Rothamsted Research
where knowledge grows

WGIN 3

Resistance to multiple foliar fungal pathogens and take-all root disease in wheat

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Wheat Genetic Improvement Network

Department for Environment Food & Rural Affairs

WGIN Stakeholder Meeting 30th November 2016

BBSRC bioscience for the future

ROTHAMSTED RESEARCH

Major foliar wheat pathogens in UK

ROTHAMSTED RESEARCH

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*

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Exploiting the Watkins landrace collection

ROTHAMSTED RESEARCH

- 2008 - Watkins landrace collection (n = 740 genotypes) phenotyped for resistance against foliar fungal pathogens and take-all root disease

- High foliar disease pressure – brown rust, yellow rust, septoria and powdery mildew assessments carried out

Wheat Genetic Improvement Network

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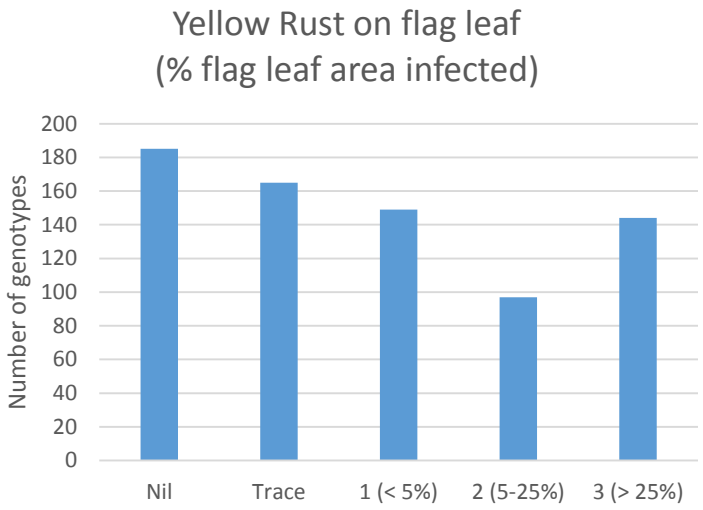
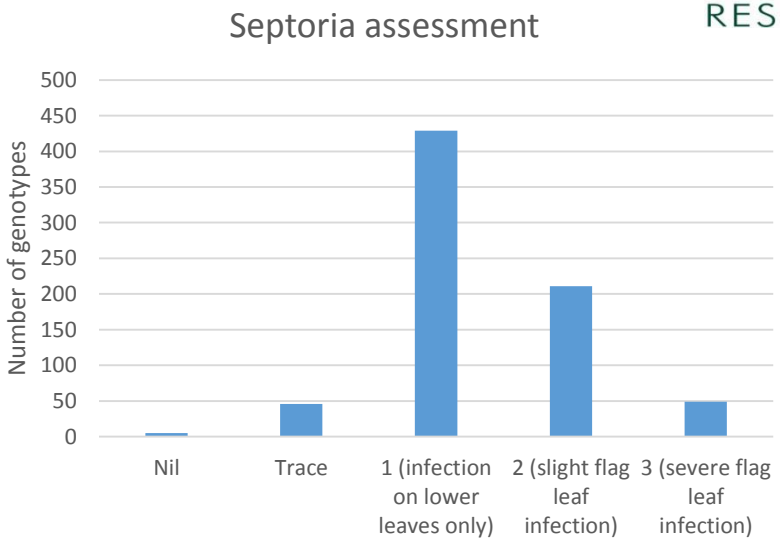
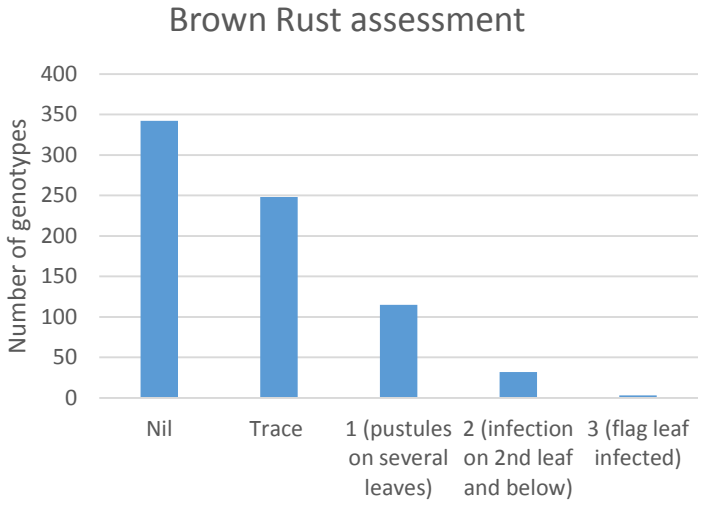
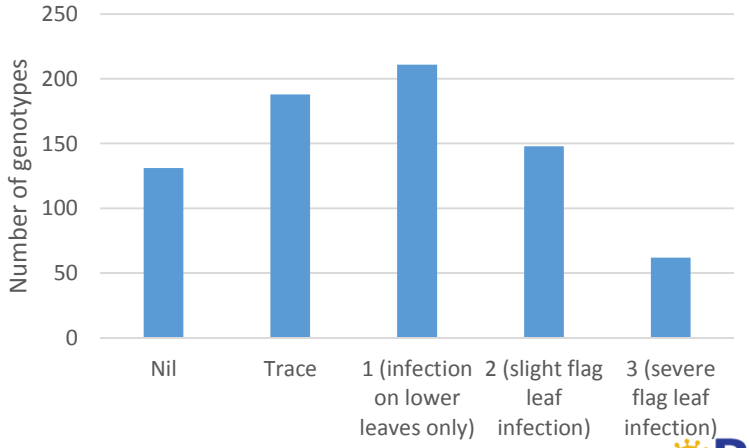
Exploiting the Watkins landrace collection

ROTHAMSTED RESEARCH









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Exploiting the Watkins landrace collection

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

Also a high take-all disease year with root infection early in the season

Was the foliar disease resistance an induced plant response?

			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

WGIN 3 Watkins foliar disease experiments

ROTHAMSTED RESEARCH

- 10 Watkins genotypes sown in both **1st wheat (no take-all)** and **3rd wheat (high take-all)** field trials in autumn 2014, 2015 and 2016
- No fungicides applied to allow natural disease to develop
- Score for foliar diseases + take-all

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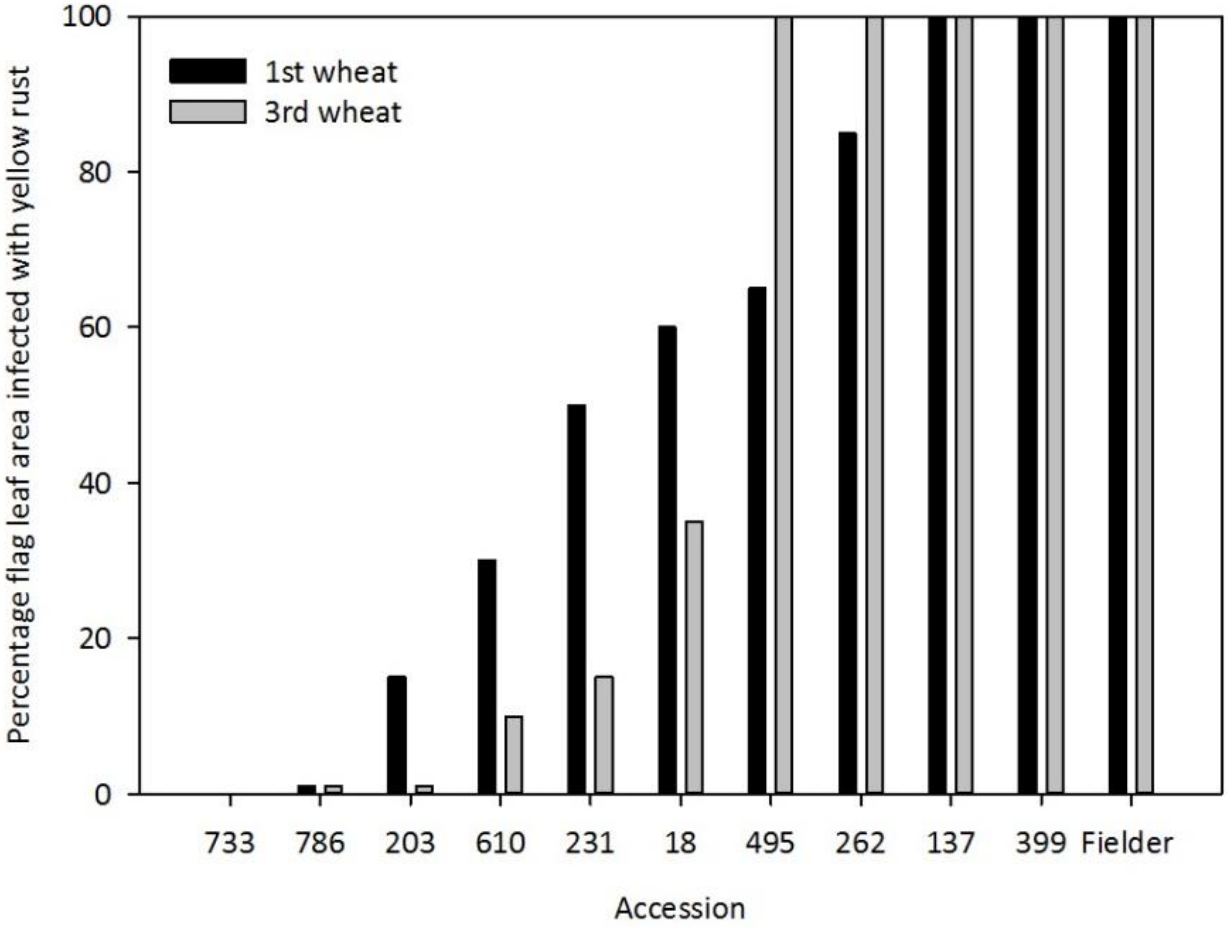
Watkins foliar disease field trial 2015

26th June 2015 1st wheat Long Hoos 4

Yellow rust dominant disease that developed across 2015 field trials

Evidence of resistance to yellow rust



- Evidence of induced response due to take-all?
- Did varieties escape YR in 2008 or different YR races?

Evidence of resistance to yellow rust

Watkins 203

Low levels of yellow rust sporulation

Watkins 733

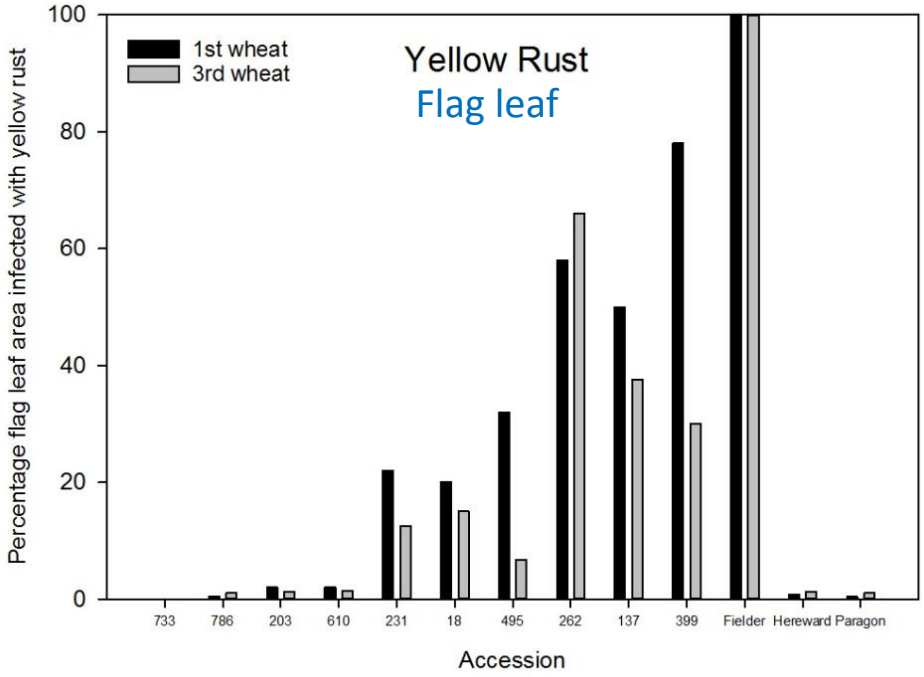
No sporulation

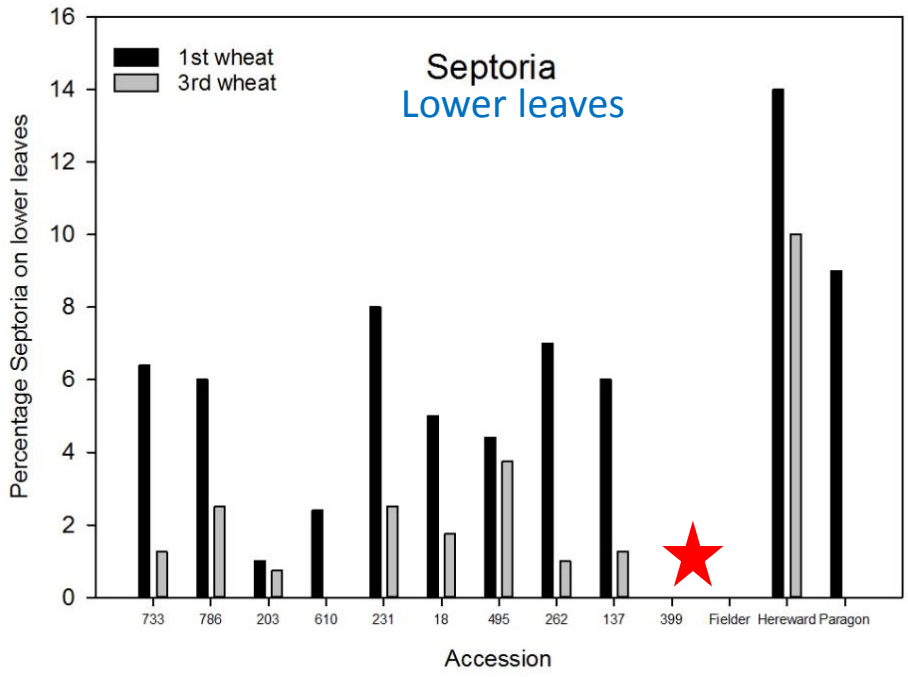
Watkins foliar disease trial 2016

- Repeat field trial with 5 replicates of each genotype sown in autumn 2015 in Long Hoos 5 (1st wheat) and Long Hoos 6/7 (3rd wheat)

- Yellow rust, septoria and brown rust developed

6th June 2016 – Yellow rust and Septoria





- Yellow Rust shows similar pattern to 2015

★ Low levels of Septoria on all genotypes except 399 and Fielder where high levels of yellow rust are found, therefore impossible to assess Septoria infections

- All genotypes at GS 57-61, except 610 at GS 47

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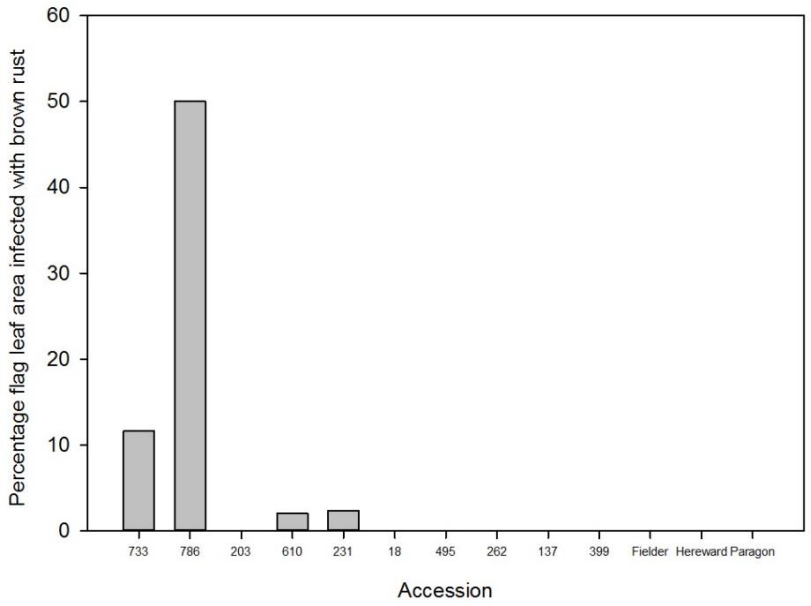
22nd June 2016 – Brown rust developed across the 1st wheat trial site



Watkins 733

Watkins 786

- Watkins 733 and 786 were most resistant to yellow rust but are very susceptible to brown rust – do not possess multi disease resistance
- Watkins 203 most promising for showing high levels of resistance against both yellow rust, brown rust and septoria

Watkins mapping population development

ROTHAMSTED RESEARCH

Summer 2015 Field crossing with cv. Fielder

Accession Number	Growth habit	Country of Origin	Ears crossed	F_1 grains
203	Winter	India	8	31
231	Spring	Hungary	8	54
610	Spring	Yugoslavia	6	33
733	Spring	Iran	6	49
786	Spring	USSR	N/A	N/A

Summer 2016

- F_1 grain sown in glasshouse to generate F_2 and for backcrossing to cv. Fielder
- Watkins 786 x Fielder crossing carried out in glasshouse
- F_1 grain included in a spring field trial 2016 to study inheritance

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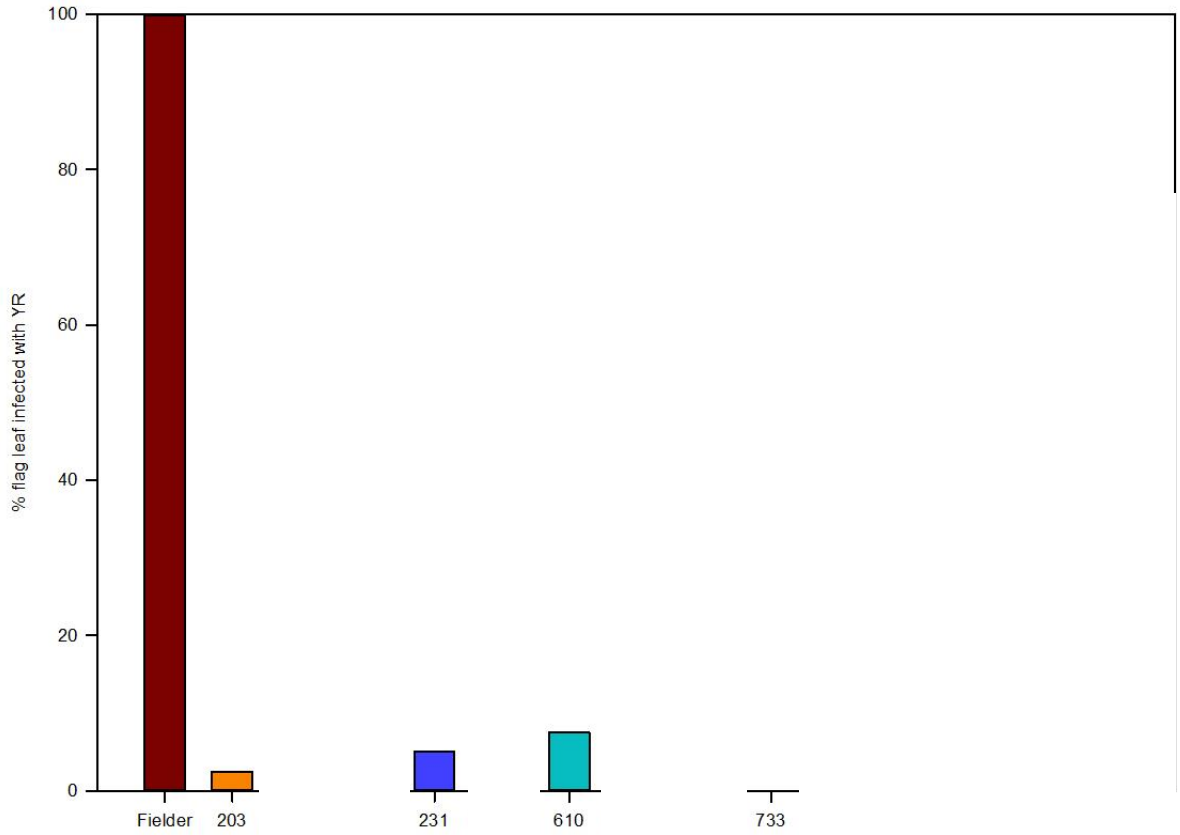
F_1 plants – spring field trial

- Six F_1 grain from each of the 4 crosses sown
- Two replicate plots of parent genotypes (40 seeds per plot)

- Yellow Rust assessments on 30th June 2016



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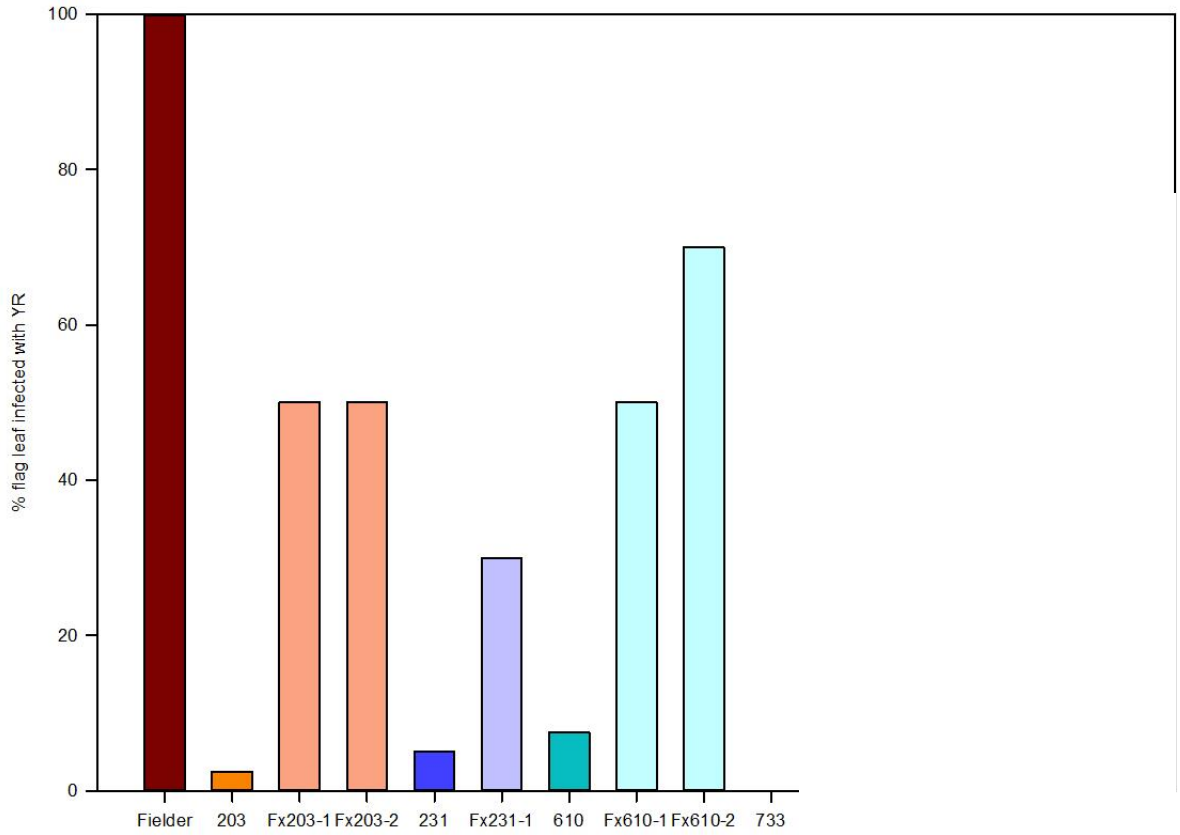

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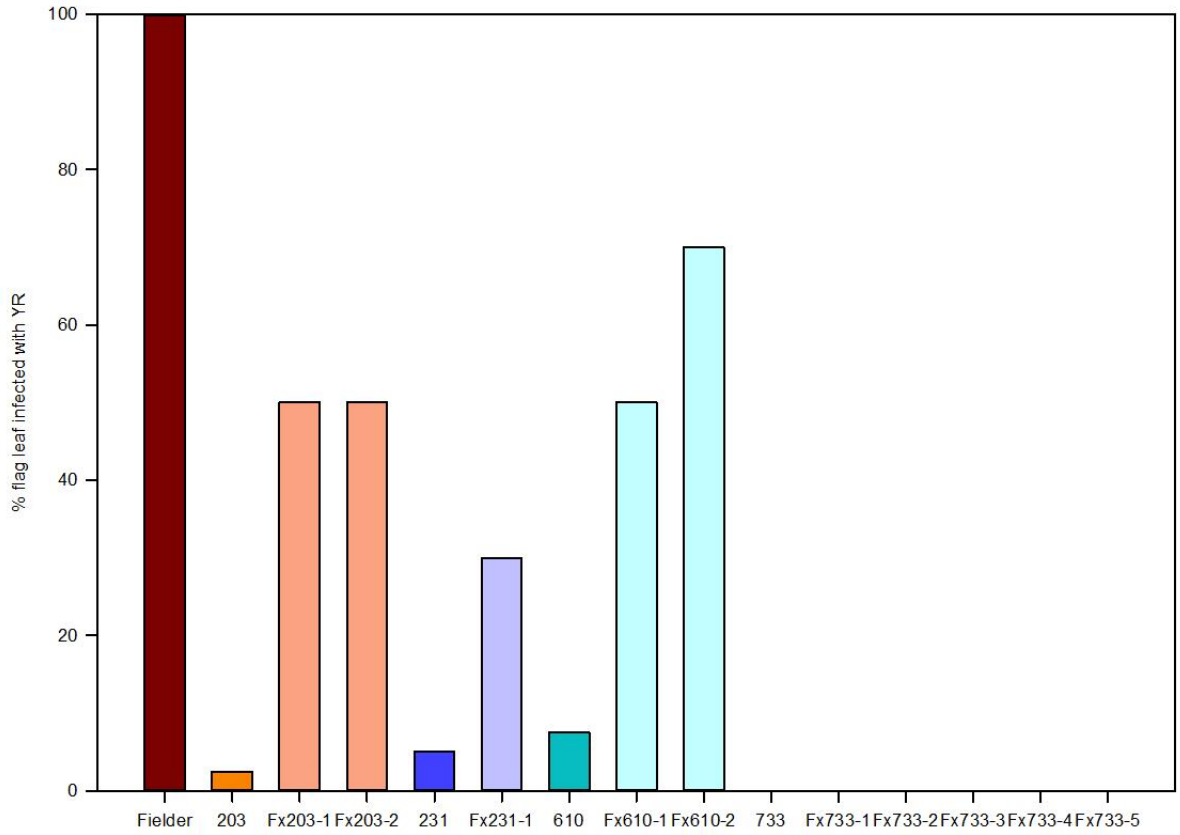

Summary

- Five Watkins genotypes with evidence of moderate-high resistance against YR
- Watkins 203 most promising genotype for multi-disease resistance
- Trend towards less foliar disease in 3rd wheat (high take-all) field trial across both seasons – to be tested in controlled environment conditions

On-going work

- Repeat 1st and 3rd wheat multi-disease resistance trials drilled autumn 2016
- *Zymoseptoria* field trial drilled autumn 2016
- F_2 inheritance trial drilled autumn 2016
- Check for known Yr and multi-disease resistance genes
- Seedling race tests

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

ROTHAMSTED RESEARCH

T. monococcum
wheat ear

- The diploid wheat, *T. monococcum* ($A^m A^m$) was widely cultivated during early cereal farming on poorer soils

- After the Bronze Age *T. monococcum* cultivation diminished

- A^m genome not directly involved in the generation of
  - modern durum wheat (tetraploid)
  - common bread wheat (hexaploid)

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RRes *Triticum monococcum* collection

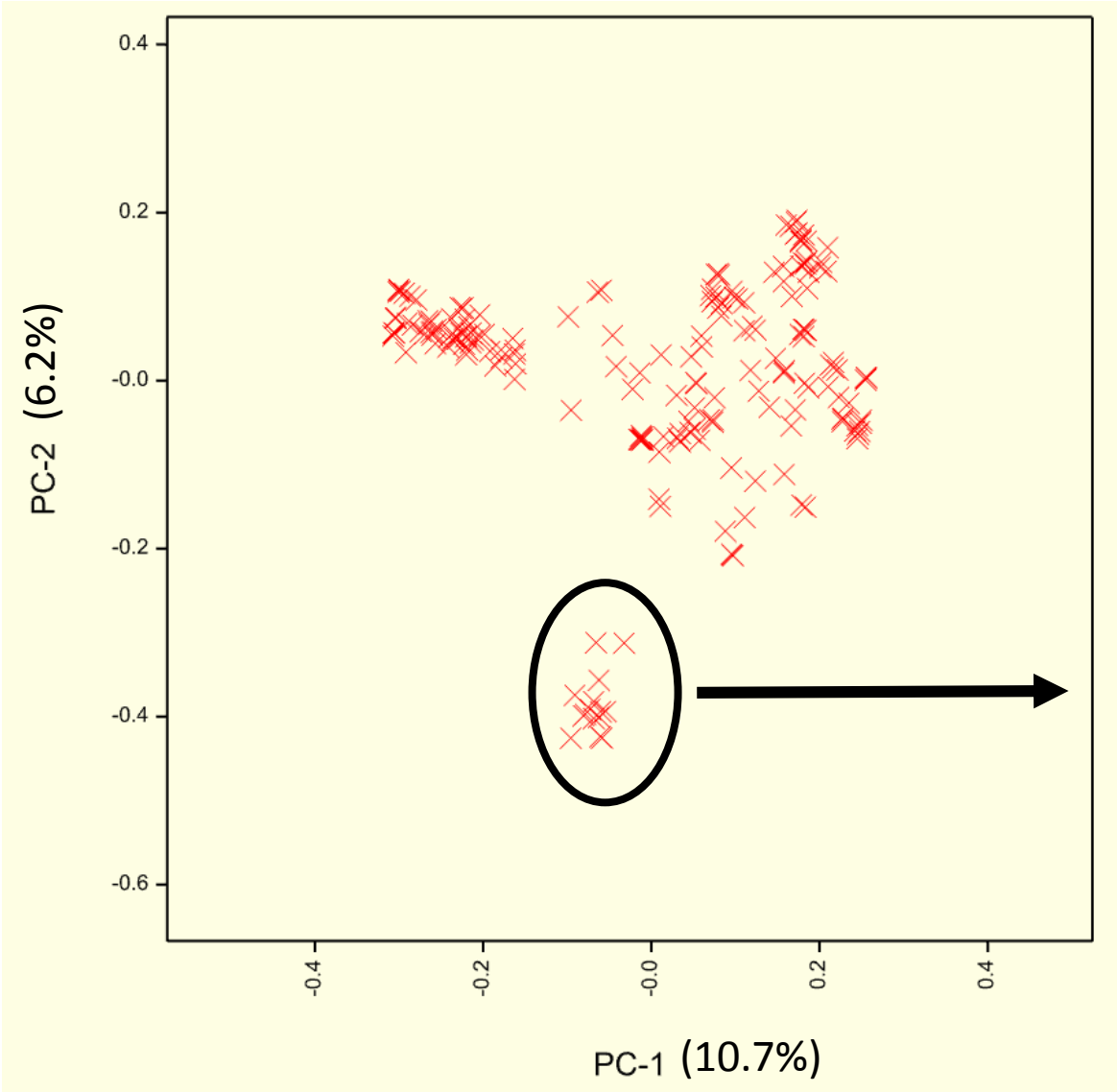
Total number	323 (Vavilov, USDA, IPK)
Country of origin	35
Spring habit	229
Winter habit	86

WGIN phenotyping

- Yellow rust
- Take-all root disease
- Eyespot
- Septoria (Kostya Kanyuka)
- Aphid resistance (Lesley Smart and Gia Aradottir)
- Root penetration (Yaoxiang Ge and Richard Whalley)

- Recently genotyped 203 viable genotypes using 35K array at Bristol University

Triticum monococcum collection
Principal Coordinates Analysis



T. boeoticum = wild einkorn wheat

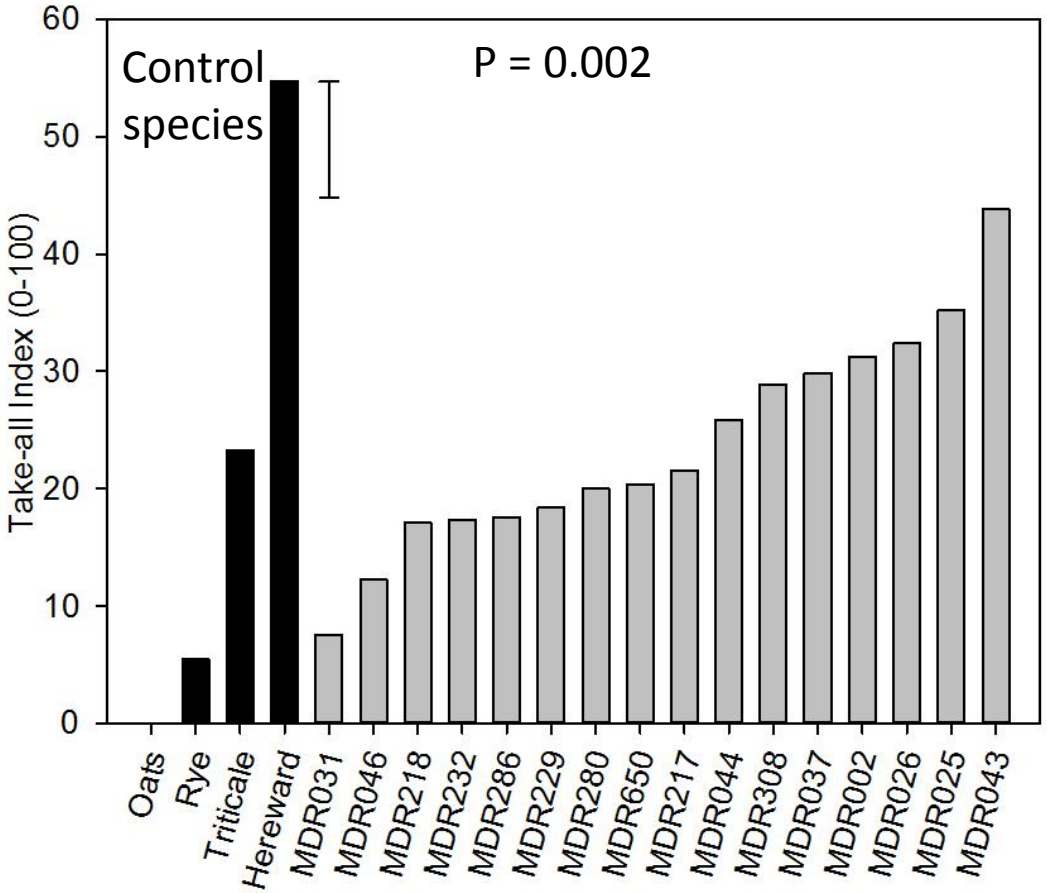
T. monococcum = domesticated einkorn wheat

Hairy leaves, possibly *T. boeoticum*
Country of origin = Turkey

203 *Tm* genotypes, 1026 markers

Take-all root disease - highly resistant genotypes identified within *T. monococcum*

- 3rd wheat field trials 2006-2011 (WGIN 1 and 2)
- **34 *T. monococcum* genotypes (AA diploid genome)** tested over 5 years



McMillan et al. (2014) BMC Plant Biology 14: 212

Take-all *Triticum monococcum* mapping populations

ROTHAMSTED RESEARCH

F_2 *Tm* cross progeny numbers:

Parentage		Estimated F_3 progeny number
MDR031 (R) x MDR043 (vS)	31 ears from 3 plants	450 ←
MDR031 x MDR229	16 ears from 1 plant	320
MDR031 x MDR650	48 ears from 3 plants	900
MDR043 (vS) x MDR031 (R)	48 ears from 3 plants	960
MDR043 (vS) x MDR046 (R)	36 ears from 3 plants	750 ←
MDR229 x MDR031	94 ears from 6 plants	2000

Populations advanced by SSD in 2015/16 from F_4 to F_6 for future field phenotyping ←

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Triticum monococcum take-all root resistance
MDR031(R) x MDR043 (S) mapping population

ROTHAMSTED RESEARCH

- 516 F_2 seeds ⟶ 380 F_6 lines
- 0.5 – 33.5 g of each line available
- **129 lines** > 18 g seed selected for field trial + parents + Hereward control plots
- Plot size 4 rows x 0.6 m length, 80 seeds per plot
- Randomised block design (3-5 reps/genotype)
- **3rd wheat field trial** drilled in Claycroft 6th Oct 2016

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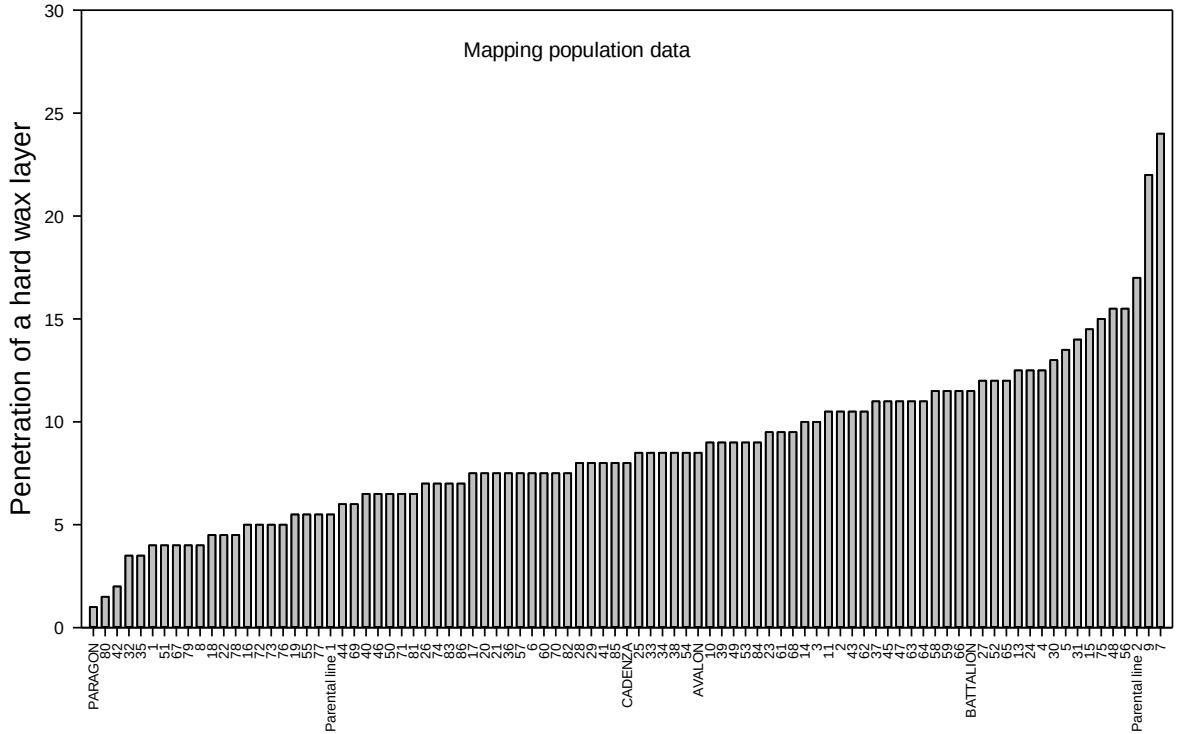
Penetration of strong layers by roots

ROTHAMSTED RESEARCH

MDR037 (poor root penetration) x MDR229 (strong root penetration) mapping population



Comprehensive data set to search for QTLs including root number, root angle, root diameter and root penetration

20:20 Wheat®

Yaoxiang Ge and Richard Whalley

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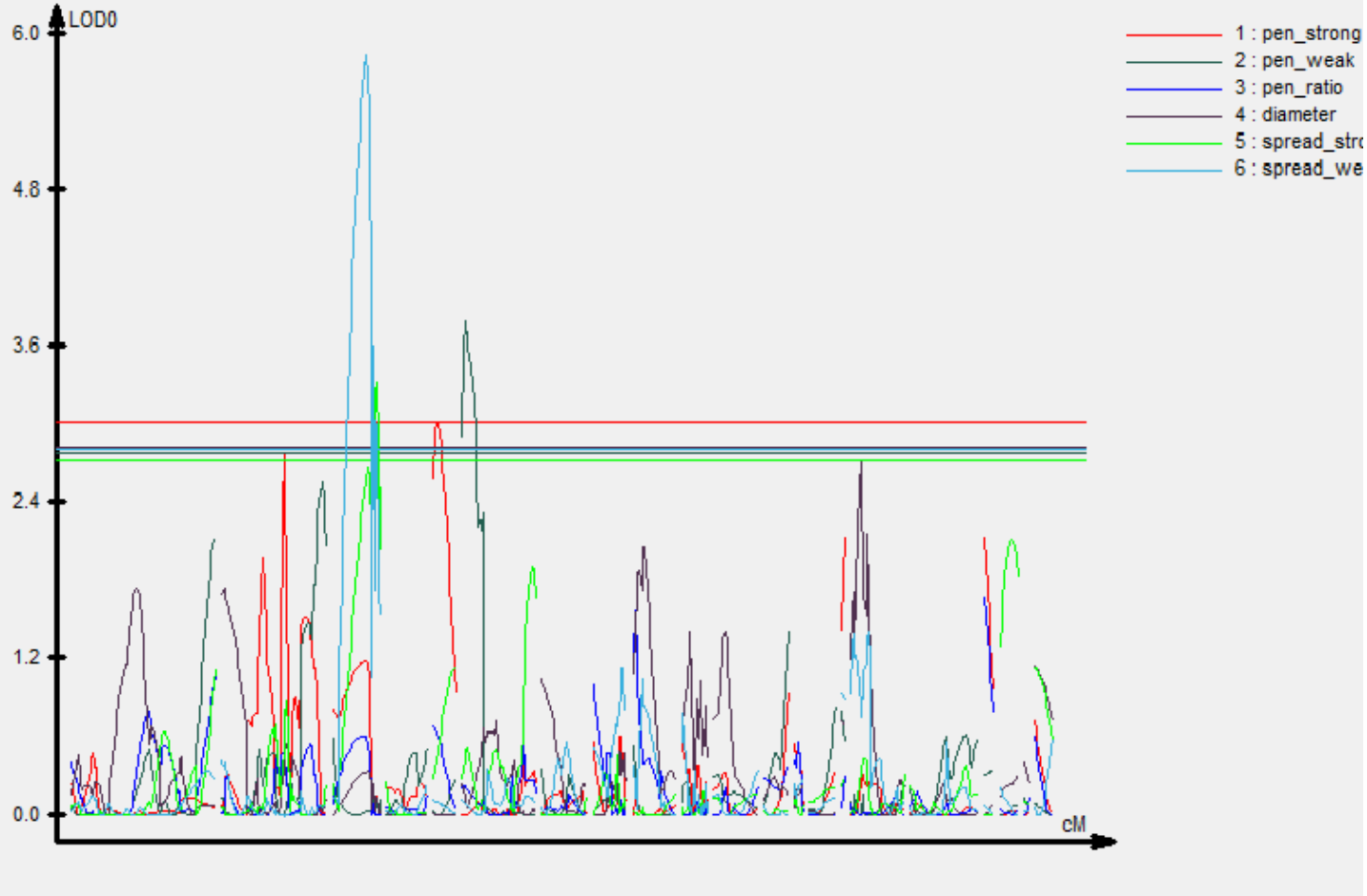
Penetration of strong layers by roots

ROTHAMSTED RESEARCH

MDR037 (poor root penetration) x MDR229 (strong root penetration) mapping population



20:20 Wheat®

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Summary

- Novel resistance traits identified within *T. monococcum*
- Preliminary evidence of different groupings based on genotyping of *T. monococcum* collection
- MDR031 (R) x MDR043 (S) F_6 take-all phenotyping trial drilled autumn 2016
- MDR037 (poor penetration) x MDR229 (strong penetration) – root strength – preliminary analyses reveal multiple QTLs
- Strategies for introgression into hexaploid wheat being tested

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Richard Whalley

Tm introgression into durum and hexaploid wheat

ROTHAMSTED RESEARCH

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 graminis* var. *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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Towards introgressing *TmStb1* into bread wheat

ROTHAMSTED RESEARCH

Current strategy (so far not very successful**)**

cross *T. monococcum* (*Tm*) to *T. aestivum* cv. Paragon *ph-1*
embryo rescue in F_1
backcross the hybrid to *T. aestivum* cv. Paragon

Trying two alternative strategies

Strategy #1

colchicin treat *Tm* to produce autotetraploid
cross *Tm* autotetraploid directly to wild-type hexaploid and durum wheat

Strategy #2

use tetraploid durum wheat as a bridging species
cross *Tm* with durum wheat
backcross this hybrid to hexaploid wheat

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