the world
  – Drought, Low N
  – Biotic stresses (MLN, FAW)
CIMMYT’s extensive maize phenotyping network in Africa

updated from Prasanna et al. 2013
Breeding for stress tolerant maize in Africa

Managed drought-Kiboko
Optimum-Embu
MLN-Naivasha
Turcicum leaf blight at Kakamega
• **81 unique varieties released across Africa, Asia and LatAm in 2018** (63 varieties based on CIMMYT germplasm; 18 based on IITA germplasm)

• **14 varieties are Combination Hybrids** (majority from SSA)

• **20 of the released varieties are nutritionally enriched** (ProA/QPM/QPM+High Zn)
3.5 million smallholder farmers planted stress tolerant MAIZE varieties in 10 target countries in Africa (2018)
Breeding Progress for MLN Tolerance (2011-2019)

- Commercial checks
- KALRO-CIMMYT MLN Screening Facility at Naivasha, Kenya
- MLN tolerant and susceptible hybrids Demo at Naivasha in 2019

Commercial checks in 2019 demo
MLN tolerant hybrid in 2019 demo
MLN Resistance through MABC
Breeding progress for MLN tolerance from 2014-2018

<table>
<thead>
<tr>
<th>Year</th>
<th># lines evaluated</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>2876</td>
</tr>
<tr>
<td>2016</td>
<td>1522</td>
</tr>
<tr>
<td>2018</td>
<td>909</td>
</tr>
<tr>
<td>Total</td>
<td>5307</td>
</tr>
</tbody>
</table>

![Graph showing breeding progress from 2014 to 2018 with data points for each year.](image-url)
Breeding for Native Genetic Resistance to FAW

- Optimization of screening protocols
- Established 13 screen houses at Kiboko, Kenya
- Screening of ~4000 maize lines and hybrids so far under artificial infestation
Breeding for Nutritional Maize

- Provitamin A content of the lines used as males ranges from 6.3 to 30.4 µg/g with an average of 15.2 µg/g.
- 17 hybrids released during 2012-2017, and under commercialisation in the region (Malawi, Tanzania, Zambia, Zimbabwe)
Benefits:
• Improved yield under stress conditions (5 – 15%)
• Improved seed purity of hybrids reaching farmers
• Production cost savings to seed companies
Introgression of Off-PVP US Temperate lines into CIMMYT’s Tropical Maize Germplasm

273 Of-PVP lines used
- Crossed with selected tropical adapted lines
- Evaluated in Stage I, II, III, RT
- Hybrids released
Comparison of Off-PVP introgressed and original tropical lines

- 5 tropical adapted lines were crossed with ex-PVP lines
- The original lines together with BC1 fixed lines crossed with 5 testers
- The hybrids were evaluated across seven optimum sites

- # Locations = 7
- Heritability = 0.95
Currently 60% of GMP-Africa maize breeding programs are using DH lines

<table>
<thead>
<tr>
<th>2018</th>
<th># of populations</th>
<th># of DH lines delivered</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIMMYT</td>
<td>137</td>
<td>25290</td>
</tr>
<tr>
<td>NARS partners</td>
<td>67</td>
<td>10630</td>
</tr>
<tr>
<td>SME seed companies</td>
<td>37</td>
<td>3674</td>
</tr>
</tbody>
</table>

Average number of DH lines produced per population: **156**

- DH lines released as CMLs and used as parents in released commercial hybrids
- MLN tolerant hybrids developed and released

- CIM2GTAIIs with 10-13% HIR + improved plant vigor, disease resistance, better pollen producibility & seed set, released in August 2017 → reduced DH development costs by 30%.
- CIM2GTAIIs shared to 21 Organization globally.
Implementation of GS in stage I trials

- # lines genotyped (Stage I)= 3000
- # lines phenotyped = 853
- # sites= 3 optimum and one managed drought
- The phenotypic data were used to predict the remaining untested lines.

\[ R^2 = 0.7249 \]

\[ R^2 = 0.7582 \]
Comparison of hybrids advanced based of PS and GS in stage II trials

<table>
<thead>
<tr>
<th>Category</th>
<th># lines</th>
<th># testers</th>
<th># of hybrids</th>
</tr>
</thead>
<tbody>
<tr>
<td>All stage II hybrids</td>
<td>347</td>
<td>3</td>
<td>1042</td>
</tr>
<tr>
<td>Hybrids advance through phenotype</td>
<td>175</td>
<td>3</td>
<td>526</td>
</tr>
<tr>
<td>Hybrids advance through GEBV</td>
<td>172</td>
<td>3</td>
<td>516</td>
</tr>
</tbody>
</table>

Beyene et al. submitted GS reduced the cost by 32% over PS with similar selection gains

<table>
<thead>
<tr>
<th>Country</th>
<th>Gain kg/ha/year</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>132</td>
<td>Luque et al., 2006</td>
</tr>
<tr>
<td>Eastern and southern Africa</td>
<td>109.4</td>
<td>Masuka et al. 2017a</td>
</tr>
<tr>
<td>China</td>
<td>94.7</td>
<td>Ci et al., 2011</td>
</tr>
<tr>
<td>Canada</td>
<td>80</td>
<td>Bruulsema et al., 2000</td>
</tr>
<tr>
<td>United States</td>
<td>65-75</td>
<td>Duvick, 2005</td>
</tr>
<tr>
<td>West Africa</td>
<td>40</td>
<td>Badu-Apraku et al. (2013, 2015)</td>
</tr>
<tr>
<td>This study</td>
<td>131</td>
<td>Unpublished</td>
</tr>
</tbody>
</table>

# of locations: 37 optimum, 7 drought locations (in Ken, Tan and Uga in 2017 and 2018)
Improved maize distribution within Africa and beyond

<table>
<thead>
<tr>
<th>Year</th>
<th># of shipments</th>
<th># of envelopes</th>
<th># of institutions</th>
<th># of countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>209</td>
<td>295,850</td>
<td>72</td>
<td>25</td>
</tr>
<tr>
<td>2013</td>
<td>192</td>
<td>643,965</td>
<td>72</td>
<td>25</td>
</tr>
<tr>
<td>2014</td>
<td>108</td>
<td>115498</td>
<td>45</td>
<td>20</td>
</tr>
<tr>
<td>2015</td>
<td>119</td>
<td>73690</td>
<td>48</td>
<td>21</td>
</tr>
<tr>
<td>2016</td>
<td>93</td>
<td>70222</td>
<td>40</td>
<td>17</td>
</tr>
<tr>
<td>2017</td>
<td>86</td>
<td>62996</td>
<td>43</td>
<td>16</td>
</tr>
<tr>
<td>2018</td>
<td>61</td>
<td>43727</td>
<td>21</td>
<td>14</td>
</tr>
<tr>
<td>Total</td>
<td>868</td>
<td>1,305,948</td>
<td>341</td>
<td>138</td>
</tr>
</tbody>
</table>

Every year 500,000 envelopes of maize seeds are sent to over 70 institutions worldwide.
International Maize Improvement Consortium in Africa (IMIC-Africa) initiated in May 2018

- 23 seed companies with annual membership fee
- 11 NARS institutions from in ESA so far as honorary members
- 3 field days were conducted
- Distributed improved lines to partners
Summary

• Incorporated new tools and technologies into product development that delivered the genetic gain 1.75 % per year

• High yielding and stress tolerant hybrids developed and grow by millions of small scale framers in SSA

• Breeding for native FAW genetic resistance initiated

• Shared improved germplasm across the world
Thank you for your interest!