Targets of the Heat and Drought Wheat Improvement Consortium (HeDWIC)

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Interdrought VI 2020 (virtual)

WHEAT INITIATIVE

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The Heat and Drought Wheat Improvement Consortium

Definition:

- A coalition of wheat improvement specialists collaborating to improve its climate resilience.
- Translational research platforms operating under realistic stress scenarios to deliver research technologies: genomic & phenomic tools, experimental germplasm, and proofs of concept.
- Pre-breeding to deliver genetically diverse heat & drought adapted lines; e.g. via the Stress Adaptive Trait Yield Nursery (SATYN)
- A germplasm and knowledge sharing mechanism

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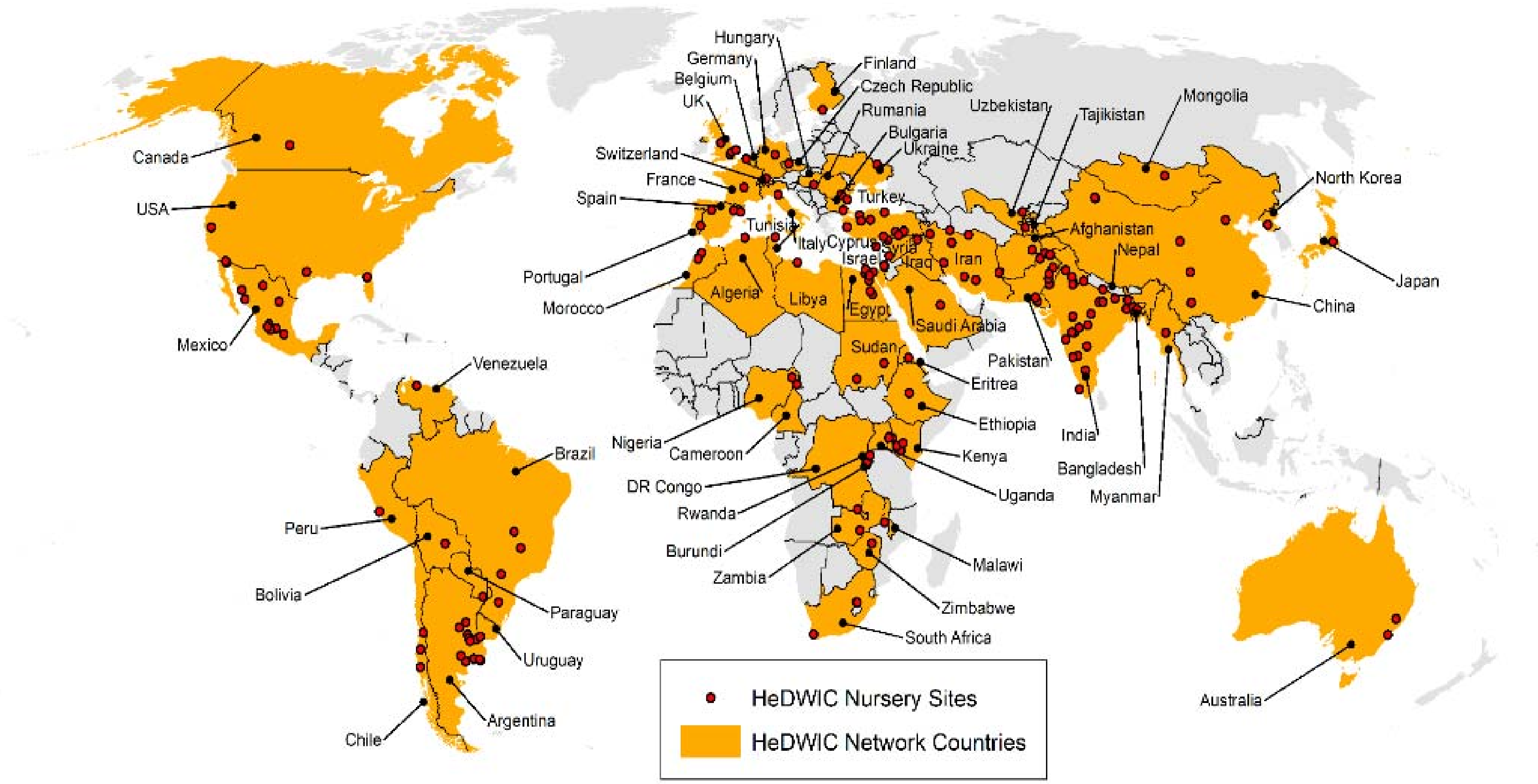
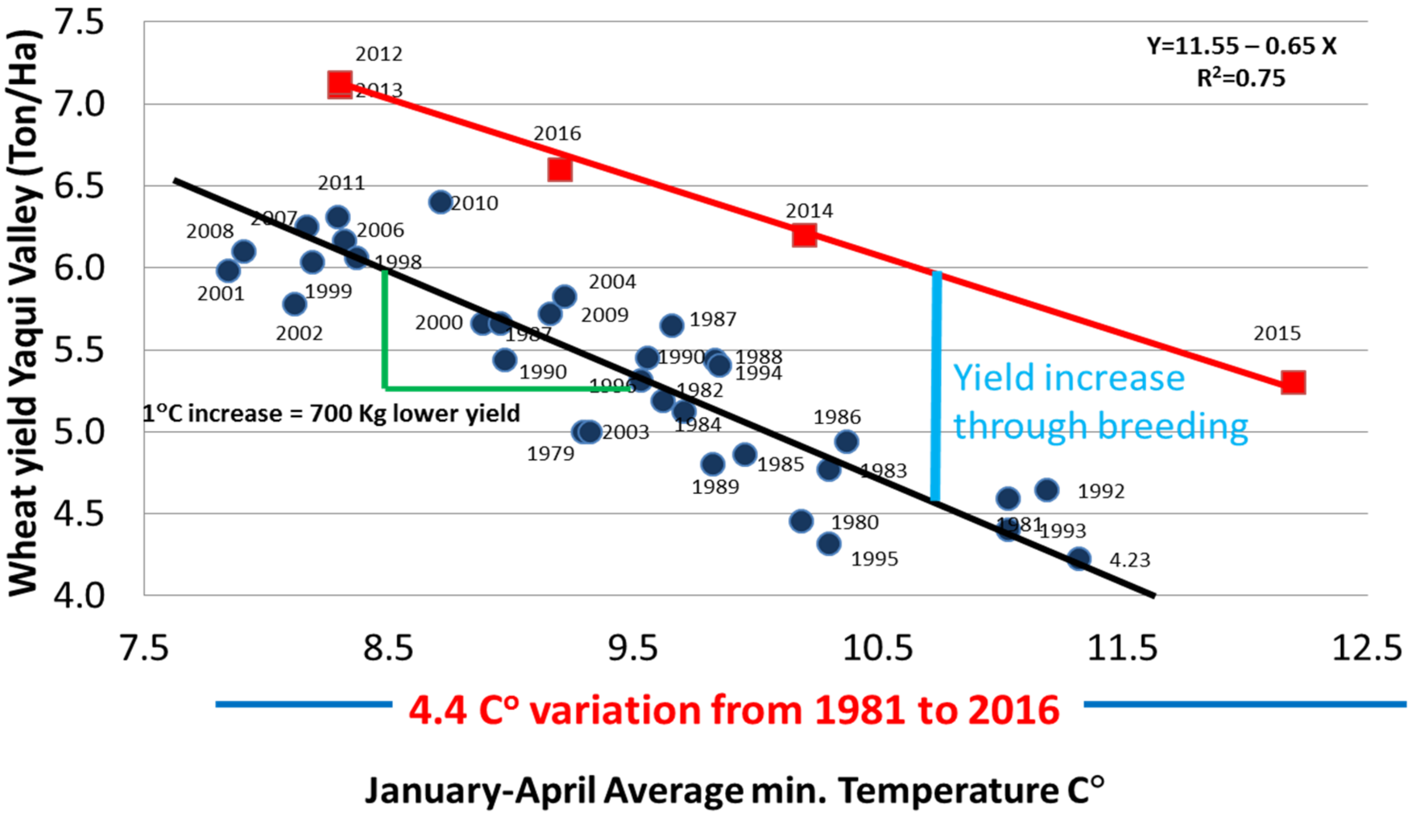
HeDWIC international collaboration including SATYN nursery sites



Research objectives

- Identify traits and networks of genes associated with superior wheat performance under diverse heat and drought scenarios
- High throughput field phenotyping to (i) access the vast reserve of wheat genetic resources for use in pre-breeding and gene discovery, and (ii) for validation of trait expression in new germplasm.
- Augment conventional wheat improvement methods using these outputs

Response of farm yield to mínimum temperature, NW Mexico



Source: H.-J. Braun and I. Ortiz-Monasterio, CIMMYT

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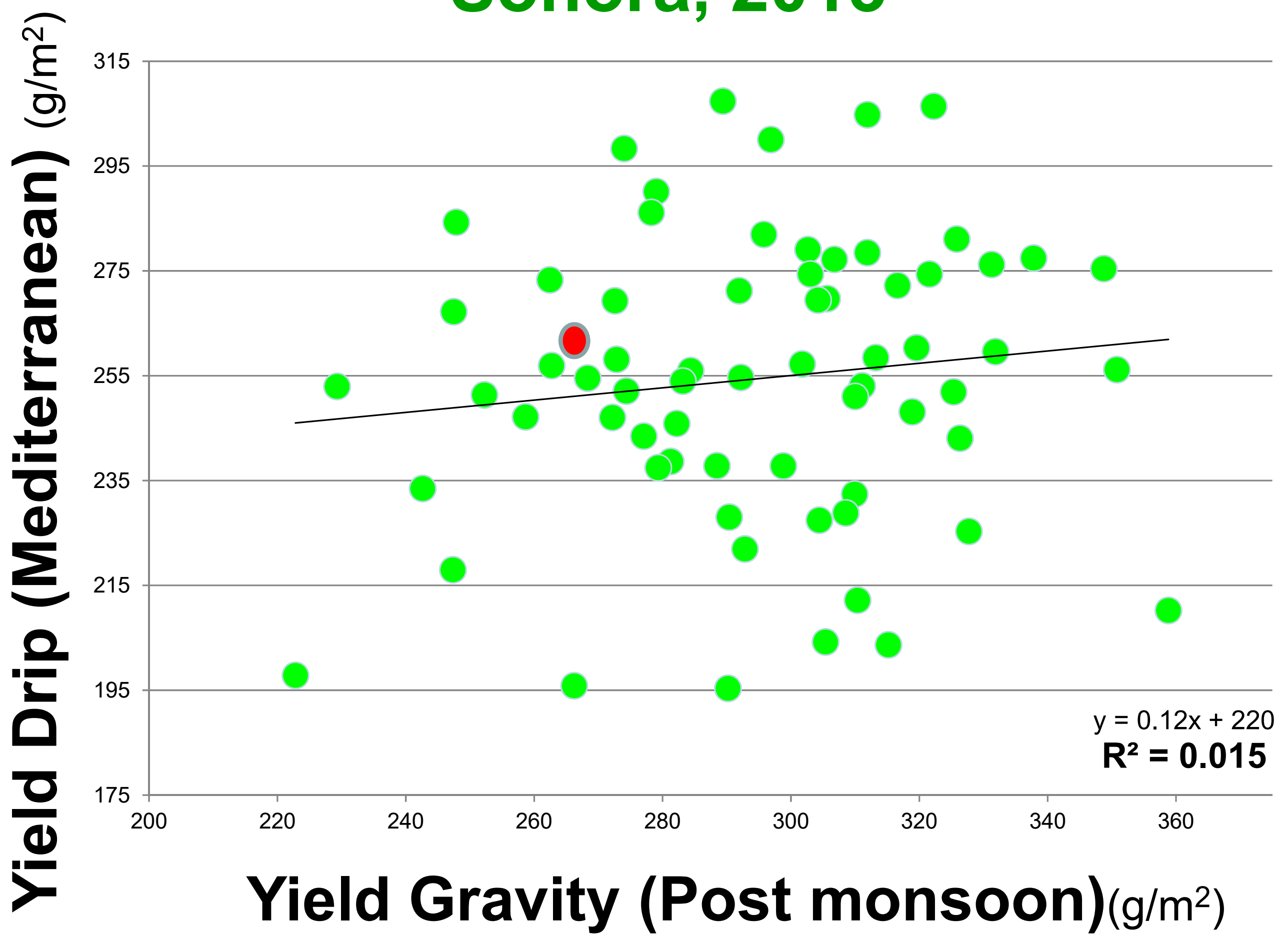
Drought Yield under Gravity vs. Drip Irrigation
Sonora, 2013



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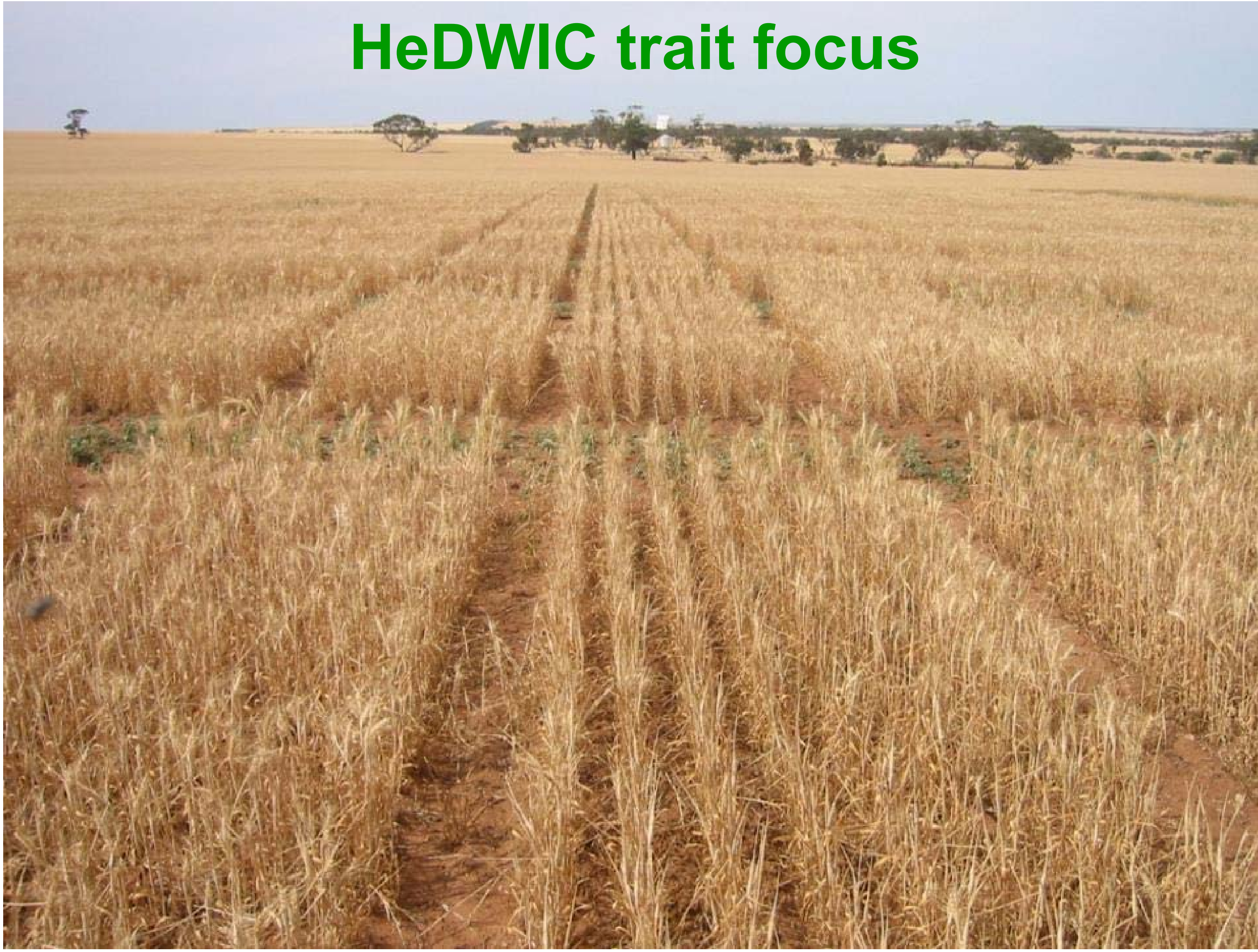
HeDWIC trait focus



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Conceptual model of drought-adaptive traits

YIELD = WU x WUE x HI

Photo-Protection

Leaf morphology
- wax/pubescence
- posture/rolling

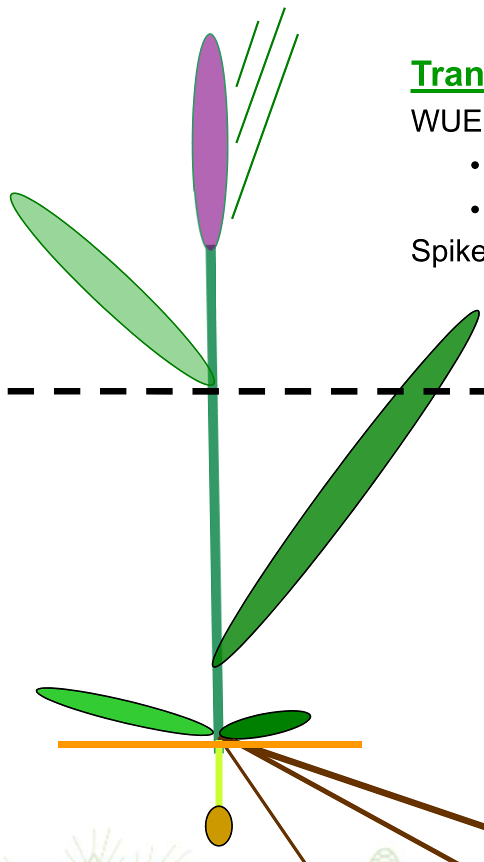
Pigments
- chl a:b
- carotenoids

Antioxidants
- various candidates

Transpiration Efficiency

WUE of leaf photosynthesis
- low 12/13C discrimination
- PGR signals (ABA, ethylene, etc)

Spike/awn photosynthesis



Partitioning (HI)

Stem carbohydrate storage & remobilization to grain

Harvest index
- Rht alleles
- Avoid grain abortion (PGR signals)

Water Uptake

Rapid ground cover
- Leaf area
- Coleoptile length/seed size

Access to water by roots
- IR thermometry
- Ψ leaf (spectrometry)

Dehydration avoidance
- osmotic adjustment

Reynolds, M.P., & Tuberosa, R. 2008. Translational research impacting on crop productivity in drought-prone environments. Current Opinions in Plant Biology, 11, 171-179.

Pre-breeding for drought adaptive traits

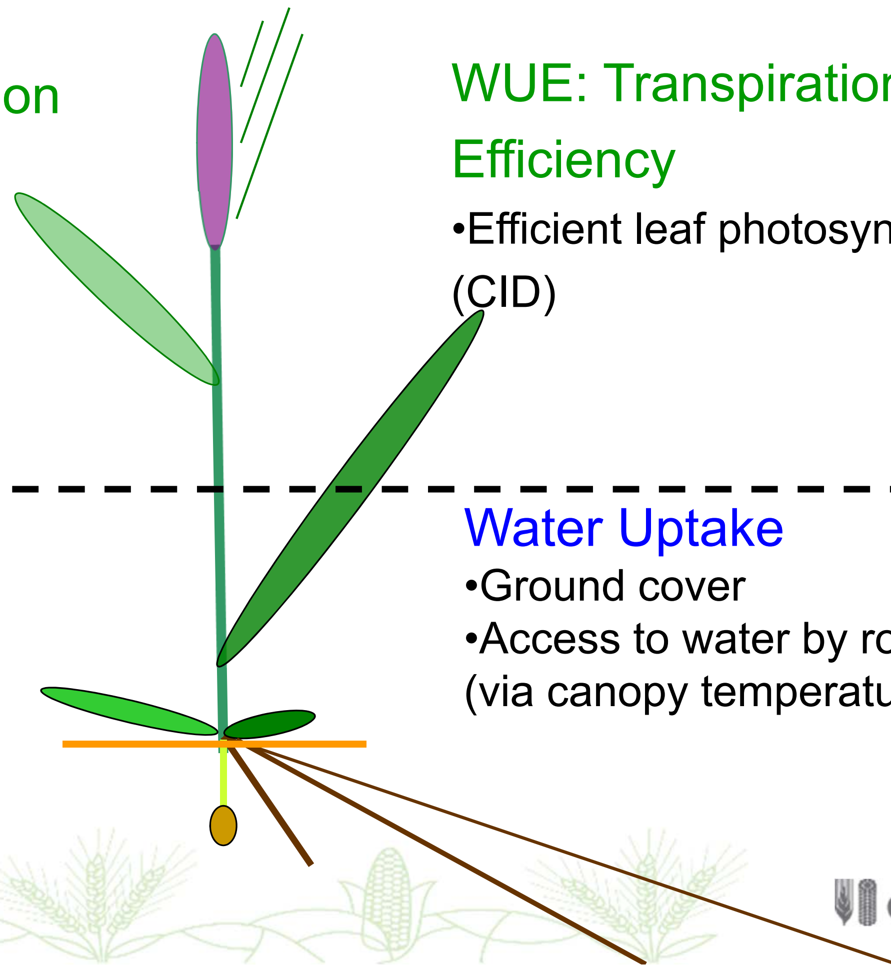
YIELD = WU x WUE x HI

WUE: Photo-Protection

- Leaf wax
- Pigments

WUE: Transpiration Efficiency

•Efficient leaf photosynthesis (CID)



Partitioning (HI)

- Stem carbohydrate storage

Water Uptake

•Ground cover
•Access to water by roots (via canopy temperature)

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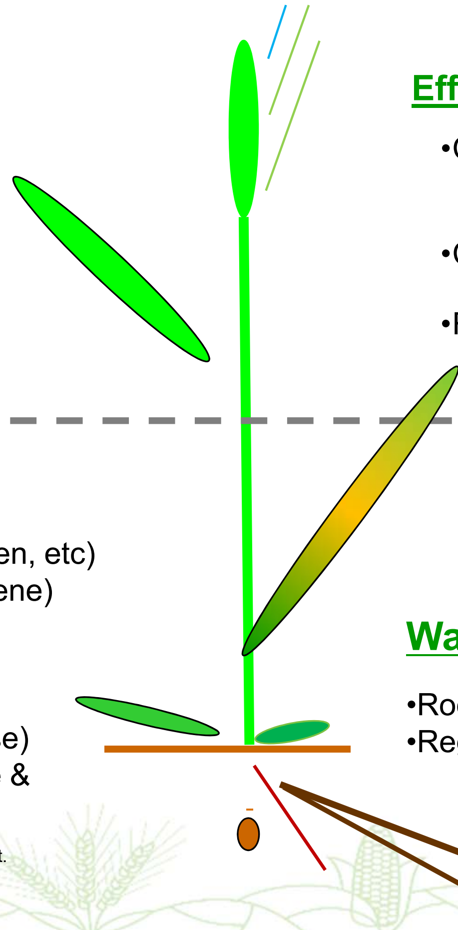
Conceptual model of heat-adaptive traits
YIELD = LI x RUE x HI

Photo-Protection (RUE)

- Leaf morphology (display, wax)
- Down regulation
- Pigment composition
  - Chl a:b
  - Carotenoids
- Antioxidants



Efficient metabolism (RUE)

- CO_2 fixation
  - CO_2 conductance
  - Rubisco (>>)
- Canopy photosynthesis
  - spike photosynthesis
- Respiration

Partitioning (HI)

- Spike fertility (meiosis, pollen, etc)
- Stress signaling (e.g. ethylene) regulating
  - senescence rate
  - floret abortion
- Grain filling (starch synthase)
- Stem carbohydrate storage & remobilization

Light interception (LI)

- Rapid ground cover
- Functional stay-green

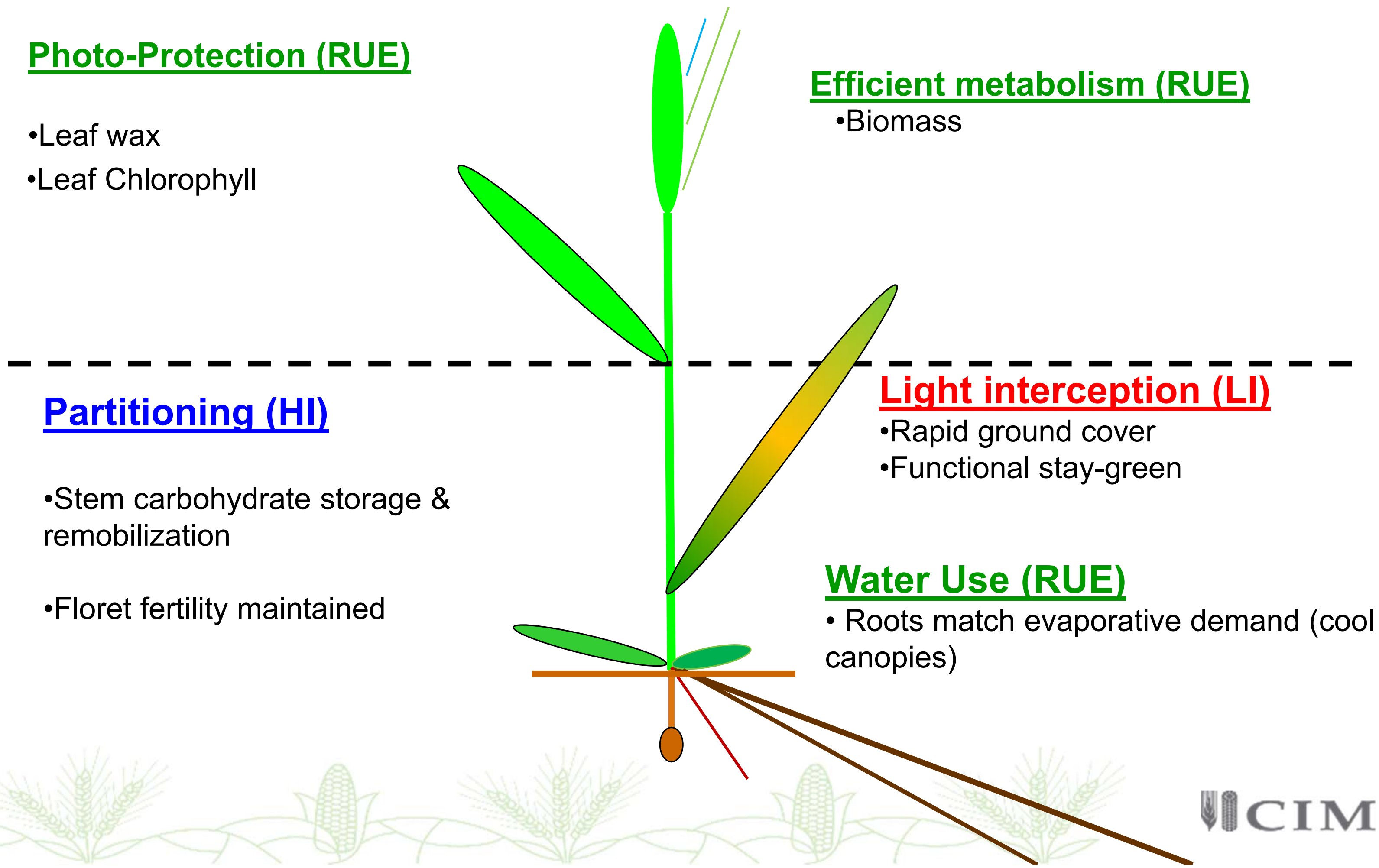
Water Use (RUE)

- Roots match evaporative demand
- Regulation of transpiration (VPD; ABA)

Cossani CM, Reynolds, MP. 2012.
Physiological traits for improving heat tolerance in wheat.
Plant Physiology 160: 1710-18

Pre-Breeding for Heat-Adaptive Traits

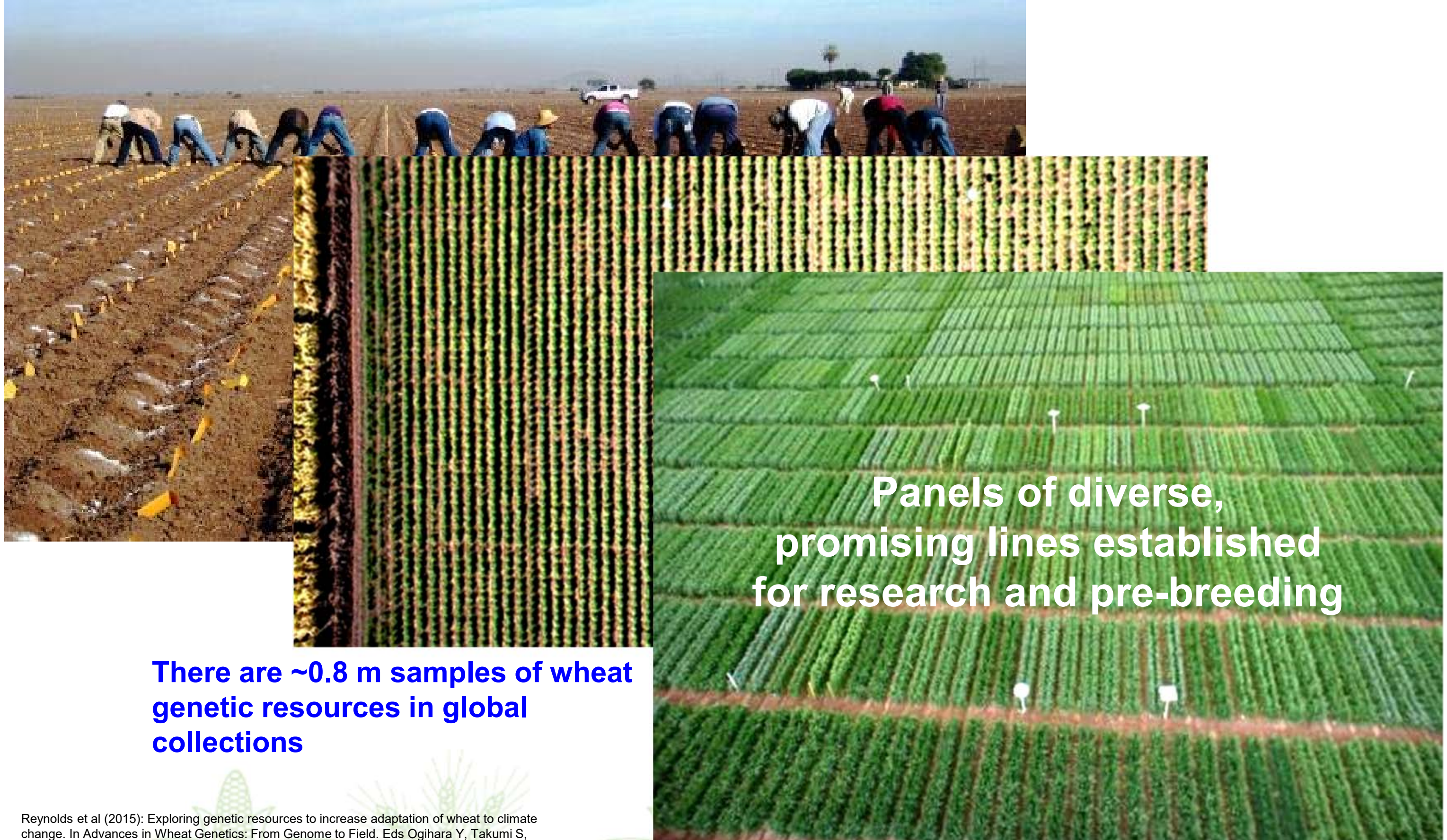
YIELD = LI x RUE x HI



70,000 wheat genetic resource samples

Screened under drought and heat, Sonora, Mexico, 2011-2013

Funded by MasAgro-SeeD



There are ~0.8 m samples of wheat genetic resources in global collections

Reynolds et al (2015): Exploring genetic resources to increase adaptation of wheat to climate change. In Advances in Wheat Genetics: From Genome to Field. Eds Ogihara Y, Takumi S, Handa H. Springer Japan; 2015

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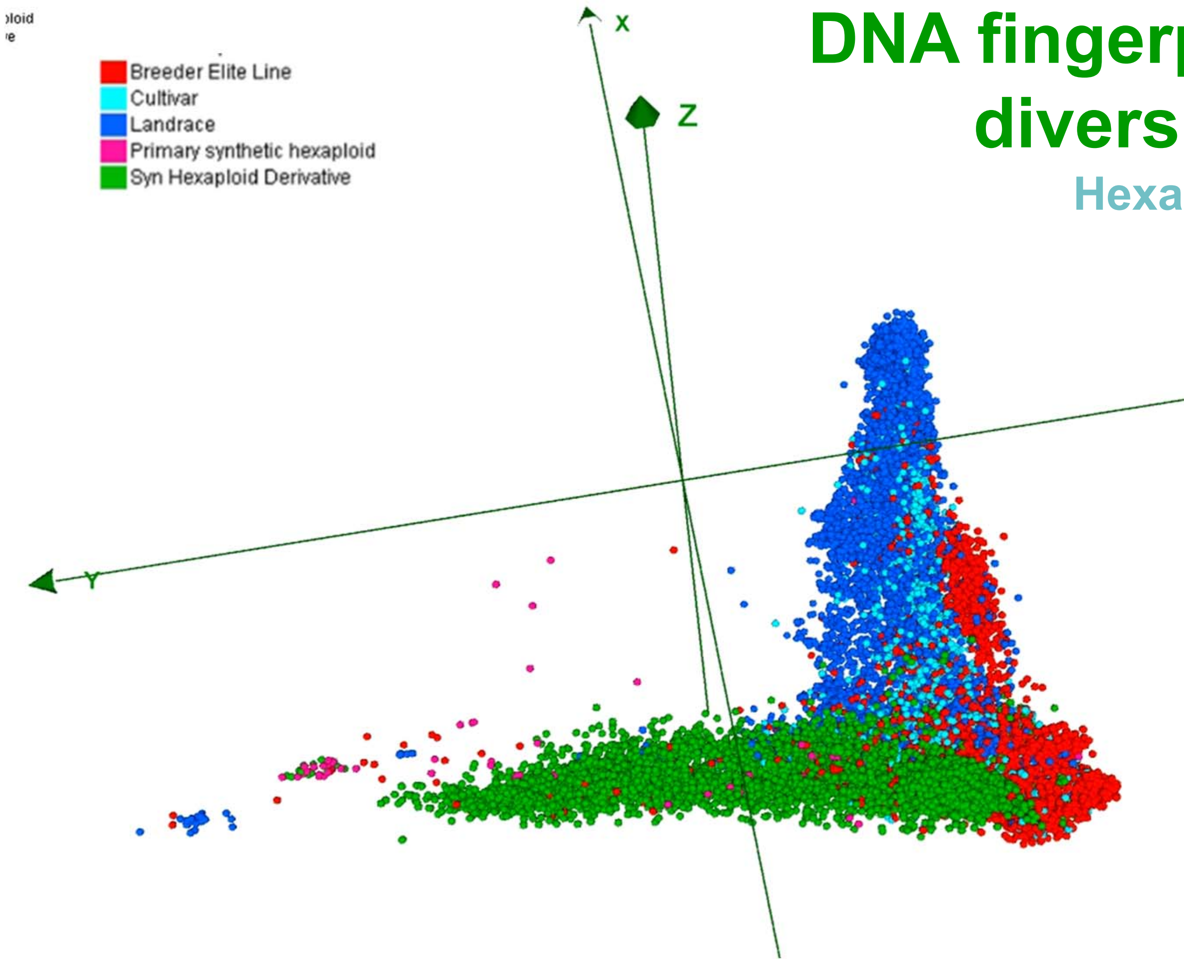
DNA fingerprinting for diversity subsets

Hexaploid diversity



60,000 accessions,

8 domesticated species:

T. aestivum subs. aestivum,
T. aestivum subs. spelta,
T. aestivum subs. campactum,
T. aestivum subs. sphaerococcum,
T. aestivum subs. macha,
Tritucum hybrid,
x Aegilotriticum
x Triticosecale

ABD genomes,

105 countries

26,500 SilicoDArT

85,500 SNP's

Sansaloni *et. al*. (in preparation)

Modified Roger distance of 60,000 hexaploid accessions displayed in a multidimentional scaling plot.

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Bread wheat diversity panel (370)

Includes best performing lines from:

- International nurseries
- Landraces/FIGS panels
- Lines derived from inter-specific hybridization

Spike diversity in BW panel

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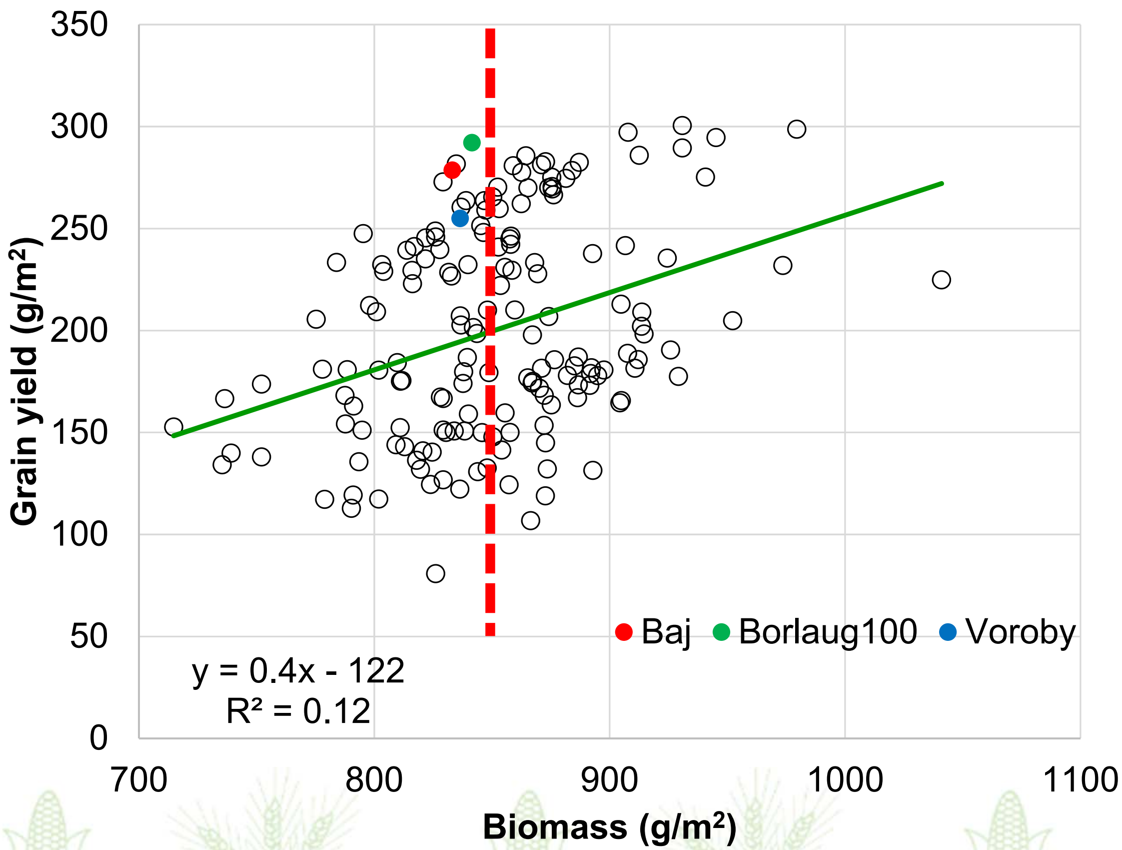
Primary synthetic panel (160)

Selected from 2,000 lines (i.e. with brand new hexaploid genomes) for adaptation to heat, drought and favorable conditions

High biomass of primary synthetic wheat: drought

Cuidad Obregón, Mexico, 2016 & 2017



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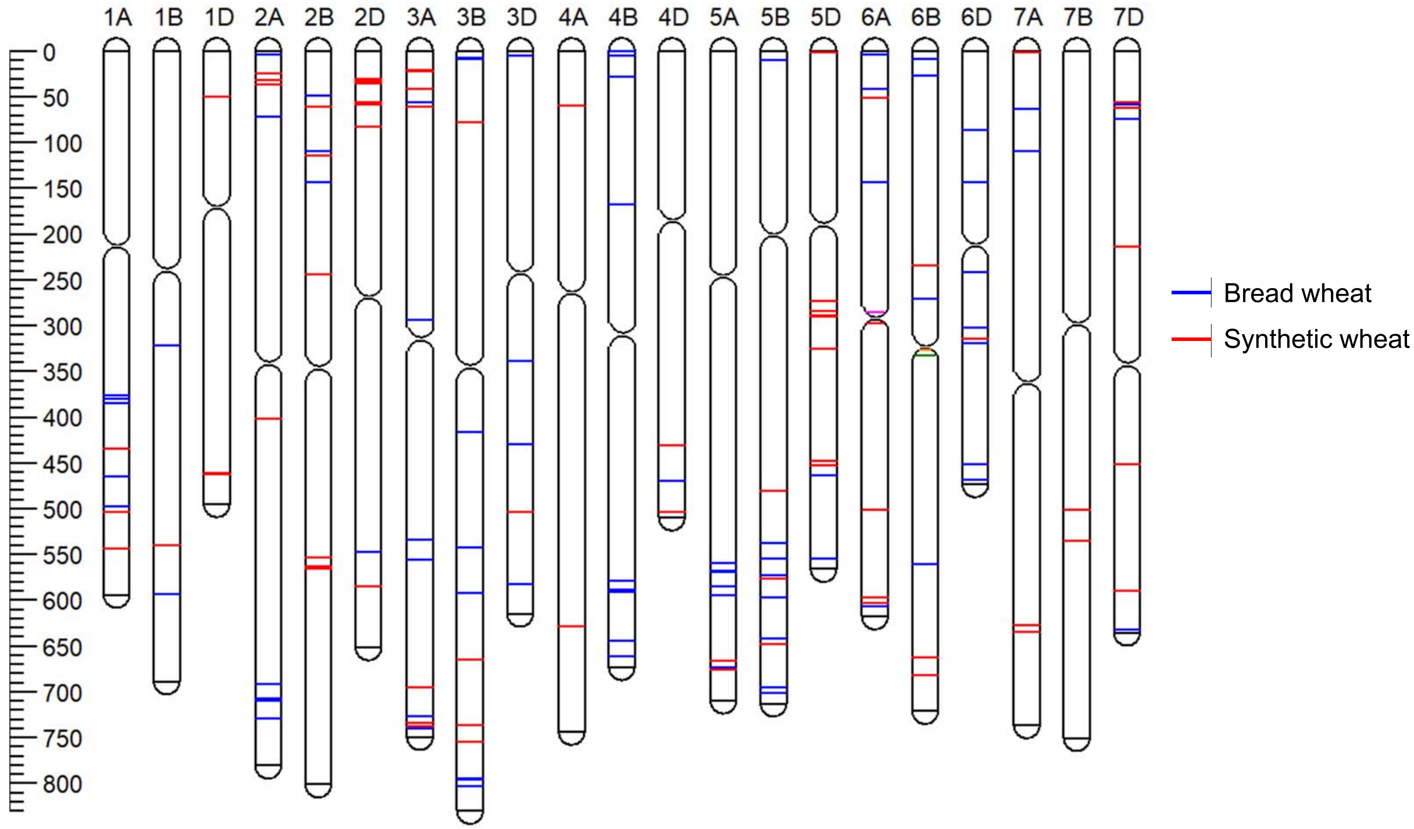
Chromosome regions for drought tolerance



Sukumaran et al., unpublished…

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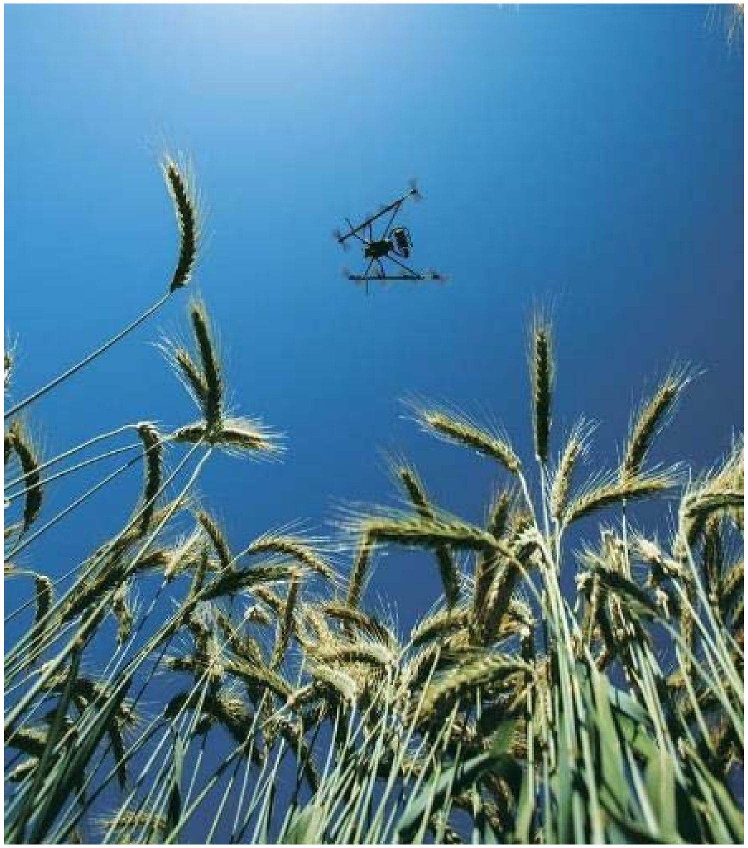
High Throughput Phenotyping



Tattaris M, Reynolds MP, Chapman SC, 2016.
A direct comparison of remote sensing approaches for high-throughput phenotyping in plant breeding.
Front. Plant Sci. 7: 1131.

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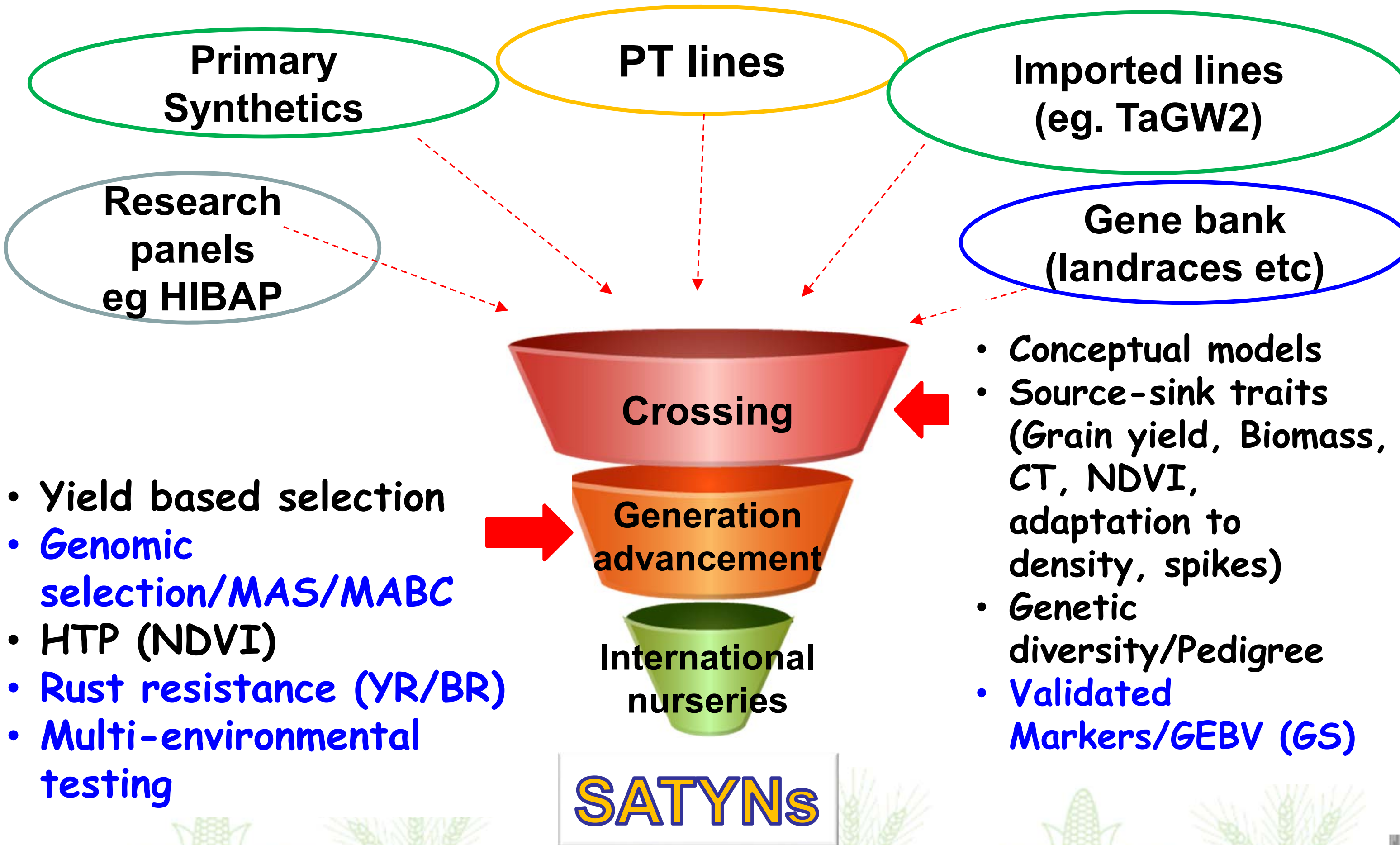
CIMMYT-HeDWIC pre-breeding pipeline



- Yield based selection
- Genomic selection/MAS/MABC
- HTP (NDVI)
- Rust resistance (YR/BR)
- Multi-environmental testing

- Conceptual models
- Source-sink traits (Grain yield, Biomass, CT, NDVI, adaptation to density, spikes)
- Genetic diversity/Pedigree
- Validated Markers/GEBV (GS)

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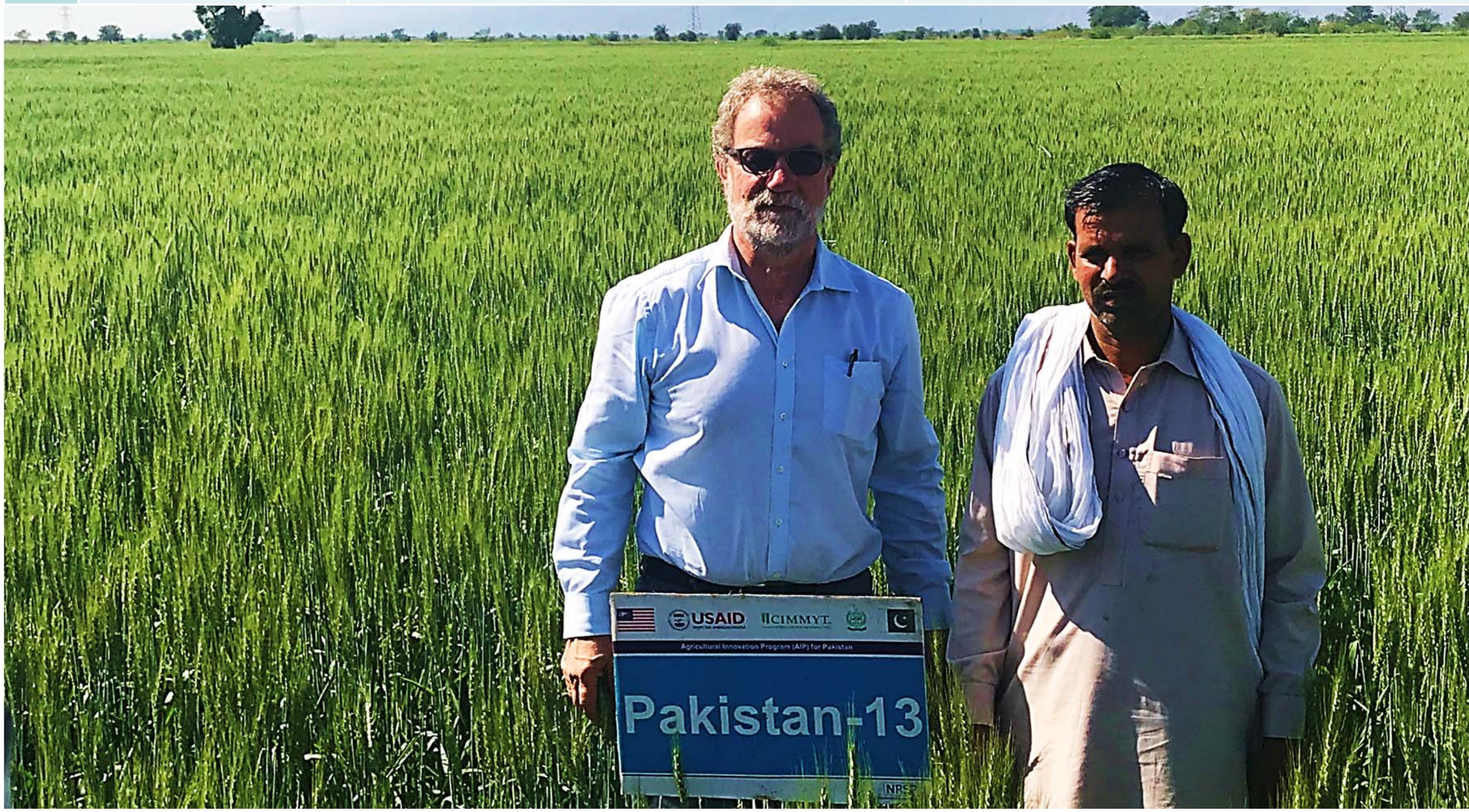
Proof of concept

Year	Name	Cross / pedigree	Selection History
2013	Pakistan-13	MEX94.27.1.20/3/SOKOLL//ATTILA/3*BCN	PTSS02B00132T-0TOPY-0B-0Y-0B-38Y-0M-0SY
2016	Borlaug-16	SOKOLL/3/PASTOR//HXL7573/2*BAU	PTSS02B00015S-0Y-0B-0Y-0B-1Y-0M-0SY
2017	Kohat-17	SOKOLL/WBLLI	PTSS02Y00021S-0Y-030ZTM-040SY-040M-5Y-0M-0SY



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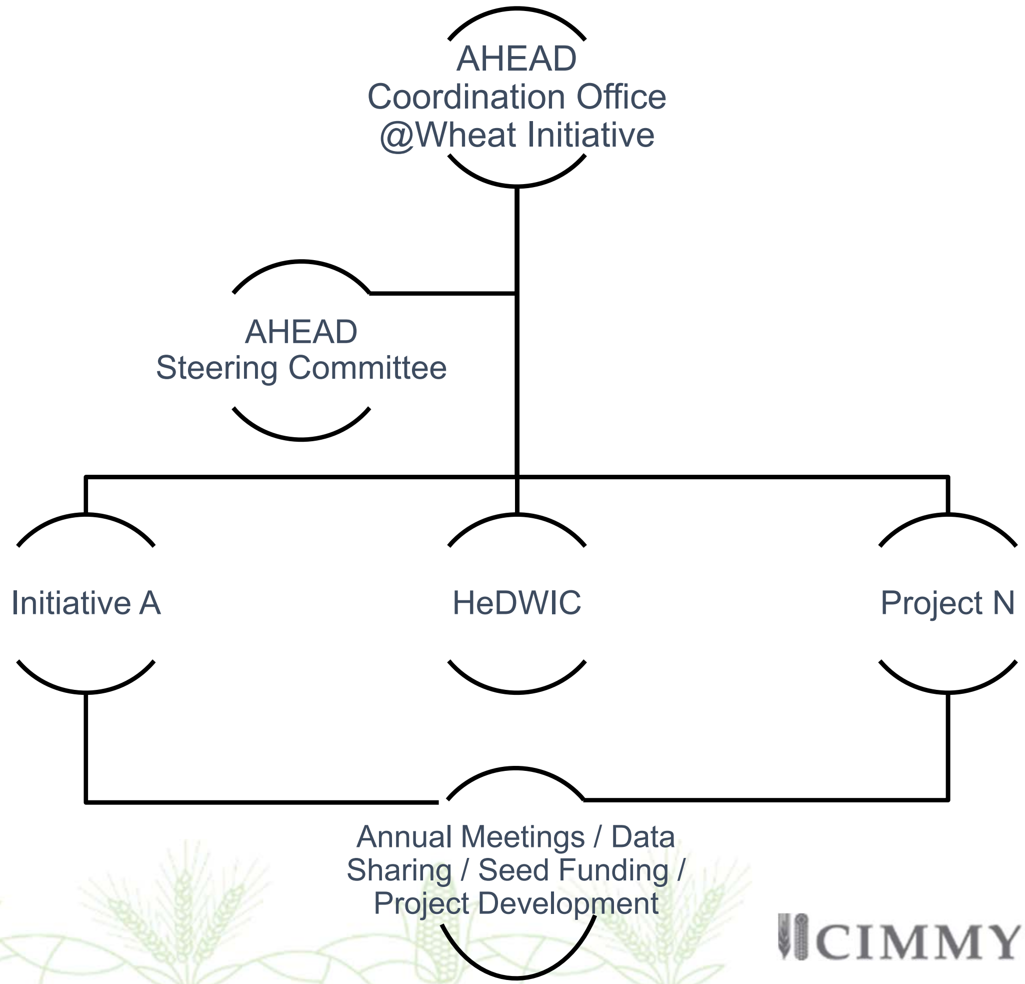
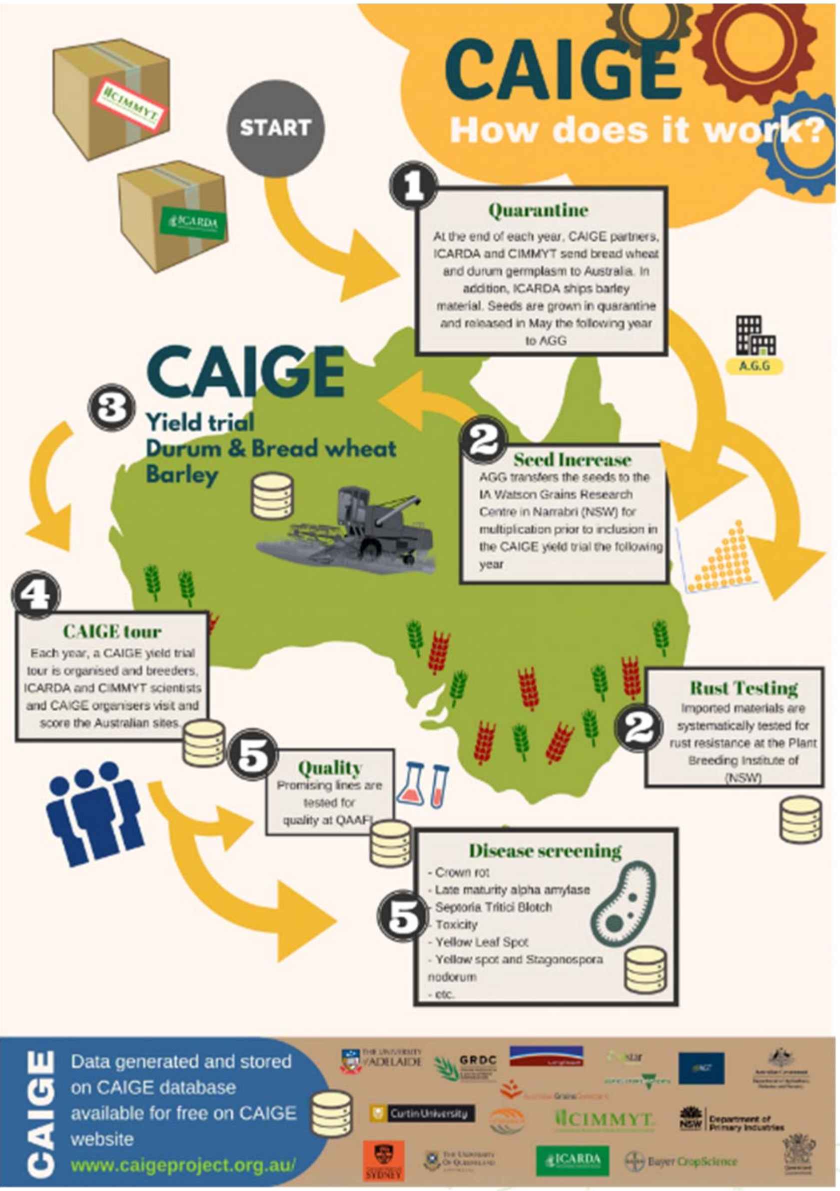
Added value of HeDWIC and the AHEAD umbrella for heat and drought:

- **Catalyzing new research opportunities**
- **Disseminating new research and breeding technologies**
- **Leverage of institutional capital**
- **Translating research outputs of HeDWIC/AHEAD communities into breeding tools through translational research**



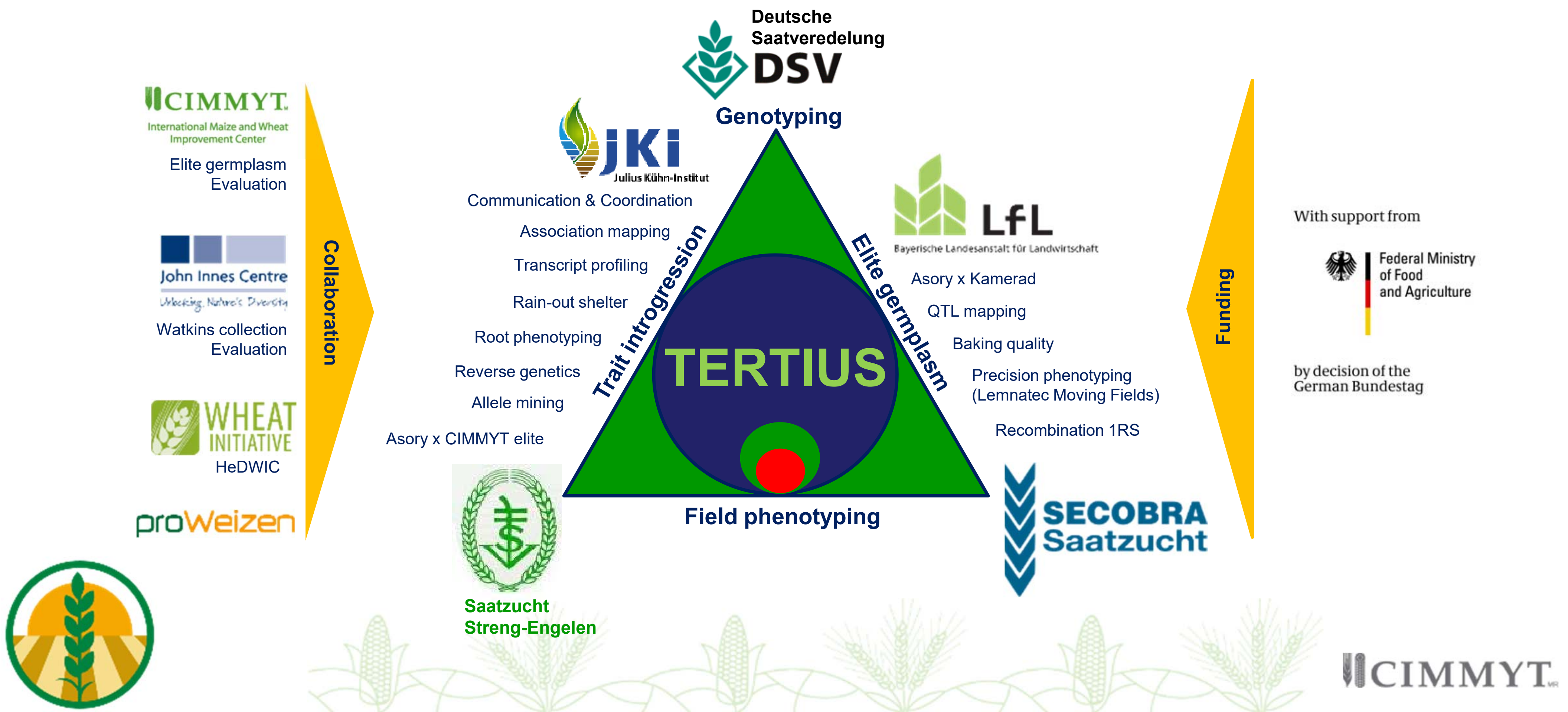


CAIGE Project in Australia: CIMMYT ICARDA Germplasm Exchange Project

www.caigeproject.org.au

- Lead by Richard Trethowan at Univ Sydney for wheat and Mark Dieters at UQ for Barley, with overall coordination by Julie Nicol.
- Funded by the Australia's GRDC with commercial and public breeders + Australian pathology and quality collaborators.
- Enables trialling of CIMMYT and ICARDA germplasm, followed by seed increase and competitive yield and pathology and quality testing Australia wide.
- Aims to provide Australian breeders and pre-breeders access to high yielding, adapted and disease resistant germplasm, and development of new varieties for Australian farmers.

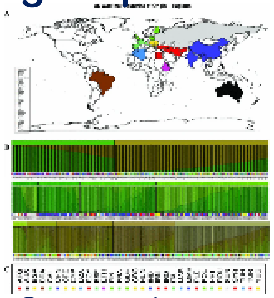
Genome-based strategies
to use the tertiary gene-pool for breeding of climate-smart wheat



UK- BBSRC's Designing Future Wheat Programme

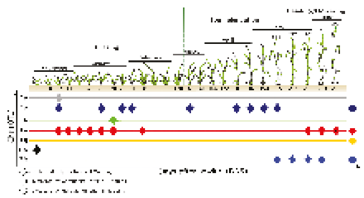
BBSRC bioscience for the future | UK Research and Innovation

Unique primary and derived germplasm

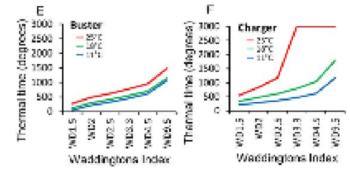


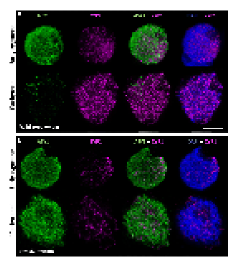
Genomics and big data handling

High throughput gene discovery



Fundamental understanding of mechanisms of temperature interaction





Advanced academic-commercial pre breeding pipeline

John Innes Centre — Unlocking Nature's Diversity
ROTHAMSTED RESEARCH
Quadram Institute — Science • Health • Food • Innovation
EMBL-EBI
University of BRISTOL
The University of Nottingham
NIAB
Earlham Institute

Take home points

- Climate is becoming warmer and less predictable
- Many opportunities exist to improve wheat's adaptation:
  - Advances in genomics and phenomics
  - Exploring untapped genetic resources
  - Physiological and molecular breeding
- Impacts will reach farmers and consumers sooner if efforts are coordinated through collaboration and technology sharing such as HeDWIC and AHEAD

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