Wheat Genetic Improvement Network

WGIN 5 (July 2024-June 2029)

Department for Environment Food & Rural Affairs

The partners

ROTHAMSTED RESEARCH

John Innes Centre

All years

NIAB

Yrs 1 - 4

Met Office

Yrs 0.5 – 2.5

WGIN 5 – The species

80% - Hexaploid wheat, AABBDD

The underutilised cereal species

10%
Durum wheat
AABB
UK crop 2024 ~0%

10%
Triticale,
AABBRR
UK crop 2024 <0.1%

WGIN 5 – The science

We aim to

- **further improve the resource use efficiency of the UK wheat crop**

- **enhance the crops intrinsic resistance to pests and pathogens – thereby reduce overall reliance on pesticide applications**

- **improve the wheat crops adaptability to the predicted impacts of climate change**

- **devise new ways to reduce the environmental impacts of the UK wheat crop**

WGIN 5 – The Methods

New Germplasm Collections – Watkins durum,
self-fertile triticale
Established Germplasm collection - Watkins, NIFTYR

Established mapping populations – Paragon x elites
Paragon x Gediflux

Genetics & Field trialling – GWAS, BP mapping pop^{n}

Precision Breeding – CRISPR / Cas9

Virus and virus vector diagnostics

Climate change modelling to predicting future UK abiotic / biotic threats + compound risks + uncertainties

WGIN 5 – The Targets

Wheat - Experimental Breeding by GE focused on Ancestral groups 1,3,4,6 and 7 (not previously used in modern breeding)

GE for conversion to Green Revolution alleles - making semi-dwarfs, heat tolerance and high protein grain

Triticale – Establish Precision Breeding by GE - reducing plant height and grain contents of non-starch polysaccharides

Durum – Pre-breeding activities by developing Watkins germplasm resources and UK climate adaptation trials

Wheat, durum and triticale - resource use efficiency – Grain Protein Deviation (GPD) – current and older germplasm

WGIN 5 – The Targets

Wheat - Biotic treats – NEW cereal viruses + insect vectors, stem rust UK arrival – by modelling

Septoria leaf blotch resistance - germplasm screening – two new germplasm collections

Improving root system health Take-all root resistance – NIFTYR collection (*T. monococcum* interogression)

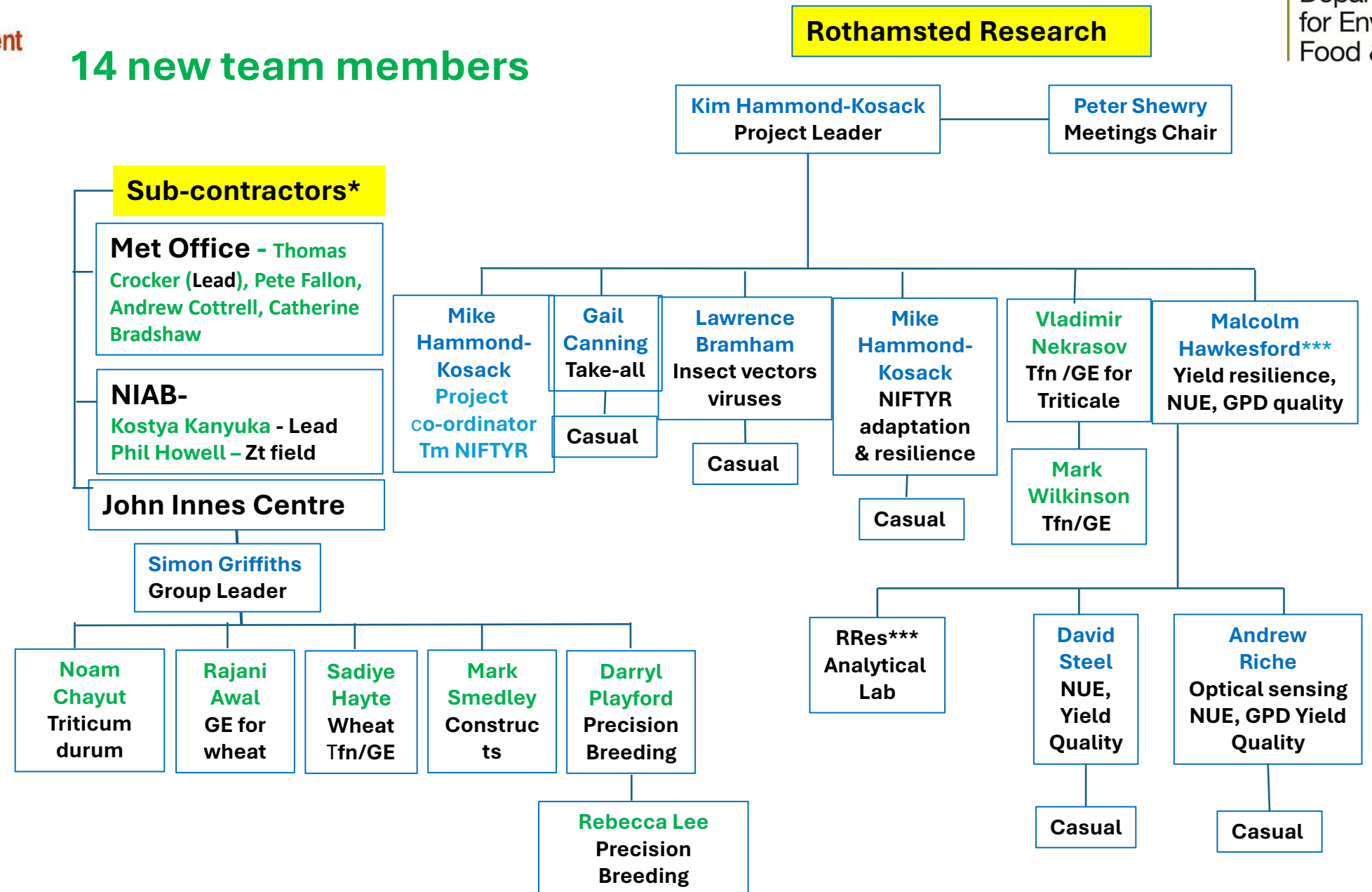
Adaptation to climate change – which new biotic targets?

THE WGIN 5 TEAM – Organogram n = 24

Wheat Genetic Improvement Network

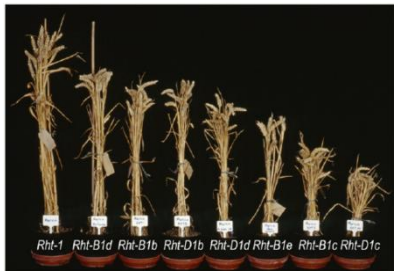
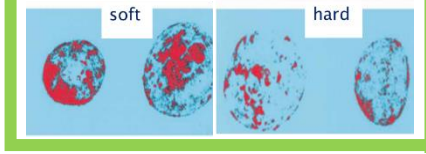
Department for Environment Food & Rural Affairs

14 new team members



Experimental breeding by GE for Watkins wheat lines in 5 ancestral groups

Constructs Prepared for Chosen Targets

	Trait	Gene	Why?	Required edit
	Height	*RHT-1*	Reduce lodging	1. Decoupling N terminal DELLA from C terminal GRAS (K/O) 2. C to T = early stop codon (Base Editing) 3. Writing an early stop codon(Prime Editing)
	Flowering time	*PPD-1*	Adapt to UK season	Reduce PPD-B1 copy number
	Grain colour	*R*	Prevent sprouting	Restore reading frame
	Grain texture	*PIN*	Suitable for leavened bread	Remove whole gene/s

Transformation of Selected Watkins Lines - details

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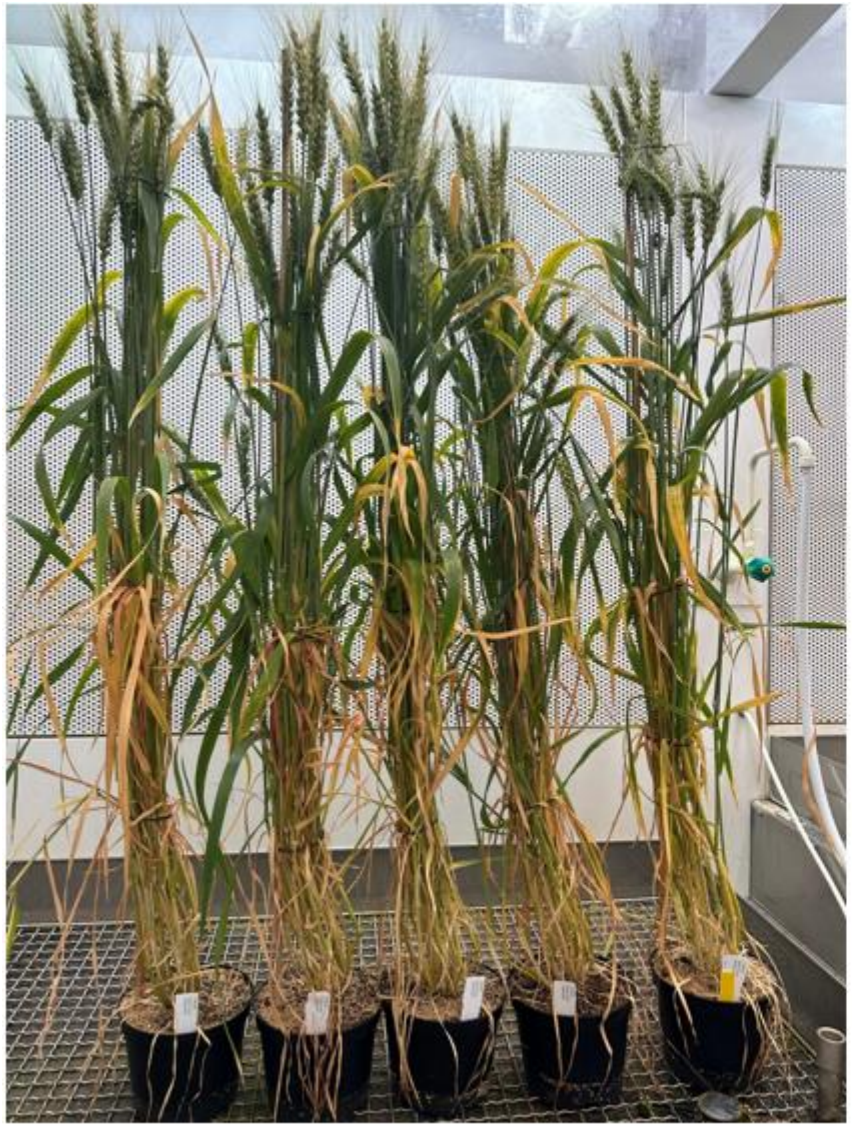
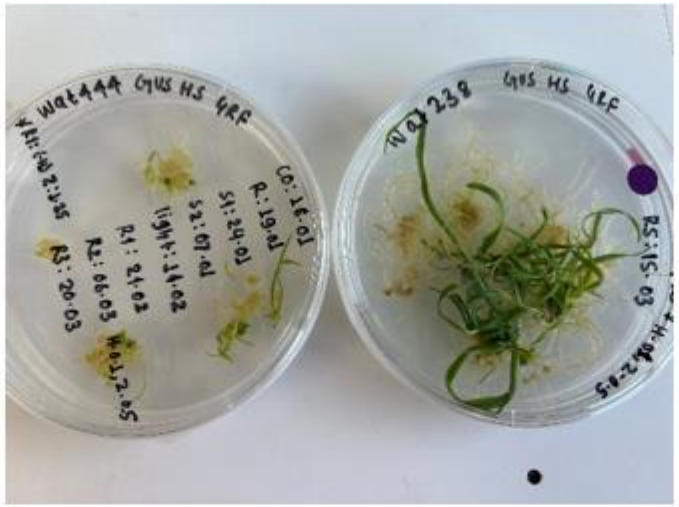
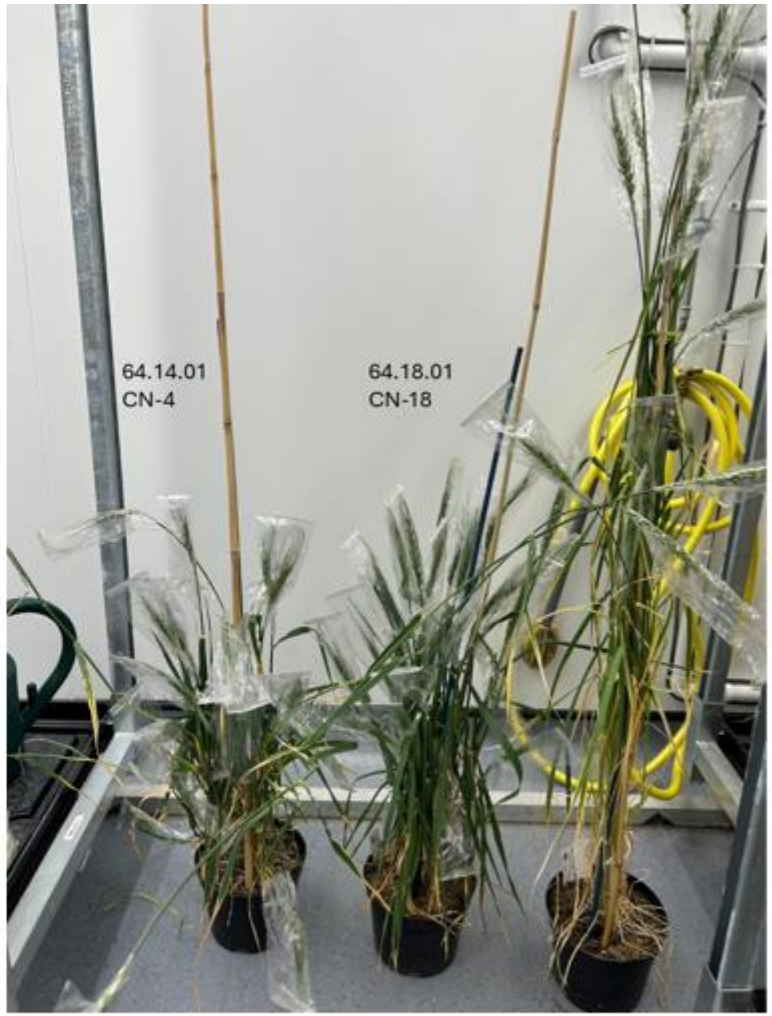




- Transformation efficiencies (4-33%)

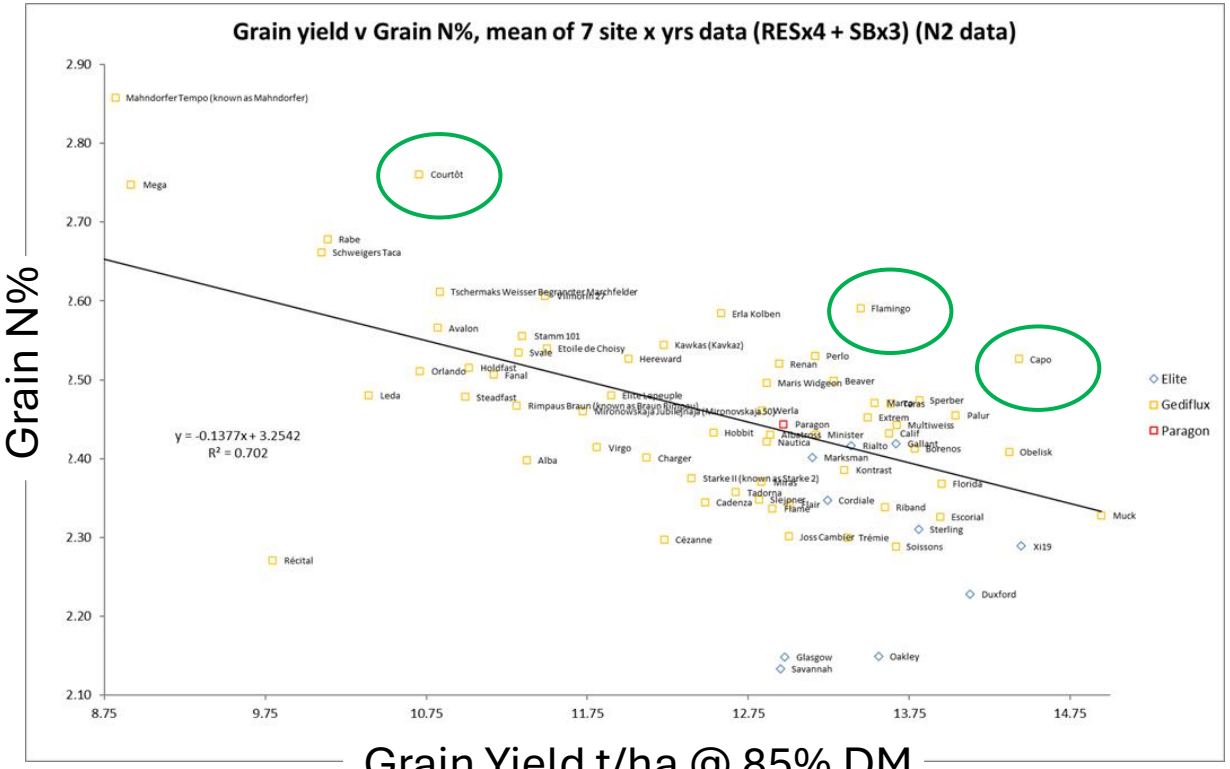
Simon Griffiths
Mark Smedley
Sadiye Hayte
Rajani Awal



- RHT1 CRISPR mutant WATDE0585

Grain Protein Deviation (GPD)

WP3.1 Trait - Resource use efficiency



Older lines, showing greater variation in GPD than modern lines

- Trait and gene discovery through selected biparental and NAM populations

Elite Parents

- **4 populations, Hereward x Malacca, Paragon x Courtot, Beaver x Soissons, Spark x Rialto**
- Seed multiplied at JIC and Rothamsted over 2 years
- 2 yrs (harvest 2027 & 28) yield plots
- Scoring of traits related to grain filling
- Genotype RILs (Bristol)
- GWAS analysis

Older, post green-revolution parents

- **2 populations, Flamingo x Paragon, Capo x Paragon**
- Seed multiplied at JIC and Rothamsted over 3 years
- 2 yrs (harvest 2028 & 29) yield plots
- Genotype RILs (Bristol)
- GWAS analysis

WP3.1 Resource Use Efficiency - details

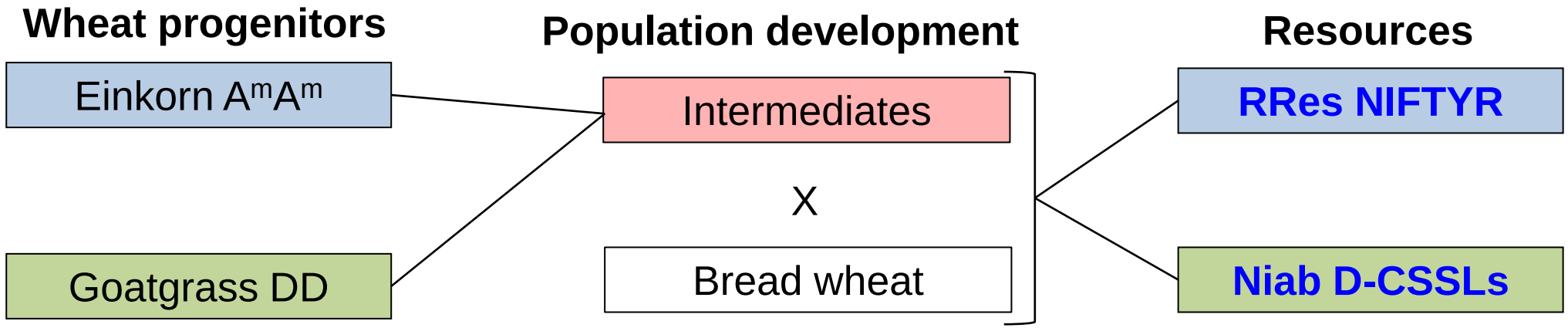
GPD Benchmarking field trials

- To determine GPD variation in a 3 year benchmarking field experiment
- 16 elite wheat lines (**six group 1**, **three gp 2**, two gp 3, two soft gp 4 and three hard gp 4) **plus 1 triticale and 1 durum**
- 2 levels of N - 125 & 250 kg/N
- Utilise the trial to evaluate the potential of a high throughput GPD screen, **measuring grain N** as an indicator of GPD

Field Experiment, 20/01/25

Malcolm Hawkesford & Andrew Riche

WP 3.2: Resilience to Pest & Pathogens (Septoria)



Genotyped resources for screening

Array analyses

All developed through previous long-term funding:

WISP / DFW (D-CSSLs) and WGIN3/WGIN4 (NIFTYR)

Genotyped using Axiom 35k (D-CSSLs) and TaNG 42k (NIFTYR) SNP-arrays

Donors MDR308 (A^mA^m), Ent-336 / Niab SHW-041 (DD), all in Paragon background

WP 3.2: Resilience to Septoria - details

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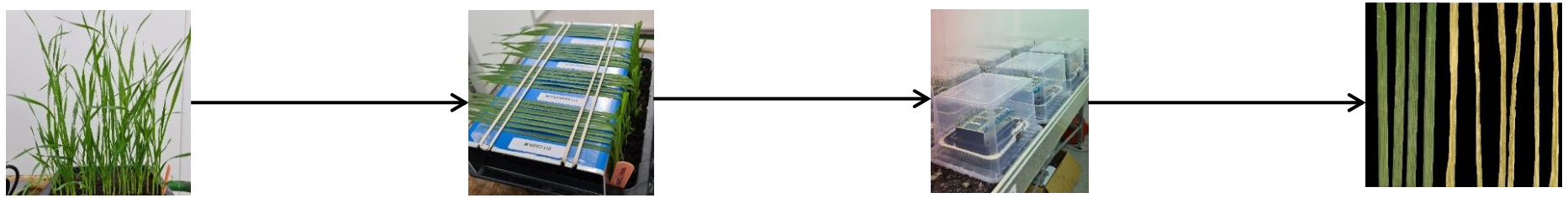
Niab (D-CSSLs) + RRes (NIFTYR): 2024-25



2-3 weeks after sowing, leaves detached from seedlings and inoculated

Controlled environment screening against STB isolates

NIAB location in Devon: high STB, low YR; 3 years of field testing

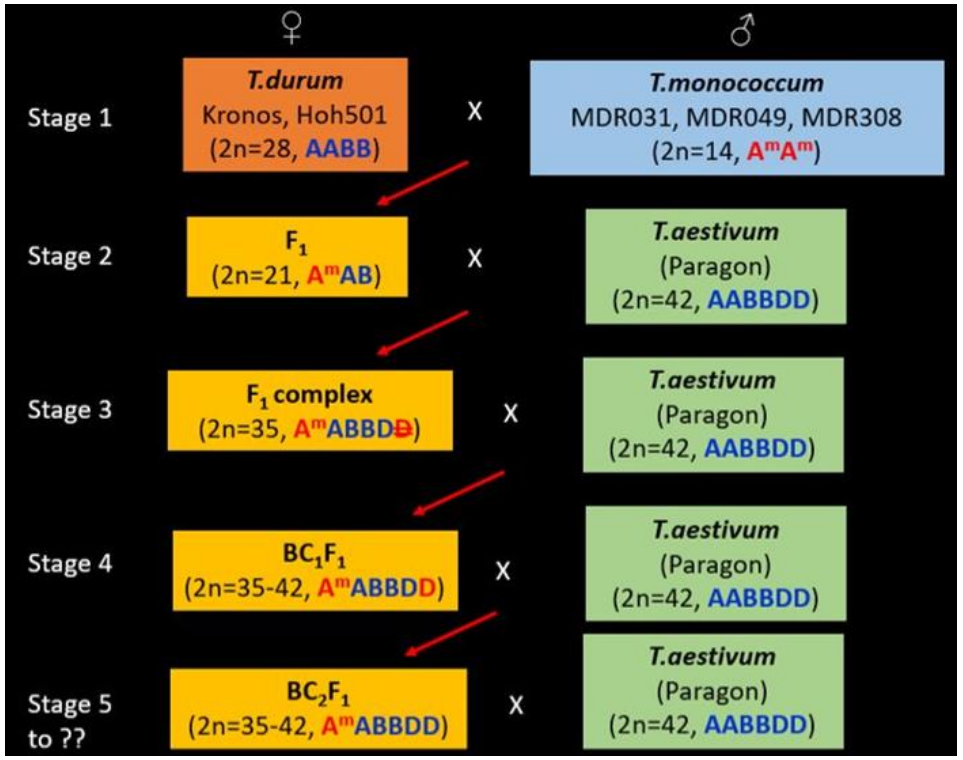
Robust field screening against natural infection

CSSL replicated trials planted autumn 2024 (M7: completed)
Trial ongoing to produce results → M26
Retest best lines + NIFTYR material in subsequent years

NIAB
Kostya Kanyuka
Phil Howell

Transferring Zymoseptoria Resistance from Diploid to Hexaploid Wheat

- ***Triticum monococcum* MDR308** (aka DV92) exhibits **complete resistance to Zymo**
- most likely *R* gene based – Tmon MDR308 gene mapped to Chr7A^{m}S (telomere end) (Hai-Chun Jing, WGIN1)
- crossing MDR308 with hexaploid wheat: introgression could result in Zymo R in bread wheat
- crosses successful only when **using *T. durum* (Hoh501) as a bridging species**:



- **2 fertile BC1F1 lines** generated from MDR308 & Hoh501
- **50 NILs** (near isogenic lines) generated from these
- all tested in multiple **Zymo attached leaf assays** with **IPO323** (standard Zymo strain), but also **Zt116**, one of the **most virulent** isolates to date:
- of the 3 parent cultivars, Paragon is fully susceptible while both Hoh501 and MDR308 are fully resistant

parents: Paragon Hoh501* MDR308

S R R

*most likely non-host resistance

WP 3.2: Resilience to Septoria in NIFTYR lines - details

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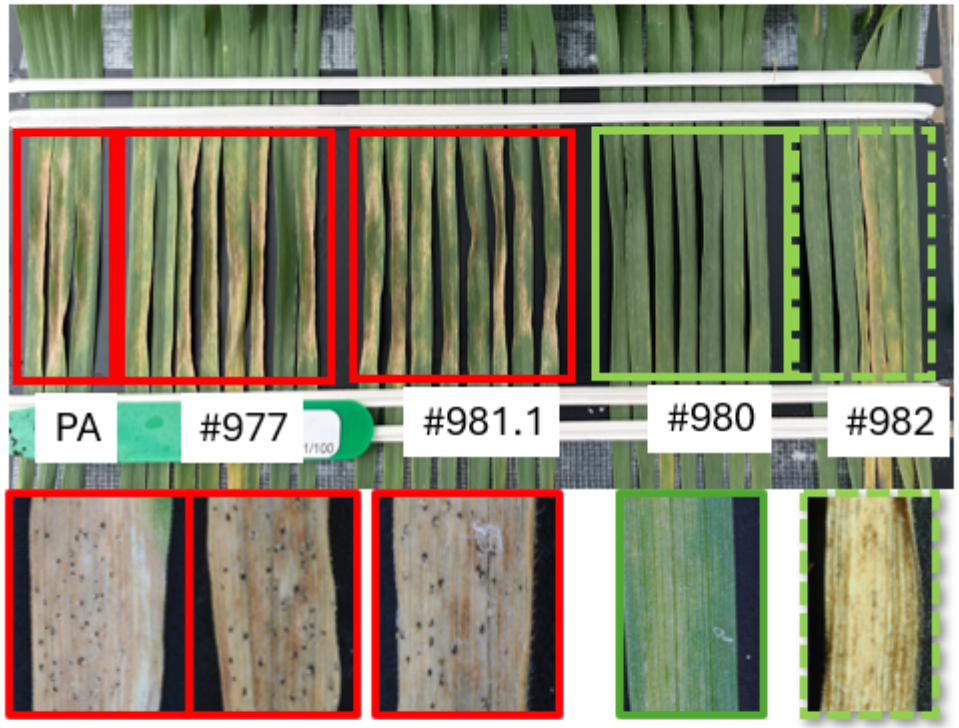
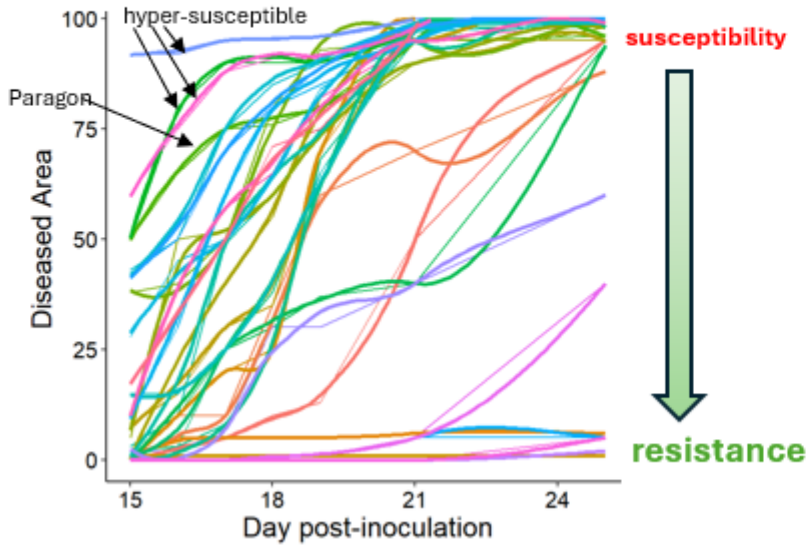
attached leaf assays:



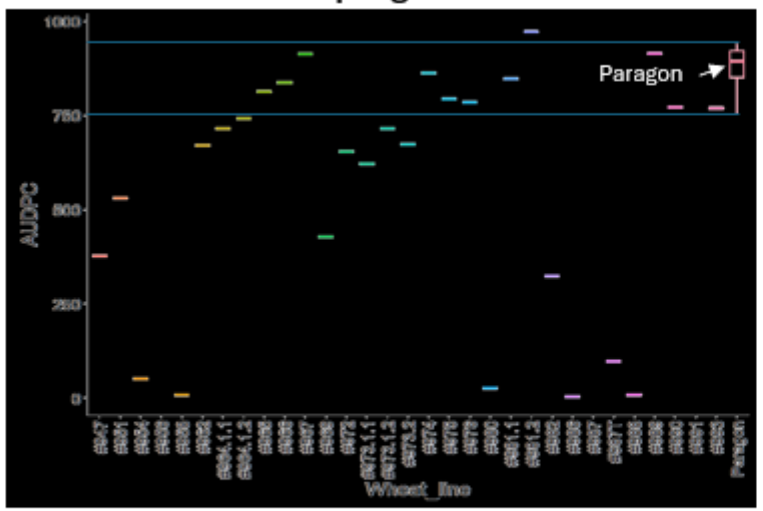
black dots = asexual sporulation structures (**pycnidia**)

- PA, introgressed NIFTYR lines #977 & 981.1 susceptible
- **NIFTYR #980 fully resistant** – no bleaching, no pycnidia
- NIFTYR #982 partially resistant (mR)/ slowed disease progression

disease progression curves:



area under disease progression curves:



Outcome:

- **6 highly resistant NIFTYR lines**
- 4 with moderate resistance
- 7 with delayed susceptibility
- 3 hyper susceptible
- T.mon MDR308 Introgression has been successful to generate Zymo resistant hexaploid wheat

Next:

- evaluate all R and some S lines under field conditions (NIAB, K.Kanyuka, WGIN5)
- use GFP-Zymo strain(s) to evaluate R mechanisms
- use TaNG genotyping to evaluate lines for introgressed segments
- skim-sequence all R and some S lines

please contact **Dr. Mike Hammond-Kosack** for enquiries at wgin.defra@Rothamsted.ac.uk **OR** scan the QR code to become a NIFTYR member ☺

Spraying of maturing plants (GS49-59) with Zymoseptoria Zt116 in controlled environment

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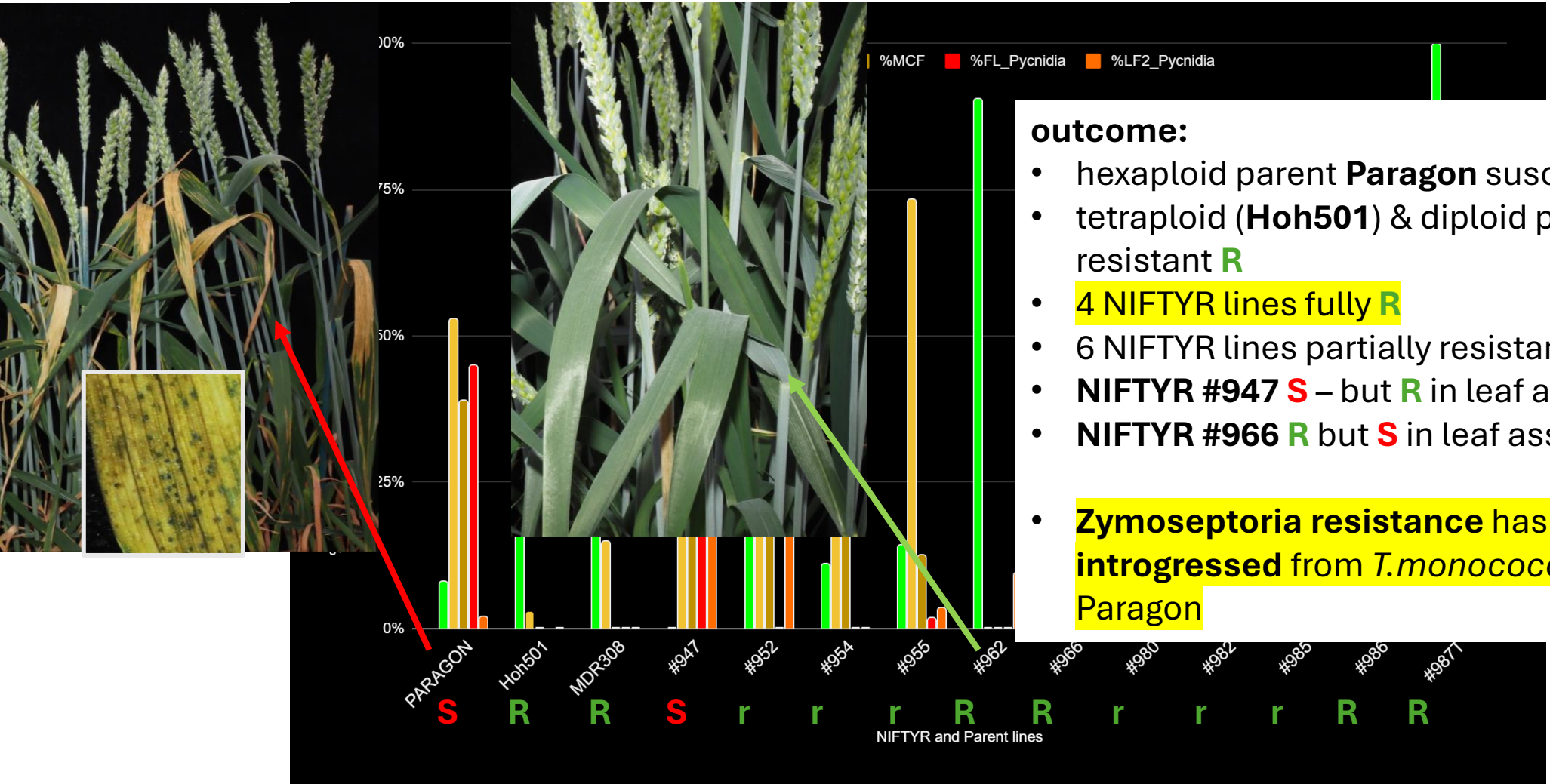
- **11 NIFTYR lines** (10**R**, 1**S**) selected from attached leaf assay results
- up to 24 plants/line **grown under CE**
- all plants **sprayed with Zt116** (10^7spores/ml) 46d after sowing when flagleaves fully extended for all lines
- **GS** varied between **49 to 59**
- Zymo symptoms emerged from 4d post infection



outcome:

- hexaploid parent **Paragon** susceptible **S**
- tetraploid (**Hoh501**) & diploid parent (**MDR308**) fully resistant **R**
- 4 NIFTYR lines fully **R**
- 6 NIFTYR lines partially resistant **r**
- **NIFTYR #947 S** – but **R** in leaf assays
- **NIFTYR #966 R** but **S** in leaf assays

- **Zymoseptoria resistance** has been **successfully introgressed** from *T.monococcum* MDR308 into Paragon

WP3.2 – Resilience to Pests and Pathogens

Wheat virus exploration, resistance identification and deployment

Wheat Genetic Improvement Network

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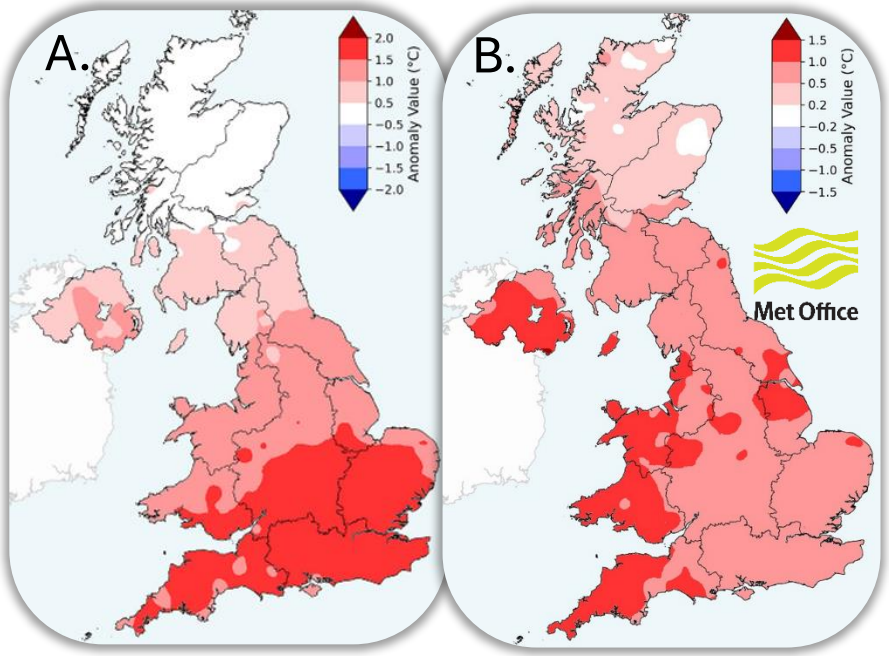
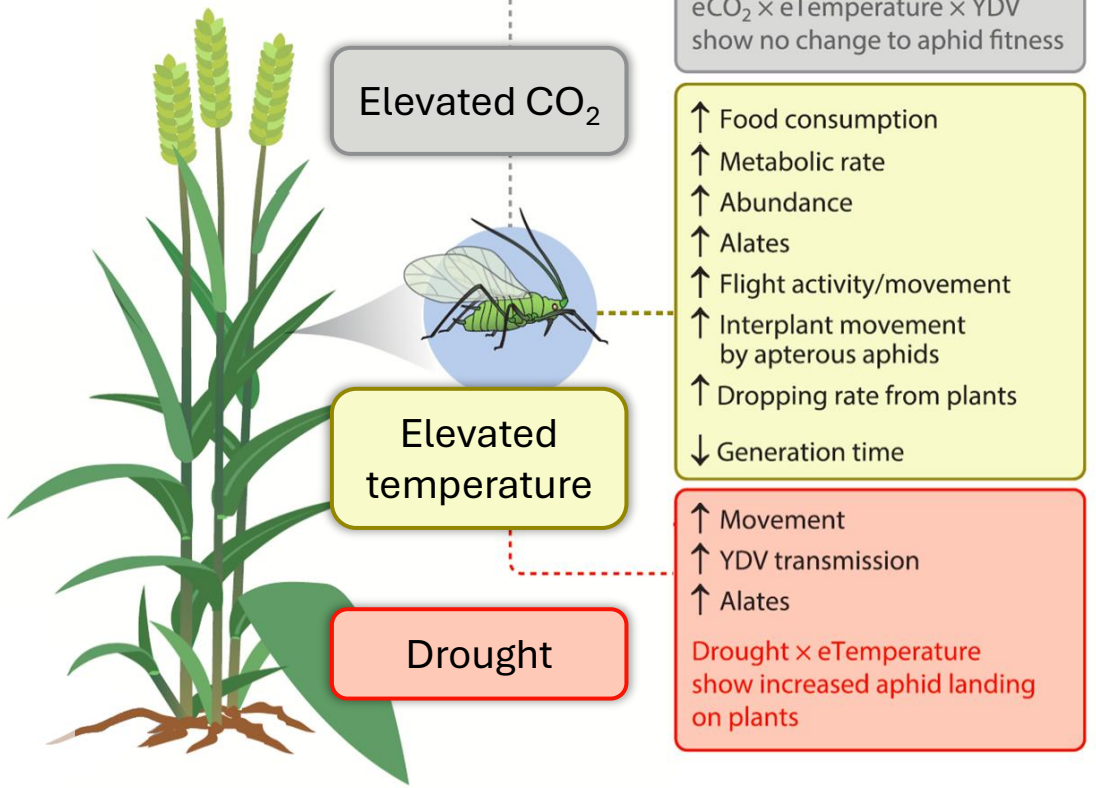
Obj 1: literature review - identify current, emerging and potential viral threats to UK wheat



[1]Mean temp anomaly (°C) vs 1991-2020 for:
A. 2023 autumn; B. 2023 minimum

Increased movement and overwintering

Adapted from Peters et al.[2]



Insect vectors and associate viral strain dynamics likely to shift

Lawrence Bramham

[1]Kendon et al., (2024) *International Journal of Climatology,* **43,** 1-83
[2]Peters et al., (2022) *Annual Review of Phytopathology,* **60,** 283-305

WP3.2 – Resilience to Cereal Viruses

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Literature review (~150 articles) - identify current, emerging and potential viral threats to UK wheat

e.g. *Rhopalosiphum padi*

e.g. *Javesella pellucida*

- **Wheat hosts - c.55 viruses of concern identified**
- **Core vectors = hemipteran insects (aphids, leaf/plant hoppers)**
- **16 viruses of interest (VOIs) identified with impact on wheat yield, incidence in UK or near-Europe, and vector component (hemipteran n=8):**

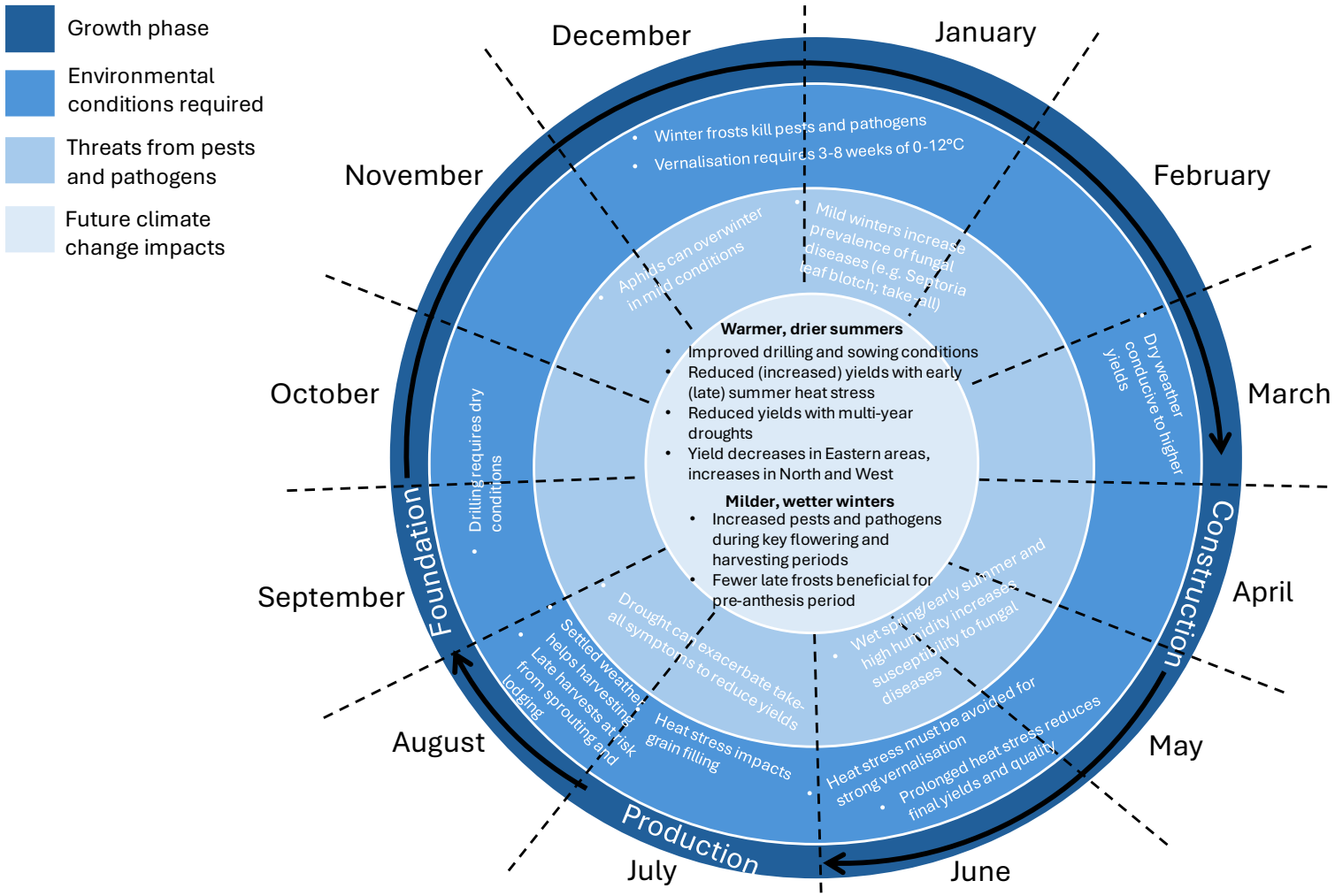
BYDV remains most important, but **BVG and WDV** highest on "WGIN5 VOI watchlist"

Virus	Acronym	Vector group	Primary vector	Virus in UK?	Vector in UK?	Virus in Europe?	Vector in Europe?
Barley virus G	BVG	Aphids	*R.padi*	Perhaps, unconfirmed records	Yes	Yes	Yes
Barley/Cereal yellow dwarf virus	B/CYDV	Aphids	*R.padi*	Yes	Yes	Yes	Yes
Cocksfoot streak virus	CSV	Aphids	*Myzus persicae*	Yes, *but impactful strain unconfirmed*	Yes	Yes	Yes
European wheat striate mosaic virus	EWSMV	Leafhoppers	*J.pellucida*	Yes	Yes	Yes	Yes
Festuca leaf streak virus	FLSV	Leafhoppers	*J.pellucida*	Unknown	Yes	Yes	Yes
Wheat dwarf virus	WDV	Leafhoppers	*Psammotettix alienus*	Perhaps, unconfirmed records	Yes	Yes	Yes
Barley yellow striate mosaic virus	BYSMV	Planthoppers	*Laodelphax striatellus*	Unknown	Perhaps, unconfirmed	Yes	Yes
Maize rough dwarf virus	MRDV	Planthoppers	*Laodelphax striatellus*	Unknown	Perhaps, unconfirmed	Yes	Yes

Lawrence Bramham

WP3 Establishing relevant climate hazards for WGIN activities

Desk-based study into relevant climate hazards for wheat and other WGIN crops



WP3.2 Climate influences on biotic hazards to WGIN crops - details

- **Majority of work complete and drafting of outputs in progress**
- **Work will inform further analysis to support WGIN deliverables**

	Milder, wetter winters	Hotter, drier summers
Biotic factors[2]	Following diseases are exacerbated by these conditions: • Black (Stem) Rust (*Puccinia graminis*) • Brown (Leaf) Rust (*Puccinia triticina*) • Bunt/Stinking Smut (*Tilletia tritici*) • Barley Yellow Dwarf (*transmitted by aphids*) • Eyespot (*Oculimacula yallundae*) • ***Septoria Leaf Blotch (*Mycosphaerella graminicola*)*** • ***Take-all (*Gaeumannomyces graminis*)***	Following diseases are hindered by these conditions: • Black point (*Alternaria* and *Cladosporium*) • Ergot (*Claviceps purpurea*) • Seedling Blight, Ear Blight, Foot Rot (*Fusarium*)[3] • Sharp Eyespot (*Cetrobasidium cereale*) • Yellow (Stripe) Rust (*Puccinia striiformis*)
		Following diseases are exacerbated by these conditions: • Brown (Leaf) Rust (*Puccinia triticina*) • Foot Rot (*Cochliobolus sativus*) • Leaf and Glume Blotch (*Phaeosphaeria nodorum*)

Met Office

Tom Crocker
Andrew Cottrell

WP4: The underutilised cereal species

10%

Durum wheat

AABB

UK crop 2024 ? > 0%

10%

Triticale,

AABBRR

UK crop 2024 <0.1%

Locally adapted Durum landraces

8000 BCE -1920s AD

Assembled by A.E Watkins from 23 countries

1920s-1930s

350 LR are stabilised through X3 SSD

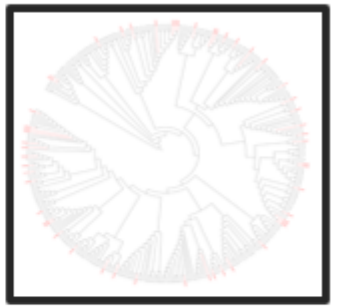
2020,2021,2023

35K Axiom® array genotyping data

To **select 50 lines** as **core collection**

	Marker 1		Marker 2		Marker 3	
	A1	A2	A4	A5	A6	A7
S1	1	0	0	1	0	0
S2	1	0	1	0	1	0
S3	0	1	1	0	1	0
S4	1	0	1	0	1	0
S5	1	0	0	1	1	0
S6	1	0	0	1	0	1

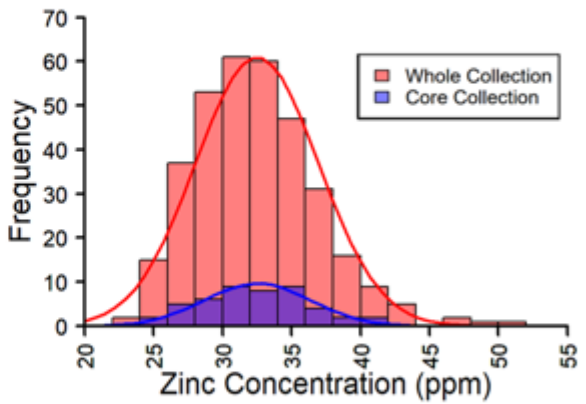
Thachuk, C., . *et al. 2009*



2024 (WGIN-5, Milestone 12)

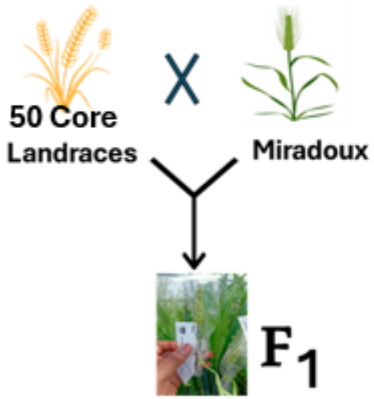
WP 4 – Durum wheat pre-breeding activities to develop Watkins germplasm resources

Phenotypic broad diversity is confirmed (e.g., mineral screen)



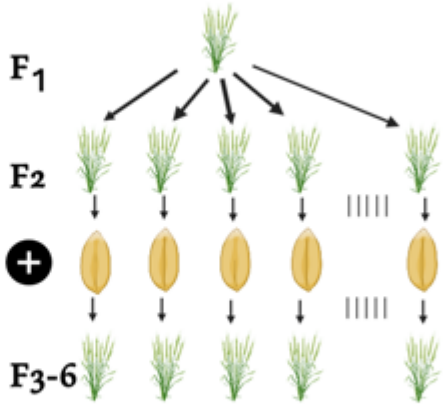
2024 (WGIN-5, milestone 12)

Durum Cross Plan initiated in the GH



2025
(WGIN-5, Ongoing)

NAM Population Development



Future work (WGIN-5)

Beneficial alleles for wheat breeding

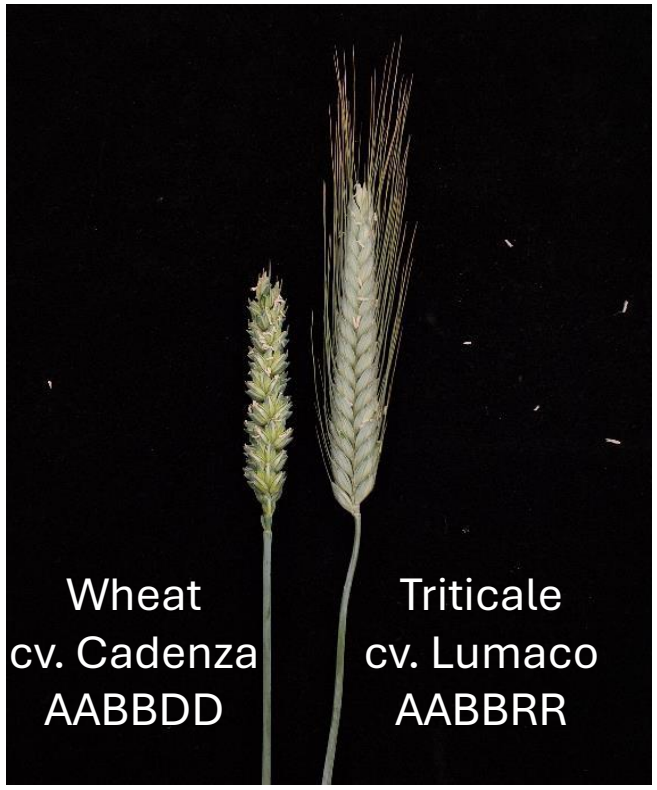
Phenotyping, Genotyping, NAM GWAS

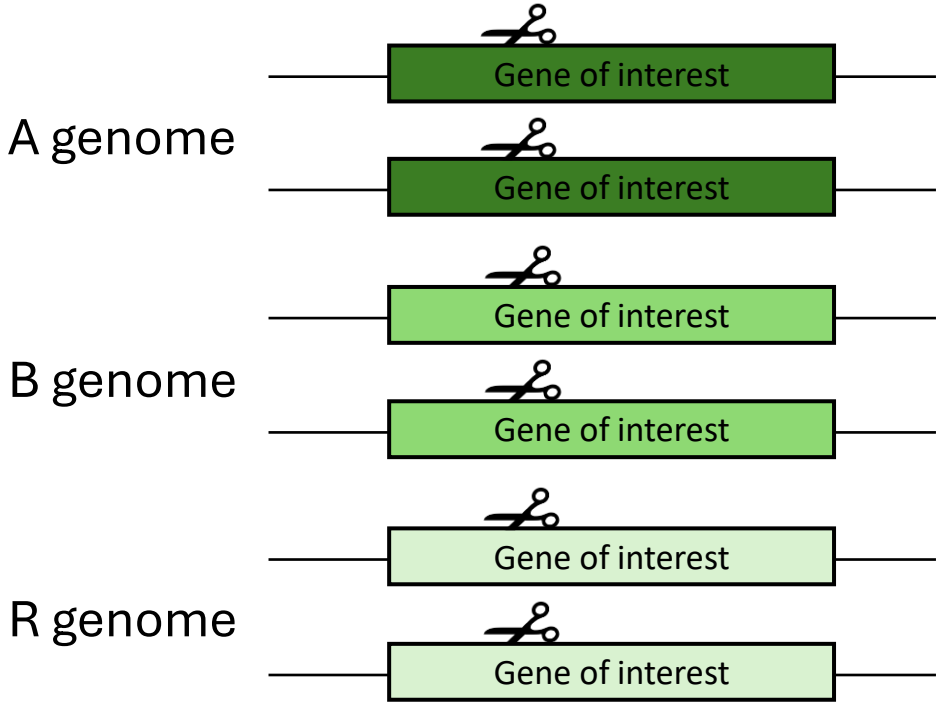
Future work (after WGIN-5)

John Innes Centre

Noam Chayut

Triticale – Establish Precision Breeding by GE (CRISPR/CAS)





Triticale, an important feed grain crop in the UK

Triticale combines the yield potential and grain quality of wheat with the disease and environmental tolerance of rye

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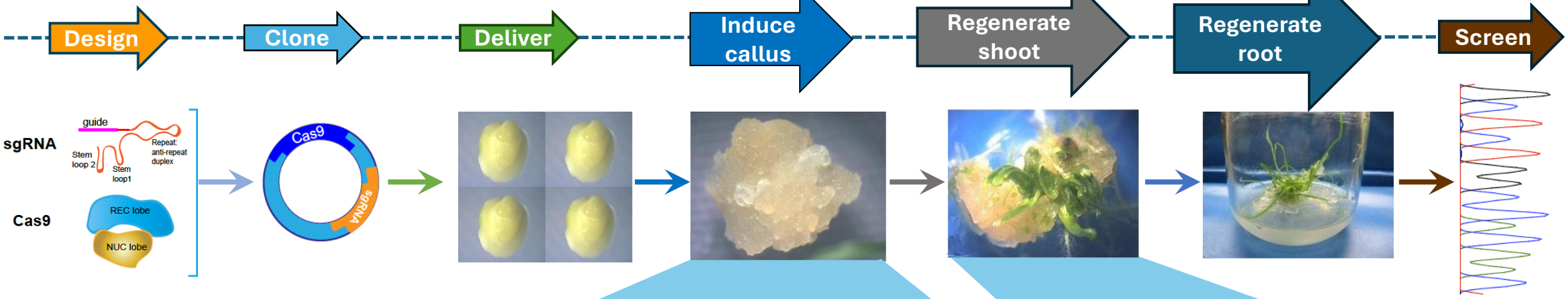
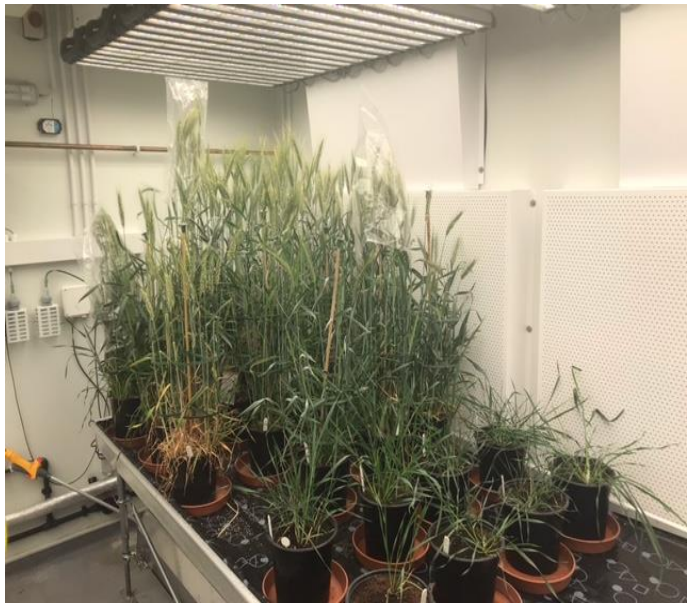
Triticale GE - details

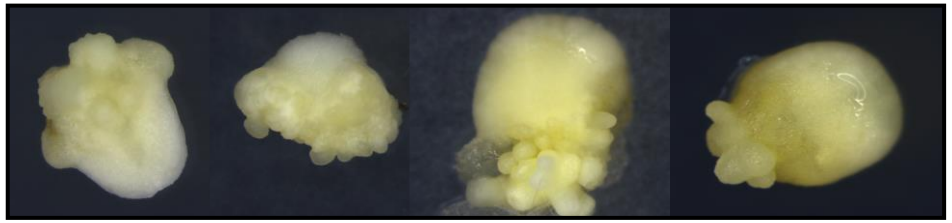
Adapted from Ahmadpour et al. (2016) BABT



Ten self-fertile winter triticale cultivars were provided by Geert Haesaert (University of Ghent, Belgium)

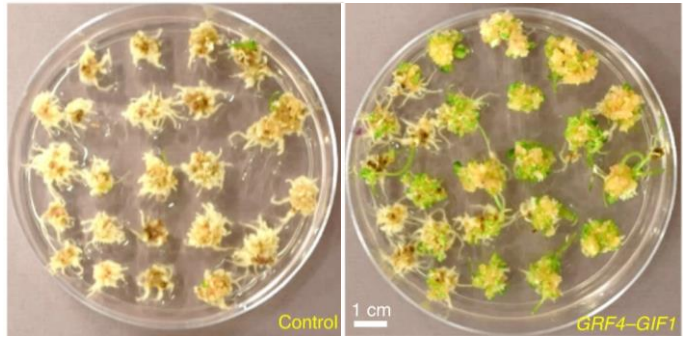


Initiation of embryogenic callus using triticale immature embryos (cv. Lumaco)



1. We are in process of establishing triticale transformation in tissue culture using immature embryos from the ten cultivars.
2. We are designing CRISPR/Cas constructs for targeting *RHT-1*, *GT43_2* and *GT47_2* genes.

GRF4-GIF1 chimeric morphogenic regulator dramatically enhances wheat transformation efficiency



Debernardi et al. (2020) Nature Biotechnolgy

Vladimir Nekrasov
Mark Wilkinson

Outreach activities

Joint GINs webpage – 'Defra Crop Genetic Improvement Platform' - https://defracropgenetics.org/

WGIN website - http://www.wgin.org.uk/ - under review

WGIN stakeholder event – Wednesday 5th Feb 2025, BASIS points registered – https://www.eventbrite.co.uk/e/22nd-wgin-stakeholders-meeting-2025-on-line-registration-tickets-1137836472519 - **open till 5th Feb**

Hybrid event at JIC 9.45 am – 4.00 pm (with 3 breaks) ~ 50 in person / ~ 110 online

2 external talks - AHDB, ADAS, 10 talks on WGIN5 project

Fireside Q & A on 'Climate Change from the Farmers' perspective', involving two farmers in conversation with the leader of the BOFIN group

Attendees ~25% farmers / farm managers and ~ 20% from commercial wheat breeding companies

Total attendees ~160

WGIN 5 – The Social Values

Understanding of employment and skills issues and shortages in the research sector - British Society for Plant Breeding

Delivery of training schemes and programmes to address any identified skills gaps and under-representation in the workforce for the contract - Gatsby Foundation Plant Sciences Summer Schools (GFSSS) programme, York + summer Rootstock event - 23rd July, 3.5 hr, Cambridge 45 UK based undergraduate students

Support the contract workforce by providing career advice and opportunities for in-work progression and career development

WGIN5 - Additional information

3 year PhD student Anisa Blower (**based at NIAB**, registered at University of Nottingham, funded through BBSRC CTP-SAI scheme and The Morley Agricultural Foundation) has carried out much of the **Septoria leaf blotch** preliminary screening and will help with data gathering from the WGIN 5 2024-25 field trial

A year in industry placement undergraduate student working in the Genetic Resources Unit at JIC is focussing on WGIN5 Durum objective
Funds: JIC Year in Industry
Title: "*Nutritional quality of traditional and modern wheat varieties*"

Potential WGIN5 aligned project in FY 25/26
Investigating wheat seed longevity association with climate
Met Office collaboration with **Noam Chayut (JIC**)
Funding from Defra FFNE service. (Still to be confirmed)

WGIN 5 Mission statement

Improving the efficiency, resilience, adaptation and sustainability of the wheat crop and alternative cereals through genetics, precision breeding and targeted trait analysis