The international task of enhancing drought stress tolerance by harnessing genetic resources

Frank Ordon & Peter Langridge

www.jki.bund.de

Challenges

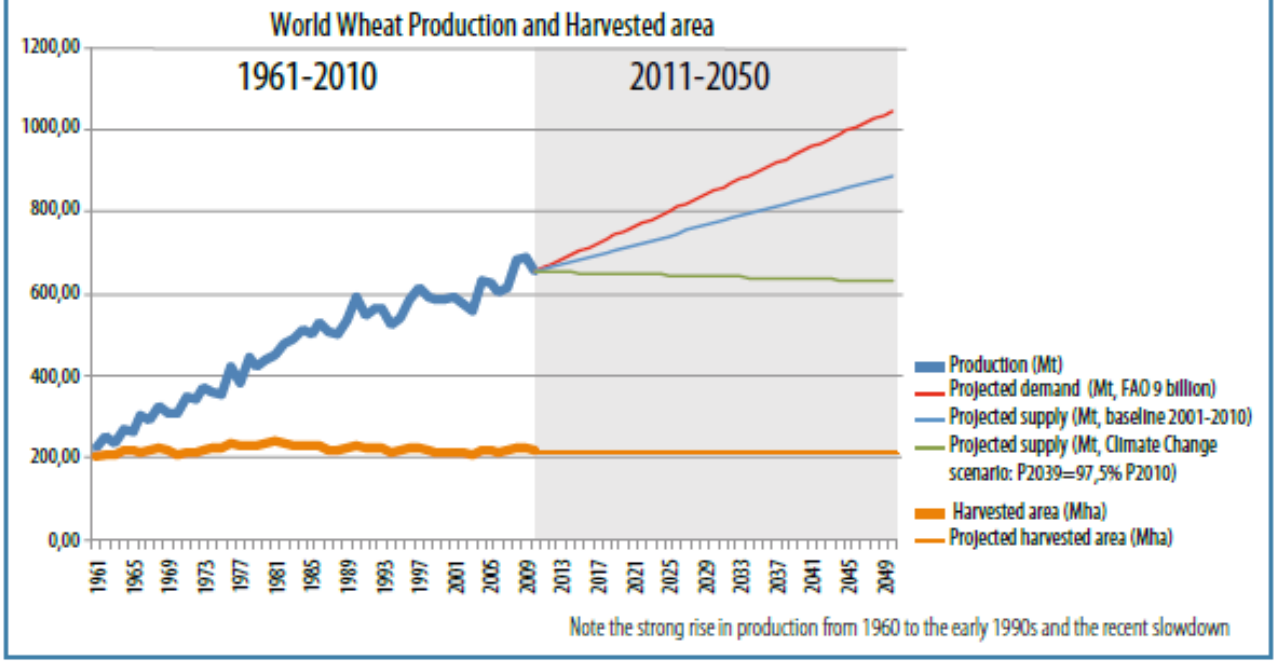
Financing for Development Office
Department of Economic and Social Affairs
United Nations

World population projected to reach 9.8 billion in 2050, and 11.2 billion in 2100

21 June 2017, New York

The current world population of 7.6 billion is expected to reach 8.6 billion in 2030, 9.8 billion in 2050 and 11.2 billion in 2100, according to a new United Nations report being launched today. With roughly 83 million

Figure 1. Total wheat production and area harvested since 1960 (FAOSTAT 2012) and 2010-2050 projections.



Wheat Initiative (Vision paper)

Institute for Resistance Research and Stress Tolerance

Drought

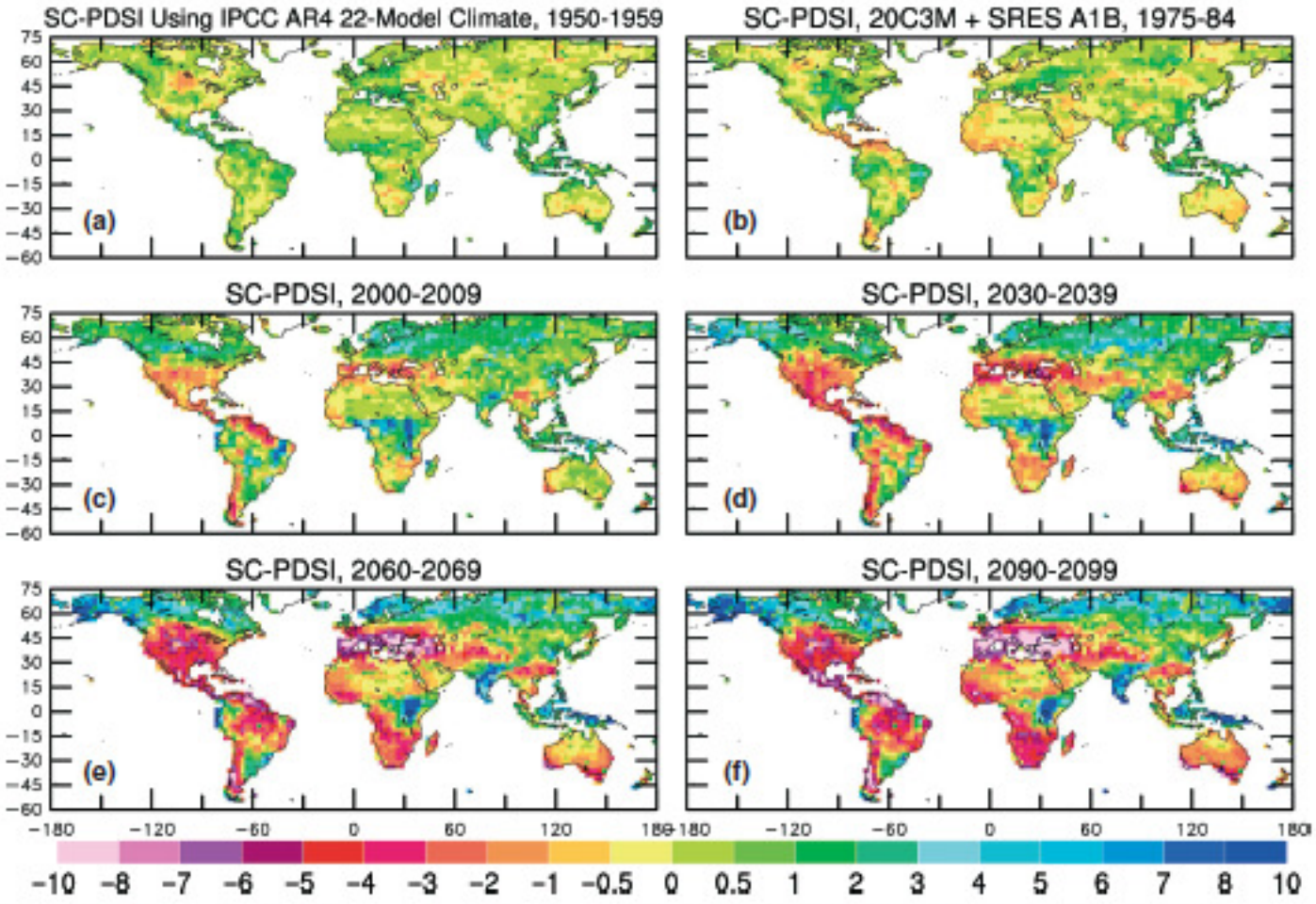
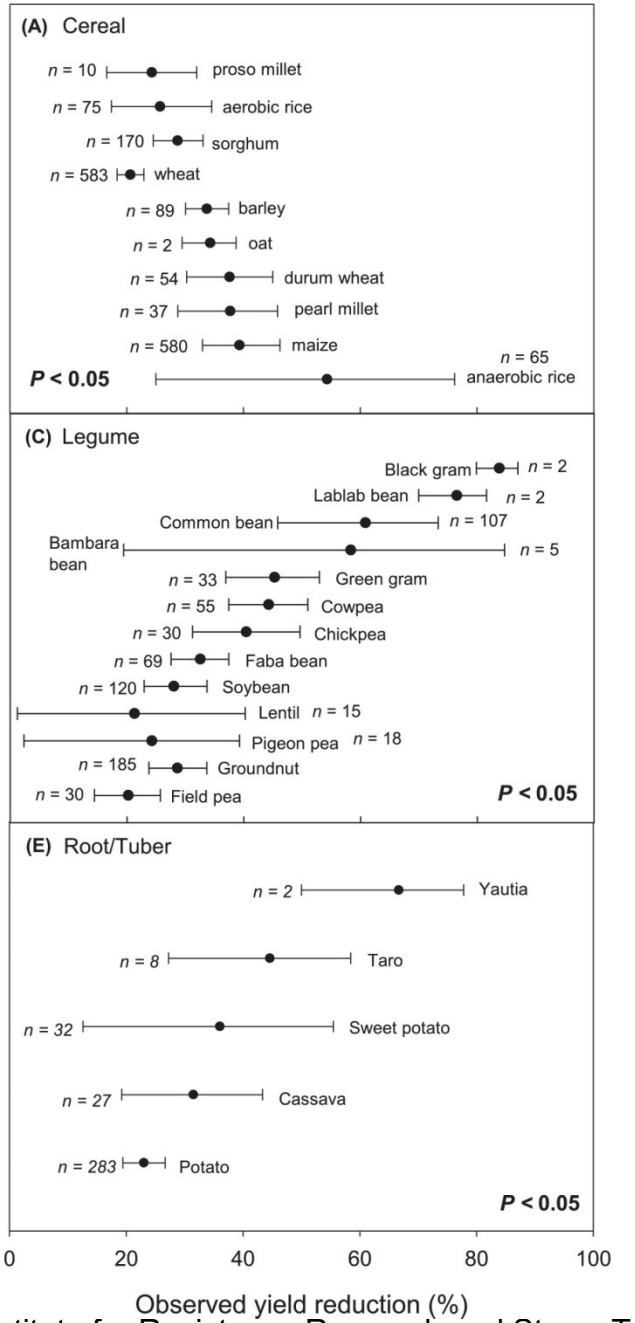


FIGURE 11 | (Corrected version) Mean annual sc-PDSI pm for years (a) 1950–1959, (b) 1975–1984, (c) 2000–2009, (d) 2030–2039, (e) 2060–2069, and (f) 2090–2099 calculated using the 22-model ensemble-mean surface air temperature, precipitation, humidity, net radiation, and wind speed used in the IPCC AR4 from the 20th century and SRES A1B 21st century simulations.128 Red to pink areas are extremely dry (severe drought) conditions while blue colors indicate wet areas relative to the 1950–1979 mean.

Dai, A. (2010) Drought under global warming: a review. Wiley Advanced Review 2, 45-66



Global yield reduction due to drought

Agricultural Water Management 179 (2017) 18–33

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Global synthesis of drought effects on cereal, legume, tuber and root crops production: A review

Stefani Daryanto, Lixin Wang*, Pierre-André Jacinthe

Department of Earth Sciences, Indiana University-Purdue University Indianapolis (IUPUI), Indianapolis, IN 46202, USA

Database for this study:

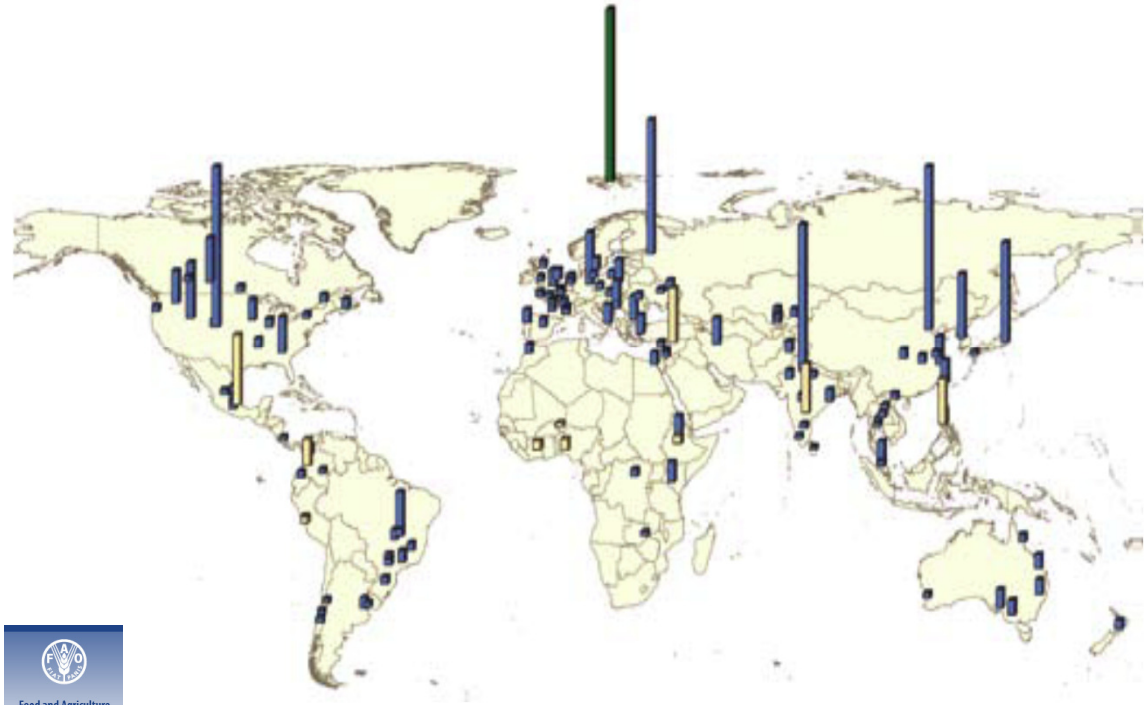
- peer-reviewed journal articles from 1980 to 2015
- field conditions, drought ~40% water deficit

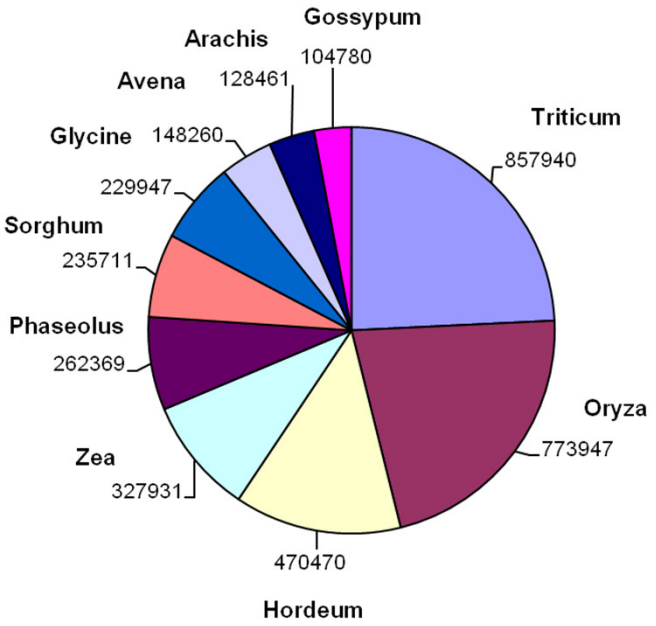
→ 1674 data points from 228 studies worldwide

Genetic Resources

1.750 genbanks worldwide, 7.4 million accessions

130 genbanks hosting more than 10.000 accessions





10 species = 3,540,000 accessions
~ 50% of the ex situ resources

Food and Agriculture Organization of the United Nations

Institute for Resistance Research and Stress Tolerance

A. Graner

G20 Agriculture Ministers' Action Plan 2017

Towards food and water security:
Fostering sustainability, advancing innovation

January 22nd 2017 in Berlin

Water-use efficiency and resilience

e) We aim to improve plant and animal **breeding** to enhance water-use efficiency and resilience. We note there is a considerable need for conserving, sustainably using and providing access to the genetic diversity of animals and crops and related wild species. We acknowledge the importance of the corresponding activities undertaken by international bodies such as the FAO Commission on Genetic Resources for Food and Agriculture (CGRFA), CGIAR and the G20 International Wheat Initiative and take note of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) to this end. We promote fair and equitable sharing of the benefits arising from the utilisation of genetic resources and promote appropriate access to such resources, as internationally agreed. We aim to enhance and better link up activities on the evaluation and utilisation of genetic resources for research and breeding related to water. Initially we will focus on the most important characteristics of water-use efficiency and drought stress and salt tolerance of crops, especially of crops with major relevance to global and regional food security and nutrition, building on the ongoing work of international institutions and networks such as the G20 Wheat Initiative in line with the Second Global Plan of Action for Plant Genetic Resources. Therefore we request FAO, through its technical committees, and CGIAR to make recommendations for strengthening international cooperation in that regard for further assessment and decision by G20.

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Questions to be answered:

•What is the current state of the genome analysis of gene bank collections regarding the main crops, what will happen in future in this regard?

•What protocols and platforms for the assessment of drought stress tolerance and water use efficiency exist or need to be developed, and what are the requirements these must fulfill?

HeDWIC Heat and Drought Wheat Improvement Consortium
A Funding Proposal

•How can an effective preliminary selection of gene bank accessions for phenotyping be made?

Genomic prediction contributing to a promising global strategy to turbocharge gene banks

Xiaoqing Yu, Xianran Li, Tingting Guo, Chengsong Zhu, Yuye Wu, Sharon E. Mitchell, Kraig L. Roozeboom, Donghai Wang, Ming Li Wang, Gary A. Pederson, Tesfaye T. Tesso, Patrick S. Schnable, Rex Bernardo & Jianming Yu

•How should the resulting data be stored and made accessible for science and breeding?

Journal of Integrative Bioinformatics, 4(1):88, 2007 http://journal.imbio.de

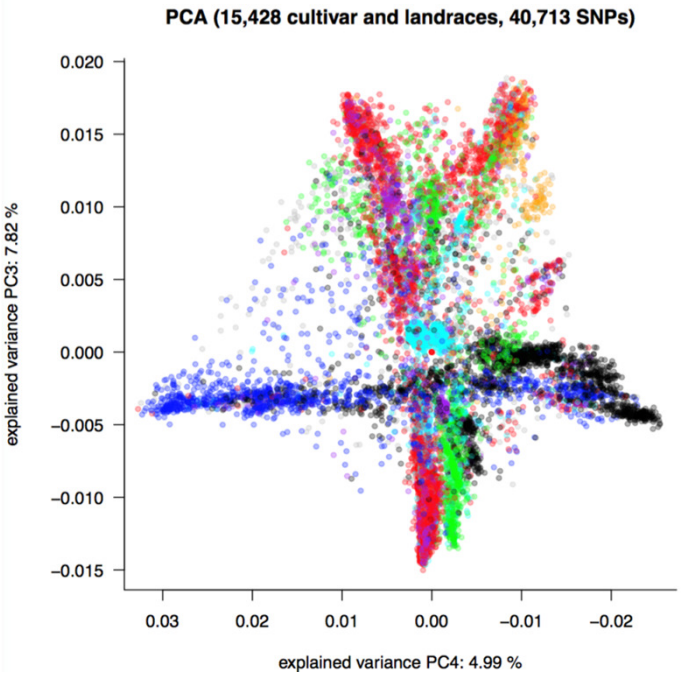
Using Data Warehouse Technology in Crop Plant Bioinformatics

Christian Kuenne, Ivo Grosse, Inge Matthies, Uwe Scholz, Tatjana Sretenovic-Rajicic, Nils Stein, Andreas Stephanik, Burkhard Steuernagel and Stephan Weise*

•What structures are necessary to achieve this objective?

WHEAT INITIATIVE

Genotyping



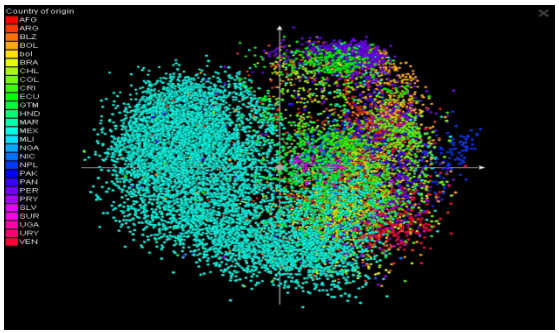
N. Stein

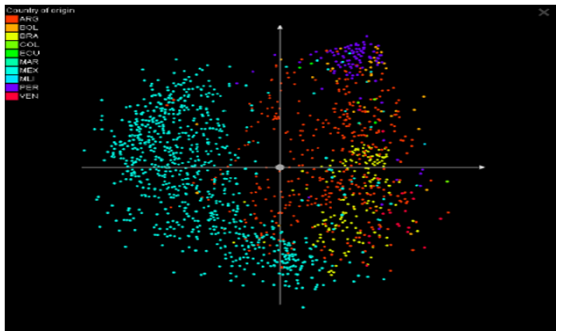
Genotyping by sequencing
Chip technologies
Imputation

- Genotyping/sequencing of gene bank collections and breeding populations is technically, economically and politically feasible
- Sequencing has begun, but efforts are sporatic, species-specific and lack coordination
- A well-coordinated, international effort would enhance efficiency, quality, & increase potential for data integration and biological insight, document plant /microbial biodiversity, and help address the grand global challenges we face

S. McCouch

Pre-selection of accessions for phenotyping



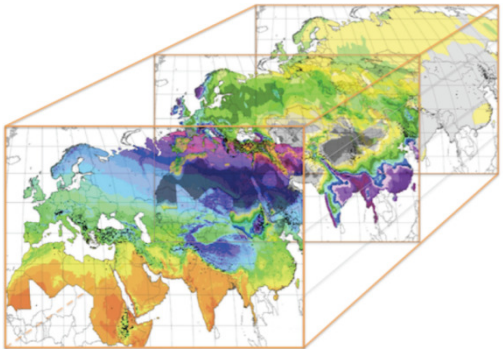


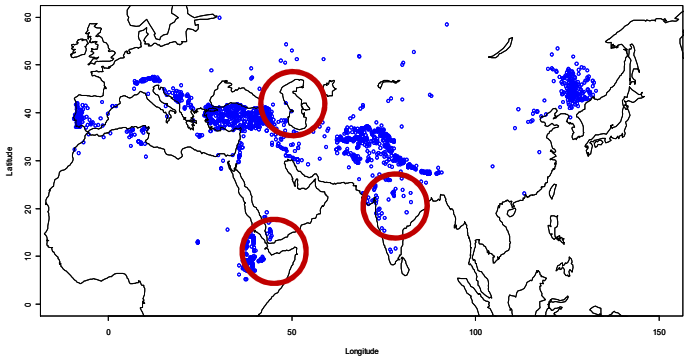
15,384 landraces

1,549 landraces from drought prone environments

H. Braun

Focused Identification of Germplasm Strategy (FIGS)





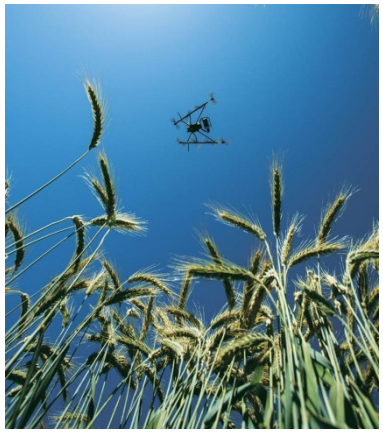
Environnement

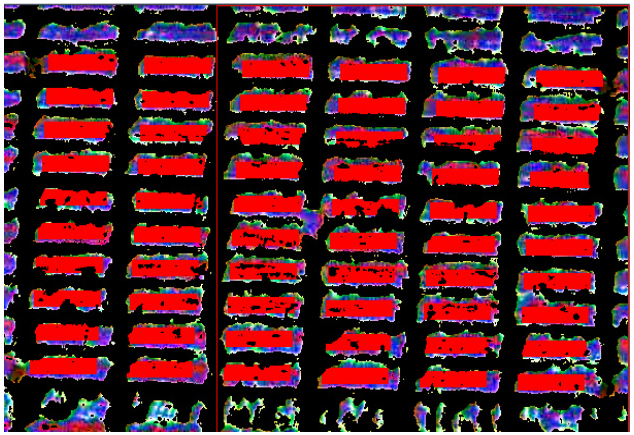
www.icarda.org/
Trait (disease score)

FIGS subset

M. Baum

Phenotyping for drought tolerance





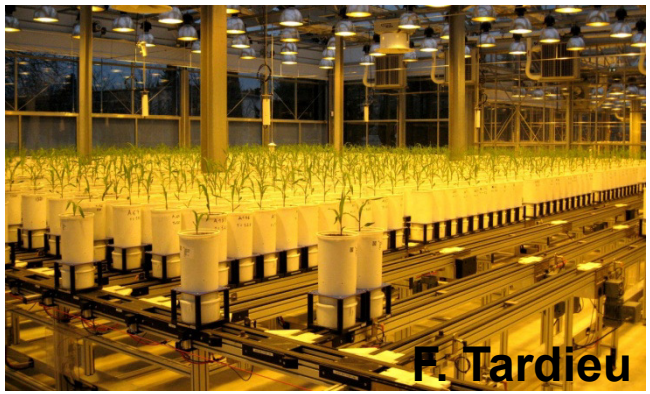
M. Reynolds

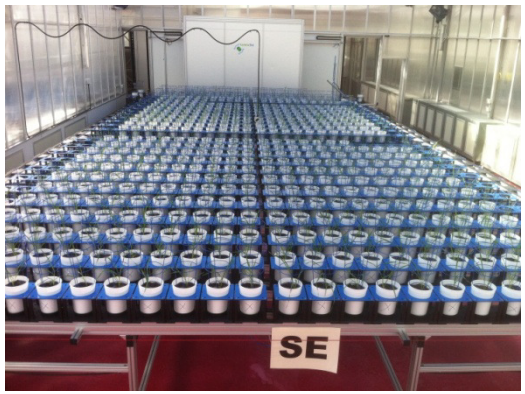
Tattaris M, Reynolds MP, Chapman SC, 2016. A direct comparison of remote sensing approaches for high-throughput phenotyping in plant breeding. Front. Plant Sci. 7: 1131.

Genomic prediction + quantitative relationships with environment.

$$Yield_{ij} = geno_i + \Sigma\,(\alpha_j\, light_i + \beta_j\, T_i + \delta_j\, \Psi_{soil\ i}) + \varepsilon_{ij}$$

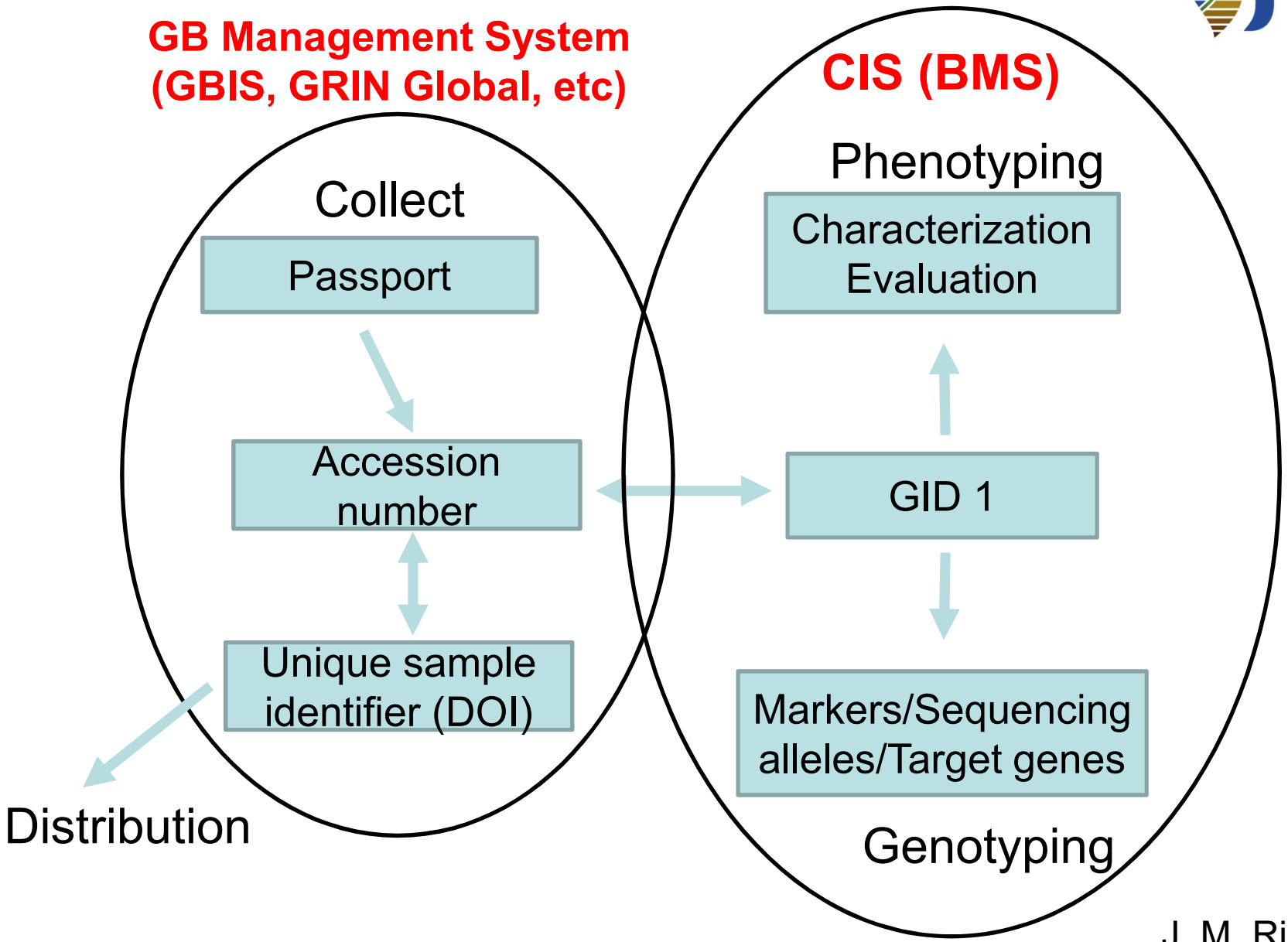
F. Tardieu





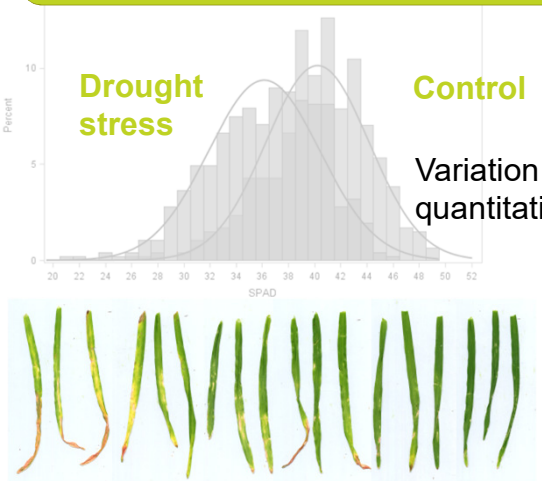
M. Tester

Data storage and management



Genome wide association study (GWAS)

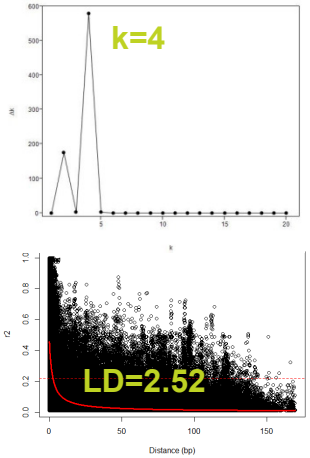
Phenotyping



Variation for quantitative Traits

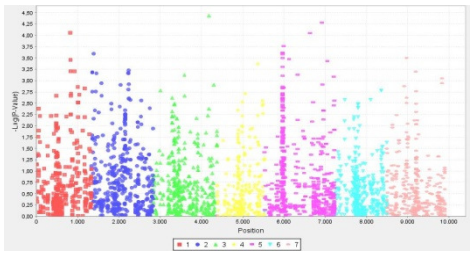
Genotyping

PCA, Dendrogram
Population structure
Linkage disequilibrium

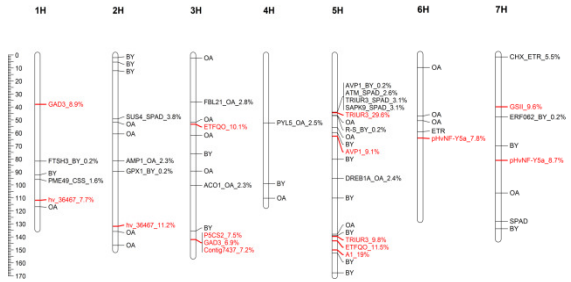


Association mapping

Detection of QTL



Localisation of QTL



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Conclusions

•Genotyping of large gene bank collections is technically feasible

•Genotypic data, in combination with geographic and other information, can be used to pre-select genotypes for detailed phenotypic analysis

•Phenotypic analysis for drought stress tolerance and of drought stress related traits is feasible

•Data storage and information systems are available

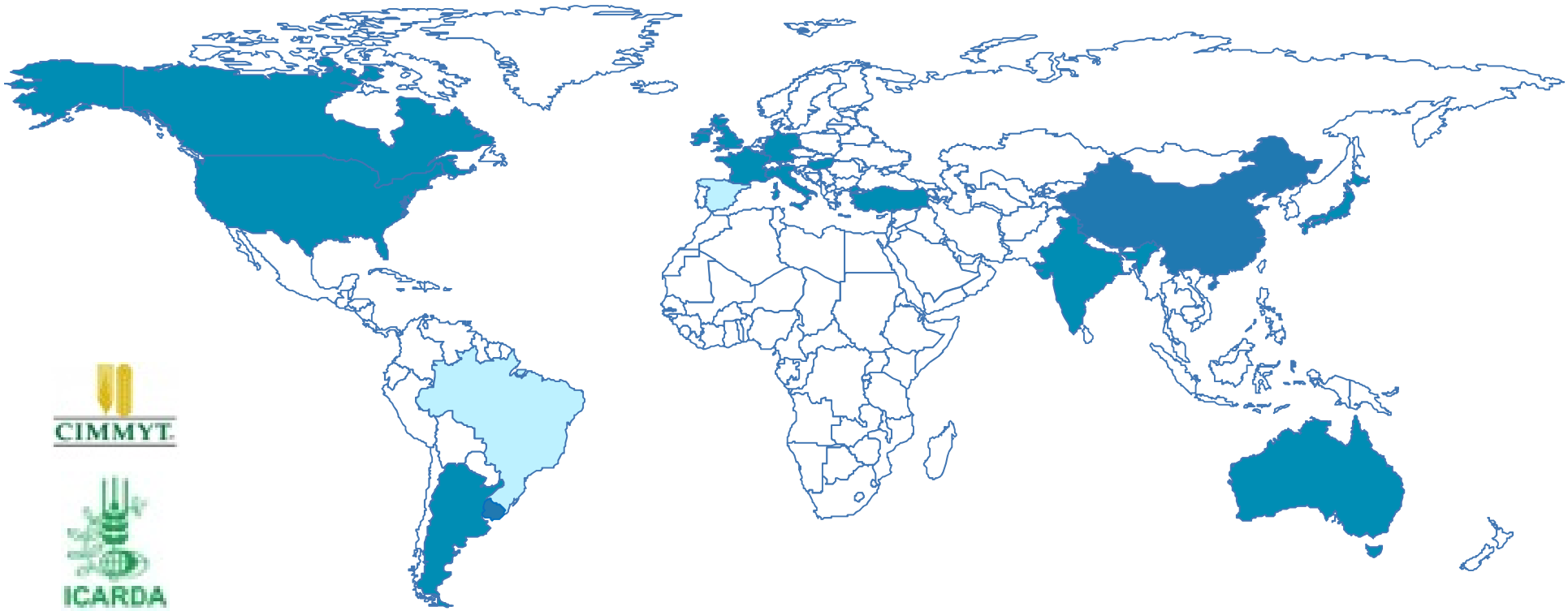
•Consequently, it is now practicable to efficiently harness genetic resources for breeding drought stress tolerant crops

But international collaboration, based on detailed discussions and planning, is now needed to achieve these goals.

The Wheat Initiative

Members

16 countries, 9 private companies, 2 CGIAR Centres



CIMMYT

ICARDA

ARVALIS Institut du végétal

FLORIMOND DESPREZ

KWS

Limagrain

MONSANTO

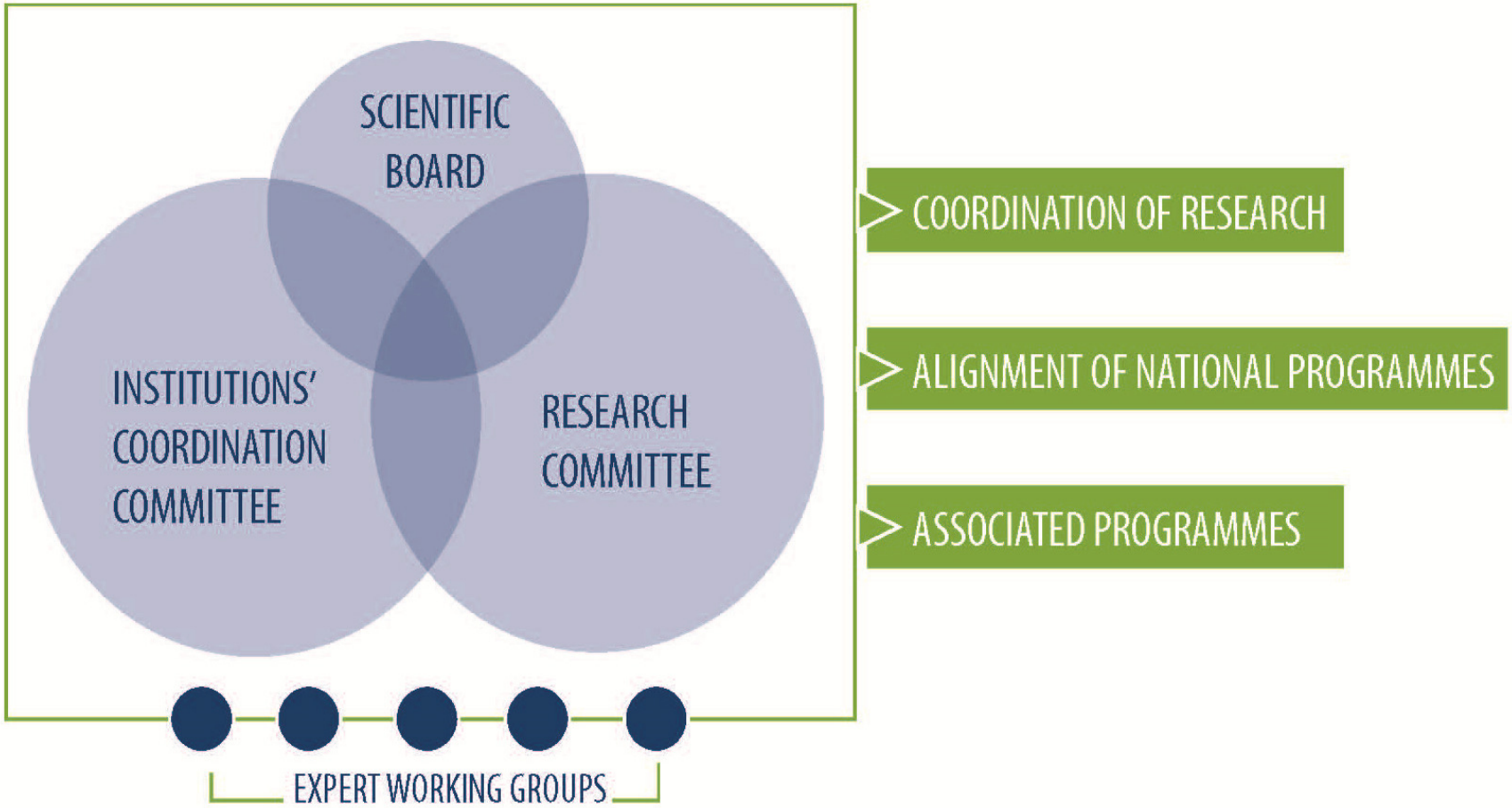
RAGT

SAATEN UNION

syngenta

WHEAT INITIATIVE

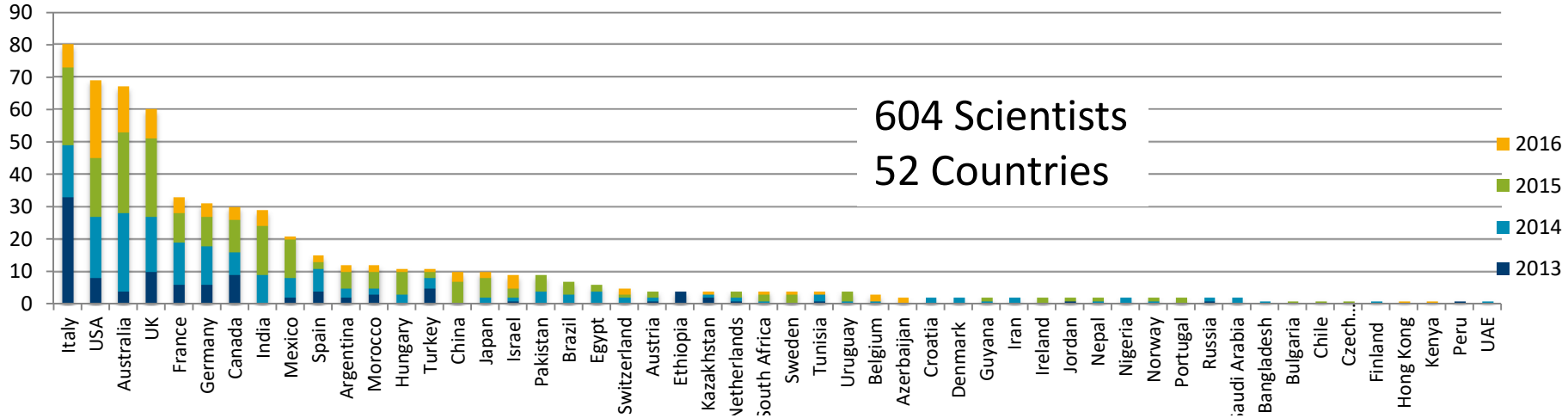
Facilitating delivery by leveraging synergies and collaborations



WHEAT INITIATIVE

Expert Working Groups

1. Wheat Information System
2. Genetics and genomics of durum wheat
3. Wheat breeding methods and strategies
4. Wheat phenotyping to support wheat improvement
5. Nutrient use efficiency
6. Control of wheat pathogens and pests
7. Adaptation of wheat to abiotic stress
8. Global wheat germplasm conservation and use community
9. Improving wheat quality for processing and health
10. Agronomy



Changes

New members

- China
- Uruguay
- Spain?

Secretariat

- 2012 – 2017
  - INRA France
- Move to Berlin – 2018 - 2022
  - Support from German Ministry for Food and Agriculture

JKI
Julius Kühn-Institut
Federal Research Centre for Cultivated Plants

WHEAT INITIATIVE

Major activities of the WI

- Weekly Wheat Media Updates
- Newsletters
- Wheat Congress
- Wheat Information System – Wheat IS
- Wheat VIVO
- Wheat genome sequencing – IWGSC and 10 Genomes
- International Wheat Yield Partnership
- Linking genomics to breeding – Durum EWG

WHEAT INITIATIVE

Associated programs

Established

- International Wheat Genome Sequencing Consortium
- International Wheat Yield Partnership
- Wheat Ten Genome Project
- Crop modelling group

Under development

- Heat and Drought Wheat Improvement Consortium
- Nutrient Use Efficiency Consortium
- Recombination

WHEAT INITIATIVE

IWYP International Wheat Yield Partnership

Research to Deliver Wheat for the Future

WHEAT INITIATIVE

International Wheat Yield Partnership

Research to Deliver Wheat for the Future

GOAL -> To increase the genetic yield potential of wheat by 50% by 2025

www.iwyp.org

IWYP Science Projects

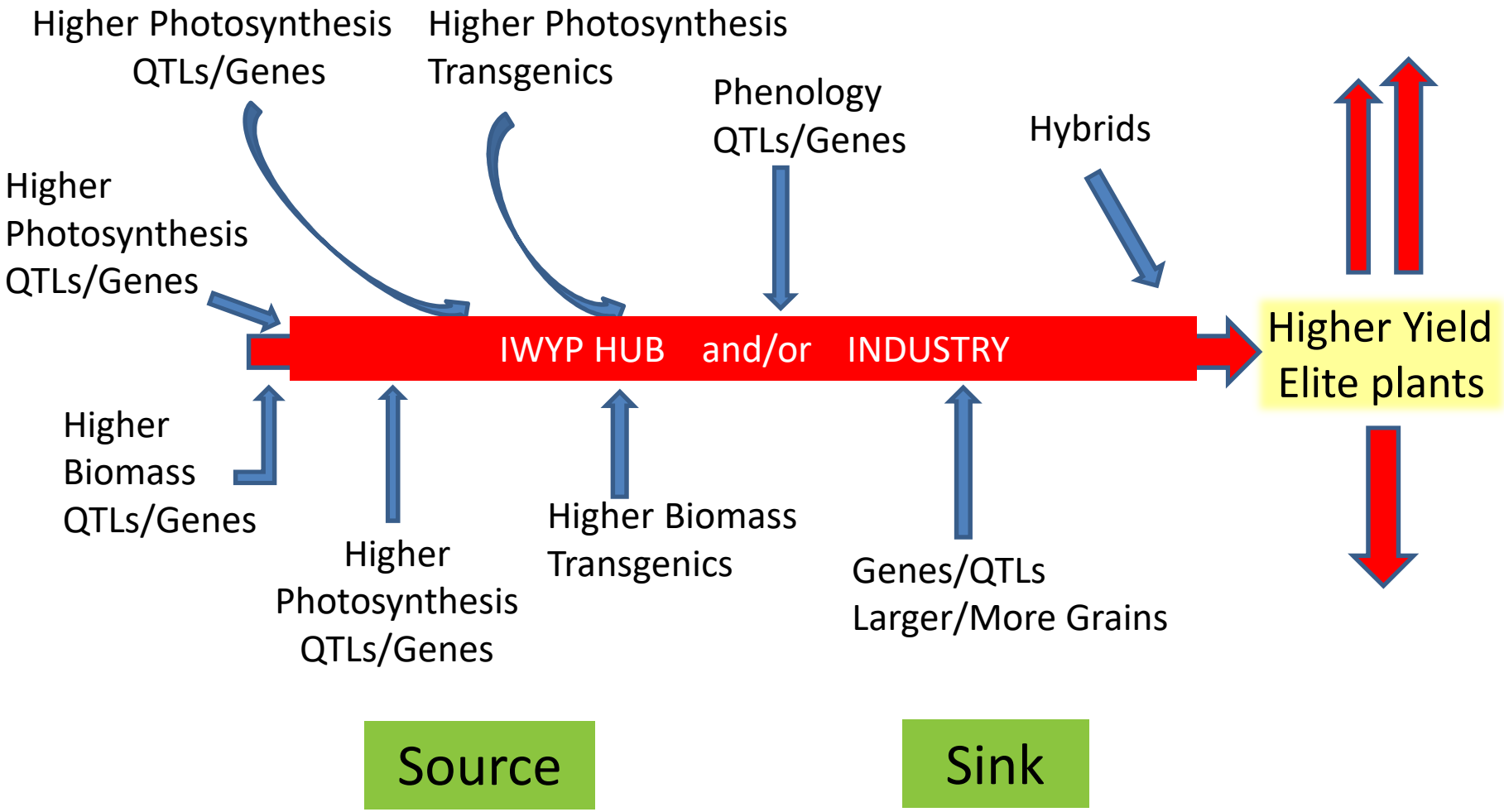
IWYP International Wheat Yield Partnership
Research to Deliver Wheat for the Future

Currently dozens of researchers from 9 countries

- 8 projects selected from IWYP 1st Competitive Call
- 7 projects selected from USDA NIFA-IWYP Call
- 8 IWYP Aligned Projects
- Science portfolio is expanding:
  - IWYP 2nd Competitive Call (in progress)
  - Future Calls (both IWYP and Aligned)
  - Aligned Projects

IWYP Deploys Gene / QTL / Trait Assembly Lines

IWYP International Wheat Yield Partnership
Research to Deliver Wheat for the Future

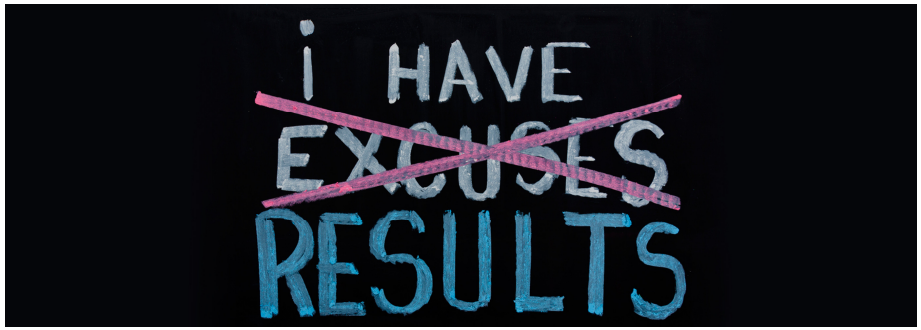


WHEAT INITIATIVE

Lessons learnt

Improvement needed

- Translation to funding outcomes
  - Response to priorities
- Assessing progress
  - Clarify objectives
  - Clear targets and timeframes
- Bureaucratic
  - Maintaining interest and engagement
- Complex structure
  - Speed of response



Lessons learnt

Worked well

- Unique opportunity for international coordination
- Expert Working Groups
  - Supports broad participation
- Strategic Research Agenda
  - Aligns well with national and international objectives
  - Vital framework for international cooperation
- Communication and awareness of wheat research
  - Media briefs
  - Newsletters
  - Planning meetings

WHEAT INITIATIVE

Contact

Frank Ordon
Julius Kühn-Institute
Institute for Resistance Research and Stress Tolerance
frank.ordon@julius-kuehn.de

Peter Langridge
Wheat Initiative
peter.langridge@adelaide.edu.au