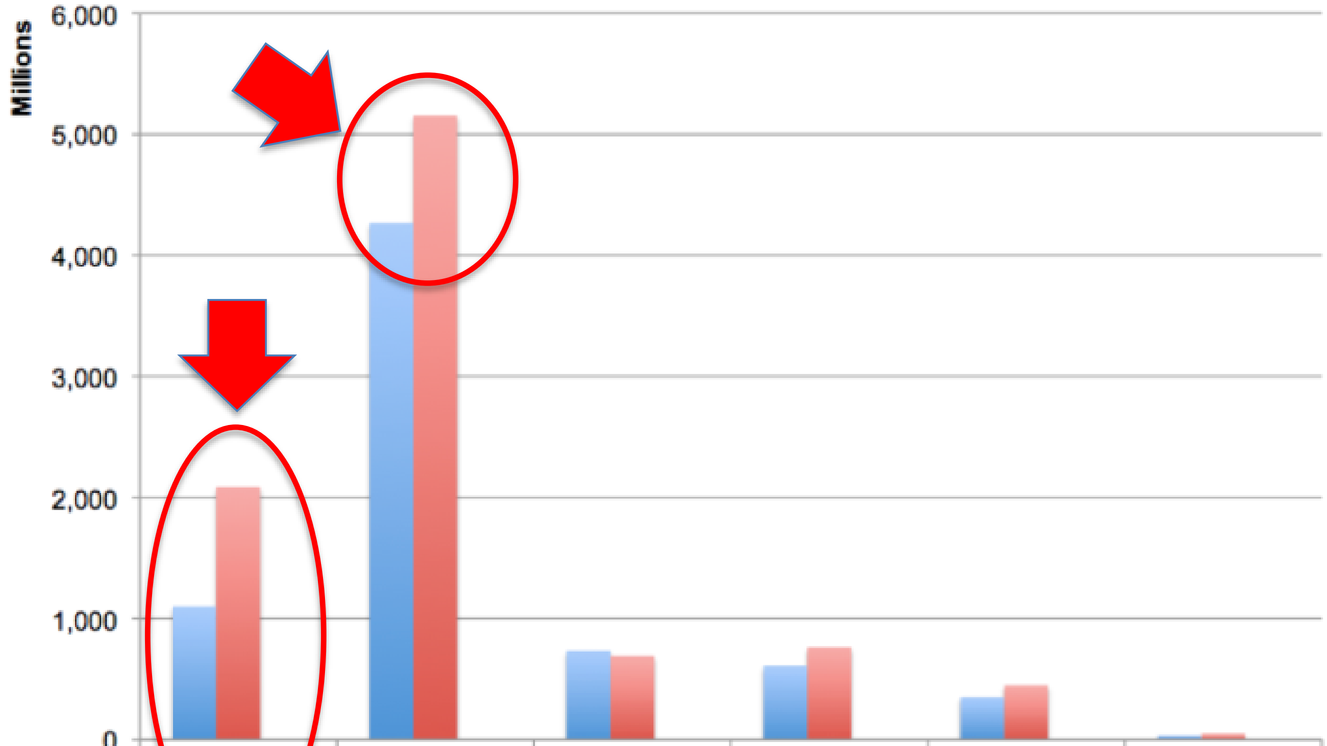
# Seeds of Discovery (SeeD)

# Harnessing Biodiversity for Food Security

CIMMYT

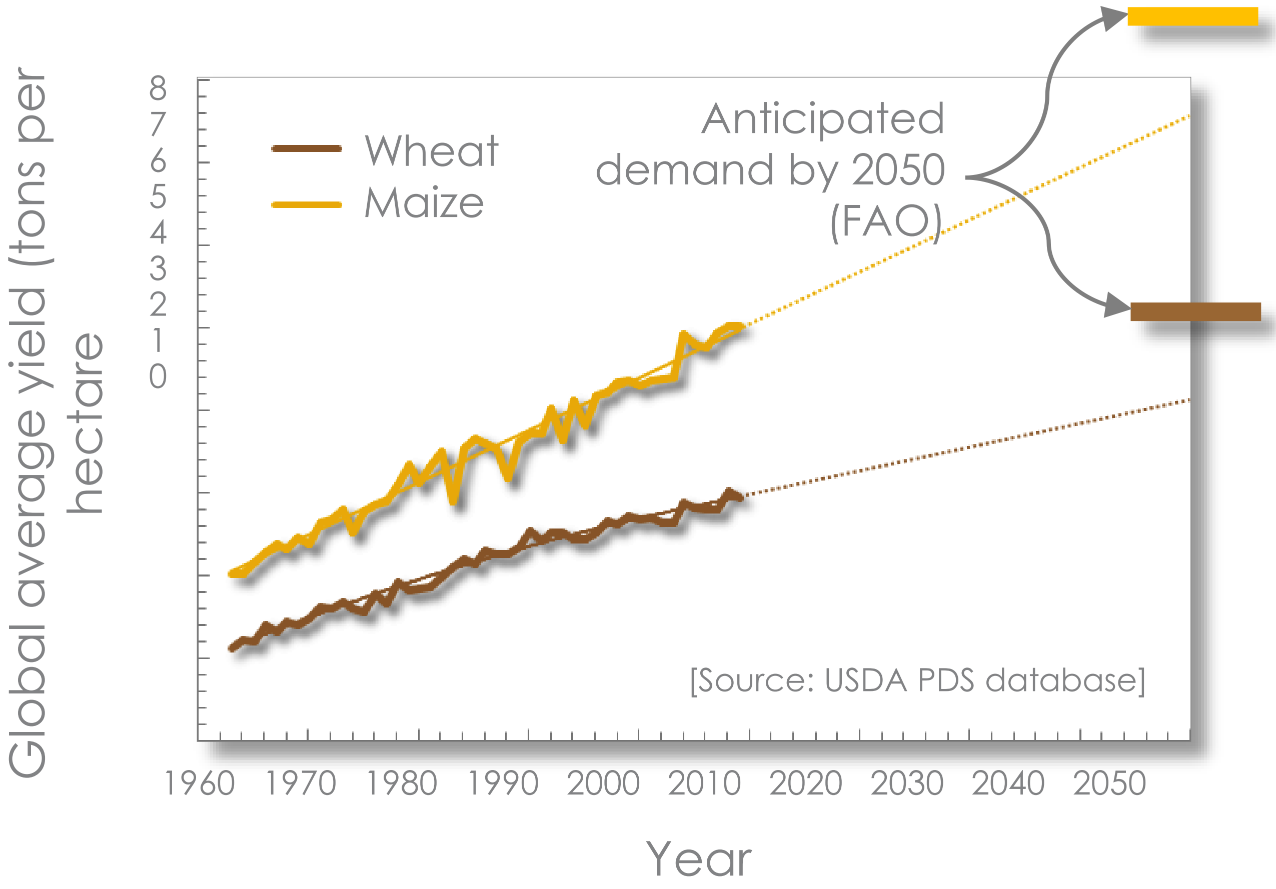
# Projected Population by Region



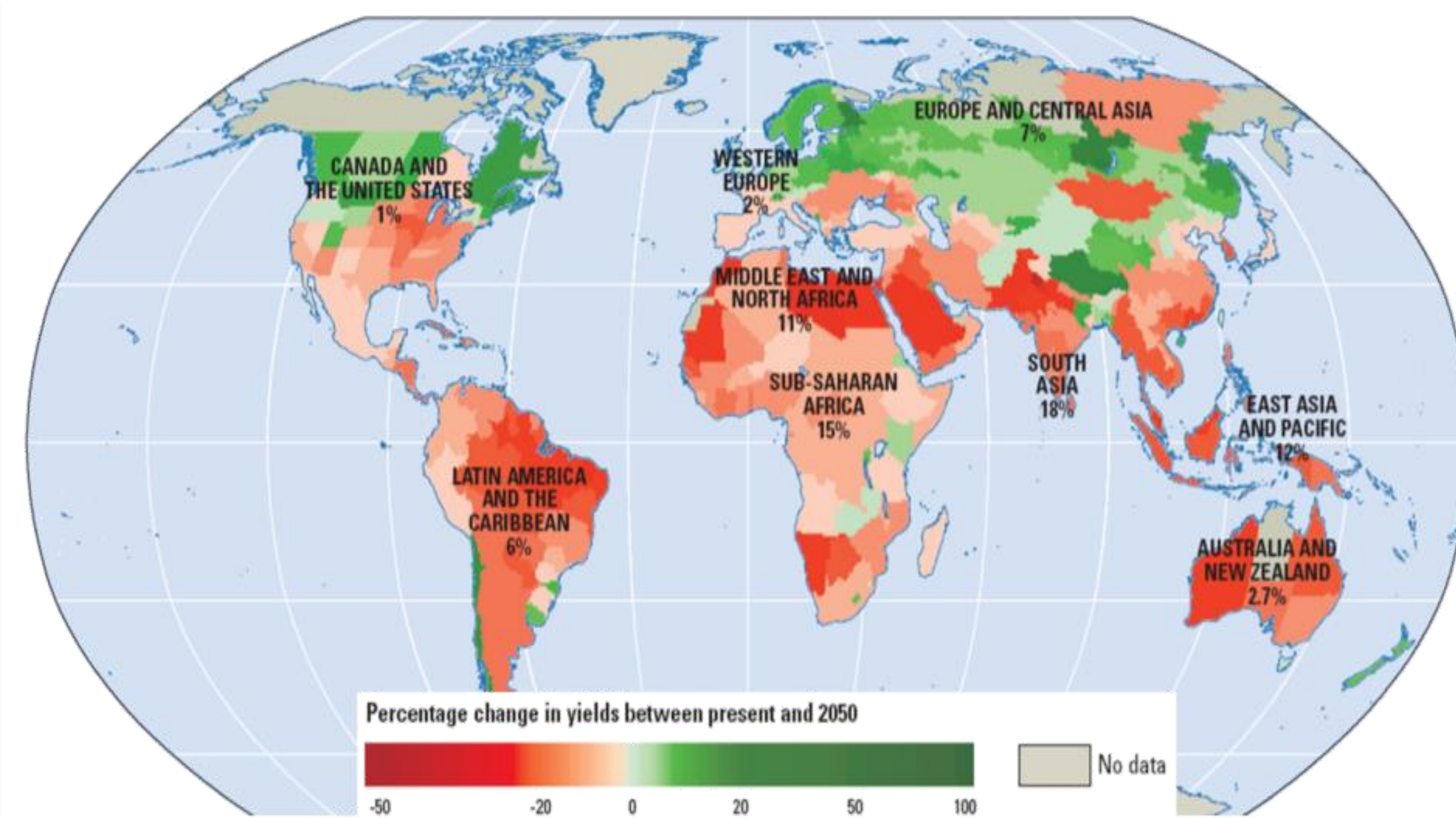

| | Africa | Asia | Europe | Latin America and the Caribbean | Northern America | Oceania |
|---|---|---|---|---|---|---|
| 2013 Population | 1,102,419,448 | 4,264,971,655 | 735,784,031 | 609,595,009 | 351,369,733 | 36,274,255 |
| 2045 Population | 2,088,696,564 | 5,153,037,795 | 692,907,973 | 762,999,599 | 448,773,375 | 47,365,645 |
| % Change | 89.46% | 20.82% | -5.83% | 25.17% | 27.72% | 30.58% |

**US Census Bureau & International Data Base, 2011**

# We are not on-track for food security



**General scientific consensus on climate change.**
**Tropical areas will be strongly affected (drought + heat)**




Sources: Krechowicz, et. al., 2010; Lobell et al 2011

CIMMYT

# We Live on Borrowed Time

Picture: IRRI

**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

CIMMYT

# Disease Epidemics Continue to Emerge

Maize Lethal Necrosis

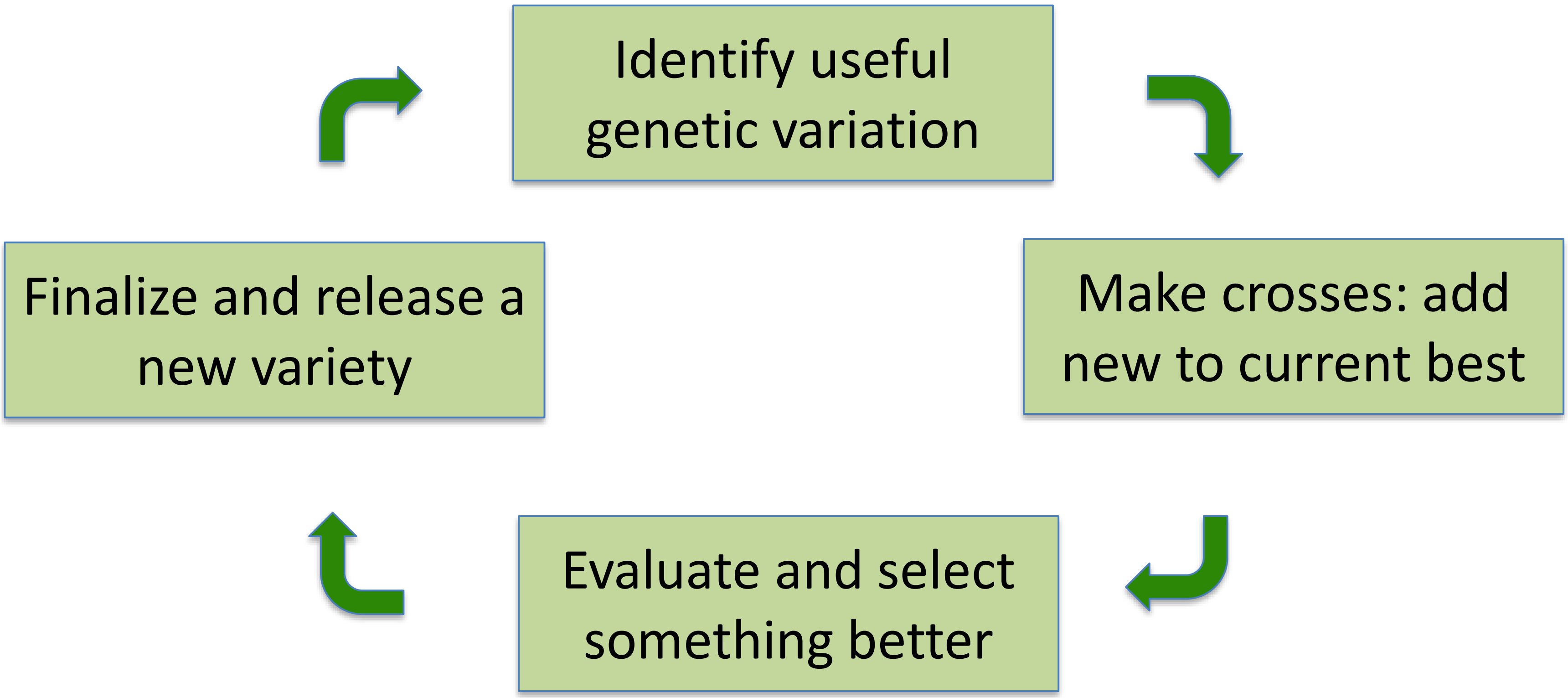
Much of Africa's maize production is at risk

Ug99

80% of the world's wheat is susceptible to stem rust

CIMMYT

# Plant breeding produces new varieties




CIMMYT

# 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.

CIMMYT

## **SeeD's Vision of Success: the wealth contained in the world's genetic resources is available to breeders globally for making new varieties**

≈ 28,000 maize

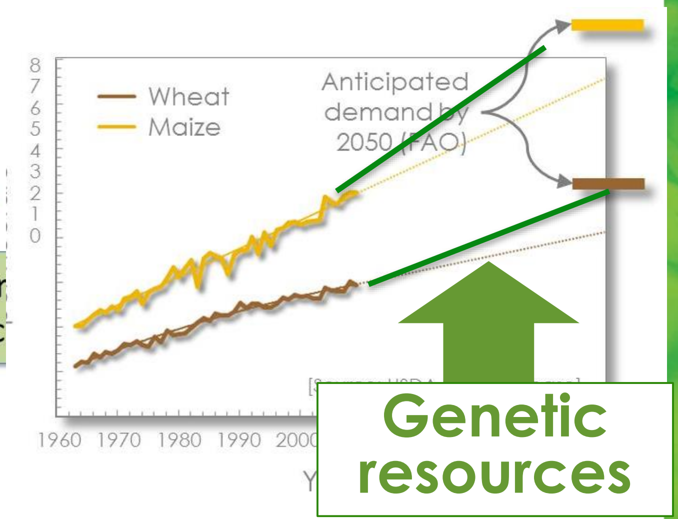
≈ 140,000 wheat

Identify useful genetic variation

Make cr new to c

Evaluate and select something better

Finalize and release a new variety



CIMMYT

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.

**+ 30 YEARS!**

Successful use of 'dwarf' gene

CIMMYT

# Successful use of ‘exotic’ sources of high provitamin A

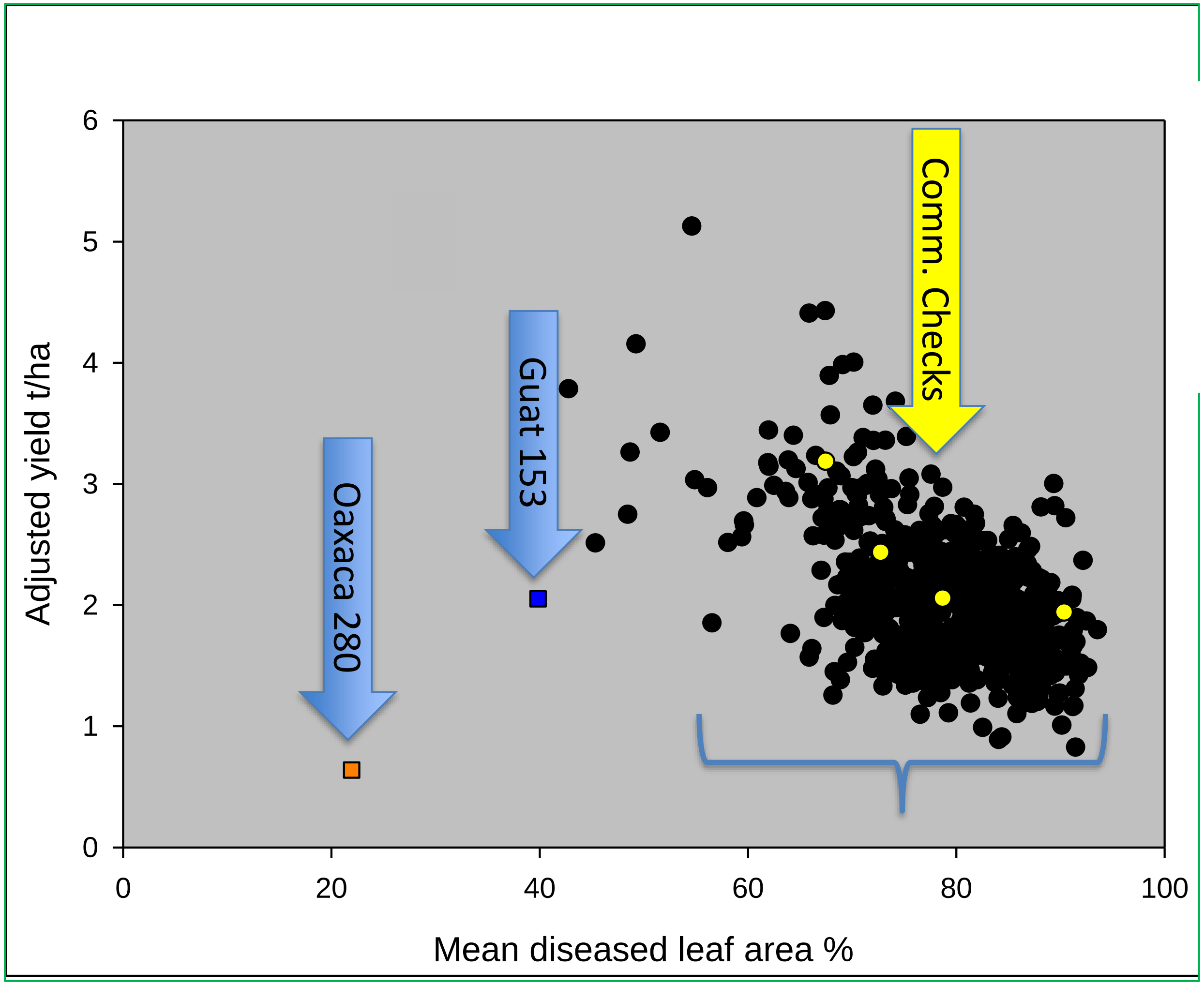
Sources from Thailand and USA - 2003

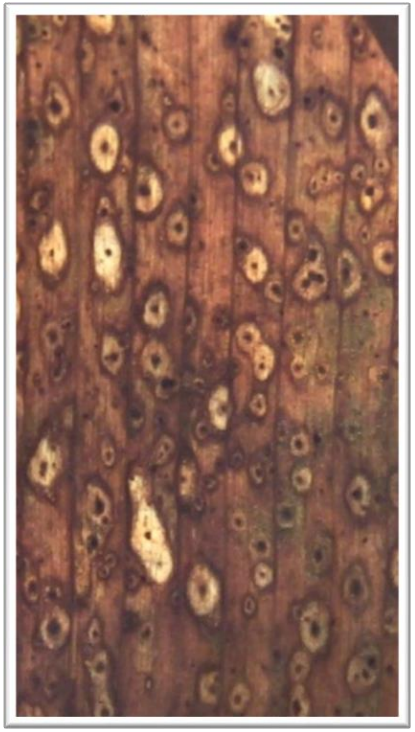
3 high provitamin A hybrids released in Zambia in 2012

9 years from source to release

CIMMYT

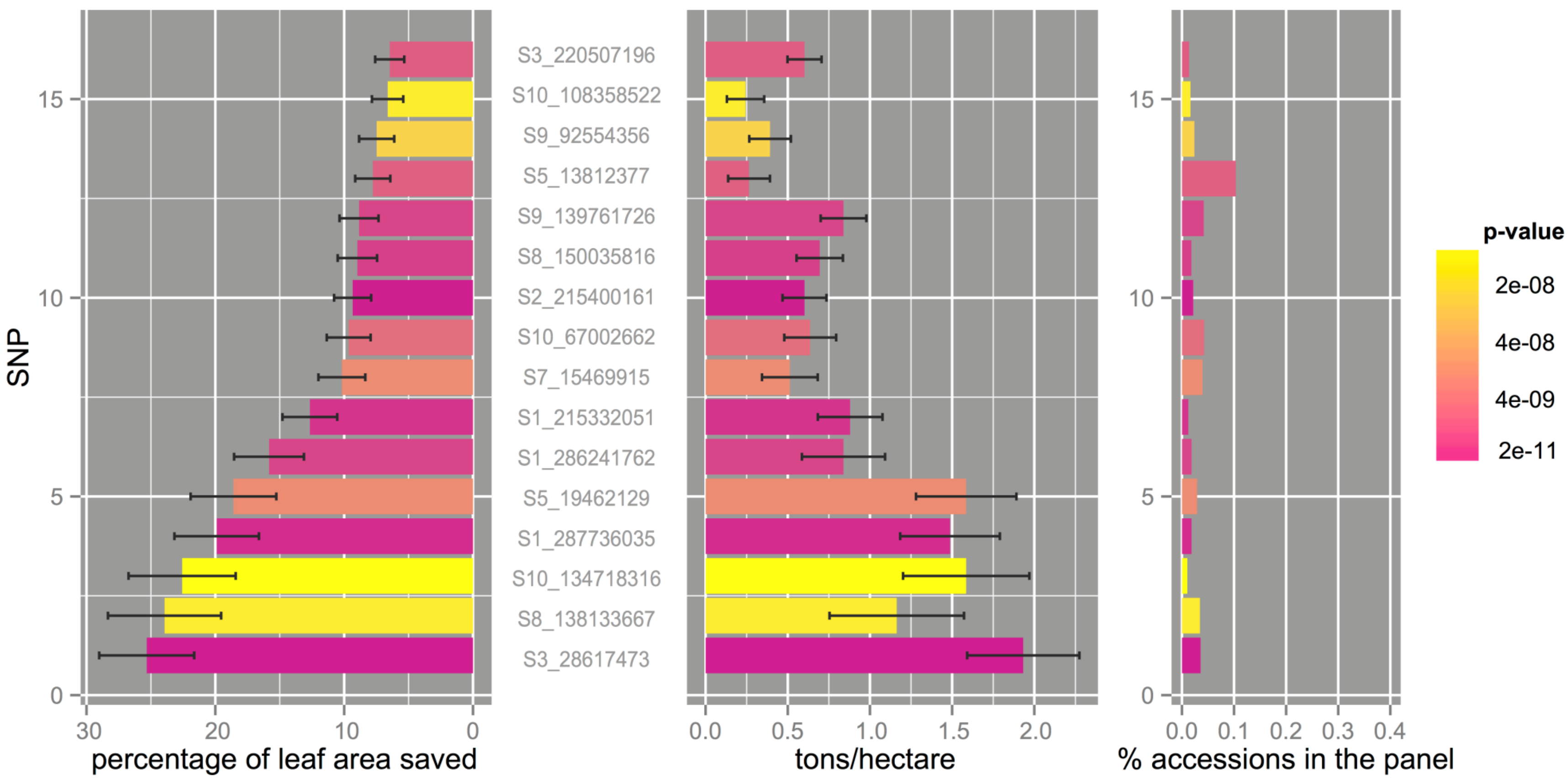
# SeeD: Emerging disease - Tar Spot (Chiapas, 2011 & 2012)



CIMMYT

# Several genetic changes can contribute to Tar Spot resistance: SNP allele effects



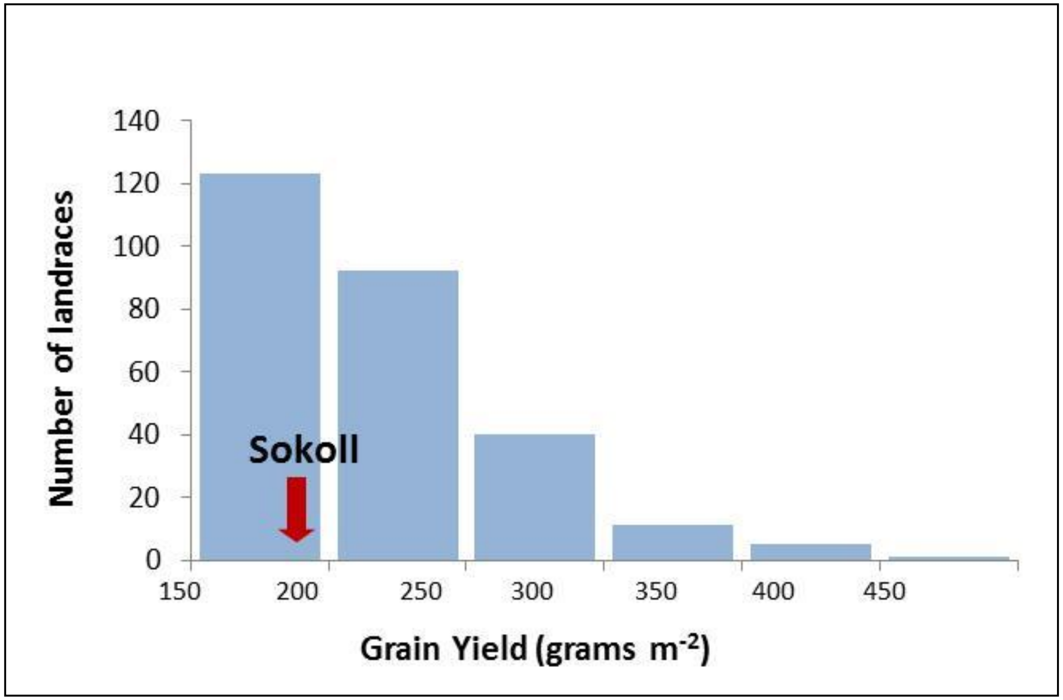
# Impact of heat on wheat

- ***~ 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)

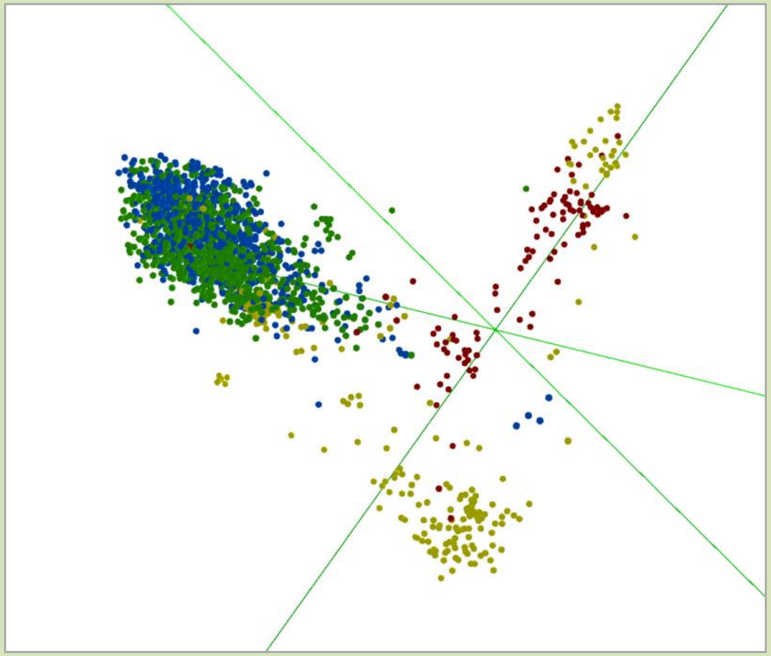
CIMMYT

# SeeD: Exploring wheat genetic resources for heat tolerance




- Heat-tolerant landraces were identified
- We discovered <u>new</u> diversity

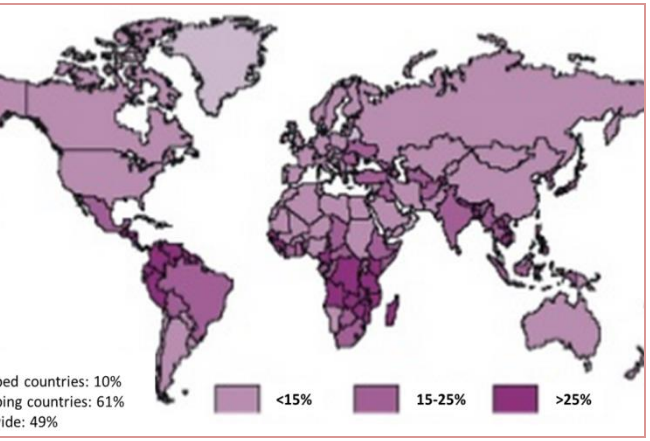
**Genetic Diversity study**



**Tolerant Mexican landraces (YELLOW)**
**Tolerant Iranian landraces (RED)**
**Elite lines (BLUE & GREEN)**

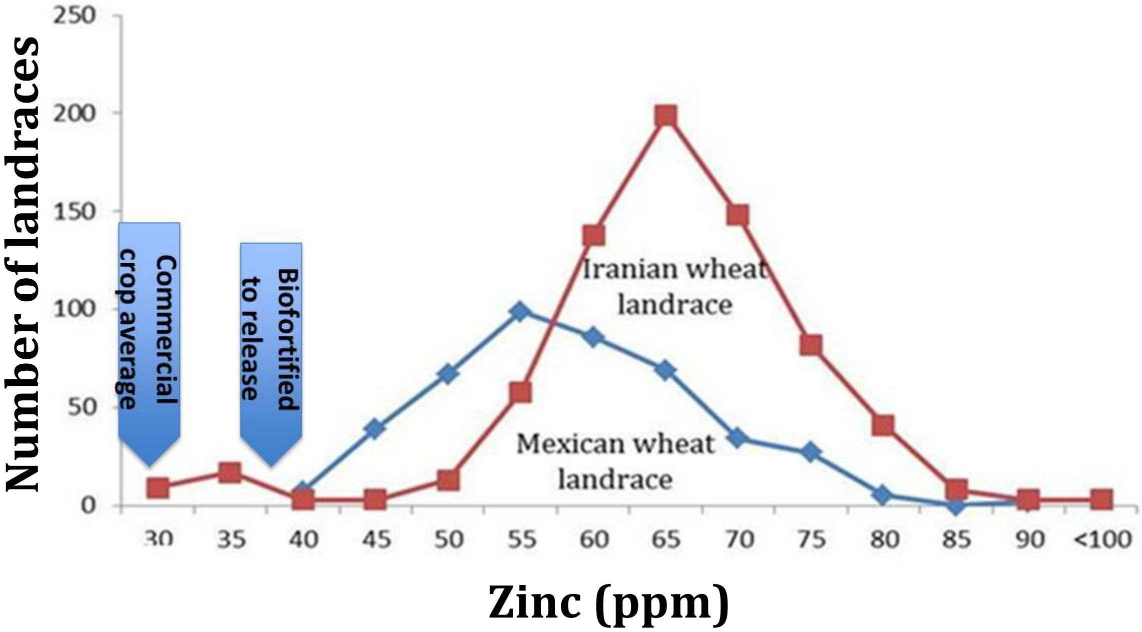
CIMMYT

# 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

Partners

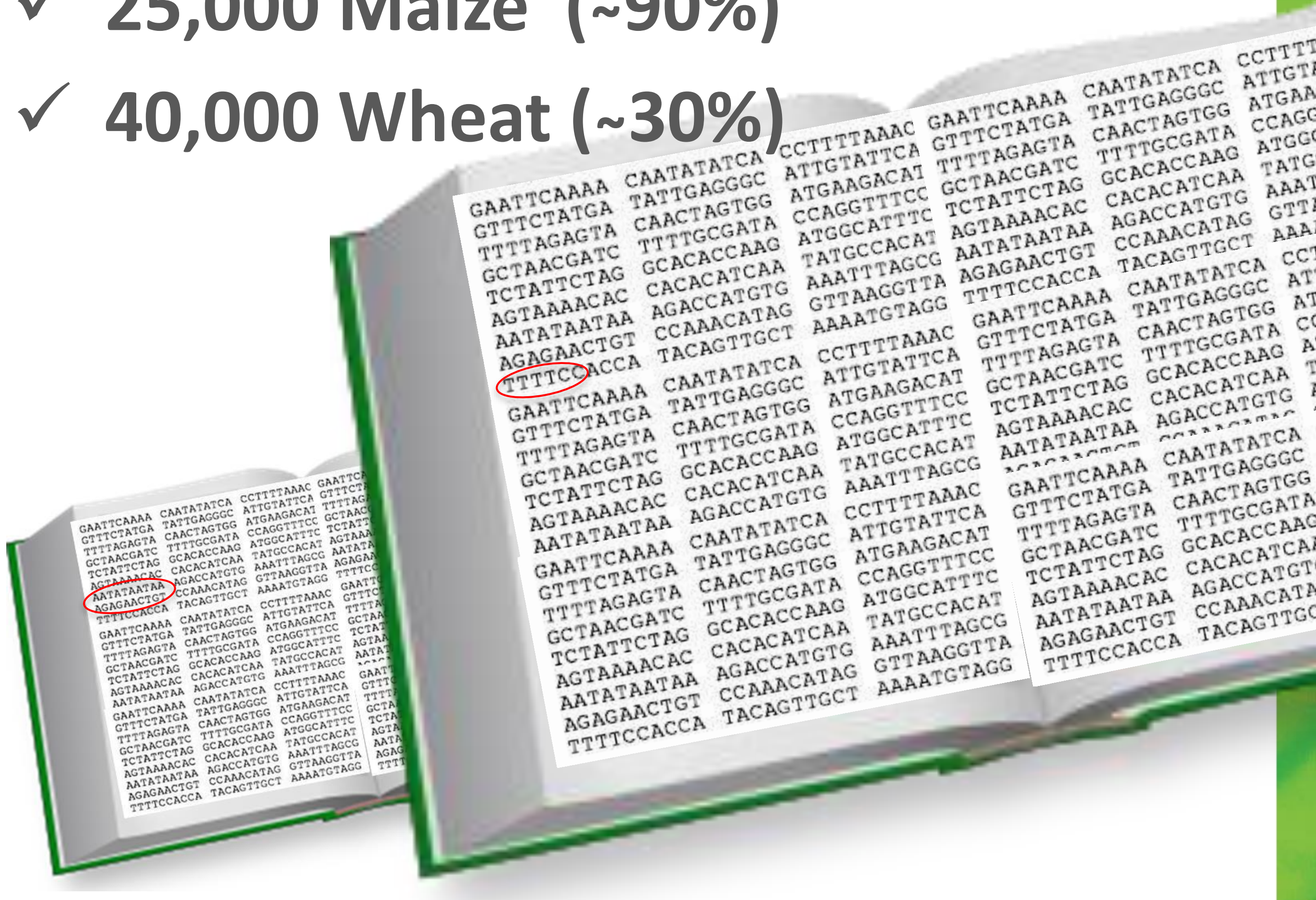
CGIAR

Jonás Aguirre (UNAM), Flavio Aragón (INIFAP), Gary Atlin, Odette Avendaño (LANGEBIO), Michael Baum (ICARDA), David Bonnett, Hans Braun, Ed Buckler (Cornell Univ.), Juan Burgueño, Vijay Chaikam, Alain Charcosset (AMAIZING), Gabriela Chávez (INIFAP), Jiafa Chen, Charles Chen, Andrés Christen (CIMAT), Angelica Cibrian (LANGEBIO), Héctor M. Corral (AGROVIZION), Moisés Cortés (CNRG), Sergio Cortez (UPFIM), Denise Costich, Lino de la Cruz (UdeG), Etienne Duveiller, Marc Ellis, Armando Espinosa (INIFAP), Néstor Espinosa (INIFAP), Gilberto Esquivel (INIFAP), Luis Eguiarte (UNAM), Mustapha El-Bouhssini (ICARDA), Gaspar Estrada (UAEM), Juan D. Figueroa (CINVESTAV), Pedro Figueroa (INIFAP), Jorge Franco (UDR), Guillermo Fuentes (INIFAP), Bonnie Furman, Amanda Gálvez (UNAM), Héctor Gálvez (SAGA), Karen García, Silverio García (ITESM), Noel Gómez (INIFAP), Gregor Gorjanc (Roslin Inst.), Sarah Hearne, Carlos Hernández, Juan M. Hernández (INIFAP), Víctor Hernández (INIFAP), Luis Herrera (LANGEBIO), John Hickey (Roslin Inst.), Huntington Hobbs, Puthick Hok (DArT), Javier Ireta (INIFAP), Andrzej Kilian (DArT), Huihui Li, Marta Lopes, George Mahuku, Francisco J. Manjarrez (INIFAP), David Marshall (JHI), César Martínez, Carlos G. Martínez (UAEM), Manuel Martínez (SAGA), Ky Matthews, Iain Milne (JHI), Terrence Molnar, Moisés M. Morales (UdeG), Henry Ngugi, Francis Ogbonnaya (ICARDA), Alejandro Ortega (INIFAP), Iván Ortíz, Leodegario Osorio (INIFAP), Natalia Palacios, José Ron Parra (UdeG), Tom Payne, Javier Peña, Cesar Petroli (SAGA), Kevin Pixley, BM Prasanna, Ernesto Preciado (INIFAP), Matthew Reynolds, Sebastian Raubach (JHI), María Esther Rivas (BIDASEM), Carolina Roa, Alberto Romero (Cornell Univ.), Ariel Ruíz (INIFAP), Carolina Saint-Pierre, Jesús Sánchez (UdeG), Gilberto Salinas, Yolanda Salinas (INIFAP), Carolina Sansaloni (SAGA), Ruairidh Sawers (LANGEBIO), Sergio Serna (ITESM), Paul Shaw (JHI), Rosemary Shrestha, Aleyda Sierra (SAGA), Pawan Singh, Sukhwinder Singh, Giovanni Soca, Ernesto Solís (INIFAP), Kai Sonder, Ken Street (ICARDA), Maria Tattaris, Maud Tenaillon (AMAIZING), Fernando de la Torre (CNRG), Heriberto Torres (Pioneer), Samuel Trachsel, Grzegorz Uszynski (DArT), Ciro Valdés (UANL), Griselda Vásquez (INIFAP), Humberto Vallejo (INIFAP), Víctor Vidal (INIFAP), Eduardo Villaseñor (INIFAP), Prashant Vikram, Martha Willcox, Peter Wenzl, Víctor Zamora (UAAAN)

CIMMYT

# SeeD – high-density genetic profiles

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



$35 per sample = $2.3 million

CIMMYT

# SeeD: More than 2 million field data

| Wheat | Maize |
|---|---|
| Grain yield | Grain yield |
| Drought | Drought |
| Heat | Heat |
| Low soil phosphorus | Low soil nitrogen |
| Tan spot | Tar spot |
| Karnal bunt | Turcicum blight |
| Spot blotch | Stalk rot |
| Wheat blast | Ear rot |
| Zinc | Cercospora (GLS) |
| Iron | Grain quality (oil…) |
| Protein | Carotenoids |
| Grain quality (twt…) | Root lodging |
| Phenology | Stem lodging |
| Morphology | Phenology |

- ✓ **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**

CIMMYT

# First value generated

Tar spot

Zn

Heat

Drought

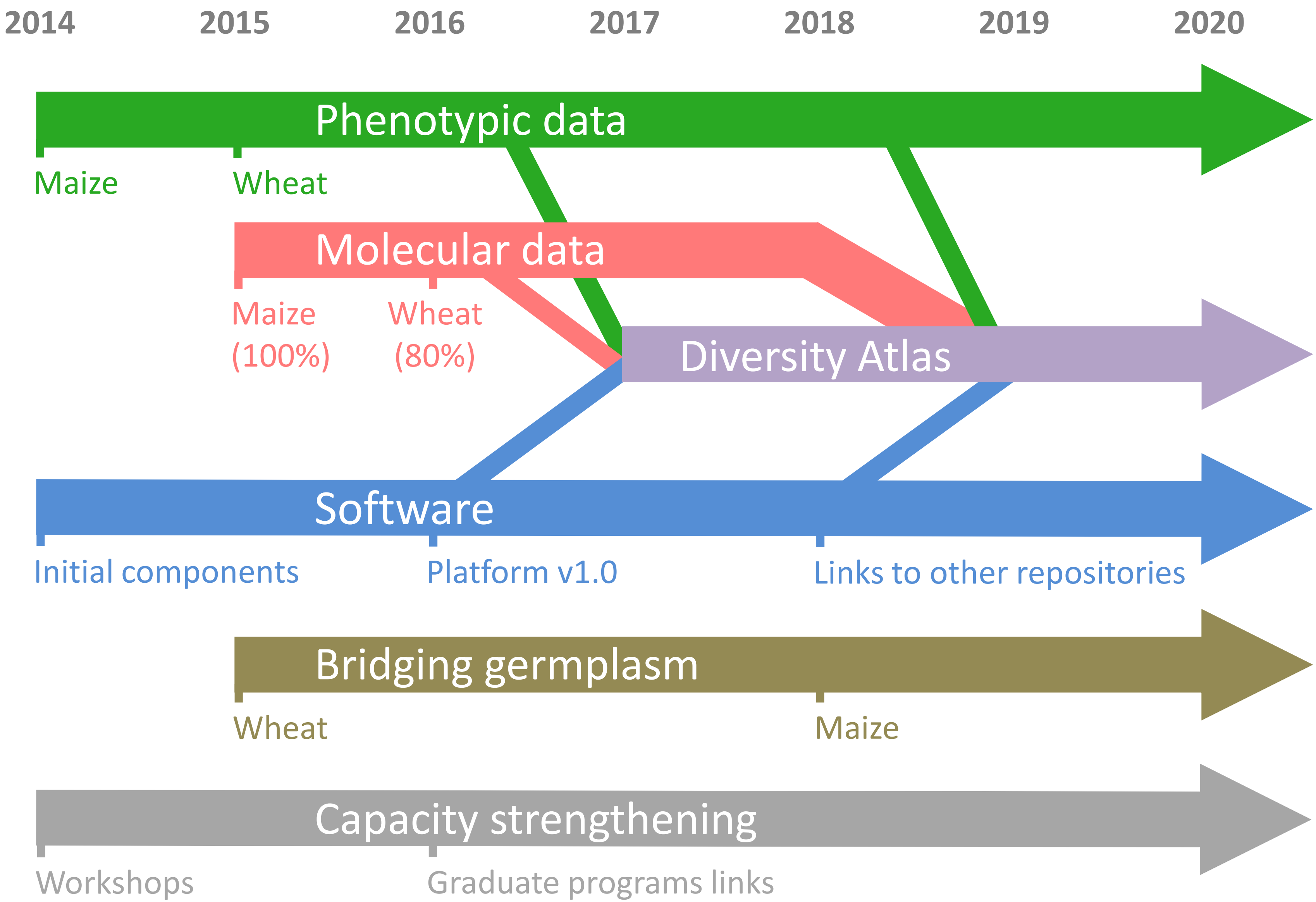
Valuable sources identified

# 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**

CIMMYT MR


2014
2015
2016
2017
2018
2019
2020
Phenotypic data
Maize
Wheat
Molecular data
Maize (100%)
Wheat (80%)
Diversity Atlas
Software
Initial components
Platform v1.0
Links to other repositories
Bridging germplasm
Wheat
Maize
Capacity strengthening
Workshops
Graduate programs links

CIMMYT

# Partnership opportunities:

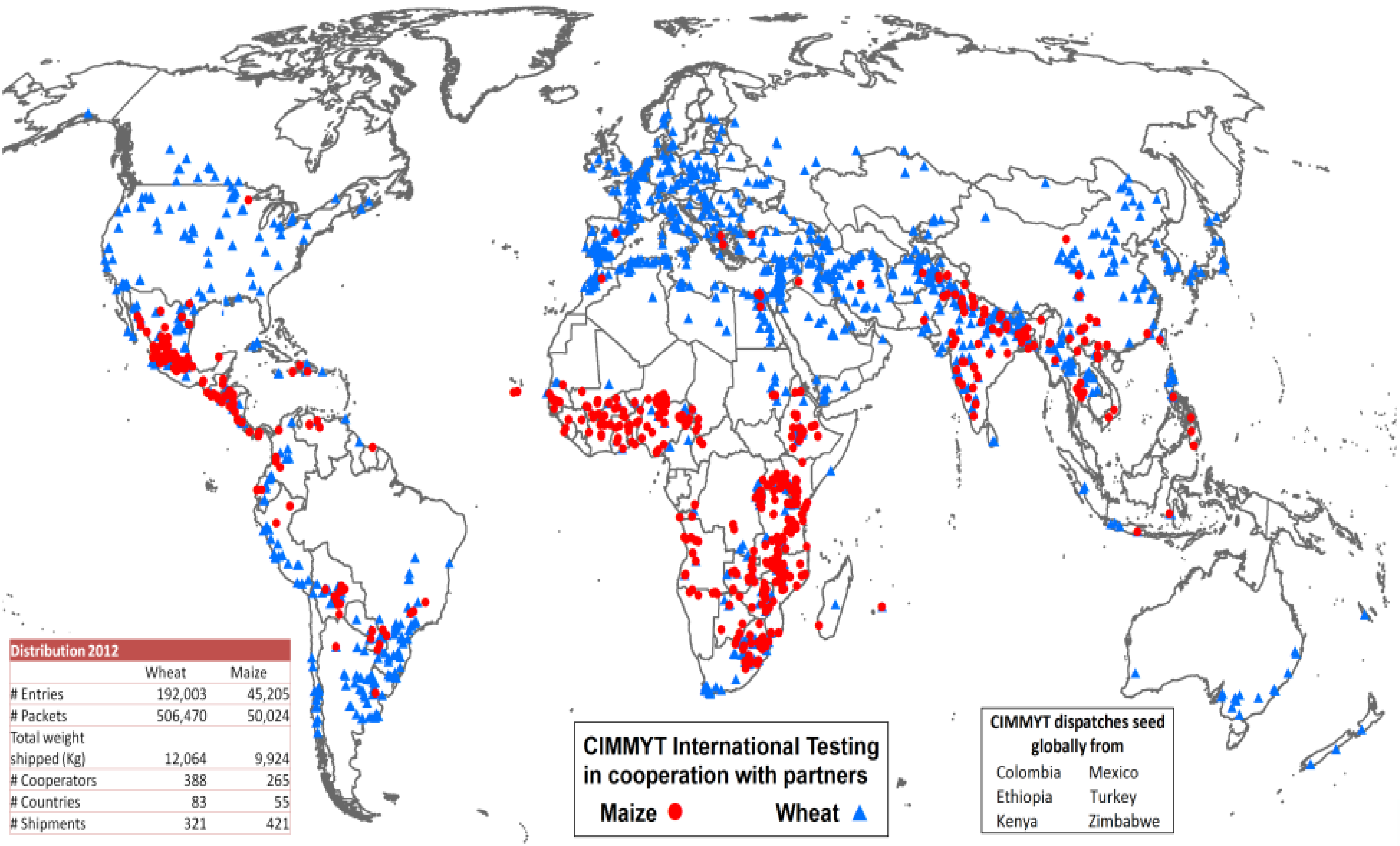
- ✓ Participate in priority setting
- ✓ Phenotype traits of interest
- ✓ Data mining; knowledge generation
- ✓ Germplasm utilization initiatives
- ✓ Capacity building providers and beneficiaries
- ✓ Other crops

# 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

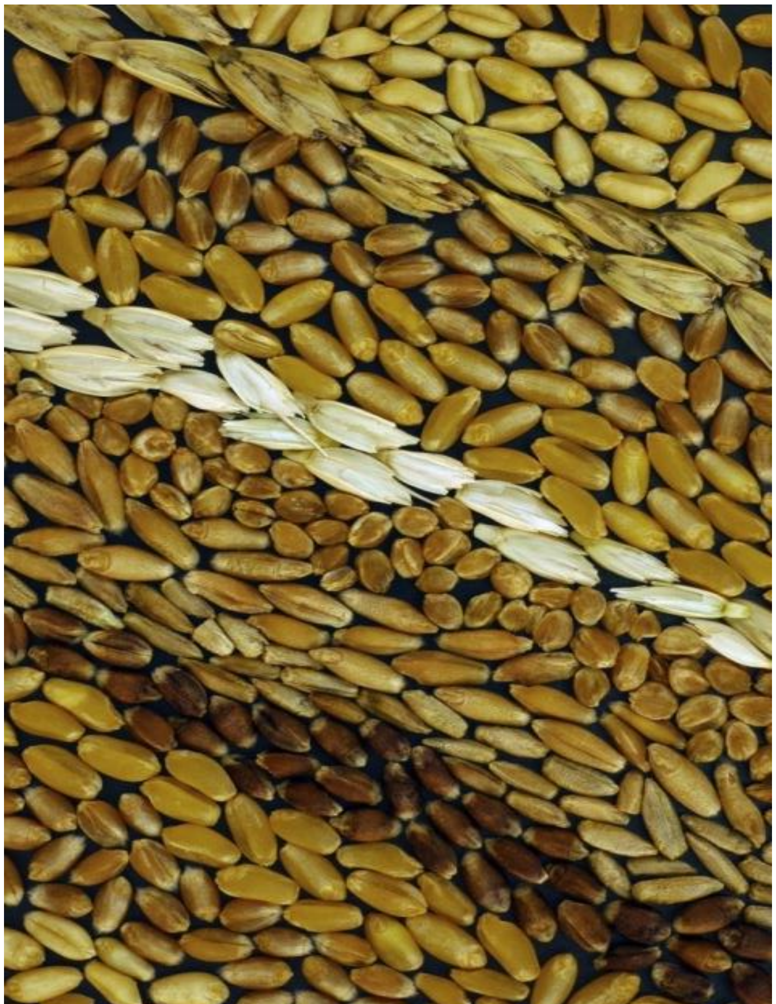
# = Those that will benefit from SeeD




**Distribution 2012**

| | Wheat | Maize |
|---|---|---|
| # Entries | 192,003 | 45,205 |
| # Packets | 506,470 | 50,024 |
| Total weight shipped (Kg) | 12,064 | 9,924 |
| # Cooperators | 388 | 265 |
| # Countries | 83 | 55 |
| # Shipments | 321 | 421 |

# Discussion



CIMMYT

# 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**

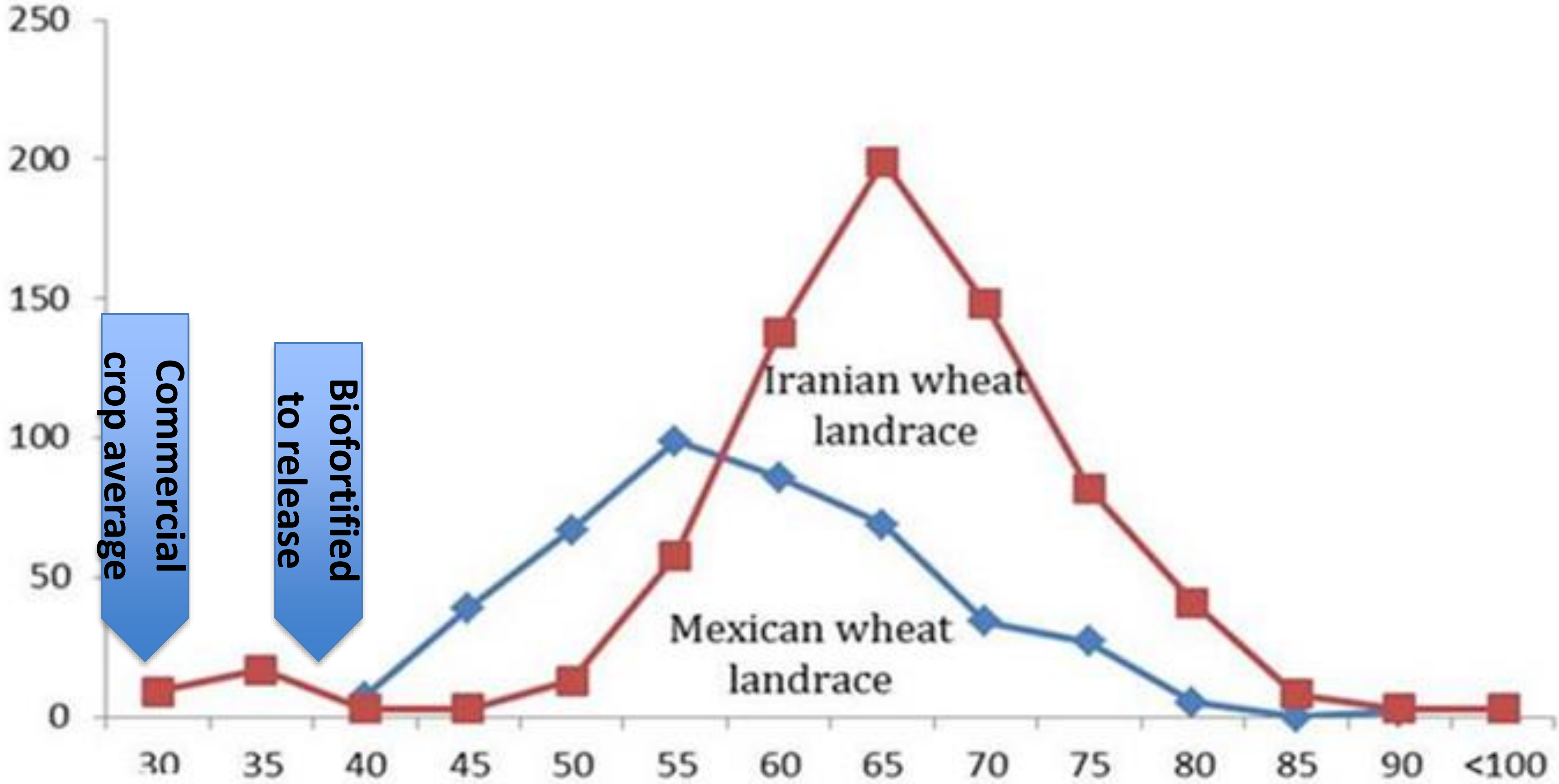
- Annual workshops with partners: 2016***
- Links to graduate programs: 2016***
- Fellowships for visiting scientists: 2015***
- Genetic resources utilization network: 2016*

# SeeD: Challenges and Opportunities

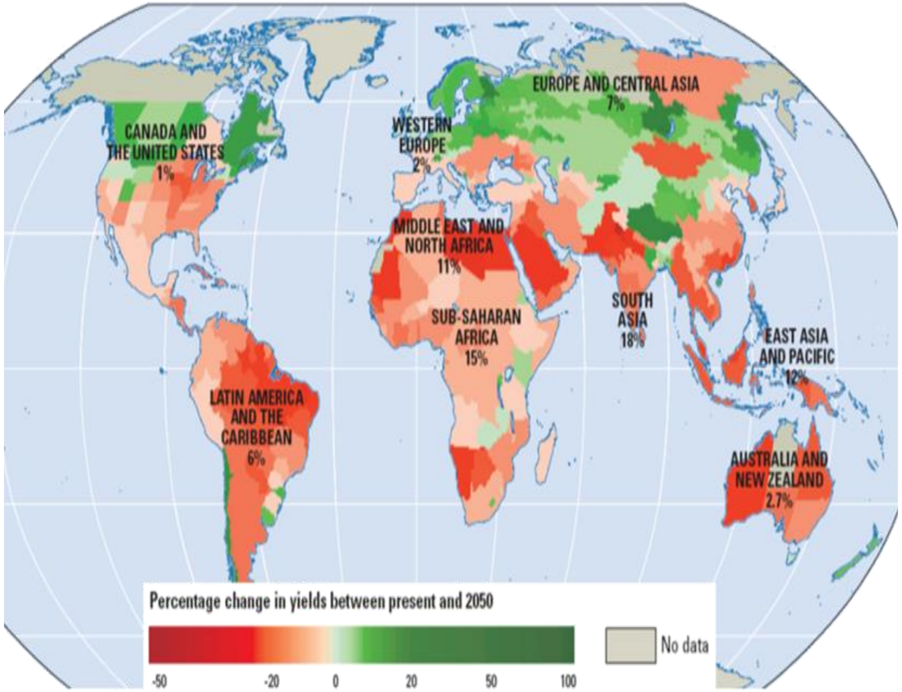
- **Government change in Mexico has led to 55% reduction in budget.**
- **Mexican government mainly interested in funding research in Mexico, for Mexico**
  - CIMMYT has global vision for project
  - is a large part of that vision
- **We currently are seeking funding to continue our activities and to expand SeeD beyond Mexico**

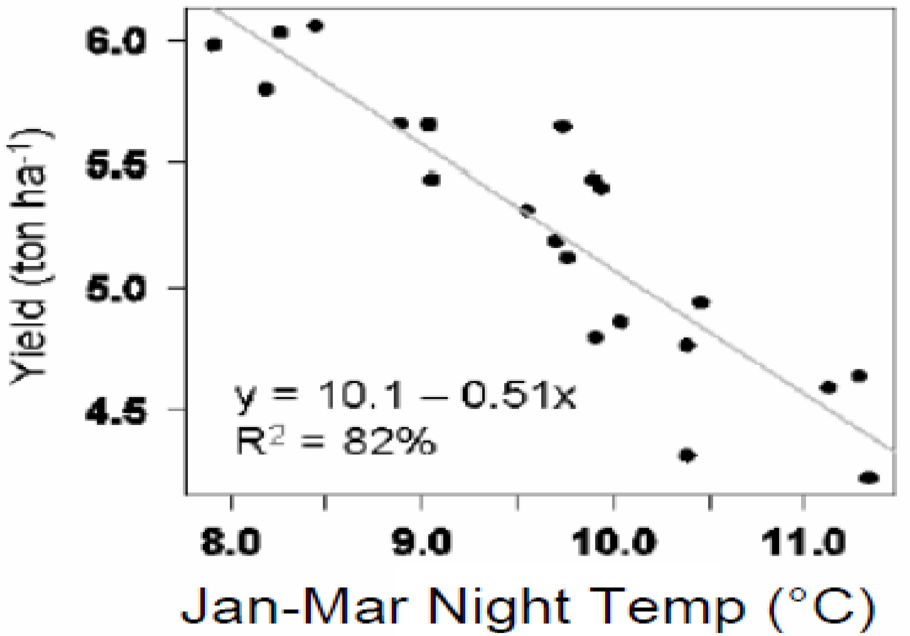
CIMMYT

# *Fishing wheat gene bank for nutritive wheat: evaluated ~15,000 landraces for quality traits*



# Higher temperatures → reduce wheat yield




Lobell 2007

## 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*

CIMMYT

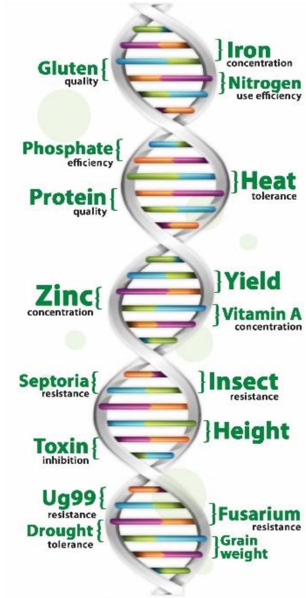
# SeeD-wheat project deliver for wheat improvement in next 3 years

- 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

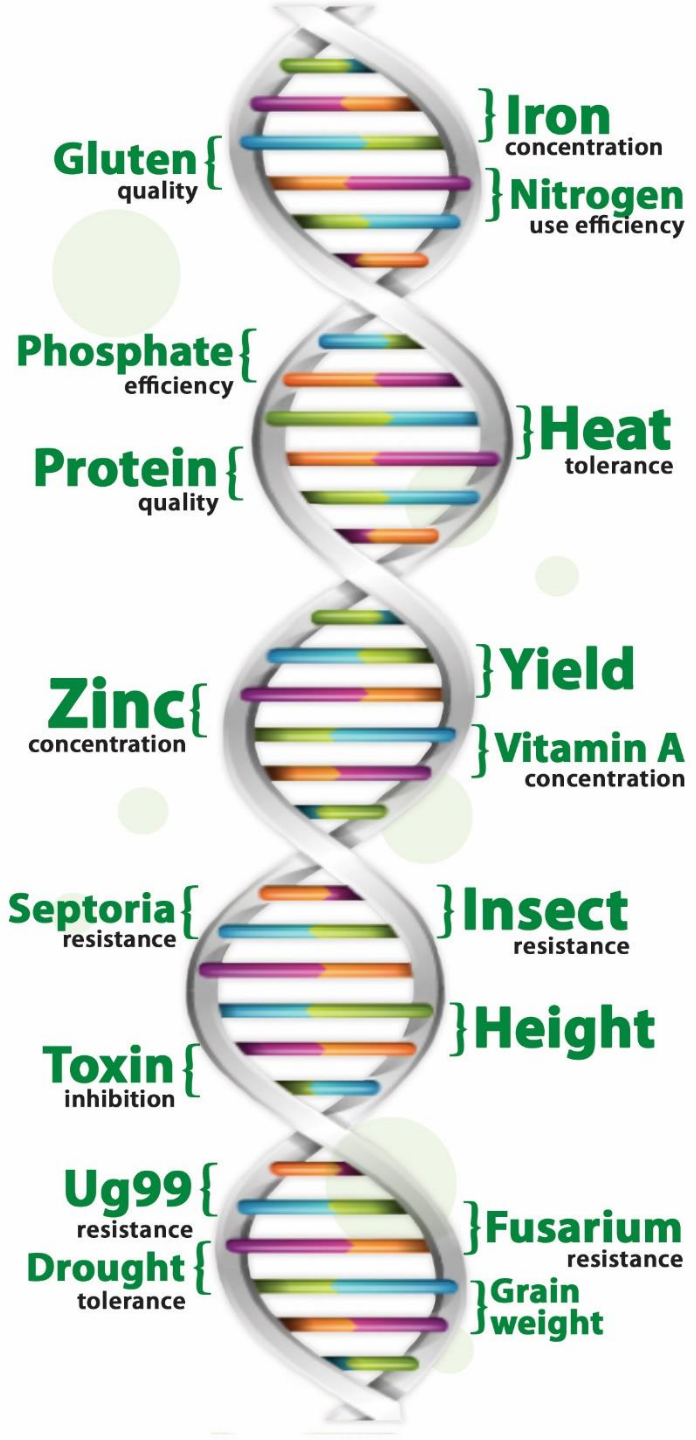
# Why a bottleneck?




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

***SeeD: New technologies to identify and facilitate the use of maize and wheat biodiversity***

CIMMYT


Iron
concentration
Gluten
quality
Nitrogen
use efficiency
Phosphate
efficiency
Heat
tolerance
Protein
quality
Yield
Zinc
concentration
Vitamin A
concentration
Septoria
resistance
Insect
resistance
Height
Toxin
inhibition
Ug99
resistance
Fusarium
resistance
Drought
tolerance
Grain
weight

CIMMYT

# Plant breeding produces new varieties

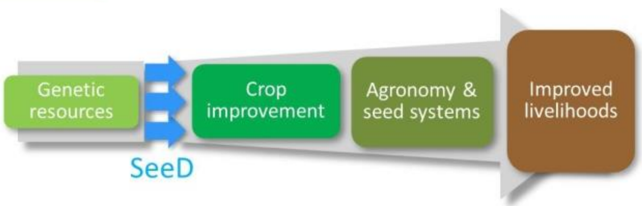
Maize Lethal Necrosis

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




Identify useful genetic variation

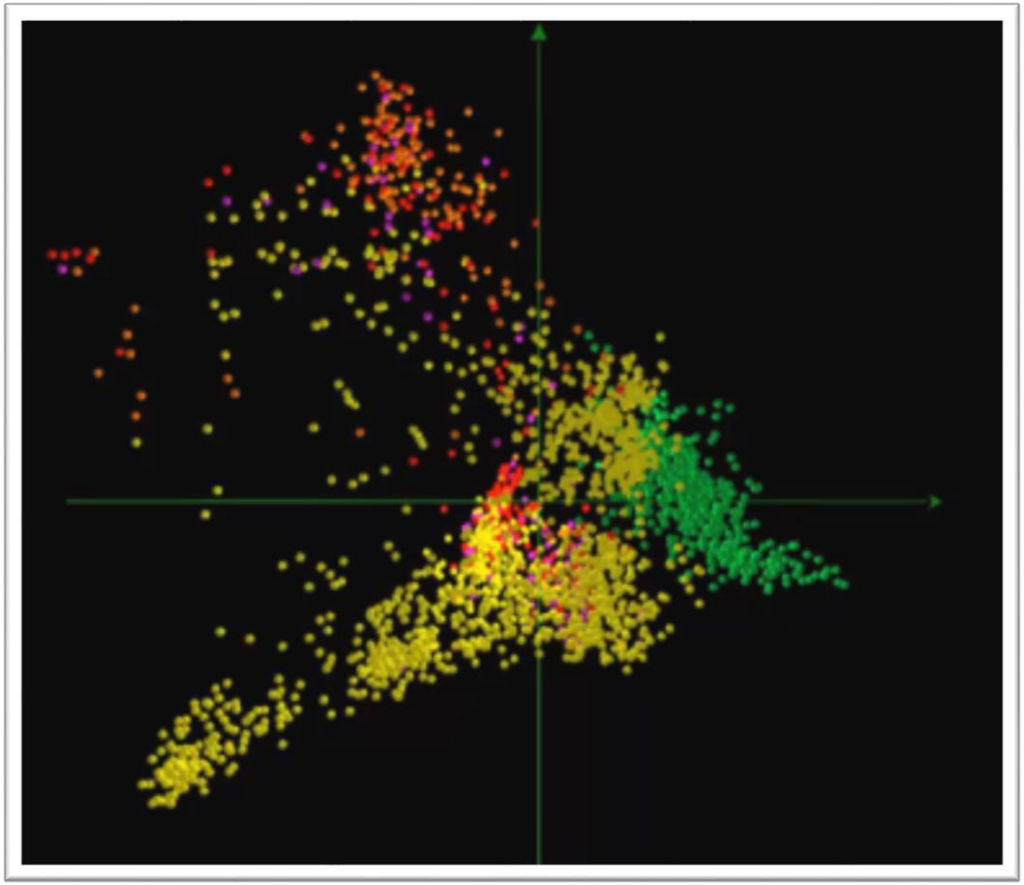
Make crosses: add new to current best

Evaluate and select something better

Finalize and release a new variety

CIMMYT

# Towards a Maize Atlas

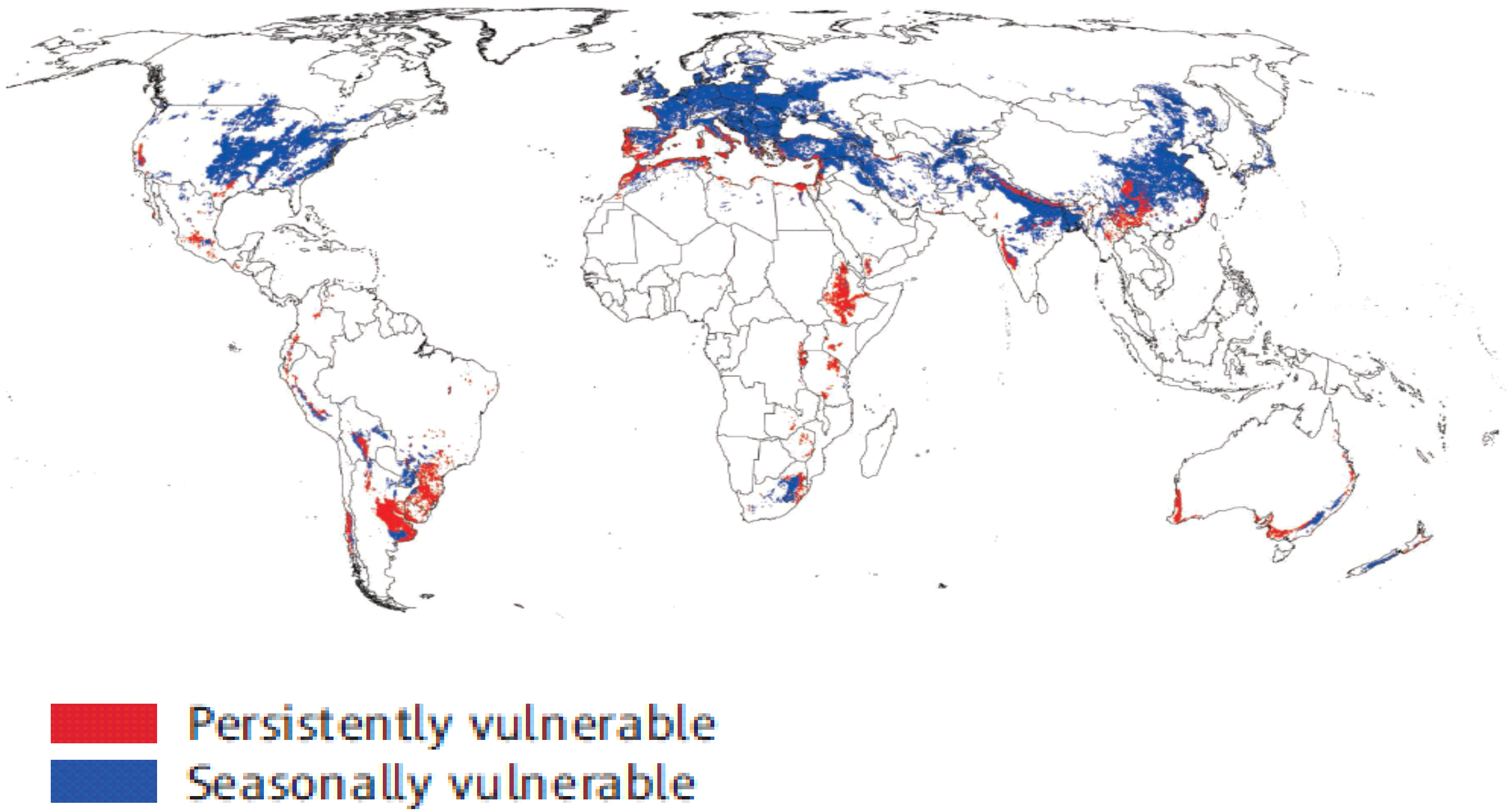


- CIMMYT elite maize lines
- Drought during vegetative cycle (+ flowering)
- Heat during flowering
- Heat and drought

- 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

# 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)**

*Science, 340:147-148(2013)*

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

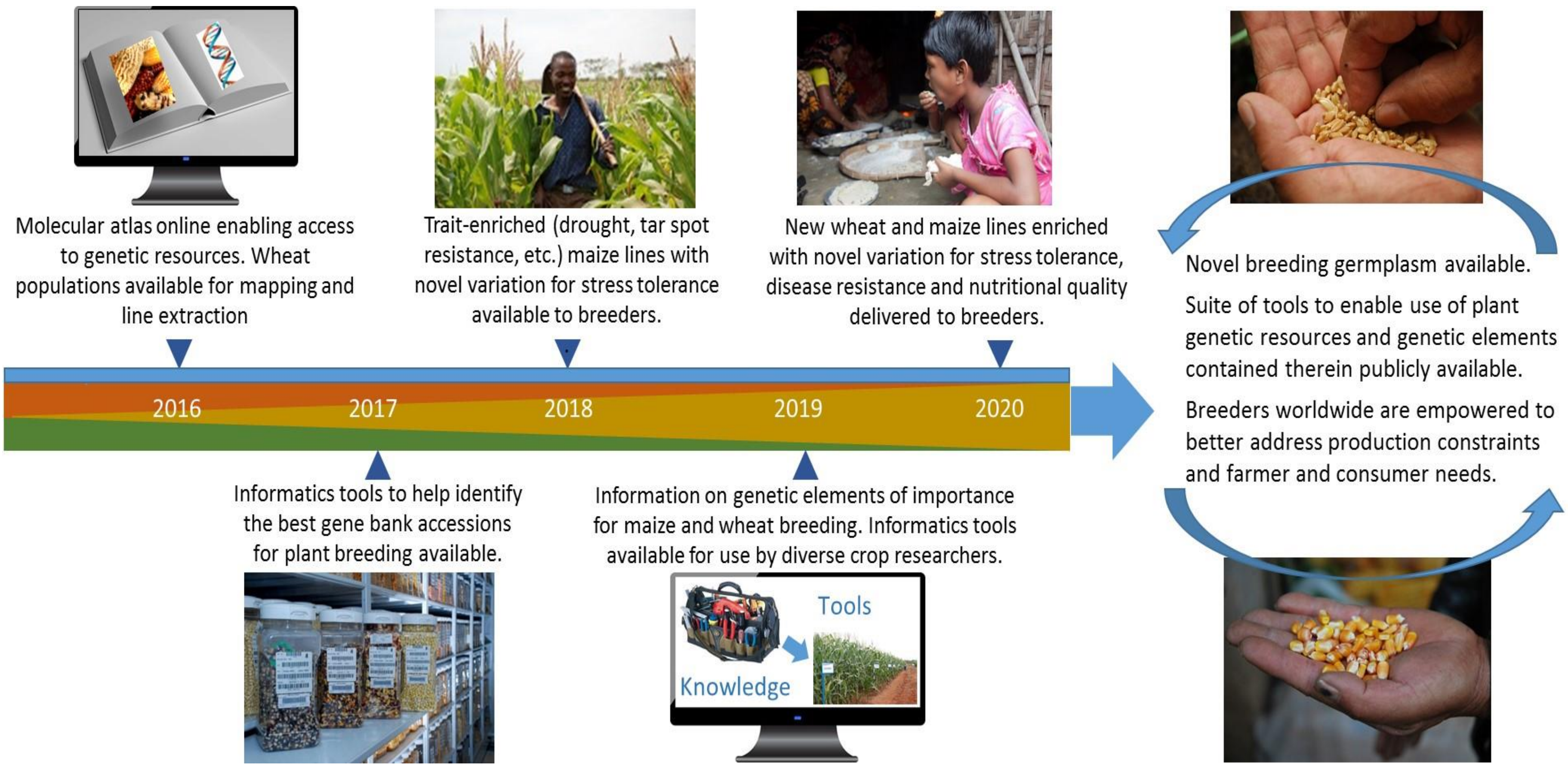
CIMMYT


Susceptible check
rust-resistant accessions
Susceptible check


- **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

CIMMYT

# SeeD – future outlook



**Genetic Resources**

**Molecular Atlas**

**Genomic Associations**

**Novel alleles and allele donors**

- **Characterize accessions by genome profiling**

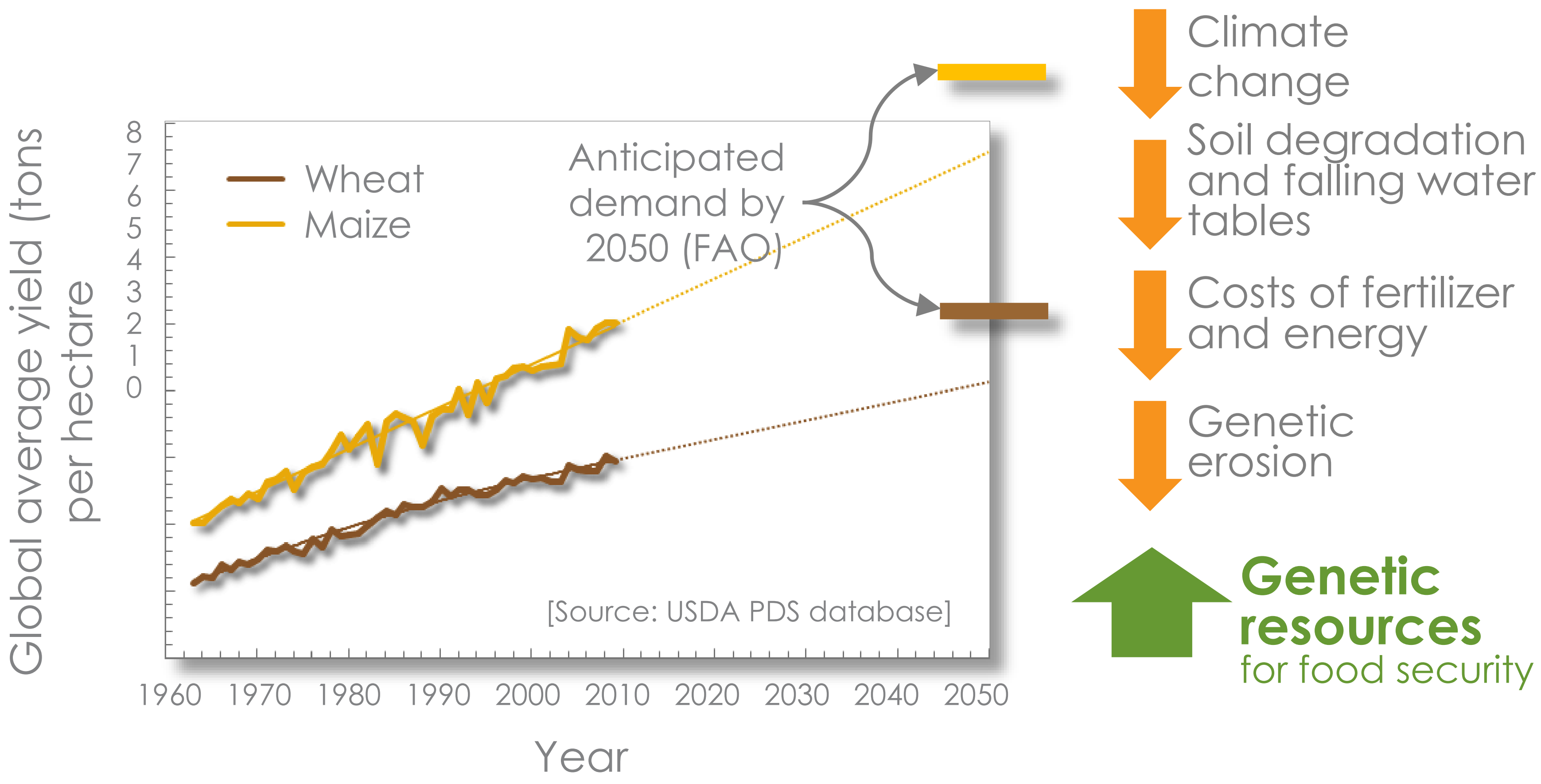
- **Phenotype under target stress**
- **Identify novel beneficial alleles**
- **Markers linked to novel alleles**

**Bridge germplasm**

- **New lines with:**
  **> Enhanced resistance to targeted stress**
  **> An acceptable agronomic background**

CIMMYT

# Why SeeD?




CIMMYT