# Valorization of PGR from a breeder's perspective

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# Outline

- How can we increase the utilization of PGR for crop improvement?
- Major initiative:

  *Collecting and using CWR - Adapting Agriculture to Climate Change*
- Genesys

# Valorizing PGR for breeding

IPK

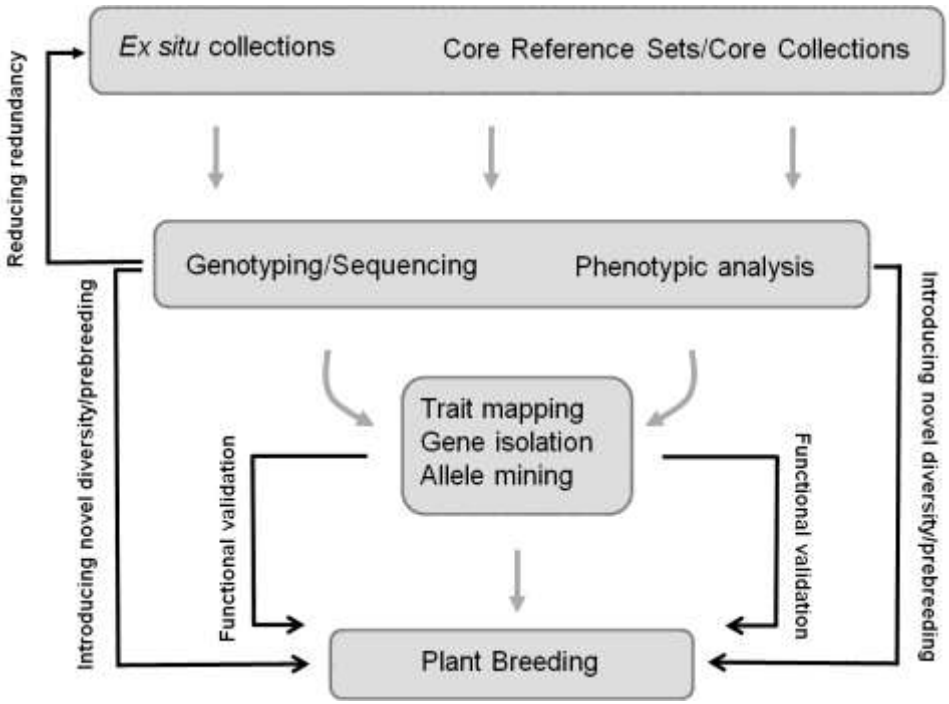
**c. 150.000 acc**

**56 documented variety releases (1946-1994)**

# Two worlds

*In situ*

*"Working collections"*




Why have we utilized so few PGR?

Kilian & Graner 2012; Hammer et al. 1994

# Rationale of utilizing PGR for breeding

Bringing in not just (neutral) genetic diversity

BUT:

- Bringing **in necessary diversity** for **specific traits** of **importance to specific breeding programs**, and, furthermore,
- Bringing in beneficial **traits that are not present** in **adapted crop genotypes**

# Specific traits desired by hybrid wheat breeders may reside in PGR

| Specific beneficial trait | Promising PGR taxa to be utilized | References |
|---|---|---|
| Floral biology<br>(improve the natural level of outcrossing necessary to economically produce the founder line seed and the actual commercial hybrid seed) | *Ae. mutica*<br>*Ae. speltoides*<br>*Ae. tauschii* | Ohta 1990<br>Zaharieva & Monneveux 2006<br>Hammer 1978 |
| Disease resistance<br>Septoria | *T. araraticum* | Brown-Guedira et al. 1996 |
| Fertile tiller number | *Agropyron cristatum*<br>*Hordeum vulgare* | Ye et al. 2015<br>Molnar-Lang et al. 2014 |
| Spike size | *Agropyron cristatum* | Zhang et al. 2015 |

# Obstacles for breeders to the usage of PGR
## - general considerations -

- Breeders prefer material which is reasonably adapted to the current target environment
- Limited resources
- Short-term breeding goals
- PGR require lengthy and expensive program of pre-breeding
- Genetic variability of some elite gene pool seems currently sufficient (in Europe)

# Additional obstacles to the usage of CWR

- Poor agronomic performance (e.g. lack of domestication traits)
- Unpredictability of both a CWR phenotype under agronomic conditions and the phenotype of crop-CWR hybrids
- (Back)-crossing can be time-consuming and difficult for various reasons incl. hybrid sterility, linkage drag
- SNP markers optimized for introgression are just becoming available

# More obstacles to the usage of PGR

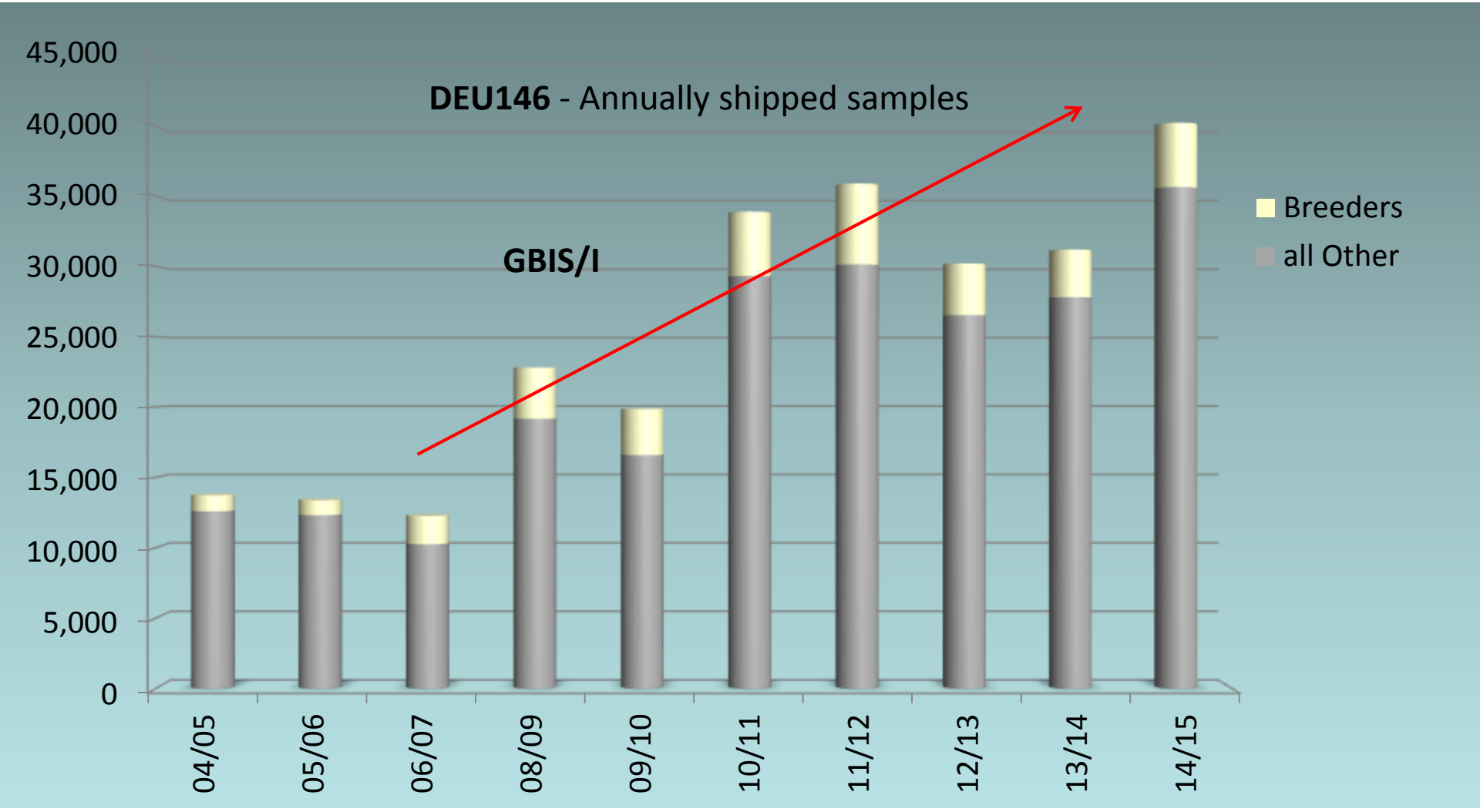
- Challenges around the understanding of access and benefit sharing provisions for germplasm and data

**Breeders simply don't know how to find the valuable materials**

- Poorly characterized PGR in genebank repositories
- If trait information available, then these are mostly not useful to breeders
- Genotypic data mostly not yet available

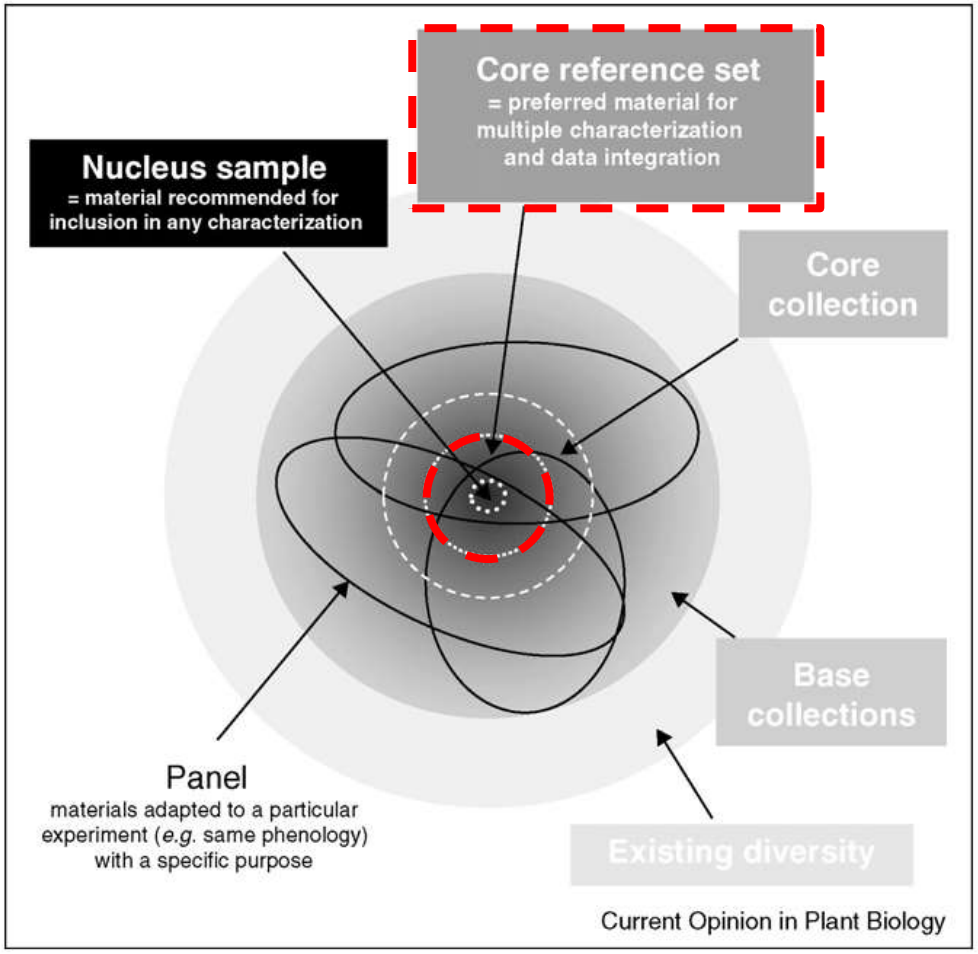
# How can we better link genebanks with breeders and farmers to increase the use of PGR?

# **(I)** Improving access to information of PGR
# - Genebank Information System -




Oppermann et al. in prep.

# **II)** Establishing Core Collections and Core Reference Sets




Glaszmann et al. 2010

# **III)** Preparing the germplasm for characterization and use

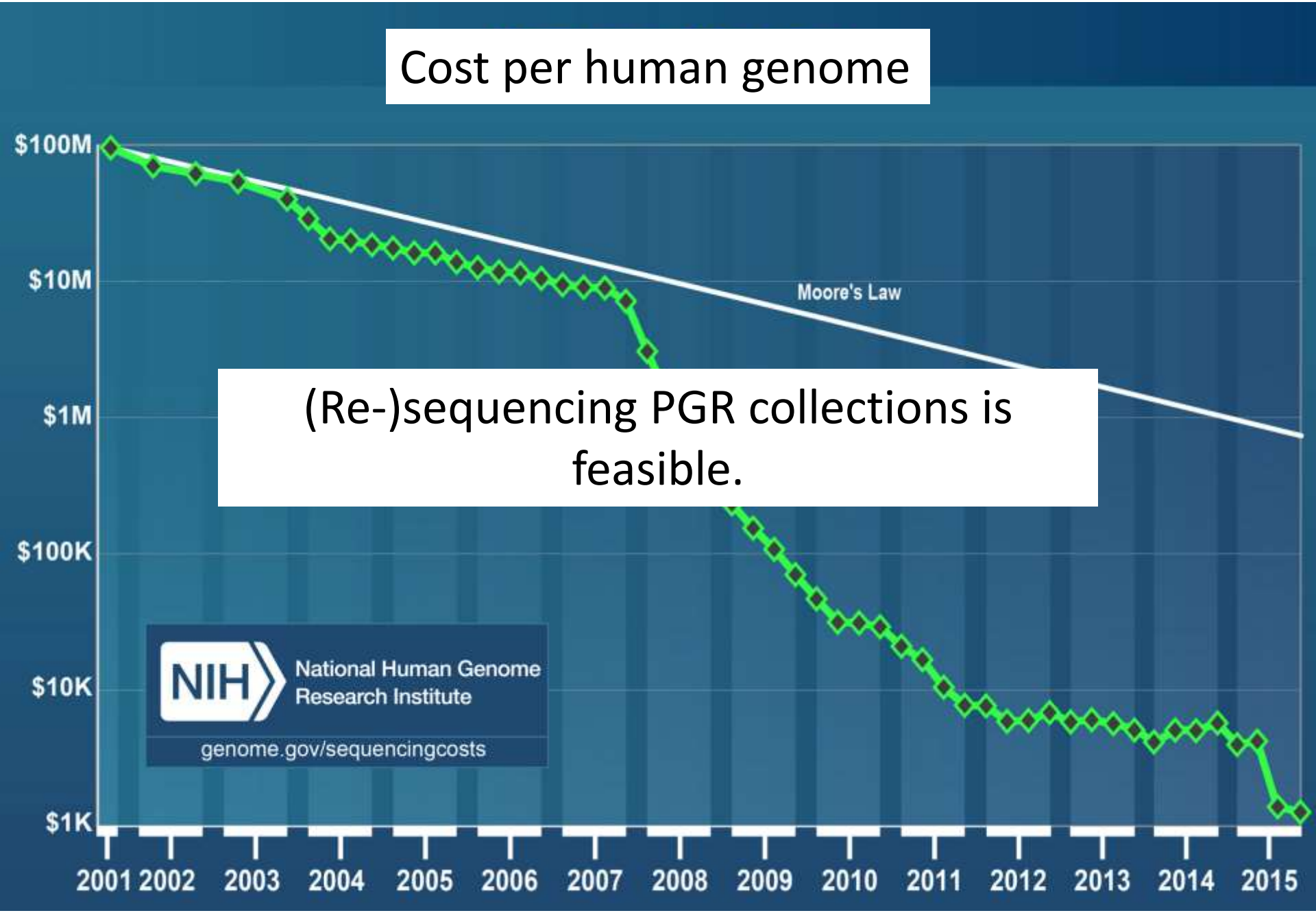
# **IV)** Genomic resources will boost the utilization of PGR

- The *right* molecular marker data to connect genebanks with breeding

  -> GBS vs SNP array-based technologies

- Performance development of sequence technologies
- Reference genome(s) sequences
- Genotyping or (re-/ de novo) sequencing of whole PGR collections is feasible

# Cost per human genome




(Re-)sequencing PGR collections is feasible.

# **V) Public Private Partnerships** (PPP) & **Pre-breeding** are critical links between genebanks and breeders

**PGR**

- Target traits should be defined first

↓

**<u>Pre-breeding pipeline</u>**

↓

- Long-term funding
- Industrially-relevant
- Pre-competitive research
- Evaluation network

**Breeding program**

# Collecting and using CWR
# Adapting Agriculture to Climate Change

- Support from Norwegian Government
- $50 million, 10 years
- Jan 2011 – Dec 2020
- 29 crop genepools
- Partnership with Millennium Seed Bank, Kew
- C. 30 national programs
- Complementary funding & linked activities
  - e.g. In-kind contributions: c. $3,5 million

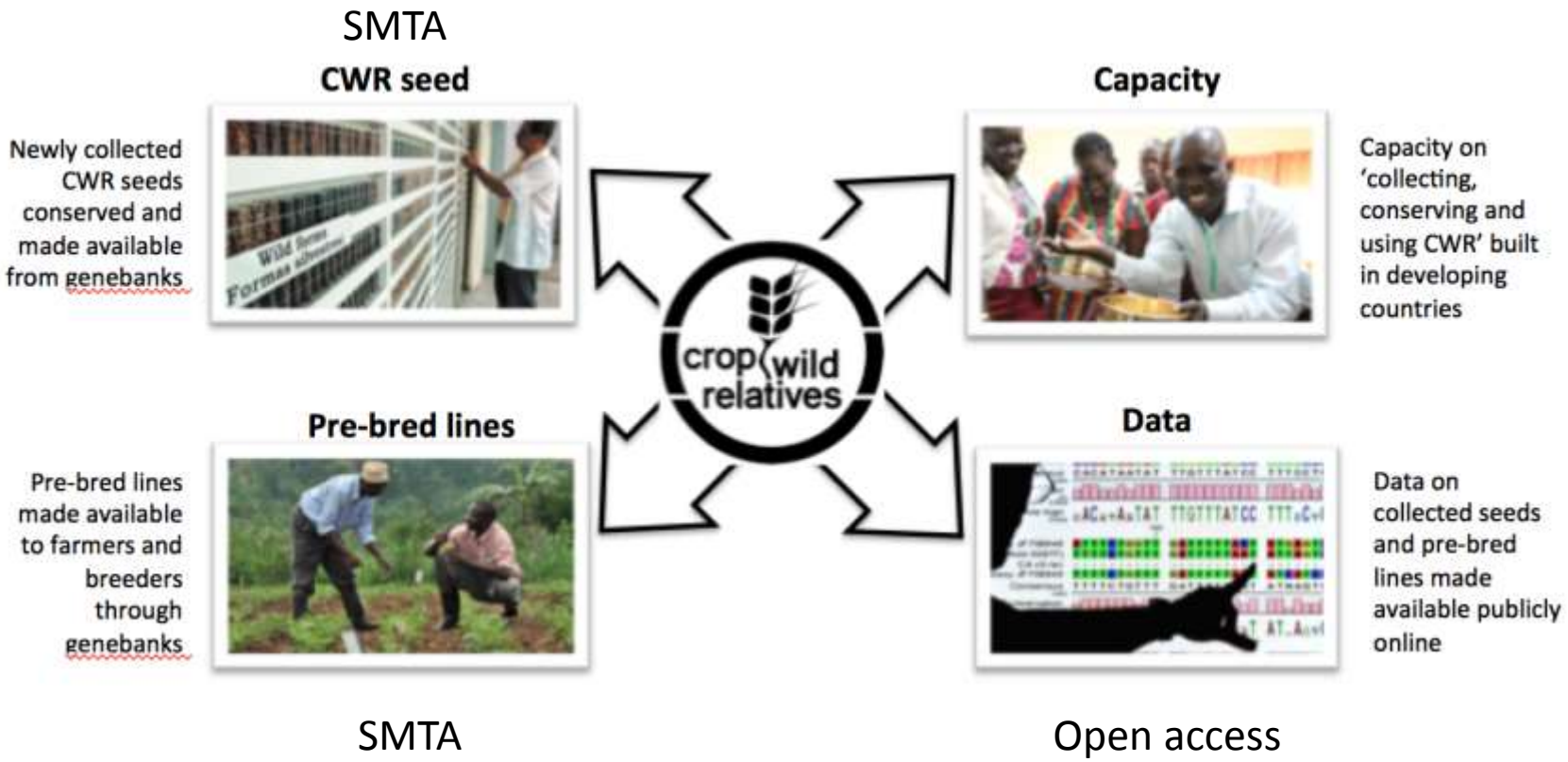
CROP TRUST

MILLENNIUM SEED BANK PARTNERSHIP
Kew

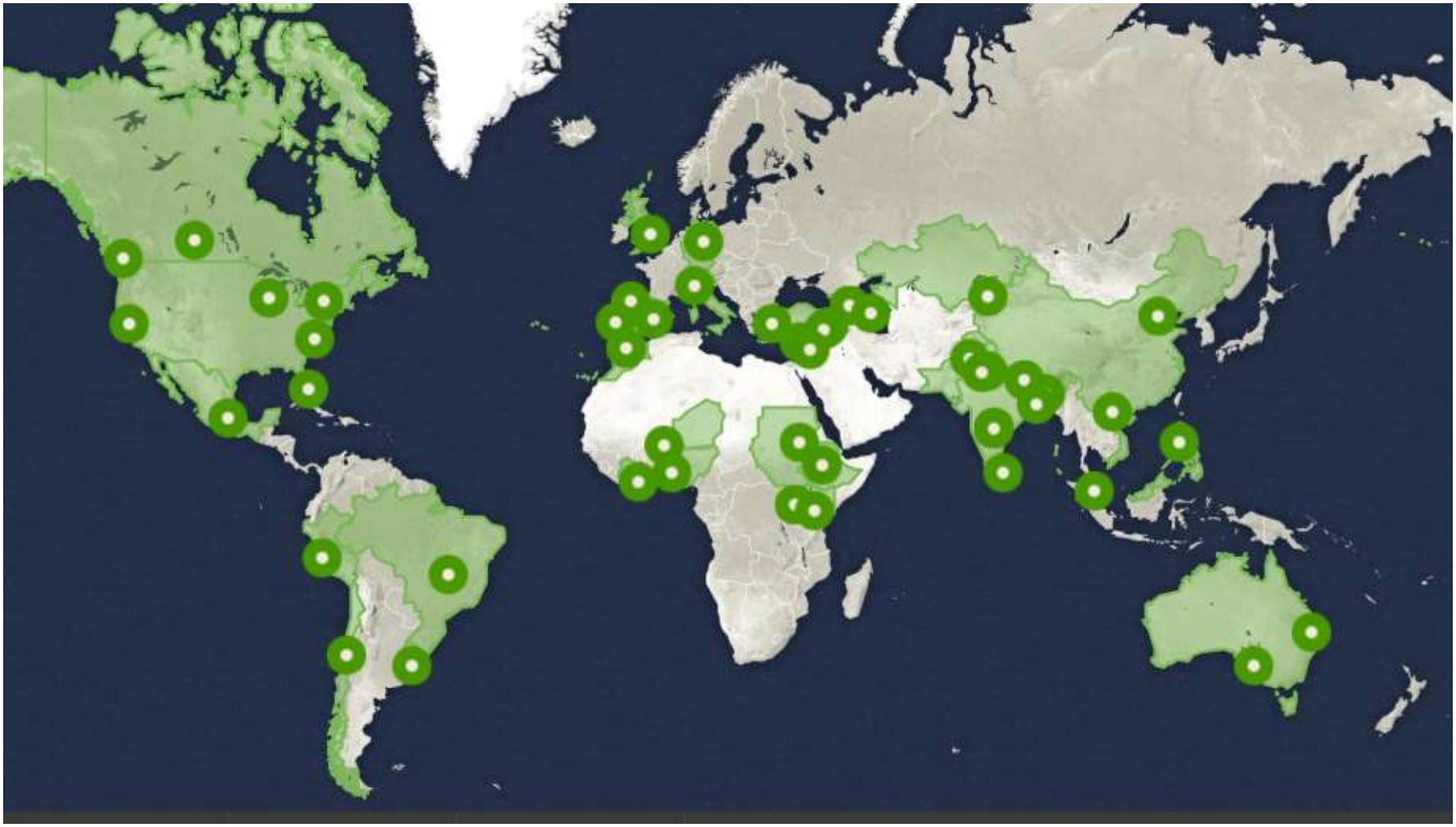
# The four major parts of the Project

1. Research & planning (Status of Conservation, prioritization)
2. Gap Filling (Collecting and Conservation)
3. **CWR Pre-breeding & Evaluation**
4. **CWR information management**

# Schematic overview of the four main outputs of the Project



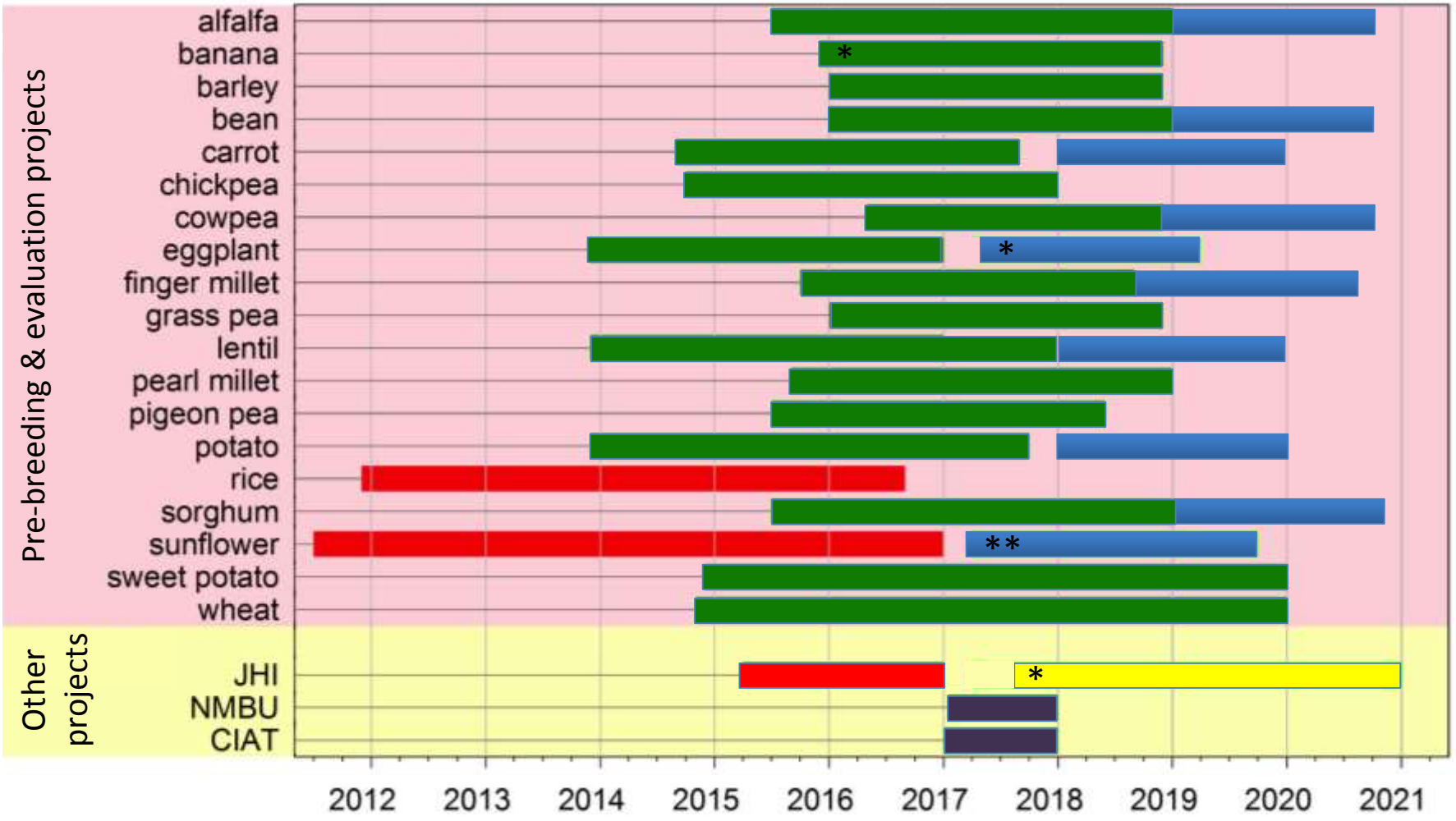
# Current extent of project partnerships, incl. both collecting & pre-breeding partners



# Pre-breeding partnerships I

| Crop | Countries | Focus traits |
|---|---|---|
| Alfalfa | Australia, INIA-Chile, GRI China, Kazakhstan | Drought tolerance |
| Banana | Belgium, **IITA** (Nigeria), partner in South-East Asia (TBD) | Drought tolerance |
| Barley | **ICARDA** (Morocco), Germany, Morocco | Drought, heat and salinity tolerance, enhanced nutritional value, disease and pest resistance |
| Bean | Colombia, **CIAT** (Colombia, Honduras) | Heat, drought, waterlogging and root rot resistance |
| Carrot | Bangladesh, Pakistan, USA | Heat, salt and drought tolerance |
| Chickpea | **ICARDA** (Morocco), Turkey, USA | Drought tolerance |
| Cowpea | **IITA**, Nigeria, Burkina Faso, Niger | Drought & heat tolerance |

# Pre-breeding partnerships – current & potential funding periods




Pilot (pre-breeding) projects

Pre-breeding projects

Evaluation projects

Data management project

Preparation for evaluation phase projects

* Currently under negotiation

** Signed

# Eggplant: Medium-long term sub-programme

*Solanum melongena* (MEL1-6)

Primary genepool

*S. incanum*

Secondary genepool

*S. pyracanthum*

Tertiary genepool

*S. sisymbriifolium*

# 3. CWR Pre-breeding & Evaluation

## Durum/wild relative Introgression

Wheat *Ph1/ph1*

A
B
D

($BC_2/BC_3/BC_4$ bread wheat)

X

Durum wheat

A
B

(CIMMYT/ICARDA durum lines)

$F_1$ ← Identification of TRUE $F_1$s (GISH and/ SNPs)

True $F_1$ X Durum line

$BC_1$ X Durum line

Self → $BC_1F_1$ Jan 2017 → Self → $BC_1F_2$ → Field testing 2018

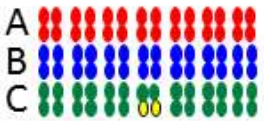
$BC_2$ Jan 2017 X Durum line

Self → $BC_2F_1$ Dec/Jan 2017/2018 → Self → $BC_2F_2$ → Field testing 2018

$BC_3$ Dec/Jan 2017/2018 → Self → $BC_3F_1$ June 2018 → Self → $BC_3F_2$ → Field testing 2018/2019

Phenotyping

Screening of $BC_1$ and subsequent BC progeny to identify recombinants



A
B
C

← Isolation of homozygous introgressions

3. CWR Pre-breeding & Evaluation

# Sweet potato pre-breeding


- c. 15 wild sweet potato species in the ‘Batatas complex’
- CIP hosts largest sweet potato germplasm collection
- First ones grown from seeds, then multiplied by cuttings

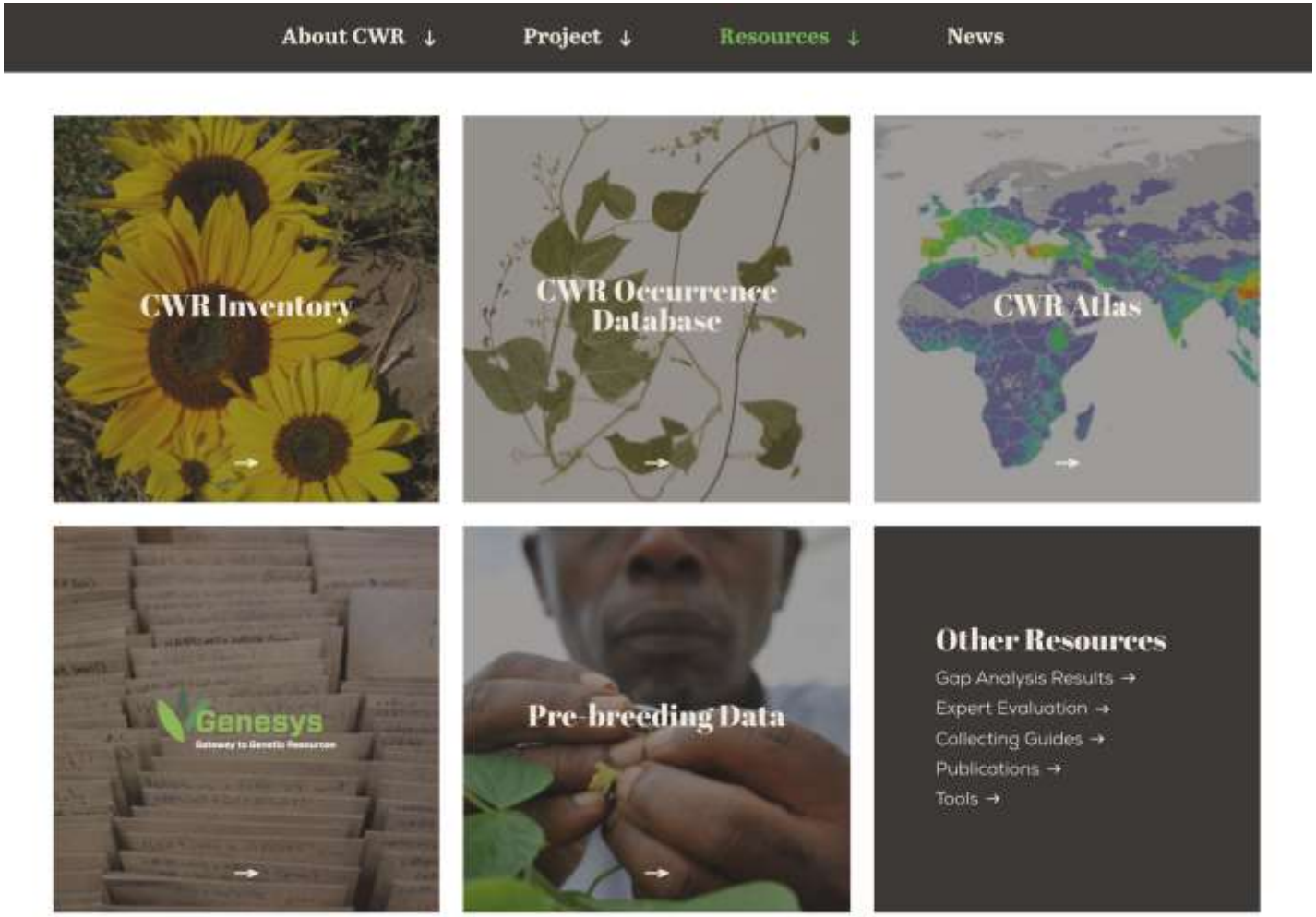
# Sweet potato pre-breeding

NSCU: Stella, PhD student in Yencho lab
CIP: 11 000 crosses at San Ramón using 9 CWR's

# Carrot pre-breeding in Bangladesh, Pakistan and USA

Target traits: enhanced tolerance to drought, heat and salinity.

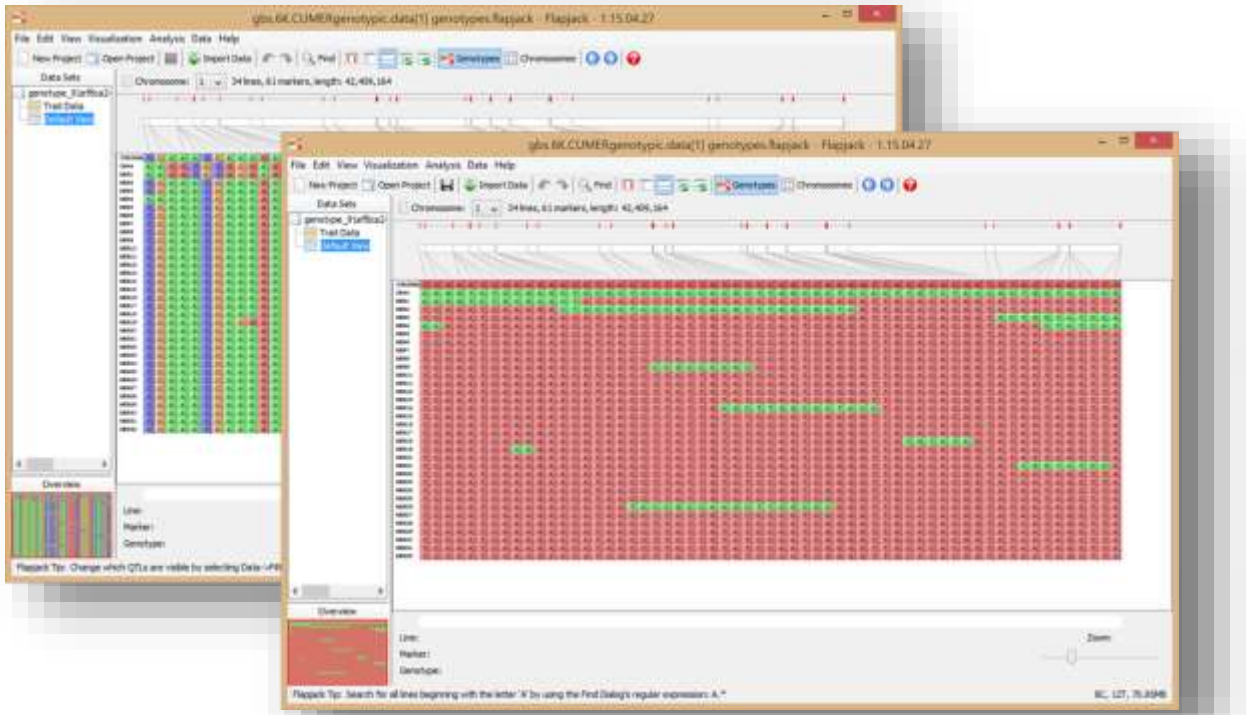
# Screenshot of the project website showing the resources that the project continues to produce




http://www.cwrdiversity.org/

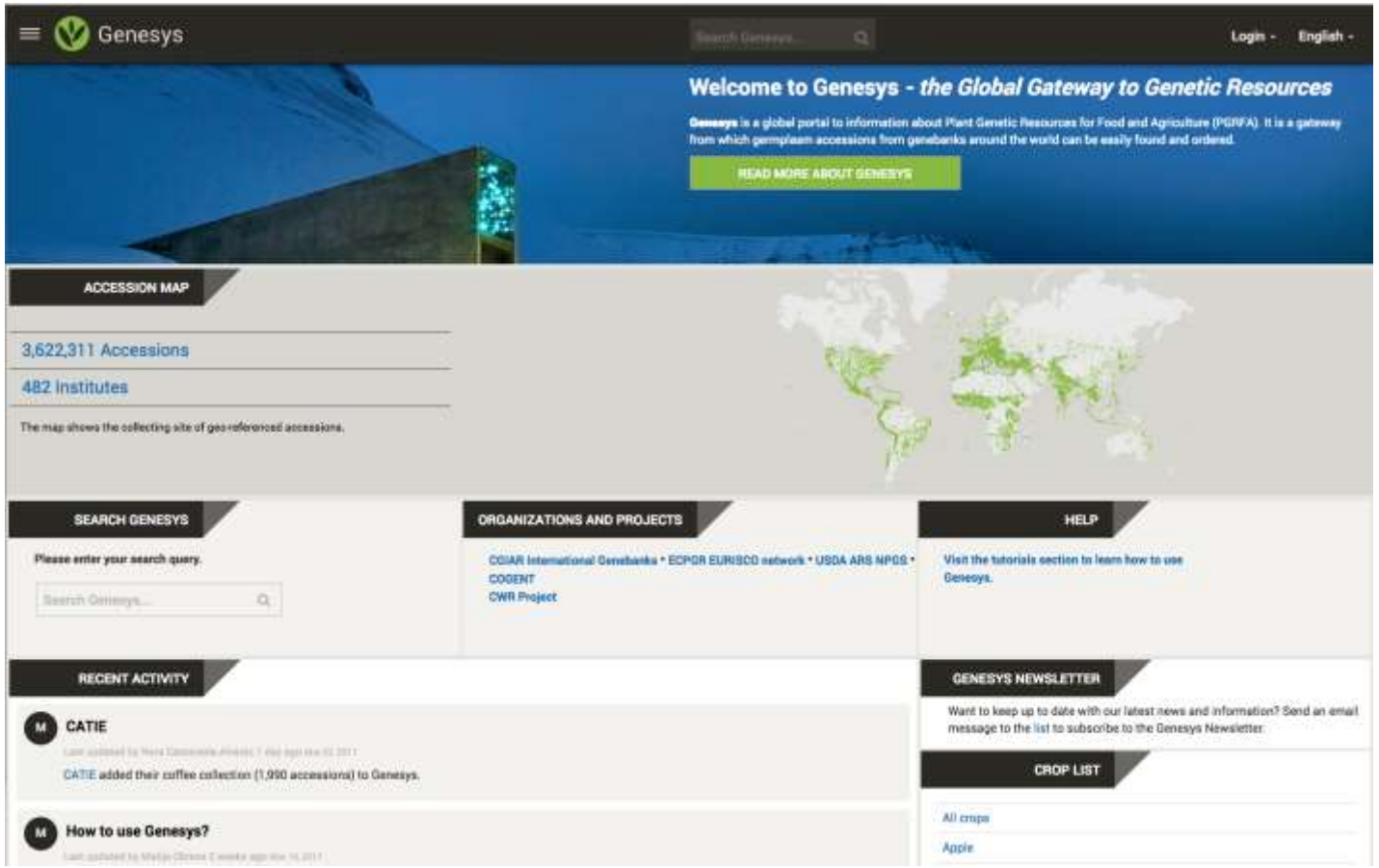
# 4. Information management

## Maintenance of, and access to data resulting from your pre-breeding projects

Introgressed regions from CWR in the Curinga rice varietal background are highlighted in green.

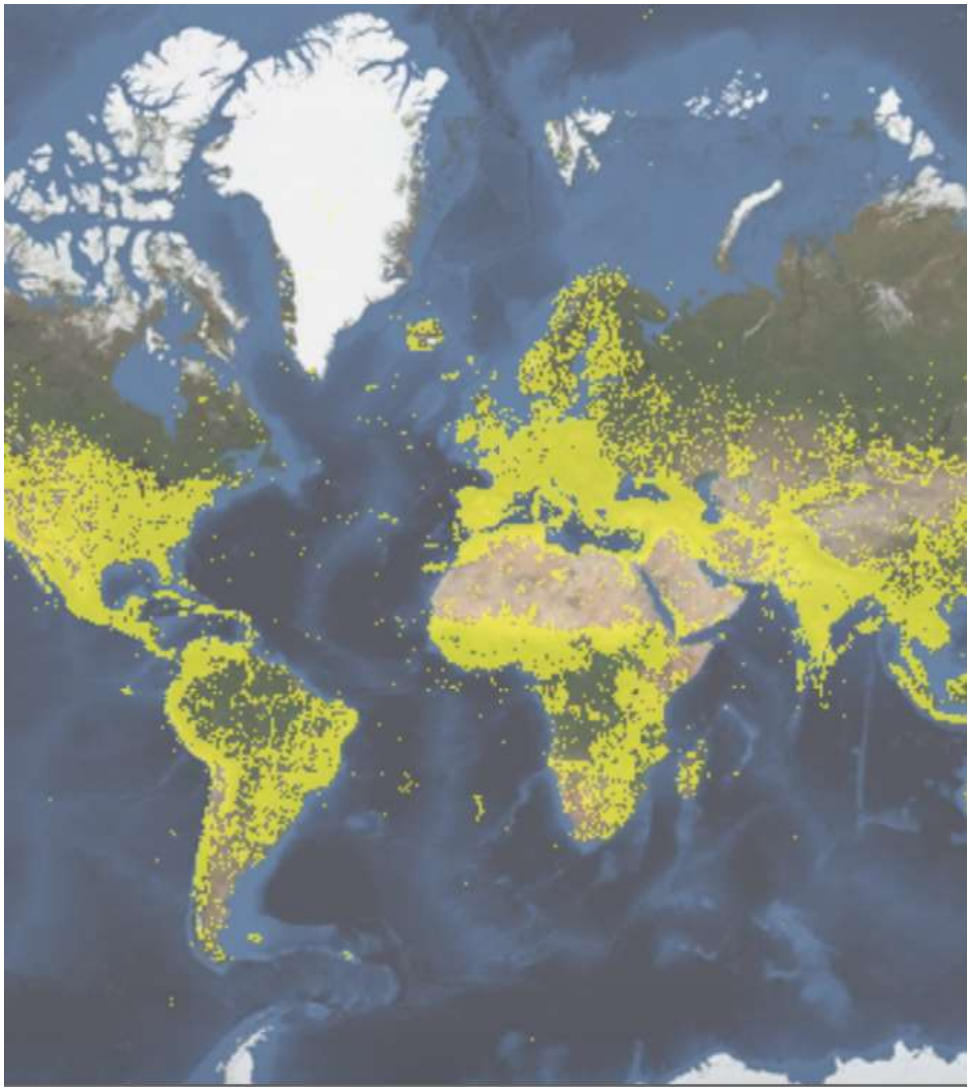
# Genesys: single-access portal to germplasm (www.genesys-pgr.org)




- Passport data
- Characterization and Evaluation data

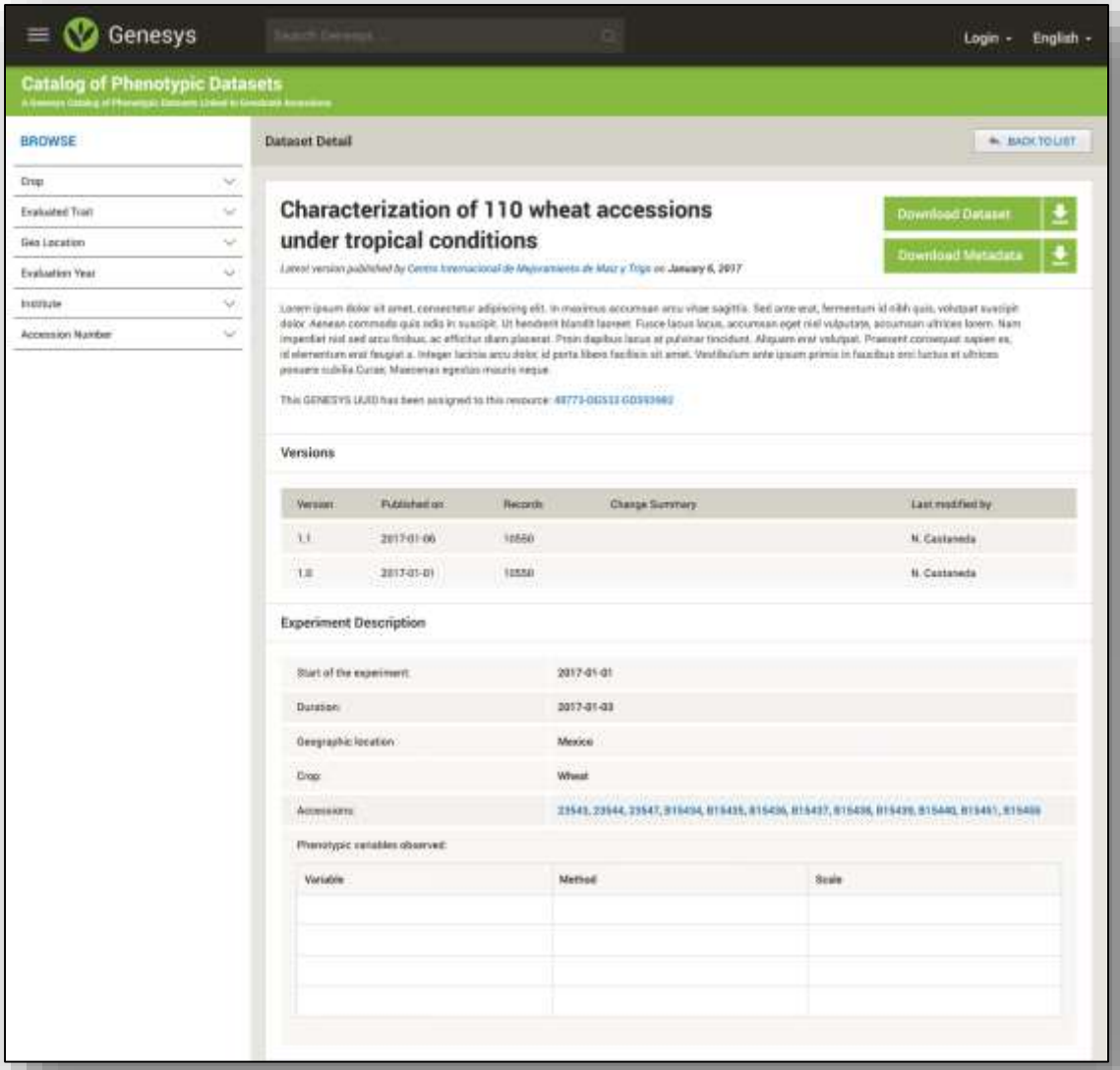
# Genesys: single-access portal to germplasm (www.genesys-pgr.org)

- Updated data: 3,624,468
- Automatic uploading
- Nine languages
- Maps, graphs, data overviews
- Search & order
- Active partnerships with CGIAR genebanks, USDA NPGS, ECPGR and other individual regional and national genebanks.



# Genesys catalog for phenotypic data sets

- Making germplasm characterization and evaluation visible and reusable.
- Improving genebank data management practices.




Federal Office for Agriculture and Food

# Acknowledgements

This work was undertaken as part of the initiative "*Adapting Agriculture to Climate Change: Collecting, Protecting and Preparing Crop Wild Relatives*" which is supported by the Government of Norway. The project is managed by the Global Crop Diversity Trust with the Millennium Seed Bank of the Royal Botanic Gardens, Kew UK and implemented in partnership with national and international genebanks and plant breeding institutes around the world. For further information, go to the project website: http://www.cwrdiversity.org/

Thank you very much!

# Genesys catalog for phenotypic data sets

Technical details

- Metadata: **Dublin Core** compliant (who, what, where, when, how).
- Use of controlled vocabularies for crop traits: **Crop Ontology**.
- Recovers the minimum information standard for plant phenotyping (**MIAPPE**).
- Will provide information in human and machine-readable formats (key for Open Data!). E.g., **ISA JSON**

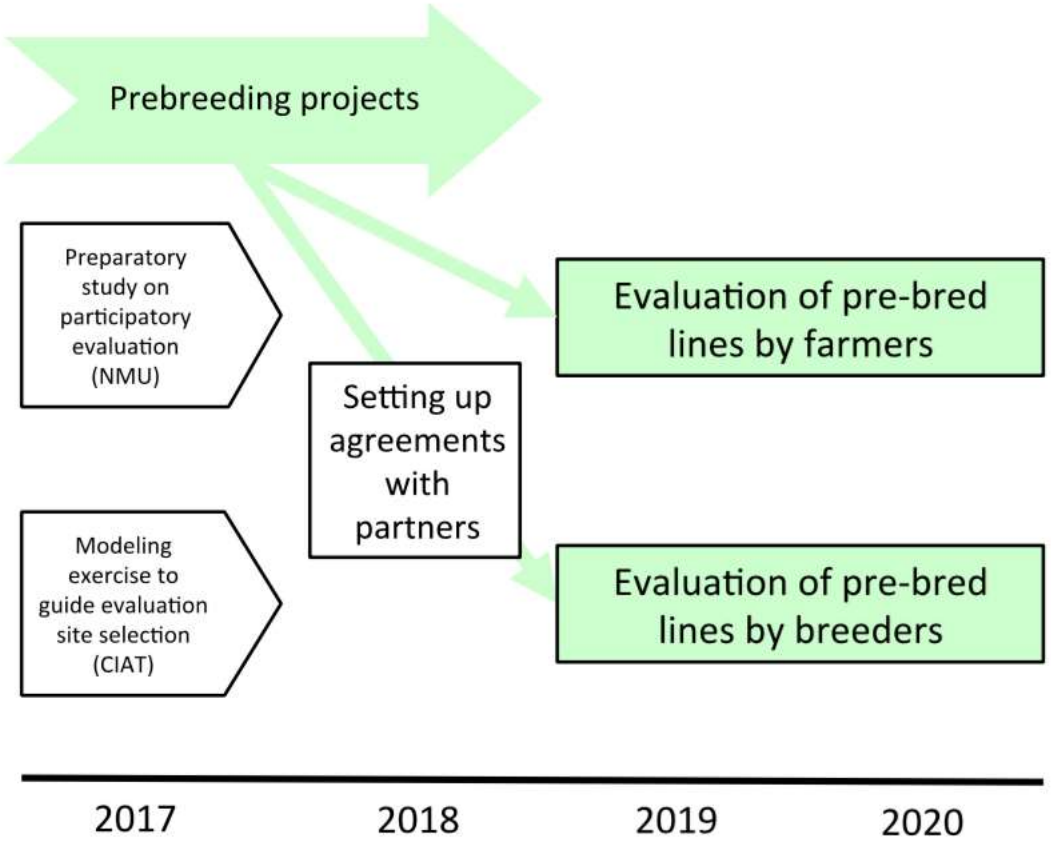
# Pre-breeding partnerships II

| Crop | Countries | Focus traits |
|---|---|---|
| Eggplant | Cote d'Ivoire, Spain, Sri Lanka | Drought resistance, waterlogging, cold and heat tolerance, root system development |
| Finger millet | **ICRISAT** (Kenya), Kenya | Drought tolerance, resistance to blast and striga, agronomic traits |
| Grasspea | **ICARDA** (Morocco), India | Heat tolerance, low toxicity, broomrape (Orobanche), powdery mildew and aphid resistance |
| Lentil | Bangladesh, Canada, **ICARDA** (Morocco), Nepal, 2x Spain, Turkey | Drought tolerance, Orobanche and Stemphyllium-blight resistance |
| Pearl millet | **ICRISAT** (India), India, ICRSIAT (Niger), Pioneer Hi-Bred, Syngenta, | Heat and terminal drought tolerance |
| Pigeonpea | **ICRISAT** (India), India | Salinity tolerance, Phytophthora blight and pod borer resistance, yield-related traits |
| Potato | EMBRAPA-Brazil, **CIP** (Peru), Peru, INIA-Uruguay | Heat and drought tolerance, late blight and bacterial wilt resistance |

# Pre-breeding partnerships III

| Crop | Countries | Focus traits |
|---|---|---|
| Rice | **IRRI** (The Philippines), USA | Yield-related traits under drought |
| Sorghum | Australia, Ethiopia, partner in West Africa (TBD) | Heat tol., cool soil cond. tol., water-use efficiancy, rust, anthracnose, grain mold, downy mildew res. |
| Sunflower | Canada, Uganda | Drought tolerance, early flowering, yield-related traits |
| Sweetpotato | **CIP** (Peru), USA, Mozambique | Heat resistance |
| Wheat (durum) | India, **CIMMYT** (Mexico), ICARDA (Morocco), Great Britain | Yield potential, heat tolerance, drought tolerance, disease resistance |

# Evaluating pre-bred lines with farmers and breeders



# Pre-breeding: eggplant

# Sunflower case study, UBC and Uganda (NARO)

Drought tolerant pre-bred lines with desirable traits (e.g., large leaves and thick stems) from 2014 evaluation experiments in Uganda.