Exploiting of plant genetic resources for resource-efficient and environmental friendly crop production

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Bundesforschungsinstitut für Kulturpflanzen
Federal Research Centre for Cultivated Plants

Rethinking plant breeding for a zero-pesticide agriculture

Bordeaux, May 14th 2024

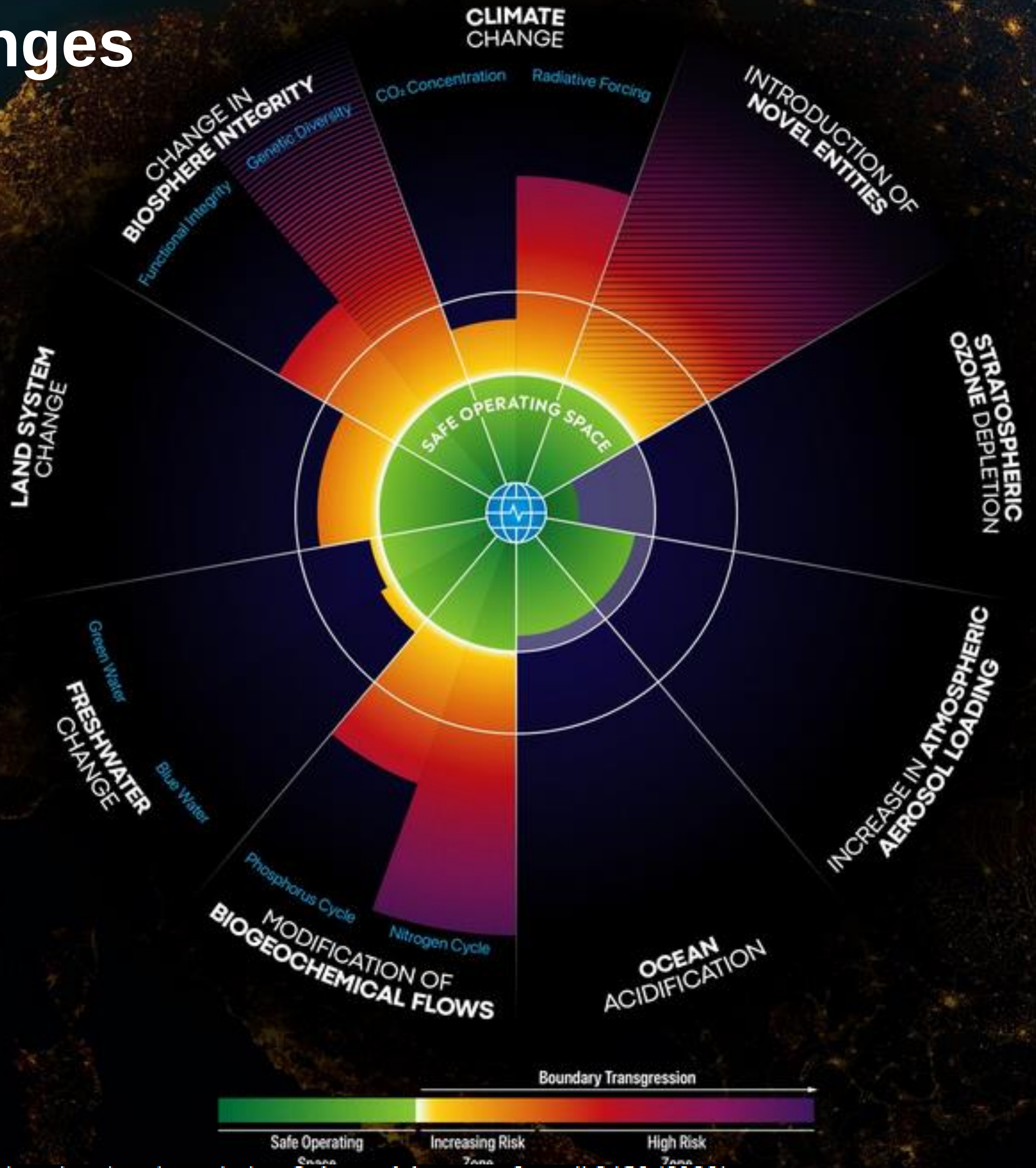

Foto: Albrecht Serfling


Foto: Lars Böge


Foto: Andreas Stahl

www.julius-kuehn.de

Our grand challenges



- Katherine Richardson et al., *Earth beyond six of nine planetary boundaries*. **Science Advances**. 9, eadh2458 (2023).
  DOI:10.1126/sciadv.adh2458

Our grand challenges

Necessity of high crop production

- Food security and food quality for a growing world population
- match the demand of further agricultural commodities
- secure crop productivity on limited arable land
- Secure income of local production (farmers income)

Crop Production

Limitations & Challenges of crop production

- Planetary boundaries (loss of biodiversity)
- Drought, heat and other weather extremes
- Reduction of CO_2 and volatile NO_x and NH_3emissions
- Avoidance of Nitrate leaching in groundwater and waterways
- Reduction of agro-chemical inputs (herbicides, fungicides, insecticides)

Make use of <u>genetic resources</u> to produce more with less!!!

Requires:

- Higher nutrient use efficiency
- Higher water use efficiency
- Enhanced disease resistance
- Higher radiation use efficiency

The formula for breeding progress

Increase selection intensity
Genomic prediction in larger populations
Novel, automated selection methods

Enhance genetic diversity
Genome/pangenome resources
Haplotype-based crossing designs
Gene editing/biotechnology

$$\Delta G = (i * r * \delta_G) / L_g$$

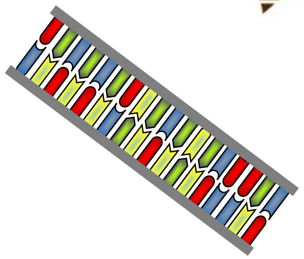
Improve selection accuracy
Knowledge-based phenotyping
Enhanced genomic prediction models
Physiological modelling, deep learning on automated phenotype data

Accelerate breeding processes (Lg)
Novel genomic prediction methods
“Speed Breeding”, gene editing
Haplotype-based crossing designs

Source: Rod Snowdon (JLU)

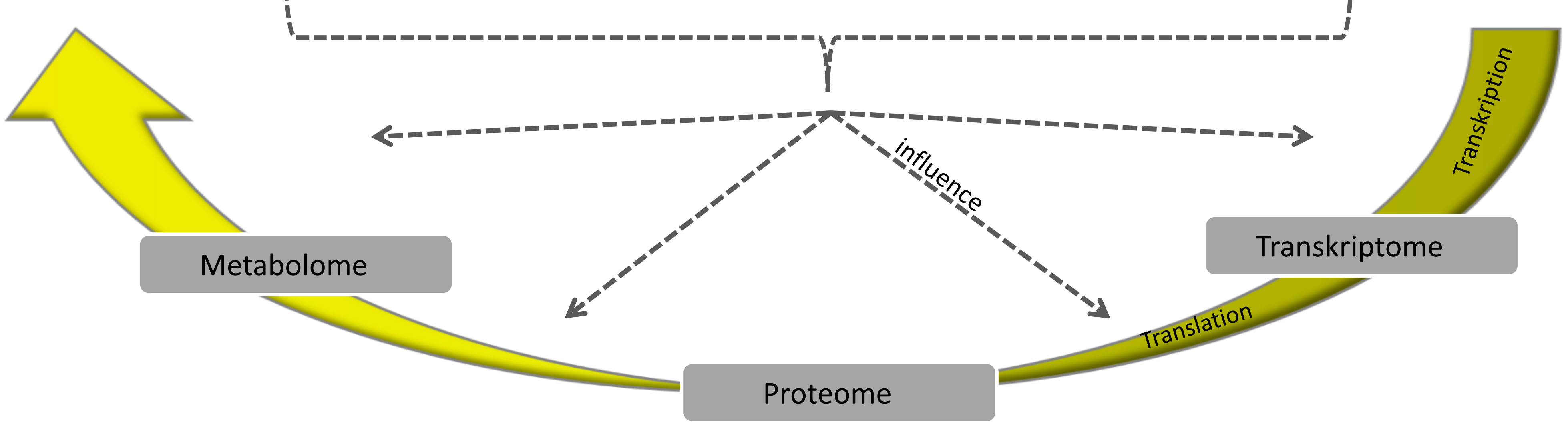
From Genoype to Phenotype

- Precipitation distribution
- Radiation
- Day lengthtemperature
- Soil parameters (chemical & physical)
- Nutrient availability (fertilisation)
- Disease pressure (plant protection)
- Management (timing, dosage, etc.)

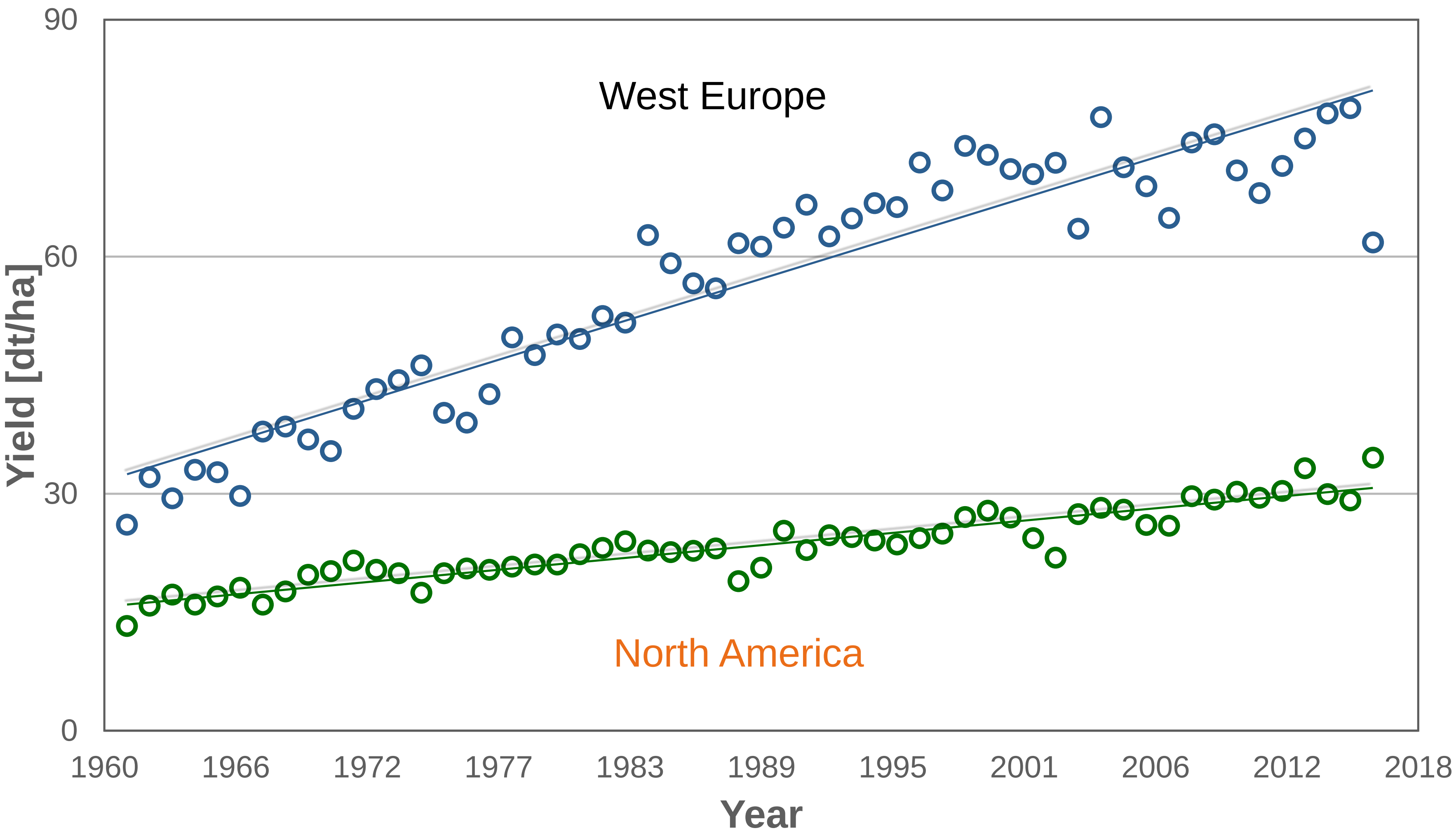


P = E + M + G*E*M + G

Phenotype | Environment + Management + Genotype-Environment-Management-Interaction | Genotype

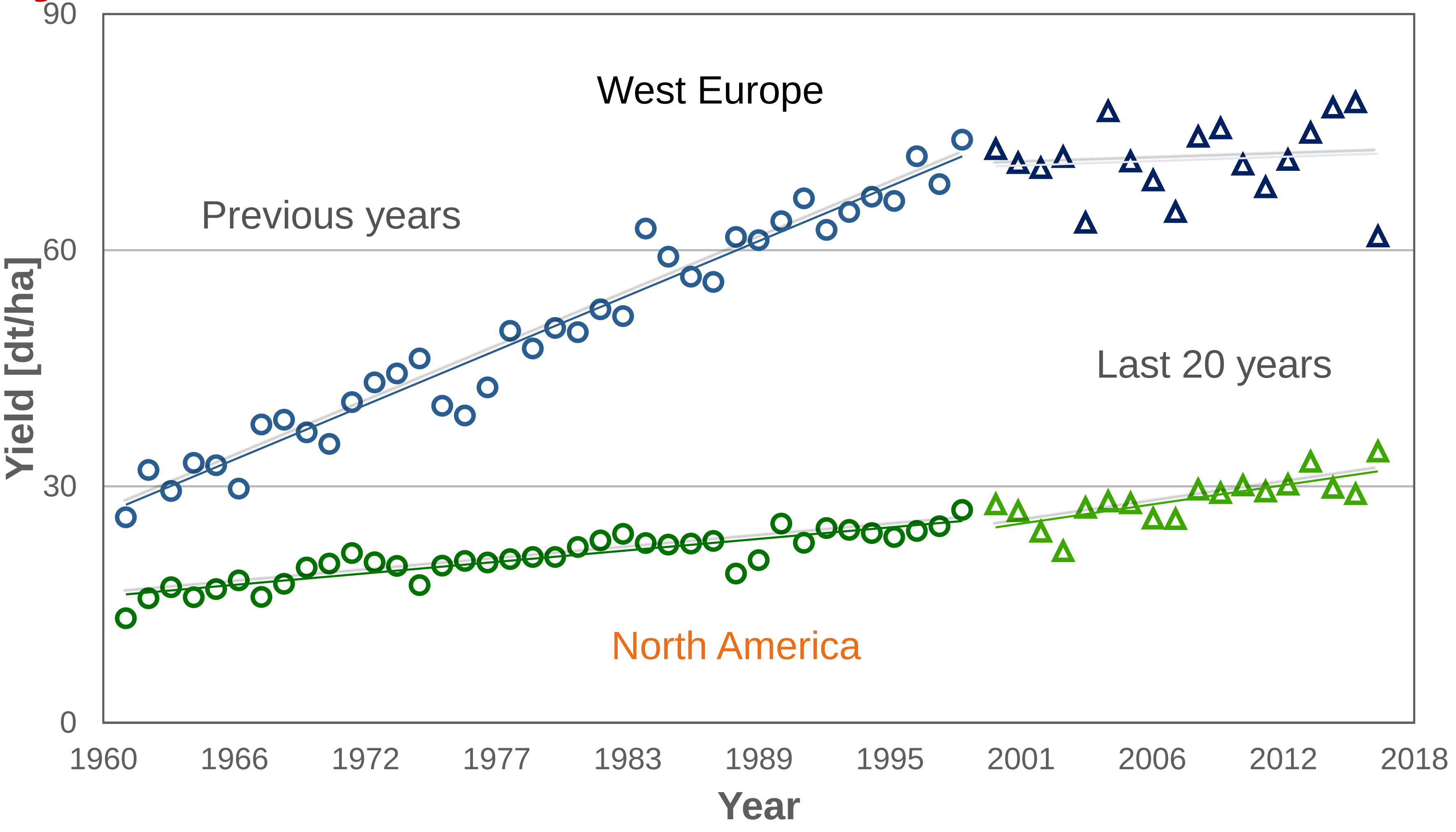


Wheat yields have been rising for 50 years



FAOstat

Wheat yields have been rising for 50 years
… or maybe not?!?!



FAOstat

Assessment of breeding progress in European Wheat

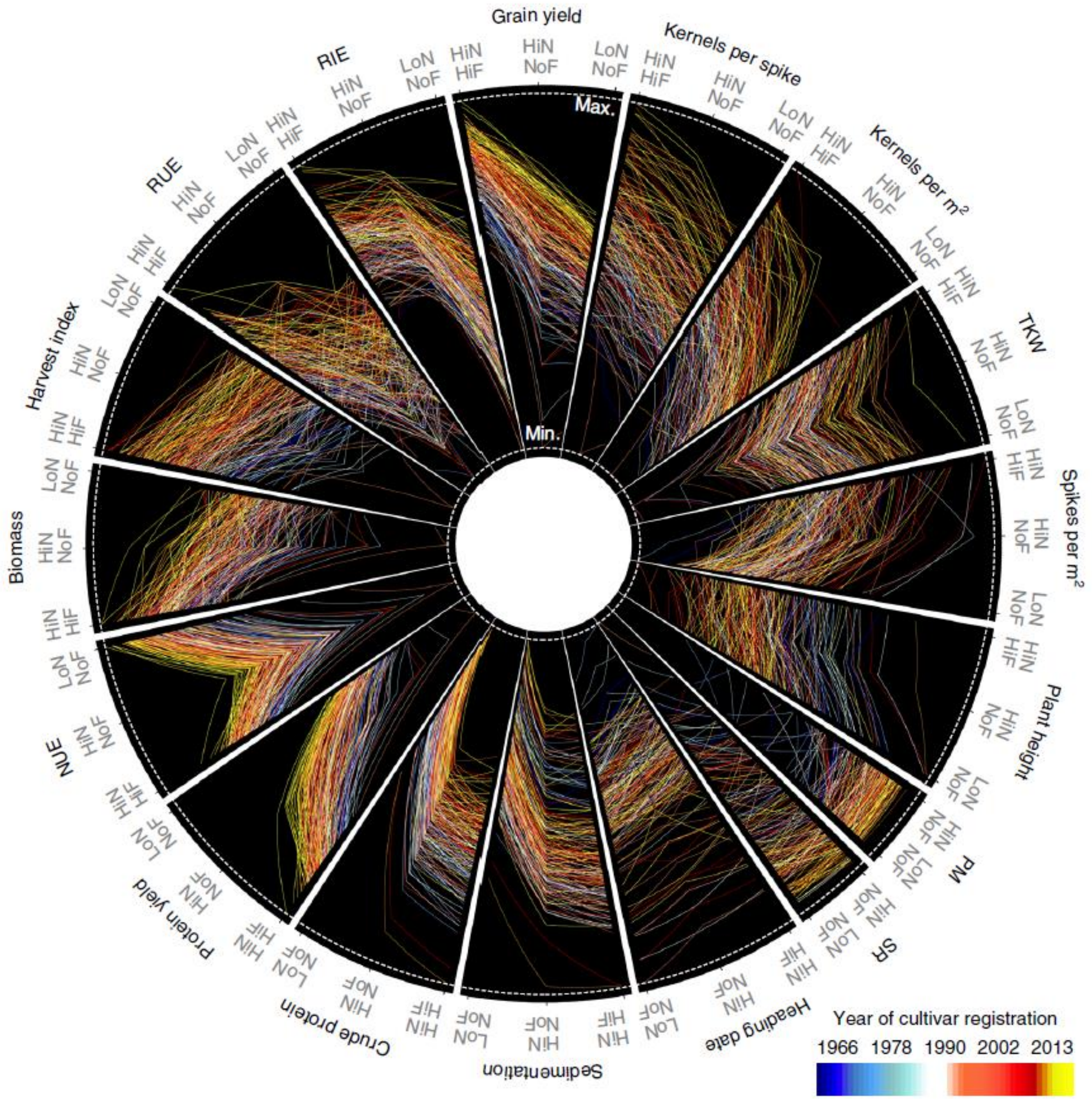
- 191 European wheat cultivars
- 6 Locations
- 2 Years
- 3 Treatments
- 2 Replications

(local natural infection pressure)

Treatment		N-Fertilisation (incl. N_{min})	Insecticide & Fungicide
BS1	low-input	110 kg ha^{-1}	No
BS2	semi-intensiv	220 kg ha^{-1}	No
BS3	intensiv	220 kg ha^{-1}	Yes

17.161 Field plots,
~250.000 phenotypic data points

50 years of breeding – a great success!



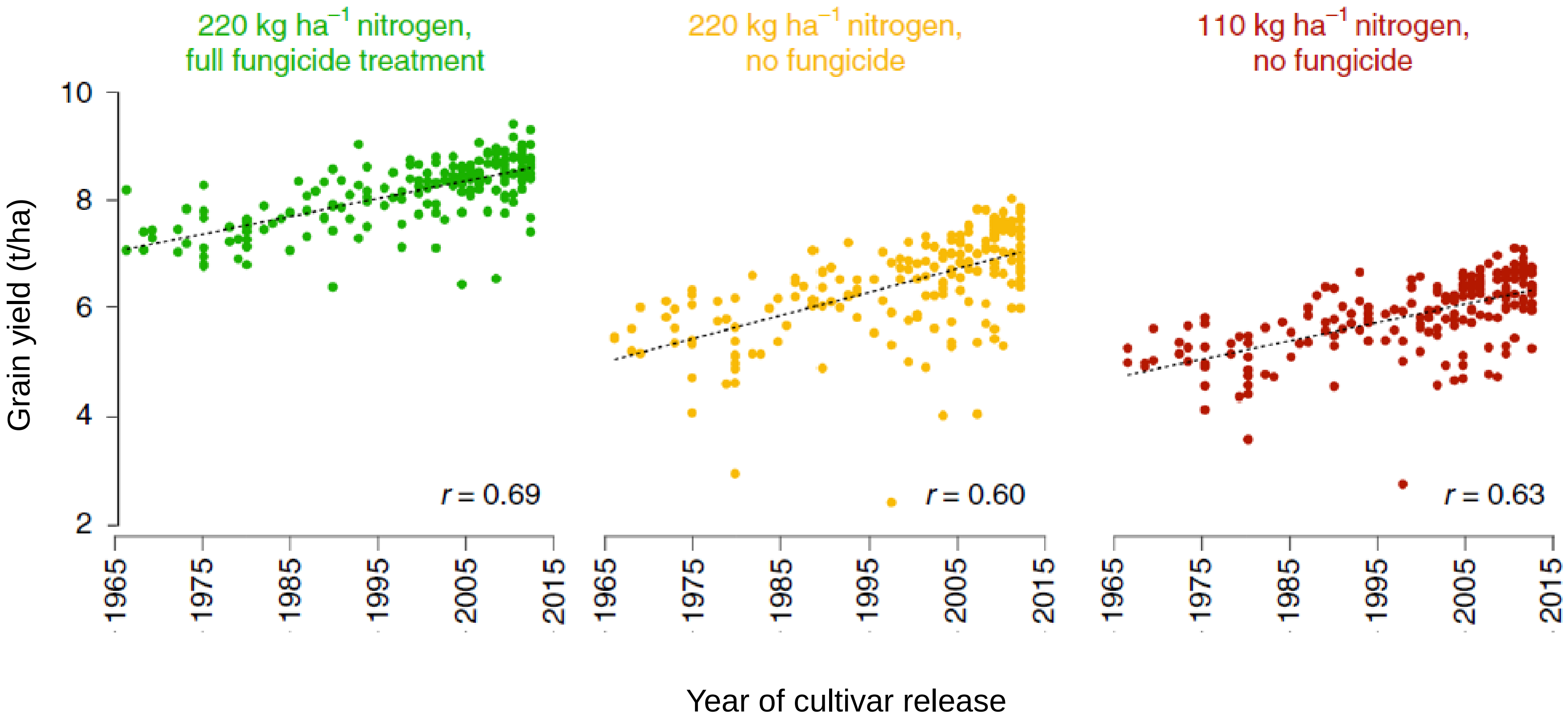
HiN = 220 kg N/ha
LoN= 110 kg N/ha

HiF = with fungicides
NoF = without fungicides

Voss-Fels, K.P., Stahl, A., Wittkop, B. et al. Breeding improves wheat productivity under contrasting agrochemical input levels. Nat. Plants 5, 706–714 (2019). https://doi.org/10.1038/s41477-019-0445-5

Breeding improves yield …

… under contrasting chemical plant protection and N fertilisation



Voss-Fels, K.P., Stahl, A., Wittkop, B. et al. Breeding improves wheat productivity under contrasting agrochemical input levels. Nat. Plants 5, 706–714 (2019). https://doi.org/10.1038/s41477-019-0445-5

Evidence in the French study: Breeding improves yield under contrasting nitrogen input

Theor Appl Genet (2013) 126:3035–3048
DOI 10.1007/s00122-013-2191-9

ORIGINAL PAPER

A multi-environmental study of recent breeding progress on nitrogen use efficiency in wheat (*Triticum aestivum* L.)

Fabien Cormier · Sébastien Faure · Pierre Dubreuil · Emmanuel Heumez · Katia Beauchêne · Stéphane Lafarge · Sébastien Praud · Jacques Le Gouis

Received: 17 June 2013 / Accepted: 6 September 2013 / Published online: 21 September 201

Abstract
Key message By comparing 195 varieties in eight trials, this study assesses nitrogen use efficiency improvement in high and low nitrogen conditions in European winter wheat over the last 25 years.

and plant heig… when needed. … highly significa… that no additive… Genotype × N …

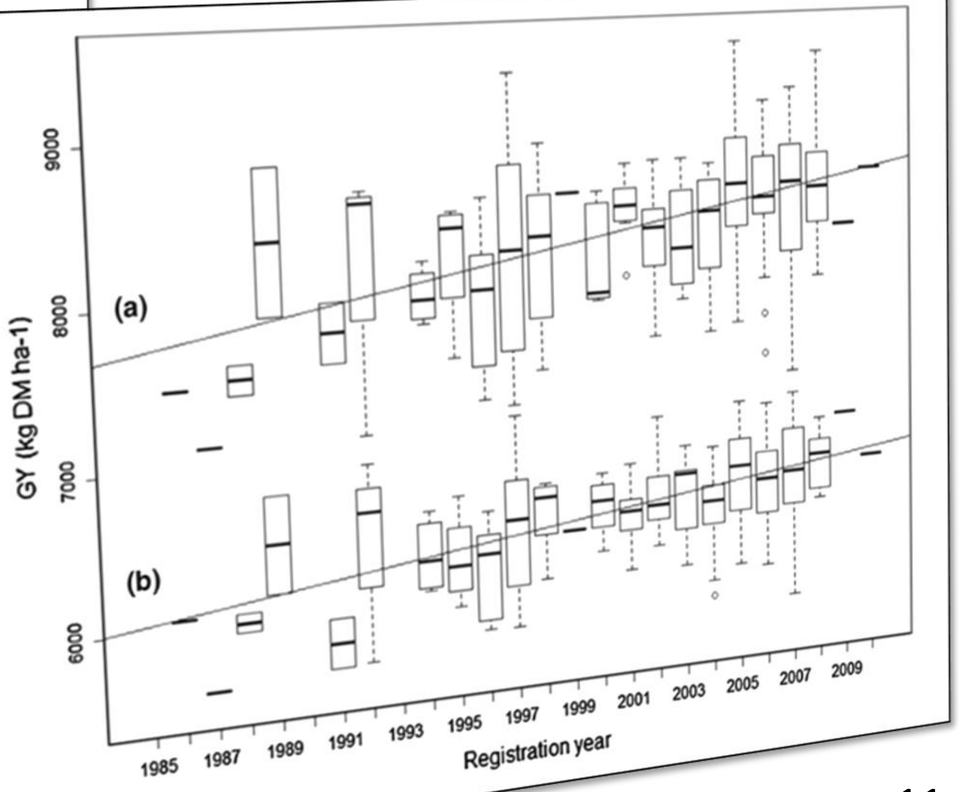
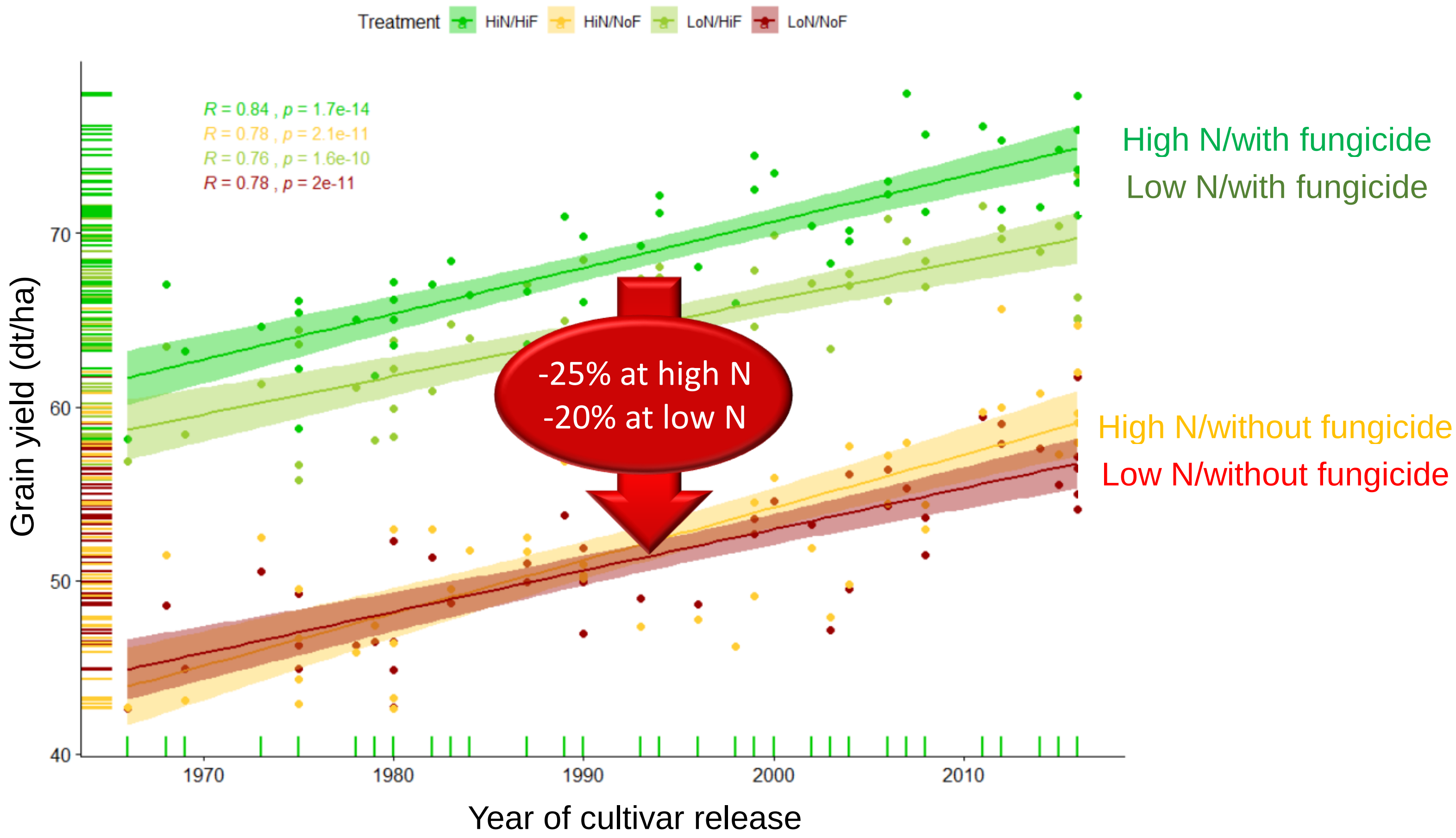


Fig. 4 Boxplot of GY genetic values by year of release and by N treatment (*LN* low N level, *HN* high N level) for 195 wheat cultivars grown in four environments. Values are the best linear unbiased estimators of NUE corrected of quality and precocity effects. **a** at HN treatment, and **b** at LN treatment. **a** At HN, regression function is GY = −69690 + YR × (34.8 ± 4.42), the complete model (with quality and precocity) adjusted r^2 is 66 % and YR effect $P < 0.001$. **b** At LN, regression function is GY = −51302 + YR × (25.64 ± 6.22), the complete model (with quality and precocity) adjusted r^2 is 70 % and YR effect $P < 0.001$. G × N on GY is significant but YR effect on this interaction is not significant ($P > 0.05$)

Breeding improves yield … but…

Validation experiment in 2016/17 & 2017/18 confirmed the findings



Source: Benjamin Wittkop, JLU

Key messages

1) Omitting the fungicide leads to substantial yield losses
2) Breeding enhanced grain yield in all treatment combinations

Voss-Fels, K.P., Stahl, A., Wittkop, B. et al. Breeding improves wheat productivity under contrasting agrochemical input levels. Nat. Plants 5, 706–714 (2019). https://doi.org/10.1038/s41477-019-0445-5

Test under controlled infection conditions

Field tests

220+8 cultivars 2x2 treatments (N, PP), 2 replications
Inoculation with *P. striiformis*, *P. triticina*, *F. culmorum*
natural with *B. graminis tritici*
3 growing seasons 2014-2017
Σ 5344 plots

Seedling tests

228 cultivars, 3 replications
Separate inoculation with
4 *P. striiformis* isolates
5 *P. triticina* isolates
Σ 6156 pots

Statistical Analyses

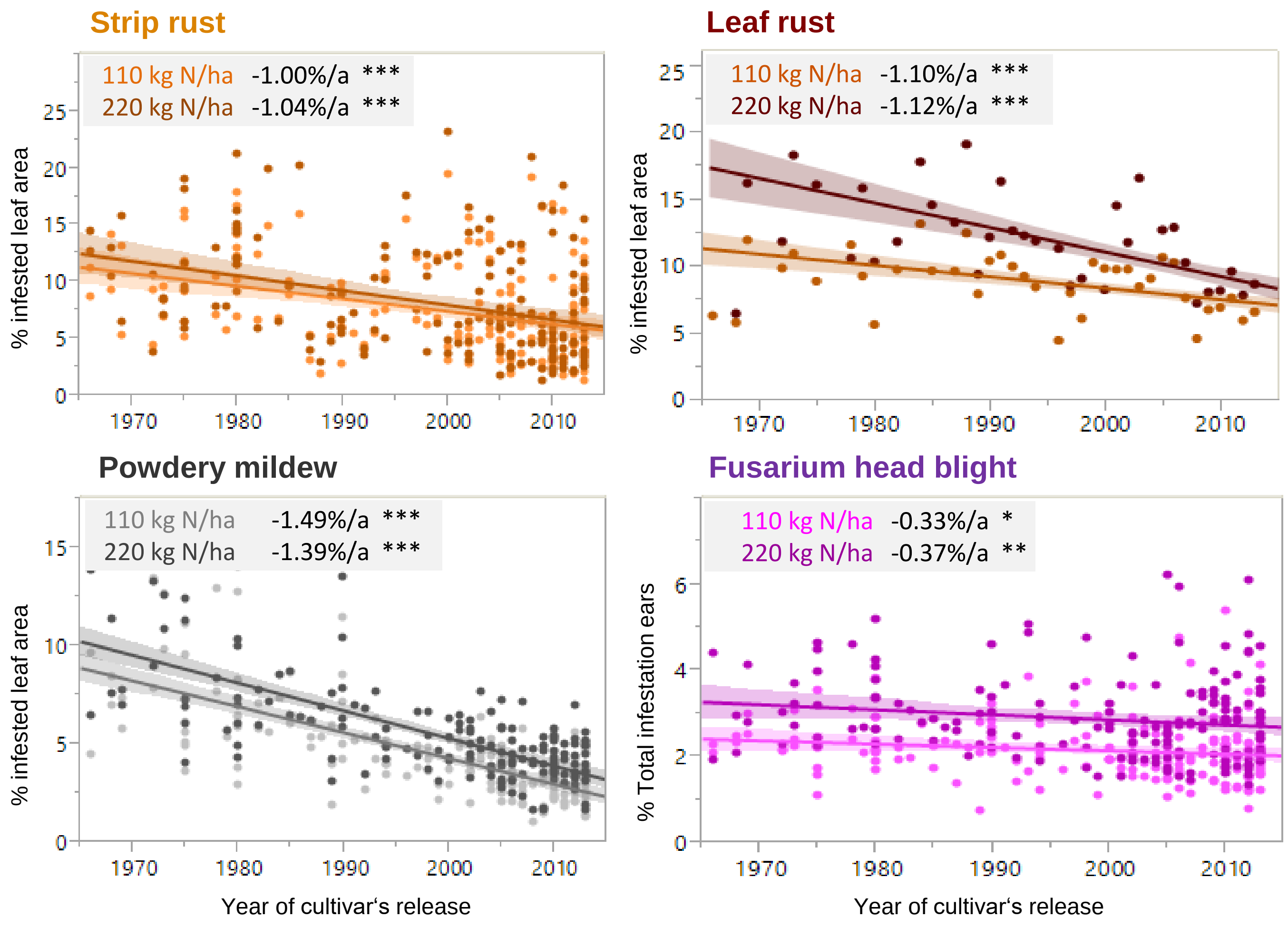
AUDPC and average ordinate (AO),
growth stages, grain yield and yield components
ANOVA, contrast and correlation analyses, GWAS

Infection type, % infected leaf area, rel. susceptibility

ANOVA, correlations, GWAS

Source: Holger Zetzsche (JKI)

Breeding progress in field resistance of European winter wheat



*** p<0.001
** p<0.01
* p<0.05
ns not significant

Note: Strong resistance enhancement against YR, LR, PM - rather slight against FHB

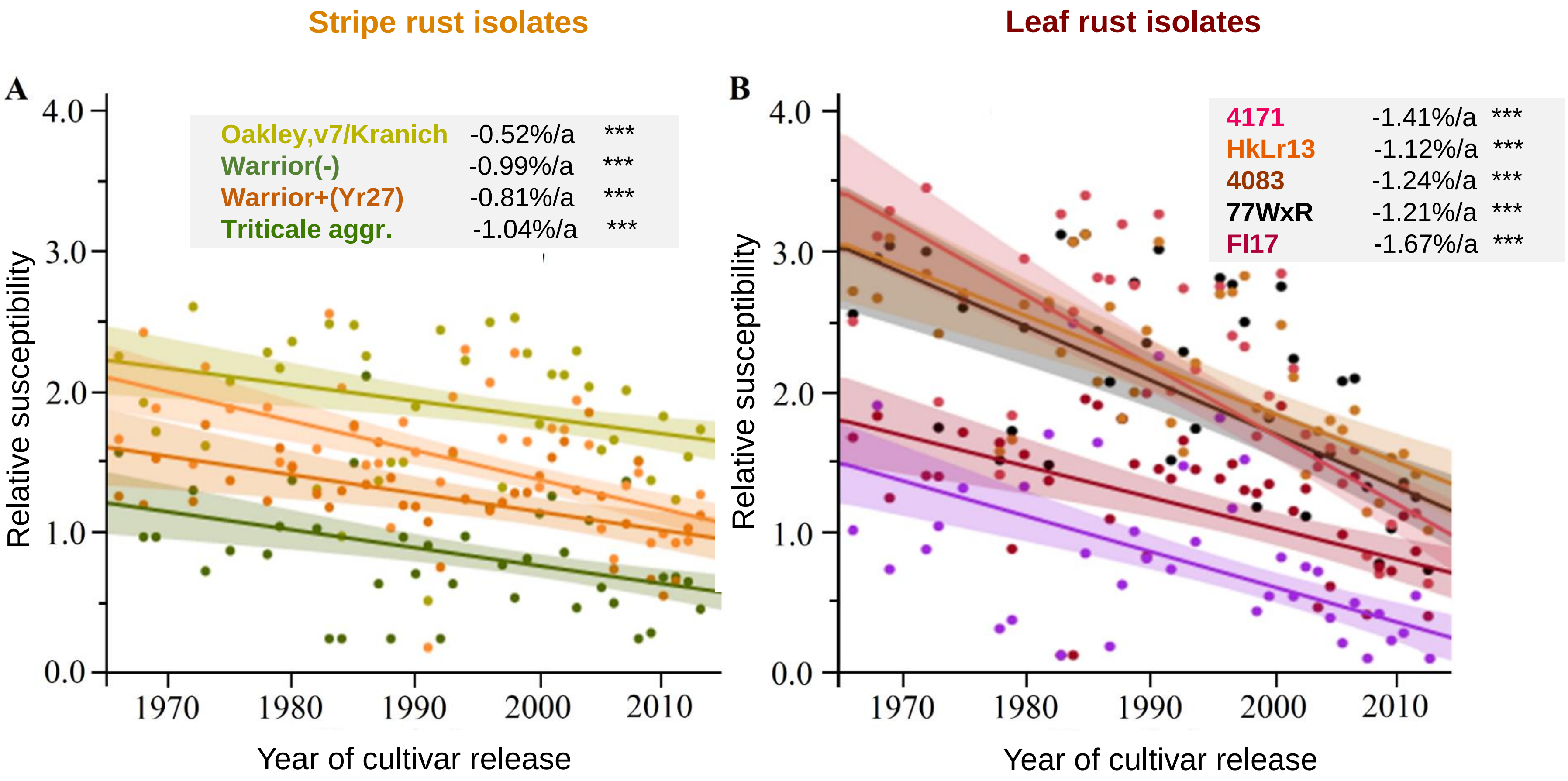
Increase stronger at higher N

Resistance progress with no indication of slowing down!

Pathogen evolution ≈ 50 % of improvement against biotroph pathogens lost

Zetzsche et al. 2019 Crop Breed Genet Genome
Zetzsche et al. 2020 Scientific Reports

Breeding improved seedling resistance against several isolates

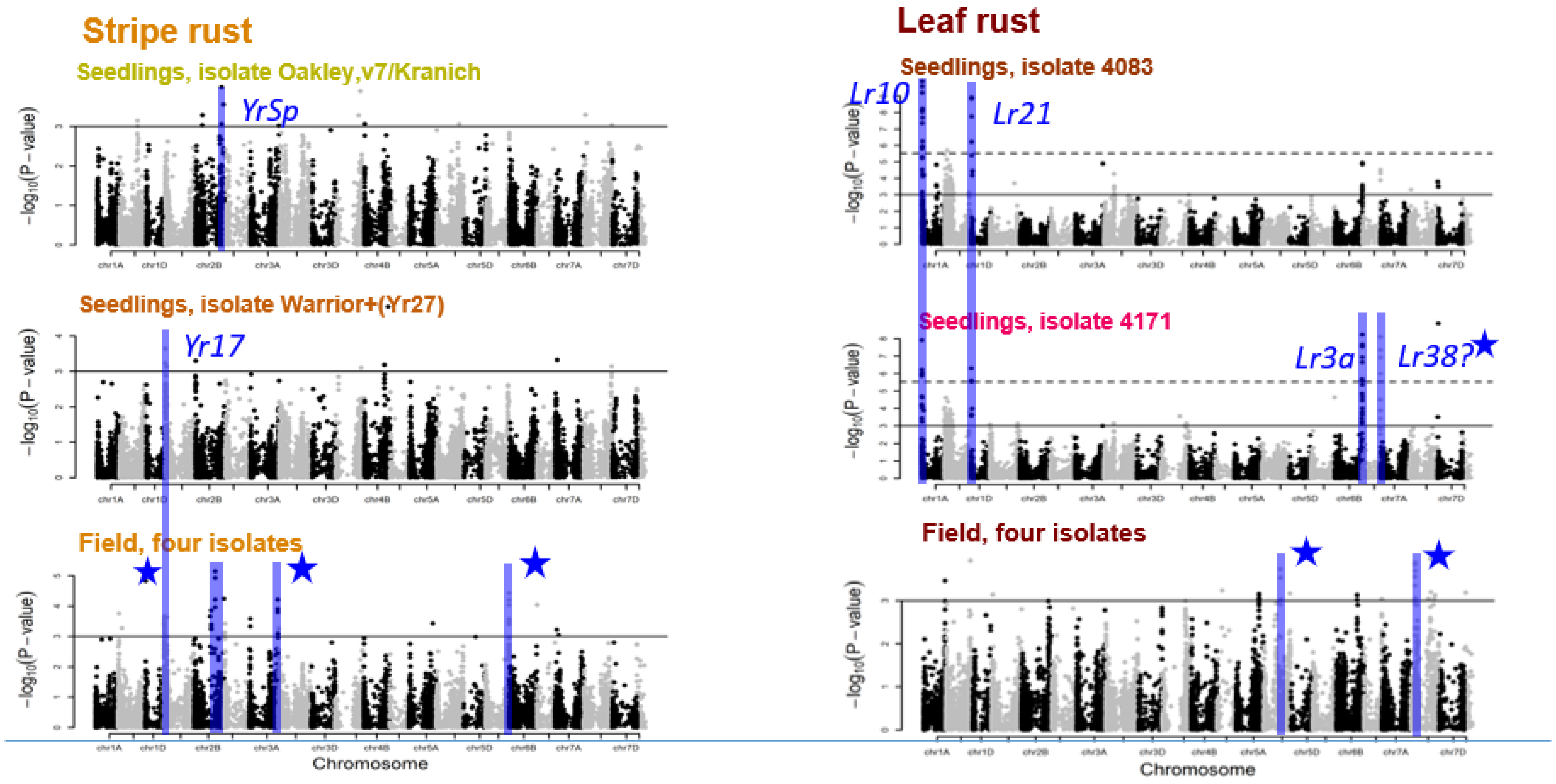


Note: Increase in race-specific seedling resistance against all rust isolates tested with similar trends
→ defeated R genes contribute to quantitative resistance or accumulation of QDR

Zetzsche et al. 2019 Crop Breed Genet Genome
Zetzsche et al. 2020 Scientific Reports

Identified QTLs for resistance against stripe and leaf rust

based on GWAS results (16853 polymorphic SNP, MAF0.05), GENABEL (R)

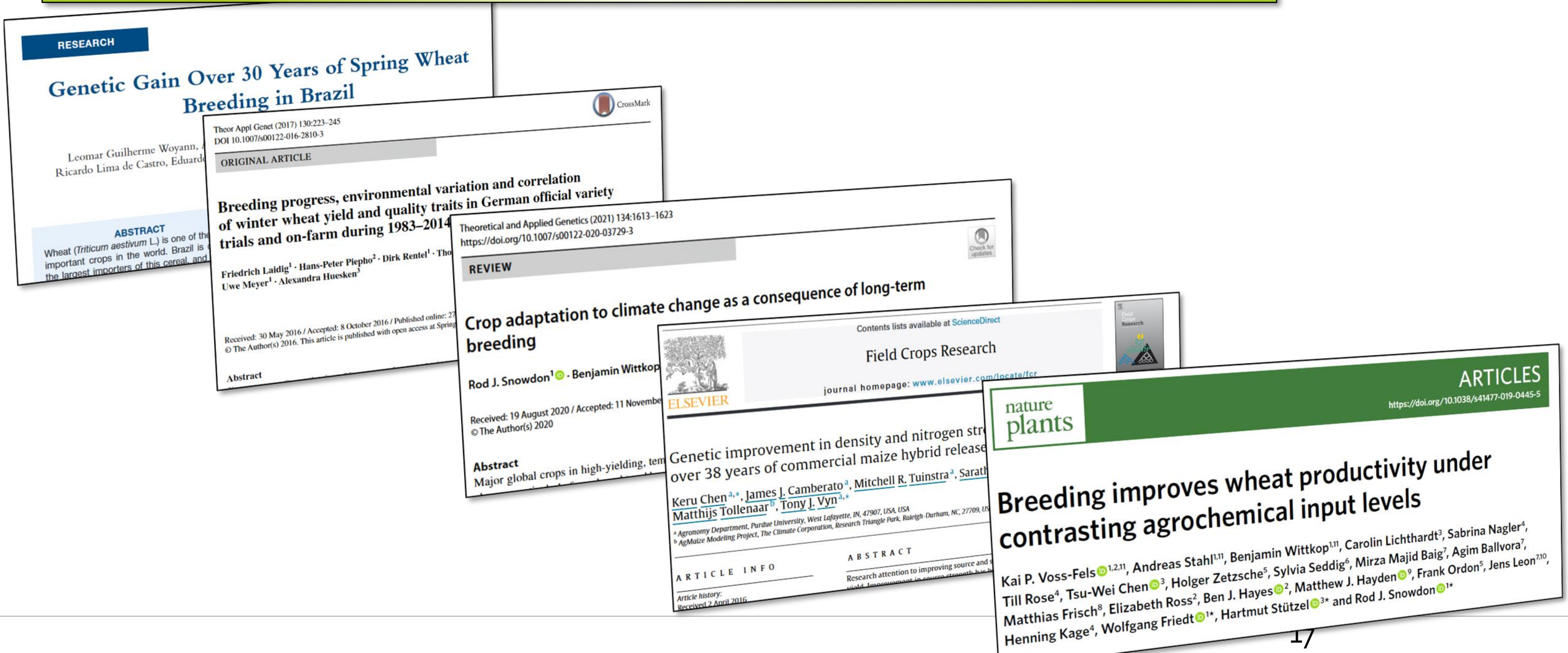


Field resistance with additional or separate QTL (APR genes★), only partly overlap with seedlings resistance

Zetzsche et al. 2019 Crop Breed Genet Genome
Zetzsche et al. 2020 Scientific Reports

Breeding increases yields in long term

Use of <u>plant genetic resources for plant breeding</u> is of vital importance in the light of climate change, consumer protection, protection of natural resources (soil, water, biodiversity), along with safeguarding a <u>highly productive and environmentally friendly plant production</u>.



RESEARCH

Genetic Gain Over 30 Years of Spring Wheat Breeding in Brazil

Leomar Guilherme Woyann, ...
Ricardo Lima de Castro, Eduardo ...

ABSTRACT

Wheat (*Triticum aestivum* L.) is one of the ... important crops in the world. Brazil is ... the largest importers of this cereal, and ...

CrossMark

Theor Appl Genet (2017) 130:223–245
DOI 10.1007/s00122-016-2810-3

ORIGINAL ARTICLE

Breeding progress, environmental variation and correlation of winter wheat yield and quality traits in German official variety trials and on-farm during 1983–2014

Friedrich Laidig[1] · Hans-Peter Piepho[2] · Dirk Rentel[1] · Tho...
Uwe Meyer[1] · Alexandra Huesken[3]

Received: 30 May 2016 / Accepted: 8 October 2016 / Published online: 27 ...
© The Author(s) 2016. This article is published with open access at Spring...

Abstract

Theoretical and Applied Genetics (2021) 134:1613–1623
https://doi.org/10.1007/s00122-020-03729-3

REVIEW

Crop adaptation to climate change as a consequence of long-term breeding

Rod J. Snowdon[1] · Benjamin Wittkop ...

Received: 19 August 2020 / Accepted: 11 Novembe...
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Abstract
Major global crops in high-yielding, tem...

Contents lists available at ScienceDirect

Field Crops Research

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

ELSEVIER

Genetic improvement in density and nitrogen str... over 38 years of commercial maize hybrid release...

Keru Chen[a,*], James J. Camberato[a], Mitchell R. Tuinstra[a], Sarath...
Matthijs Tollenaar[b], Tony J. Vyn[a,*]

[a] Agronomy Department, Purdue University, West Lafayette, IN, 47907, USA, USA
[b] AgMaize Modeling Project, The Climate Corporation, Research Triangle Park, Raleigh-Durham, NC, 27709, US...

ARTICLE INFO

Article history:
Received 2 April 2016

ABSTRACT

Research attention to improving source and s...

nature plants

ARTICLES

https://doi.org/10.1038/s41477-019-0445-5

Breeding improves wheat productivity under contrasting agrochemical input levels

Kai P. Voss-Fels[1,2,11], Andreas Stahl[1,11], Benjamin Wittkop[1,11], Carolin Lichthardt[3], Sabrina Nagler[4], Till Rose[4], Tsu-Wei Chen[3], Holger Zetzsche[5], Sylvia Seddig[6], Mirza Majid Baig[7], Agim Ballvora[7], Matthias Frisch[8], Elizabeth Ross[2], Ben J. Hayes[2], Matthew J. Hayden[9], Frank Ordon[5], Jens Leon[7,10], Henning Kage[4], Wolfgang Friedt[1*], Hartmut Stützel[3*] and Rod J. Snowdon[1*]

Evaluation in multi-location field trials



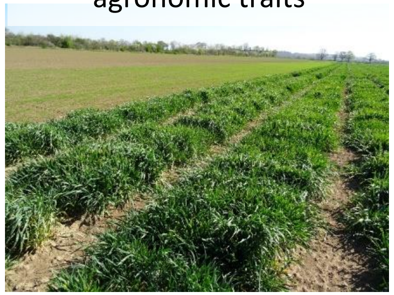

European Cooperative Programme for Plant Genetic Resources

Trials with up to 200 wheat genotypes annually at up to 30 locations across europe

EVA
European Evaluation Network

multiplication

First selection by testing agronomic traits




Start of the evaluation with Winter types 2020/2021

Standardized evaluation methods and documentation

Rhynchosporium secalis _ SB

spring barley

Rhynchosporium Blattflecken
scald

Testdesign: micro plots

The screening for resistance is achieved by field experiments in micro plots or hill plots without replications. For the common diseases standard comparators are included. Inoculation, data collection and data processing are carried out as described below

Inoculation: **inoculation stage:**

standard method natural infection

alternative

At EC-stage 37 – 39 a suspension of conidia (4.000 to 6.000 conidia/ml) with detergent (0,05% Tween 20) is applied to the plants, which are then protected overnight (10 to 12 h) with a plastic sheet to maintain optimal infection conditions (100 % rH).

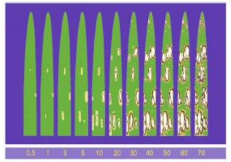
Rating

rating date: At heading (BBCH 37) Repeated estimations of infested leaf area are carried out weekly over the complete disease period. Three estimations at weekly intervals might be the minimum

rating trait

1. Symptom expression as percentage of infected leaf area

alternatively: Symptom expression as score



additional traits:

2. Date
3. Developmental Stage (average/plot – min and max)

Standards:

resistant: **Westminster**

susceptible: **Lenka**

Puccinia hordei-WB

Puccinia hordei - leaf rust

winter barley

Testdesign: micro plots

The screening for resistance is achieved by field experiments in micro plots or hill plots without replications. For the common diseases standard comparators are included. Inoculation, data collection and data processing are carried out as described below.

Inoculation: Natural occurence

artificially:

A suspension of spores in oil (Isopar M from Solitrol) is sprayed with a micro sprayer over the spreader rows (80-100 mg spores in 30 ml oil for 100m) on a cloudy day and high atmospheric humidity at beginning of May (BBCH 29-30)at temperatures from 10° to 15°C. The plant leaves need to be dry.

inoculation stage: BBCH 25-29

Rating

rating date: BBCH 51-55

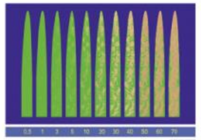
parameter to assess :

1. Symptom expression as percentage of infected leaf area

alternatively: Symptom expression as score

additional traits:

2. Date
3. Developmental stage average/plot - min - max

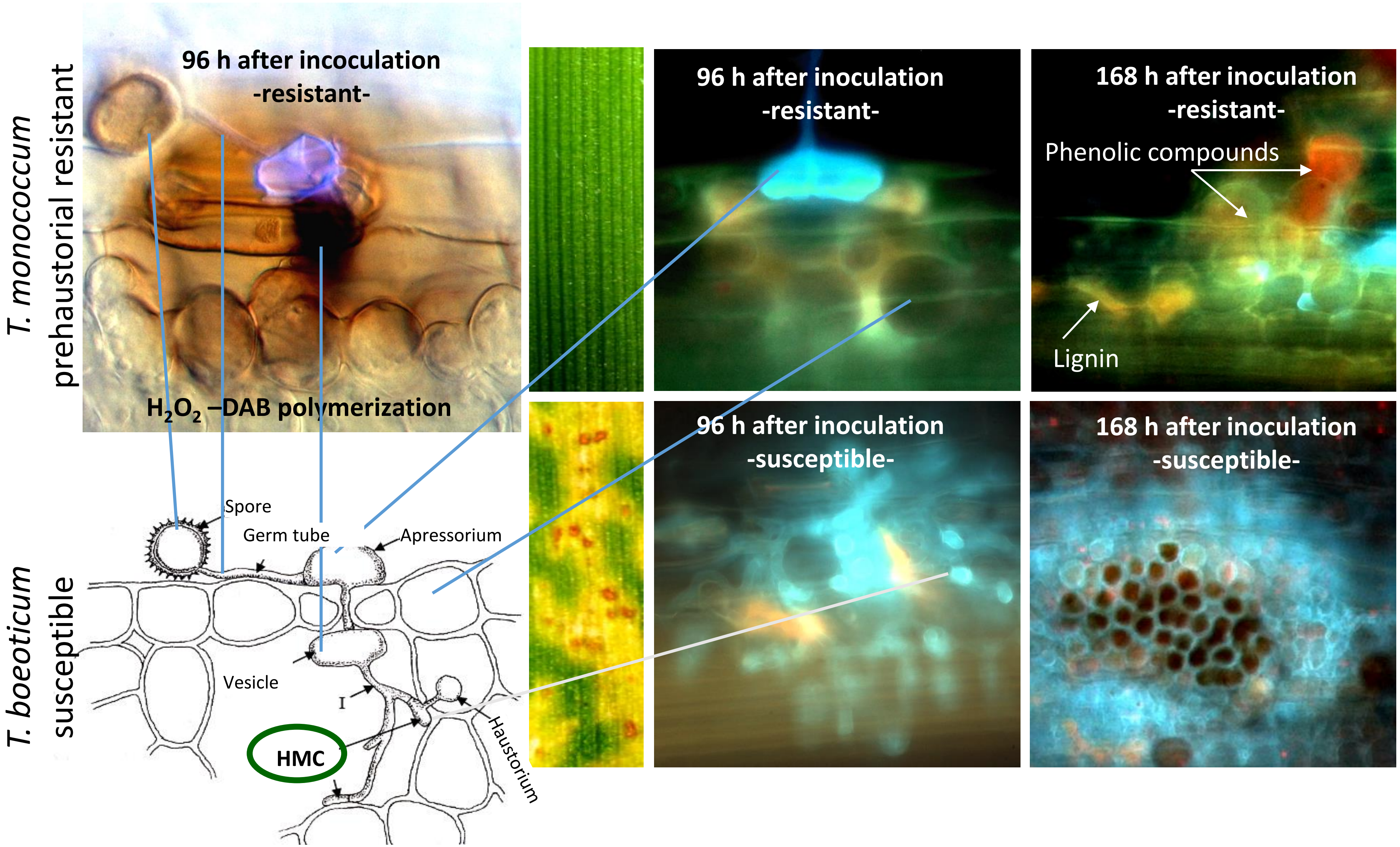


resistant standard variety: **Merlot**

susceptible standard variety: **Candesse**

Characterization of resistance mechanisms in genetic resources of wheat

Albrecht Serfling and Team



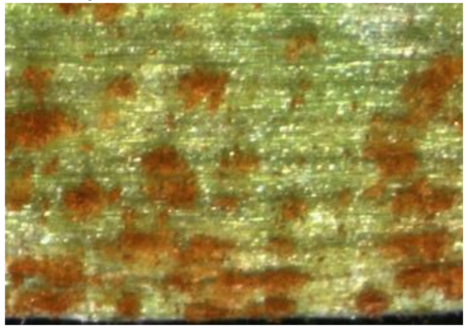
Evaluation of the efficacy of resistance genes by near-isogenic lines

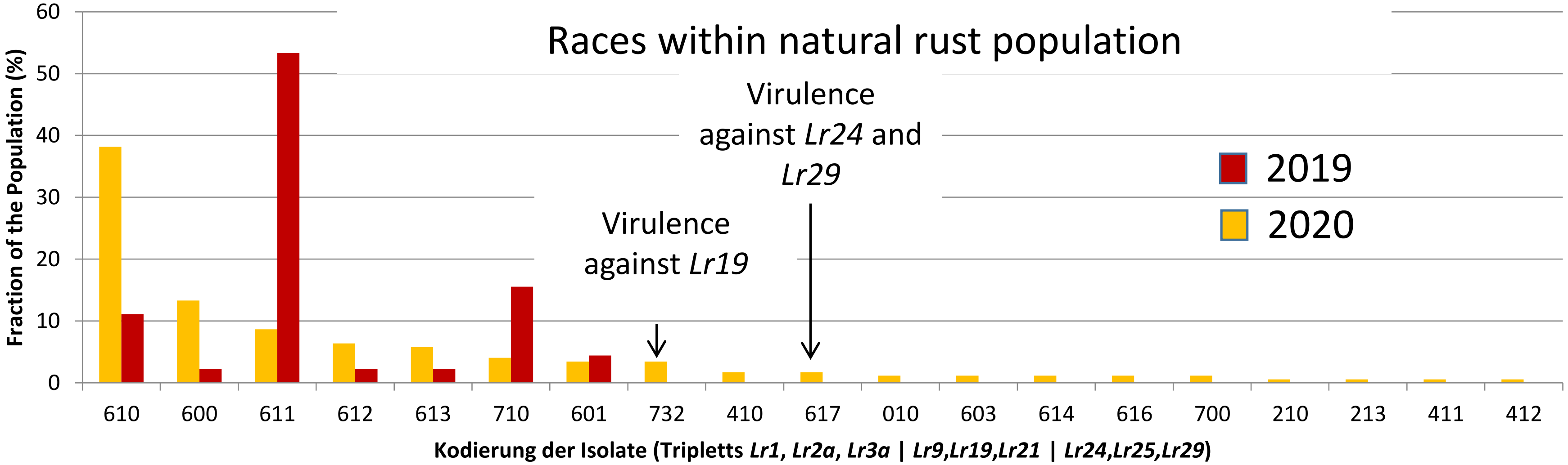
Albrecht Serfling and Team

Occurance on different locations

Obtaining single spore isolates

Multiplication & Maintainance





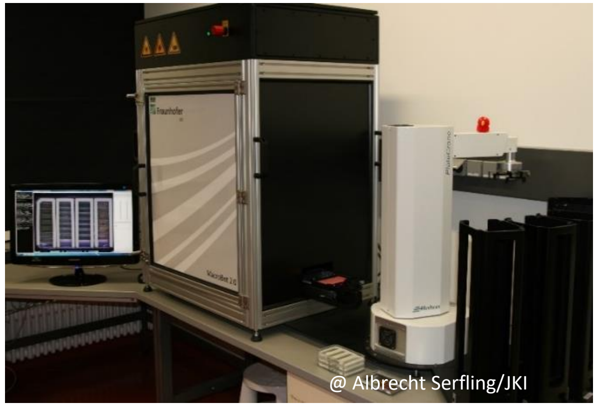
Use of breeds with previously unknown virulences.

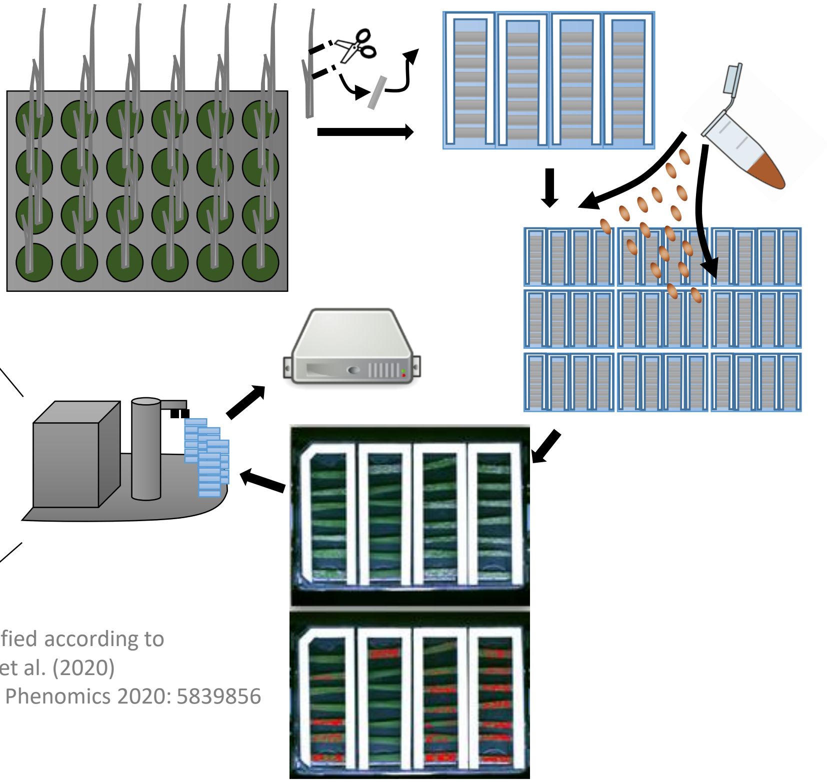
Aggressive breeds (strong sporulation, symptom expression, leaf damage)

➔ How effective is resistance to such races?

Digital phenotyping of stripe and leaf rust infection

Semi-automated phenotyping as a high-throughput method, allows larger sample numbers, increased accuracy, and more replicates to be collected in a short time.



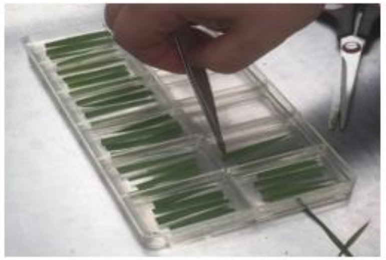


Modified according to
Lück et al. (2020)
Plant Phenomics 2020: 5839856

In the "GeneBank2.0" project approximately 9,700 winter wheat and 9,500 spring wheat accessions of the IPK genebank are screened using detached leaf assays for effective sources of resistance to stripe and leaf rust.

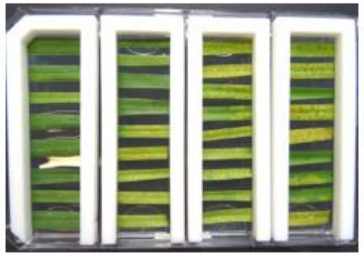
JKI
Ulrike Beukert
Anne-Kathrin Pfrieme
Albrecht Serfling
IPK LEIBNIZ-INSTITUT
Jochen Reif
Albert Schulthess
PLANT 2030
Bundesministerium
für Bildung
und Forschung

Digital phenotyping of stripe and leaf rust infection

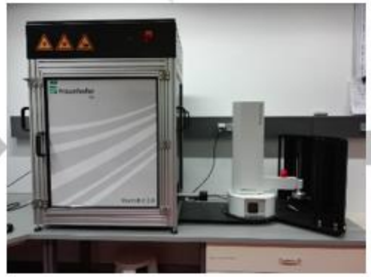


@ Albrecht Serfling/JKI

Leaf segment tests with repeats and control genotypes.
96 plates are processed per rotation.

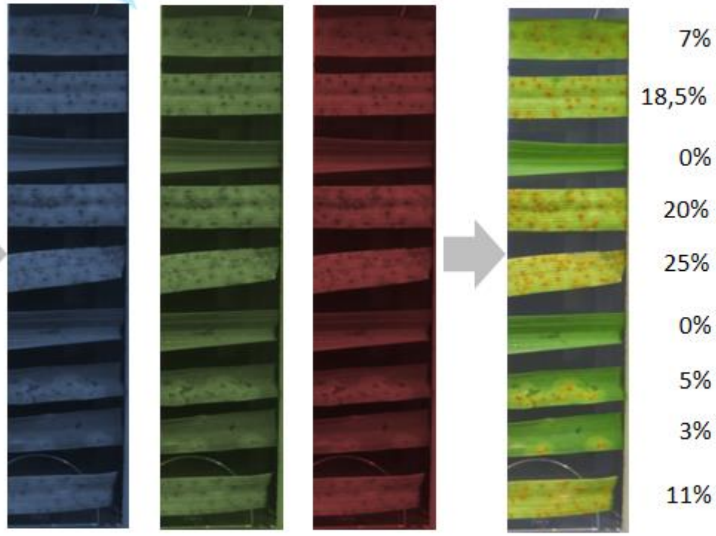


Macrobot transports plates from stack to image box.
Identification of the plates by means of barcode scanner.



Images of different light conditions (green, blue, red, UV) are captured and stored.

Merging of images and analysis of quantitative infestation by special evaluation software.



Ulrike Beukert
Anne-Kathrin Pfrieme
Albrecht Serfling

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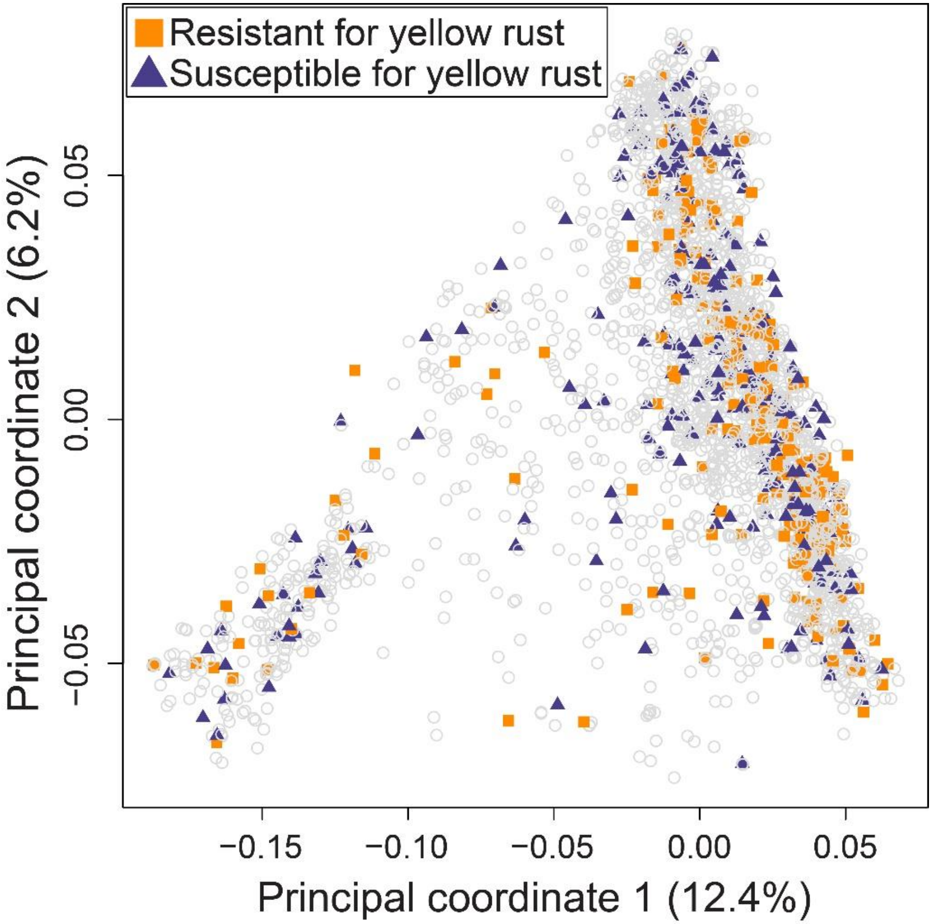
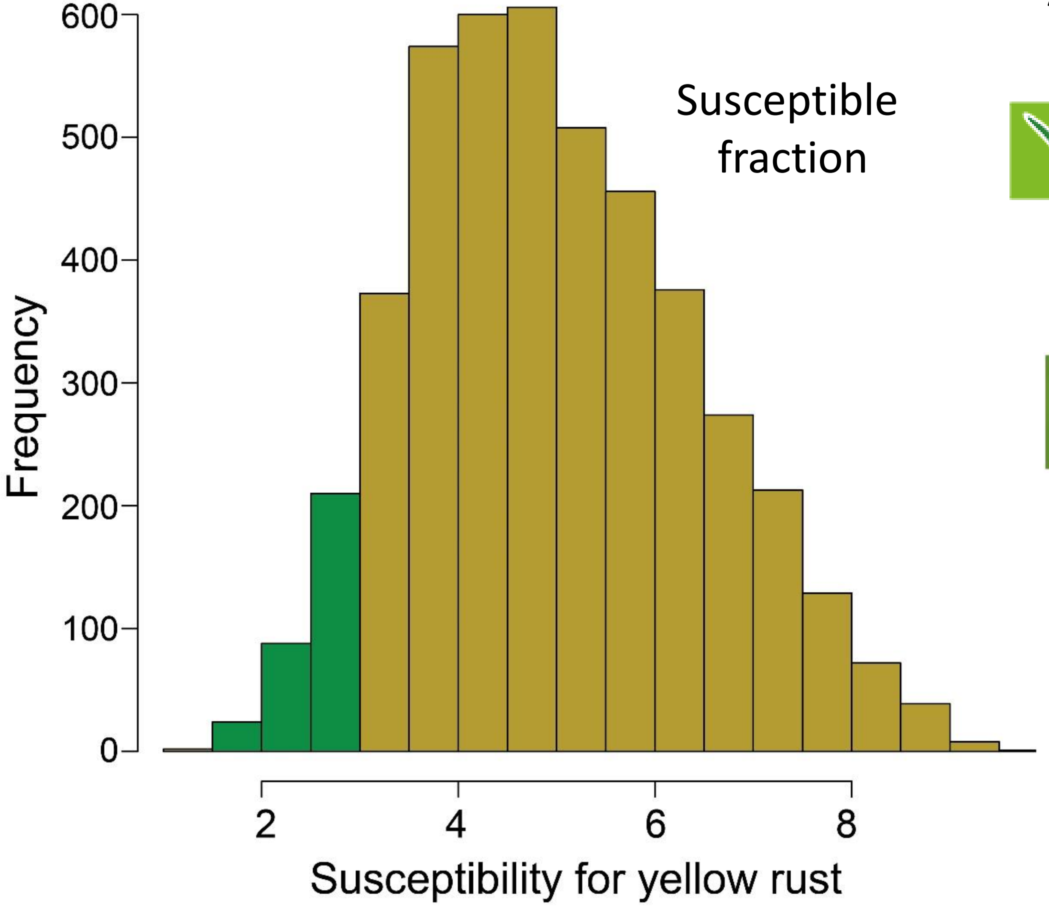
Digital phenotyping enables screening of very large genotype collections





Ulrike Beukert
Anne-Kathrin Pfrieme
Albrecht Serfling

Jochen Reif
Albert Schulthess

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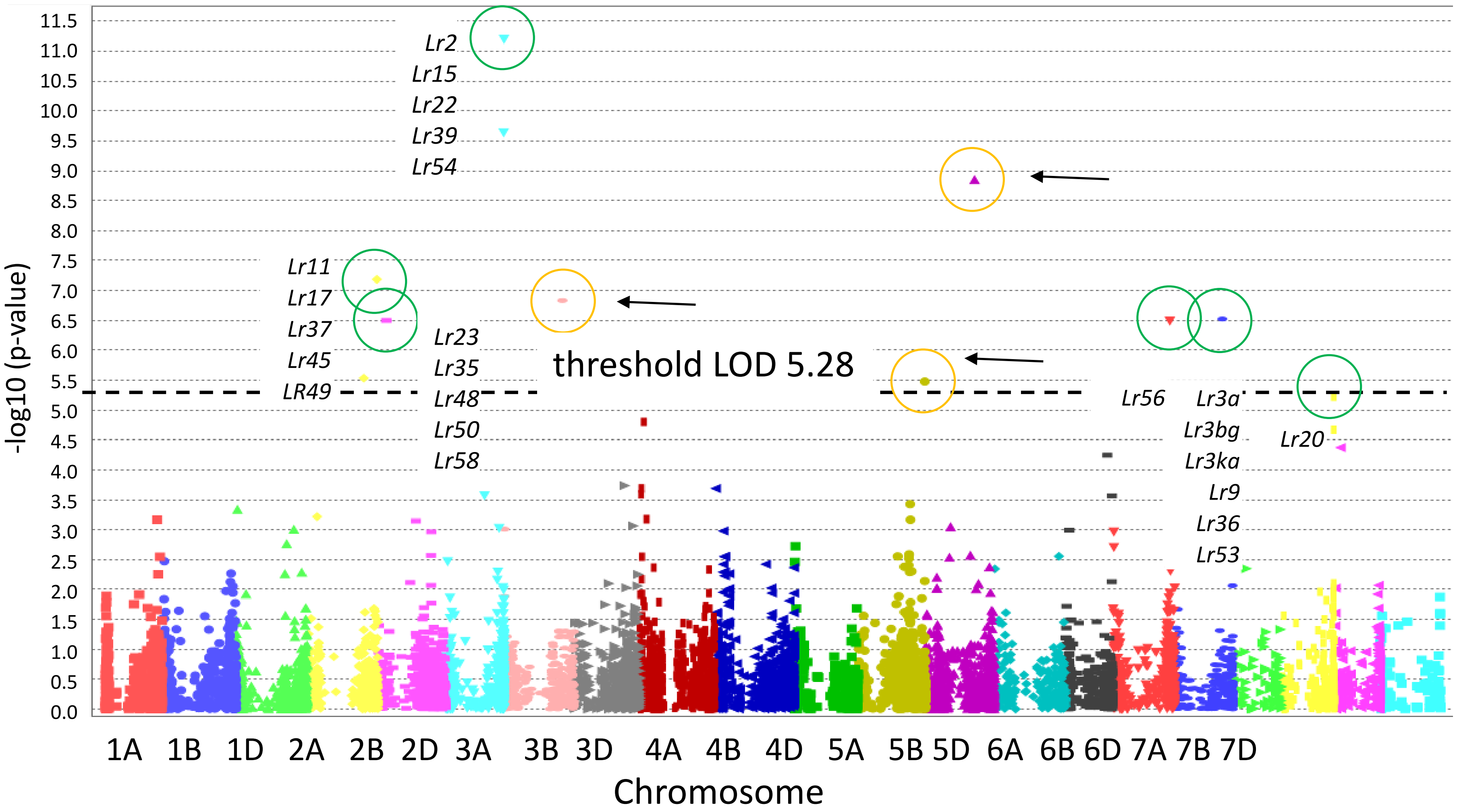
Identification of unknown resistance loci

GWAS of more than 1000 wheat genetic resources from the ECPGR evaluation program



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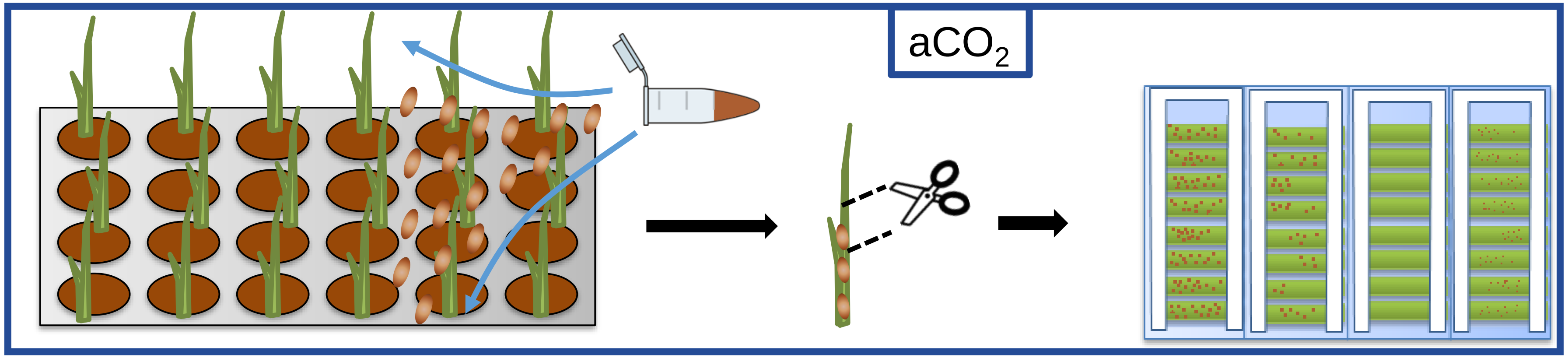
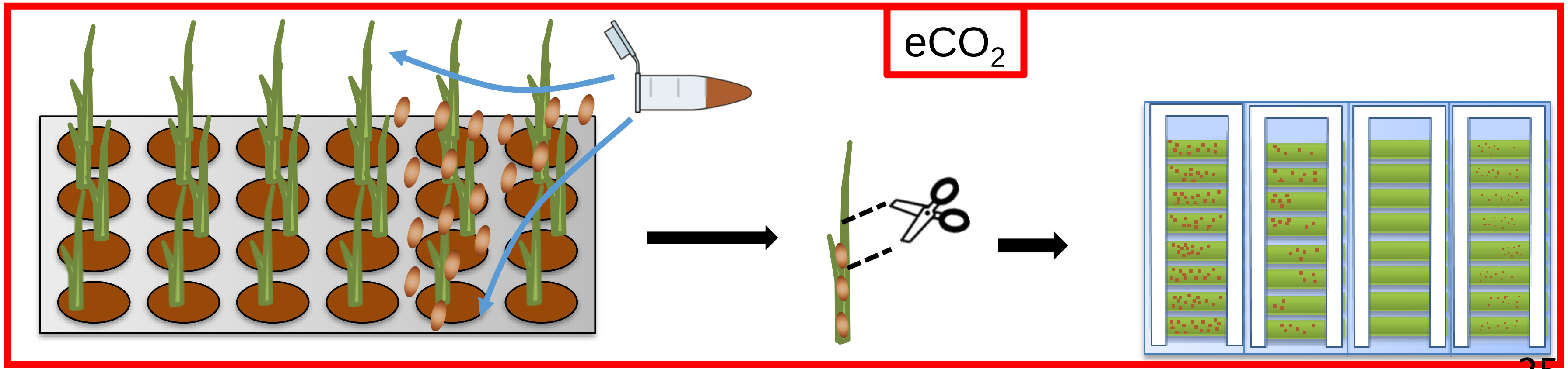
Quantification of the effect of elevated CO_2 on rust resistance

Jasper Krößmann
Albrecht Serfling



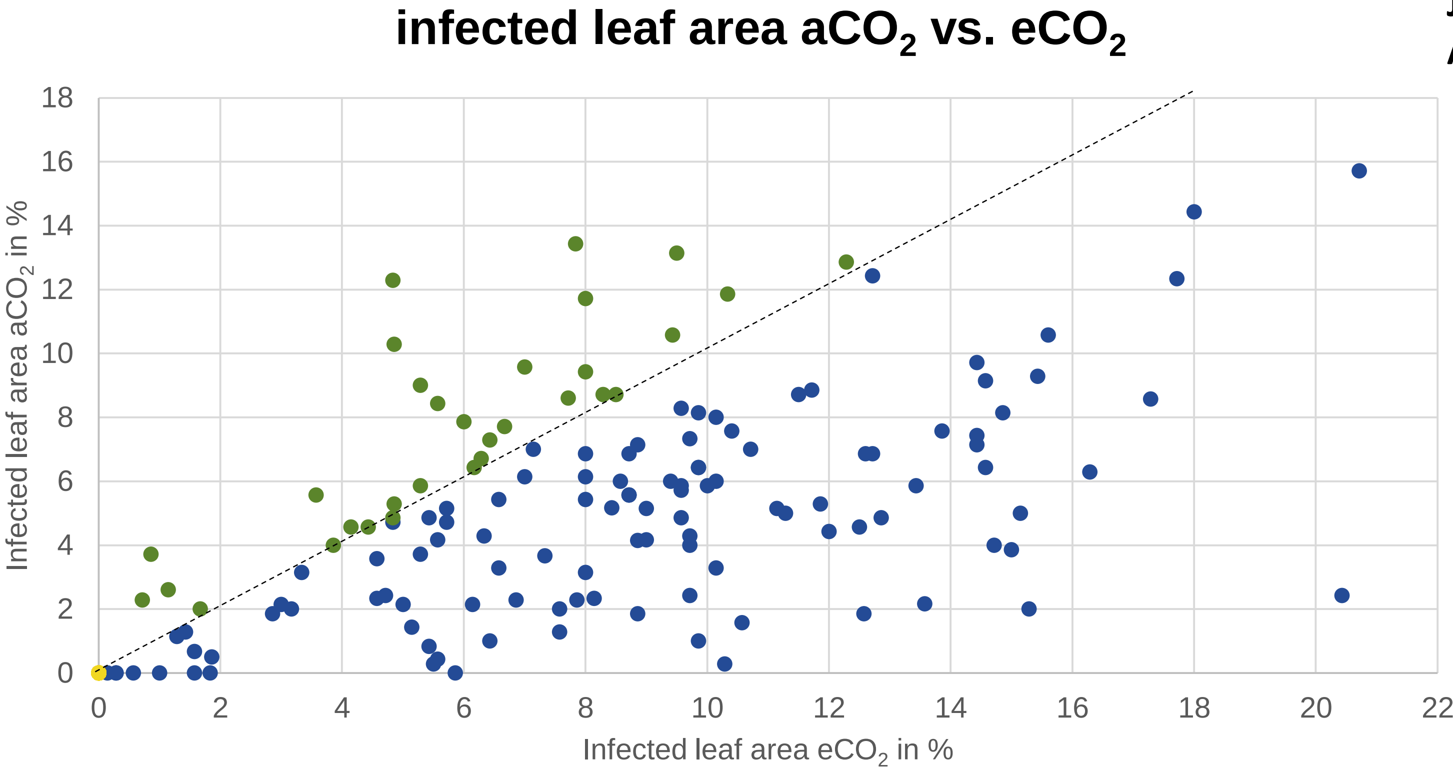
inoculation of the plants with leaf rust by air-blowing of uredospores

cutting and transferring of leaf segments to a standard 4-wells micotiter plate



Quantification of the effect of elevated CO_2 on rust resistance

Jasper Krößmann
Albrecht Serfling



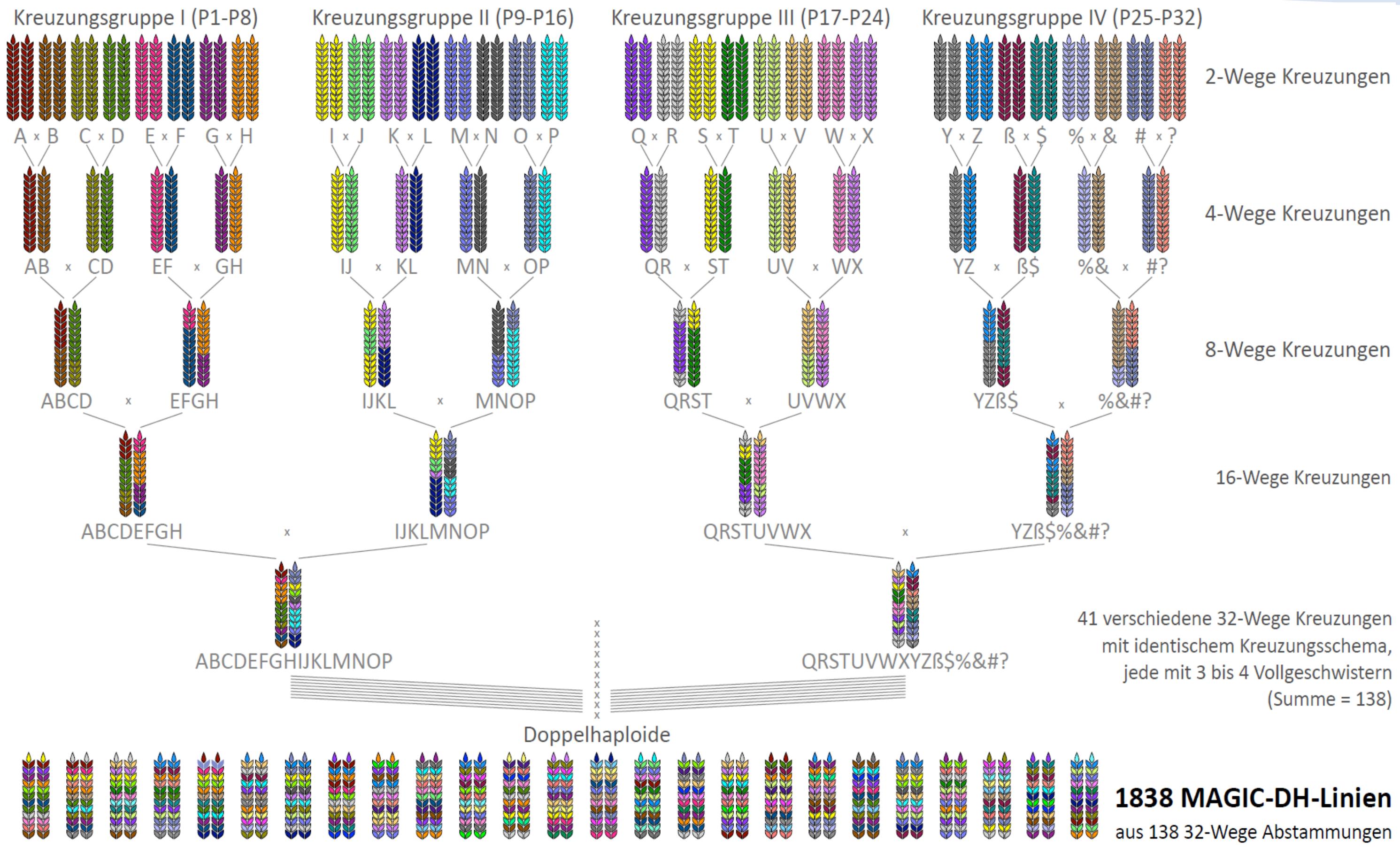
109 varieties ● (50.9%) showed an increased susceptibility under eCO_2
74 varieties ● (36.6%) showed no susceptibility under both CO_2 conditions
31 varieties ● (14.4%) showed a higher susceptibility under aCO_2

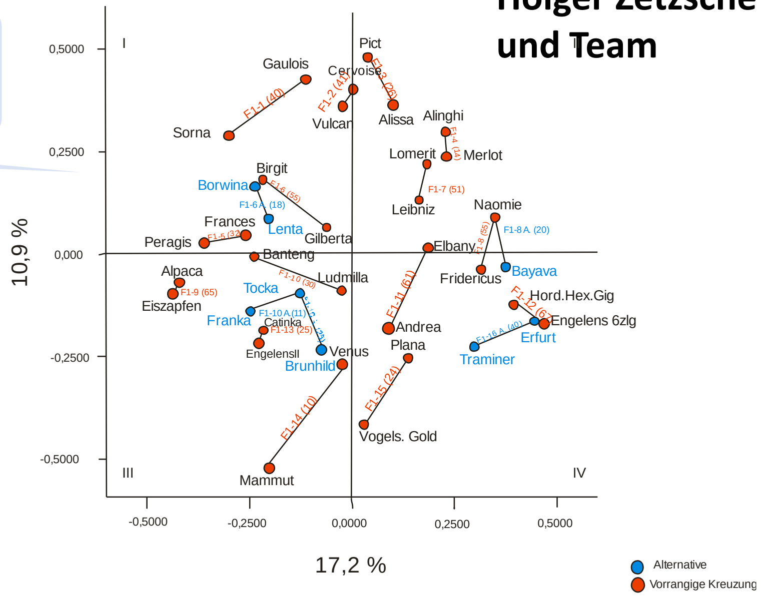
Utilization of genetic diversity:
32-parent winter barley MAGIC population

Multiparent **a**dvanced **g**eneration **i**ntercross (MAGIC)

Holger Zetzsche und Team

32 parents with significant differences in leaf rust, powdery mildew net blotch etc.
Breeding history and genetic diversity of barley in central Europe (1933-2007)





ca. 1200 Parzellen am Trockenstressstandort der JLU in Groß Gerau

Research to increase smut and bunt Resistance in wheat and barley

GFPi

BÖL
BUNDESPROGRAMM
ÖKOLOGISCHER LANDBAU

JKI

Claire Ferreira
Albrecht Serfling

Aim: Identification of previously not used sources of resistance from genetic resources. To this end, >800 accessions from the IPK gene bank are inoculated and tested

Source: Claire Ferreira & Danny Denks

Source: Danny Denks

Dottenfelderhof

UNIKASSEL VERSITÄT

IPK LEIBNIZ-INSTITUT

BREUN SAATZUCHT

KWS

ECKENDORFER SORTEN

Nordic Seed

Use of digital phenotyping…

….in disease resistance research

Source: Albrecht Serfling

Source: Albrecht Serfling

Source: Andreas Stahl

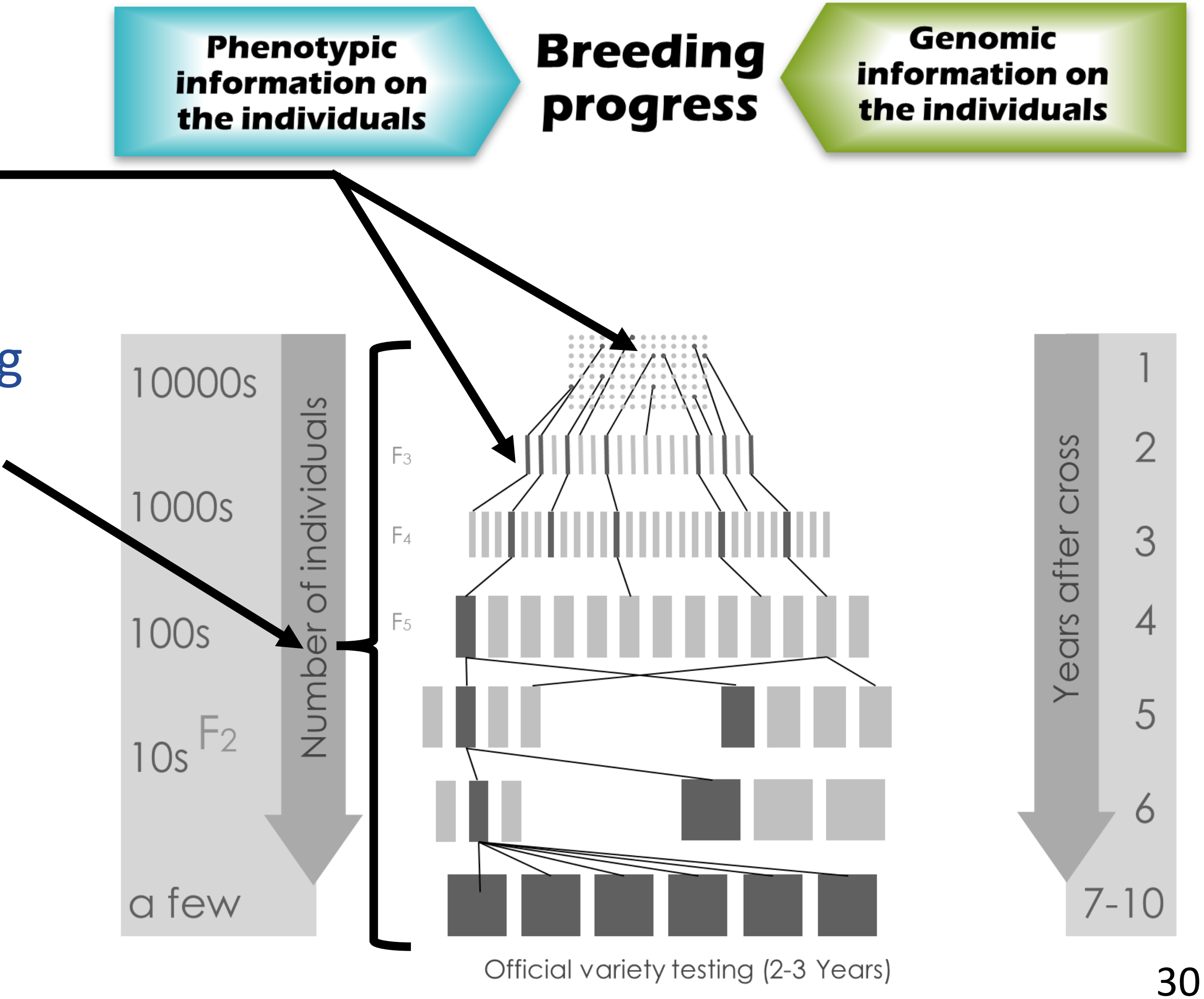
Breeding is a long-term process

Digital methods can speed it up!

Digital phenotyping…

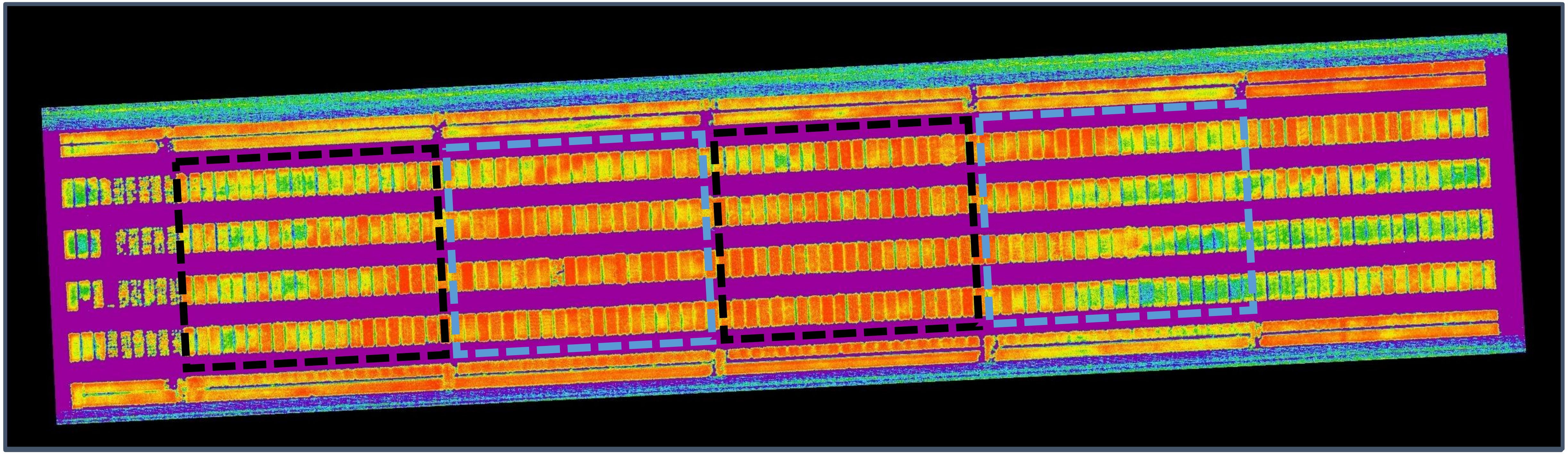
1) … for disease resistance research

2) … in non-destructive field phenotyping



Field Overview with RGB and Vegetation Indexes

Heike Lehnert
Sebastian Warnemünde



Repetition 1
drill sowing

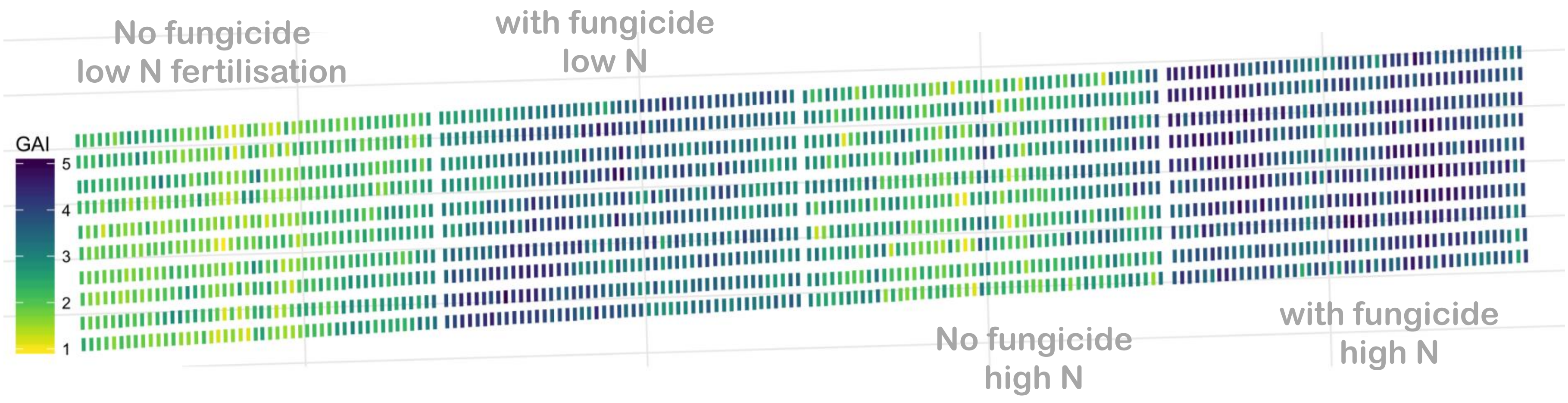
Repetition 1
equal sowing

Repetition 2
drill sowing

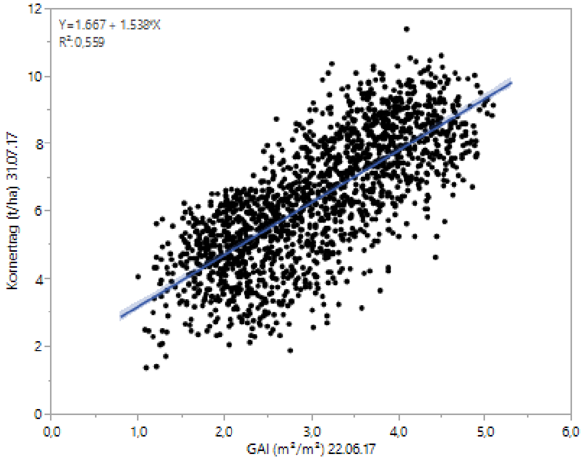
Repetition 2
equal sowing

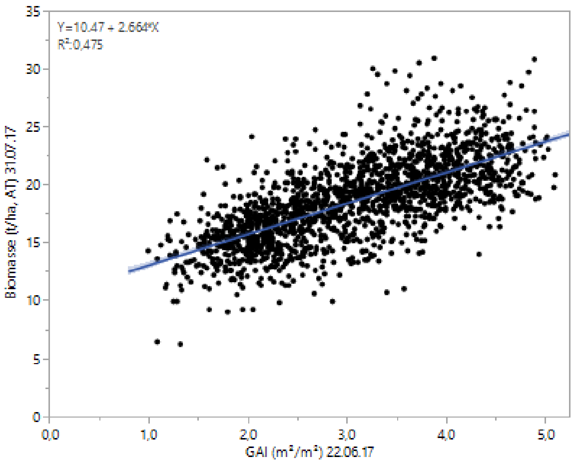
GenRes QLB 07.06.2023, MicaSense Dualcam, GSD: 2 cm/pix

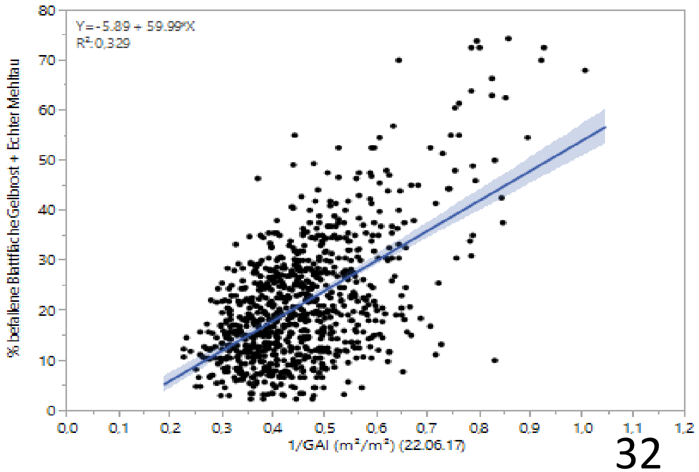
Digital field phenotyping

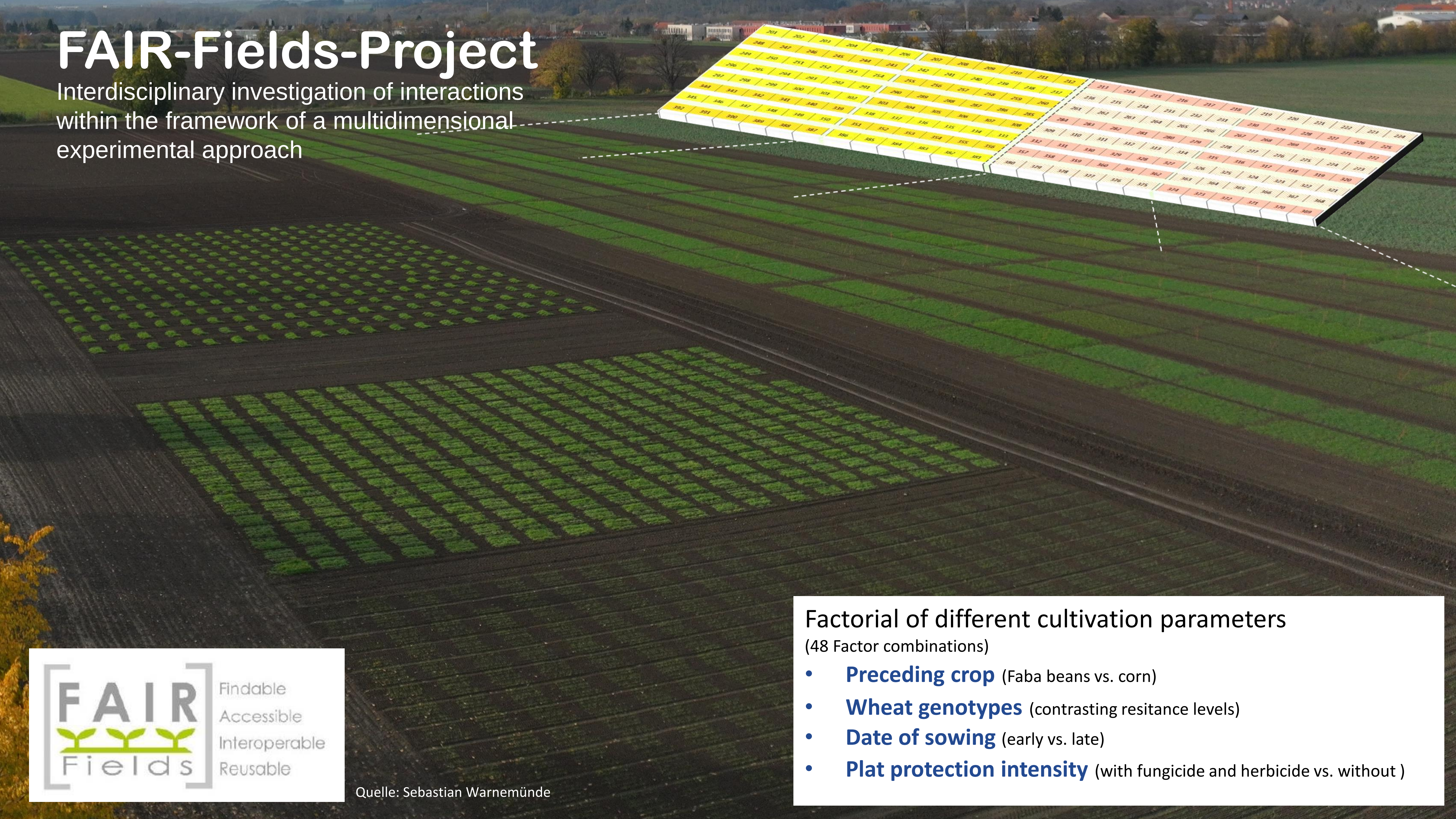


- Recording of different wavelengths after heading
- Calculation GAI (T. Rose, Uni Kiel)
- Correlation of plot mean values
- with yield, biomass and yellow rust+mildew.









FAIR-Fields-Project

Interdisciplinary investigation of interactions within the framework of a multidimensional experimental approach

FAIR Fields

Findable
Accessible
Interoperable
Reusable

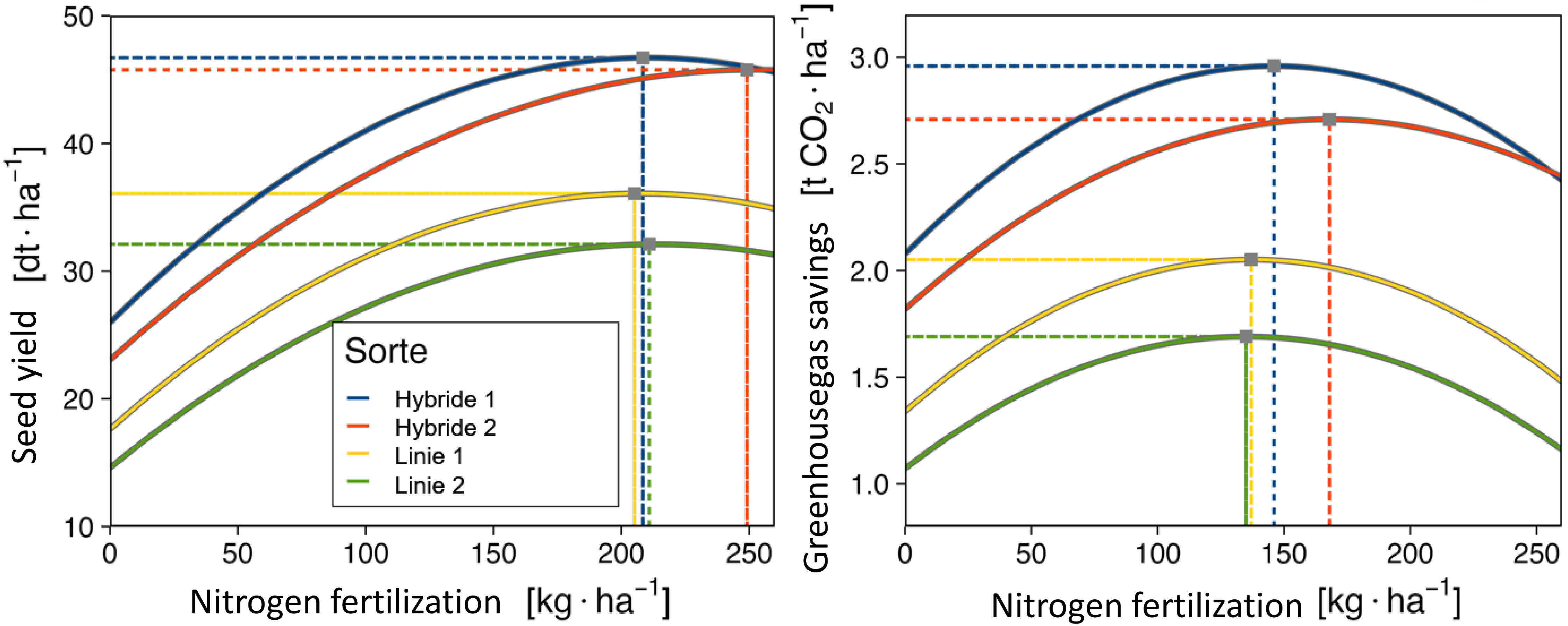
Quelle: Sebastian Warnemünde

Factorial of different cultivation parameters

(48 Factor combinations)

- **Preceding crop** (Faba beans vs. corn)
- **Wheat genotypes** (contrasting resitance levels)
- **Date of sowing** (early vs. late)
- **Plat protection intensity** (with fungicide and herbicide vs. without)

Yield response to nitrogen fertilization
(here winter oilseed rape)



Data from: Till Rose, Klaus Sieling und Henning Kage

Breeding driven enhancement of NUE

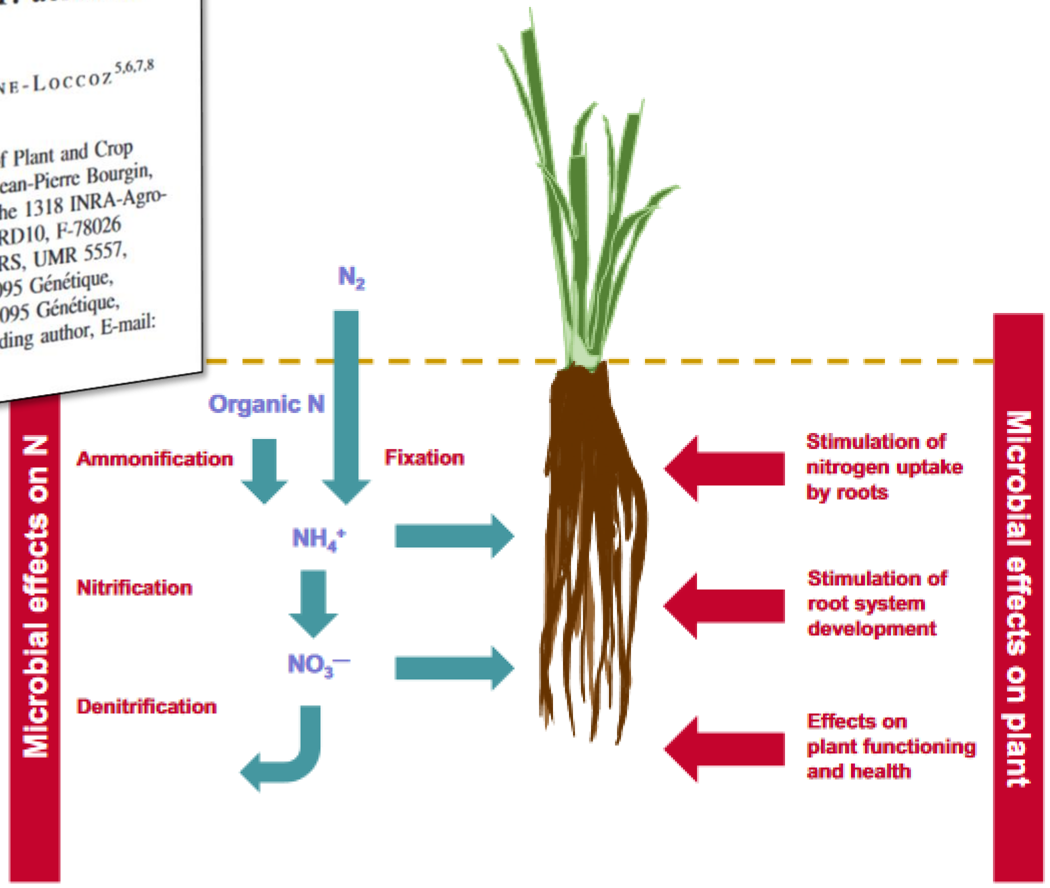
doi:10.1111/pbr.12371
Plant Breeding, 135, 255–278 (2016)

Review

Breeding for increased nitrogen-use efficiency: a review for wheat (*T. aestivum* L.)

Fabien Cormier[1], John Foulkes[2], Bertrand Hirel[3], David Gouache[4], Yvan Moënne-Loccoz[5,6,7,8] and Jacques Le Gouis[7,8]

[1]Biogemma, Centre de Recherche de Chappes, Route d'Ennezat CS90126, 63720 Chappes, France; [2]Division of Plant and Crop Sciences, The University of Nottingham, Sutton Bonington Campus, Loughborough LE12 5RD, UK; [3]Institut Jean-Pierre Bourgin, Institut National de la Recherche Agronomique (INRA), Centre de Versailles-Grignon, Unité Mixte de Recherche 1318 INRA-Agro-ParisTech, Equipe de Recherce Labellisée (ERL), Centre National de la Recherche Scientifique (CNRS) 3559, RD10, F-78026 Versailles Cedex, France; [4]Arvalis Institut du Végétal, Station Expérimentale, 91720, Boigneville, France; [5]CNRS, UMR 5557, Ecologie Microbienne, 69622 Villeurbanne, France; [6]Université Lyon 1, 69003 Lyon, France; [7]INRA, UMR 1095 Génétique, Diversité et Ecophysiologie des Céréales, 5 Chemin de Beaulieu, F-63-039 Clermont-Ferrand, France; [8]UMR 1095 Génétique, Diversité et Ecophysiologie des Céréales, Université Blaise Pascal, F-63177 Aubière Cedex, France; Corresponding author, E-mail: jacques.legouis@clermont.inra.fr



Breeding driven enhancement of NUE

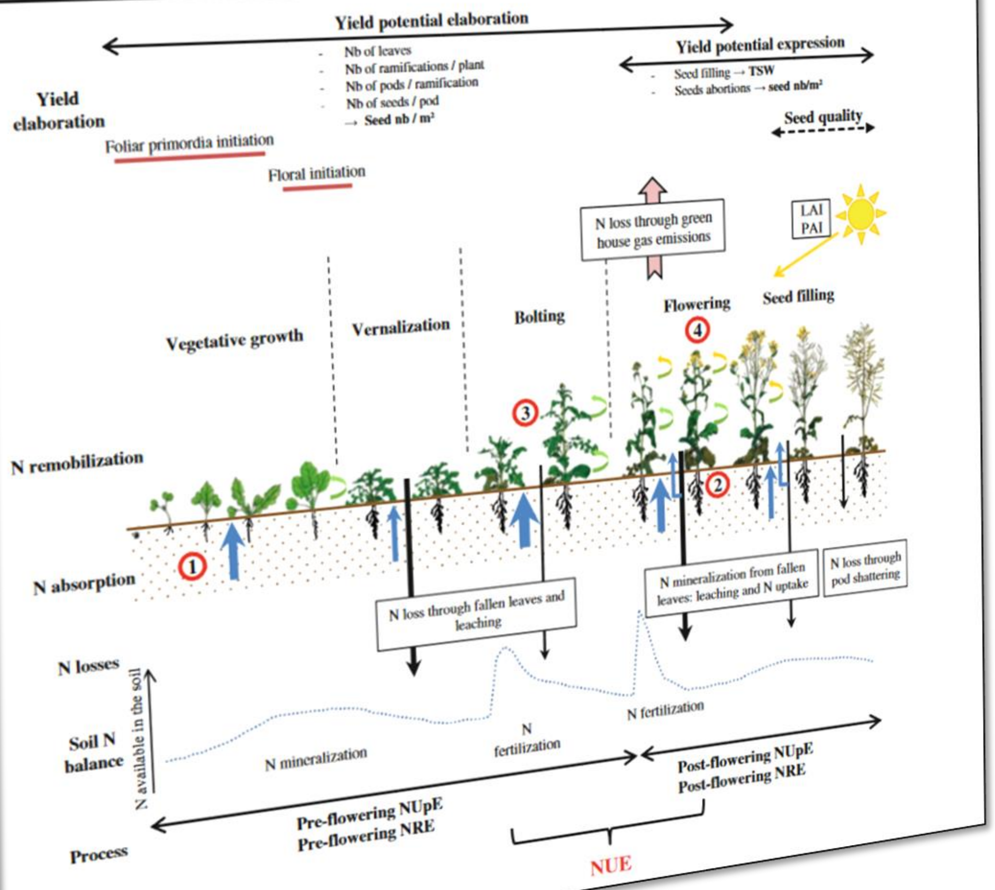
Agron. Sustain. Dev. (2016) 36: 38
DOI 10.1007/s13593-016-0371-0

REVIEW ARTICLE

Nitrogen use efficiency in rapeseed. A review

Anne-Sophie Bouchet[1] · Anne Laperche[2] · Christine Bissuel-Belaygue[2] · Rod Snowdon[3] · Nathalie Nesi[1] · Andreas Stahl[3]

Fig. 6 Comparison of root morphology at harvest between winter oilseed rape genotypes grown under semicontrolled conditions with low N input. Cultivar "Expert" showing few lateral roots (**a**). Cultivar "Groß Lüsewitzer" with intense lateral root network (**b**). Both pictures were taken on the day of seed harvest and represent the roots from nine container-grown plants grown with low N-fertilization levels (75 kg N ha⁻¹ as an equivalent) (A. Stahl and R. Snowdon, unpublished data)



Thinking beyond current systems

Priming as a new resistance strategy
Systemic resistance in cereals by bacteria

Dwarf rust
Puccinia hordei
in Berley

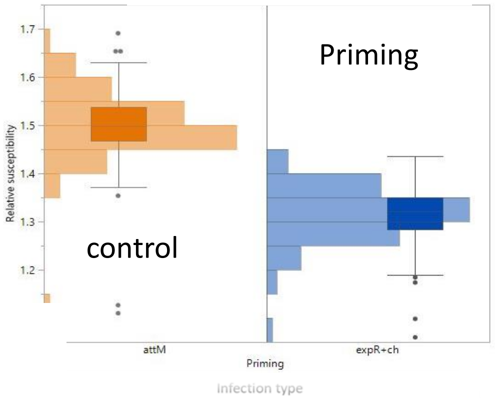
Net blotches
Pyrenophora teres
in Barley

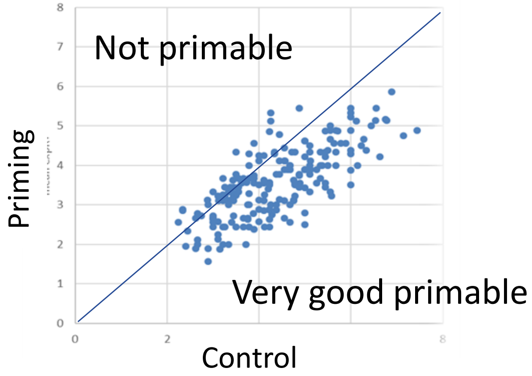
Brown rust
Puccinia
Triticinia
in Wheat

Priming of 200 genotypes with *Ensifer meliloti*

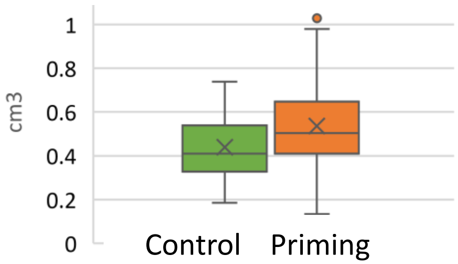
AHL induced systemic Resistance

Relative infection



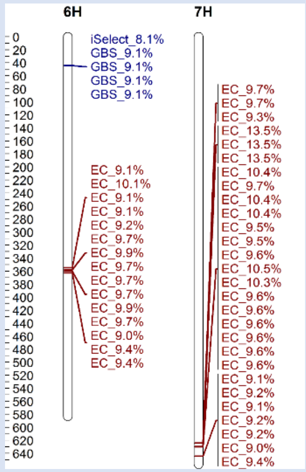


Root Biomass



Identifikation of molecular marker (GWAS)

Development of molceular marker for priming efficiency



Christiane Seiler
Behnaz Soleimani
Andrea Matros
Gwendolin Wehner

Primed Plant

JKI

Bundesministerium für Bildung und Forschung

Bundesministerium für Ernährung und Landwirtschaft

PLANT 2030

GFPi

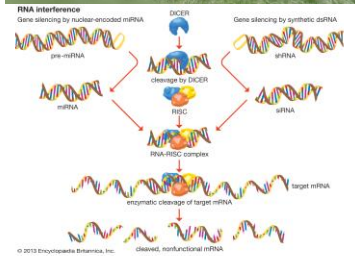
AHL = N-Acyl-Homoserin-Lacton

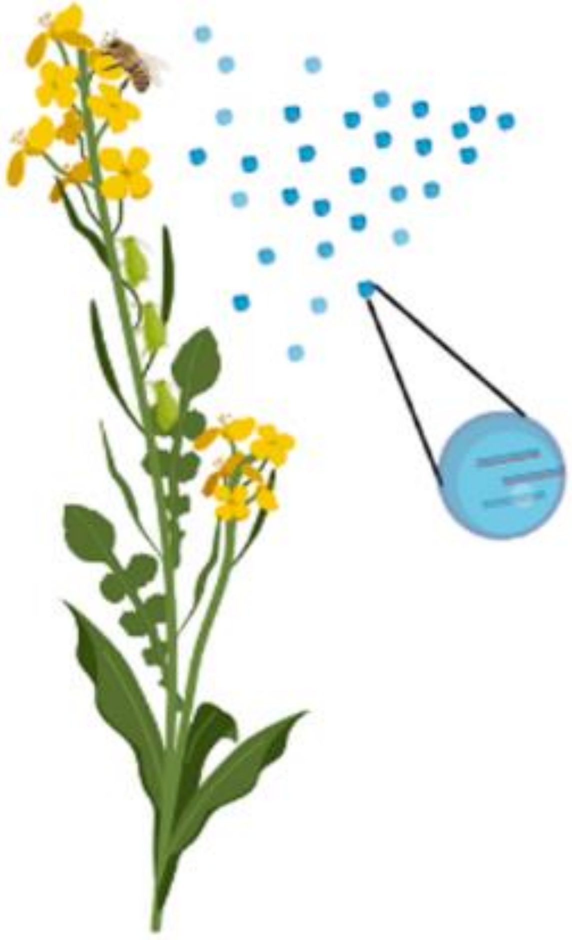
RNAi_safe

Torsten Will
JKI-A; JKI-BS; JKI-SB

SprayRNA (Spray induced gene silencing)
Promising & highly flexible approach for the control of insect pests and pathogens








Focus Group RNAi

Composition of the focus group from scientists of the JKI institutes with competence in the field of RNAi.
Expansion to include possible external scientists and BVL.

Investigation:

- Expression of the RNAi effect at different temperatures.possible routes of exposure of dsRNA and siRNA after spray application (e.g. via nectaries as well as a possible transmission along the food chain.)
- Bundling of expertise through formation of a "Focus Group RNAi",Networking within the JKI

Projects on minor crops
Accelerating Crop Genetic Gain

ACCELERATING CROP GENETIC GAIN
https://www.irtg2843.de/

JKI




Sorghum
Insect-friendly, multi-use cereal crop with excellent drought and heat tolerance *(but poor cold adaptation)*

Faba bean
Insect-pollinated, nitrogen-fixing pulse crop *(but poor yield stability due to low drought and heat tolerance)*

Winter lentil - new project for mixed crop cultivation

Christoph Germeier

Lentillon de Champagne, winterharte Champagnerlinse mit Winterhartweizen als Stützfrucht. ©Frauke Germer, JKI, 18.04.2024

Dornburger Speiselinse, alte Thüringer Sorte mit recht guter Winterhärte, mit Winterhartweizen als Stützfrucht. ©Christoph Germeier, JKI, 21.04.2024

Kafkas, türkische Winterlinsensorte, mit Winterhartweizen als Stützfrucht. ©Christoph Germeier, JKI, 21.04.2024

Blockanlage: 5 Wiederholungen, (z.T. ^{15}N-Anreicherung mit Guano in Streifen zur Bestimmung von N-Fixierung und Transfer über Isotopenmassenspektrometrie)

https://www.julius-kuehn.de/rs/n/projekt-wilger-will-linsenanbau-in-deutschland-wiederbeleben

Outlook & Summary

Phenotypic information on the individuals → **Breeding progress** ← **Genomic information on the individuals**

- Breeding contributes significantly to securing high yield potential and counteracts yield-limiting factors (temperature and drought stress, diseases, etc.).
- Breeding usually takes many years - but can be accelerated and fine-tuned.
- Therefore, digital tools help to better understand plant characteristics and physiological determinants.
- Together with genetic information, breeders can act faster than before and accelerate breeding progress.

Gefördert durch:

Bundesministerium für Ernährung und Landwirtschaft

Bundesministerium für Bildung und Forschung

aufgrund eines Beschlusses des Deutschen Bundestages

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

PLANT 2030

PtJ Projektträger Jülich Forschungszentrum Jülich

JKI

DAAD

C A U

INRES Institut für Nutzpflanzenwissenschaften und Ressourcenschutz

TÄT BONN

Leibniz Universität Hannover

FNR Fachagentur Nachwachsende Rohstoffe e.V.

ECKENDORFER SORTEN

GFPi

SAATZUCHTGESELLSCHAFT M.B.H. NORDSAAT

IPK GATERSLEBEN

DSV

SU BIOTEC

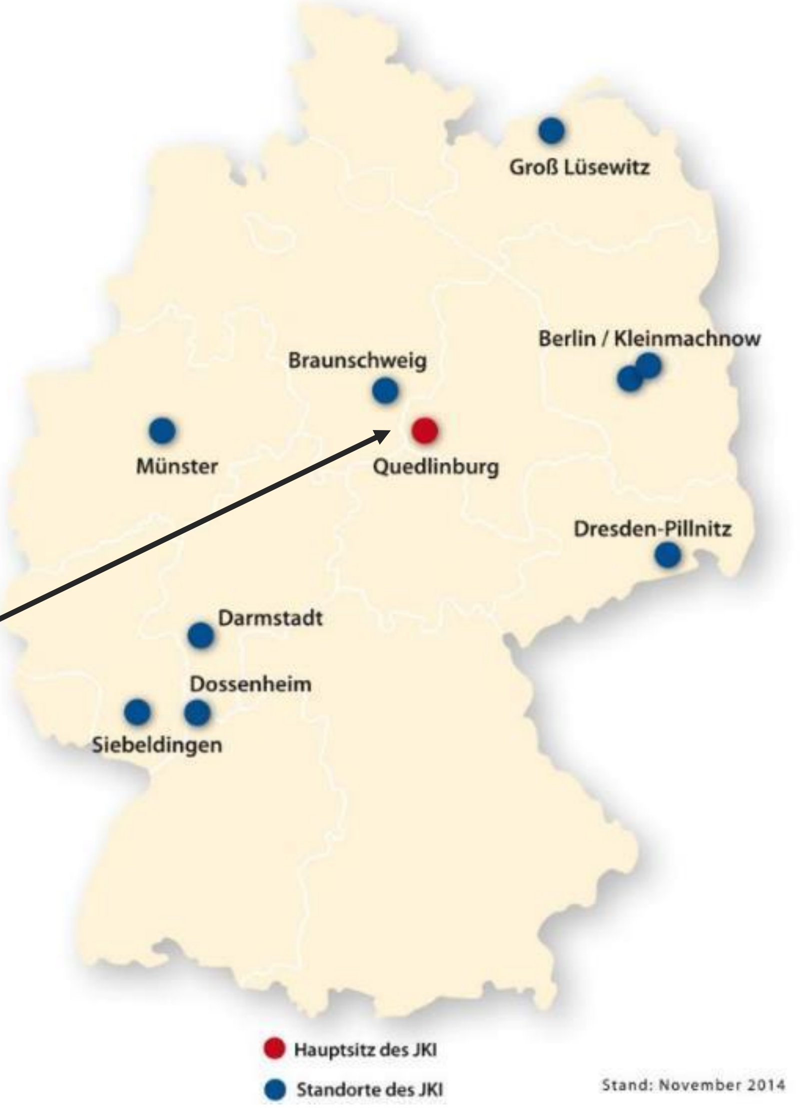
All members of the Institute RS

... and all cooperation partners

Research at Julius Kühn-Institute

Resistance research
viruses, fungi, insects a. bacteria


Stress tolerance
heat, frost, drought a. nutrient deficiency


Merci beaucoup pour
votre attention