Disease Resistant Wheat

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ROTHAMSTED RESEARCH

WGIN Stakeholders Meeting 16th November 2018

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Wheat Genetic Improvement Network

Major wheat pathogens in UK

Wheat yellow rust
Puccinia striiformis f.sp. *tritici*

Septoria leaf blotch
Zymoseptoria tritici

Wheat brown rust
Puccinia triticina

Powdery mildew
Blumeria graminis f.sp. *tritici*

Take-all disease
Gaeumannomyces tritici

Exploiting the Watkins landrace collection

- Landraces collected by A.E. Watkins in the 1920s and 1930s
- Wide geographic distribution – Africa, Australia, Amercias, Middle East and Europe
- Novel genetic diversity compared to elite bread wheat (Winfield *et al*. 2017)

- Initial foliar and root disease screening carried out in 2008 on the RRes Farm

Exploiting the Watkins landrace collection

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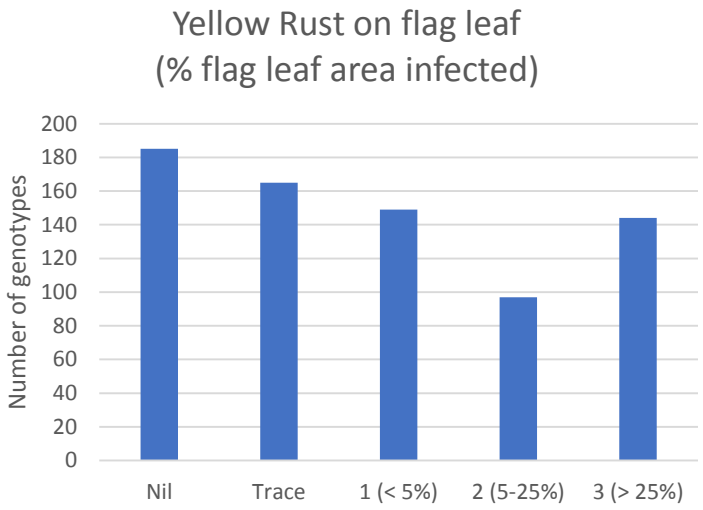

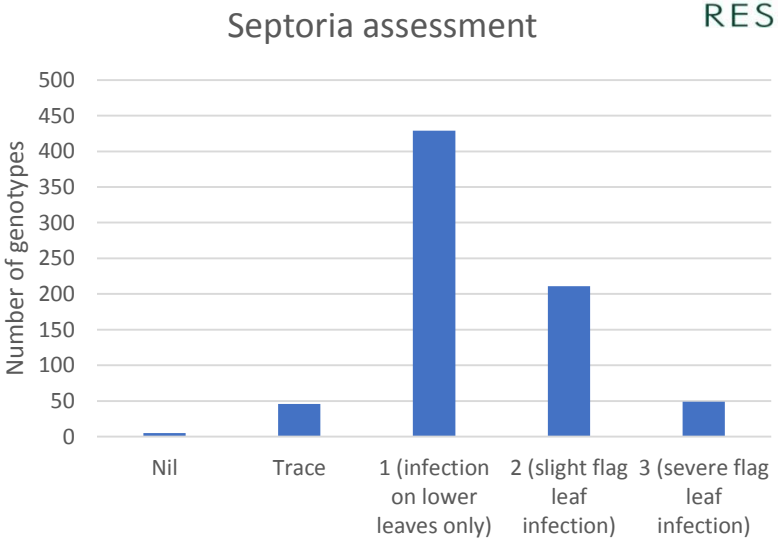

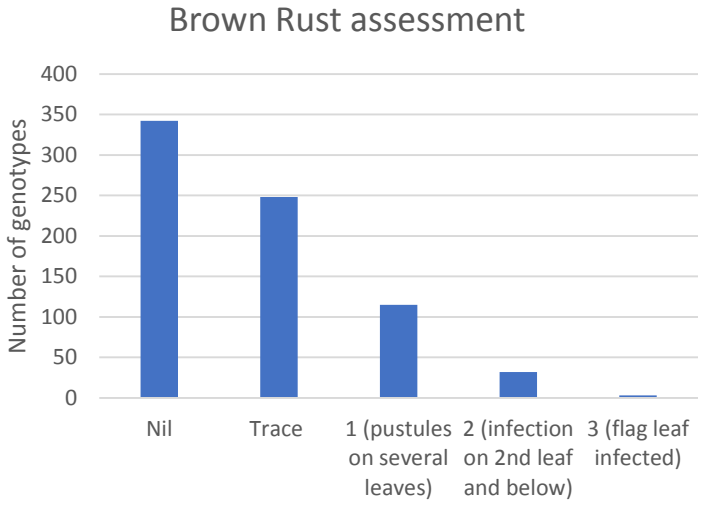

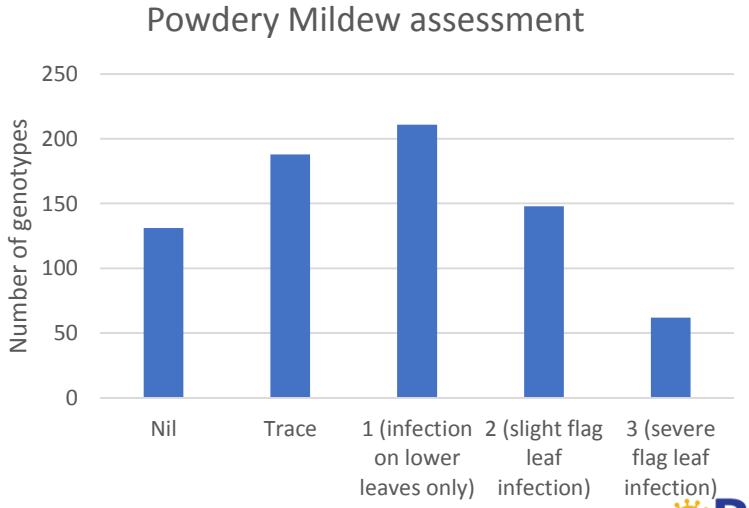

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Exploiting the Watkins landrace collection

10 Watkins genotypes with a high degree of resistance to all 4 foliar pathogens

			2008 Disease assessments			
Accesssion	Growth habit	Country of Origin	Yellow rust	Brown rust	Septoria	Mildew
18	Spring	India	0	0	T	T
137	Spring	Australia	T	T	0	T
203	Winter	India	0	0	0	T
231	Spring	Hungary	0	0	T	0
262	Spring	Canary Islands	0	0	0	0
399	Spring	China	T	0	T	0
495	Spring	Morocco	0	0	T	0
610	Spring	Yugoslavia	0	0	T	T
733	Spring	Iran	T	T	T	T
786	Spring	USSR	0	T	T	0

0 – no disease , T = trace

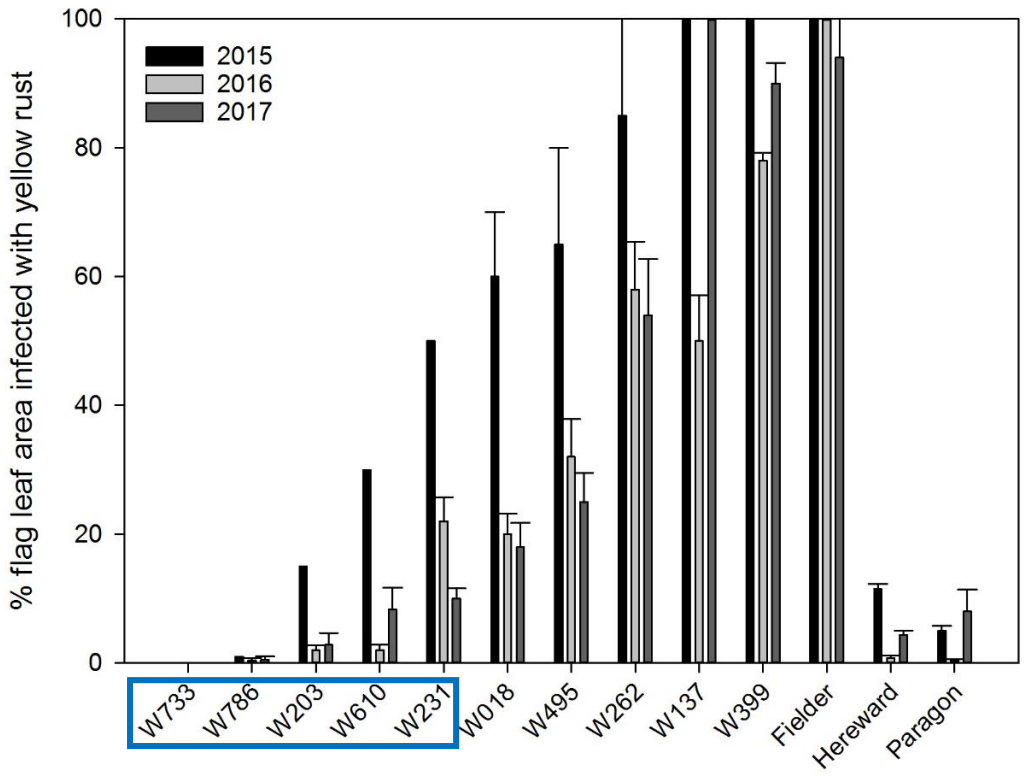
Watkins foliar disease field trials (2015-2017)

26th June 2015 1st wheat Long Hoos 4

Yellow rust dominant disease that developed across field trials

No fungicides applied to allow natural disease to develop

Evidence of resistance to yellow rust



Disease assessments carried out during flowering/grain filling

- W733, W786, W203, W610 and W231 all show moderate to strong adult plant resistance against yellow rust under field conditions

Watkins 733 – no yellow rust sporulation

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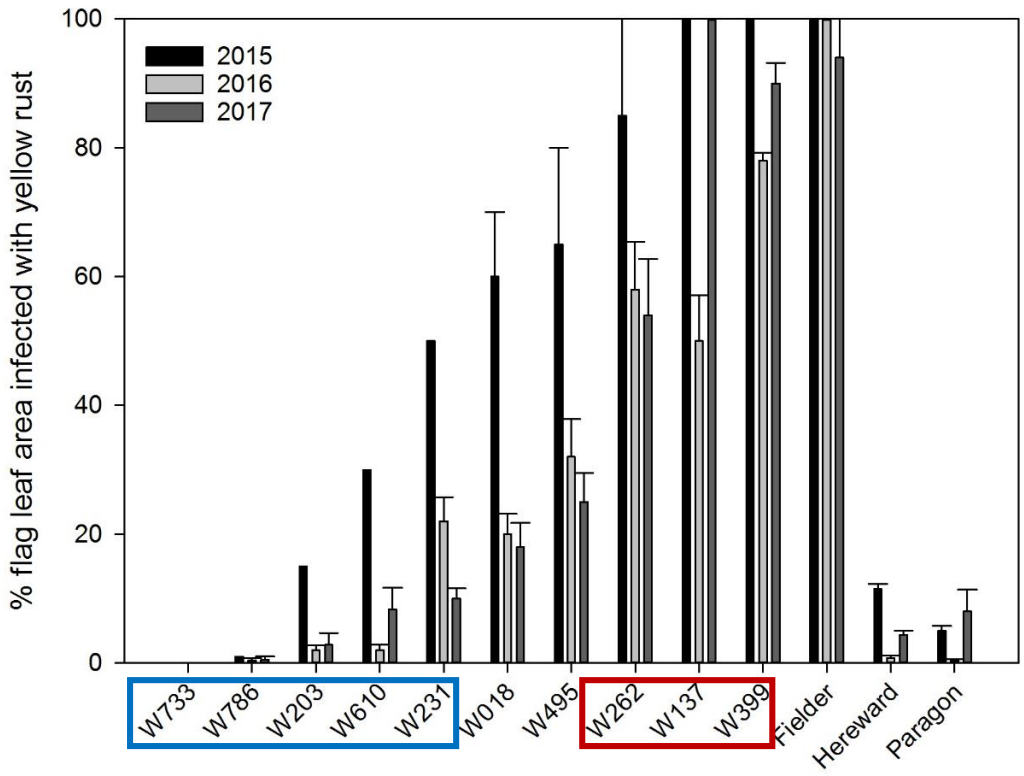
Evidence of resistance to yellow rust



Disease assessments carried out during flowering/grain filling

- W733, W786, W203, W610 and W231 all show moderate to strong adult plant resistance against yellow rust under field conditions
- Did susceptible varieties escape YR in 2008 or are they now susceptible due to new YR races?

Watkins 137 – fully susceptible to yellow rust

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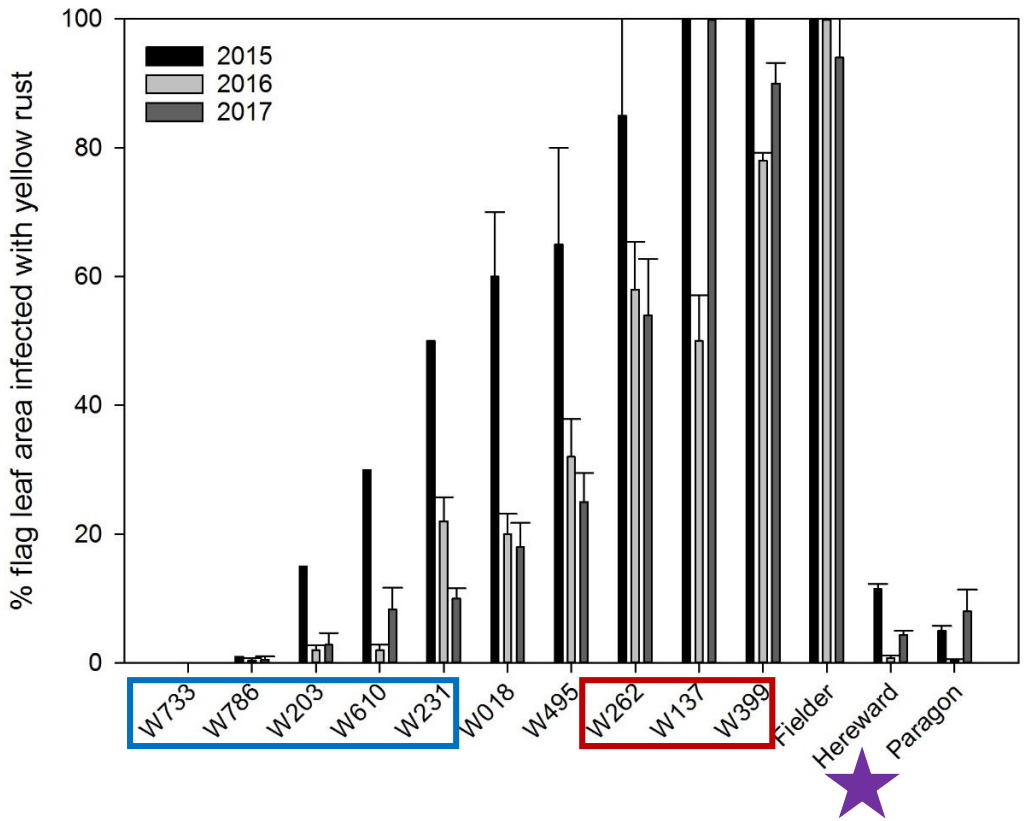
Evidence of resistance to yellow rust



Disease assessments carried out during flowering/grain filling

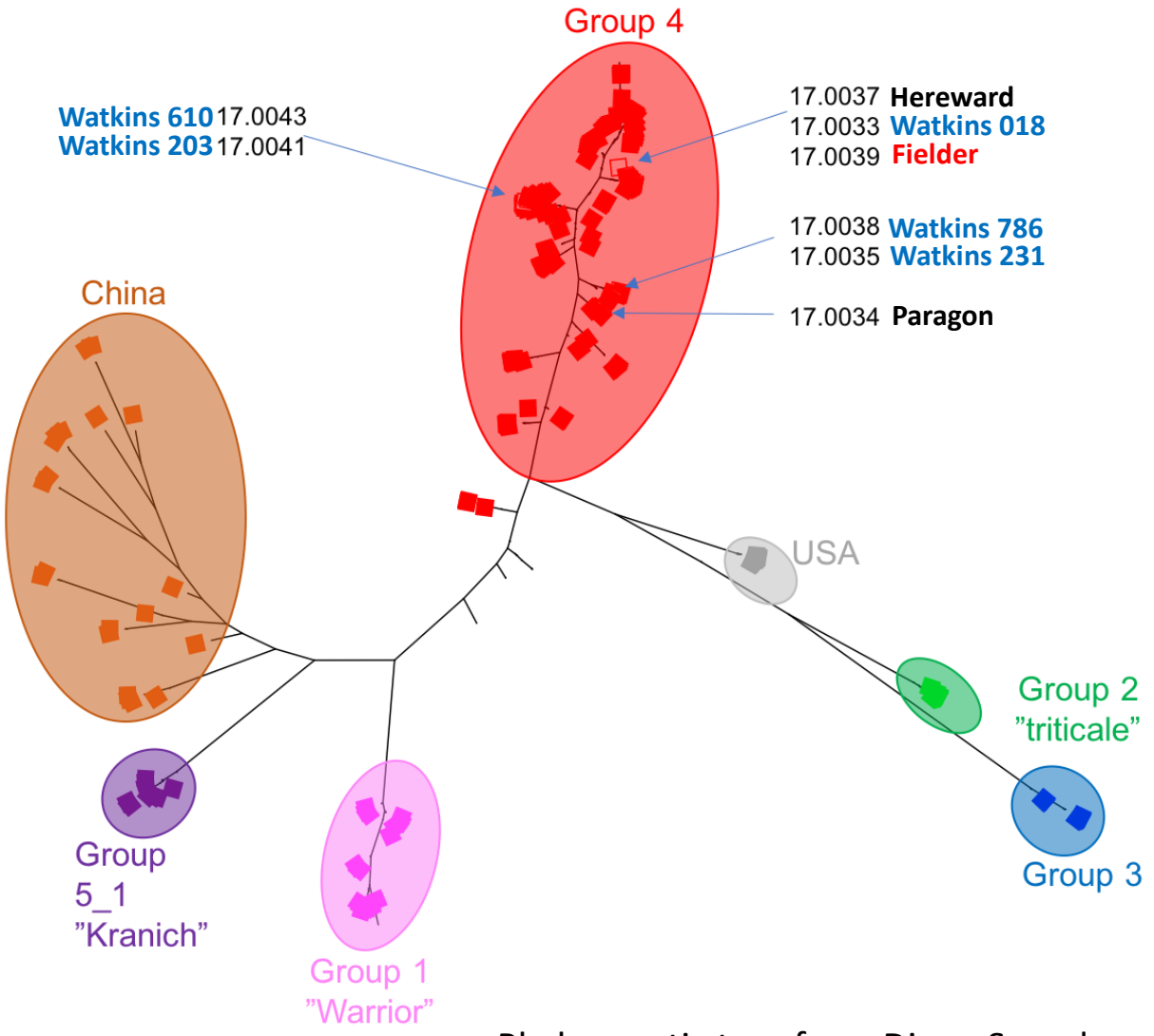
- W733, W786, W203, W610 and W231 all show moderate to strong adult plant resistance against yellow rust under field conditions
- Did susceptible varieties escape YR in 2008 or are they now susceptible due to new YR races?
- Semi-modern wheats Hereward and Paragon are fairly resistant to current YR races

Hereward and Paragon

Hereward – leaves fairly green, some yellow rust stripes

Paragon – very little yellow rust sporulation but large host response, necrotic stripes abundant on all leaves

Which YR races are causing disease on Watkins genotypes?



All samples from the 2017 field trial belong to Group 4

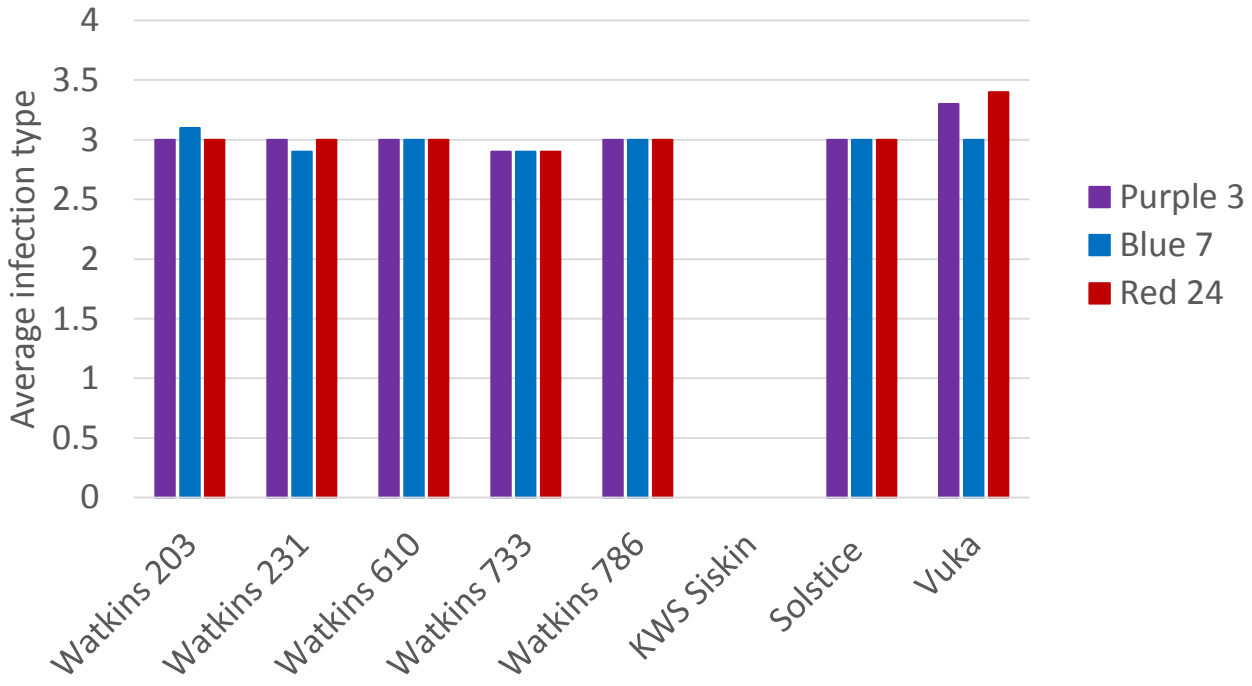
Group 4 is the dominant genetic group of YR in the UK

Phylogenetic tree from Diane Saunders, JIC

Are the Watkins genotypes susceptible at the seedling stage?

- **Purple 3** (previously known as the Kranich race)
- **Blue 7** (previously known as the Invicta race)
- **Red 24** (new in 2016, caused disease on Britannia, Myriad, Zulu, Reflection amongst others)

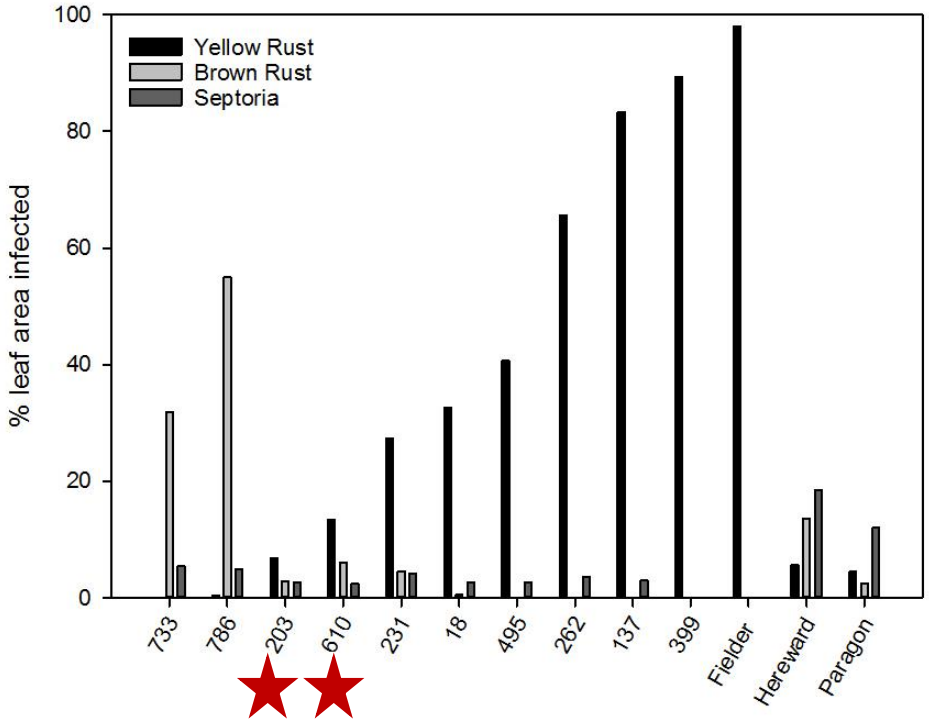
All Watkins genotypes are susceptible at the seedling stage



Seedling virulence testing carried out by NIAB

Multi disease resistance?

Average disease score across all three field seasons



2014-2015	YR only
2015-2016	YR, BR and S
2016-2017	YR, BR and S

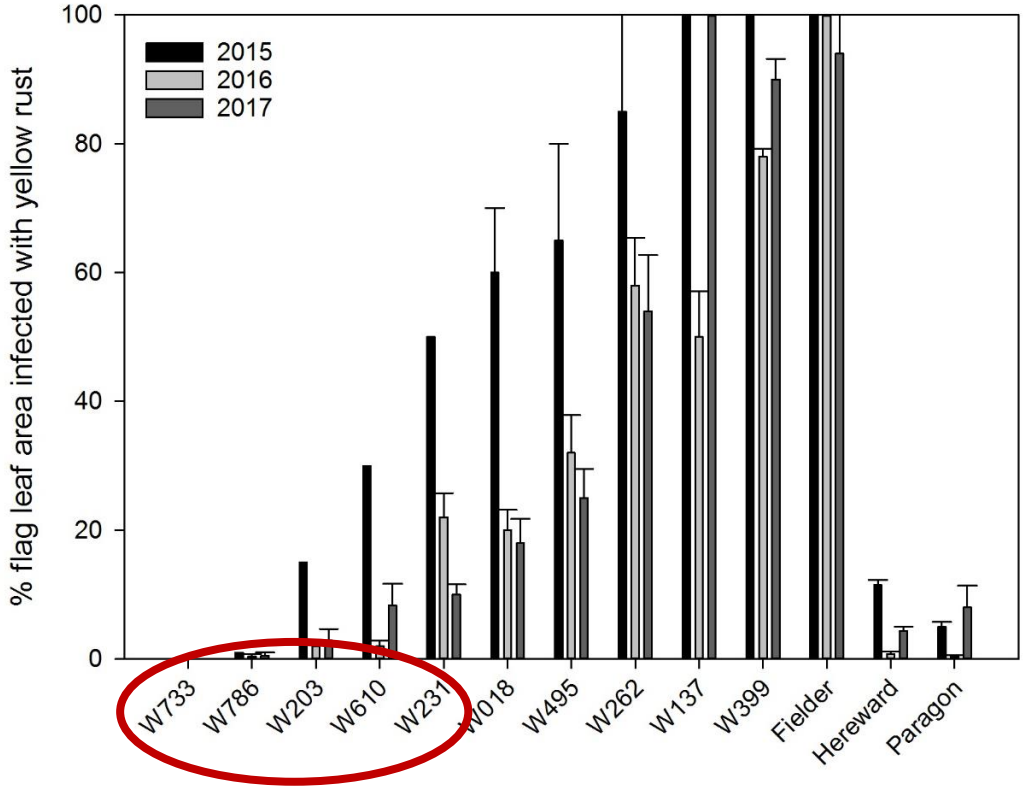
Septoria levels low across both field seasons

Very little powdery mildew across all three field seasons on wheats – not scored

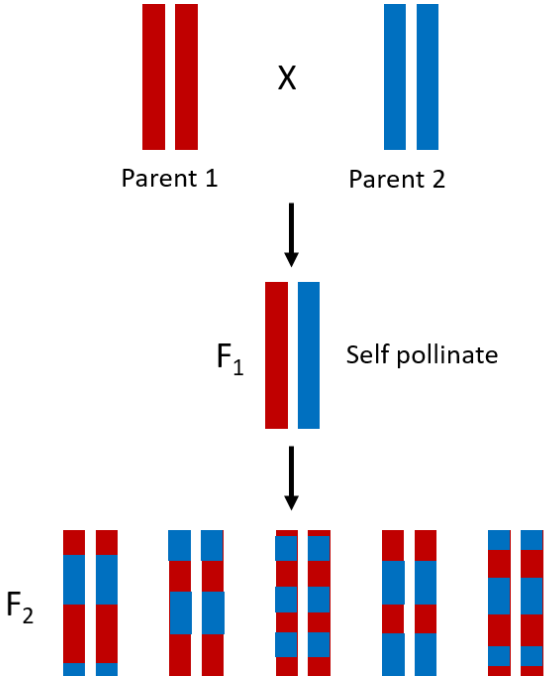
★ Watkins 203 and 610 most promising for showing high levels of resistance against multiple foliar diseases

- Watkins 610 may be escaping disease through later leaf emergence
- Watkins 733 and 786 were most resistant to yellow rust but are very susceptible to brown rust – do not possess multi rust resistance

Genetics of yellow rust resistance



Chosen for mapping population development



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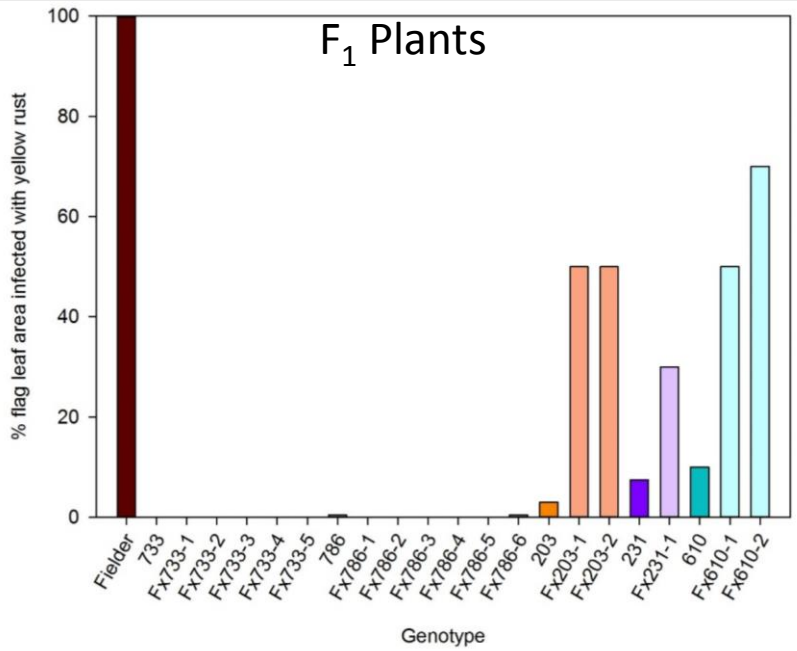
Genetics of yellow rust resistance



- Yellow rust resistance dominantly inherited in Fielder x W733 and Fielder x W786
- Genetic basis of resistance currently being further explored in F_2, F_3 and backcross generations

Pool of susceptible lines

Pool of resistant lines

WGIN4 = F_3 bulked segregant analysis on two most resistant Watkins genotypes (W733 and W786)

Expected outcome – identification of molecular markers linked to resistance

Exploiting *Triticum monococcum* as a novel source of genetic diversity for improvement of hexaploid wheat

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- **Diploid wheat (A^mA^m)**
- Domesticated from its wild progenitor *Triticum boeoticum* ~10,000 years ago
- Abandoned before the Bronze Age
- Left to grow in its natural environment

- ***T. monococcum* A genome underrepresented in modern wheat germplasm**

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Triticum monococcum – a rich source of beneficial traits

ROTHAMSTED RESEARCH

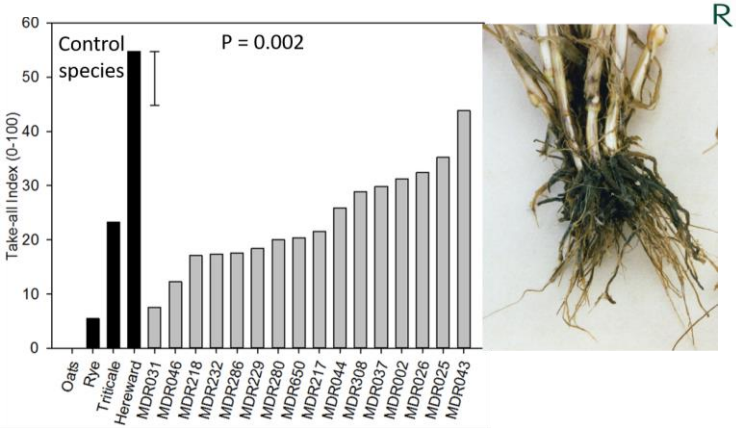
Septoria leaf blotch

DV92/MDR308 (resistant)

MDR2 (susceptible)

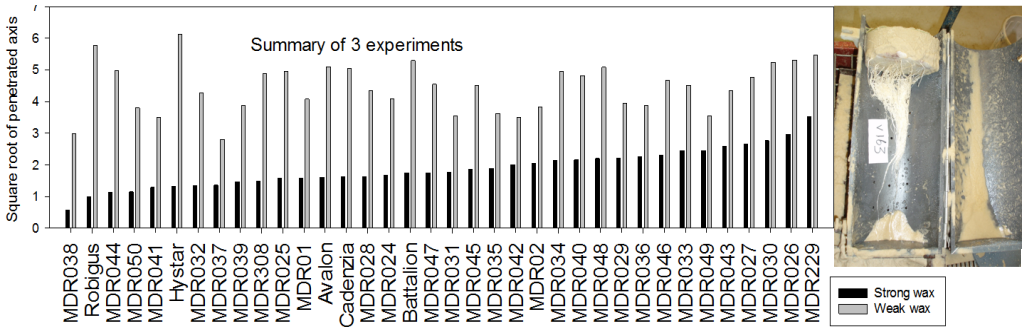
- No septoria disease on 24 *Tm* accessions tested over 5 years under field conditions
- Mapped to a single genetic locus, designated as *TmStb1*, on chromosome 7A^{m} (Jing *et al*. 2008)

Take-all disease



- 34 *Tm* accessions phenotyped in 3rd wheat field trials
- Strong resistance to take-all disease in MDR031 and MDR046 (McMillan *et al*. 2014)

Root penetration



- Enhanced root penetration of strong wax layer for some *Tm* accessions (Richard Whalley *et al.*)

Cereal aphids

- Resistance to Bird-cherry oat aphid and English grain aphid identified within *Tm*
- Mapping populations currently being developed and phenotyped for genetic analysis of resistance traits (Gia Aradottir *et al*.)

Tm introgression into hexaploid wheat

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T. monococcum source genotypes

MDR 308 (DV92) - ***TmStb1*** **locus mediated resistance to *Zymoseptoria tritici***

MDR 031 - Seedling and adult plant root resistance to the take-all fungus (*Gaeummannomyces tritici*)

MDR 049 - Seedling and adult plant resistance to two aphid species

- o Bird cherry-oat aphid *Rhopalosiphum padi*
- o Grain aphid *Sitobion avenae*

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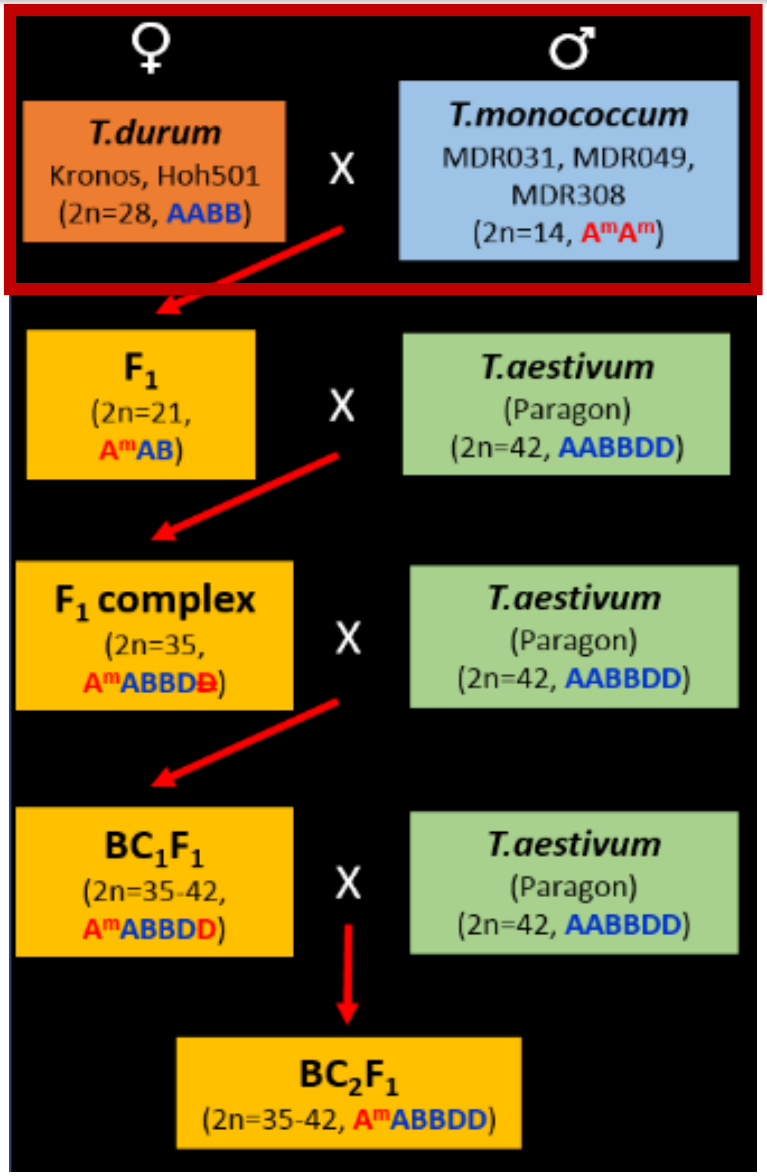
WGIN 4 Introgression strategy – using tetraploid wheat as bridging species



- Used tetraploid wheat (***T. durum*** cvs. Kronos and Hoh501) as a bridging species in first cross

- Result of the first round of crossing *T. monococcum* to *T. durum*:

cross	Grains (F_1)	Ears
Kronos x MDR031	7	7
Kronos x MDR049	4	3
Kronos x MDR308	12	6
Hoh501 x MDR031	8	4
Hoh501 x MDR049	3	3
Hoh501 x MDR308	0	0

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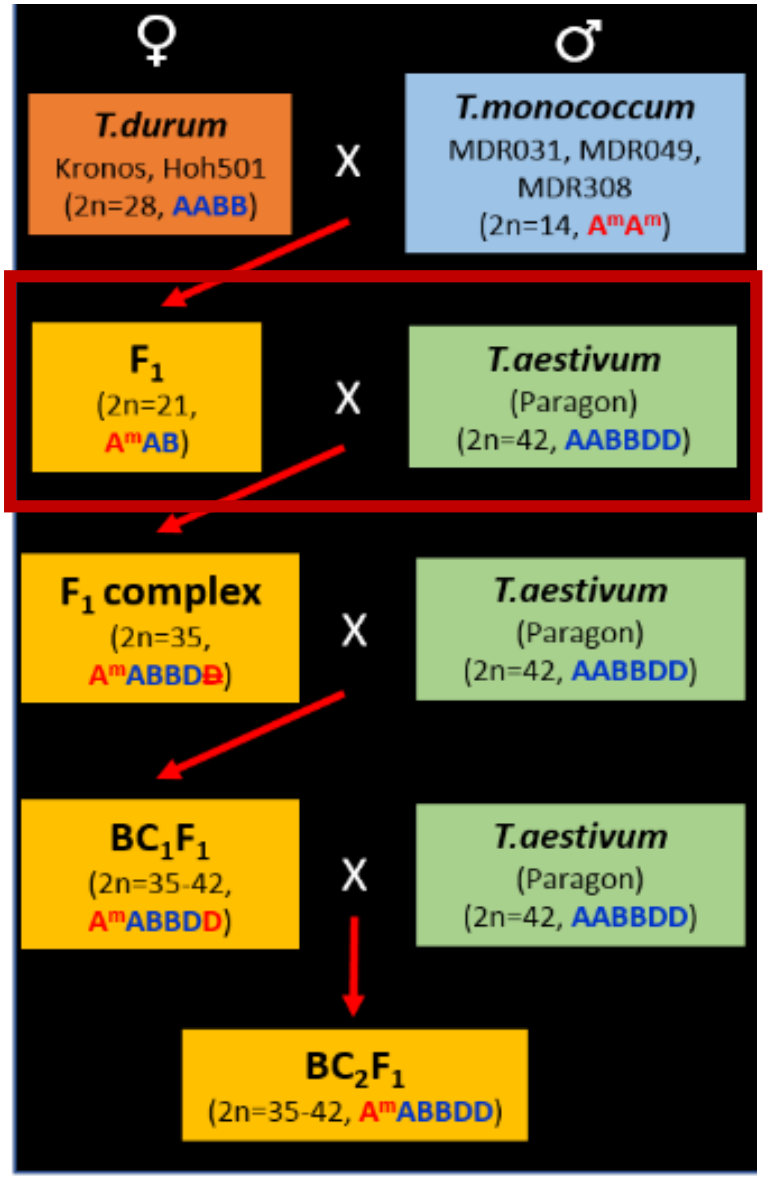
WGIN 4 Introgression strategy – crossing to hexaploid wheat cv. Paragon



No of F_1 stigmas pollinated with Paragon and 'F_1 complex' grains obtained

	MDR031	MDR049	MDR308
Kronos	960 stigmas	120 stigmas	120 stigmas
Grains (% of stigmas)	**7** (0.73%)	**0**	**1** (0.83%)
Hoh501	1920 stigmas	400 stigmas	none
Grains (% of stigmas)	**9** (0.47%)	**0**	**n/a**

- Left = Triploid F_1 plant
- Right = Hoh501

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WGIN 4 Introgression strategy – backcrossing to hexaploid wheat cv. Paragon

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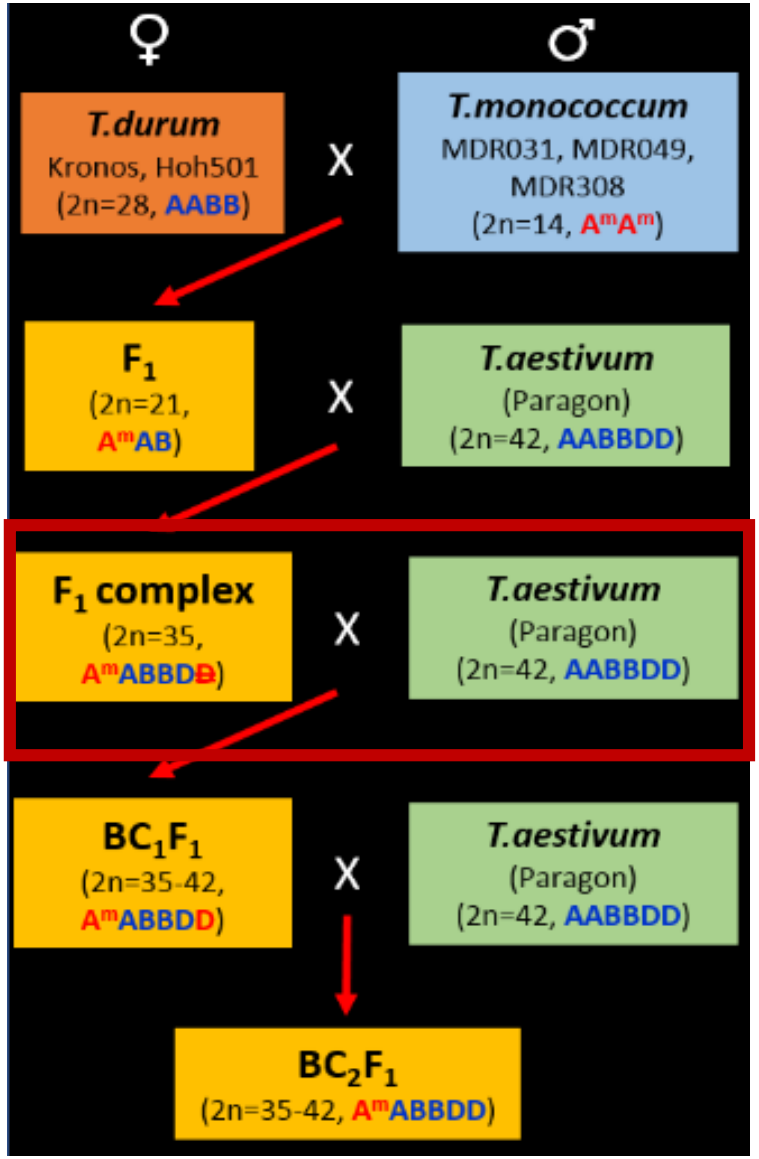

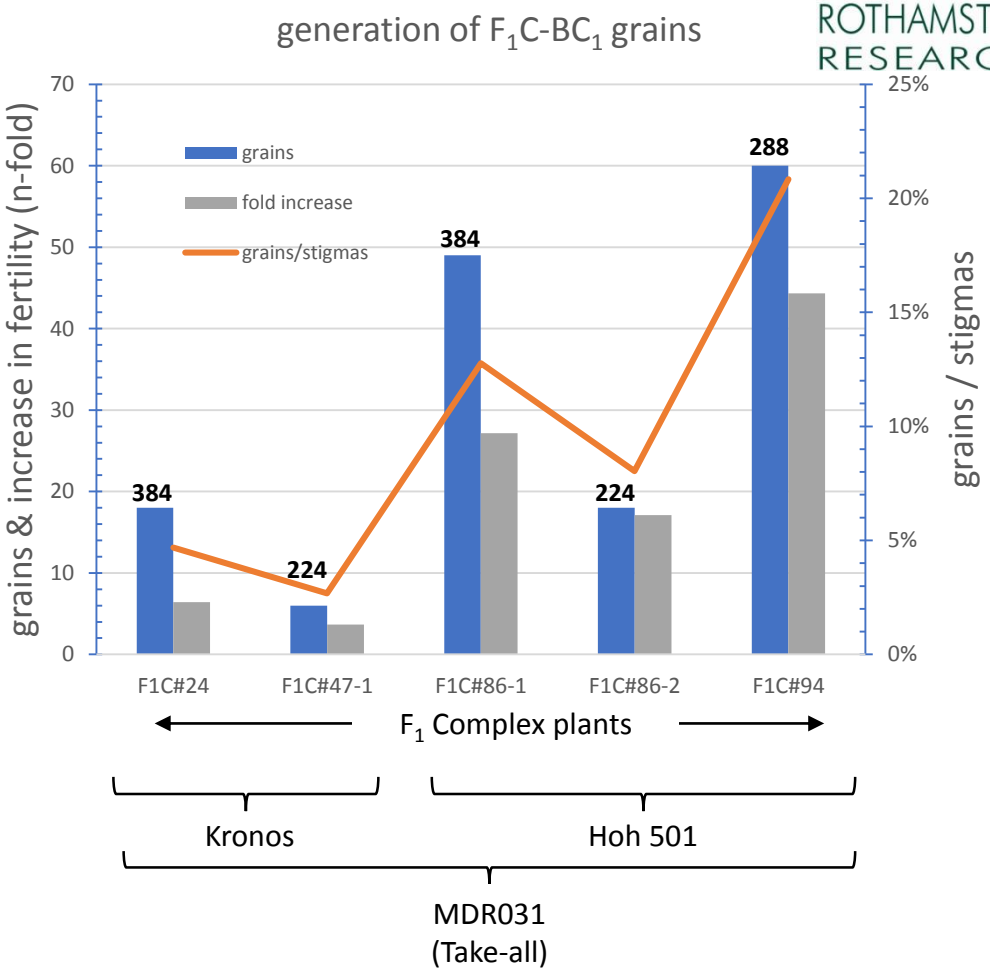

$$\text{n-fold increase in fertility} = \frac{F_1C\text{-}BC_1 \text{ grains/stigmas}}{F_1C \text{ grains/stigmas}}$$

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WGIN 4 Other biotic stress experiments

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- Resistance to Septoria leaf blotch

(Watkins genotypes, known stb genes, CIMMYT germplasm)

Septoria leaf blotch

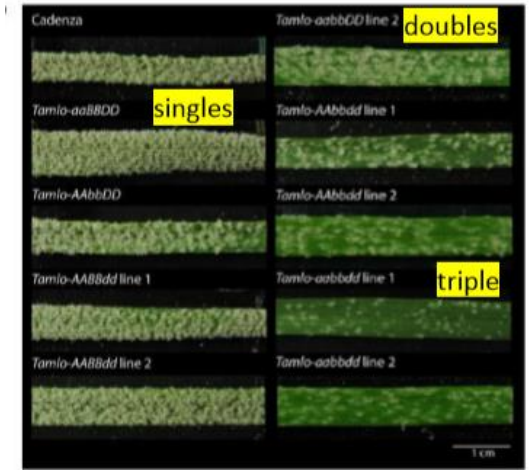
- 3N ancestral introgression rooting trait

Does this confer resistance/tolerance to take-all disease?

Aegilops uniaristata

- *mlo* mediated powdery mildew resistance in wheat

Are there trade offs under field conditions?



Wheat *mlo* mutants

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Many thanks to

ROTHAMSTED RESEARCH

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