Genomics to boost durable leaf rust and stripe rust resistance in U.S. Great Plains wheat

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PAG 2024

International Wheat Genome Sequencing Consortium –
From Structural to Functional Wheat Genomics

January 16, 2024

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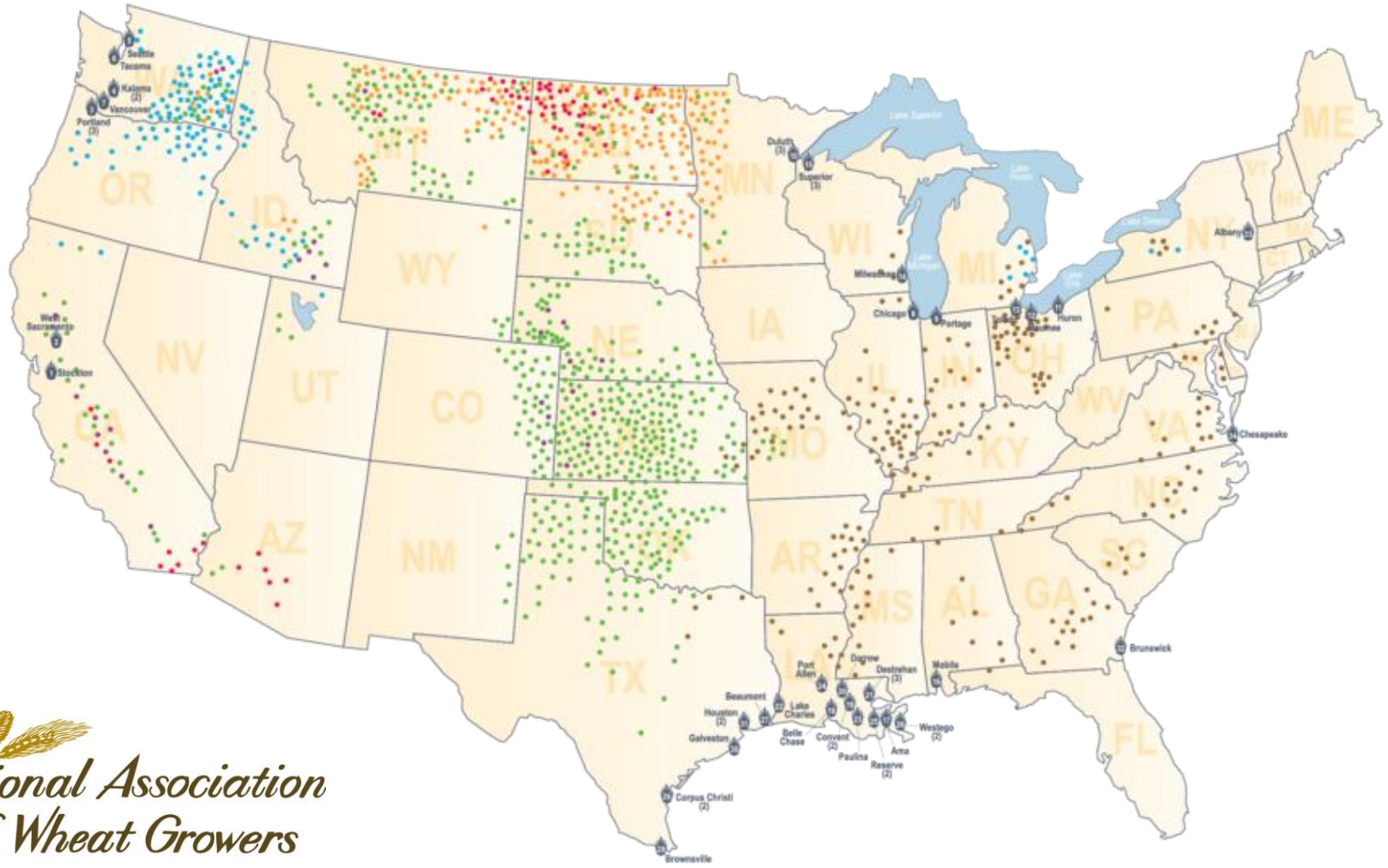
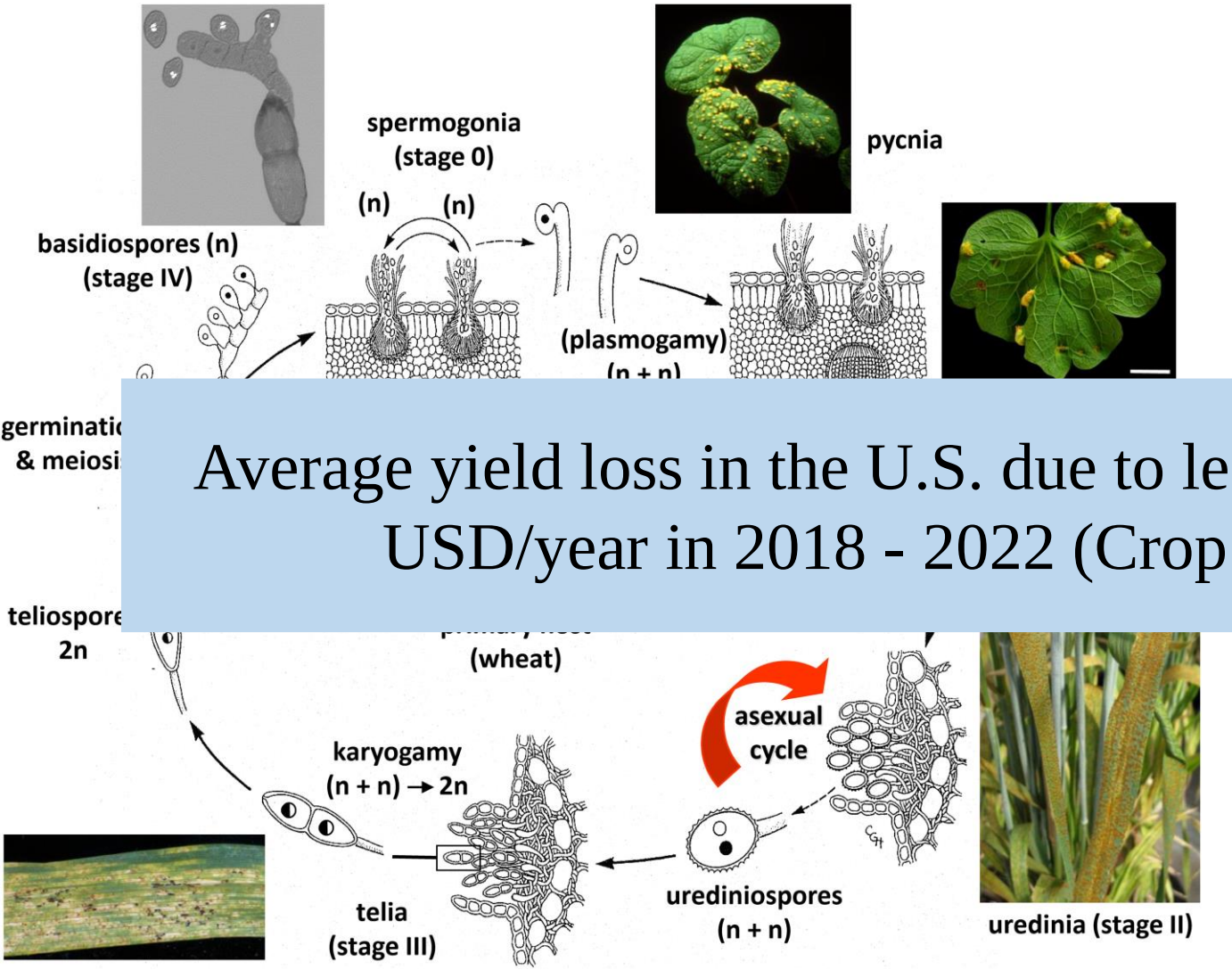
Wheat is grown in 42 states in the U.S.



National Association of Wheat Growers

HARD RED WINTER · HARD RED SPRING · SOFT RED WINTER · SOFT WHITE · HARD WHITE · DURUM

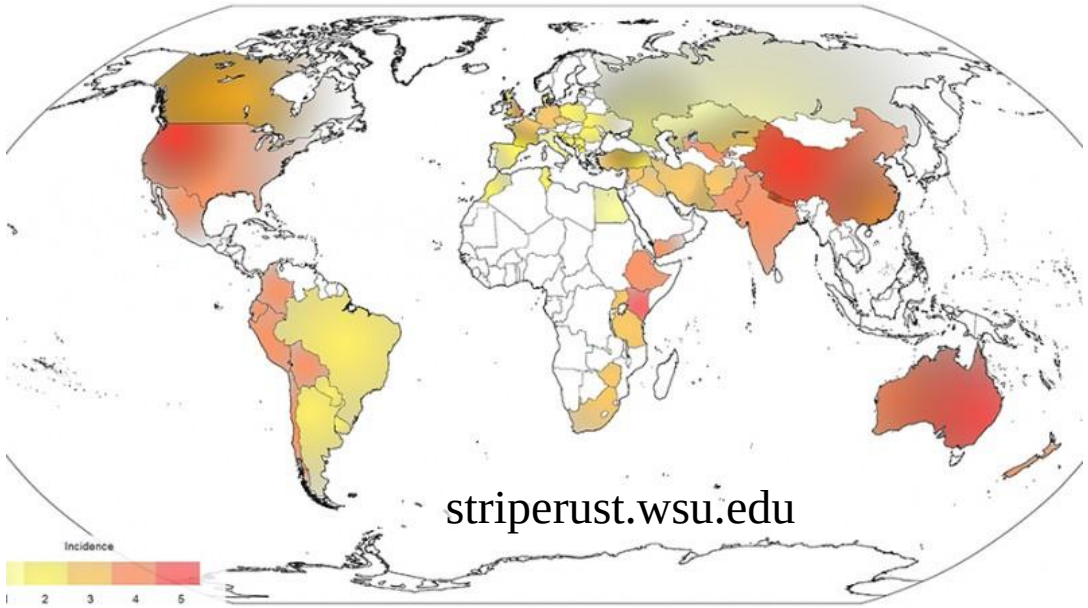
Leaf rust: *Puccinia triticina*



Average yield loss in the U.S. due to leaf rust was estimated at 72 million USD/year in 2018 - 2022 (Crop Protection Network, 2022)

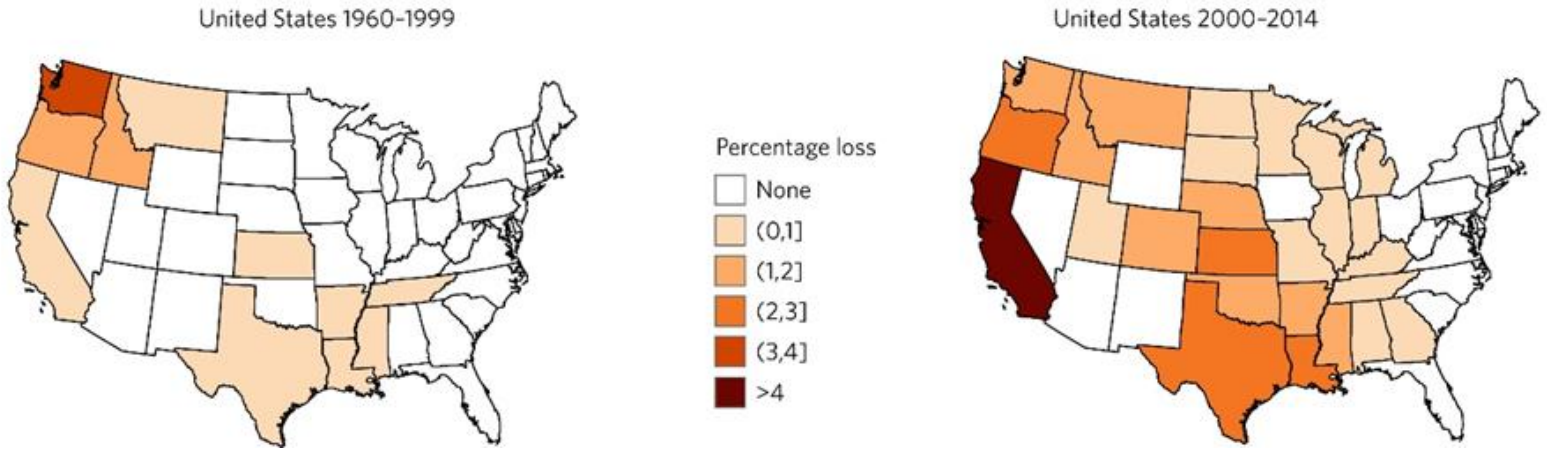
Bakkeren and Szabo, 2020

Stripe rust: P*uccina striiformis* f. sp. *tritici*



Average yield loss in the U.S. due to stripe rust was estimated at 81 million USD/year in 2018 - 2022 (Crop Protection Network, 2022)

Stillwater, OK, 2021



Beddow et al., 2015

Pyramid rust resistance genes to achieve durable rust resistance

RUST RESISTANCE

Seedling/All-stage Resistance (ASR)

- ❑ Qualitative
- ❑ Hypersensitive response
- ❑ Usually race-specific
- ❑ Short lived

Adult Plant Resistance (APR)

- ❑ Quantitative
- ❑ Diverse resistance mechanism
- ❑ Usually resistant to multiple races and pathogens
- ❑ Durable

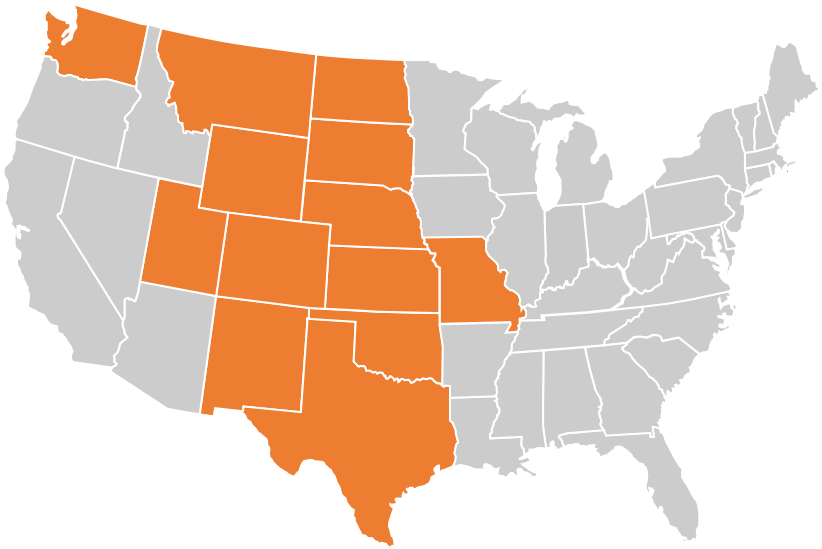
Leaf rust resistance

- 30-60 races detected on an annual basis in the US
- 83 characterized *Lr* genes in wheat: 68 ASR and 15 APR. 11 cloned genes
- Many genes no longer provide resistance to current races
- Known *Lr* genes in hard winter wheat: *Lr21*, *Lr24*, *Lr26*, *Lr37*, *Lr39*, *Lr42*, *Lr34*, *Lr46*, *Lr68*, *Lr77*, *Lr78*

Stripe rust resistance

- PSTv-37 is the predominant race in the US, diverse races in the Pacific Northwest
- 86 characterized *Yr* genes in wheat: 58 ASR, 28 APR. Seven cloned genes
- Many genes no longer effective
- Known *Yr* genes in hard winter wheat: *Yr5*, *Yr15*, *Lr37/Yr17*, *Qyr.tamu-2B*, *Lr34/Yr18*, *Lr46/Yr29*, *Yr36*.

Effective rust resistance genes in contemporary hard winter wheat are largely unknown

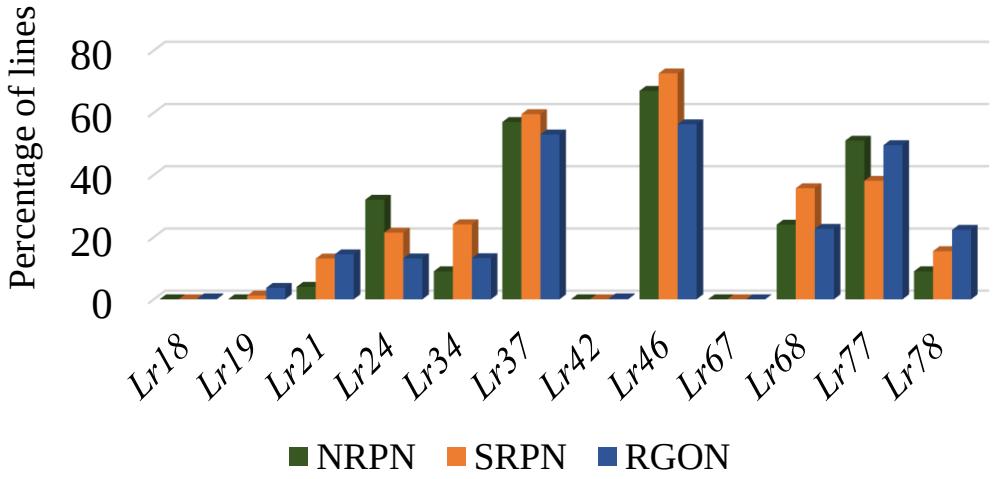


459 U.S. hard winter wheat (2021 & 2022)

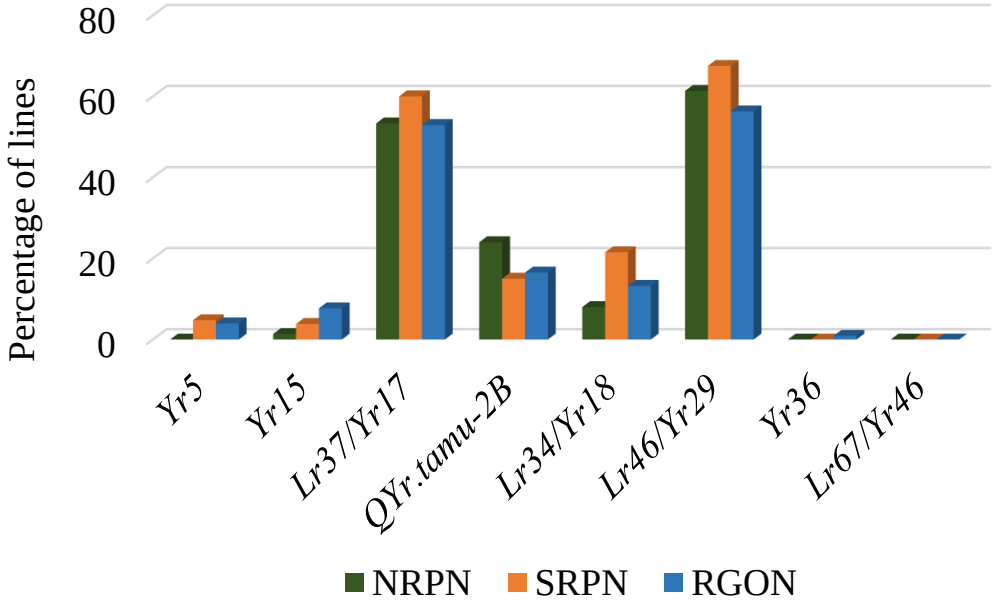
- Northern Regional Performance Nursery (NRPN)
- Southern Regional Performance Nursery (SRPN)
- Regional Germplasm Observation Nursery (RGON)

USDA

Leaf rust resistance genes

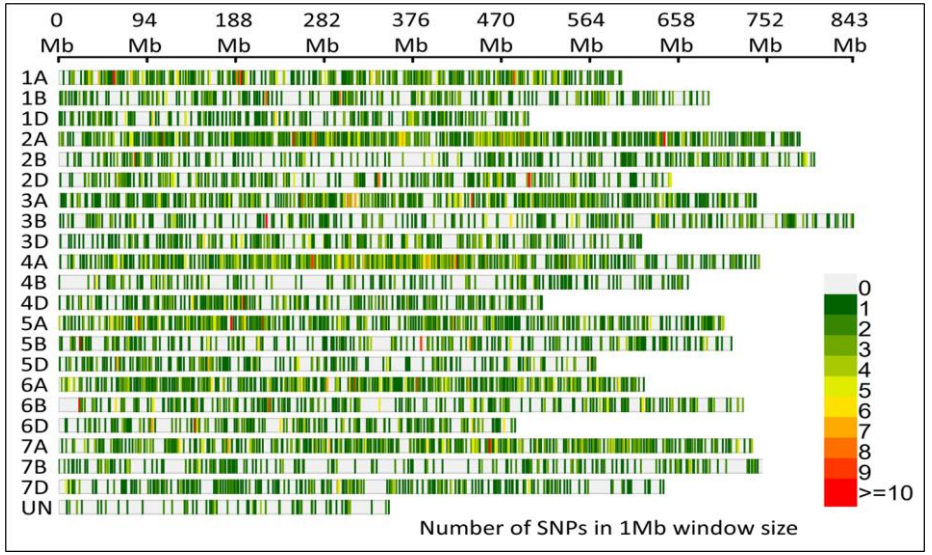


Stripe rust resistance genes

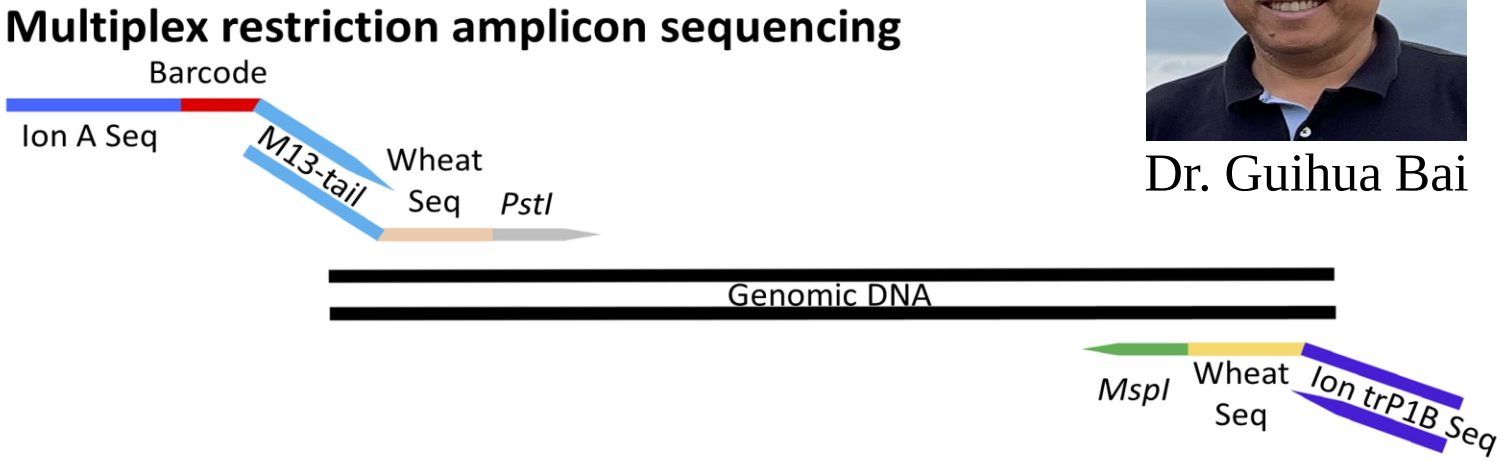


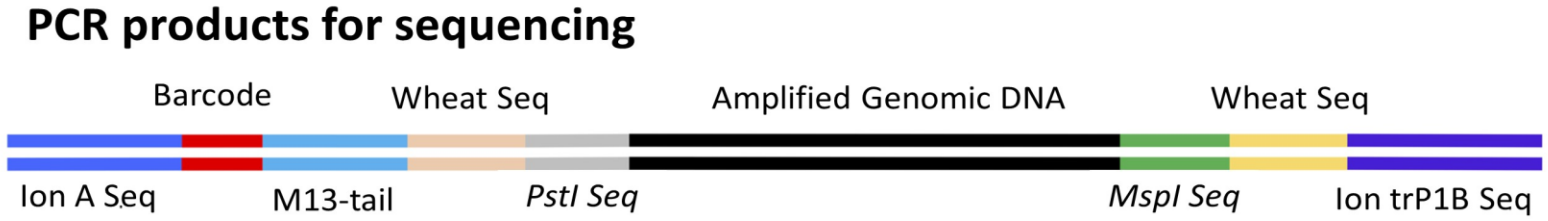
HWW breeding lines from regional nurseries were genotyped using MRASeq

Dr. Guihua Bai

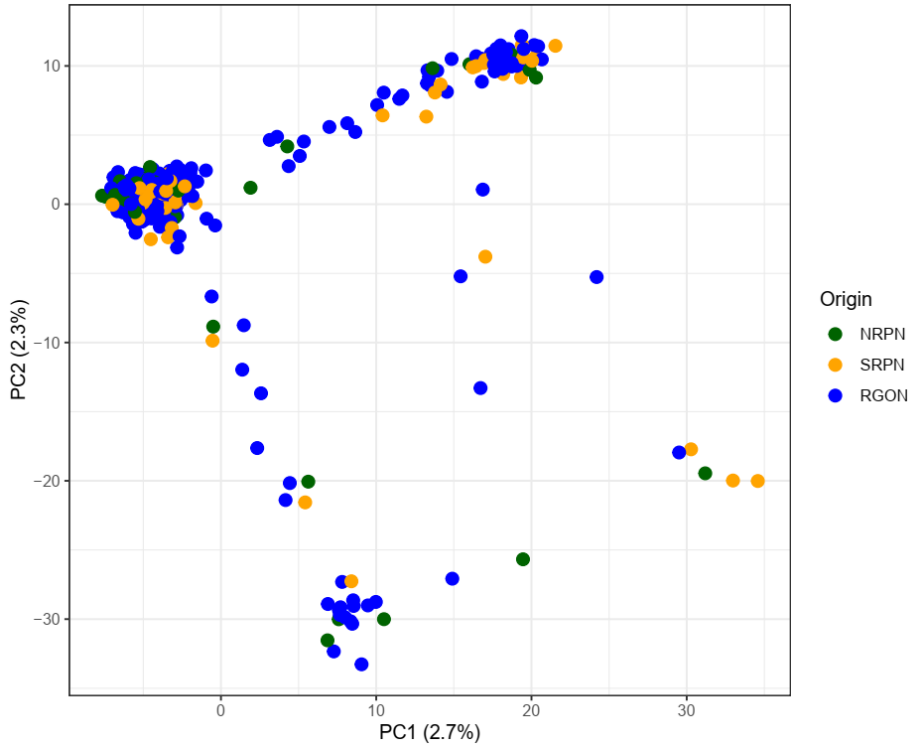


Genotyping: 9,858 filtered SNPs



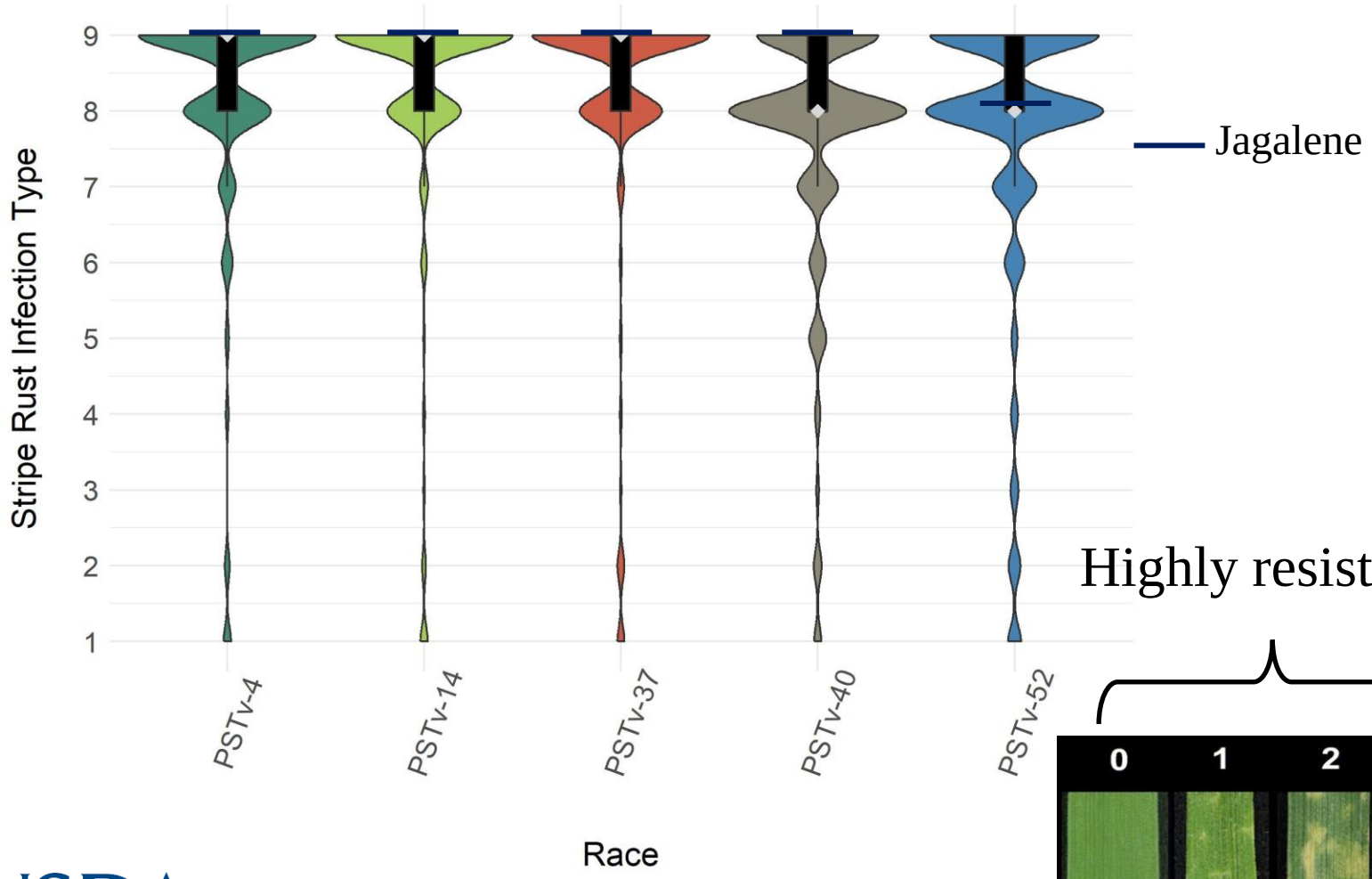


Bernardo et al., 2019



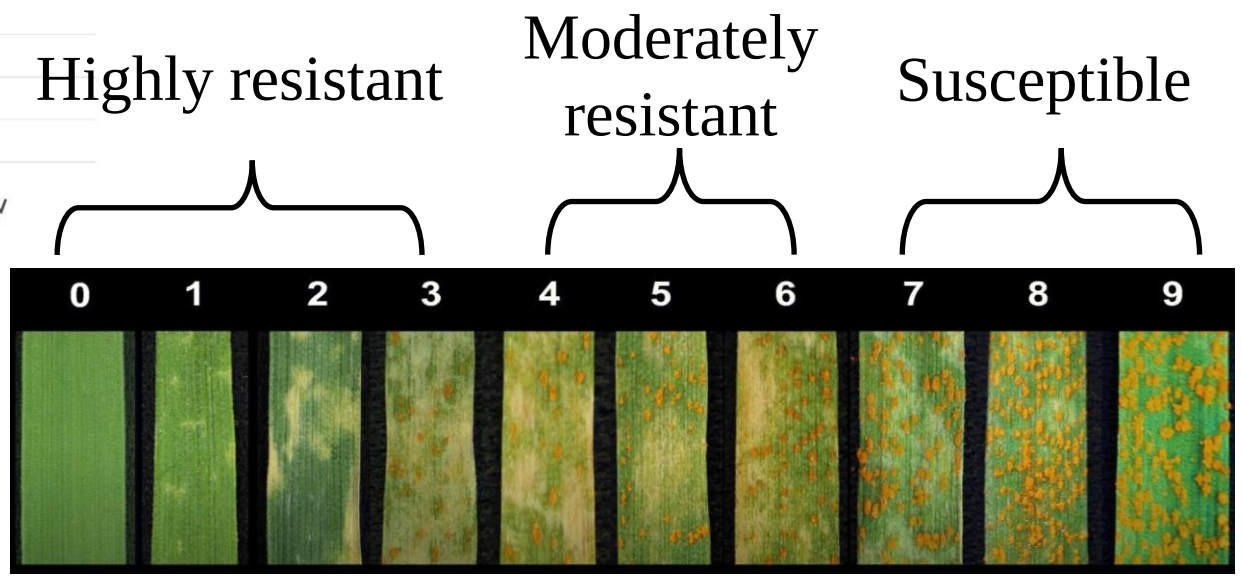
USDA

Low frequencies of stripe rust resistance at seedling stage in HWW



Dr. Xianming Chen

Dr. Meinan Wang

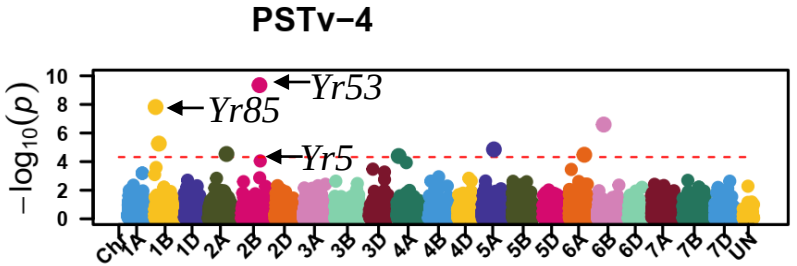


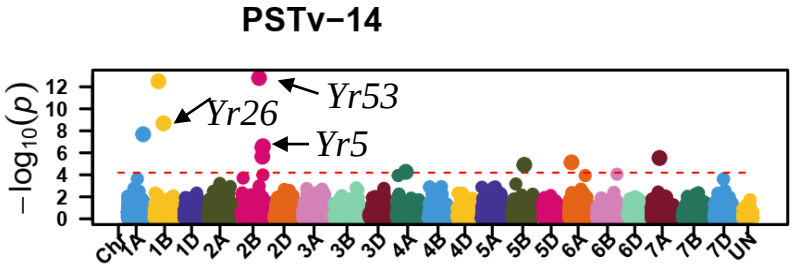
5 – 7% were resistant to *Pst* races

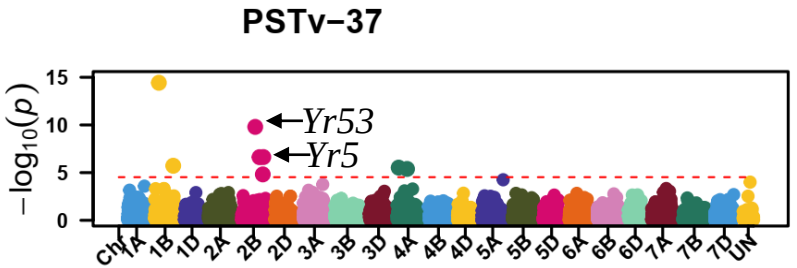
Sources of stripe rust ASR in Great Plains HWW

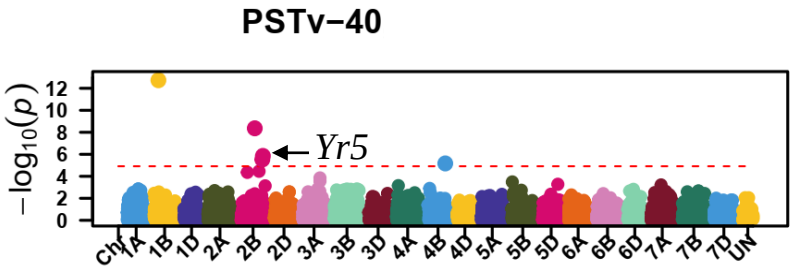
Line name (RGON 2022)	Origin	Known *Yr* genes based on diagnostic markers
TX18DH313	Texas	*Yr5*, *QYr.tamu-2B*
KS21U7494.H5.C1	Kansas	*Yr5*, *Yr15*, *QYr.tamu-2B*
KS21U7321.B2.B7	Kansas	*Lr37/Yr17*, *Yr5*, *Yr15*, *QYr.tamu-2B*
KS21U7445.H9.C3	Kansas	*Lr37/Yr17*, *Yr5*, *Yr15*, *QYr.tamu-2B*
TX18DH305	Texas	*Lr37/Yr17*, *Yr5*, *Yr15*, *QYr.tamu-2B*
TX18DH266	Texas	*QYr.tamu-2B*, *Lr46/Yr29*
TX18DH319	Texas	*Lr37/Yr17*, *Yr15*, *Lr46/Yr29*
KS21HD144	Kansas	*Lr37/Yr17*, *Yr15*, *Lr46/Yr29*
KS21U7274.A.G149	Kansas	*Lr37/Yr17*, *Yr15*, *Lr46/Yr29*
KS21HD147	Kansas	*Lr37/Yr17*, *Yr5*, *Lr46/Yr29*
KS21U7494.G14.C6	Kansas	*Yr5*, *Yr15*, *QYr.tamu-2B*, *Lr46/Yr29*
KS21U7494.H1.B8	Kansas	*Yr5*, *Yr15*, *QYr.tamu-2B*, *Lr46/Yr29*
KS21HD154	Kansas	*Lr37/Yr17*, *Yr5*, *QYr.tamu-2B*, *Lr46/Yr29*
TX18DH303	Texas	*Lr37/Yr17*, *Yr5*, *QYr.tamu-2B*, *Lr46/Yr29*
KS21U7266.E1.B2	Kansas	*Lr37/Yr17*, *Yr15*, *QYr.tamu-2B*, *Lr34/Yr18*, *Lr46/Yr29*
CO19D304R	Colorado	No known genes

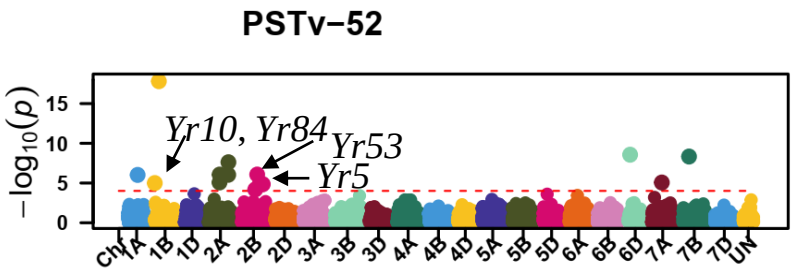
Significant SNPs associated with stripe rust response at seedling stage











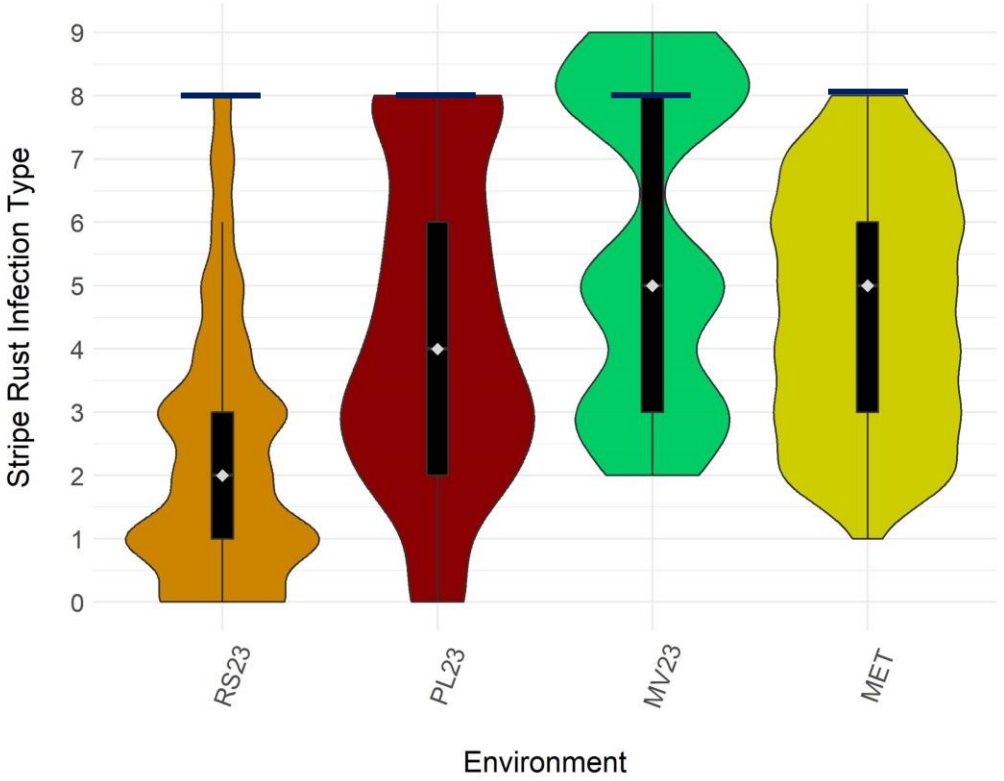
Four stable SNPs associated with ≥ 3 races

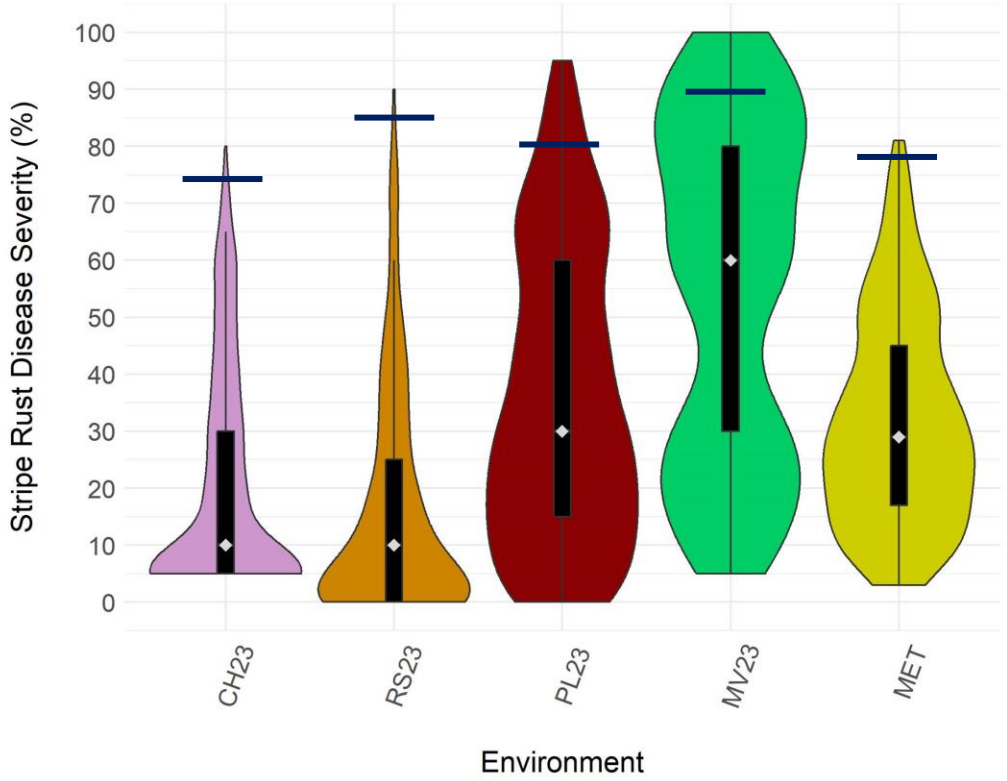
- *S1B_141 655 194*
- *S2B_458 606 839*
- *S2B_598 744 752* (*Yr53*?)
- *S2B_70 650 6028*

GWAS: BLINK

Stripe rust resistance in Great Plains HWW is due to adult plant resistance

140 lines were found to have adult-plant resistance



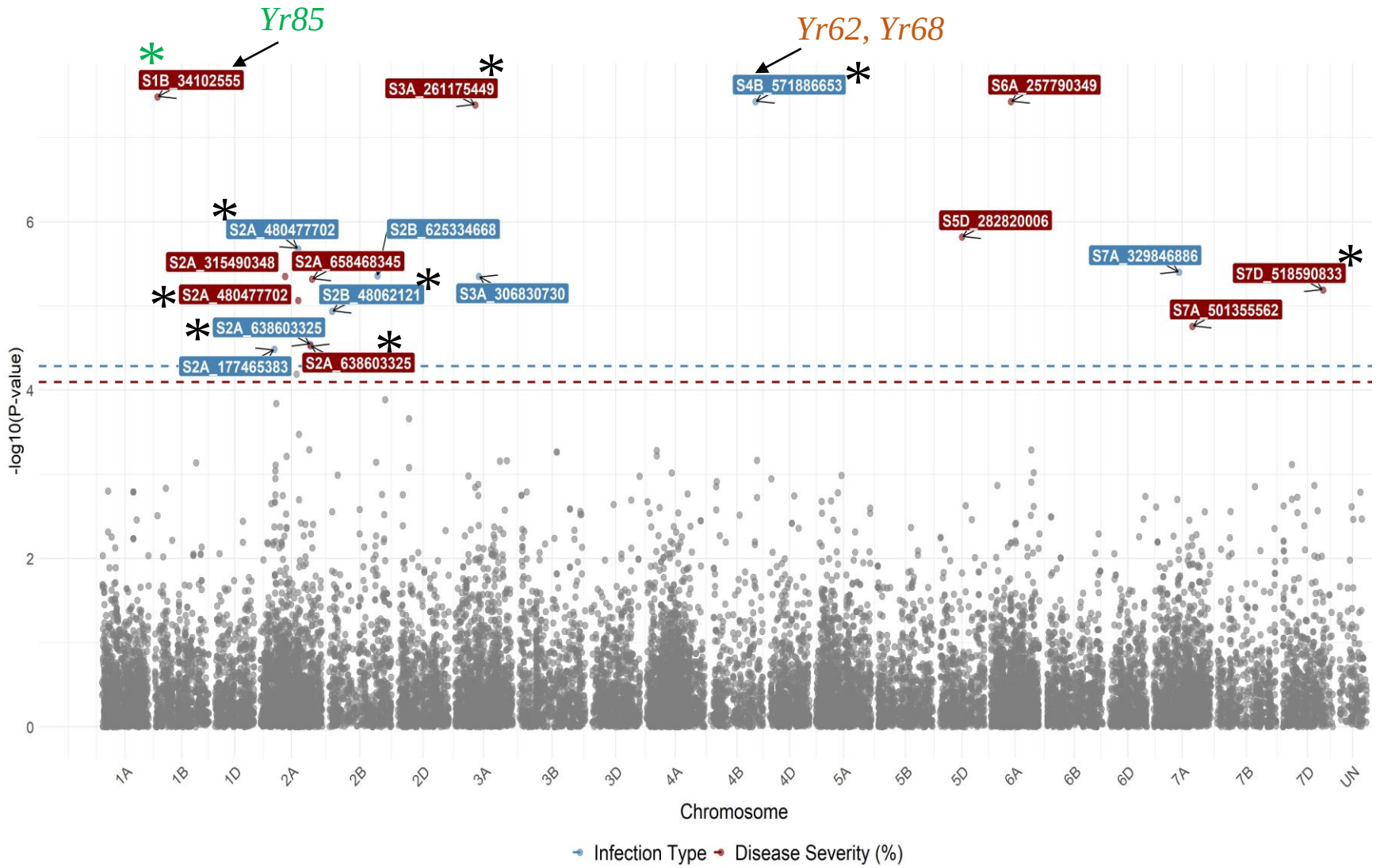


Rajat Sharma

Jagalene

CH23: Chickasha, OK; RS23: Rossville, KS; PL23: Pullman, WA; MV23: Mount Vernon, WA; MET=Multi-environment BLUEs

Significant SNPs associated with stripe rust response at adult plant stage across field experiments

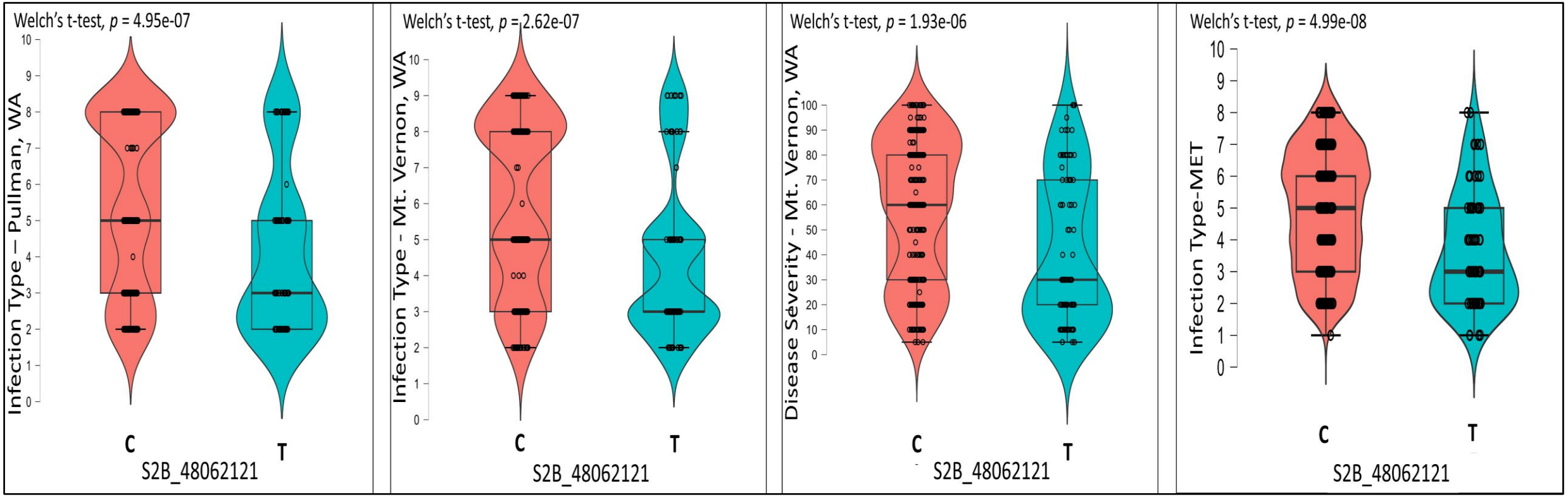


Stable loci

- *S2A_480 477 702*
- *S2A_638 603 325*
- *S2B_48 062 121*
- *S3A_261 175 449*
- *S4B_571 886 653*
- *S7D_518 590 833*

Stable stripe rust APR loci are prioritized for KASP marker development

Marker *S2B_48 062 121*

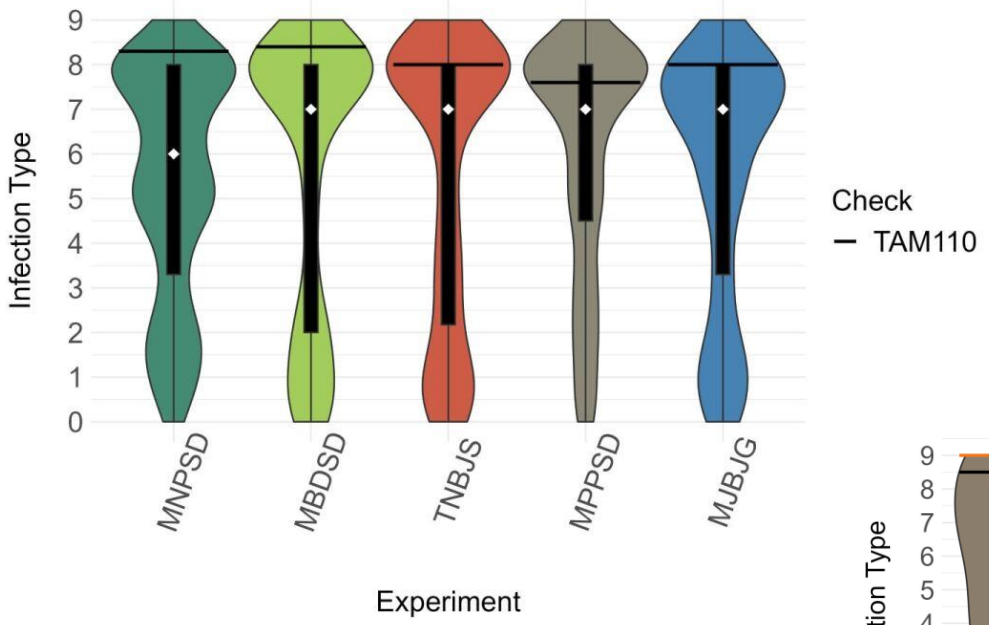


Poster: PE0374

Seedling and adult-plant stage responses to leaf rust in Great Plains HWW

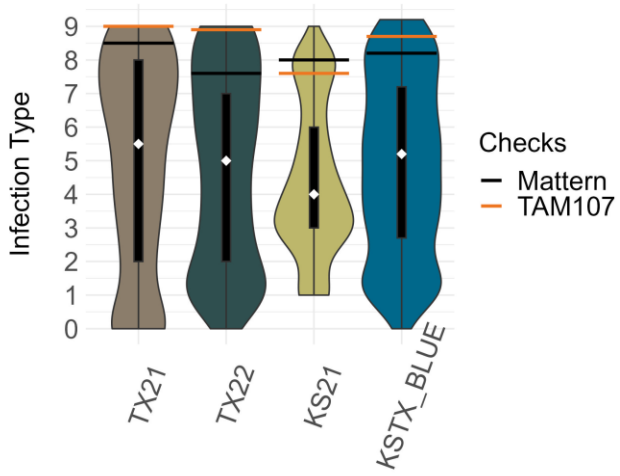
Indira P. Lakkakula

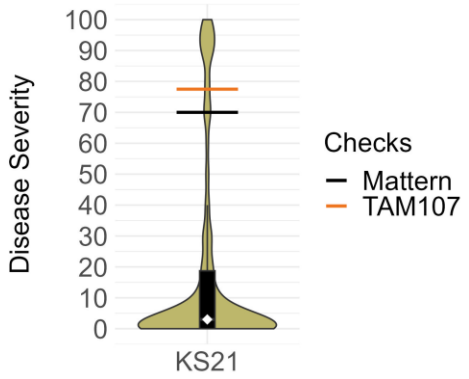
Seedling stage in the greenhouse

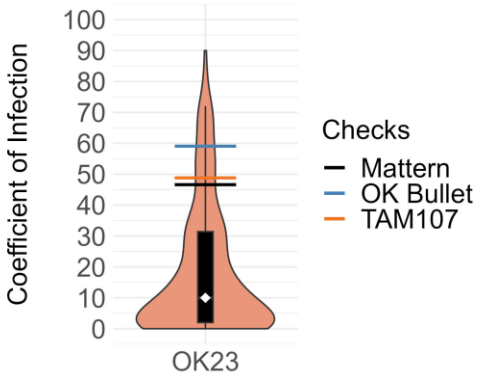


39- 59% of the lines were resistant

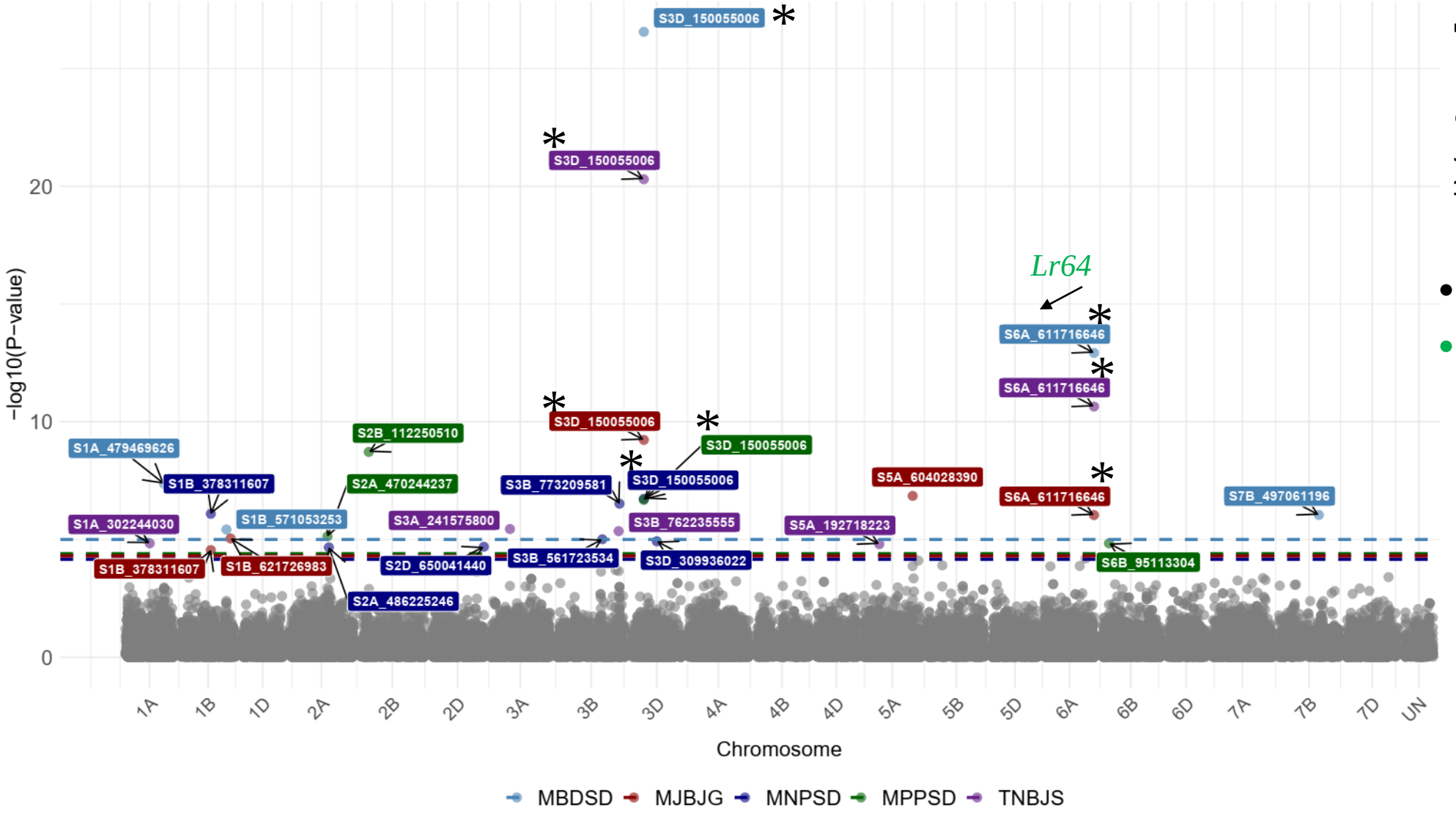
Adult plant stage in field experiments







Significant SNPs associated with leaf rust response at seedling stage

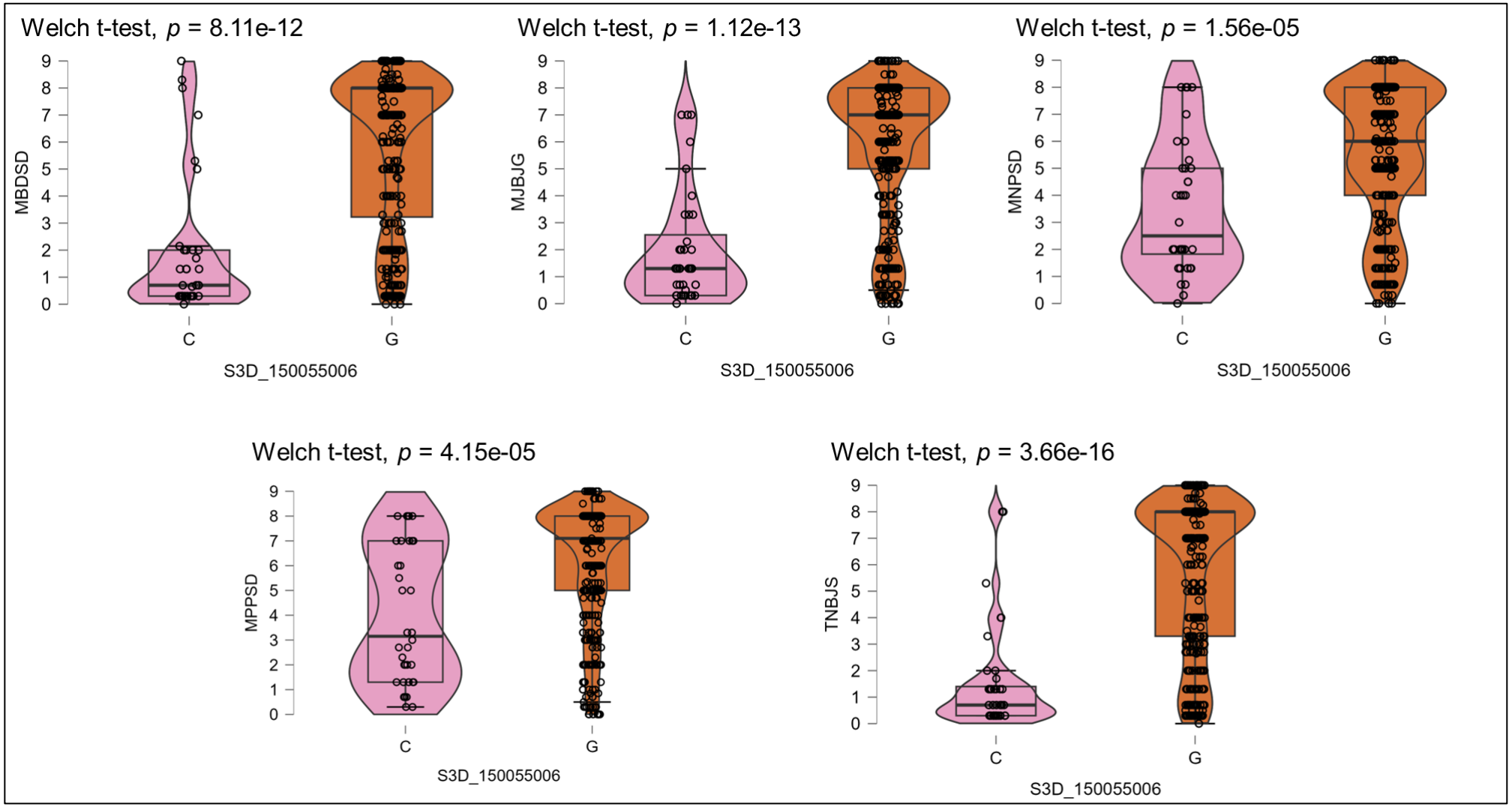


Two stable SNPs associated with ≥ 3 races

- ***S3D_150 055 006***
- *S6A 611 716 646*

GWAS: BLINK

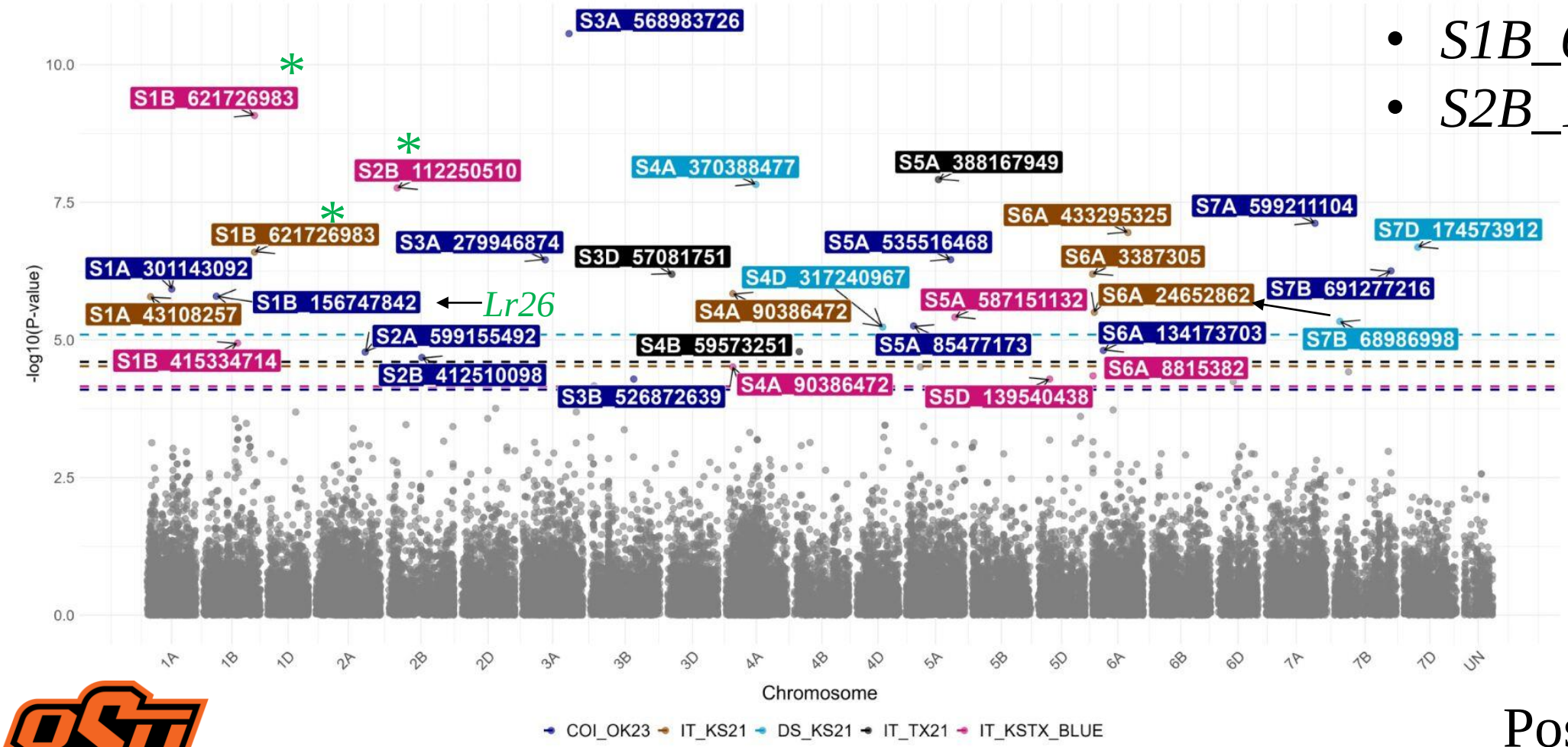
S3D_150 055 006 is associated with ASR against all five *P. triticina* races



Significant SNPs associated with leaf rust response at adult plant stage in field experiments

Identified ASR loci

- *S1B_621 726 983*
- *S2B_112 250 510*



Poster: P00407

Summary

Stripe rust

- A few sources of effective ASR to stripe rust
- 16 lines had a broad spectrum ASR
- Stripe rust resistance in HWW in primarily conferred by APR genes
- Six APR loci are promising for MAS: 2A, 2B, 3A, 4B, and 7D

Leaf rust

- ASR sources were identified
- Novel and stable ASR locus associated with *S3D_150 055 006*
- APR sources?

Acknowledgements

Dr. Jeffrey Boehm

Dr. James A Kolmer

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USDA-AFRI: Award # 2023-67014-39298