WGIN3 Legacy and Overview of the WGIN4 Core Project

Wheat Genetic Improvement Network

Kim Hammond-Kosack

Rothamsted Research

Department for Environment Food & Rural Affairs

16th November 2018, 16th Stakeholder meeting, RRes, Herts

Wheat Genetic Improvement Network

Department for Environment Food & Rural Affairs

WGIN provides a research platform for the delivery of

- **tools**
- **resources**
- **bioinformatics (large scale DNA analyses)**

- **expertise for the identification of naturally occurring (useful) genetic variation in new traits**

Yield and quality per se are excluded





The Defra WGIN

started in 2003

Grain Producers and Utilisers

9 UK WHEAT BREEDING COMPANIES

MODEL SPECIES

OTHER CEREALS

WGIN

EU

INTERNATIONAL

BBSRC

The WGIN funds would attract additional funds to wheat research by other sponsors

Projects of 5 years and 3 years duration

WGIN 1 (2003-2008) project funded partners
John Innes Centre
Rothamsted Research
+ 2 pilot projects (2 yr)

WGIN 2 (2009-2014) project funded partners
John Innes Centre
University of Nottingham
Rothamsted Research
+ 2 pilot projects (1 yr / 2 yr)

£942K **WGIN 3 project (2015-2018) – funded partners**
John Innes Centre
Rothamsted Research
+ Bristol Genomics Facility, Univ. Bristol, UK
+ Arbor Biosciences, Michigan, USA
} **Two specialist sub-contractors**

£1,600K **WGIN 4 project (2018-2023) – funded partners**
John Innes Centre
Rothamsted Research
+ Bristol Genomics Facility, Univ. Bristol, UK (35K wheat array)
+ Arbor Biosciences, Michigan, USA (MyBaits exome capture WAKs)
+ NIAB, Cambridge, UK (yellow rust race tests)
+ Dovetail Genomics, San Diego, USA (sequence / assemble one wheat chromosome)
} **Four specialist sub-contractors**

Mission statement - WGIN 2003 to 2014

Improving the environmental footprint of farming through crop genetics and targeted traits analysis

Mission statement - WGIN 2015 to 2023

Improving the resilience of the wheat crop through genetics and targeted traits analysis

What has WGIN achieved ?

- New genetic resources and tools
- Defining new traits for wheat improvement
- Maintaining and enhancing the public – private network
- Increasing funding into wheat research
- Training the next generation

New resources / tools developed in WGIN
THE BIG FIVE

- **A reference UK mapping population**
  Avalon x Cadenza (DH pop^{n}, 203 lines + 584 lines)
- **Restoration of the AE Watkins wheat collection**
  > 1200 lines from 31 countries
  never previously used in modern breeding
- **EMS chemical mutagenised TILLING populations**
  Cadenza and Paragon (> 5000 lines + 1200C lines DNA)
- **A global collection of *T. monococcum* accessions (AA genome) ~ 323 lines, 34K breeders array + 5 F_6 pop^{n}**
- **Grain samples from WGIN cultivar diversity trials since 2003 (3 or 4 nitrogen treatments / all plots)**

Trait identification

Consecutive years of field trials

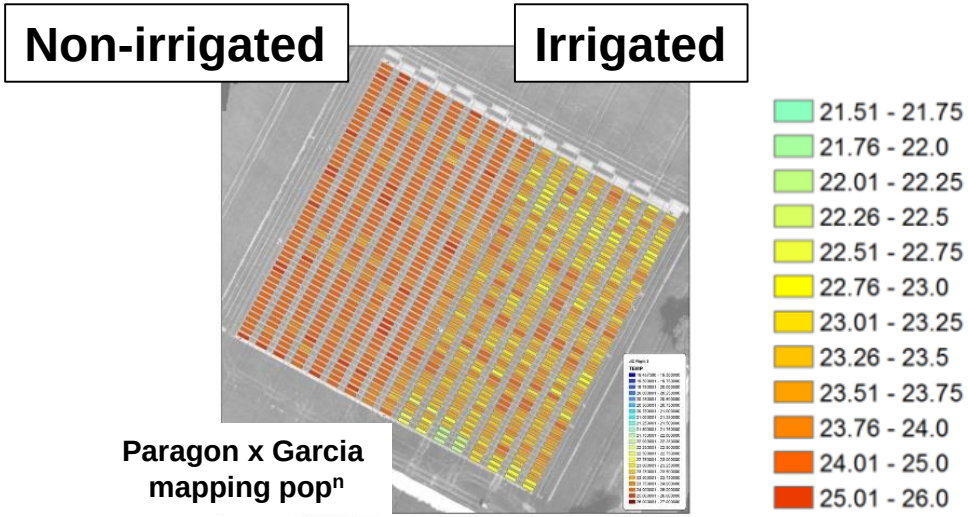
1. Improved nitrogen use efficiency (NUE)

2. Grain quality traits linked to NUE

3. Tolerance to spring drought

Malcolm Hawkesford, RRes

10:40am, 28.2^{0}C



Clare Lister, JIC

2017

Trait identification – RRes

2. Reducing pest and disease pressure

Aphids

***Septoria* leaf blotch**

Yellow rust

Take-all fungus

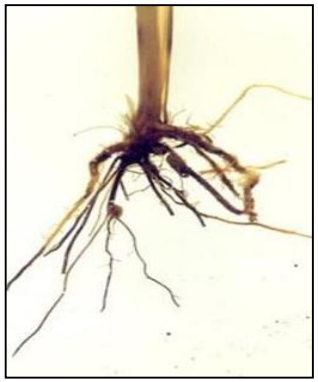
a major problem for 2nd / 3rd wheat crops

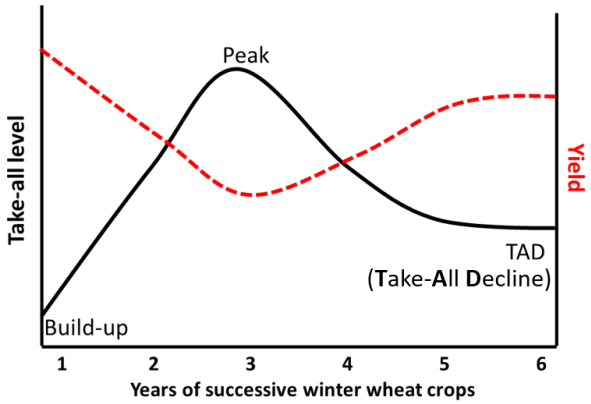
annually all crops at high risk

2nd wheat syndrome

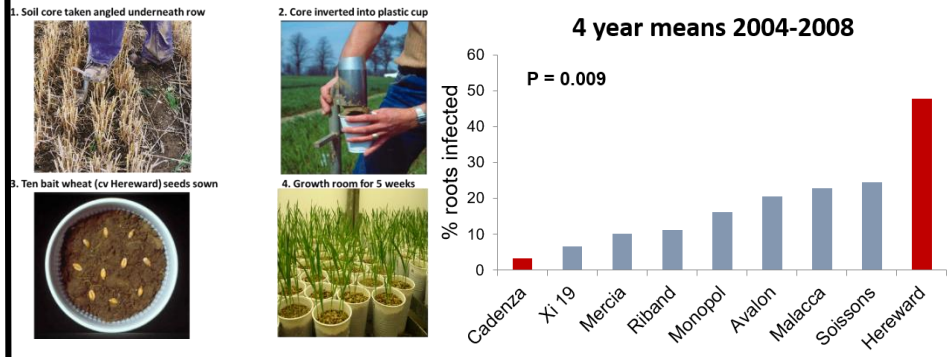
Take-all build-up (TAB) trait

Take-all disease = a major problem for 2nd/3rd wheat crops



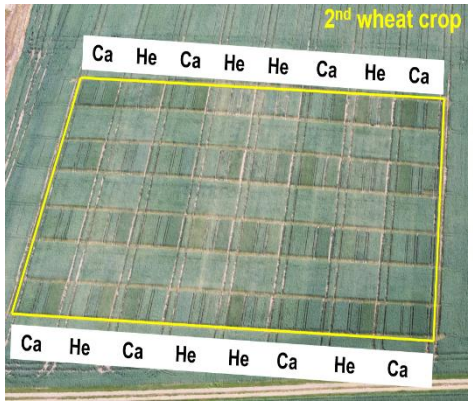


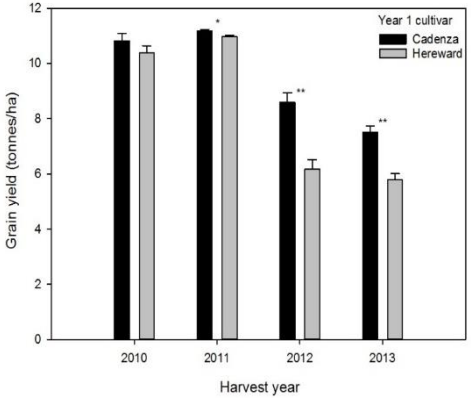
Wheat cultivars differ in their ability to build-up inoculum of the take-all fungus



McMillan *et al*. (2011) Plant Pathology.

2nd wheat yields improved by up to 2.4 t/ha by growing a Low TAB 1st wheat cultivar

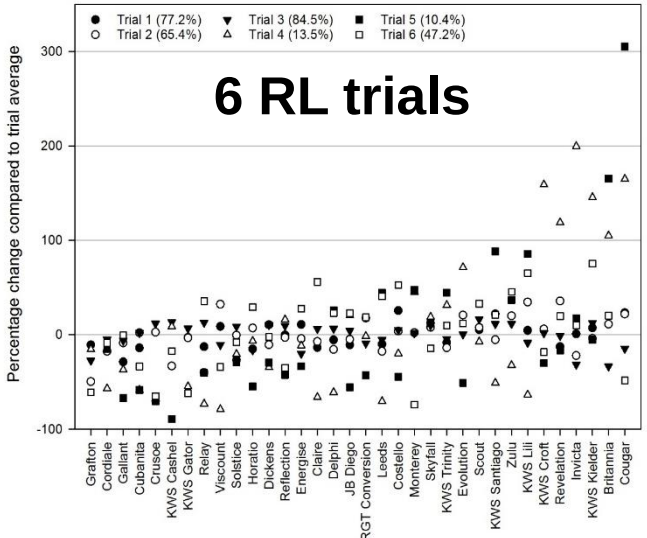




Vanessa McMillan, RRes

Nature Scientific Reports (2018)

Commercial RL wheats differ in TAB but there was evidence of an environmental effect



Grafton, Cordiale and Gallant were the most consistent Low TAB cultivars

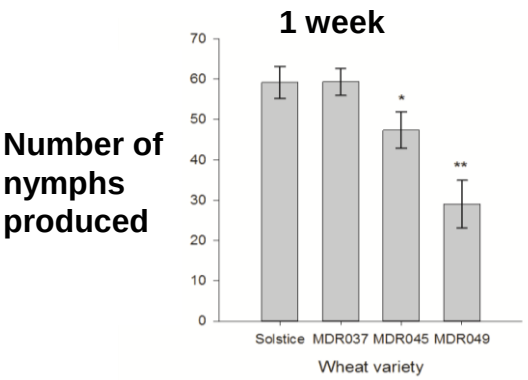
Cereal aphid resistance in wheat

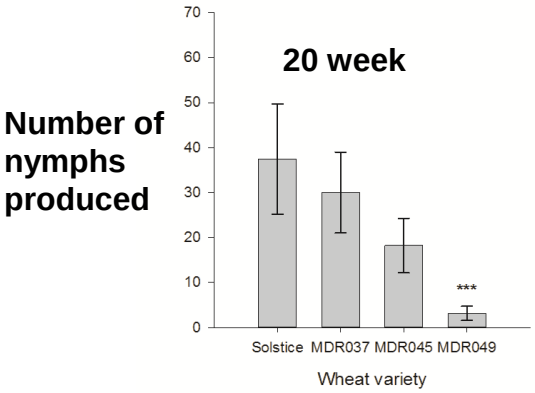
Growth room tests

T. monococcum

Bird cherry-oat aphid

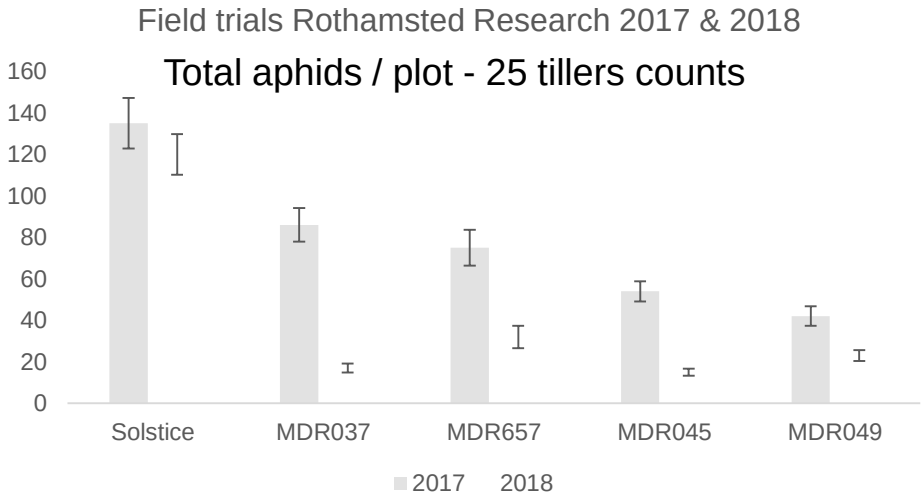
English grain aphid



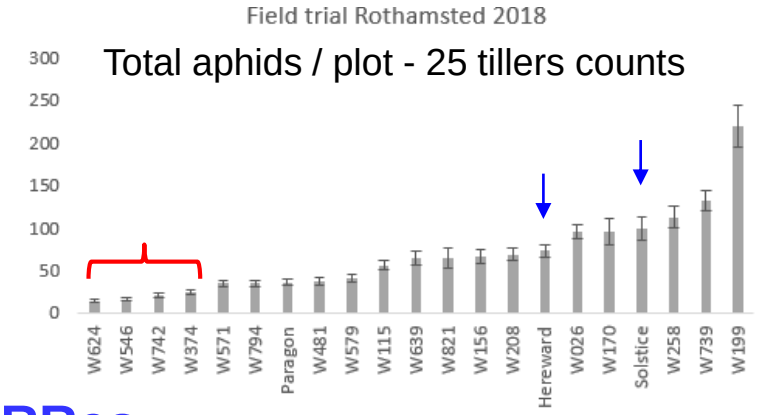


Field trials

T. monococcum (diploid wheat)



Watkins Landraces



Gia Aradottir, RRes

A global collection of *T. monococcum* Einkorn wheat accessions (A^mA^m genome) ~ 323 lines

Rarely used in modern wheat breeding

Core collection

- **50 accessions from the Vavilov Institute in St Petersburg, Russia**
- **pre-selected for high resistance to pests and diseases from 19 field trials / multiple years across Russia (1950-1980s)**
- **50 small batches of 'mixed' seed arrived @RRes in 2004, WGIN 1**

Triticum monococcum traits and introgression

2004 - 2006 – generated pure lines by single seed decent

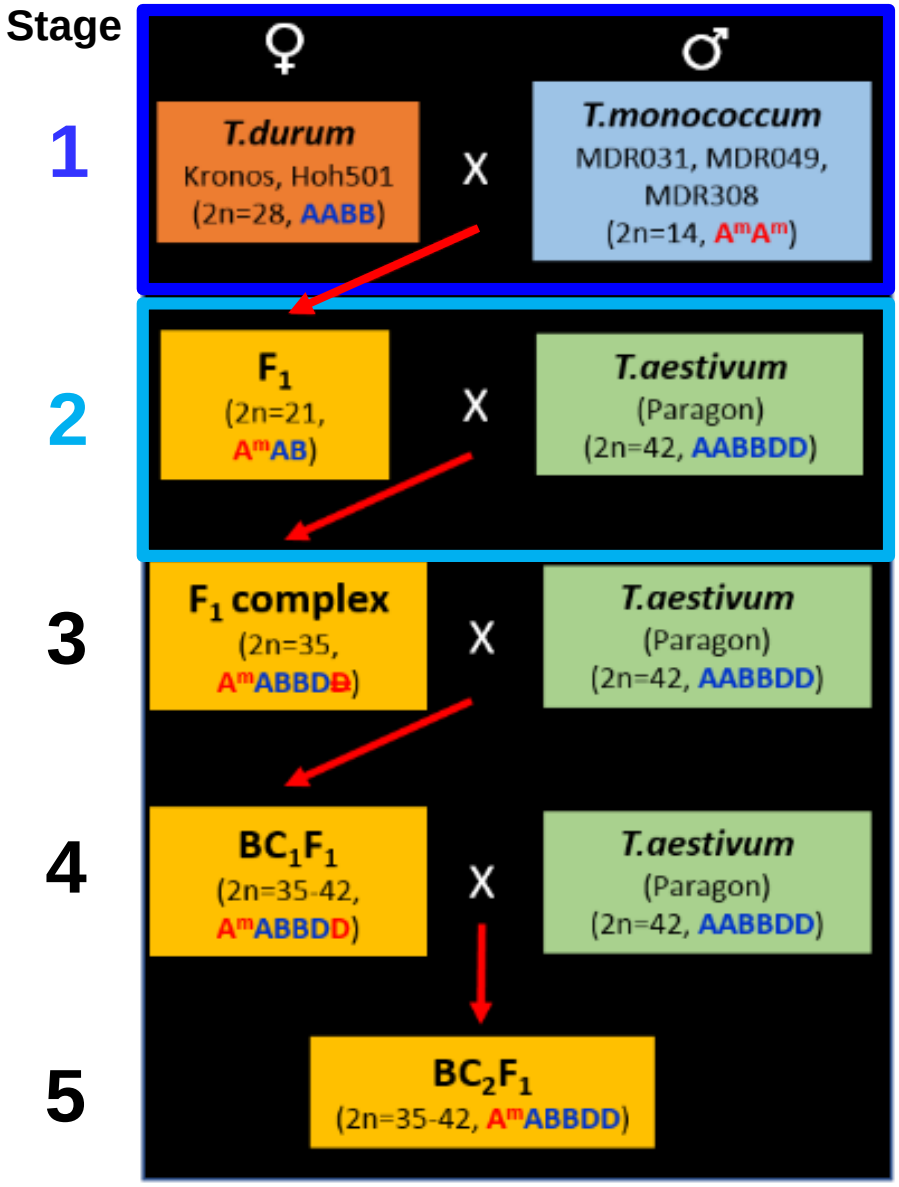
2005 onwards glasshouse and small plot field trials (numerous traits)

Introgression

started in 2006 (WGIN 2) and 11 years later crossing strategy No 3 is working !

Mike Hammond-Kosack, RRes

WGIN 3 *Tm* introgression strategy No 3 – using tetraploid durum wheat as bridging species



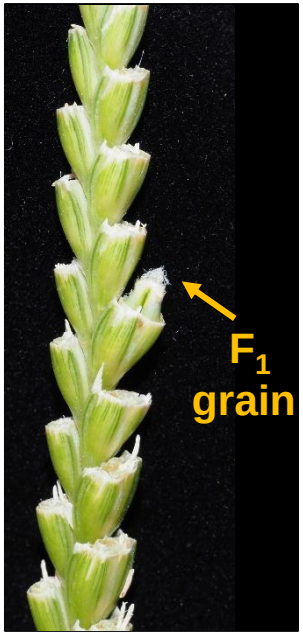
The traits

- MDR031 – take-all resistance
- MDR049 – aphid resistance
- MDR308 – septoria leaf blotch resistance

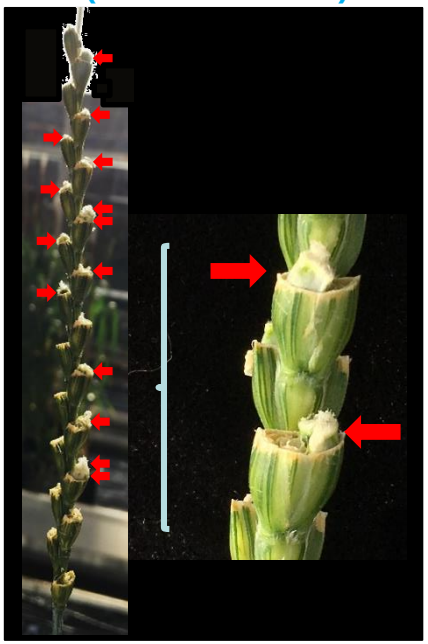
- All 3 *Tm* lines fully resistant to mildew, brown and yellow rust (all growth stages)

- Fertility rates

Stage 1 - 0.47%



Stage 2
17.52%
(37 fold increase)



The Networking objectives

Maintaining and enhancing the public – private network

8 of the 20 activities

The Defra WGIN: Dissemination, Liaison and Communication

Annual "Stakeholders' Forum" (Nov) 70-100 attendees

Focussed Workshop – 2009, 2013 'A x C mapping pop^{n}'

2010 – DArT marker analysis

Workshops with overseas partner organisations:

Seven in total funded by BBSRC (2018 – Kazakhstan)

Web Site (www.WGIN.org.UK)

Electronic Newsletters

Scientific publications ~ 78 articles

Annual displays at 'Cereals'

E. mail: wgin.defra@bbsrc.ac.uk

Twitter Handle - **@WheatGIN**

Wheat Genetic Improvement Network

The WGIN 3 legacy so far

Scientific publications - 23 peer reviewed articles

Helping in the training of 11 PhD students

Since 2015 – new funding **Total = £29,940,463**

Designing Future Wheat (2017)

BBSRC Institute Strategic Programme Grant (2017-2022)

– combines six Institutes and two Universities

£19 million (PI Graham Moore, JIC)

£10.94 million for 16 new wheat projects involving various sponsors

11 projects on new topics

80% lead by PIs not sponsored in WGIN

WGIN 4

WGIN Breeders Priority Traits Questionnaire (August – November 2017)

- **Based around the 10 main traits** (used for the promotome capture exp) **plus additional traits identified by the WGIN team**

  107 sub-traits

  - Eight breeding companies contacted individually

  - Outcome: high level of consistency between companies but also notable differences

  - Summary of the top results. Max score 30

WGIN Breeders Priority Traits Questionnaire (August – November 2017)

Presented to all the breeders at WGIN MM 1st Feb 2018

Resilience	Sustainability	Quality	Resource efficiency
29* Septoria leaf blotch	24* Lodging	**25* Specific weight**	23* Nitrogen
29 BYDV	24 Deep rooting	23 Grain protein deviation	
28 Loss of chemistry	24 Early root establishment	22 Pre harvest sprouting	
25 Yellow Rust	24 Floret fertility	22 Grain size	
24 Floral health - ergot	23 Yield stability	22 Grain filling rate	
24 Floral health - fusarium	23 Season independent yield QTLs	22 Grain filling duration	
23 Aphids	22 Context independent yield QTLs		
22 Bulb Fly	22 Sterility		
	22 Staygreen - canopy senescence		
	22 Stem Height		
	22 Spikelet fertility		
* max value 30	22 Ear size		

WGIN Breeders Priority Traits Questionnaire (August – November 2017)

➡ **included in WGIN 4**

Resilience	Sustainability	Quality	Resource efficiency
29* Septoria leaf blotch	24* Lodging	**25* Specific weight**	23* Nitrogen
29 BYDV	24 Deep rooting	23 Grain protein deviation	
28 Loss of chemistry	24 Early root establishment	22 Pre harvest sprouting	
25 Yellow Rust	24 Floret fertility	22 Grain size	
24 Floral health - ergot	23 Yield stability	22 Grain filling rate	
24 Floral health - fusarium	23 Season independent yield QTLs	22 Grain filling duration	
23 Aphids	22 Context independent yield QTLs		
22 Bulb Fly	22 Sterility		
	22 Staygreen - canopy senescence		
	22 Stem Height		
	22 Spikelet fertility		
* max value 30	22 Ear size		

Wheat Genetic Improvement Network (WGIN4) 2018-2023

Department for Environment Food & Rural Affairs

Wheat Genetic Improvement Network

WP1 Management Meetings – The Network

Red text - new to WGIN 4

WP1 Enhancing the Network and Communication of Results

- AHDB strategic and monitor farms
- Website
- Annual Stakeholders forum
- International collaborations
- Electronic Newsletter
- Focussed UK/intl. workshops
- Public outreach
- Publications + data deposits

WP2 Tools and Resources

- Maintain and further develop, mapping popⁿ, Paragon lib, Watkins/Gediflux, *T. monococcum* collections
- Observation plots on candidate cultivars
- Complete the A x C NIL TILING popⁿ / CSSL
- Complete the *T. monococcum* introgression
- Sequence and assemble *T. monococcum* Chr 7A
- Trait related gene-specific marker development (KASP) from the *PROMOTOME* capture and *WAK* capture exps

WP3 Targeted Traits

Improving Crop Resilience (30%)
- BYDV resistance, slug resistance
- Take-all resistance and 3N re-rooting
- Septoria and yellow rust resistance

Yield Stability / Sustainability (25%)
- Spring drought tolerance
- Lodging resistance, stem anchorage

Enhanced Resource Use Efficiency (20%)
- Nitrogen use efficiency (NUE)

Quality Resilience (25%)
- Yield-to-grain protein, NUE
- Nutrient partitioning vis N-input and disease

Fine Phenotyping at Multiple Scales

WP4 Genetic and QTL Analyses

for each of the targeted traits (WP3)

Sub-Contractors – NGS Genome / Exome Analyses / Yellow Rust Races

[red text - new to WGIN4] [black text - continuing from WGIN3]

@WheatGIN

www.WGIN.org.UK

Defra

Martin Cannell, Giulia Cuccato and David Cooper (RAG)

WGIN 3 / WGIN 4

RRes - Kim Hammond-Kosack
Peter Shewry
Malcolm Hawkesford
Vanessa McMillan
Kostya Kanyuka
Lesley Smart
Gia Aradottir
Michael Hammond-Kosack

JIC – Simon Griffiths
Clare Lister

UoN - John Foulkes (WGIN 2)

Bristol Genomics – Jane Coghill's team
Arbor Biosciences – Michigan, USA

The Management team

The Plant Breeders (9)
ADAS
AHDB
Camden BRI
NIAB
Univ Bristol
Defra

The farm / trials staff at all the sites used
Numerous summer students

Department
for Environment
Food & Rural Affairs