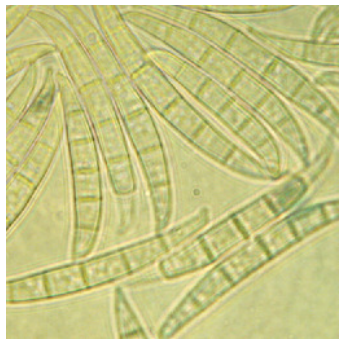
Current Knowledge on the Genetics of Fusarium Head Blight Resistance in Wheat - Implications for Resistance Breeding

Hermann Buerstmayr, Barbara Steiner, Marc Lemmens

BOKU-University of Natural Resources and Life Sciences Vienna, Department IFA-Tulln, Institute for Biotechnology in Plant Production, Konrad Lorenz Str. 20, A-.3430 Tulln, Austria,

Overview

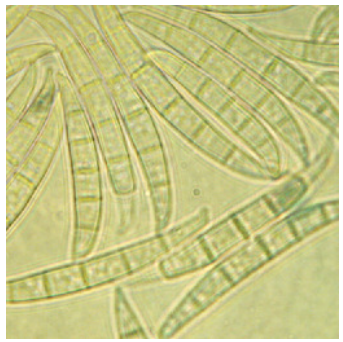
Introduction



Current knowledge about FHB-resistance QTL:
Two QTL meta analysis and one QTL review

A few recent projects at IFA-Tulln

Summary and conclusions

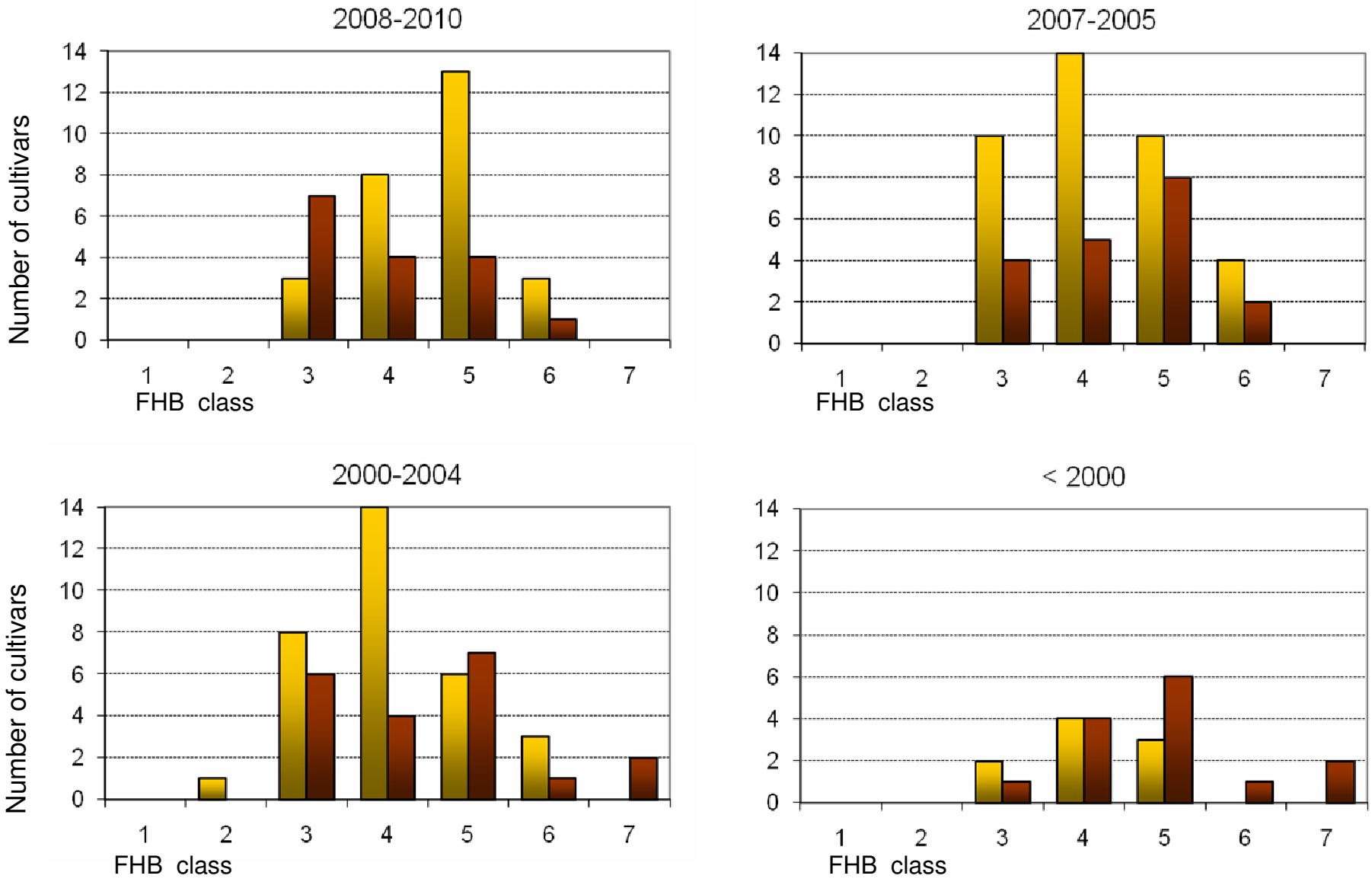


Some (still ?) interesting plant breeding questions

- Which level of FHB resistance is currently available/should a cultivar have?
- Are the moderately effective resistance genes in the native gene pool sufficient?
- Association of FHB resistance with other traits: plant height, flower morphology?
- Which selection tools are available/useful?

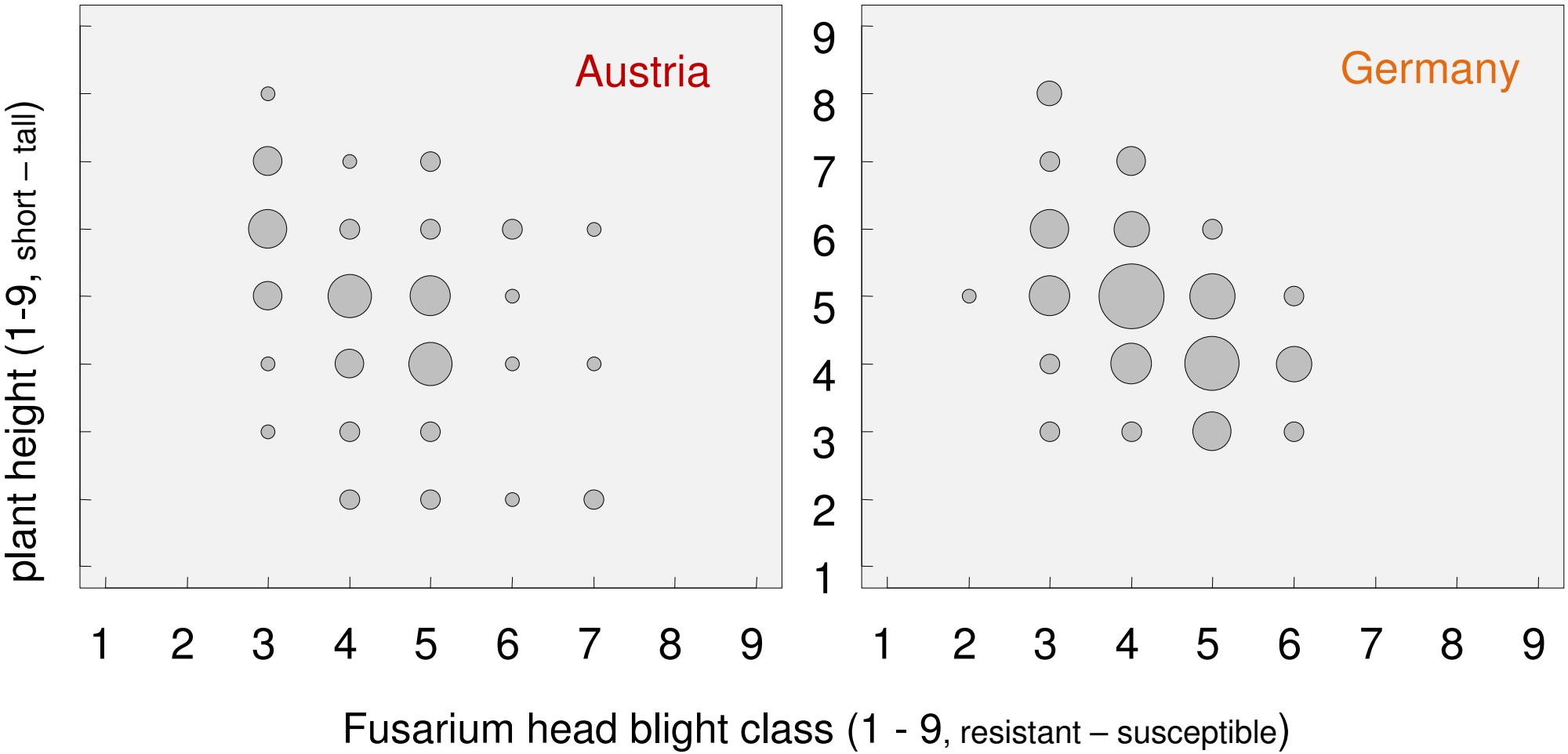
Currently registered winter wheat cultivars in Austria and Germany

Fusarium head blight rating (1-9) of WW cultivars released during four periods in DE, AT

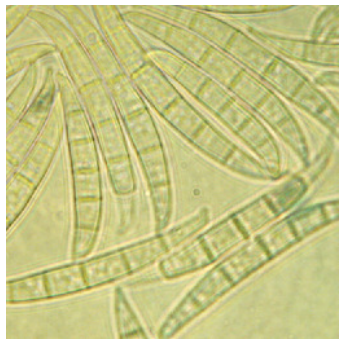


Datasource: Lists of registered cultivars, DE, AT

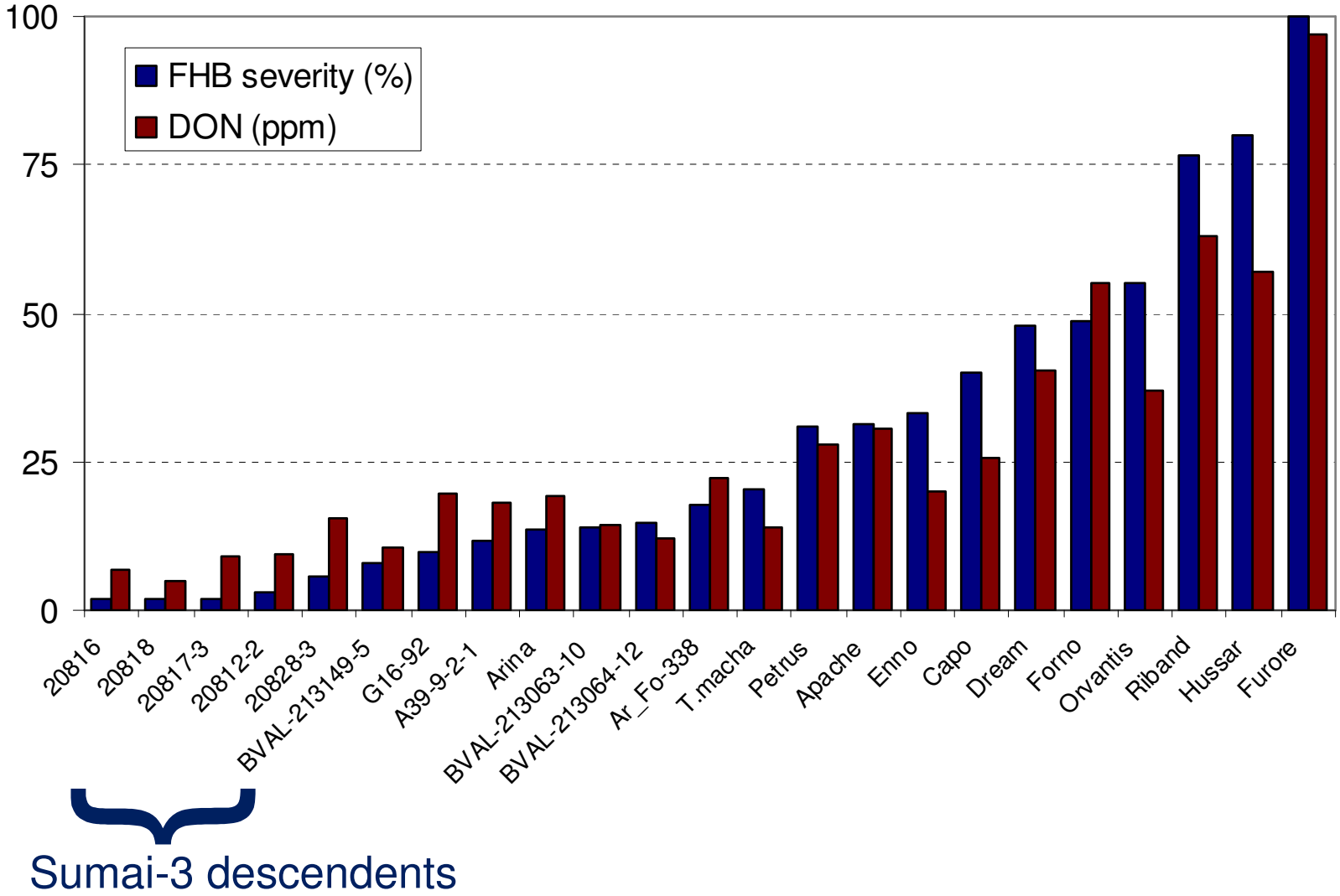
FHB rating *vs.* plant height of registered cultivars in Austria and Germany



Datasource: Lists of registered cultivars, DE, AT



Fusarium resistance level in cultivars compared to the most resistant experimental lines



Options for selection

Phenotypic Selection

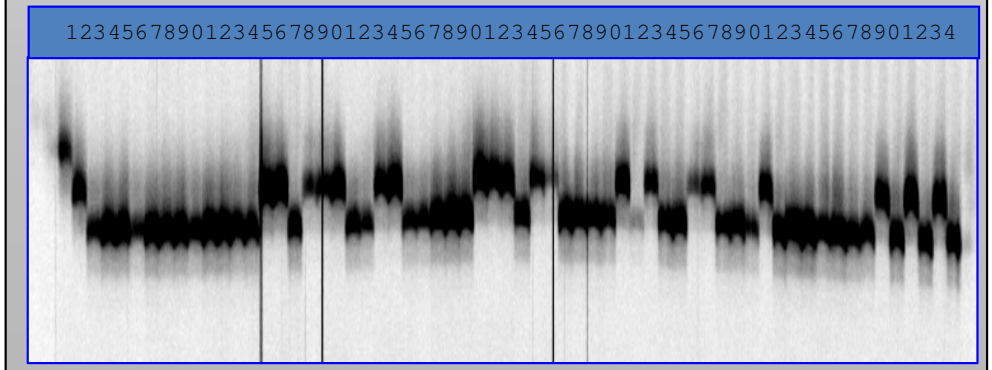
Selection on the plants for e.g. low disease symptoms.

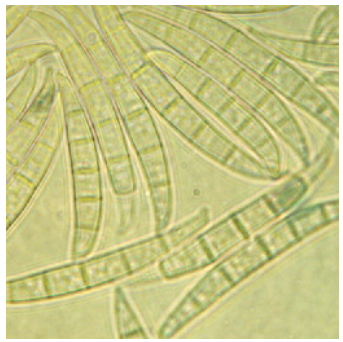
Usually in special nurseries with measures to provoke infection (**artificial inoculation**)

Genotypic Selection

Selection based on genetic fingerprints (DNA markers)

- **Marker alleles linked to resistance genes (QTL). In the ideal case '*perfect*' markers.**
- **Selection based on whole genome marker information (genomic selection)**





Current knowledge on FHB resistance QTL

Buerstmayr et al. (2009) Review. Plant Breeding 128: 1-26.
Löffler et al. (2009) Meta QTL analysis. Mol. Breeding 23: 473-488.
Liu et al. (2009) Meta-analysis of QTL Crop Science 49: 1955-1968.

QTL reported in hexaploid wheat

Over 46 publications, since 1999.

> 200 QTL reported,
on all wheat chromosomes

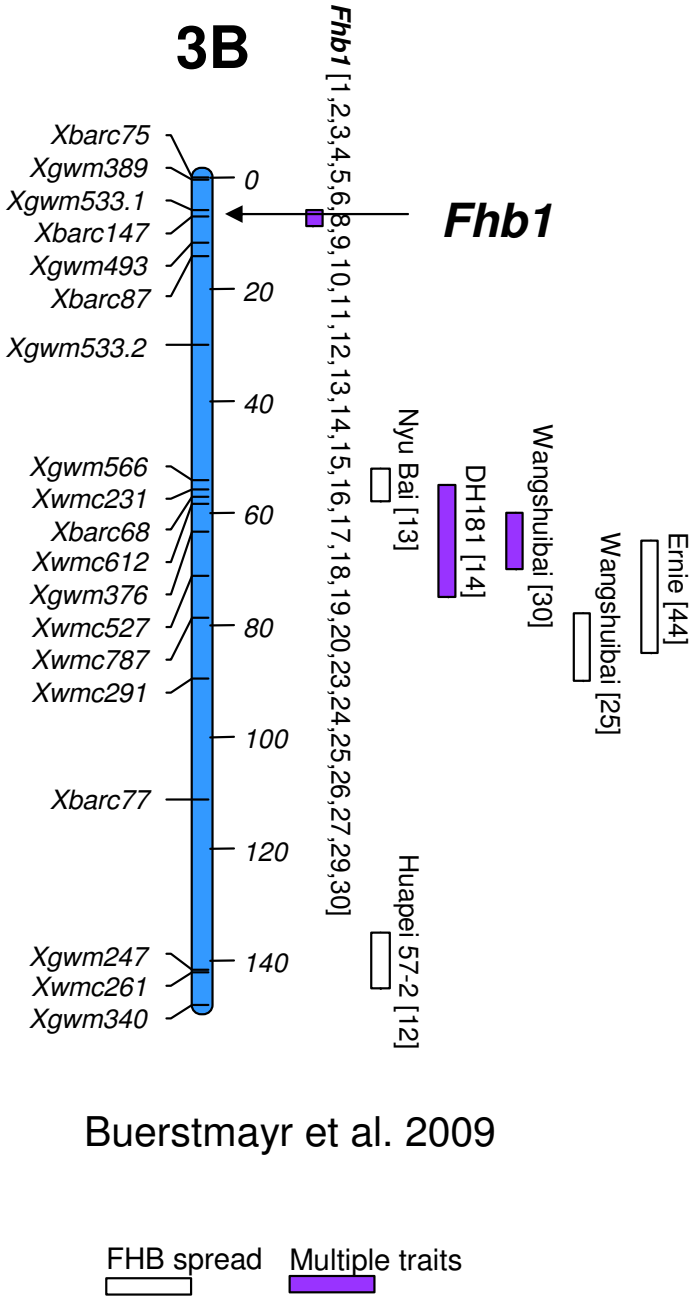
QTL in tetraploid wheat

4 publications, resistance was mainly based on
T. dicoccoides or *T. carthlicum*

QTL in related species

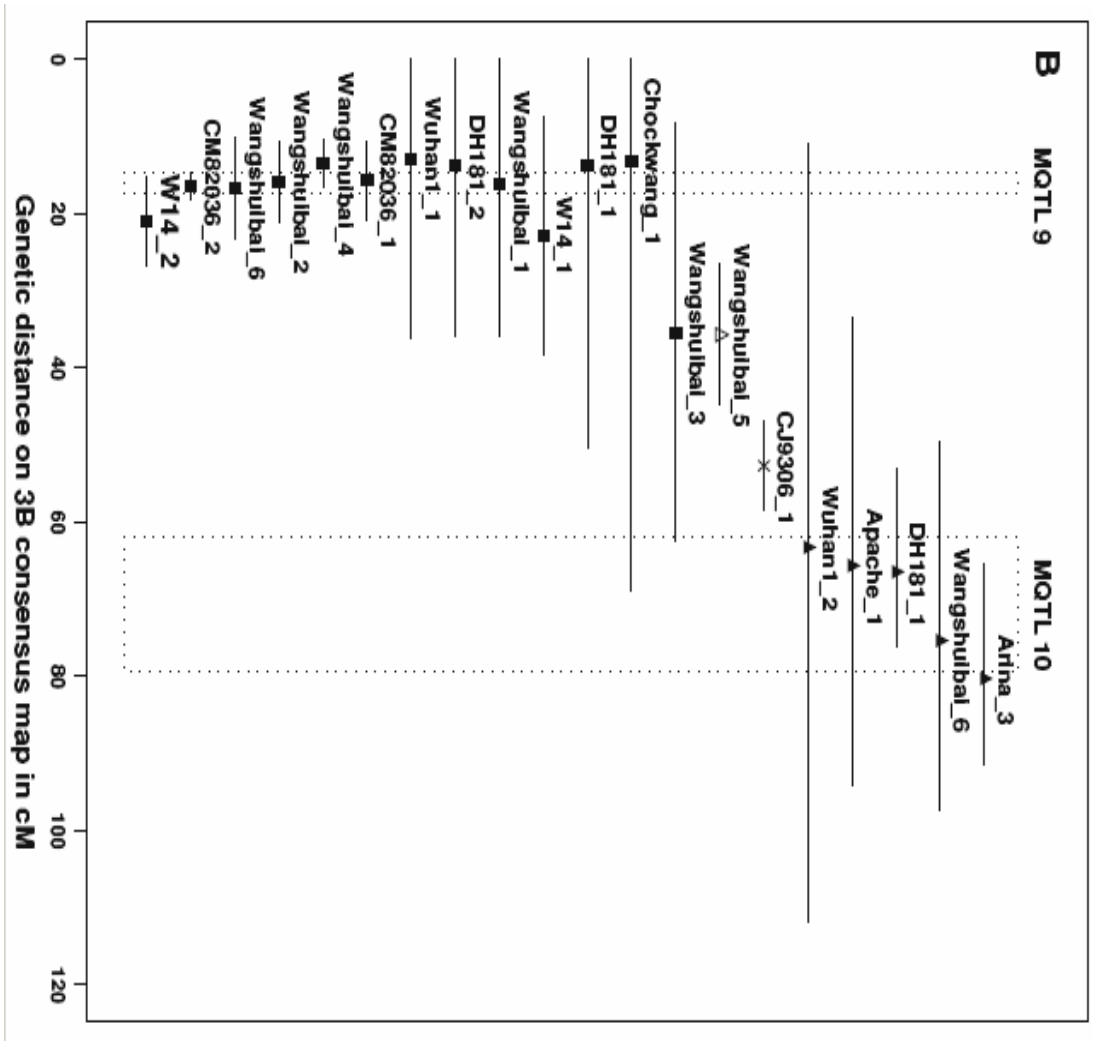
2 publications (*Triticum macha, Thinopyrum ponticum*)

QTL Review



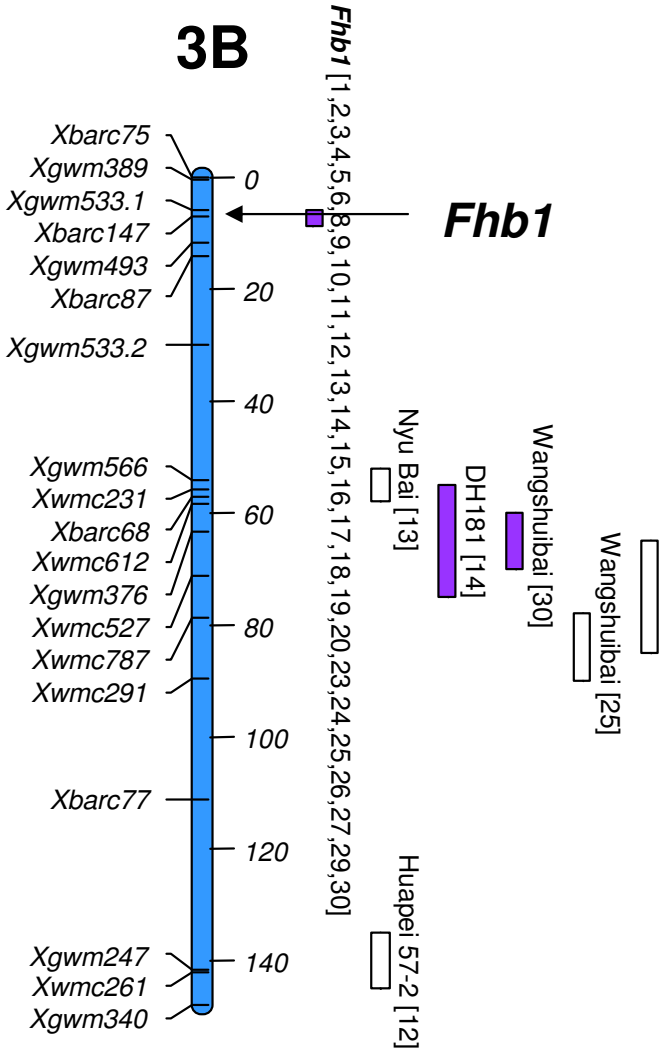
Buerstmayr et al. 2009

Meta QTL analysis



Löffler et al. 2009

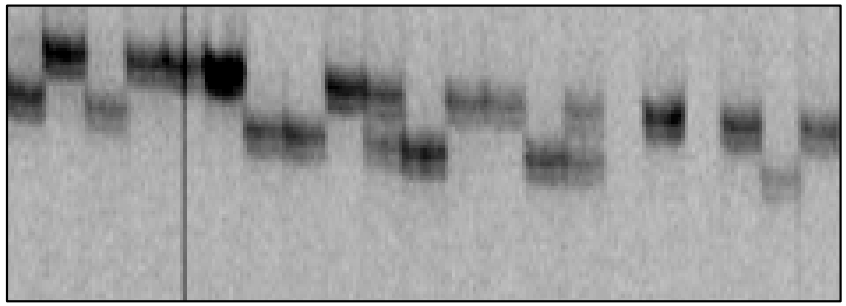
QTL Review



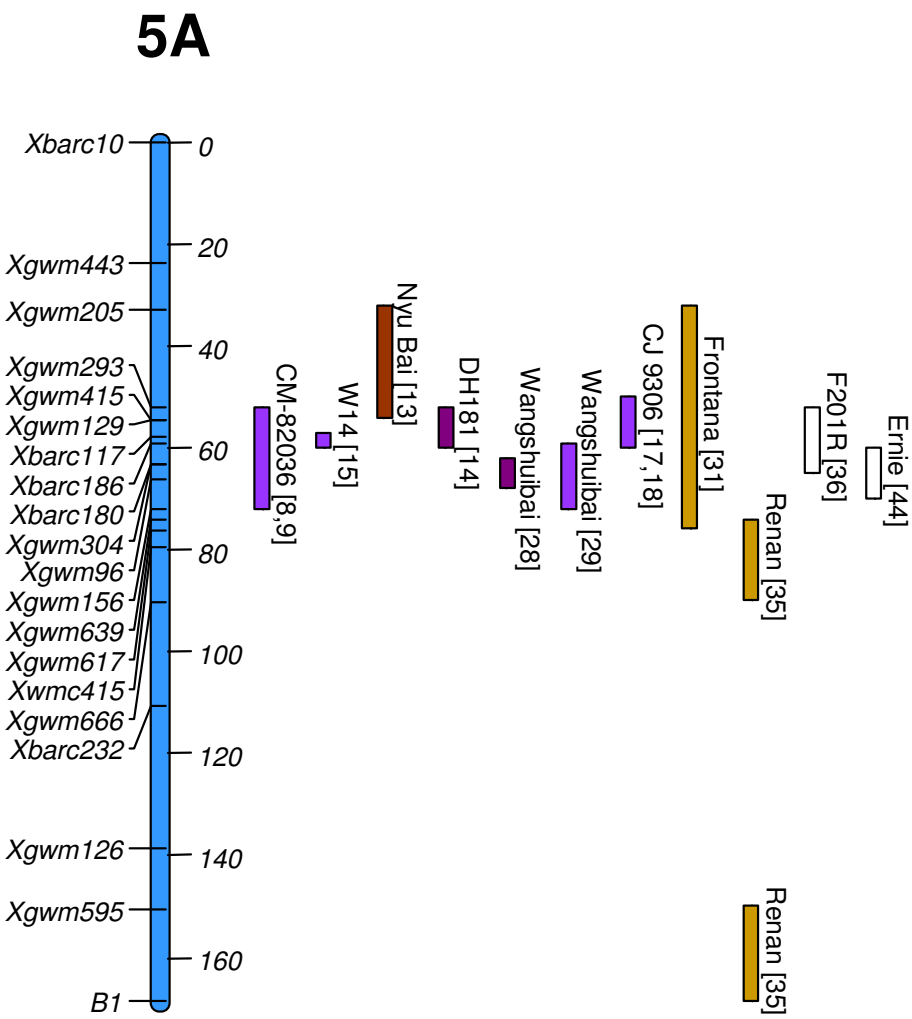
Buerstmayr et al. 2009

FHB spread Multiple traits

*** *Fhb1*** (*Qfhs.ndsu-3BS*)
Nearly perfect marker:
Umn10
PCR, co-dominant
Liu et al. 2008

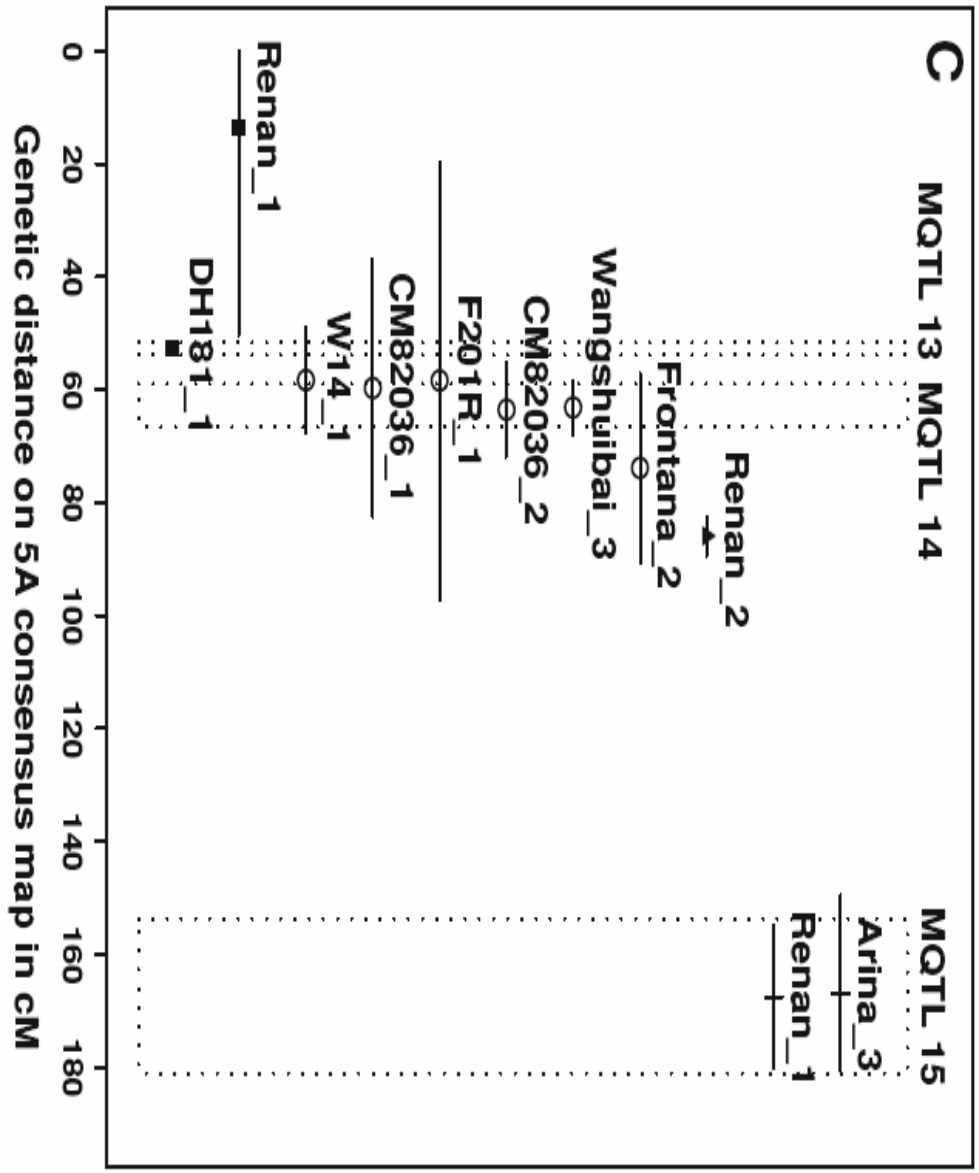


QTL Review



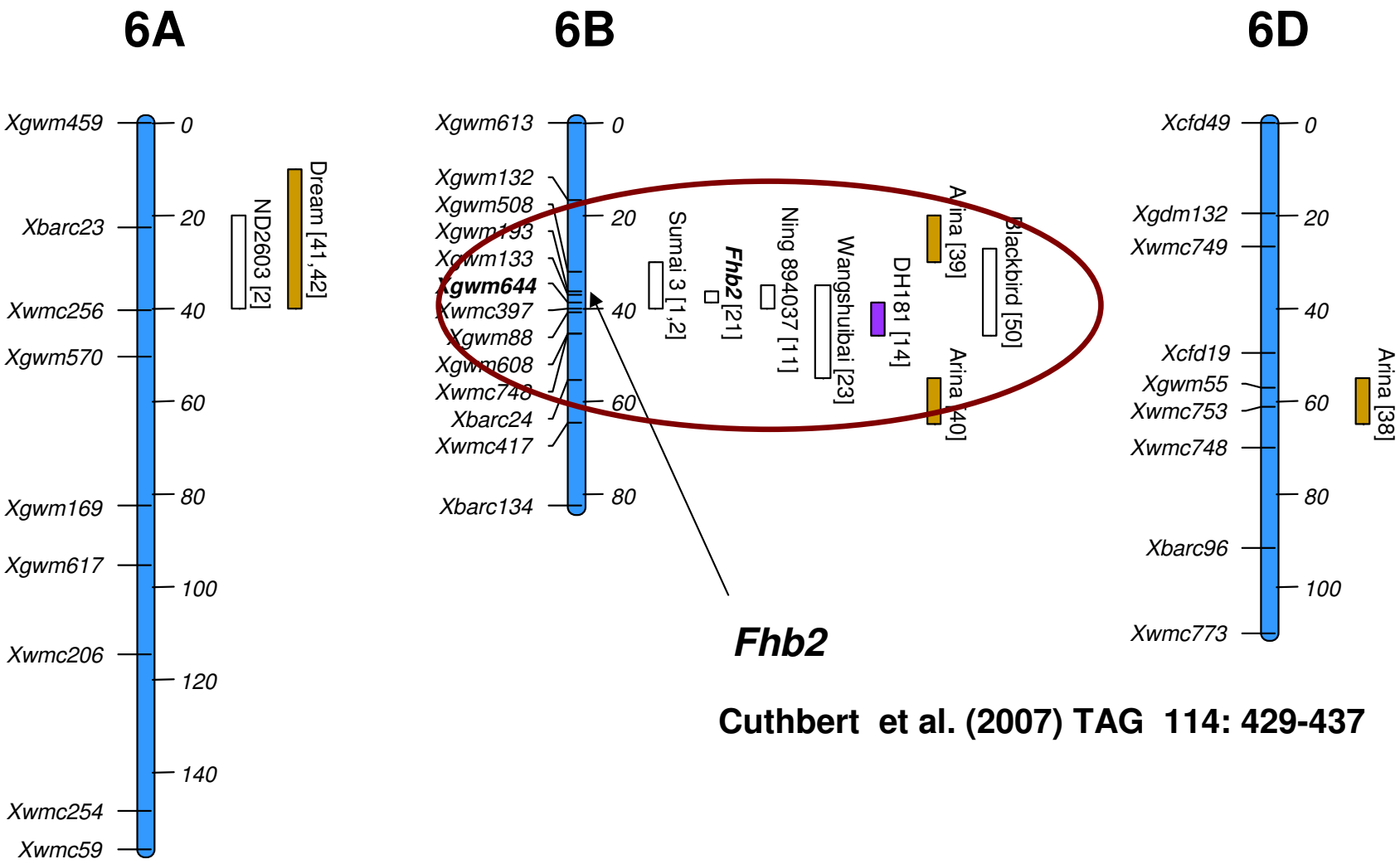
Buerstmayr et al. 2009

Meta QTL analysis



Löffler et al. 2009

FHB spread | FHB incidence | FHB severity | DON | Multiple traits

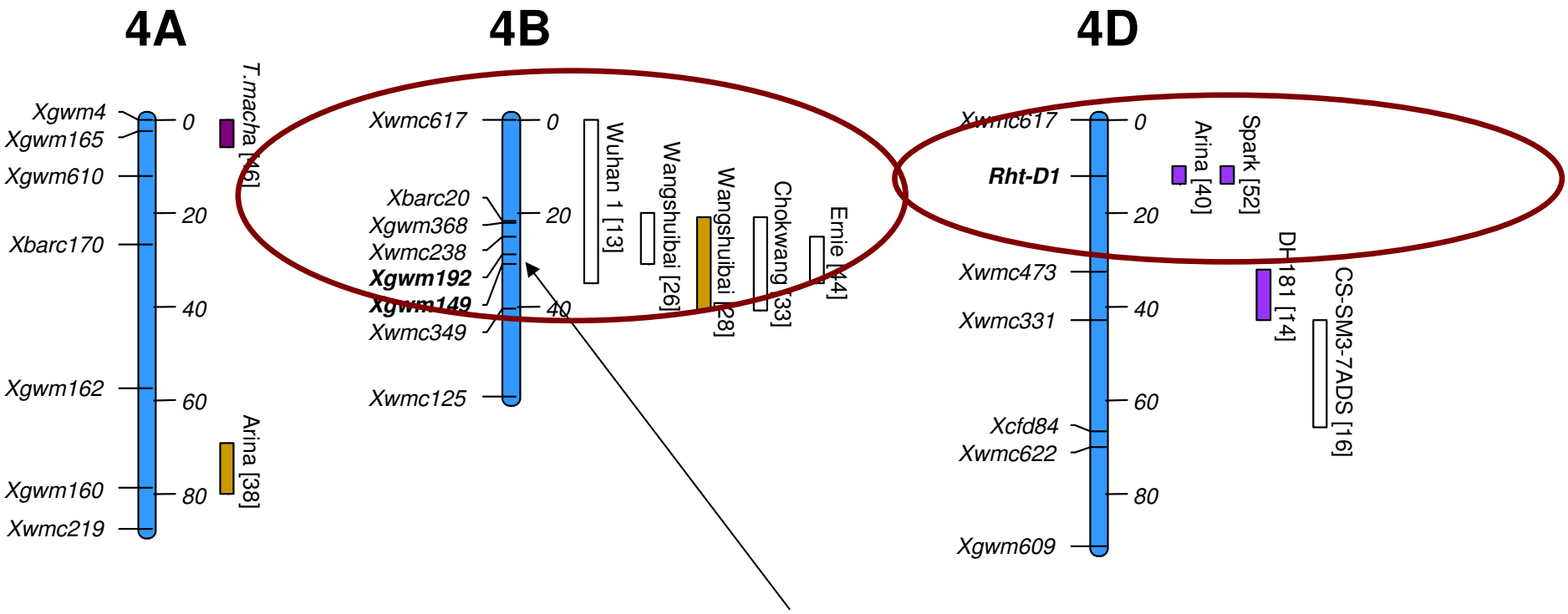


Cuthbert et al. (2007) TAG 114: 429-437

Buerstmayr et al. 2009

FHB spread | FHB incidence | FHB severity | DON | Multiple traits

Buerstmayr et al. 2009



Fhb4

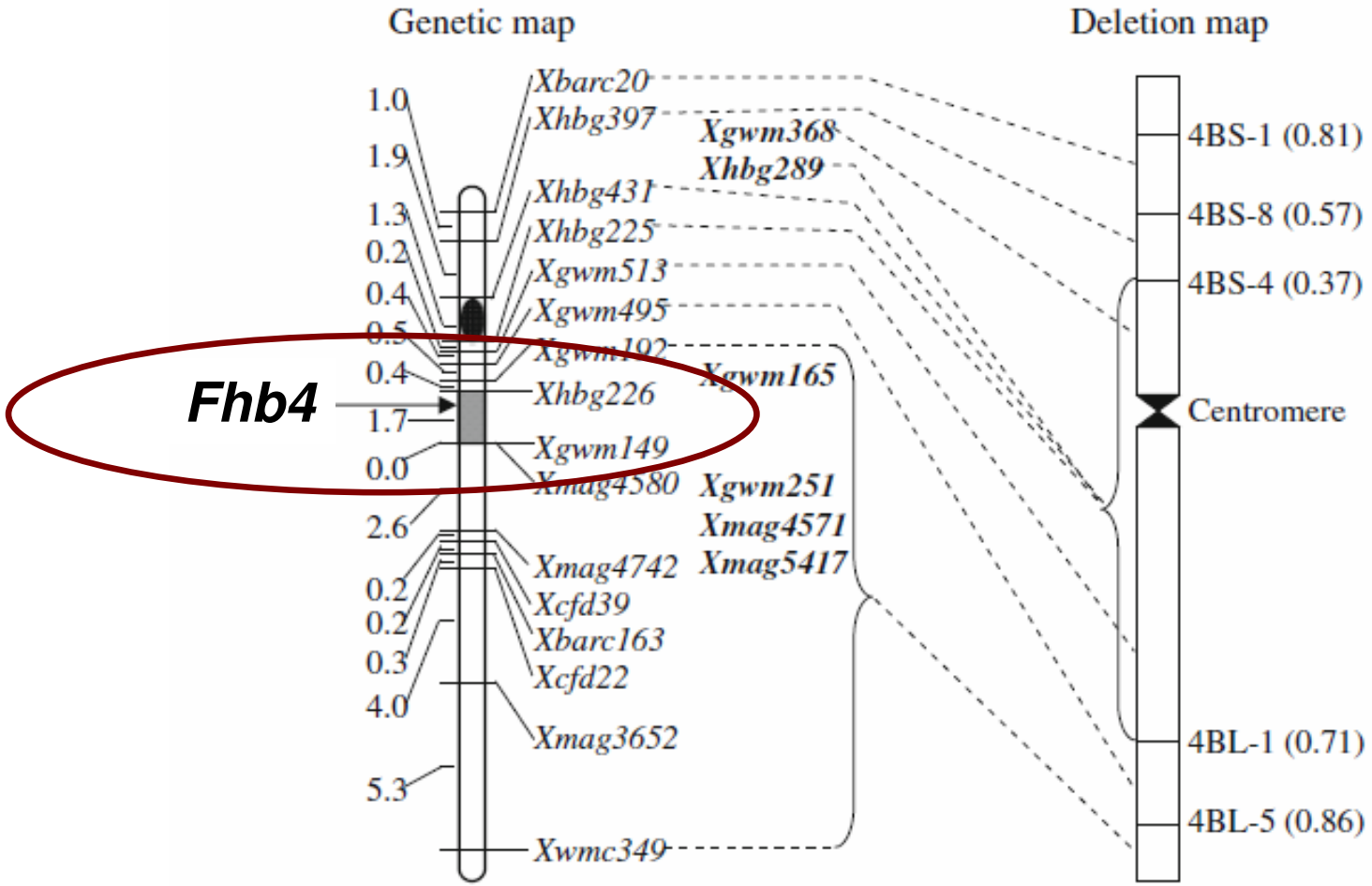
Xue et al. (2010) TAG 121: 147–156

Buerstmayr et al. 2009

FHB spread | FHB incidence | FHB severity | DON | Multiple traits

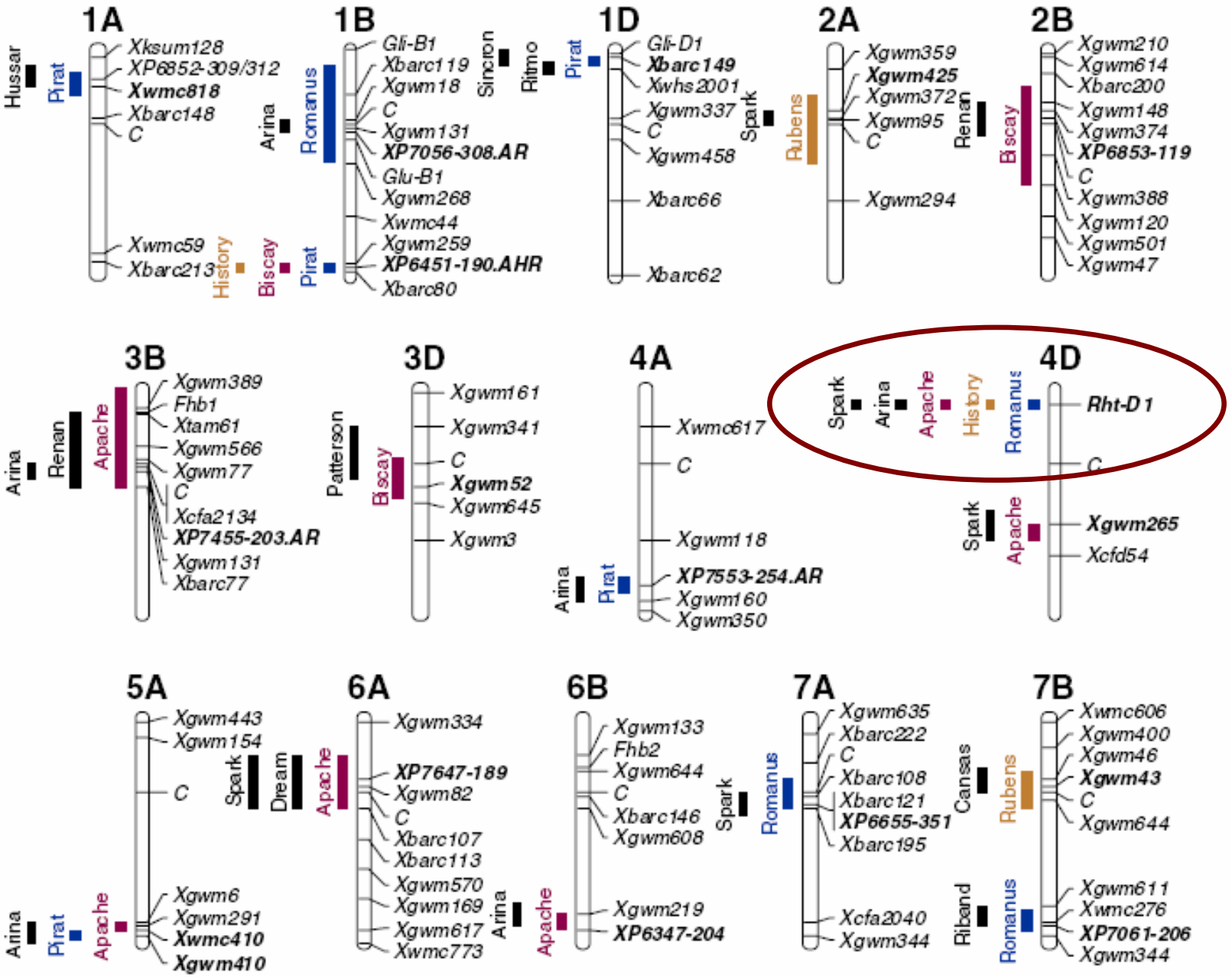
Buerstmayr et al. 2009

4B



Xue et al. (2010) TAG 121: 147–156

QTL summary for winter wheat (Holzapfel *et al*. TAG 2008)

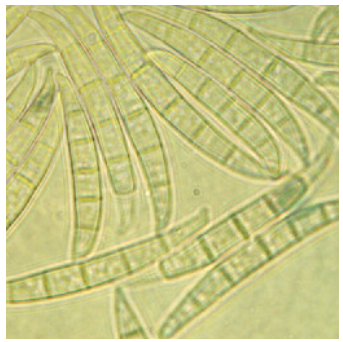


Introgression of the spring wheat derived QTL on 3BS and 5A into European winter wheat

Marker assisted back-crossing of QTL on chromosomes **3BS and 5A**

Salameh *et al*. (2010) Molecular Breeding, *online first*

von der Ohe *et al*. (2010), Crop Science 50



Back-crossing of resistance QTL

Selection by using DNA markers linked to *Fusarium* resistance QTL.

CM-82036 x Winter Wheat (9 different cultivars)

F_1 x WW

Marker selection for 2 QTL

BC_1 x WW

Marker selection for 2 QTL

BC_2 selfed

Marker selection for 2 QTL

Qfhs.ifa-5A	AA	AA	aa	aa
Fhb1(3BS)	BB	bb	BB	bb

Salameh et al. (2010)

Ten wheat varieties used for developing BC_2F_2 derived sister lines

Variety	Origin	Pedigree	FHB reaction
CM-83036	MX	Sumai-3/Thornbird-'S'	**HR**
Apache	FR	Axial/NRPB-84-4233	**MR**
Petrus	DE	Nimbus/Vuka//Falke/4/Benno/Caribo//Kormoran/3/Kronjuwel	**MR**
Enno	DE	Hustler/Achat/3/Caribo/Tadorna/2/Ibis/Ferto	**MR**
Augustus	AT	Caribo/Multiweiss// MarisHuntsman/Disponent/3/Ikarus/Granada	**MS**
P581	AT	Herzog/Orbis	**MS**
Ludwig	AT	Ares/Farmer	**MS**
CH76152	CH	NR399-84/EA8	**S**
Charger	UK	Fresco'sib'/Mandate	**S**
Orvantis	FR	Thesee//Disponent/Monopol/3/Torfrida	**S**

Salameh et al. (2010)

Evaluation of FHB resistance

Location: Experimental field
at IFA-Tulln, AT

3 Seasons (2006, 2007, 2008)
2 Isolates: *F. graminearum, F. culmorum*

➔ 6 experiments

Spray inoculation, mist irrigation

5 visual scorings of FHB severity, calculation of the area under the disease progress curve (AUDPC)

Salameh et al. (2010)

Evaluation of yield and quality traits

Subset of 8 families and several modern cultivars as checks

3 field experiments: Tulln 2008, Reichersberg 2008, Tulln 2009.

5m^2 plots
2 replications
lattice design

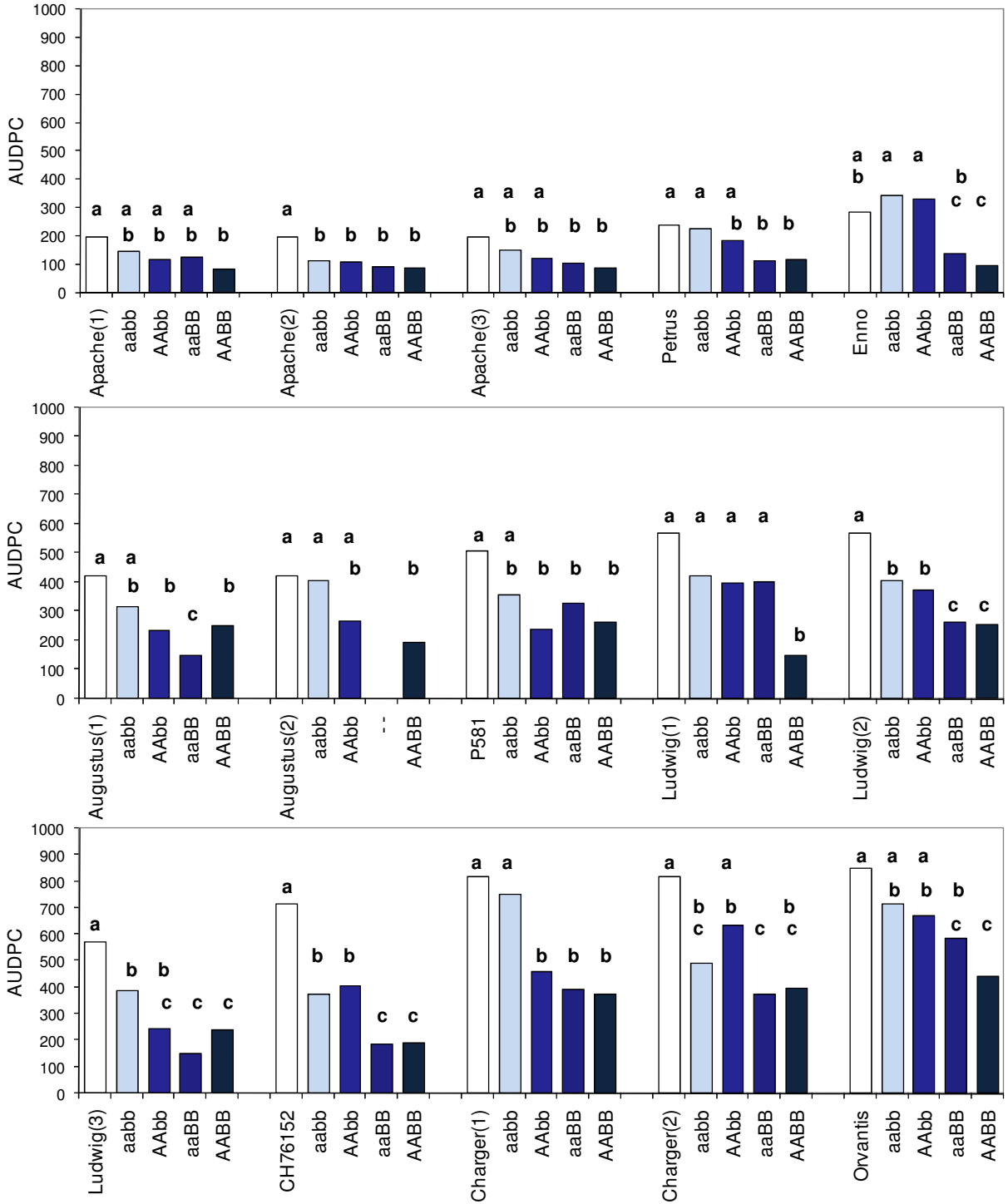
Yield
Agronomic traits
Quality traits

Salameh et al. (2010)

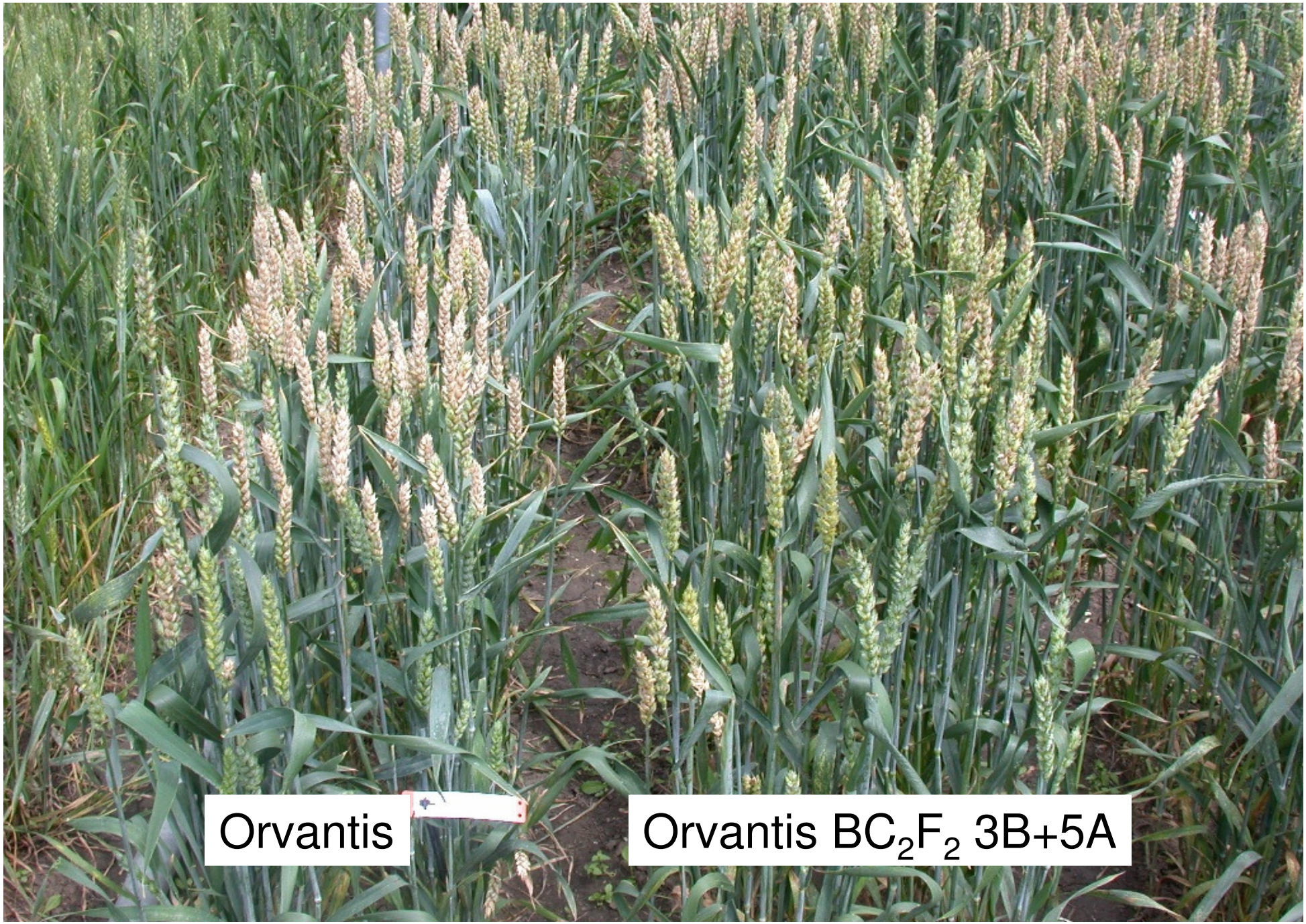
FHB severity (AUDPC) on BC_2 derived sister lines

means over
6 experiments

Salameh et al. (2010)

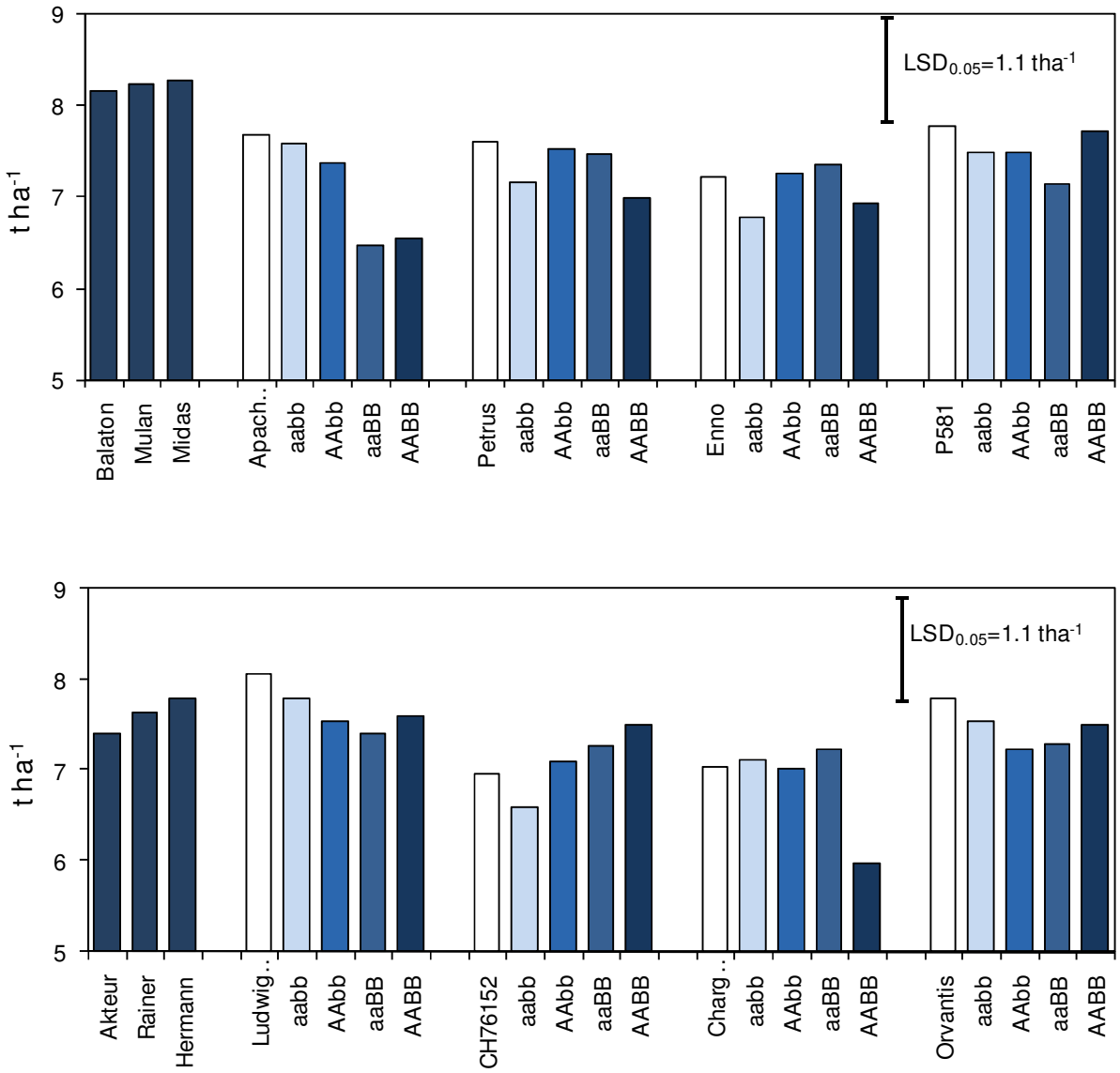


Tukey test $p<0.1$


Orvantis
Orvantis BC_2F_2 3B+5A

Yield performance of BC_2 derived sister lines

means over 3 experiments



Salameh et al. (2010)

RESEARCH

Agronomic and Quality Performance of Winter Wheat Backcross Populations Carrying Non-Adapted Fusarium Head Blight Resistance QTL

C. von der Ohe, E. Ebmeyer, V. Korzun, and T. Miedaner*

Published in Crop Sci. 50:2283–2290 (2010).
doi: 10.2135/cropsci2010.03.0135
Published online 27 Sept. 2010.

Resistance donor: ***CM-82036*** *(Fhb1 + Qfhs.ifa-5A)*

Recurrent winter wheat lines:
Opus**:** highly FHB susceptible (7 on a 1-9 scale)
Anthus**:** moderately resistant (4 on a 1-9 scale)

Marker assisted selection of BC_3F_2 plants: aabb, AAbb, aaBB, AABB

Field testing of $BC_3F_{2:5}$ lines in 10 experiments (5 locations, 2 years) for

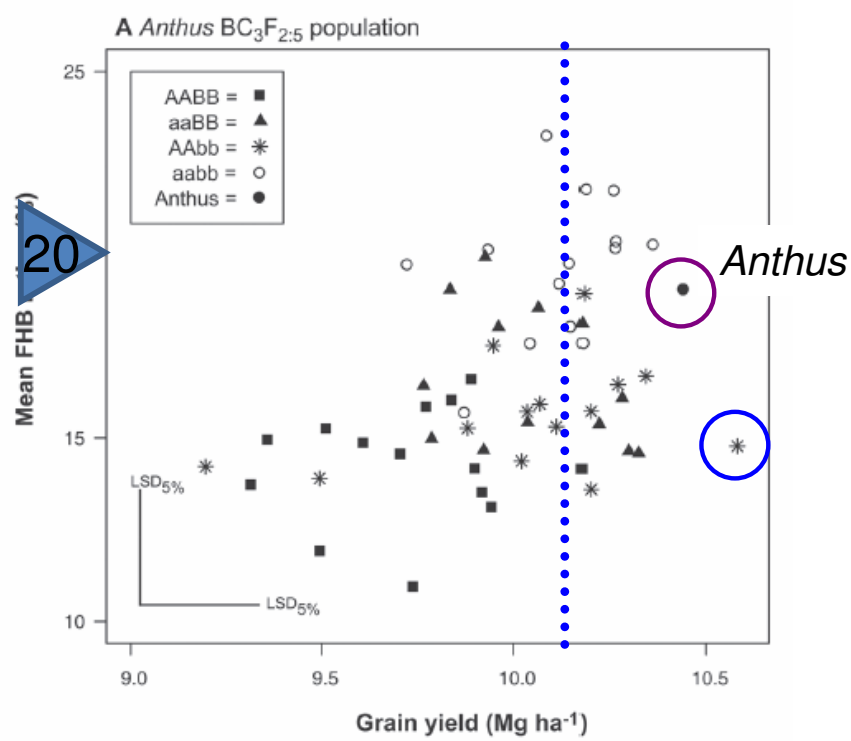
1) FHB resistance: *F. culmorum* spray inoculations
2) Yield and quality: high-input production system (150 -200 kgN, fungicides, CCC)

von der Ohe *et al.* (2010)

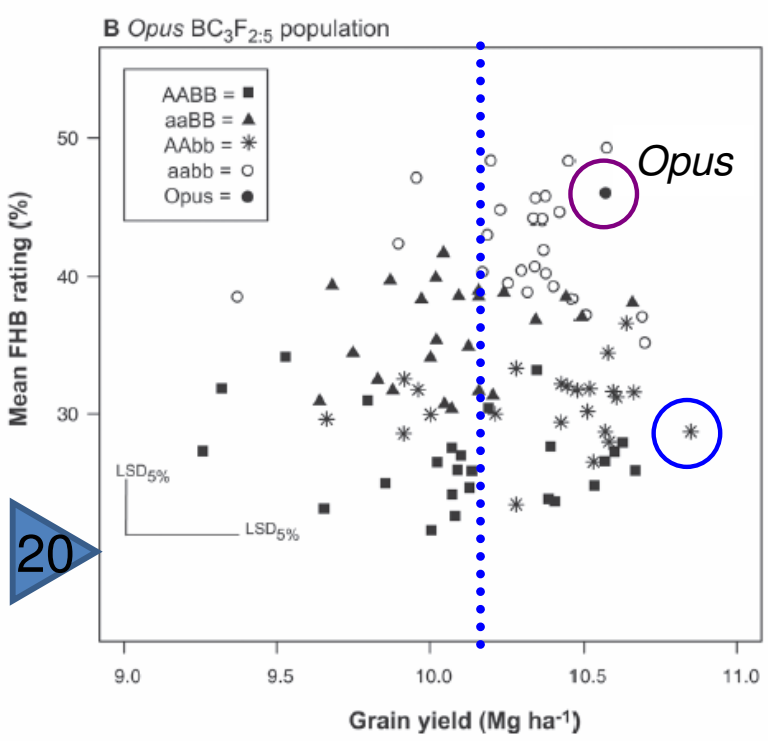
Yield *vs.* FHB resistance in two BC_3 populations

14-24 lines within each QTL class, replicated FHB resistance and yield testing

Anthus $BC_3F_{2:5}$ lines



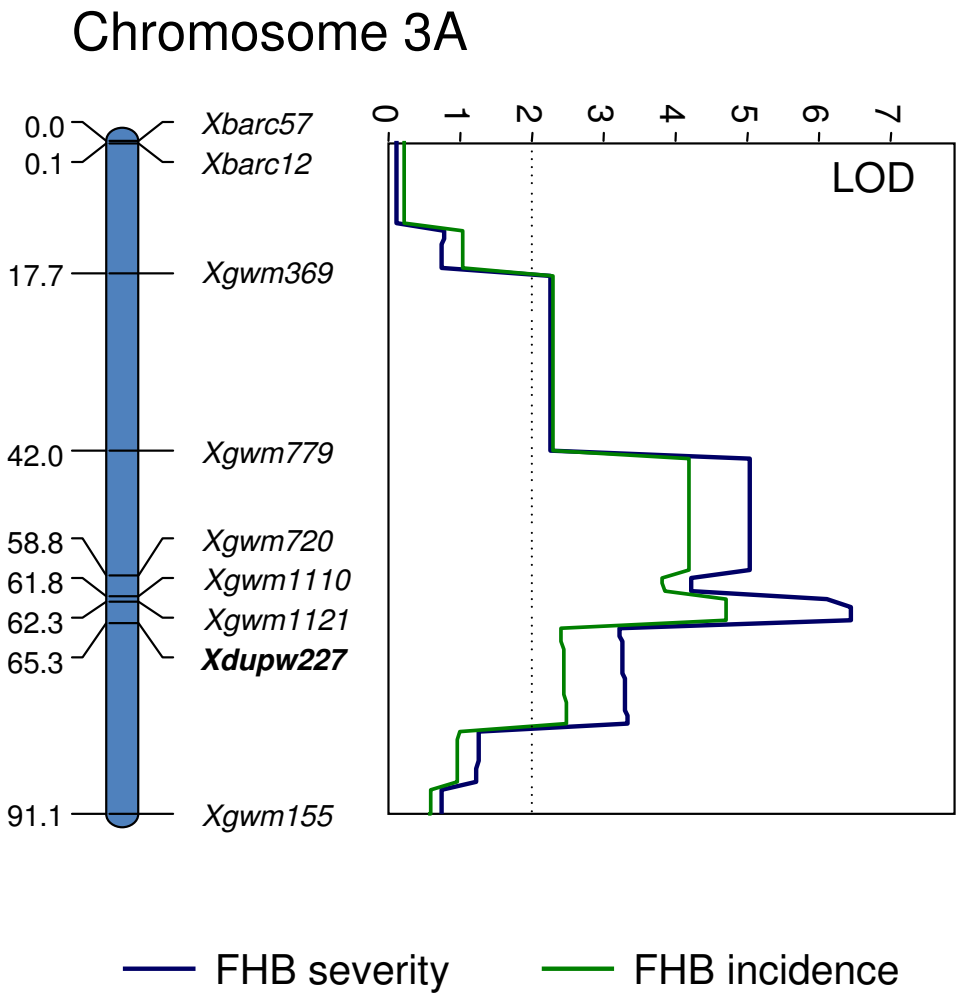
Opus $BC_3F_{2:5}$ lines



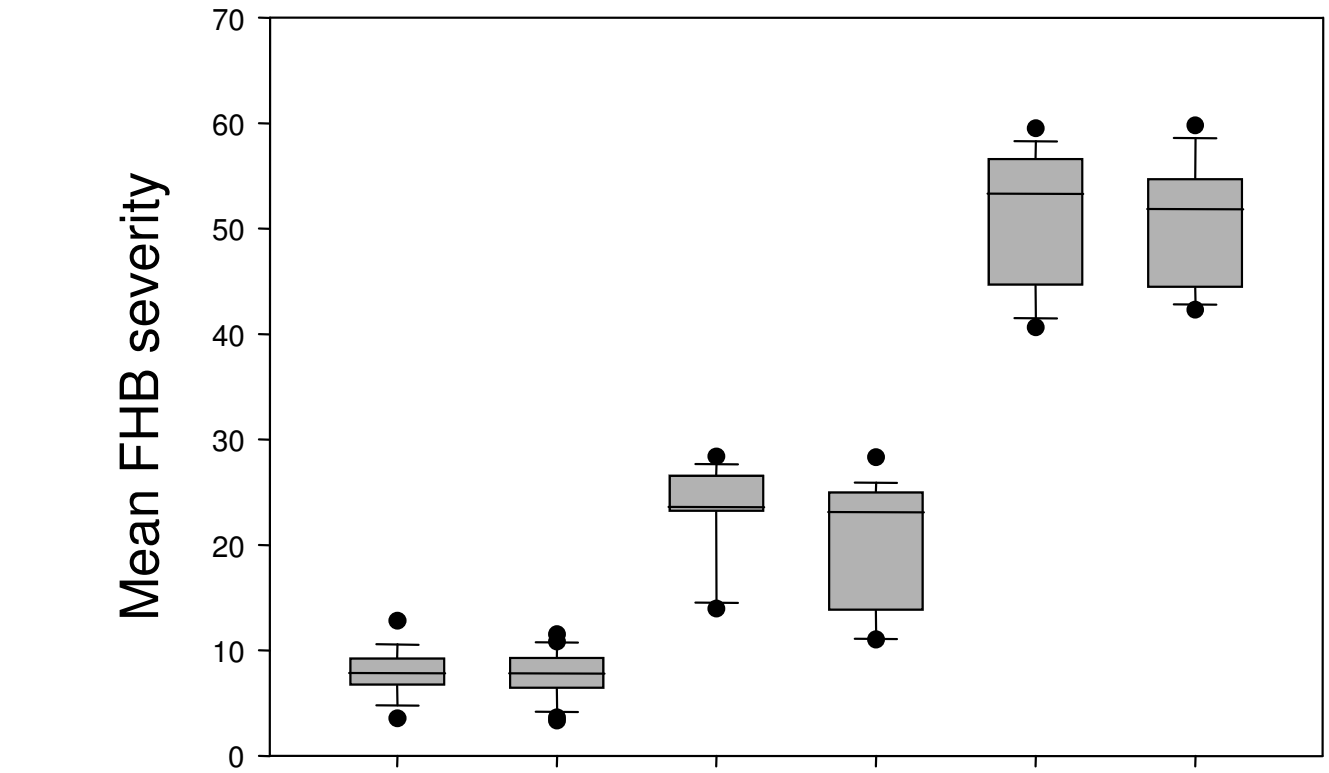
von der Ohe *et al.* (2010) (modified)

Frontana derived QTL

'Frontana' is a well known source of FHB resistance since many decades.
QTL mapped to chromosomes 3A and 5A (Steiner et al. 2004)

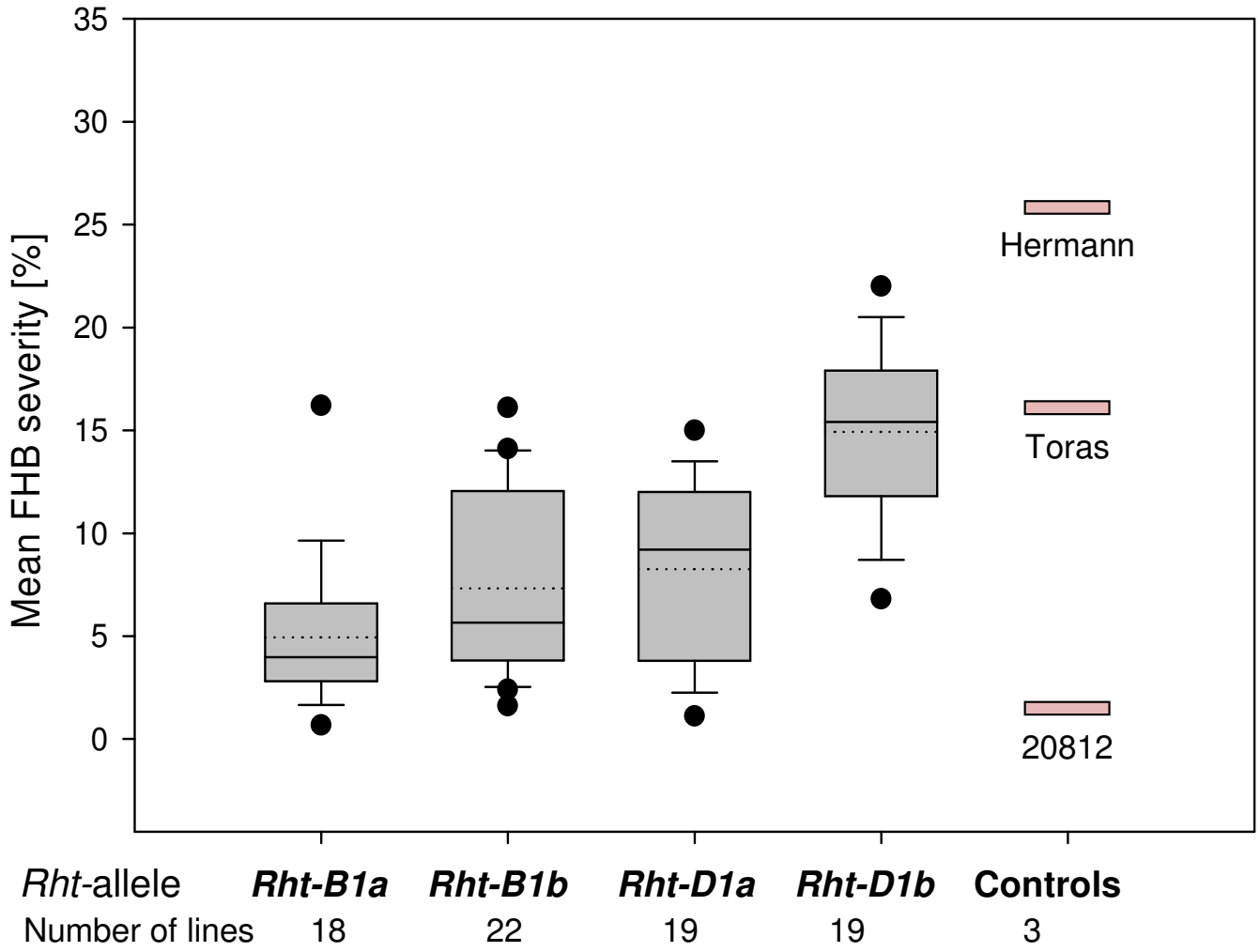


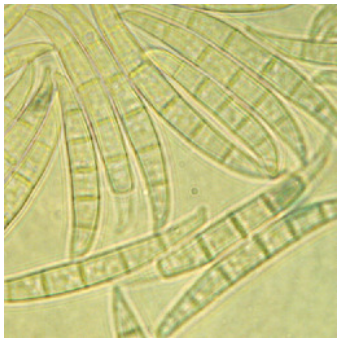
FHB severity in BC_2-derived sister lines for the marker *Dupw227* at chromosome 3A in three *‚Frontana‘* derived crosses with Apache, Augustus and Orvantis



Association of the semi-dwarf alleles *Rht-B1a/b* or *Rht-D1a/b* with FHB resistance

Marker assisted development of BC_2F_2 sister lines
recurrent parent: line **'20812'** (*Rht-B1a/Rht-D1a*), highly resistant
donor: **'Hermann'** (***Rht-B1b***/*Rht-D1a*) and **'Toras'** (*Rht-B1a*/***Rht-D1b***)





Summary

Breeding for FHB resistance is (still) resource demanding

Classical phenotypic selection for resistance is a successful strategy

Molecular marker assisted selection is promising for large effect QTL

Perfect markers still needed for most of the useful QTL

Association (correlation, linkage, pleiotropy) between FHB resistance and other plant traits warrants further investigation

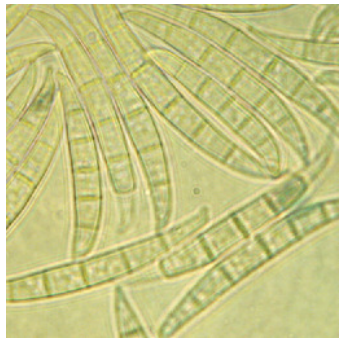
The potential of genomic selection should be explored

Fulbright Visiting Professor
at the University of Natural Resources and Life Scienes Vienna

Autumn 2011

Clay Sneller, Ohio State University

Genomic Selection in Wheat Breeding.



Acknowledgments

Barbara Steiner
Marc Lemmens
Aziz Salameh
Apinun Limmongkon
Abdallah Alimari
Karin Huber
Johannes Heckmann
Katharina Schießl
Maria Buerstmayr
Matthias Fidesser
Andrea Koutnik

Gerhard Adam
Wolfgang Schweiger

Rainer Schuhmacher
Franz Berthiller
Kurt Brunner
Rudi Krska

James A. Anderson
Tomohiro Ban

Austrian Science Fund

Federal State
Lower Austria

Austrian Academic
Exchange Service

Eurotransbio