Identification, characterization and combination of novel resistance genes against rust in wheat

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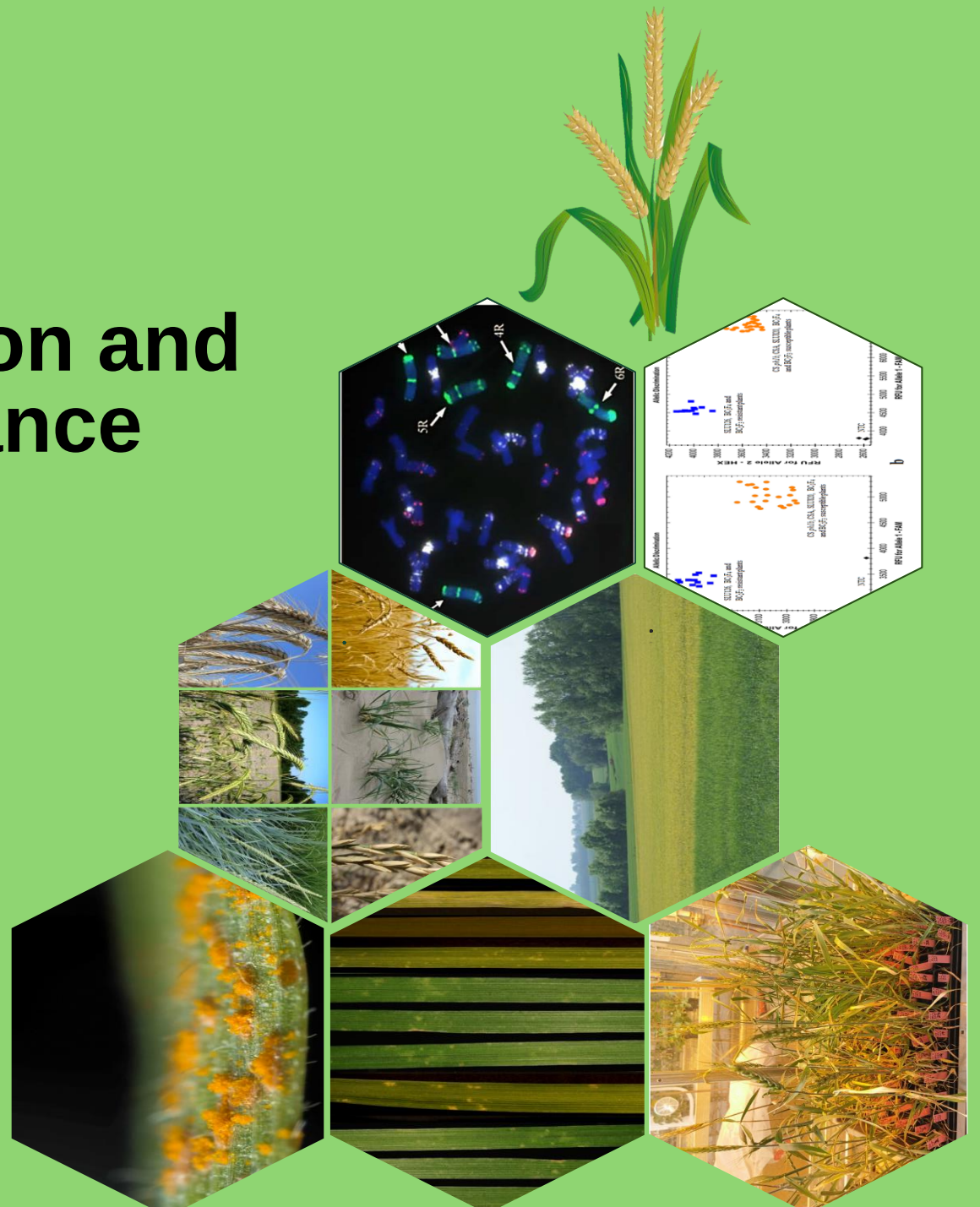

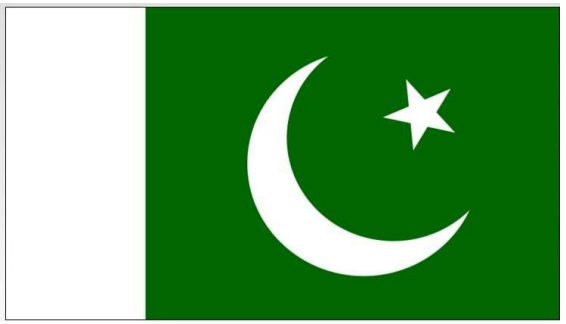

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SWEDISH UNIVERSITY OF AGRICULTURAL SCIENCES

P.hD (Plant Breeding)

Outline

1. Background
2. Aims and objectives
3. Potential of wheat-alien Introgression lines
4. Rye chromosome against Stripe rust (*Yr*)
5. Combination of *Sr* and *Yr* resistance genes
6. Conclusions
7. Future Directions
8. Acknowledgements

Wheat rust 'Cereal killers'

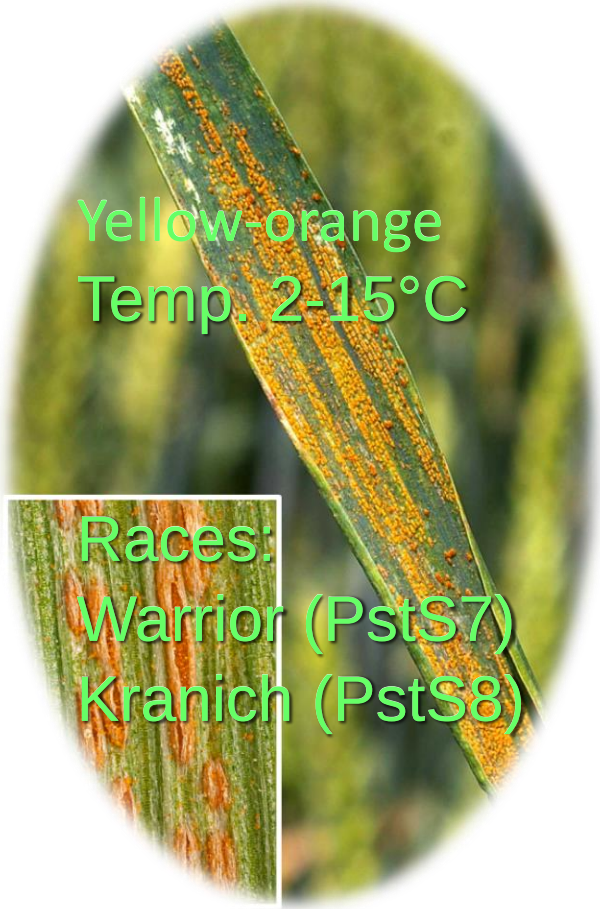
15 million tons of wheat are lost yearly, resulting in a $3 billion loss.

Enough to bake ~ 25.5 billion loaves of bread

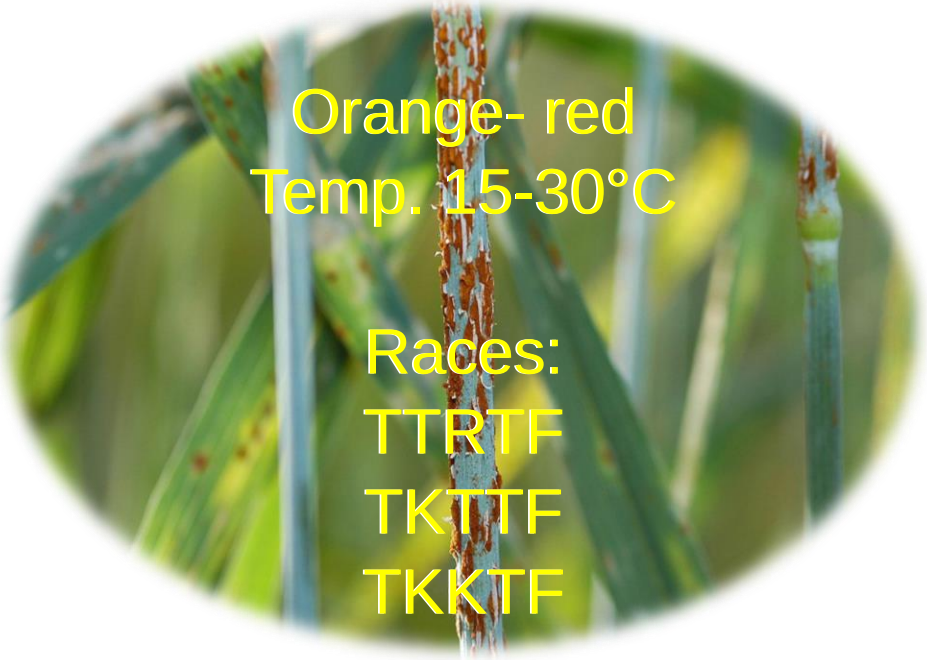
425 million peoples annual bread consumption

https://www.cimmyt.org/news/tackling-wheat-rust-diseases-requires-108-million-a-year-study-shows/

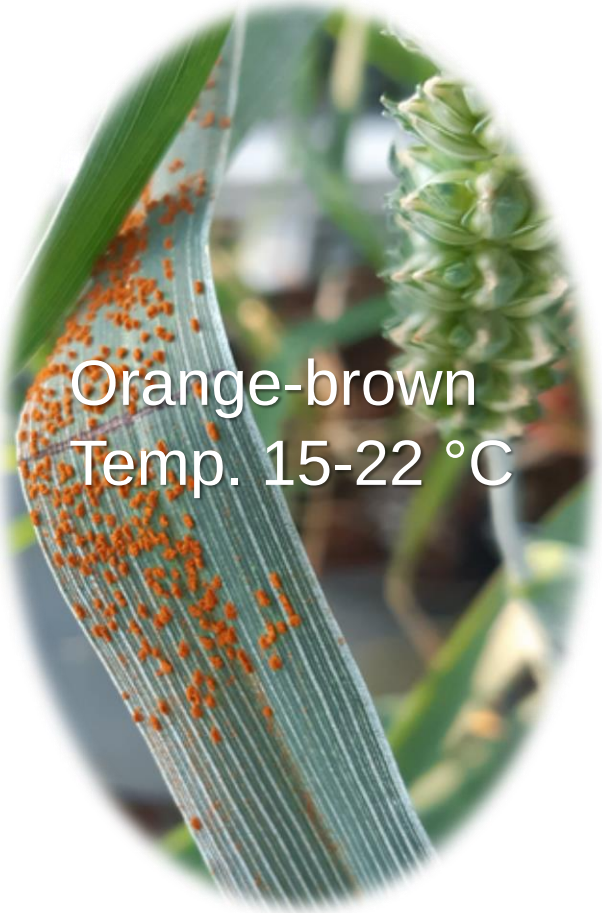
The three wheat rust fungi



Yellow/Stripe rust
Puccinia striiformis f.sp.tritici/Pst



Black/Stem rust
Puccinia graminis f.sp. tritici/Pgt



Brown/Leaf rust
Puccinia triticina

Life cycle of Rust fungi (Cereal Killer)

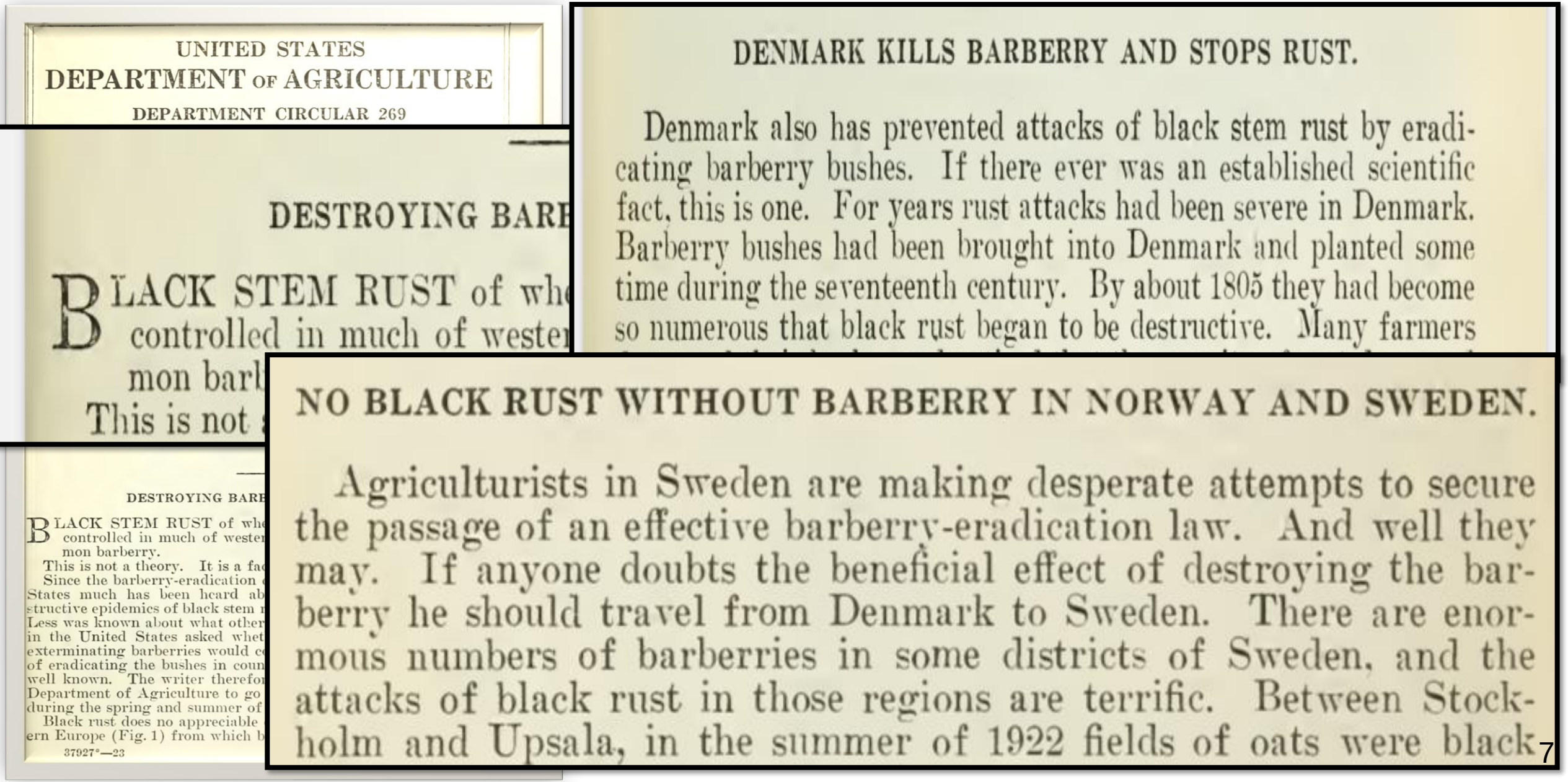
https://bengaluru.sciencegallery.com/phytopia/exhibits/plant-disease

Common barberry removal Campaign (1918 to 1980)

BARBERRY BEE, RED WING, MINNESOTA, SEPTEMBER 20, 1922

https://www.mnopedia.org/thing/barberry-eradication-program-1918-1980

Barberry eradication in Western Europe



UNITED STATES
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DESTROYING BARB

BLACK STEM RUST of whe
controlled in much of weste
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This is not

DESTROYING BARB

BLACK STEM RUST of whe
controlled in much of weste
mon barberry.
This is not a theory. It is a fa
Since the barberry-eradication
States much has been heard ab
structive epidemics of black stem r
Less was known about what other
in the United States asked whet
exterminating barberries would c
of eradicating the bushes in coun
well known. The writer therefo
Department of Agriculture to go
during the spring and summer of
Black rust does no appreciable
ern Europe (Fig. 1) from which b
37927°—23

DENMARK KILLS BARBERRY AND STOPS RUST.

Denmark also has prevented attacks of black stem rust by eradicating barberry bushes. If there ever was an established scientific fact, this is one. For years rust attacks had been severe in Denmark. Barberry bushes had been brought into Denmark and planted some time during the seventeenth century. By about 1805 they had become so numerous that black rust began to be destructive. Many farmers

NO BLACK RUST WITHOUT BARBERRY IN NORWAY AND SWEDEN.

Agriculturists in Sweden are making desperate attempts to secure the passage of an effective barberry-eradication law. And well they may. If anyone doubts the beneficial effect of destroying the barberry he should travel from Denmark to Sweden. There are enormous numbers of barberries in some districts of Sweden, and the attacks of black rust in those regions are terrific. Between Stockholm and Upsala, in the summer of 1922 fields of oats were black

NEWS

TTTTF, a kind of stem rust, damages tens of

By Chris Hill

@ChrisHill75

Agricultural editor

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News > Successful surveillance results in early first detection of Ug99 in South Asia

NEWS DISCOVERY ENVIRONMENTAL HEALTH AND BIODIVERSITY INNOVATIONS

Successful surveillance results in early first detection of Ug99 in South Asia

The detection of a Ug99 race in Nepal highlights the effectiveness of the wheat rust surveillance and monitoring systems developed by CIMMYT and partners.

By CIMMYT

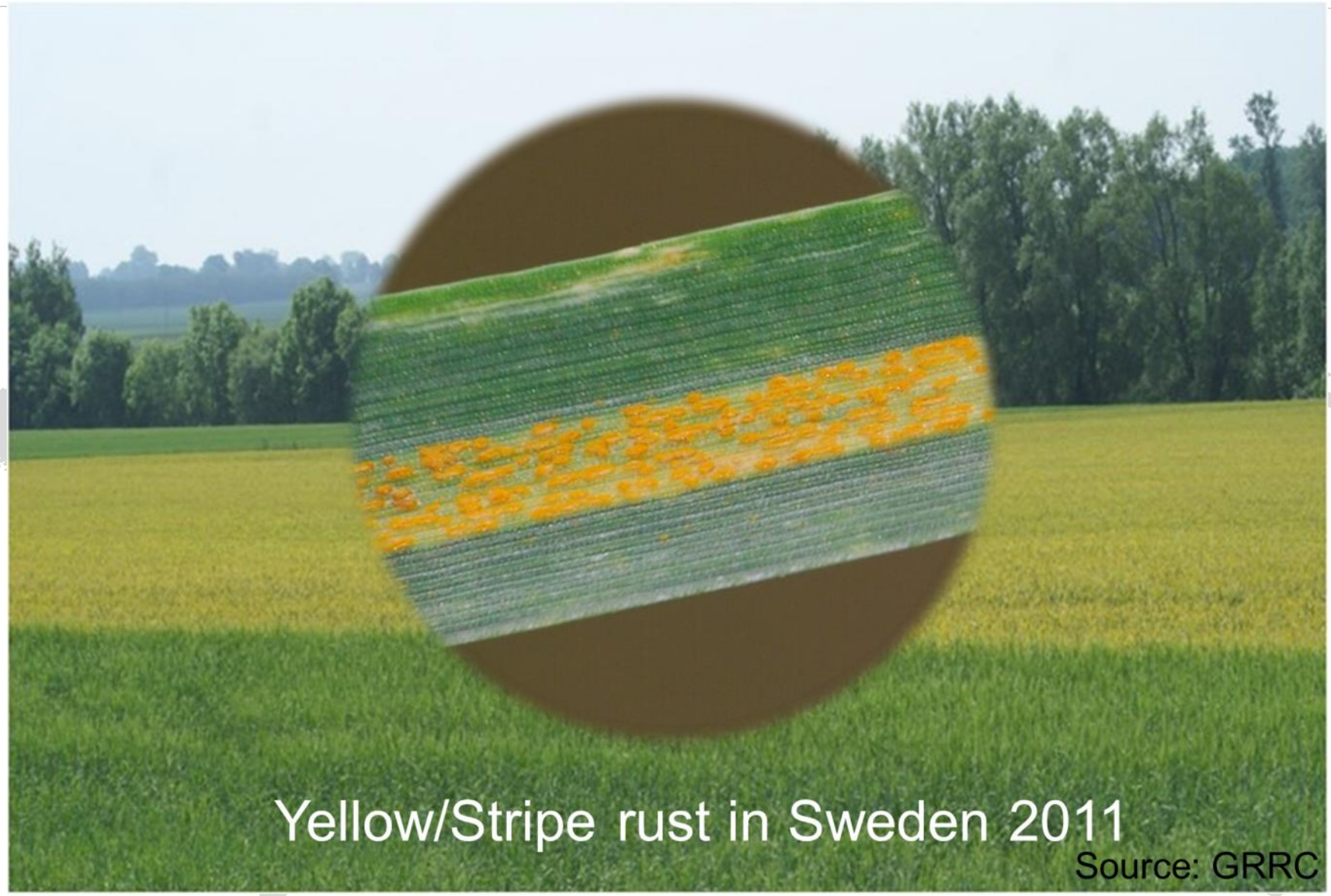
April 3, 2024

Grass has, for millions of years, been attacked by rust fungi. When man began farming and breeding various types of grass, such as our common grains, the

Picture: Paul Fenwick, Limagrain UK.

(Image: Paul Fenwick, Limagrain UK)

Stripe Rust is spreading rapidly across the globe.



Data collected from GRRC and RustWatch

How to respond once disease becomes established?

Agronomic practices

Modern Fungicides

Resistance breeding

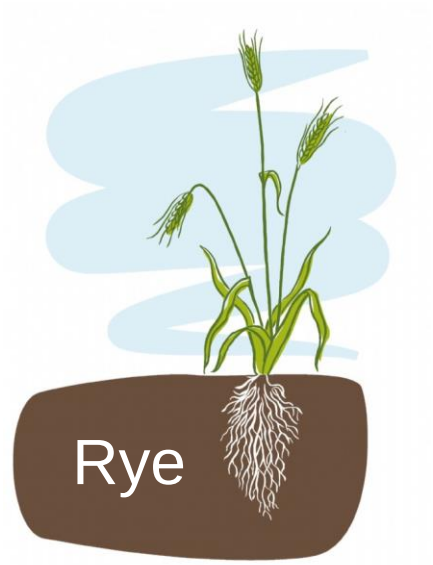
European Union Farm to Fork strategy aims to reduce pesticide use and risk by 30% by 2030

Resistance breeding

- Environmental friendly
- Economical effective

Wild relative to wheat

Durable source
Biotic/abiotic



(Secale cereale)

Rye chromosomes
1R
2R
3R
4R
5R
6R
7R

Study Aim and Objectives

Identifying new sources for stripe rust resistance

✓Wheat-alien introgression lines

✓Wheat-rye introgression lines

Characterization of stripe-rust resistance genes

✓ Physical mapping and developing KASP markers

Incorporating small rye chromatin

✓ In wheat genome

Combination of stripe rust and stem rust

✓ Adapted cultivar


Wheat-alien introgression lines

Plant materials

- ✓ **Wheat-rye introgression lines i.e., SLU124, SLU126, SLU128 etc.**
- ✓ **Wheat-*Leymus racemouses* introgression lines**
- ✓ **Wheat-*Leymus mollis* introgression lines**
- ✓ **Wheat-*Thinopyrum junceiforme* introgression lines**

Prof. Arnulf Hans Merker (1945-2010)

Materials and Methods

- ✓A set of winter and spring wheat-alien introgression lines
- ✓Agronomic performances, diseases and pests screenings
- ✓Allelopathic Potential
- ✓End-use quality analysis (Grain Samples for Micronutrients Concentration and Protein Composition)

Results

- ✓wheat–rye introgression lines highly resistant
- ✓Resistance towards the Hessian fly
- ✓High levels of zinc and iron
- ✓Very low cadmium concentrations
- ✓Large variation in bread-making quality
- ✓Improve production, resistance and quality

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Basis for Durable Resistance and Quality Characteristics in Bread Wheat

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Staffan Andersson[1] Rimsha Ashraf[1] Mahbubjon Rahmatov[1]

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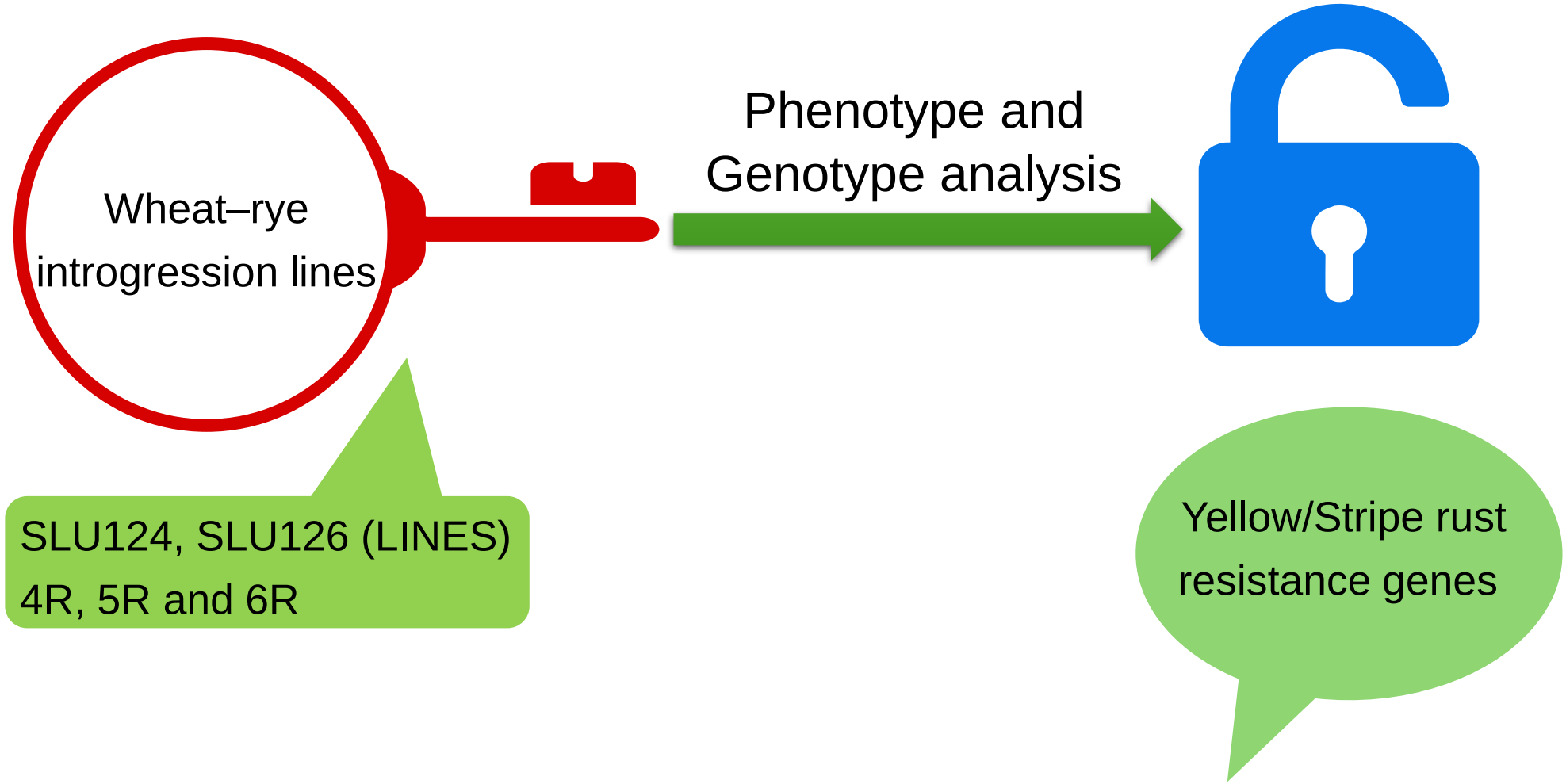
Wheat productivity has been significantly improved worldwide through the incorporation of novel genes from various gene pools, not least from wild relatives of wheat, into the commonly cultivated bread and durum wheat. Here, we present and summarize results obtained from a diverse set of wheat-alien introgression lines with mainly introgressions of rye, but also of

Rye chromosome (6R) for stripe rust resistance gene (*YrSLU)*

Source:https://bengaluru.sciencegallery.com/phytopia/exhibits/plant-disease

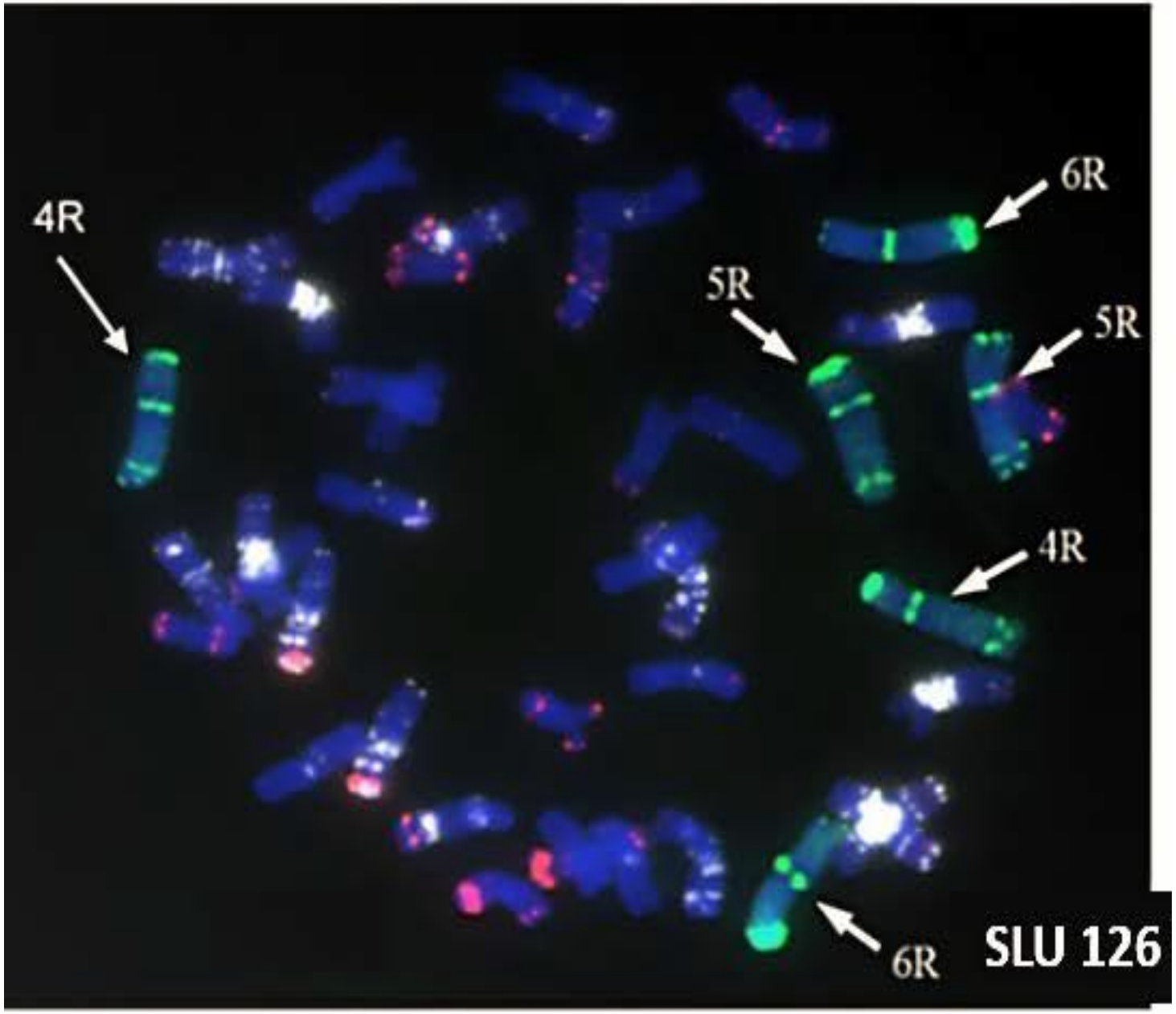

Wheat–rye introgression lines
Phenotype and Genotype analysis
SLU124, SLU126 (LINES) 4R, 5R and 6R
Yellow/Stripe rust resistance genes

Line SLU126

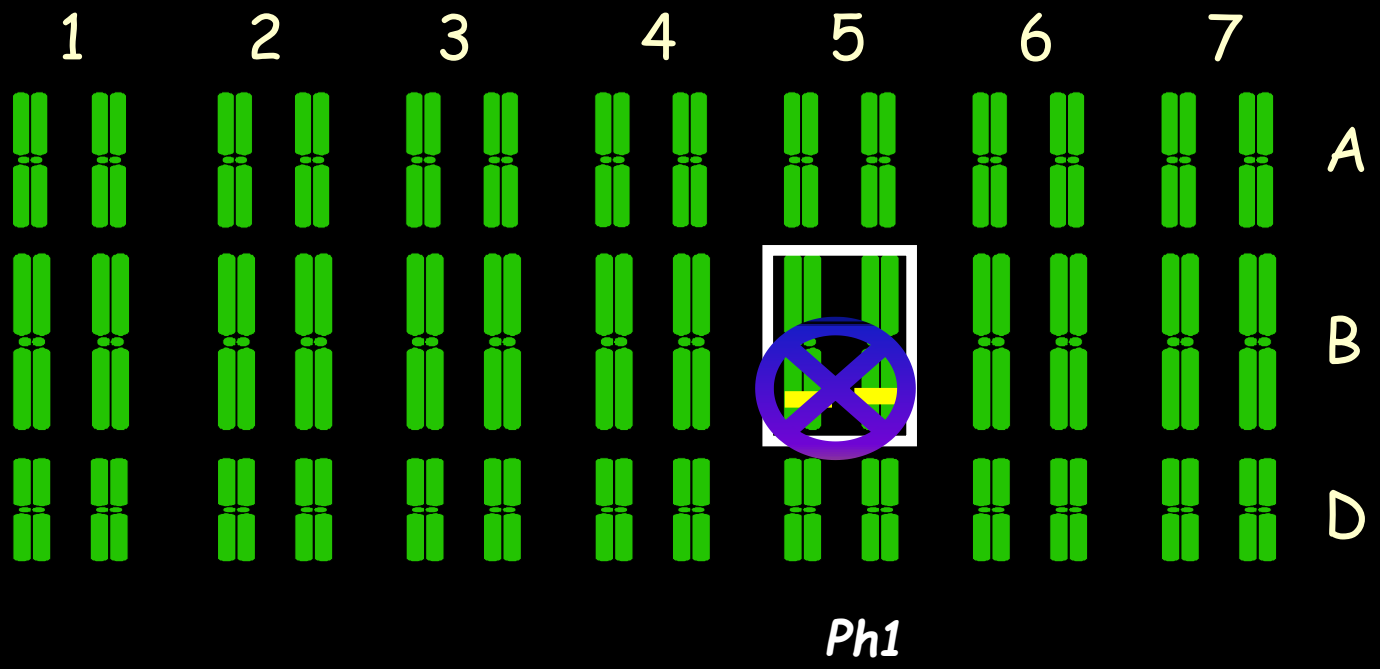
KRANICH UK94/519 DK66/02 Taj01a/10 ER02/03 DK11/09 DK71/93 AF87/12 DK09/11 SE100/09 TR34/11

30 *Yr* races

Fluorescent in situ hybridization (FISH)



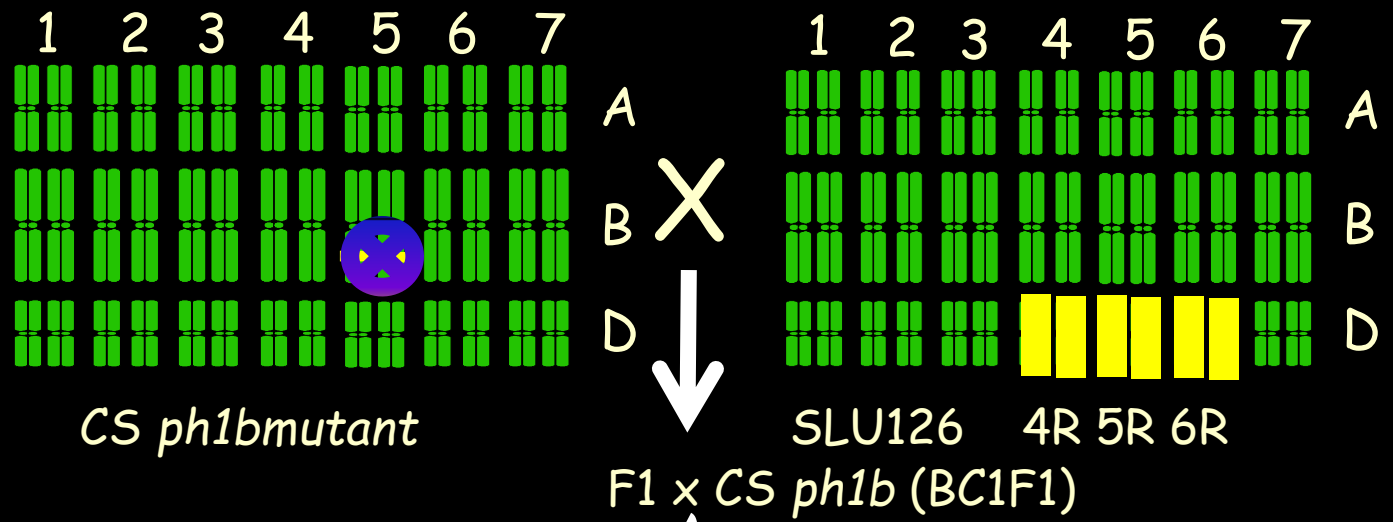
The role of *Ph* (*Ph1*) locus



Pairing homoeologous loci (*Ph*)

(Sears, 1977)

Induce Homoeologous Recombination Using CS *ph1b* Mutant



BC1F2
BC1F3
BC1F4

BC2F1
BC2F2
BC2F3

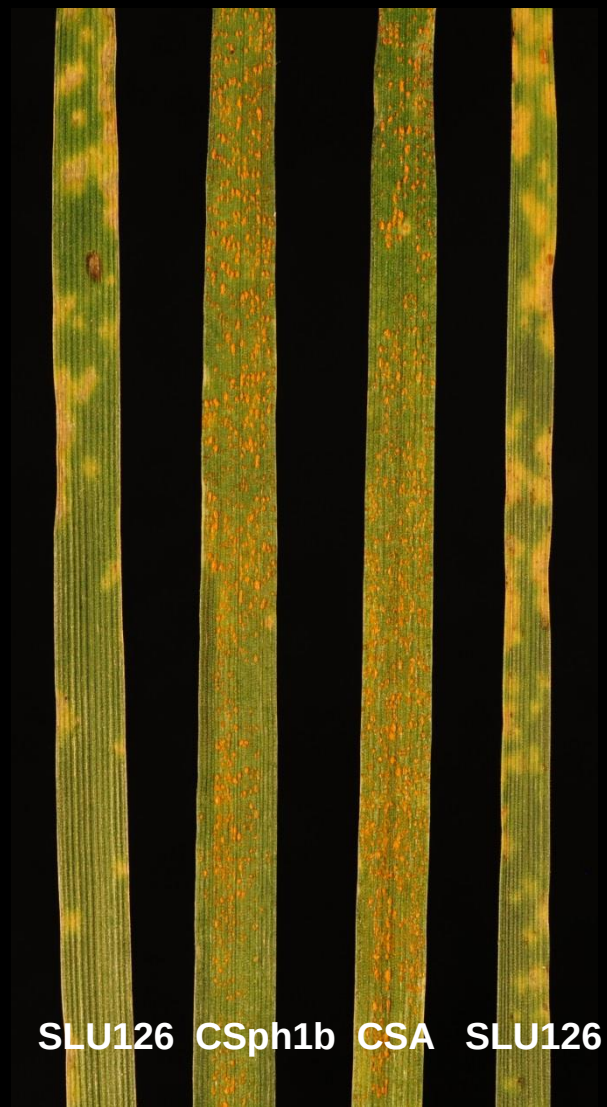
- **Identify recombinants**
  - Yellow rust seedling resistance tests PSTv-14, PSTv-37,PSTv-40, PSTv-218 and PSTv-221
  - Molecular markers analysis for 4R, 5R, 6R rye chromosomes

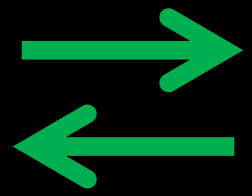
Yr seedling resistance tests in BC_1F_1

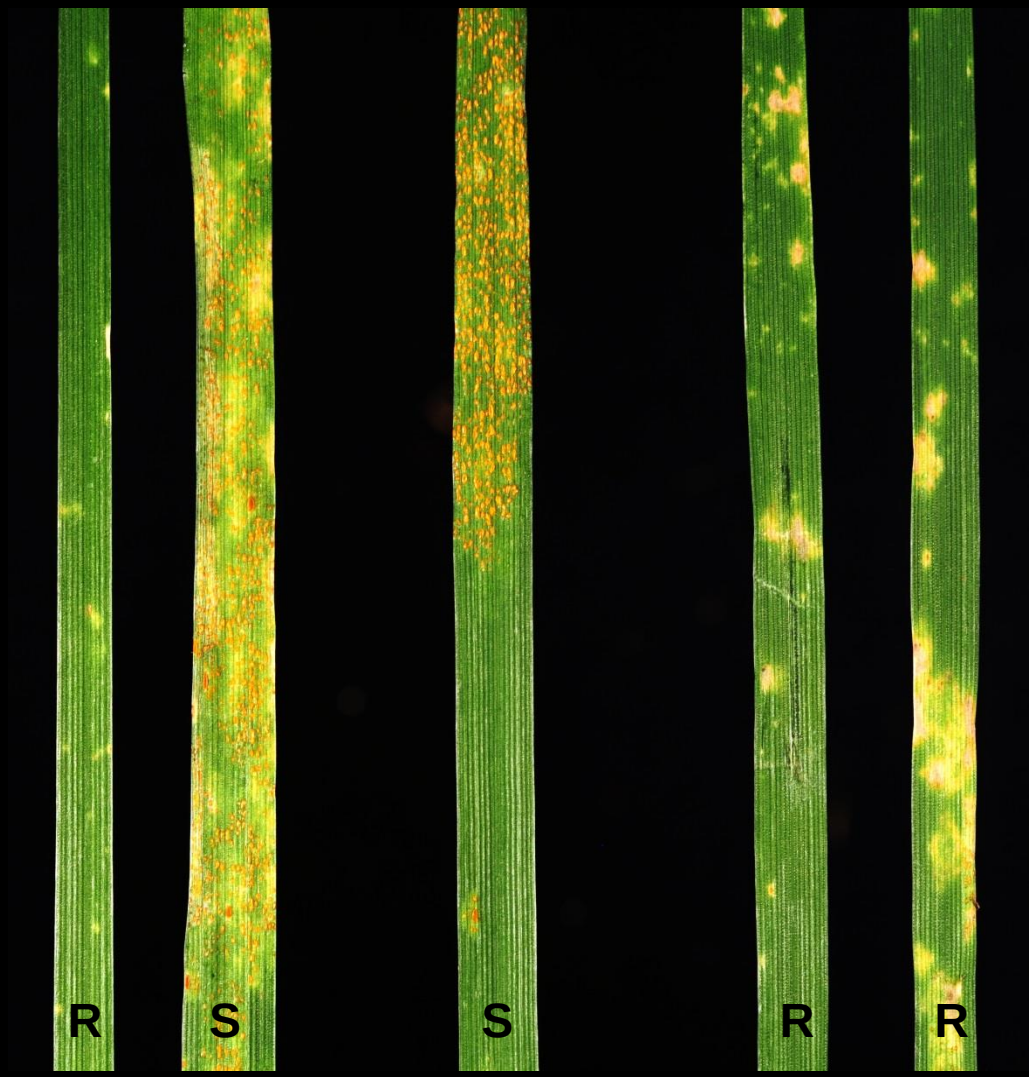
Mix of PSTv14 and PSTv37 races

Parental Lines

BC_1F_1







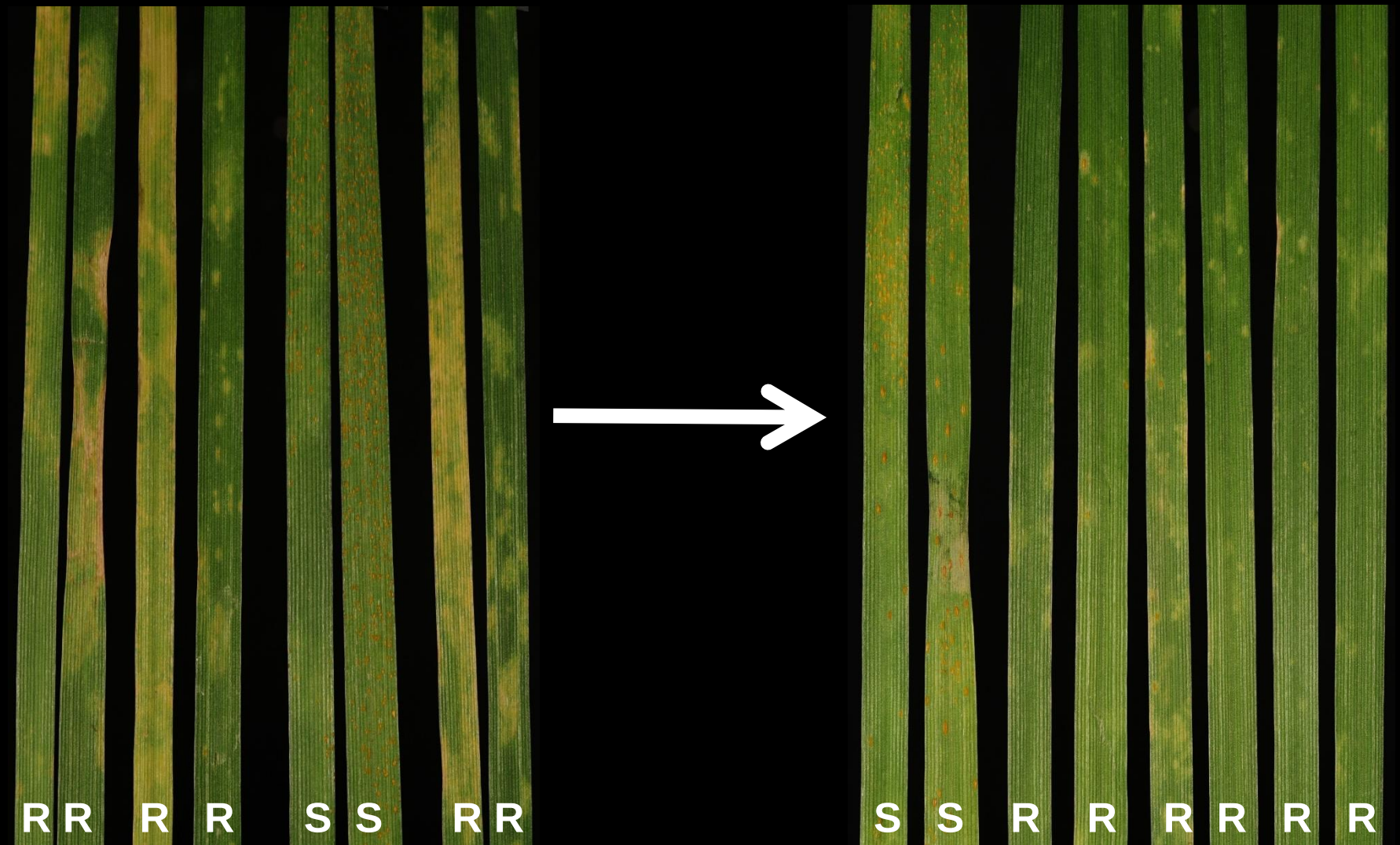
Yr seedling resistance tests in BC1F4 and BC2F3 (Family N3-5)

Line 245
BC_1F_3

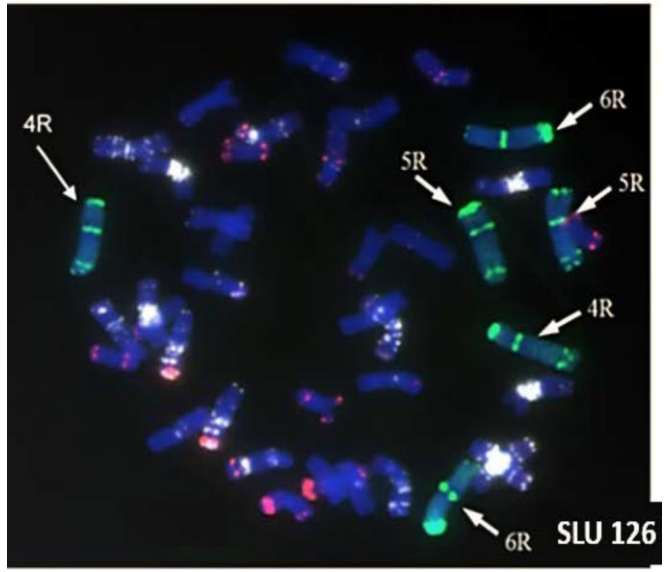
Line 180
BC_2F_2

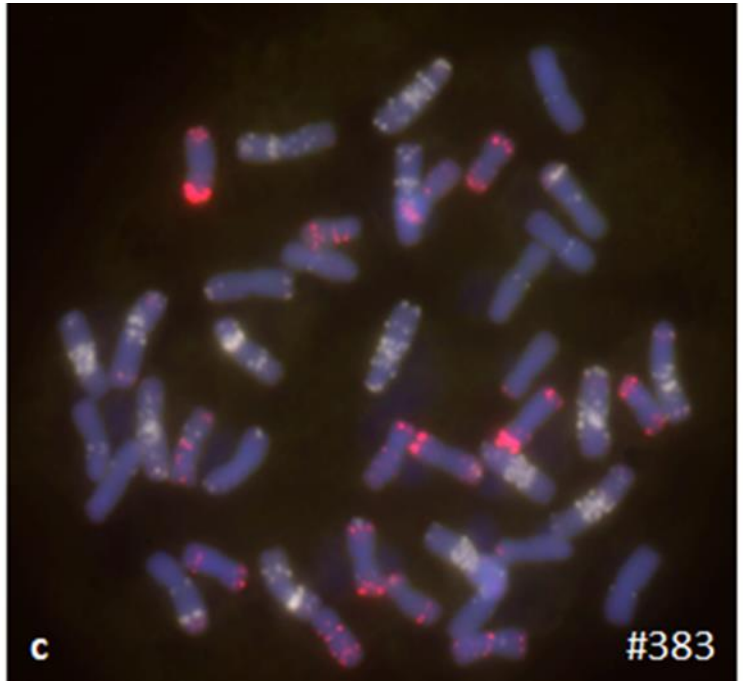
Line 180
BC_2F_3

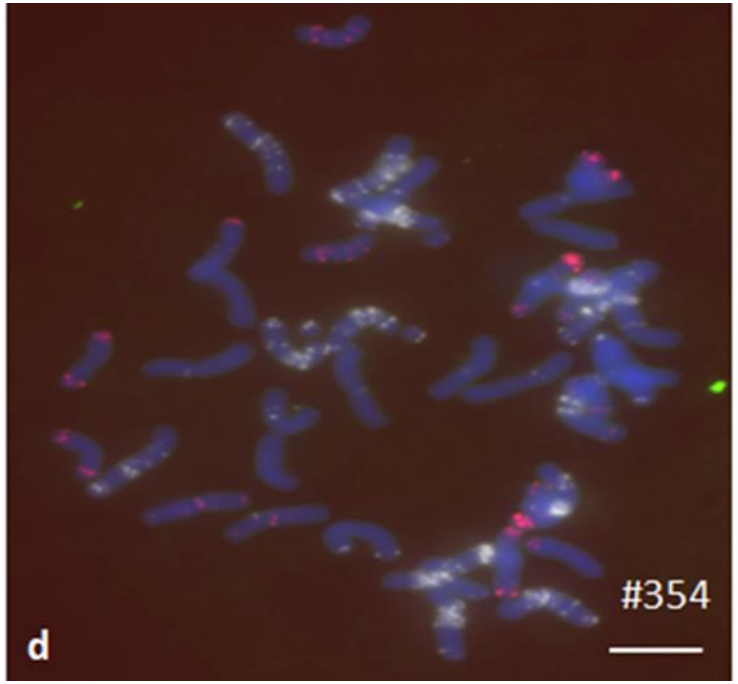
Line 245
BC_1F_4



Cytogenetic analysis (FISH and GISH) in BC1F4 and BC1F3







Genotyping by Sequencing (GBS)

✓GBS in parental lines (SLU126, CS*ph1b*, CSA)

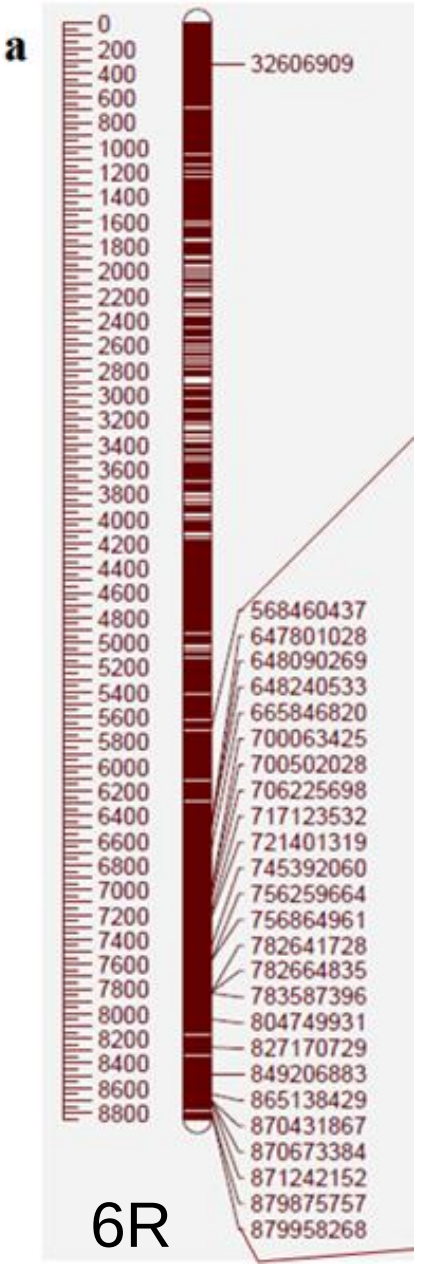
✓Aligned the GBS to wheat and rye reference genomes

Chromosome	High-quality SNP (after filtering)
6R	10675

NLR (Nucleotide binding site leucine rich repeats) sequences for Rye

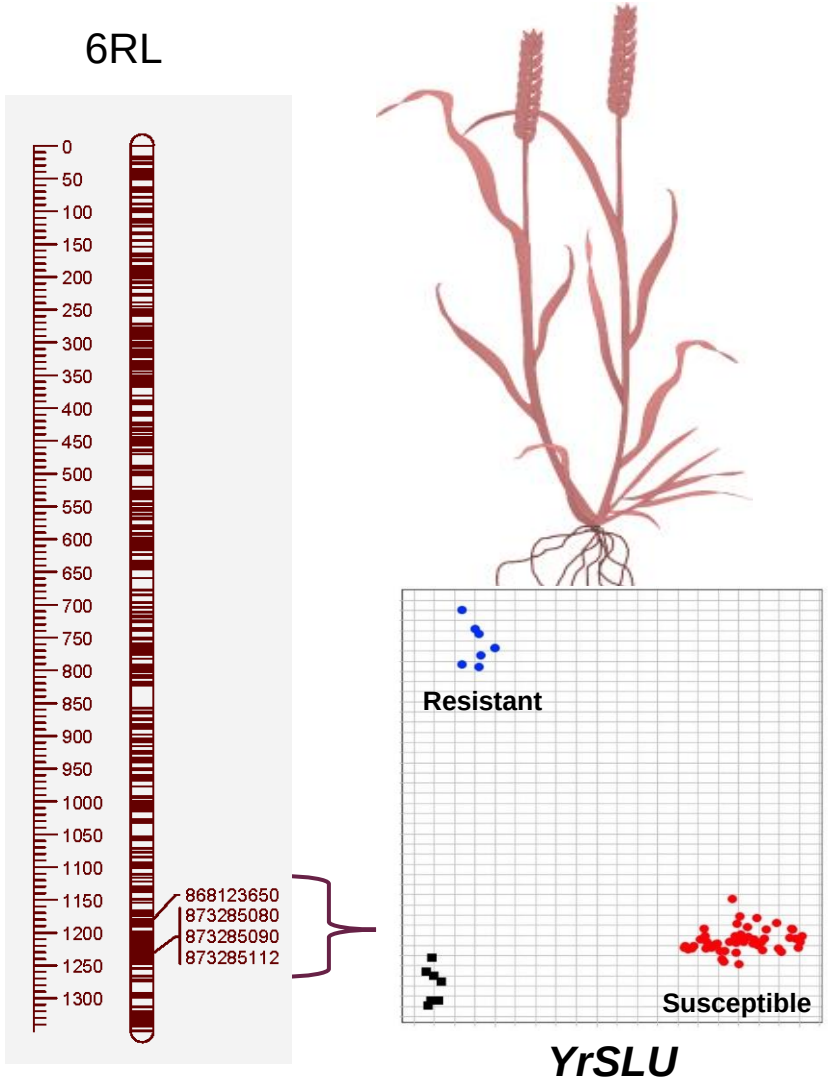
✓NLR genes for Rye by using NLR parser software

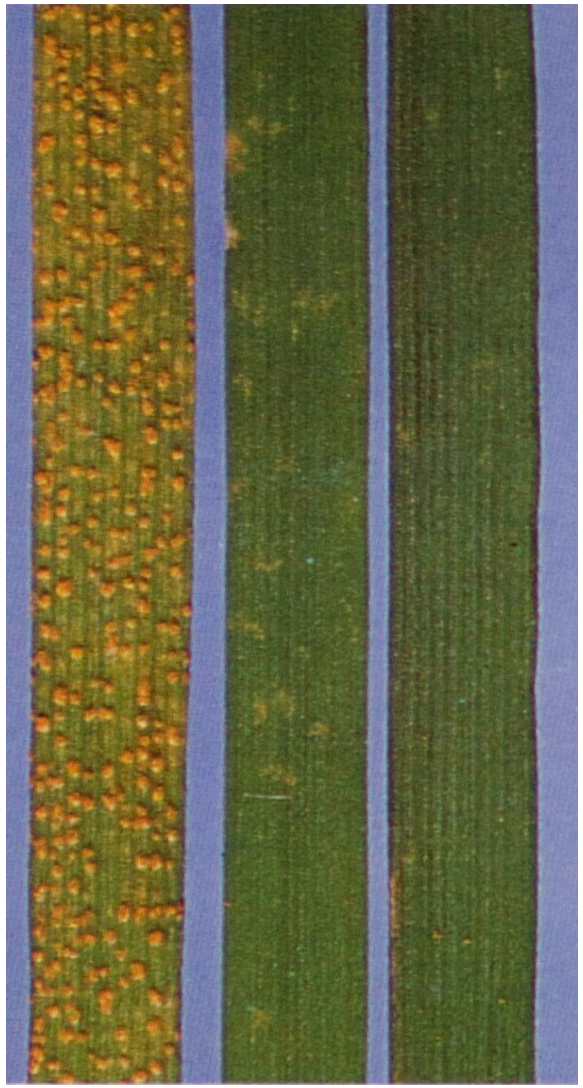
Rye Chromosome	NLR genes	Designated NLR to SLU126 (6R)
6R	184	26



New resistance genes *YrSLU*

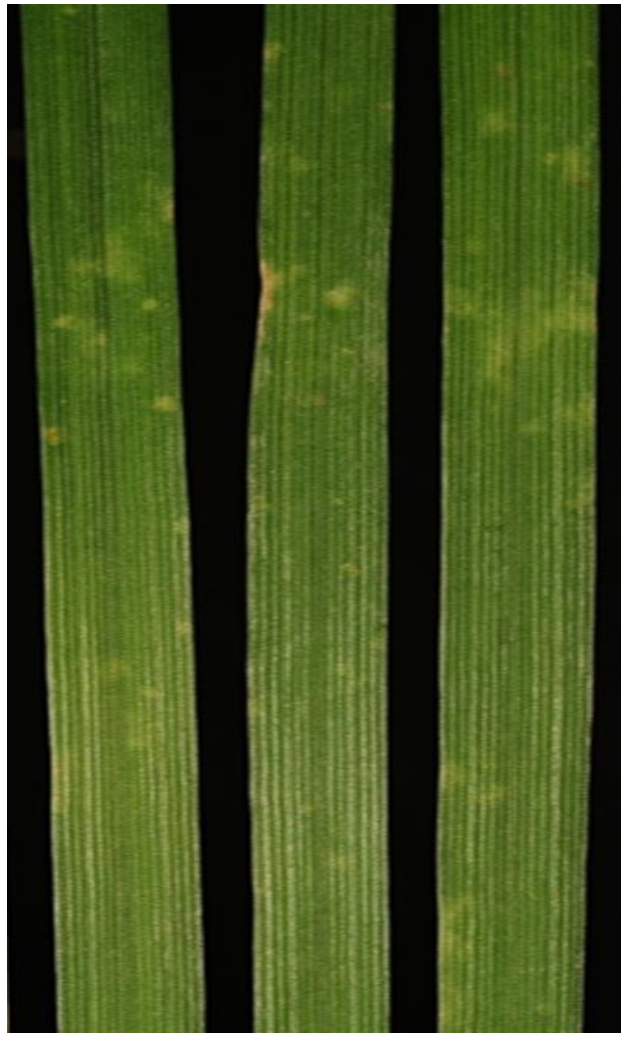
6DS.6DL.6RL.6DL
wheat-rye cryptic translocation





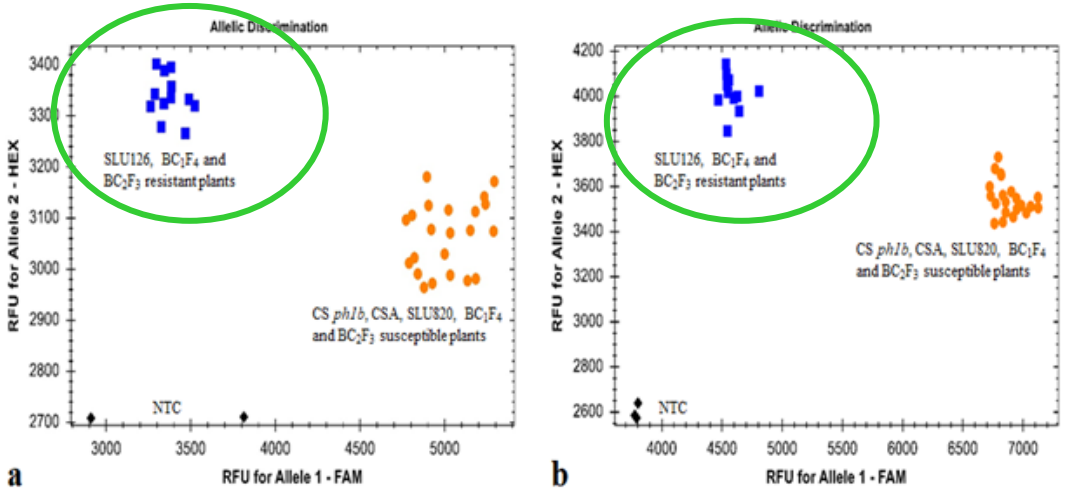
CSph1b *YrSLU1* *YrSLU2*

Further analysis



Resistant to PSTv-14, PSTv-37,PSTv-40 and PSTv-221

Segregating against Pstv-218



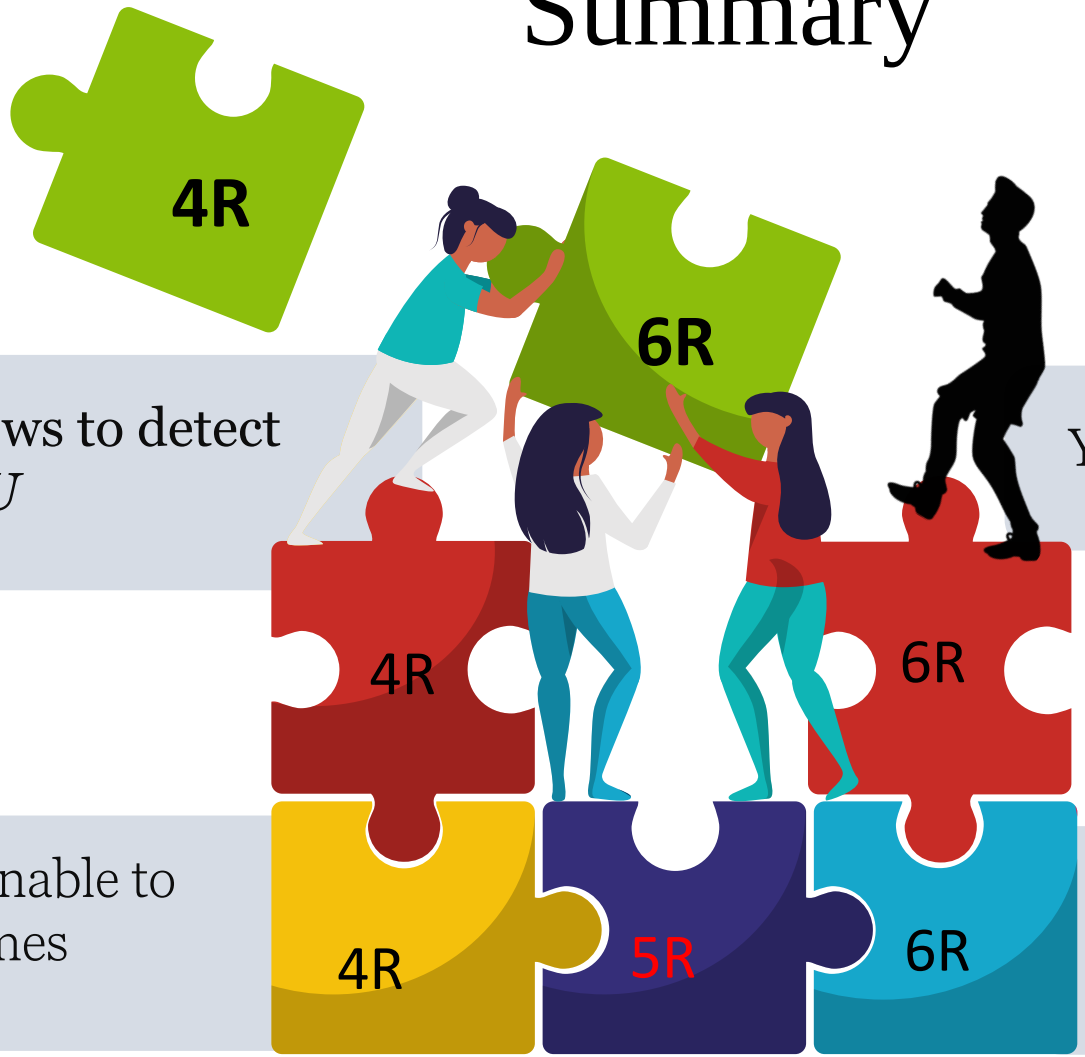
YrSLU1 ***YrSLU2***

Yellow/Stripe rust resistance genes

Summary

GBS analysis allows to detect *YrSLU*

Yes, its 6R Cryptic translocation



Molecular **markers** unable to detect rye chromosomes

Cytogenetic also confirms no rye chromosome in resistant lines

Wheat-rye introgression lines **SLU126 (6R)**

APS Publications

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Identification of a Small Translocation from 6R Possessing Stripe Rust Resistance to Wheat

Rimsha Ashraf, Eva Johansson, Pernilla Vallenback, Brian J. Steffenson, Prabin Bajgain, and Mahbubjon Rahmatov

Affiliations

Published Online: 23 Mar 2023 | https://doi.org/10.1094/PDIS-07-22-1666-RE

Abstract

Wheat stripe rust, caused by *Puccinia striiformis* f. sp. *tritici* Eriks. & E. Henn, is the most devastating fungal disease of bread wheat. Here, a wheat-rye multiple disomic substitution line, SLU126 4R (4D), 5R (5D), and 6R (7D), possessing resistance against

Opportunities and challenges with the combining of novel stem and stripe rust resistance genes in the same genotype

Marker-assisted gene pyramiding

Stem and stripe rust races

Seedling analysis
TTKSK, TTRTF, and TTTTF
Psts10, Psts16, Psts7, Psts13

KASP Markers

Speed Breeding
Normal Green house

Linkert, Navruz, SLU-Elite

Crossed with Adapted Cultivars

Sr59+YrSLU
Single wheat cultivar

Sr59 and YrSLU

Sr59 ✕ *YrSLU*

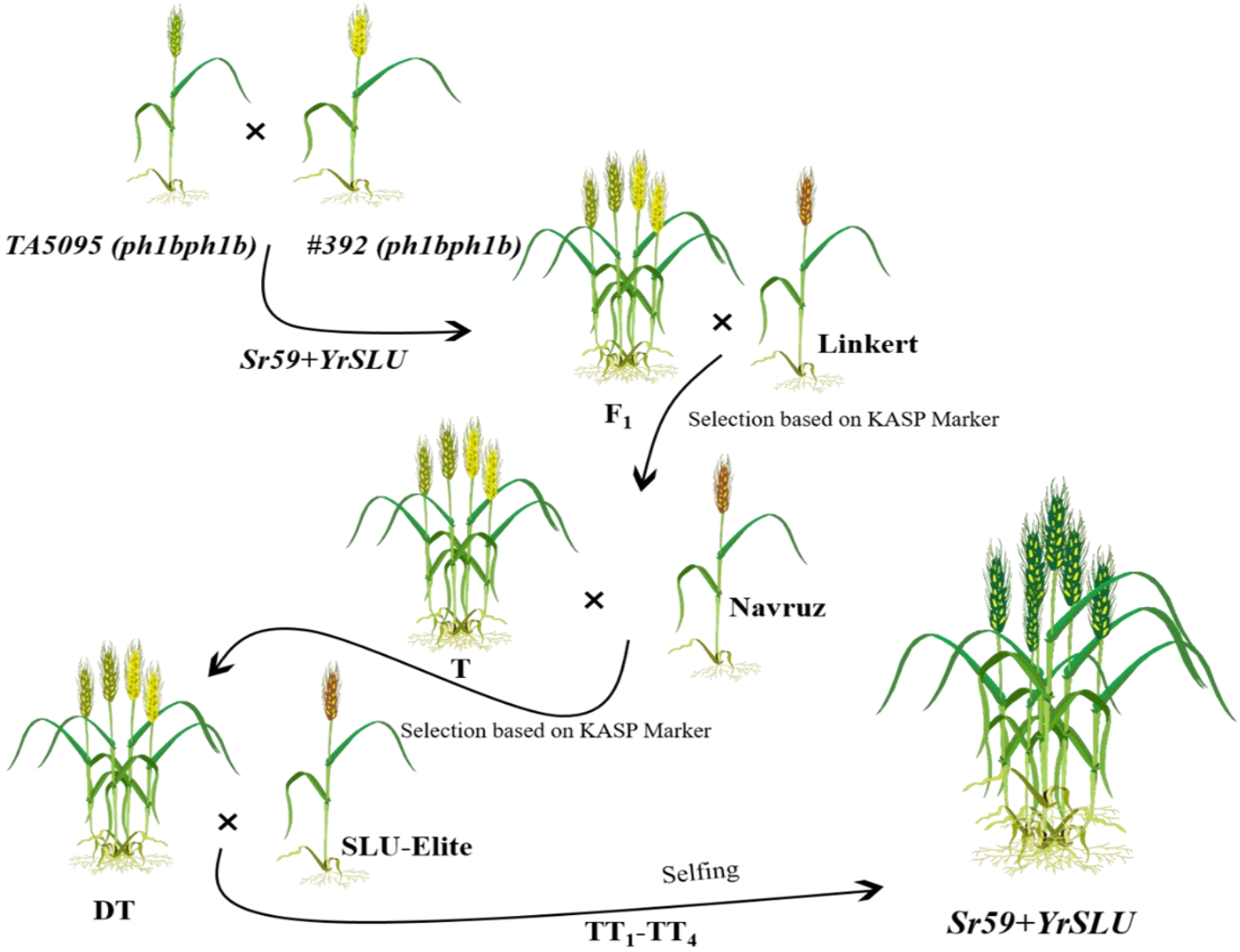

Figure . Scheme of the performed marker-aided gene pyramiding for stem rust and stripe rust resistance, Top-cross (T), Double Top-cross (DT), Triple Top-cross 1 (TT_1), Triple Top-cross 4 (TT_4)

Speed Breeding

21 April 2021

Planting

2 June 2021

Grain Filling

7 June 2021

Dough Development

- Within 6-7 weeks

Greenhouse condition

- Humidity: 40-80%
- Temperature: 18º-24ºC (20 hours Photoperiod)
- High pressure sodium lamps

Main Results

✓Successful transfer of *Sr59* and *YrSLU*

✓Complete resistance to stem rust races

✓Segregated against stripe rust races

✓Confirm genes of interest

Conclusions

Wheat-alien introgression lines has distinct potential for wheat improvement

Validation of KASP markers for *YrSLU* genes transferred from 4R and 6R

Wheat-rye substitution lines possess resistance to 30 races of stripe rust.

Cryptic translocation 6DS.6DL.6RL.6DL temporarily designated *YrSLU* genes

NLR genes for 4R, 5R and 6R rye chromosomes

MAS gene pyramiding provide durable disease resistance against stripe and stem rust

Phenotype and genotype analysis, effective in identifying the source of resistance to stripe rust

Future Directions

06 Gene pyramiding into Swedish wheat cultivar

05 End-use quality analysis

04 Agronomic Performances, Diseases and Pests

03 Evaluation with additional *Yr* races

02 Functional Analysis

01 Gene Designation for *YrSLU*

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Dr. Pernilla Vallenback,
wheat breeder
Lantmännen Lantbruk

Prof. Mogens Støvring Hovmøller
GRRC, Denmark

Thank You

? What's there?

? How does it work?

? How did it come to be this way?