Seeds of Discovery (SeeD)
Harnessing Biodiversity for Food Security
Projected Population by Region

<table>
<thead>
<tr>
<th>Region</th>
<th>2013 Population</th>
<th>2045 Population</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>1,102,419,448</td>
<td>2,088,966,564</td>
<td>89.46%</td>
</tr>
<tr>
<td>Asia</td>
<td>4,264,971,655</td>
<td>5,153,037,795</td>
<td>20.82%</td>
</tr>
<tr>
<td>Europe</td>
<td>735,784,031</td>
<td>692,907,973</td>
<td>-5.83%</td>
</tr>
<tr>
<td>Latin America and the Caribbean</td>
<td>609,595,009</td>
<td>762,999,599</td>
<td>25.17%</td>
</tr>
<tr>
<td>Northern America</td>
<td>351,369,733</td>
<td>448,773,375</td>
<td>27.72%</td>
</tr>
<tr>
<td>Oceania</td>
<td>36,274,255</td>
<td>47,365,645</td>
<td>30.58%</td>
</tr>
</tbody>
</table>

US Census Bureau & International Data Base, 2011
We are not on-track for food security

Global average yield (tons per hectare)

Year

[Source: USDA PDS database]
General scientific consensus on climate change. Tropical areas will be strongly affected (drought + heat)

Sources: Krechowicz, et. al., 2010; Lobell et al 2011
We Live on Borrowed Time

**India:** 175 million people are sustained with grain from over-pumping from irrigation wells

**China:** 130 million people are sustained with grain from over-pumping

How will India and China make up for the inevitable shortfalls when the aquifers are depleted?

**Source:** World Bank

Picture: IRRI
Disease Epidemics Continue to Emerge

Maize Lethal Necrosis

Much of Africa’s maize production is at risk

Ug99

80% of the world’s wheat is susceptible to stem rust
Plant breeding produces new varieties

- Identify useful genetic variation
- Make crosses: add new to current best
- Evaluate and select something better
- Finalize and release a new variety
Achieving Food Security in view of Climate change & population growth

- Current breeding materials contain only a fraction of the useful genetic variation available.
- Much of the needed diversity exists, like needles in a haystack, on the shelves of gene banks.
- Genomic tools enable us to search for useful diversity much more effectively.
SeeD’s Vision of Success: the wealth contained in the world’s genetic resources is available to breeders globally for making new varieties.

Approximately 28,000 maize and approximately 140,000 wheat genetic resources are available. The process involves identifying useful genetic variation, evaluating and selecting something better, finalizing and releasing a new variety, and making crops new to consumers.

Genetic resources are anticipated to meet demand by 2050.
ARS agronomist Cecil Salmon acquired seeds from Japan in 1946.

ARS plant breeder Orville Vogel worked with it for 13 years.

Borlaug crossed these with Mexico's best wheats.

Borlaug's semi-dwarf wheats enabled India to launch its Green Revolution.

Wheat production doubled by 1970 and then tripled by 1982.

Successful use of ‘dwarf’ gene
Successful use of ‘exotic’ sources of high provitamin A

Sources from Thailand and USA - 2003

3 high provitamin A hybrids released in Zambia in 2012

9 years from source to release
SeeD: Emerging disease - Tar Spot (Chiapas, 2011 & 2012)
Several genetic changes can contribute to Tar Spot resistance: SNP allele effects
Impact of heat on wheat

- ~10% yield loss per 1°C increase in temperature
- By 2050, 20-30% yield loss in South Asia alone, affecting over 1 billion people

SeeD: ~70,000 wheat gene bank lines screened under heat stress (2011-2013)
SeeD: Exploring wheat genetic resources for heat tolerance

- Heat-tolerant landraces were identified
- We discovered new diversity
Zinc deficiency afflicts ~2 billion people

- Stunted & underweight children
- Brain development disorders

Use biodiversity for bio-fortification

Fishing in the wheat gene bank: evaluated ~15,000 landraces
Seeds of Discovery (SeeD)

- Initiated in 2011
- Mostly funded by the Mexican government
- Four Components
  1. Molecular & phenotypic characterization → open-access database(s)
  2. Informatics Tools & knowledge extraction
  3. Bridging Germplasm
  4. Capacity building
Supported by a strong partnership network

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SeeD – high-density genetic profiles

✓ 25,000 Maize (~90%)
✓ 40,000 Wheat (~30%)

$35 per sample = $2.3 million
SeeD: More than 2 million field data

<table>
<thead>
<tr>
<th>Wheat</th>
<th>Maize</th>
</tr>
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<tbody>
<tr>
<td>Grain yield</td>
<td>Grain yield</td>
</tr>
<tr>
<td>Drought</td>
<td>Drought</td>
</tr>
<tr>
<td>Heat</td>
<td>Heat</td>
</tr>
<tr>
<td>Low soil phosphorus</td>
<td>Low soil nitrogen</td>
</tr>
<tr>
<td>Tan spot</td>
<td>Tar spot</td>
</tr>
<tr>
<td>Karnal bunt</td>
<td>Turcicum blight</td>
</tr>
<tr>
<td>Spot blotch</td>
<td>Stalk rot</td>
</tr>
<tr>
<td>Wheat blast</td>
<td>Ear rot</td>
</tr>
<tr>
<td>Zinc</td>
<td>Cercospora (GLS)</td>
</tr>
<tr>
<td>Iron</td>
<td>Grain quality (oil...)</td>
</tr>
<tr>
<td>Protein</td>
<td>Carotenoids</td>
</tr>
<tr>
<td>Grain quality (twt...)</td>
<td>Root lodging</td>
</tr>
<tr>
<td>Phenology</td>
<td>Stem lodging</td>
</tr>
<tr>
<td>Morphology</td>
<td>Phenology</td>
</tr>
</tbody>
</table>

- Wheat: 1.4 million data points from 30 trials
- Maize: 0.7 million from 34 trials

Lots of data still to analyze and extract value
First value generated

Tar spot
Zn
Heat
Drought

Valuable sources identified
Seeds of Discovery (SeeD)

- Initiated in 2011
- Mostly funded by the Mexican government
- Four Components
  1. Molecular & phenotypic characterization → open-access database(s)
  2. Informatics tools & knowledge extraction
  3. Bridging germplasm
  4. Capacity building

Our challenge: to attract global support for an initiative with truly global impact
Partnership opportunities:

- Participate in priority setting
- Phenotype traits of interest
- Data mining; knowledge generation
- Germplasm utilization initiatives
- Capacity building providers and beneficiaries
- Other crops
Why CIMMYT?

• Most extensive wheat & maize collections in the world.
• >50 years working with maize & wheat genetic resources.
• Unparalleled network of partners and testing sites around the world.
CIMMYT Varieties are Grown ALL Over the World

= Those that will benefit from SeeD
Discussion
What SeeD will Deliver (launch):

Open access molecular data
- Maize: 2015 (MGB100%)*
- Wheat: 2016 (WGB80%)**

Open access phenotypic data
- Wheat: 2015***
- Maize: 2015 ***

Open access software
- Initial components: 2014 *
- Platform v1.0: 2016 *
- Linkages to other public databases: 2018 *
What SeeD will Deliver (launch):

**Diversity atlas:**
- Decision support tools: 2017*
- Molecular “maps” with donors for key traits: 2018***

**Bridging germplasm:**
- Wheat: 2015**
- Maize: 2018**

**Capacity building**
- Annual workshops with partners: 2016***
- Links to graduate programs: 2016***
- Fellowships for visiting scientists: 2015***
- Genetic resources utilization network: 2016*
SeeD: Challenges and Opportunities

- Government change in Mexico has led to 55% reduction in budget.
- Mexican government mainly interested in funding research in Mexico, for Mexico
  - CIMMYT has global vision for project
  - is a large part of that vision
- We currently are seeking funding to continue our activities and to expand SeeD beyond Mexico
Fishing wheat gene bank for nutritive wheat: evaluated ~15,000 landraces for quality traits
Impact of climate change on wheat

- ~10% yield loss per 1°C increase in temperature
- 20-30% yield loss in South Asia alone, affecting over 1 billion people
SeeD-wheat project deliver for wheat improvement in next 3 years

- Heat tolerant wheat bridging germplasm
- New rust resistance germplasm for breeders across the global
- Germplasm lines with high micro-nutrient/quality traits
- Characterize genetic materials as potential donors for biotic and abiotic stresses to NARS partners
Partnership opportunities:

– Participate in priority setting: 2014
– Phenotype traits of interest: 2015
– Data mining; knowledge generation: 2015
– Germplasm utilization initiatives: 2015
  – Heat and Drought Wheat Improvement Consortium (HeDWIC)
  – Drought Tolerant Maize for Africa (DTMA)
  – International Wheat Yield Partnership (IWYP)
  – HarvestPlus – Breeding crops for better nutrition
  – Improved Maize for African Soils (IMAS)
– Capacity building providers and beneficiaries: 2012
– Other crops: 2015
Why a bottleneck?

SeeD: New technologies to identify and facilitate the use of maize and wheat biodiversity
Plant breeding produces new varieties

Maize Lethal Necrosis

Much of Africa’s maize production is at risk

Identify useful genetic variation

Make crosses: add new to current best

Evaluate and select something better

Finalize and release a new variety

Make crosses: add new to current best

Evaluate and select something better

Genetic resources

Crop improvement

Agronomy & seed systems

Improved livelihoods

SeeD
Towards a Maize Atlas

- Sequencing of entire CIMMYT maize genebank (27,000)
- Initial analysis of 20,000 accessions:
  - 80–100K loci in a particular accession (~20% missing data)
  - 1.2 million loci in total (only 20% map to B73)
- Genotyping CMLs and ex-PVP lines for comparison
- GWAS study genotyping
- Next: Selection imprints

CIMMYT elite maize lines
Drought during vegetative cycle (+ flowering)
Heat during flowering
Heat and drought
Wheat rusts: Major threat to food security

- Research on wheat rust during 1961-2009 added to world wheat harvests worth US $1.12 billion per year (at 2010 prices)

- Wheat Rust disease: Present in all 6 continents
- Cause loss in yield up to 100%
- Pathogen keeps evolving: Difficult to manage

*Science, 340:147-148(2013)*
• 700,000 data points over 2 years, from 34 trials across 14 locations
• Heat, drought, low N, tar spot, ear rot, stalk rot, *Turcicum*, *Cercospora* (GLS), grain quality
SeeD – future outlook

- **2016**: Molecular atlas online enabling access to genetic resources. Wheat populations available for mapping and line extraction.

- **2017**: Trait-enriched (drought, tar spot resistance, etc.) maize lines with novel variation for stress tolerance available to breeders.

- **2018**: New wheat and maize lines enriched with novel variation for stress tolerance, disease resistance and nutritional quality delivered to breeders.

- **2019**: Informatics tools to help identify the best gene bank accessions for plant breeding available.

- **2020**: Information on genetic elements of importance for maize and wheat breeding. Informatics tools available for use by diverse crop researchers.

**Novel breeding germplasm available.** Suite of tools to enable use of plant genetic resources and genetic elements contained therein publicly available. Breeders worldwide are empowered to better address production constraints and farmer and consumer needs.
Enhanced resistance to targeted stress
An acceptable agronomic background

- Characterize accessions by genome profiling
- Phenotype under target stress
- Identify novel beneficial alleles
- Markers linked to novel alleles

Bridge germplasm

- New lines with:
  - Enhanced resistance to targeted stress
  - An acceptable agronomic background
Why SeeD?

- Climate change
- Soil degradation and falling water tables
- Costs of fertilizer and energy
- Genetic erosion

Global average yield (tons per hectare)

Year

Anticipated demand by 2050 (FAO)

[Source: USDA PDS database]

Genetic resources for food security