

WGIN : Wheat Genetic Improvement Network

A Public - Private Partnership Project
started in 2003



Kim Hammond-Kosack
Rothamsted Research



22nd February 2016, joint GENie Stakeholders' meeting @JIC

Wheat - the UK's No 1 crop

Environmental footprint

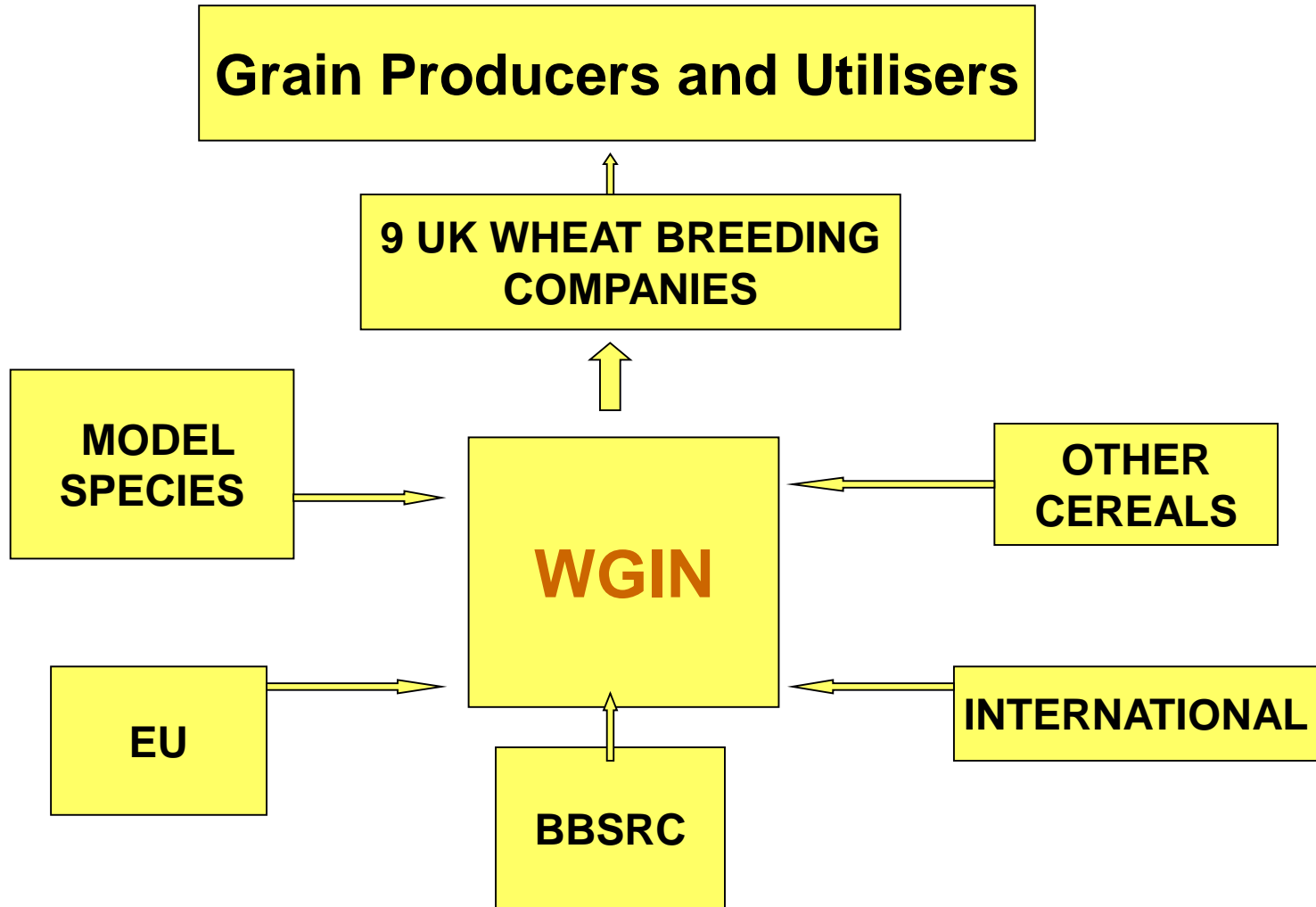
Resilience



NVZ

The Defra WGIN vision

A powerful multi-partner collaboration



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

Projects of 5 years and 2 years duration

The WGIN 1 project (2003 – 2008) - £1.80 million

The WGIN 2 project (2008 – 2014) - £2.05 million

The WGIN 3 project (2015 - 2017) - £669, 938

£4.52 million

**WGIN 1 project
funded partners**

John Innes Centre

Rothamsted Research

+ 2 pilot projects (2 yr)

WGIN 2 project

funded partners

John Innes Centre

University of Nottingham

Rothamsted Research

+ 2 pilot projects (1 yr / 2 yr)

WGIN 3 project – funded partners

John Innes Centre

Rothamsted Research

+ Bristol Genomics Facility, Univ. Bristol, UK

+ MYcroarray, Michigan, USA

WGIN key successes

Research

- **Developing novel tools and resources**
- **Novel trait identification**

Network

- Establish a reference UK mapping population

Avalon x Cadenza

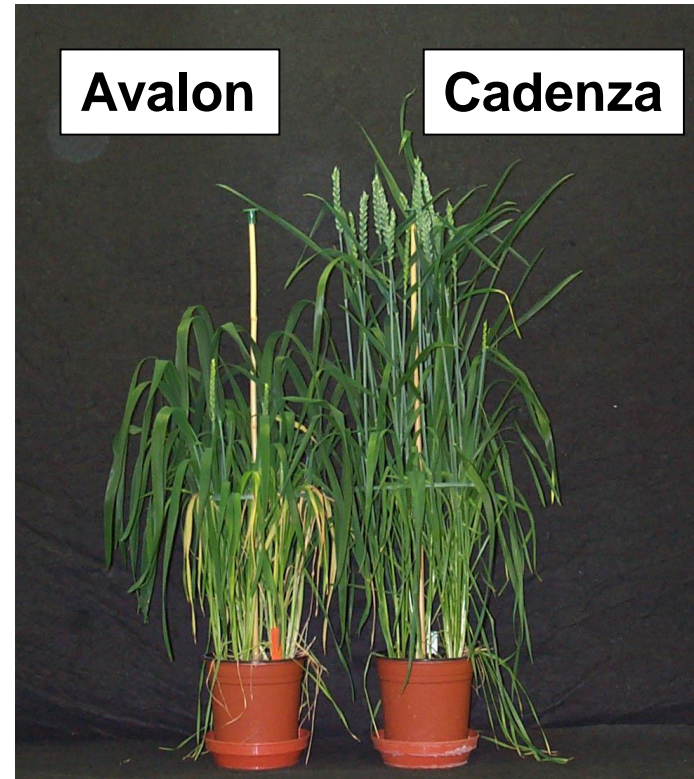
203 double haploid lines

- Switch to 'within the gene'

KASPar molecular markers

Axiom® SNP markers

- Extended A x C population
for fine mapping - 574 lines



Two WGIN workshops solely on this population

2013@JIC ~ 60 participants

Near Isogenic lines (NILs) with validated QTLs for Avalon x Cadenza

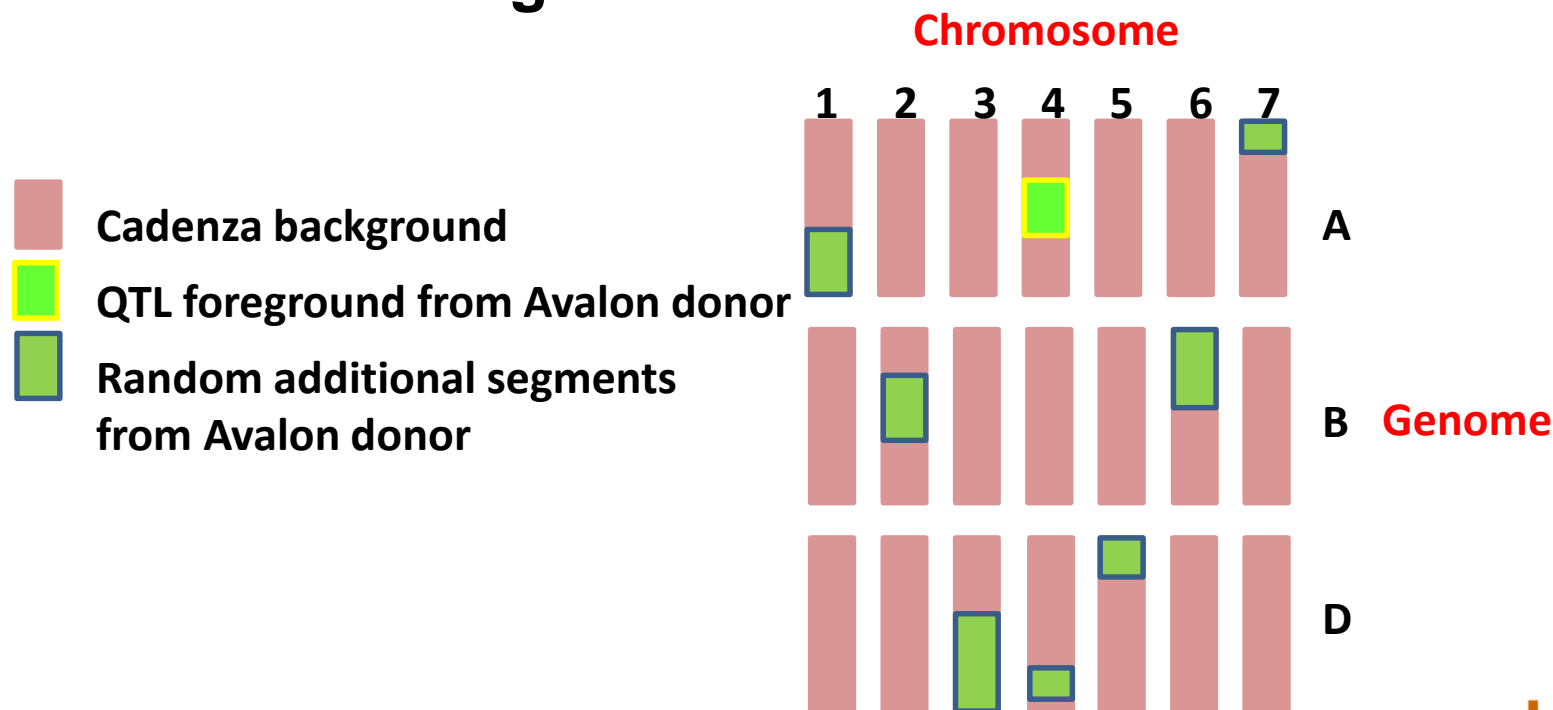
- **18 NILs** derived from this population have validated QTL discovered in WGIN and beyond.

QTL	Background
1B DTEM	Cadenza
1D DTEM	Cadenza
2D Ht	Cadenza
3A Ht	Cadenza
3B Ht	Cadenza
3B YLD	Cadenza
6A Ht	Cadenza
6A Ht	Cadenza
6B DTEM/Ht	Cadenza
6B Ht	Cadenza
7B YLD	Cadenza

QTL	Background
1B DTEM	Avalon
1D DTEM	Avalon
2D Ht	Avalon
2D YLD	Avalon
3A Ht	Avalon
5A YLD	Avalon
7D YLD	Avalon

A chromosome segment substitution library (CSSL) for Avalon x Cadenza

- The NILs carry selected genetic foreground in the QTL regions
- In addition each line carries ~12.5% random chromosomal segments.

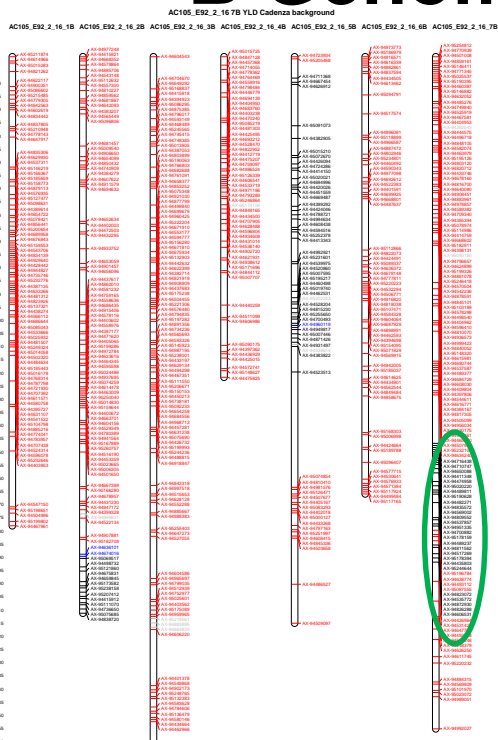


A chromosome segment substitution library (CSSL) for Avalon x Cadenza

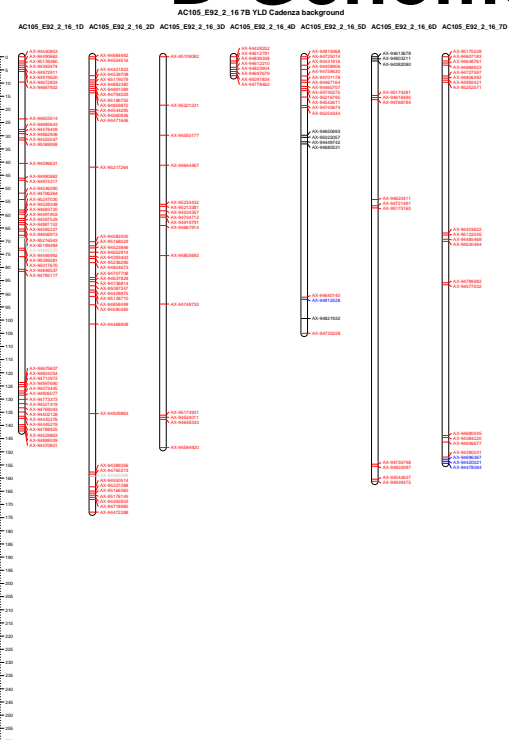
A Genome



B Genome



D Genome



Cadenza background - Avalon *random* background
and **QTL** region

To develop reciprocal 'TILING' libraries for Avalon x Cadenza

- The next stage involves genotyping another **94 lines** representing the QTLs in the AxC NILs (DTEM, Ht, YLD)

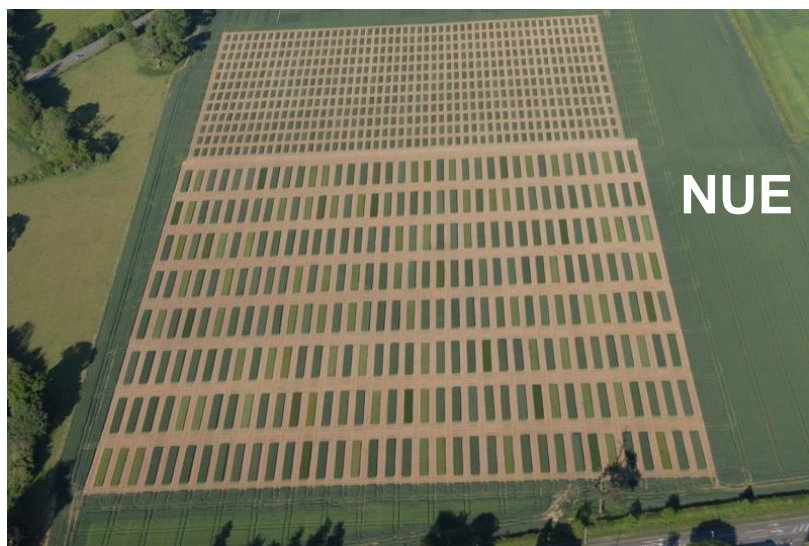
Background	Chromosome	Trait	QTL Allele	# of lines
Avalon	1B	EM	Cadenza	5
Avalon	1D	EM	Cadenza	3
Avalon	2A	Ht	Cadenza	2
Avalon	2D	Ht	Cadenza	5
Avalon	2D	YLD	Cadenza	3
Avalon	3A	Ht	Cadenza	5
Avalon	3B	Ht	Cadenza	5
Avalon	5A	YLD	Cadenza	5
Avalon	6A	Ht	Cadenza	5
Avalon	6B	Ht	Cadenza	5
Avalon	7B	YLD	Cadenza	1
Avalon	7D	YLD	Cadenza	3

Background	Chromosome	Trait	QTL Allele	# of lines
Cadenza	1B	EM	Avalon	5
Cadenza	1D	EM	Avalon	5
Cadenza	2A	Ht	Avalon	5
Cadenza	2D	Ht	Avalon	6
Cadenza	3A	Ht	Avalon	6
Cadenza	3B	Ht	Avalon	5
Cadenza	3B	YLD	Avalon	5
Cadenza	6A	Ht	Avalon	5
Cadenza	6B	EM & Ht	Avalon	5

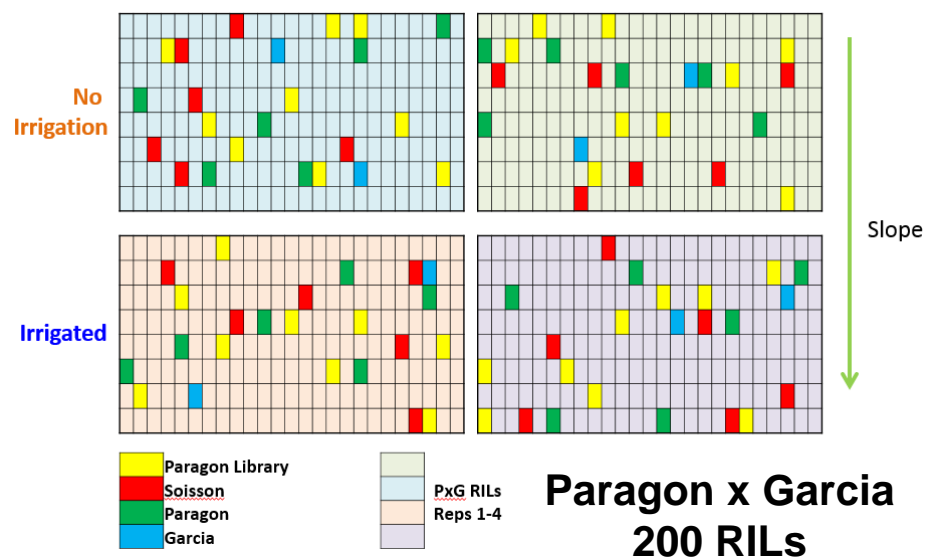
- The 18 and 94 NILs are being backcrossed to the recurrent parent twice to generate lines in which the **QTL region and random segments have been separated.**

Consecutive years of field trials

1. Improved nitrogen use efficiency (NUE)
2. Crop resilience (QTLs) linked to NUE
3. Improved tolerance to UK drought



Malcolm Hawkesford, RRes



Simon Griffiths, Clare Lister (JIC)
John Foulkes (Uni Notts)

WGIN: The Nitrogen-Diversity trial

2004 - 2016

58 varieties

20 in at least 9 years

All 4 nabim groups

4 N levels

(0, 100, 200 and 350 kg/ha)

Grain and straw, yield and %N

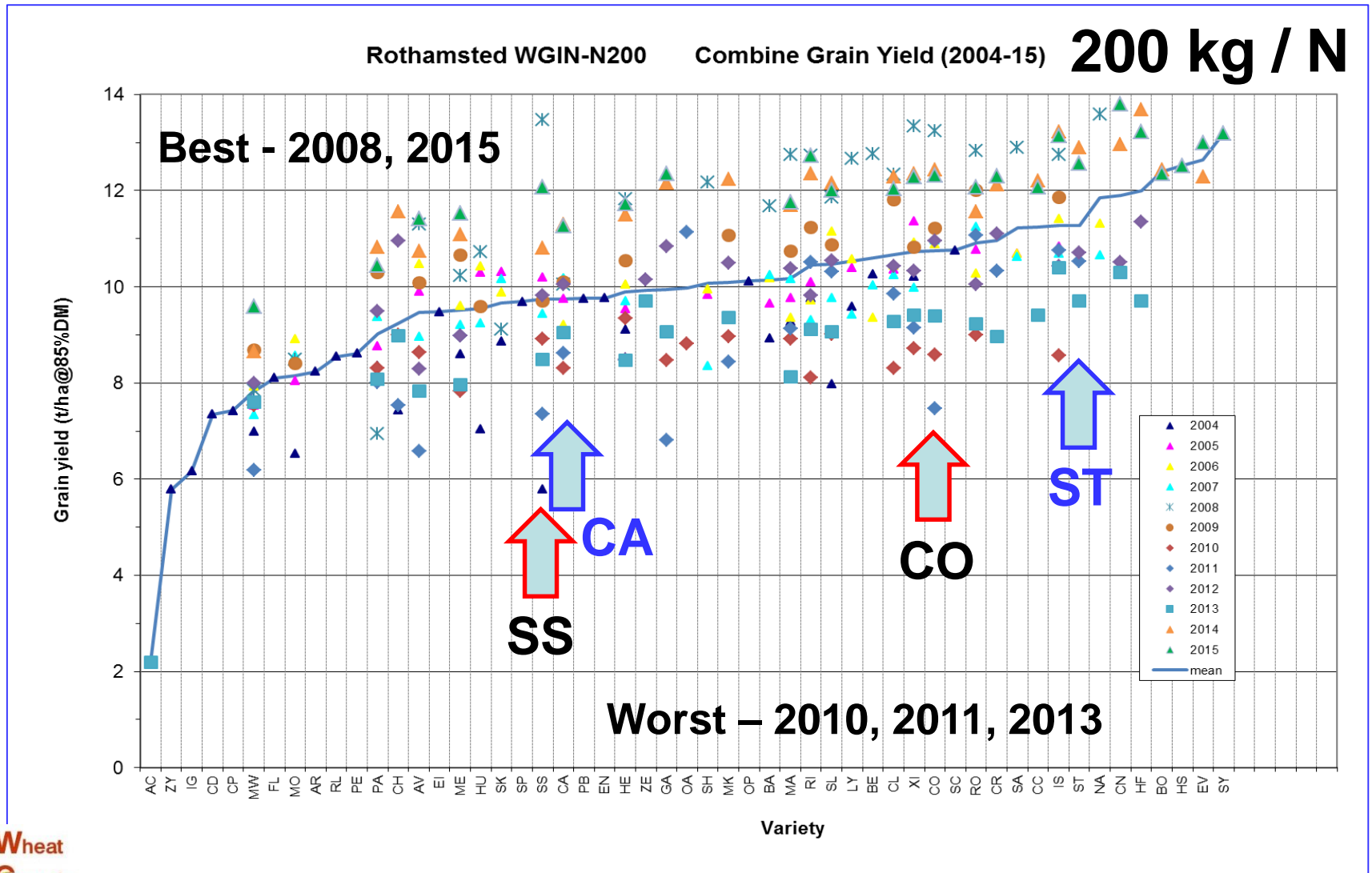
Archived fresh grain

**Archived dry milled grain and
straw**

Many spin-off projects



Rothamsted WGIN Trials – yield stability



No wheat varieties are perfect!



ROTHAMSTED
RESEARCH

Variety Performance at 200 kg-N/ha (2004-08)

Variety	Code	Nabim	Years	Yield	%N	Uptake	Utilisation
Avalon	AV	1	5				
Flanders	FL	1	1				
Hereward	HE	1	5				
Hurley	HU	1	5				
Malacca	MA	1	5				
Mercia	ME	1	4				
Maris Widgeon	MW	1	5				
Shamrock	SH	1	4				
Solstice	SL	1	5				
Spark	SP	1	1				
Xi 19	XI	1	5				
Cadenza	CA	2	5				
Cordiale	CO	2	3				
Einstein	EI	2	1				
Lynx	LY	2	5				
Rialto	RL	2	1				
Scorpion	SC	2	1				
Soissons	SS	2	5				
Beaver	BE	3	4				
Claire	CL	3	4				
Riband	RI	3	5				
Robigus	RO	3	4				
Istabraq	IS	4	4				
Napier	NA	4	3				
Savannah	SA	4	4				
Paragon (spring)	PA	1	5				
Chablis (spring)	CH	2	1				
Arche	AR	F	1				
Batis	BA	G	5				
Caphorn	CP	F	1				
Cappelle Desprez	CD	F	1				
Enorm	EN	G	1				
Isengrain	IG	F	1				
Monopol	MO	G	5				
Opus	OP	G	1				
PBis	PB	G	1				
Petrus	PE	G	1				
Sokrates	SK	G	5				
Zyta	ZY	P	1				

Upper-Q
Inter-Q
Inter-Q
Lower-Q

Summary of variety performance (quartile rankings) based on 2004-07 WGIN datasets

Barraclough *et al.*,(2010)
European Journal of Agronomy 33, 1-11



Increasing the precision of field phenotyping



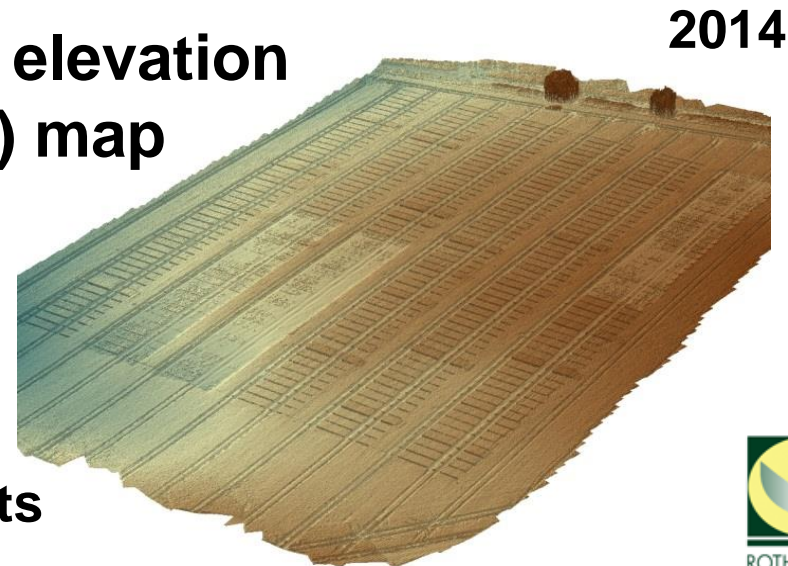
Mini WGIN diversity trial in the Phenotyping Platform @ RRes



UAV



A digital elevation (surface) map



Plot heights
~ cm

Trait identification – RRes

2. Reducing current pest and disease pressures

Aphids



***Septoria* leaf blotch**



Annually all crops at high risk

The Target Insect Pests in WGIN3



ROTHAMSTED
RESEARCH



Rhopalosiphum padi

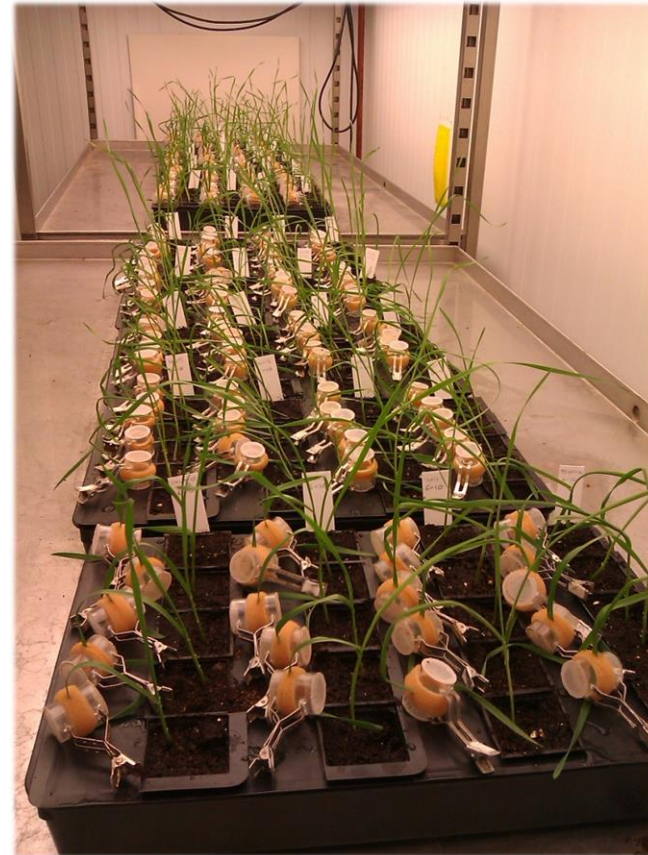


Sitobion avenae

Phenotyping Screen



Replicate 1

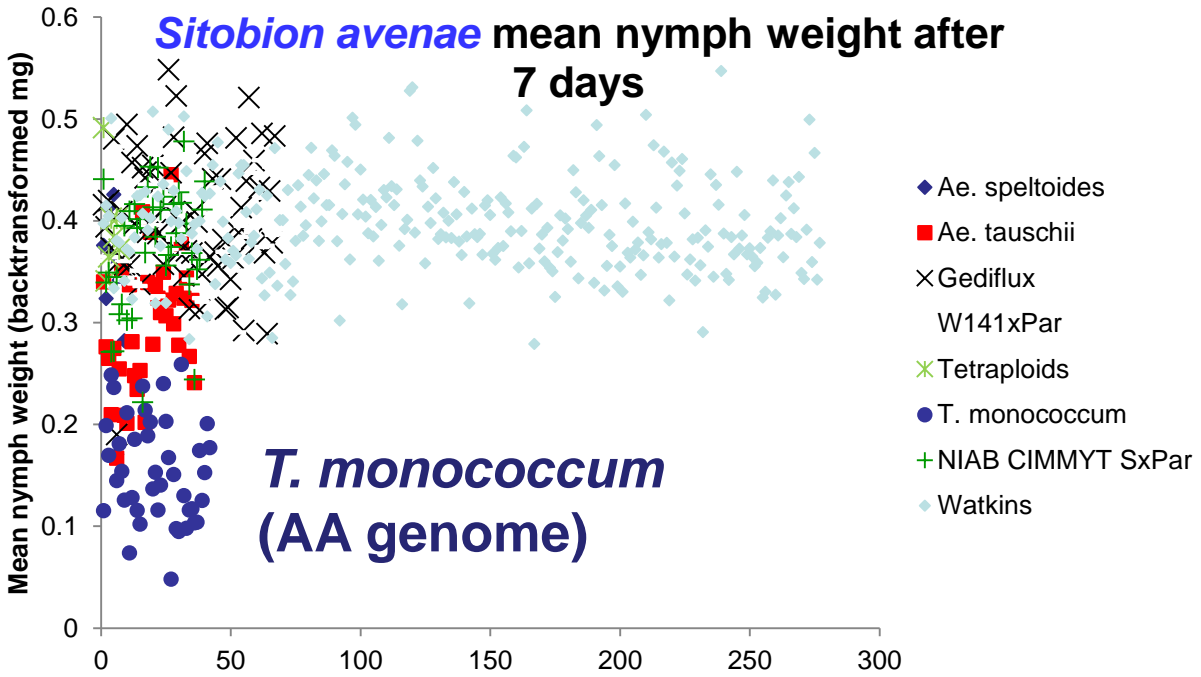
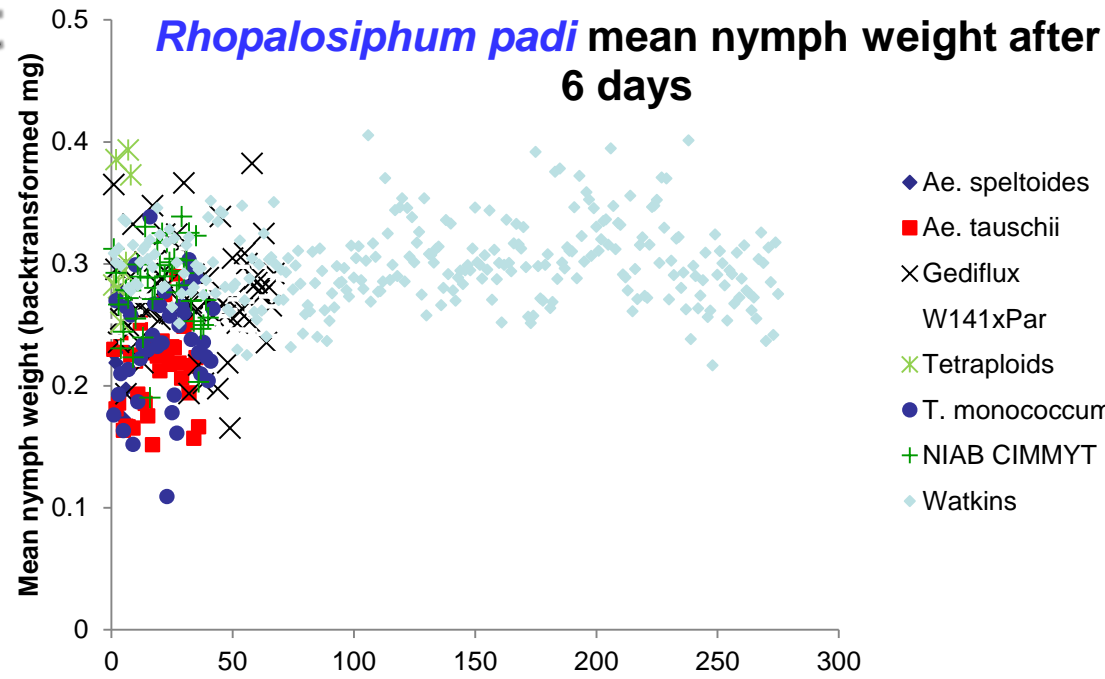


Replicate 2

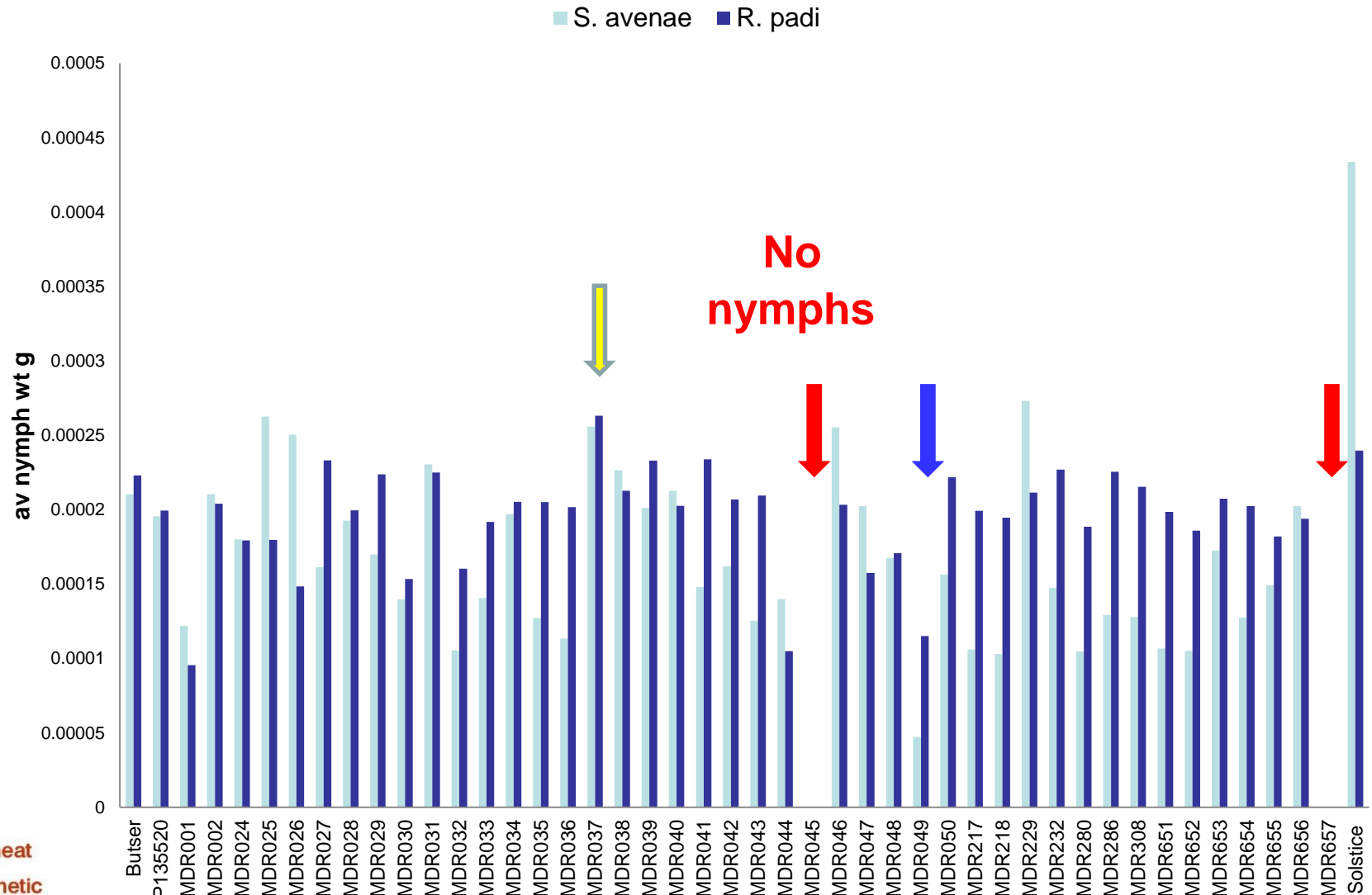
WV1				WV17	WV1				WV17
WV2				WV18	WV2				WV18
		...		C1			...		C1
				C2					C2
Tray 1	Tray 2	Tray 3	Tray 4	Tray 5	Tray 1	Tray 2	Tray 3	Tray 4	Tray 5

Row 1
Row 2
Row 3
Row 4

Nymph weight



Nymph weight on *T. monococum* lines

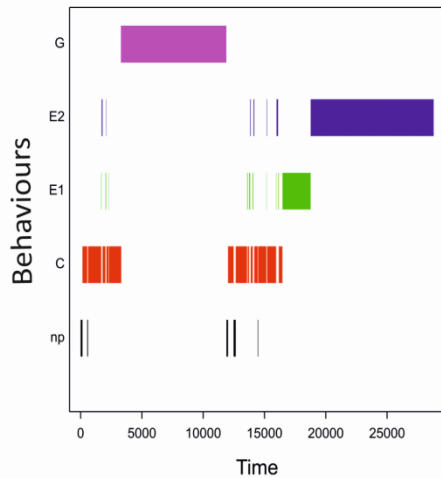


Reduced feeding by *R. padi* in Electro-Penetration Graph bioassays

Behaviours: np: not probing, **C: pathway phase**, **E1: salivation**, **E2: phloem ingestion (feeding)**, **F: derailed stylet mechanics**, **G: xylem ingestion (drinking)**

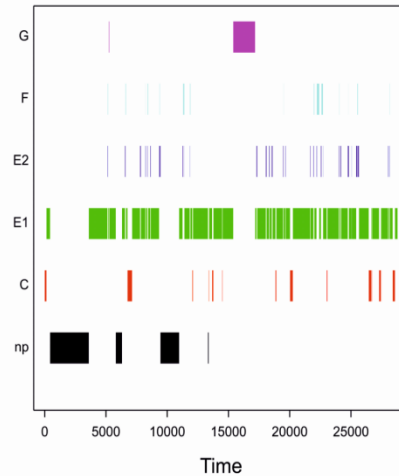
Susceptible

MDR037



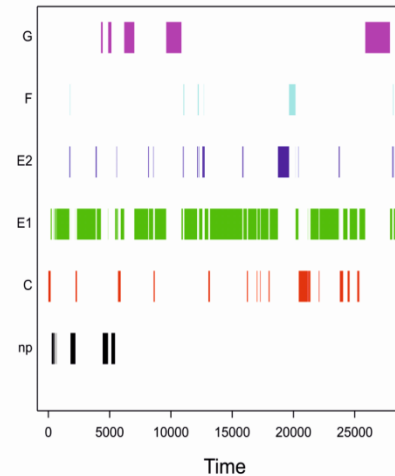
Semi-resistant

MDR049



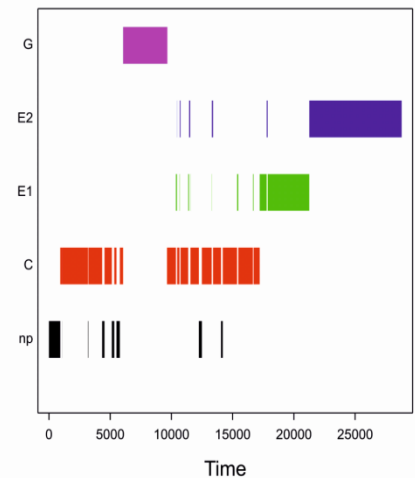
Resistant

MDR657



Susceptible

Solstice



➤ Crosses made:

MDR037(S) x MDR045 (R)

MDR037(S) x MDR049 (R)

MDR037(S) x MDR657 (R)

F₂ screening stage



Trait identification – RRes

2. Reducing current pest and disease pressures

Take-all fungus



A major problem
for 2nd / 3rd wheat
crops

2nd wheat syndrome

1st wheat crop WGIN diversity trial



WGIN 1 winter wheat soil core bioassay

(4 year means from the diversity trial)

New trait is called **TAB** (Take-All inoculum Build-up)

1. Soil core taken angled underneath row



2. Core inverted into plastic cup



THE
SOIL CORE
BIOASSAY

3. Ten bait wheat (cv Hereward) seeds sown



4. Growth room for 5 weeks

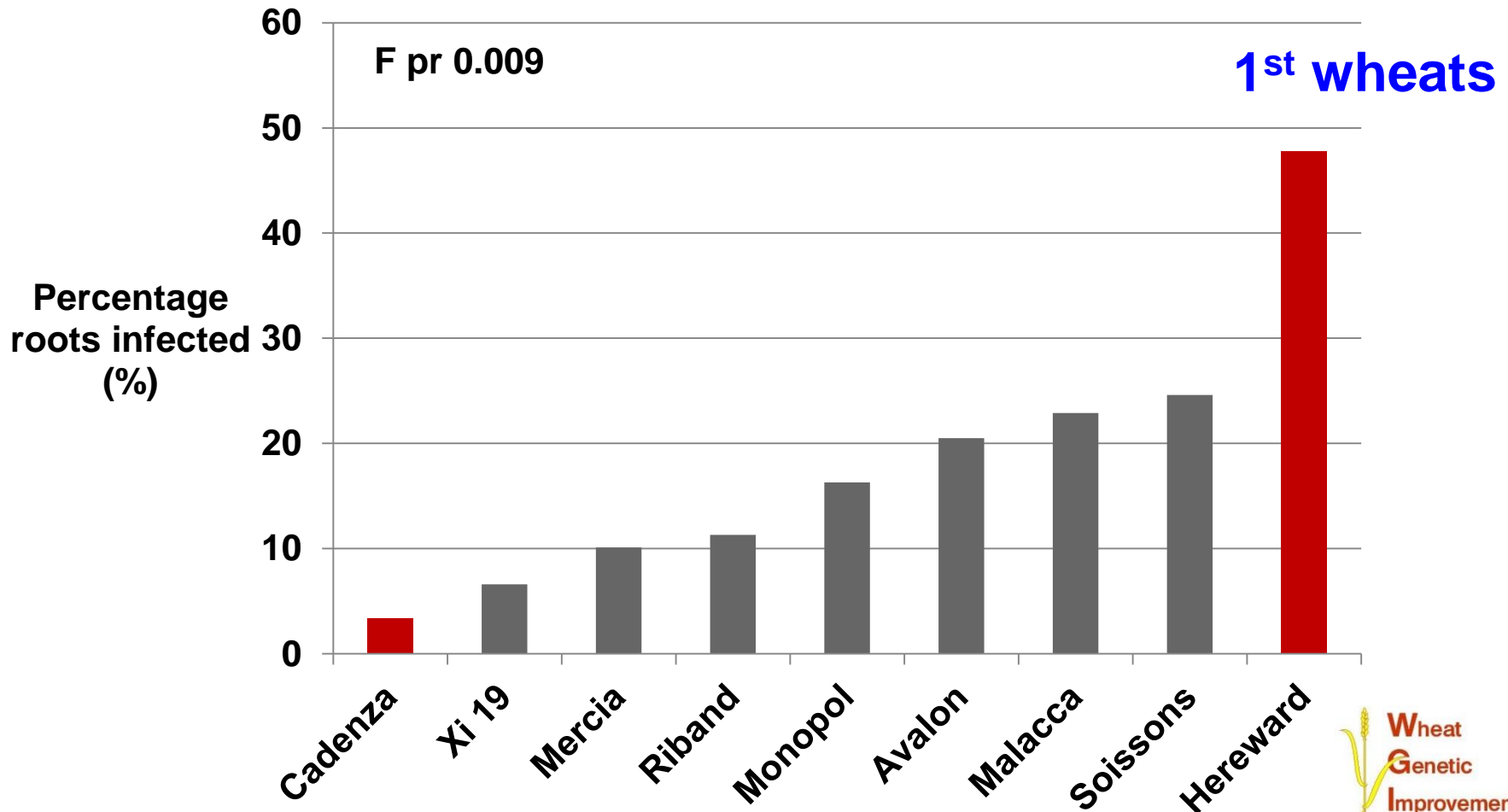


1st wheat

WGIN 1 winter wheat soil core bioassay

(4 year means from the diversity trial)

New trait is called **TAB** (Take-All inoculum Build-up)



McMillan *et al.* 2011, *Plant Pathology*, 60, 200-206



Using 1st wheat genetics to improve 2nd wheat crop yield performance

- Grain yield advantage in the 2nd wheat crop @ RRes
- Cultivar and Nabim group independent

0.4 t/ha (2010) very dry low take-all

0.2 t/ha (2011) very dry low take-all

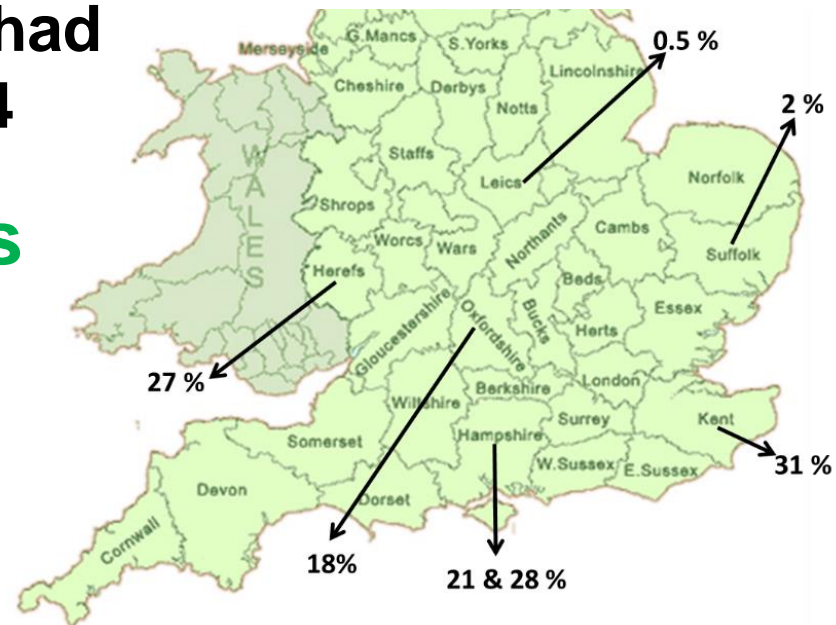
2.42 t/ha (2012) very wet very high take-all

1.73 t/ha (2013) average high take-all

5 of 7 AHDB RL 1st wheat sites had good take-all build-up in 2014

Consistent TAB differences between cultivars

Cereals 2016



The Networking objectives

8 of the 20 activities

Welcome to WGIN 3rd Phase (2015-2017)

Defra Wheat Genetic Improvement Network - Improving the resilience of the wheat crop through genetics and targeted trait analysis

WGIN 3 has been funded by Defra until March 2017

IMPORTANT:

1) Joint GINs Stakeholders Event:

A special all day joint GINs stakeholder event will be held

on 22nd February 2016 at the John Innes Centre

"DEFRA GINs Meeting: Uncorking the genetic 'GINie' for British crops"

to highlight the decade of science done within WGIN, OREGIN, VEGIN and PGIN core projects. You can register [here](#) up to February 15th.

2) The 13th WGIN STAKEHOLDERS' MEETING was held on *Friday November 20th 2015 @ Fowden Hall, Rothamsted Conference Centre, Rothamsted Research, Harpenden*. Presentations can be found in 'meetings' under the 'Information' tab.

3) The 3rd WGIN 3 Management Meeting was held at Rothamsted Research on October 28th 2015. Details can be found in 'meetings' under the 'Information' tab.

4) The WGIN Legacy document, covering the achievements and outcomes of the first TEN years (WGIN 1 2003-2008, WGIN 2 2009-2014) is now available to peruse by clicking this link: [WGIN 1&2 Legacy](#)

***** High Density Genotyping of
18 WGIN AxC Near Isogenic Lines*****



RECENT UPDATES

OLD Site - [The old site is still available here.](#)

Disclaimer: WGIN is a publicly funded project and the data and resources it generates are freely available to the research community, providing that the use of any WGIN data and resources are acknowledged.

wgin.defra@rothamsted.ac.uk

site guide

The site is grouped into the following four sections:

ABOUT - for general information about WGIN, including news items and contacts.

INFORMATION - for more detailed information about WGIN, including reports and information tools.

RESOURCES - for experimental resources and research related tools

STAKEHOLDERS - for information on the Stakeholders Forum

Please use our interactive dropdown menus, the side menus, or the link tracker to navigate the site.

--see [site-map](#) for overview

**Project assistant
1 day / week**

**All research
powerpoint
ppts available
from all meetings**

WGIN Newsletter

**Legacy document
2003 – 2014**

**Accessible via the
MONOGRAM
website**

**BSPB – British
Society for
Plant Breeders**

The WGIN legacy so far

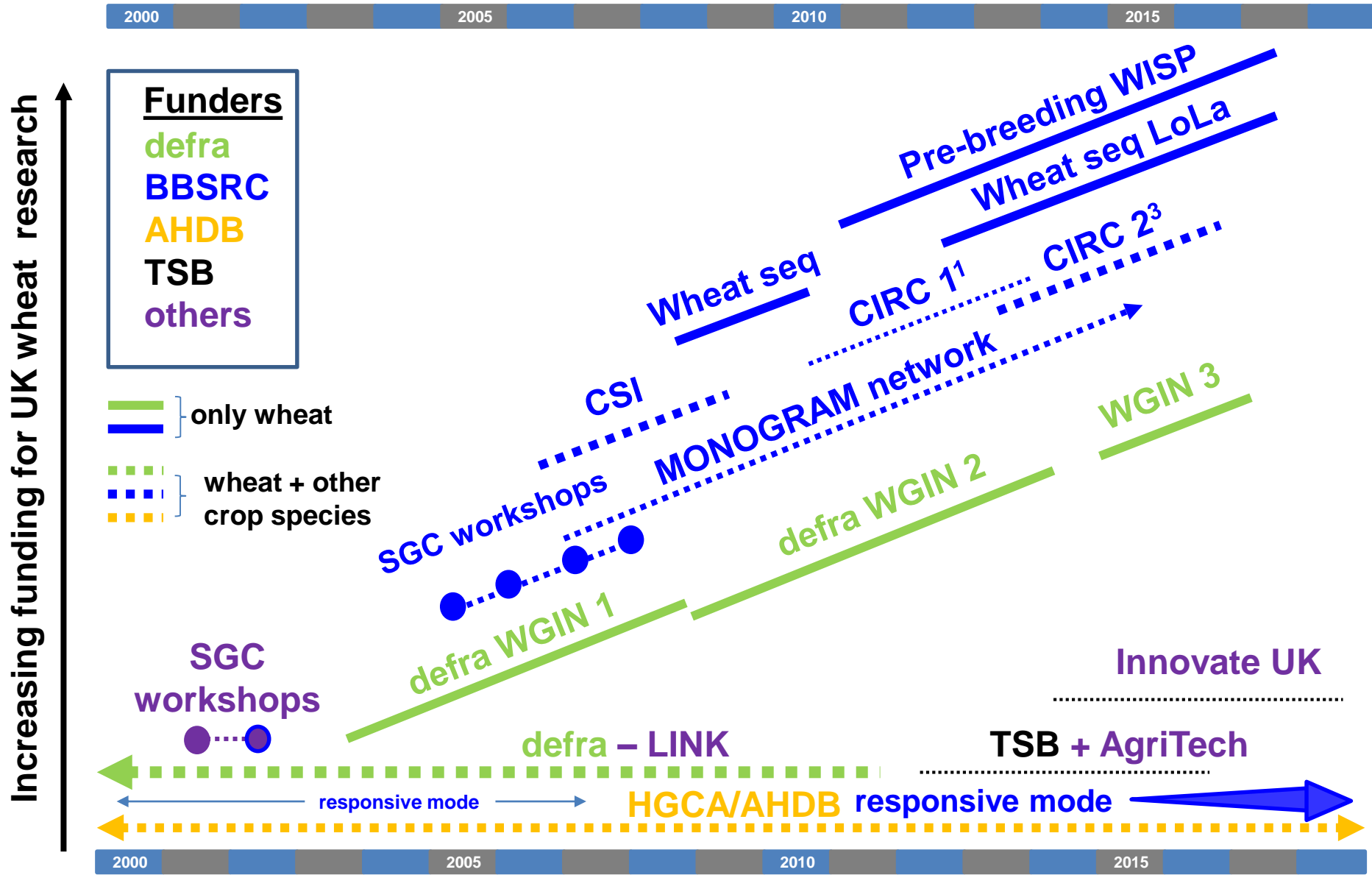
Scientific publications ~ 50 peer reviewed articles

£4.52 million from defra has generated in excess of
**£41 million for 48 new wheat projects involving
various sponsors (mid 2014)**

29 projects on new topics

£11.0 million lead by PIs not sponsored in WGIN

The relationship between WGIN and the major funding initiatives supporting UK wheat research (2000-2017)



The WGIN legacy so far

Training the next generation of wheat crop scientist

A total of **20 PhD students** have directly benefitted from the ongoing field experiments, genetic resources and stored grain samples provided by WGIN (**mid 2014**).

Ten PhD students have already graduated

Five main supervisors received no WGIN funding

Poster presentation today

Topical discussions by an invited panel of experts



- UK wheat field yields lagging behind breeders projections
- Growing successful 2nd and 3rd wheat crops
- Emerging disease patterns
- Yield and quality stability / resilience

2016 – proposing - Optimising crop nutrition

Collective outcome – Identification of many GAPS in our current knowledge of the wheat crop and key traits

Central storage of grain from the field trials

**12 years of field trials (24-31 cultivars / 4 N regimes)
2003 – 2015**

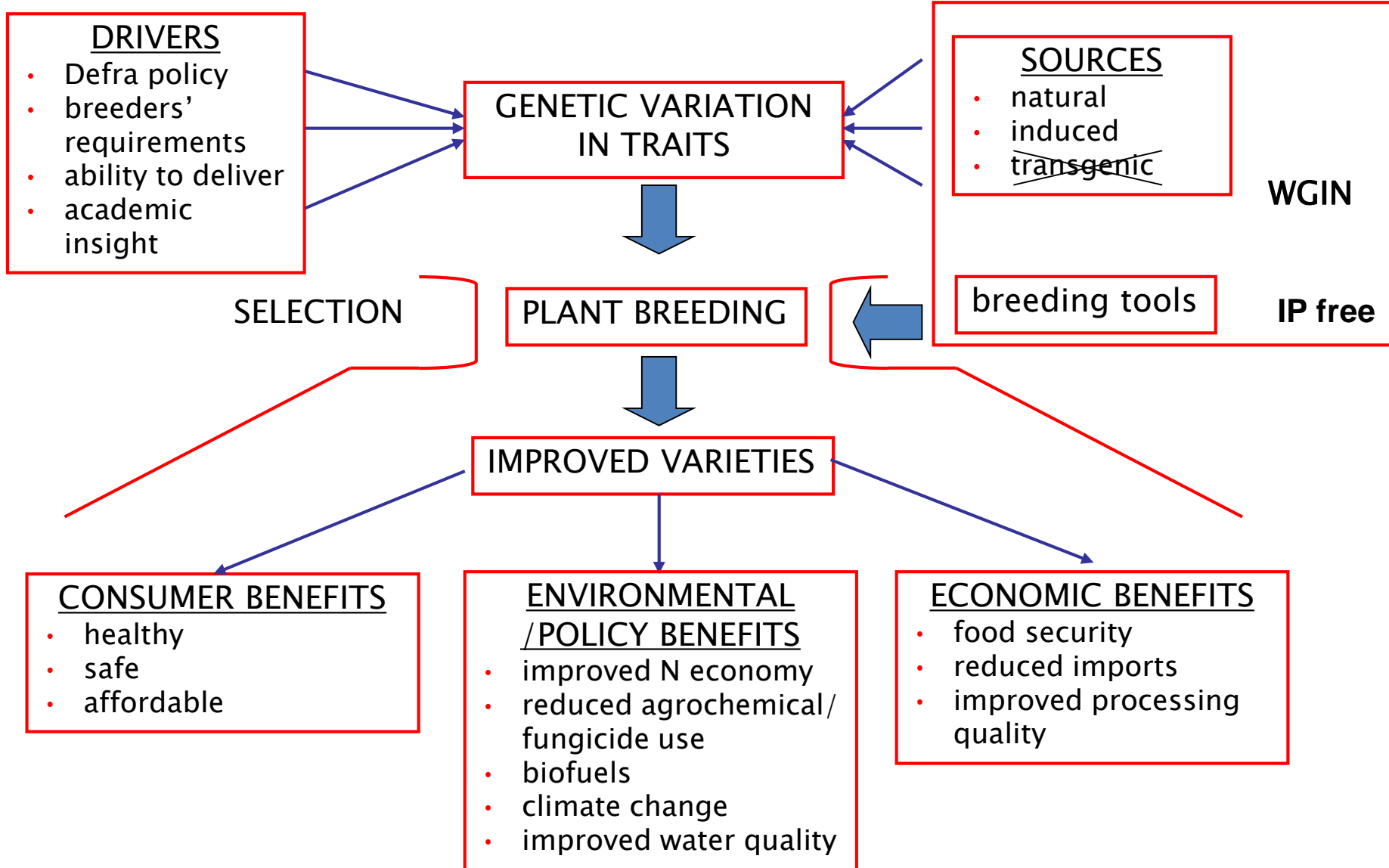
The stored samples - 100 g / 500 g at - 20 C

~ 8,000 samples with associated metadata

**Key biological resources for new projects
and / or pilot studies**

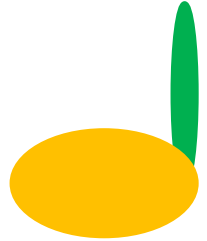
wgin.defra@rothamsted.ac.uk

WGIN in the wider context



The future

‘ Sustainable Intensification’ through crop genetics



‘Improving crop resilience’ to ensure good yields in difficult seasons

‘Environmental Footprint’ reductions

Embracing new technologies

- UAVs and Phenotyping Platforms
- Soil probes
- Rapid genome analyses for pests / pathogens
- Wheat Gene Editing, exome capture
- F₁ hybrid crops

Defra

Giulia Cuccato and David Cooper

WGIN 3

**RRes - Kim Hammond-Kosack
Peter Shewry
Malcolm Hawkesford
Vanessa McMillan
Kostya Kanyuka
Lesley Smart
(Janet Martin)
Michael Hammond-Kosack**

**JIC – Simon Griffiths
Clare Lister**

UoN - John Foulkes

**Bristol Genomics – Jane Coghill's team
MYcoarray – 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

www.WGIN.org.UK

Defra

**Donal Murphy-Bokern, Bruno Viegas, Kath Bainbridge,
Farhana Amin, Giulia Cuccato and **David Cooper****

WGIN 2

**RRes - Kim Hammond-Kosack
Peter Shewry
Malcolm Hawkesford
Vanessa McMillan
Kostya Kanyuka
Michael Hammond-Kosack**

**JIC – Simon Griffiths
Susan Freeman
Cathy Mumford
Clare Lister**

**UoN - John Foulkes
Jayalath DeSilva**

S/C ADAS – Richard Weightman

**The Plant Breeders
The Management team**

WGIN 1

**RRes – Andy Phillips Lesley Smart
Katie Tearall Ruth Gordon-Weeks
Peter Barraclough Elke Anzinger
Hai-Chun Jing Richard Gutteridge

Carlos Bayon
Sam Irving / Suzanne Thrussell**

**JIC - John Snape Simon Orford
Robert Koebner Michelle Leverington
Liz Sayers
Christian Rogers
Pauline Stephenson
Leodie Alibert**

S/C ADAS - Neil Paveley NIAB- Rosemary Bayles

The farm / trials staff at all the sites used

www.WGIN.org.UK



Many, many thanks to



David Cooper defra



WGIN stakeholder 2013

The Defra WGIN: Dissemination, Liaison and Communication

Annual “Stakeholders’ Forum” (Nov) 70-90 attendees
Focussed Workshop – 2009, 2013 ‘A x C mapping popⁿ’
2010 – DArT marker analysis

Workshops with overseas partner organisations:

Six in total funded by BBSRC

Web Site (www.WGIN.org.UK)

Electronic Newsletters

Scientific publications ~ 50 articles

Annual displays at ‘Cereals’

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



Rotation trial: harvest years 2012 and 2013

Second wheat yields

Main effect of:

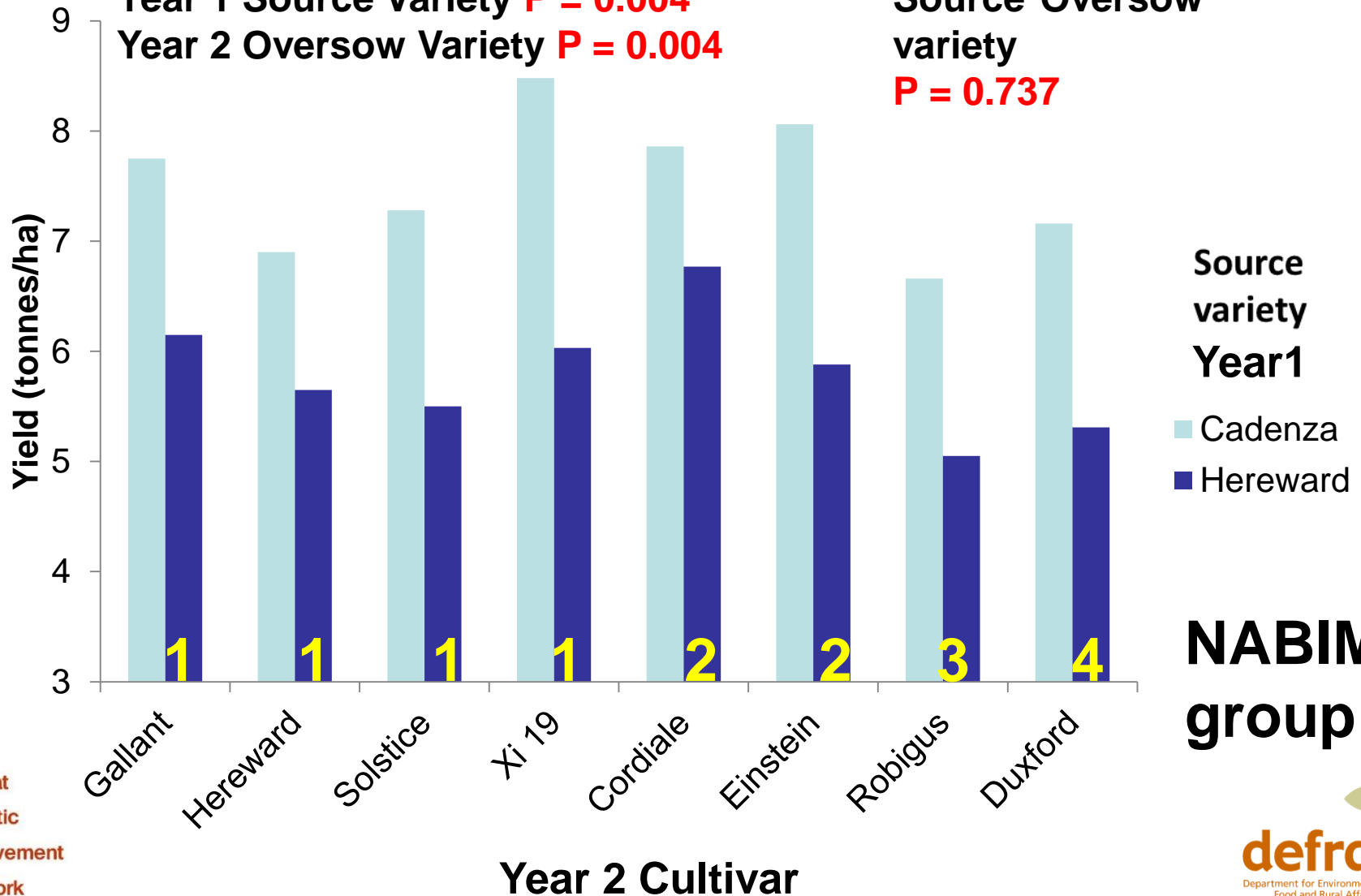
Year 1 Source Variety **P = 0.004**

Year 2 Oversow Variety **P = 0.004**

Interaction:

Source*Oversow
variety

P = 0.737



Mission statement - WGIN 2003 to 2014

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

Mission statement - WGIN 2015 to 2017

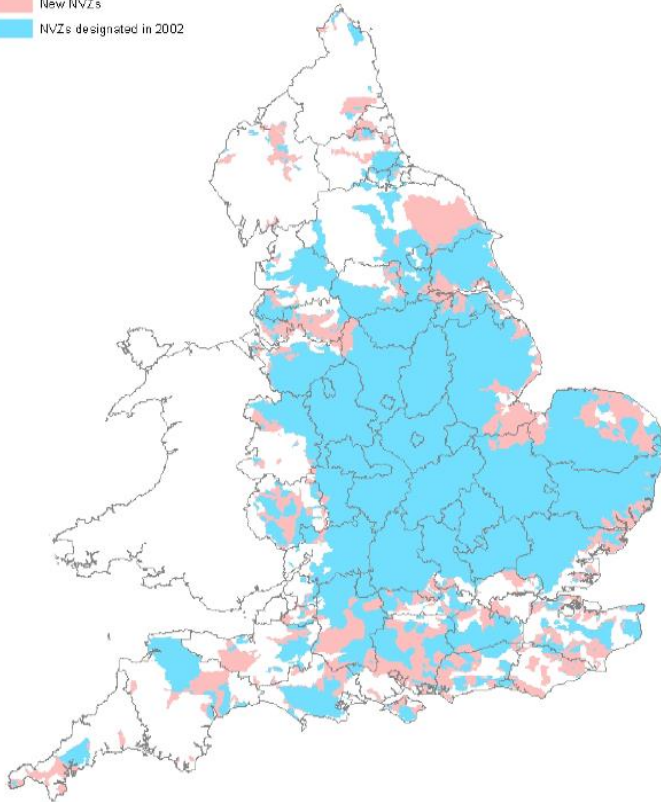
Improving the **resilience of the wheat crop through genetics and targeted traits analysis**

Increase in England Nitrate Vulnerable Zones (NVZ) due to arable activities

2002 (blue) to 2009 (pink)

2013 (blue)

New NVZs
NVZs designated in 2002



Wheat Genetic Improvement Network (WGIN3) 2015-2017

Red text -
new to WGIN3

WP1 Management meetings (3 per year) – The Network

WP3 Tools and Resources

Maintain and further develop, mapping popⁿ,
Watkins/Gediflux, *T. monococum* collections (3.1)

Create an A x C NIL TILING popⁿ (3.2)

T. monococum introgression (3.3)

WPs 2 & 4 Genetic and QTL analyses

For each of the targeted traits

Gene-specific marker development (2.4)

WPs 2, 3 & 4 Targeted Traits

Aphid resistance (2.2)

Take-all resistance (2.2, 3.4)

Septoria, mildew and rust resistance (2.2)

Yield and quality resilience (2.2, 3.4)

Yield components (2.2)

Drought tolerance (2.2, 3.4)

Root system function (3.4)

Sub-contractors – WP1.3 & 4.2 NGS genome / promoter analyses

WP1 Enhancing the network and communication of results

Website (1.2)

Annual Stakeholders forum (1.1)

International collaborations (1.4)

Publications + data deposits (1.4)

Electronic Newsletter (1.4)

Focussed workshops (1.1)

Public outreach

Industry-led forum (1.5)

Wheat Genetic Improvement Network (WGIN) 2003-2014

6,7,9,12 = WGIN 2 only

Tools and Resources

2. Near Isogenic lines (NILs) *

3. The Avalon x Cadenza Mapping popⁿ

4. Paragon gamma and EMS popⁿ
TILLING

5. AE Watkins and Gediflux collections

6. New mapping popⁿ for WUE (9) and 2
new popⁿ to align WGIN 2 with the
international wheat genome sequencing
effort

Targeted traits

7. Insect resistance (RRes) *

8. Nitrogen use efficiency (NUE) *
Quality QTLs linked to NUE (RRes)

9. Drought tolerance (UoN) *

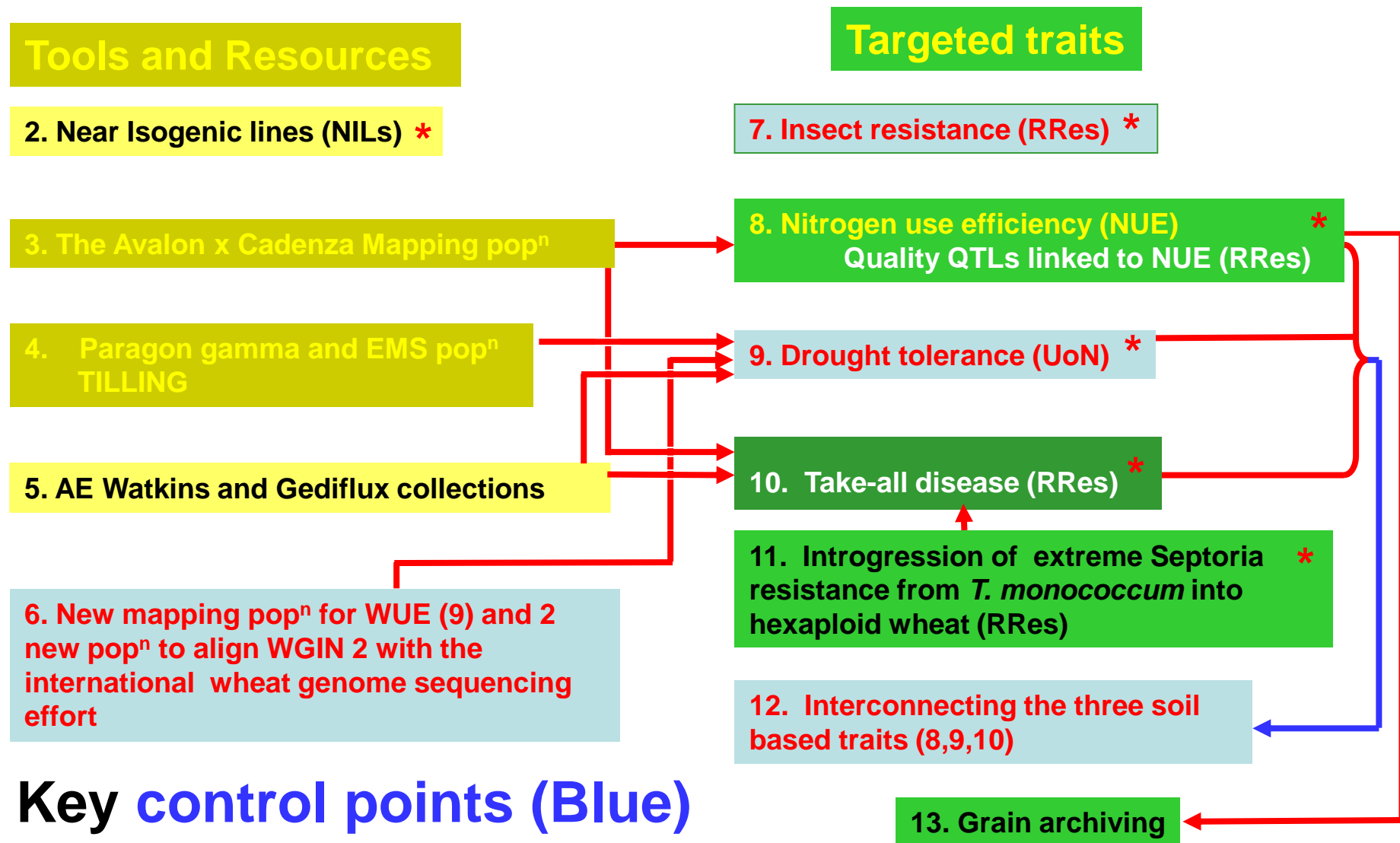
10. Take-all disease (RRes) *

11. Introgression of extreme Septoria
resistance from *T. monococcum* into
hexaploid wheat (RRes)

12. Interconnecting the three soil
based traits (8,9,10)

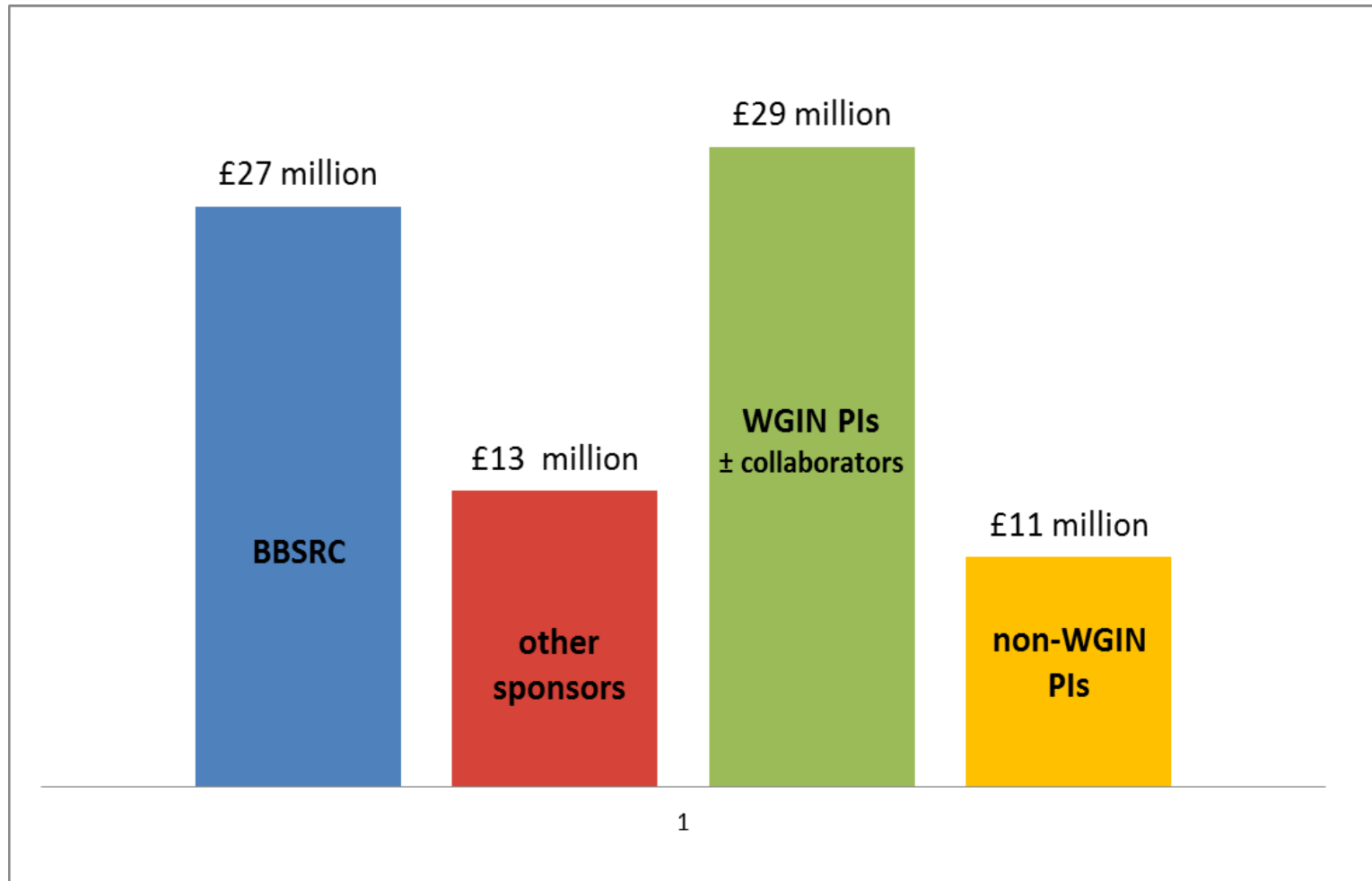
13. Grain archiving

Key control points (Blue)
cross connections (Red)



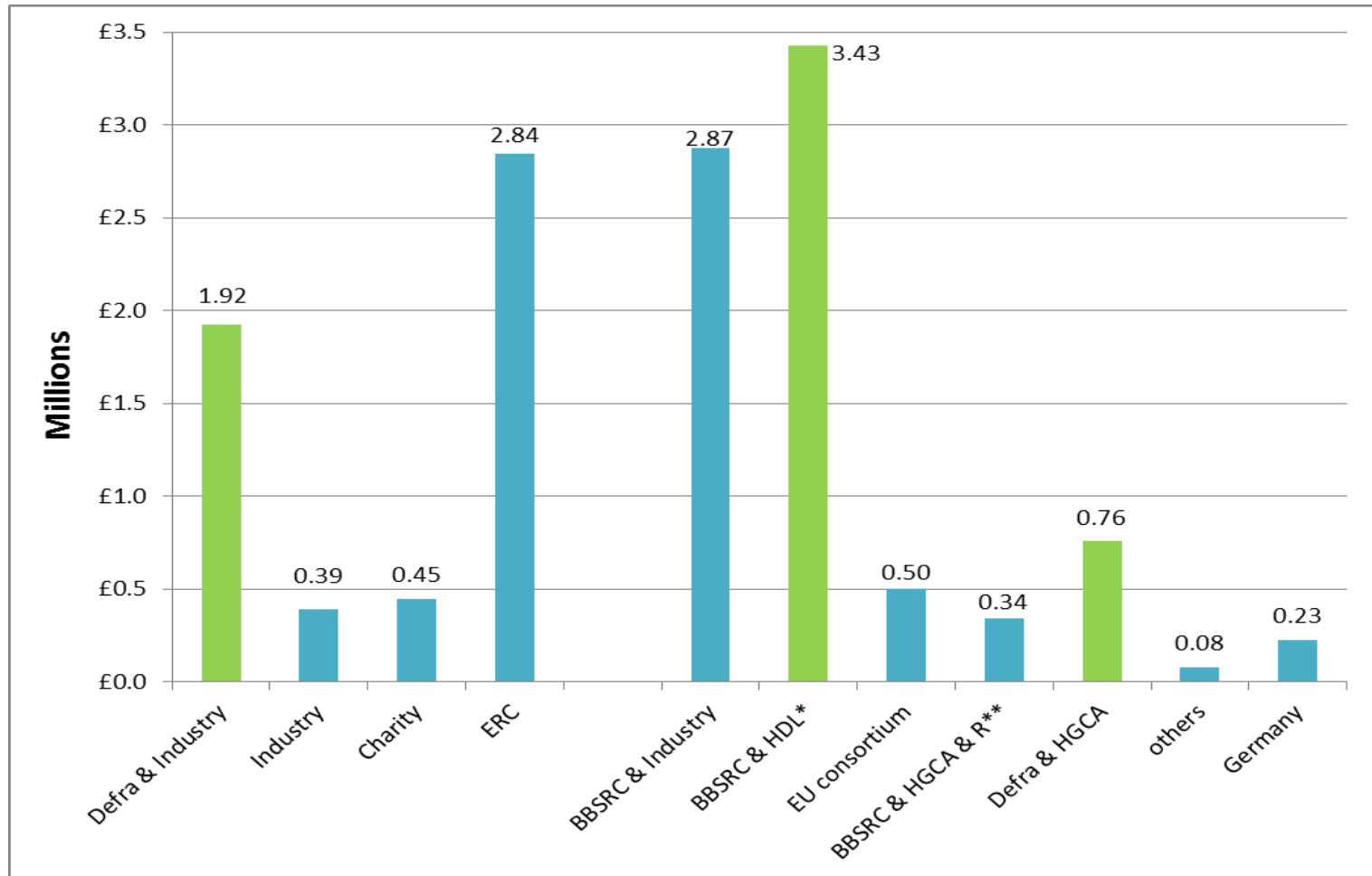
New funds won for wheat research using WGIN resources and knowledge

The main funding sources and PIs



New funds won for wheat research using WGIN resources and knowledge

Details of the other sponsors



Abbreviations: HDL* - HGCA, Defra and LINK and R** - Scottish Government (RESAS)