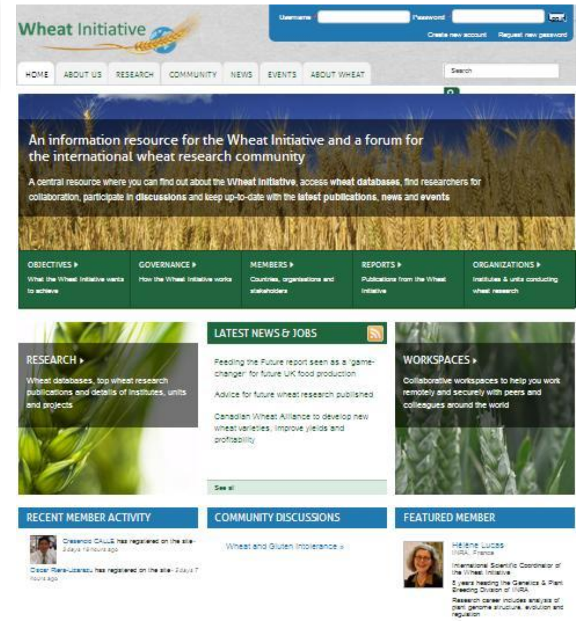
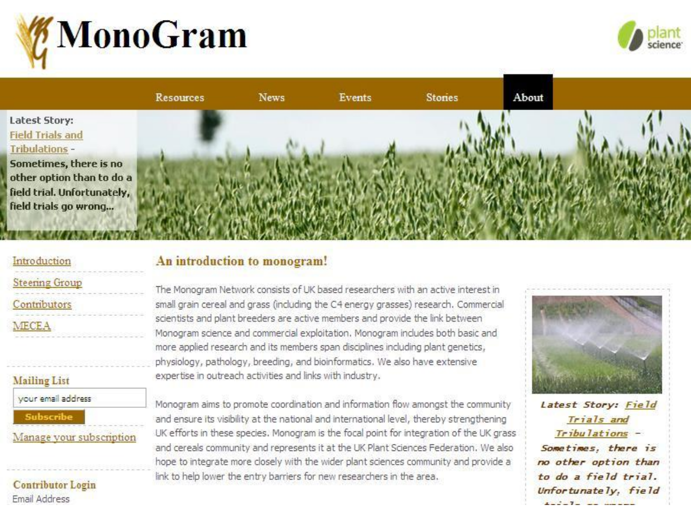
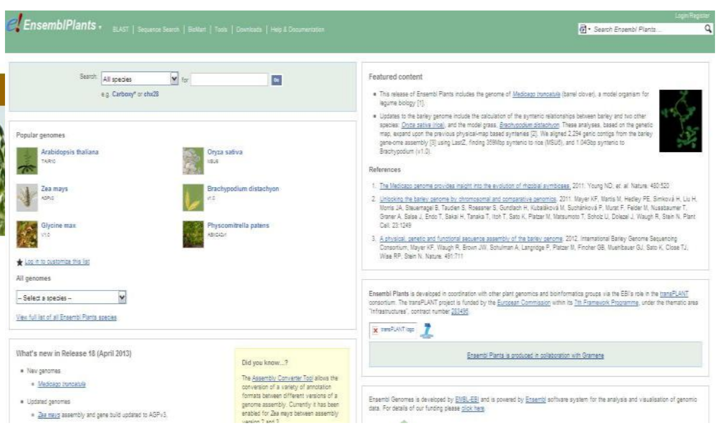
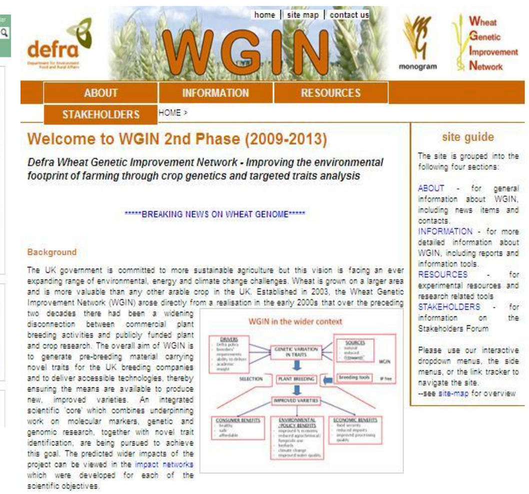
Ideas for creating a website to host the new wheat genome and marker data









University of
BRISTOL

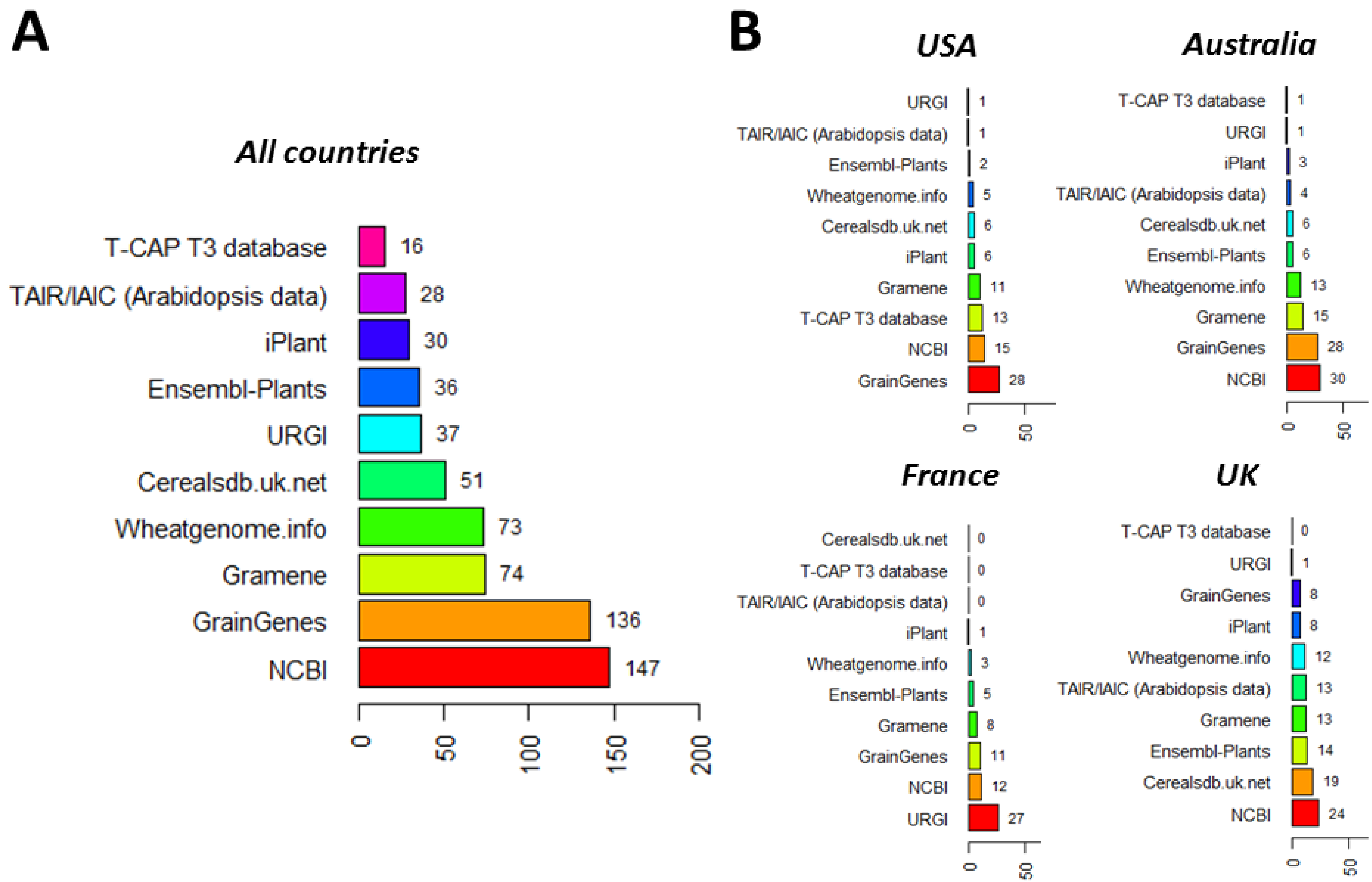
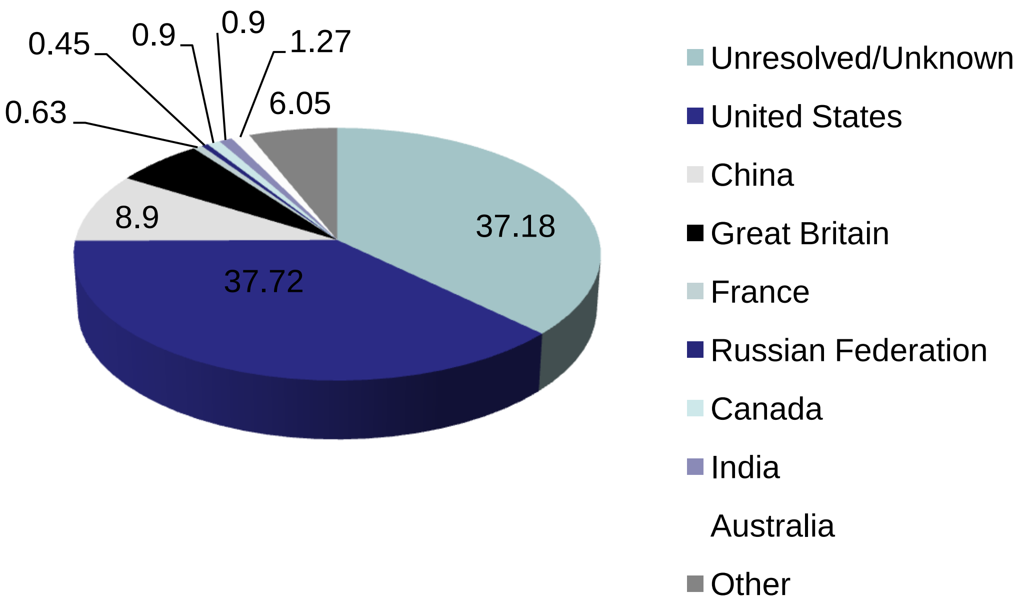


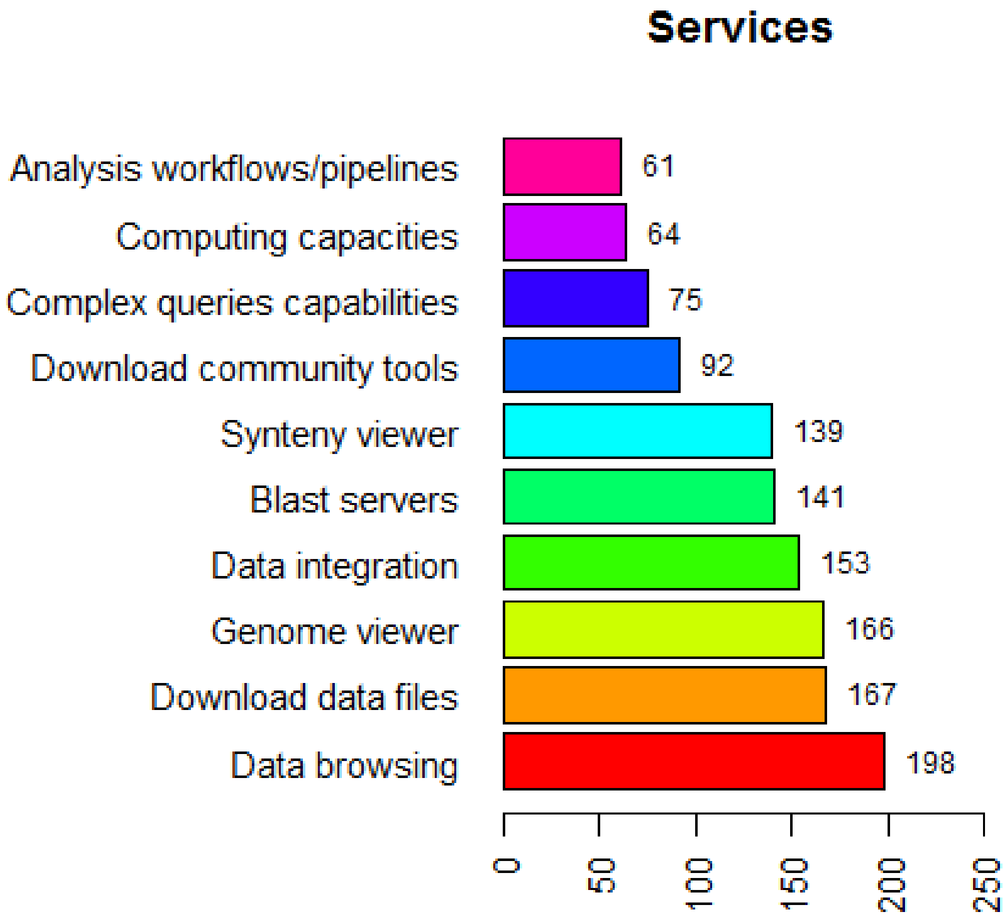
Figure 5*: Other bioinformatics portals where data would have to be accessible from (X axis: number of positive answers)*

Visits to CerealsDB web site (http://www.cerealsdb.uk.net/) during the period 2009-2012

	2009	2010	2011	2012	2013 (to 31st May)
Total	45,511	67,269	199,139	196,303	112,946



Summary of the locations of the users of CerealsDB (during 2012)

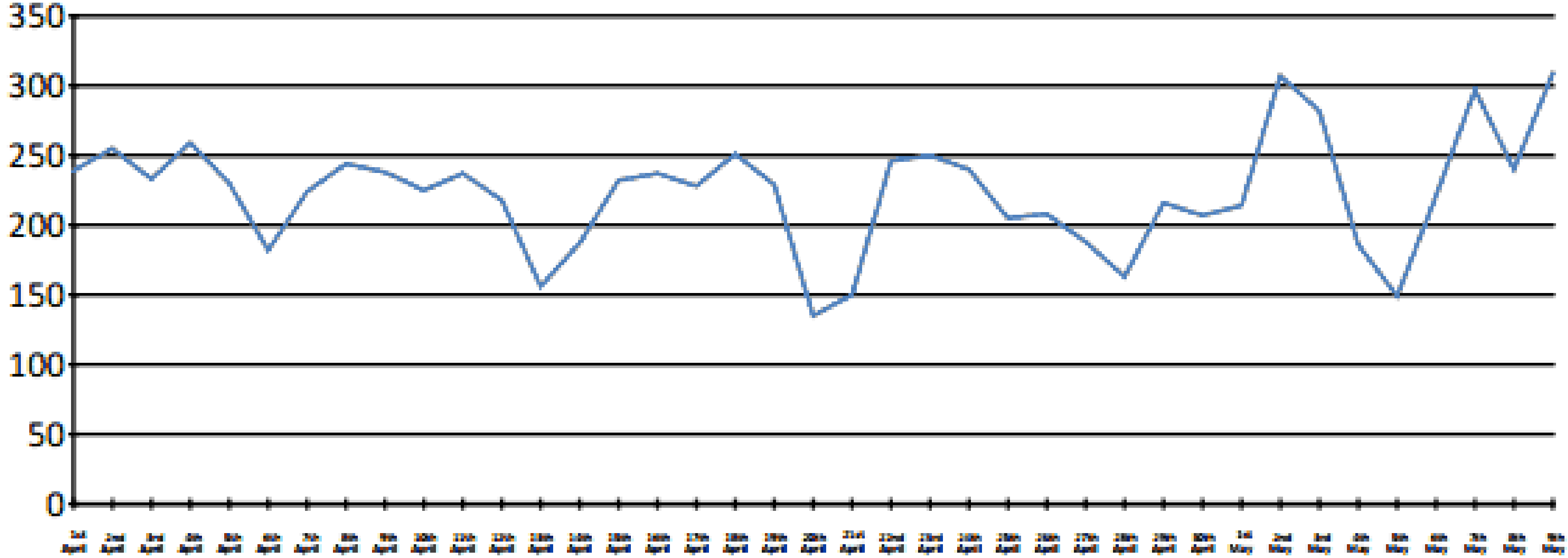


When asked what kind of services (the WheatIS) should provide, wheat researchers placed data browsing, data downloading and genome viewer respectively in first, second and third position (Figure 6). Interestingly, data Integration was placed only in fourth position, indicating that this is not considered yet as a top priority. surprisingly, we also noted that analysis workflows and computing capacities were ranked last. again this might be due to current technological limitations and lack of access to more advanced bioinformatics tools.

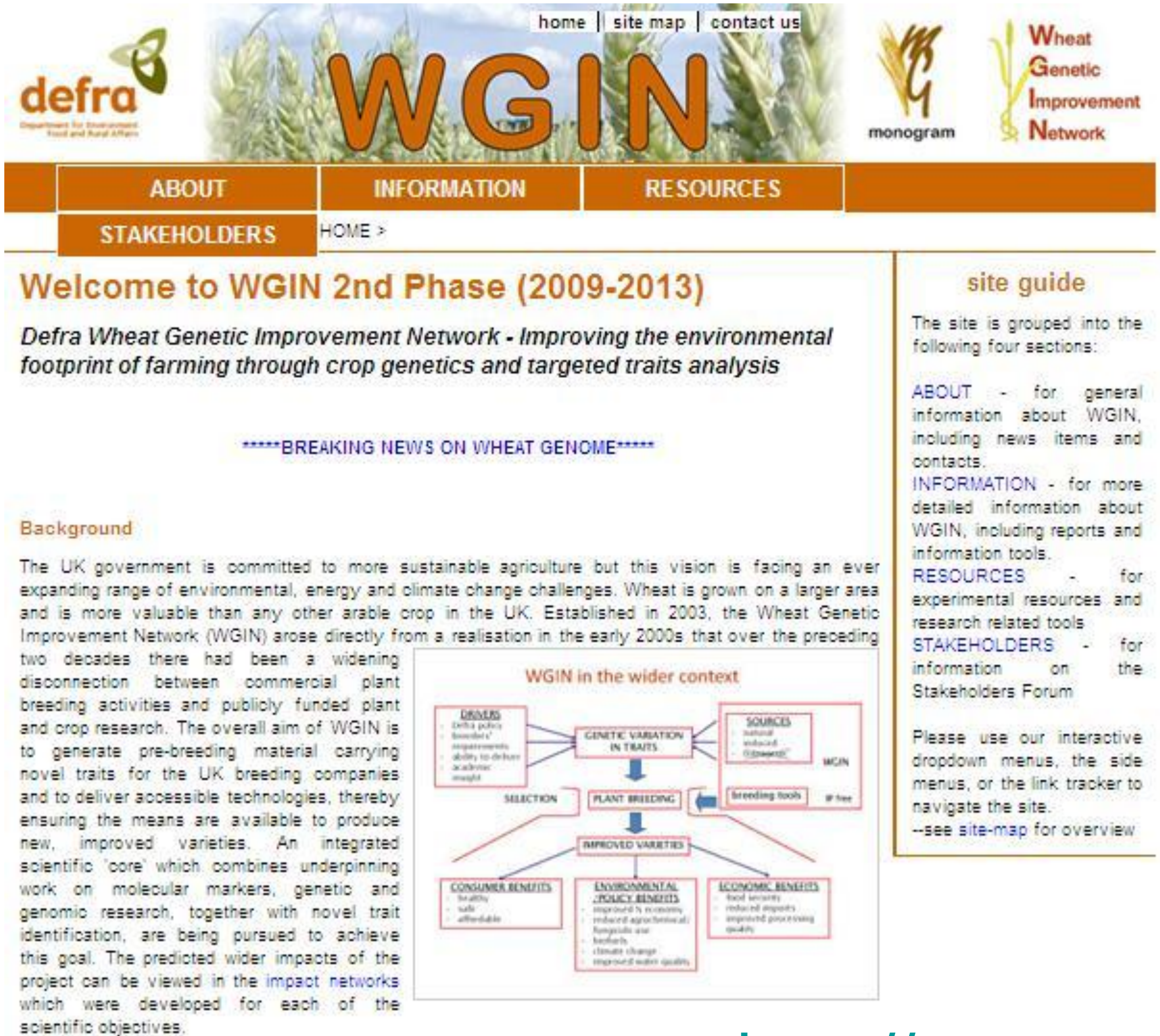
- Many web sites are created in the image of the group creating the site. i.e. they are designed for the creators not the wider community.

To make a web site useful, it should:

1. Know who it is targeting
2. Make data browsing easy (for others)
3. Allow data to be downloaded in easy to use formats
4. If required provide a genome viewer, along with a variety of easy to use tools which add value to the data that can be downloaded
5. (in my view) Be designed by experts, but in conjunction with the users
6. Be updated at regular intervals
7. Avoid passwords



Unique hits April 2013 – 9th May 2013-05-14



home | site map | contact us

defra

WGIN

monogram

Wheat Genetic Improvement Network

ABOUT | INFORMATION | RESOURCES | STAKEHOLDERS

HOME >

Welcome to WGIN 2nd Phase (2009-2013)

Defra Wheat Genetic Improvement Network - Improving the environmental footprint of farming through crop genetics and targeted traits analysis

*****BREAKING NEWS ON WHEAT GENOME*****

Background

The UK government is committed to more sustainable agriculture but this vision is facing an ever expanding range of environmental, energy and climate change challenges. Wheat is grown on a larger area and is more valuable than any other arable crop in the UK. Established in 2003, the Wheat Genetic Improvement Network (WGIN) arose directly from a realisation in the early 2000s that over the preceding two decades there had been a widening disconnection between commercial plant breeding activities and publicly funded plant and crop research. The overall aim of WGIN is to generate pre-breeding material carrying novel traits for the UK breeding companies and to deliver accessible technologies, thereby ensuring the means are available to produce new, improved varieties. An integrated scientific 'core' which combines underpinning work on molecular markers, genetic and genomic research, together with novel trait identification, are being pursued to achieve this goal. The predicted wider impacts of the project can be viewed in the impact networks which were developed for each of the scientific objectives.

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

http://www.wgin.org.uk/

"In the next 50 years, we will need to harvest as much wheat as has been produced since the beginning of agriculture, some 10,000 years ago."

The BBSRC wheat breeding programme is divided into 4 pillars (Landraces, Synthetics, Alien Introgression, Elite Wheats) and 2 themes (Phenotyping and Genotyping) These are represented by the 6 circles below; each is clickable and takes you to the website of the respective area).

http://www.wheatisp.org/

BBSRC
bioscience for the future

Bristol's future plans for CerealsDB:

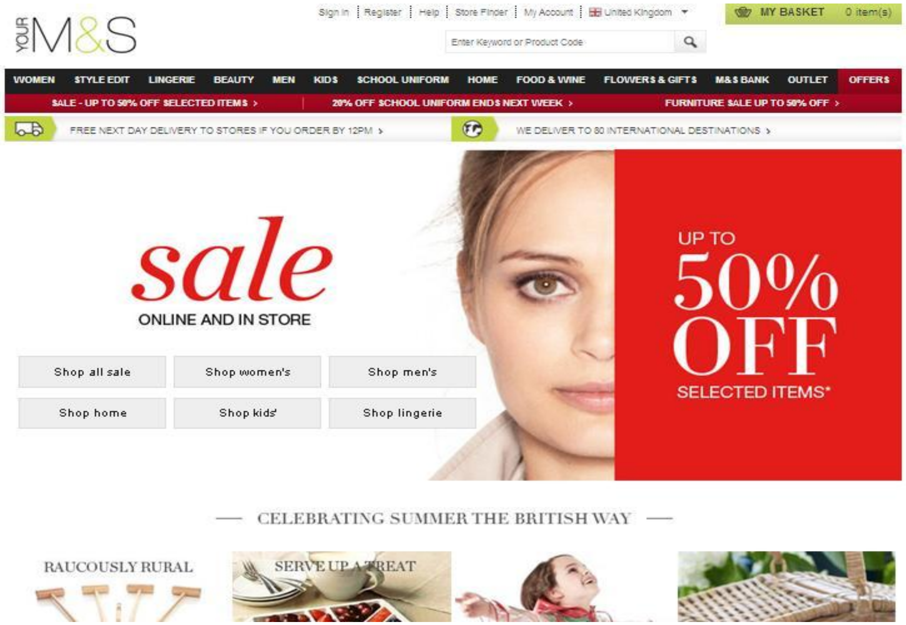
1. Incorporate CerealsDB with the WISP web site (underway)
2. Expand the remit of WISP to include a more extensive international profile
2. Expand WISP to include facilities for screening and analysing iSelect and Axiom based genotyping datasets
3. Develop an easy to use tool to identify and characterise functional SNPs
4. Provide the non-expert user community (breeders and others) with tools to link mapped and non-mapped SNPs/genes across a variety of wheat related species (the Bristol Burdock)
5. Develop Wheatbp (within WISP) to include a wheat genomics tool kit to stimulate the teaching of wheat genetics at the undergraduate level

The WGIN program has and continues to generate exciting data/resources of use to the wheat community.

One of the future objectives has to be to make these and the future resources more available and hence more useful. A useful interactive web site is one of the best ways to do this.

Amazon or M&S?

amazon.co.uk
Your Amazon.co.uk | Today's Deals | Gift Cards | Sell | Help
Shop by Department
Search All
MP3s & Cloud Player
Amazon Cloud Drive
Kindle
Appstore for Android
Books
Music, Games, Film & TV
Electronics
Computers & Office
Home, Garden & Pets
Toys, Children & Baby
Clothes, Shoes & Watches
Sports & Outdoors
Grocery, Health & Beauty
DIY, Tools & Car
Full Shop Directory
Cloud Player
LOVEFILM
Kindle
Cloud Drive
Meet the Kindle Family
Kindle £69
Kindle Paperwhite £109
Kindle Fire HD from £159
Kindle Books
Kindle Accessories
Up to 50% Off Fashion
See more
What Other Customers Are Looking At Right Now



YOUR M&S
MY BASKET 0 item(s)
WOMEN STYLE EDIT LINGERIE BEAUTY MEN KIDS SCHOOL UNIFORM HOME FOOD & WINE FLOWERS & GIFTS M&S BANK OUTLET OFFERS
FREE NEXT DAY DELIVERY TO STORES IF YOU ORDER BY 12PM
WE DELIVER TO 80 INTERNATIONAL DESTINATIONS
sale
ONLINE AND IN STORE
Shop all sale
Shop women's
Shop men's
Shop home
Shop kids'
Shop lingerie
UP TO 50% OFF SELECTED ITEMS*
CELEBRATING SUMMER THE BRITISH WAY
RAUCOUSLY RURAL

JIC germplasm resource update

Rres 03.07.13

Resources

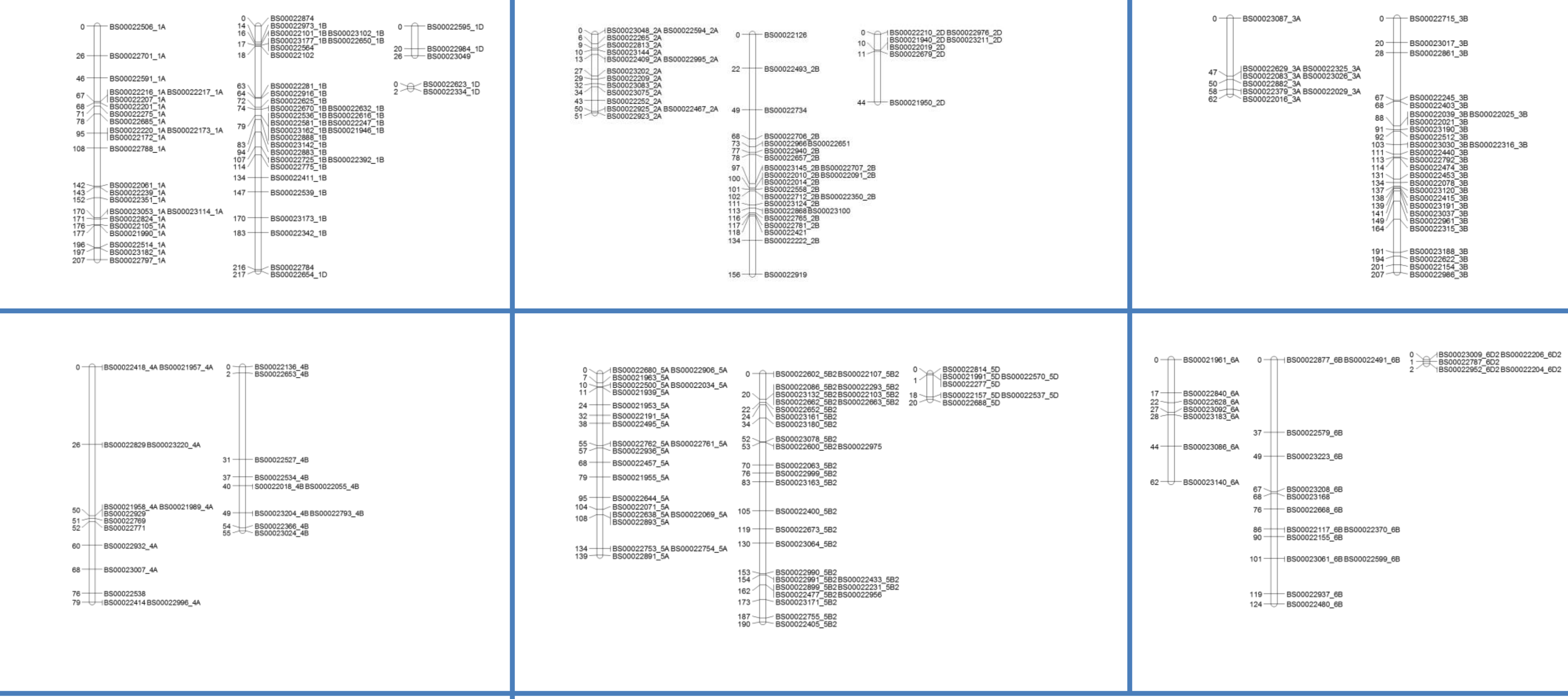
- Segregating populations and genetic maps
  - Paragon x Chinese Spring
  - Paragon x Synthetic
  - Paragon x Garcia

Resources

- Segregating populations and genetic maps
  - Paragon x Chinese Spring
  - Paragon x Synthetic
  - Paragon x Garcia

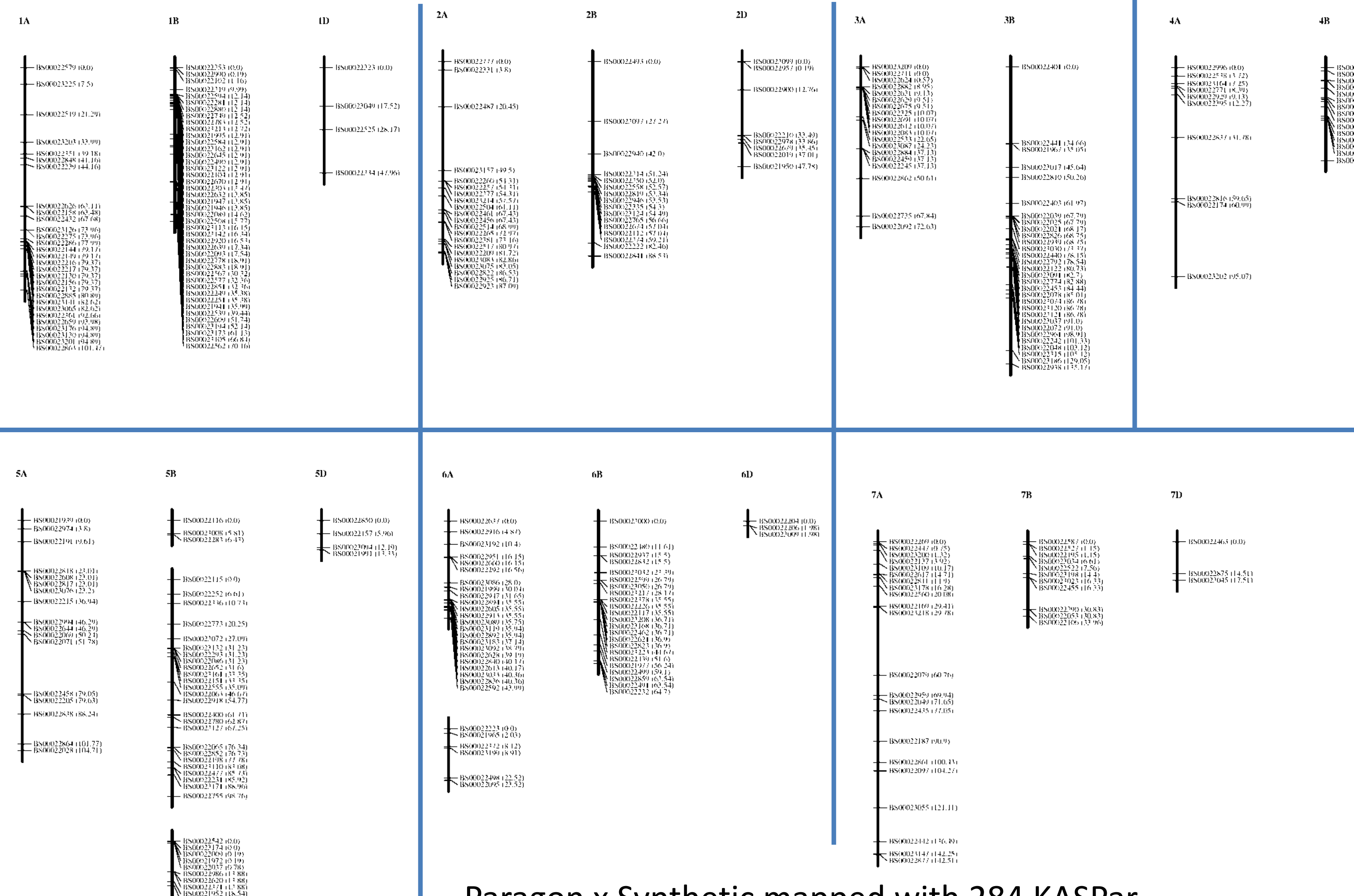
Populations developed in WGIN
genotyping done in CiRC

Paragon X Chinese Spring



Paragon x Chinese Spring mapped with 345 KASpar markers on 283 lines

Paragon X Synthetic Map



Paragon x Synthetic mapped with 284 KASPar markers on 283 lines

Paragon X Garcia

- Relatively large segregating population developed -283
- Ready for mapping now
- Parents screened along with WISP panels
- Map by October (end of CiRC)

Resources

- Near Isogenic Lines
  - Stem solidity, grain shape/size, Malacca x Herward functionality, 3N, Lr19
  - Avalon x Cadenza- 2012-13 trials 7.4m² x 600 entries x 3 reps

Avalon x Cadenza NILs

	Avalon Background	Cadenza background
Number of lines	225	342
QTL	1B ear emergence	1B ear emergence
	1D ear emergence	1D ear emergence
	2A height	2A height
	2D height	2D height
	2D yield	3A height
	3A height	3B height
	3B height	3B yield
	5A yield	6A height
	6A height	6B ear emergence & height
	6B height	
	6B height &7D yield	
	1D ear emergence & 5A yield	
	7B yield	
	7D yield	

Wheat Genetic Improvement Network

Wheat Genetic Improvement Network

AvCad NIL Phenotyping

- Establishment - % cover
- GS31 – first node detectable
- Ear emergence
- Height
- Ear number/m^2, grab samples
- Yield, Marvin (TGW)

Heading date 1D AxC NILs

QTL	trait	stream	BCparent	no A	no B	t-stat	df	Ava mean	Cad mean	p.val	signif
1D	FT	AC49-E11-5	Ava	9	3	2.65	9.8	63.7	61.3	0.0249	**
1D	FT	AC49-E11-6	Ava	2	3	3.46	1.7	63	59	0.0941	*
1D	FT	AC49-E14-12	Ava	3	5	1.52	5.8	62.7	60.6	0.18	
1D	FT	AC120-E28-1	Cad	3	9	2.59	8.2	63.7	60.9	0.0315	**
1D	FT	AC120-E7-1	Cad	6	6	3.08	7	61.3	56.8	0.0181	**
1D	FT	AC120-E7-3	Cad	5	6	0.32	8.8	60.6	60.3	0.7581	
1D	FT	AC158-E14-1	Cad	12	6	2.12	8.4	63.2	60.7	0.065	*
1D	FT	AC163-E12-1	Cad	3	11	3.73	4.8	62.3	59.2	0.0146	**
1D	FT	AC33-E11-12	Cad	6	3	5.01	5.2	63.2	58.7	0.0036	***
1D	FT	AC33-E11-5	Cad	6	8	-0.23	11.9	60.7	60.9	0.8222	
1D	FT	AC33-E36-2	Cad	12	11	2.13	18	62.2	60.6	0.0469	**

Heading date 6A AxC NILs

QTL	trait	stream	BCparent	no A	no B	t-stat	df	Ava mean	Cad mean	p.val	signif
6A	FT	AC43-E55-4	Ava	26	12	0.31	14.3	61.8	61.4	0.7625	
6A	FT	AC43-E55-6	Ava	41	12	-1.96	19.7	63.2	64.7	0.0649	*
6A	FT	AC104-E6-8	Cad	12	27	-1.94	21.1	59.2	60.4	0.0655	*
6A	FT	AC104-E6-9	Cad	15	13	-3.1	18	57.9	61.3	0.0062	***
6A	FT	AC89-E5-1	Cad	30	12	-0.49	17	60	60.4	0.6324	
6A	FT	AC89-E5-2	Cad	17	11	0.11	26	59.5	59.5	0.9163	

Heading date 3A AxC NILs

QTL	trait	stream	BCparent	no A	no B	t-stat	df	Ava mean	Cad mean	p.val	signif
3A	FT	AC144-E32	Ava	3	2	-0.38	1.4	61.3	63	0.7536	
3A	FT	AC144-E32-7	Ava	14	12	-2.51	18.9	61.1	63.4	0.0215	**
3A	FT	AC179-E27	Ava	6	6	1.1	8.5	61.7	59.3	0.3009	
3A	FT	AC69-E44-4	Ava	12	6	-1.24	7.6	62.2	63.7	0.2518	
3A	FT	AC113-E113	Cad	3	3	-0.85	2.6	60.7	62	0.4647	
3A	FT	AC113-E113-10	Cad	27	17	-2.4	37.8	59.9	61.4	0.0213	**
3A	FT	AC113-E113-8	Cad	16	30	-1.72	30	61.1	62	0.096	*
3A	FT	AC179-E27-2	Cad	21	14	-3.54	27.5	58.2	60.5	0.0015	***
3A	FT	AC179-E27-8	Cad	5	6	-3.79	8.8	57.4	61.2	0.0045	***

Conserved Orthologous Set (COS) Markers

- WGIN and BBSRC Tools and resources funded
- Published studies for B granules and Pch1
- New:

Syntenic relationships between the U and M genomes of Aegilops, wheat and the model species Brachypodium and rice as revealed by COS markers

István Molnár, Hana Šimková, Michelle Leverington-Waite, Richard Goram, András Cseh, Jan Vrána, András Farkas, Jaroslav Doležel, Márta Molnár-Láng, Simon Griffiths

PLOS ONE

Thanks to the current WGIN team at JIC –

Sue Freeman and Cathy Mumford

Drought tolerance

WGIN-2 SG meeting

Rothamsted Research 3 July 2013

The University of Nottingham

John Innes Centre

Activity 9, Drought tolerance (2009-14)

Obj 1. **Identify traits for WUE and drought tolerance (DT) in elite winter wheat varieties. (*Yrs 1-2*)**

Obj 2. **Identify QTLs for WUE and DT traits using one DH pop in an elite background. (*Yrs 2-3*)**

Obj 3. **Develop one new DH pop for drought research. (*Yrs 2-4*)**

Obj 4. **Identify novel genes and alleles for WUE and DT using the AE Watkins and Gediflux collections. (*Yrs 2-4*)**

Obj 5. **Collate germplasm (cvs, advanced lines) for future genetics studies. (*Yrs 4 -5*)**

18 Cultivar wheat panel selection informed by LINK 0986 Wheat WUE project, Eric Ober

Wheat
Genetic
Improvement
Network

Years: 2009-10 & 2010-11
Split plot design (3 reps): plot size 1.6 x 12 m
Main plot: Fully irrigated (trickle irrigation)
Unirrigated

Split plot (variety):

1. Avalon
2. Beaver
3. Cadenza
4. Cappelle Desprez/Sterling
5. Cordiale
6. Glasgow
7. Hereward
8. Hobbit
9. Istabraq
10. M. Widgeon
11. Oakley
12. Panorama
13. Paragon
14. Rialto
15. Savannah
16. Soissons
17. Xi 19
18. Zebedee

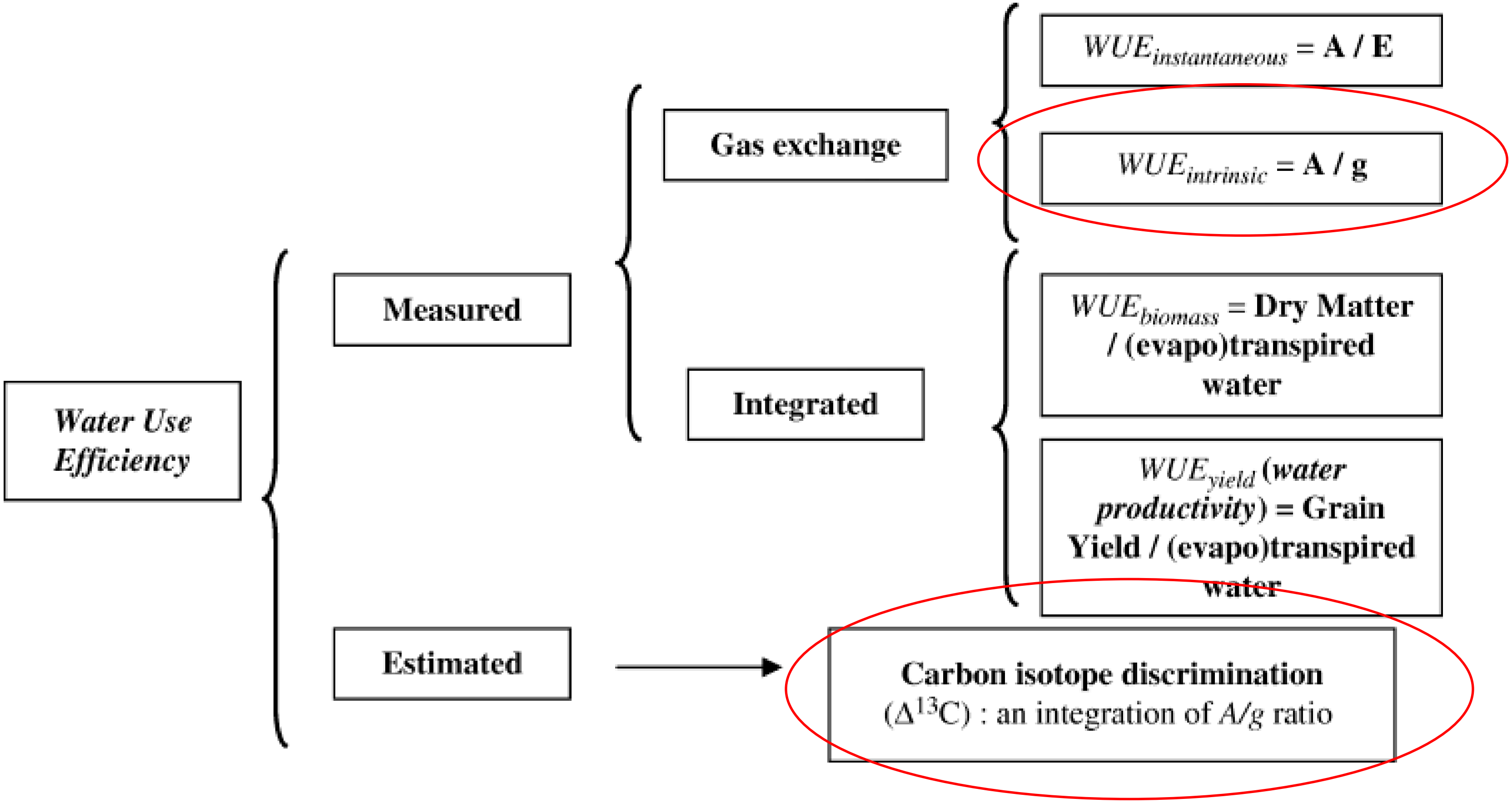
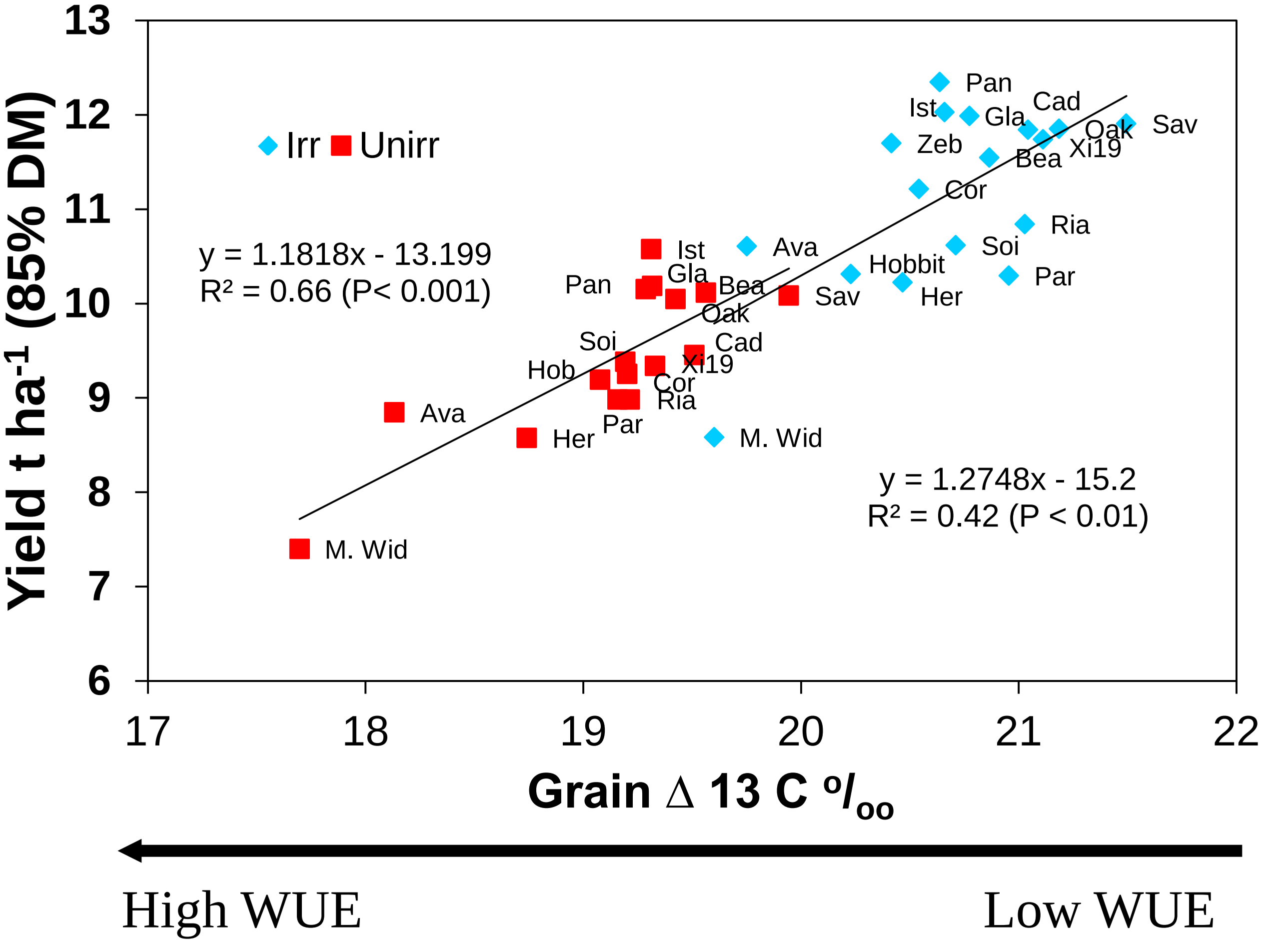


Figure 1. Definitions of ‘water use efficiency’. The scheme represents the several definitions of water use efficiency (WUE) used in the text. *A*, net photosynthetic rate expressed as µmol CO_2 m^{-1} s^{-1}; E, transpiration rate expressed as mmol H_2O m^{-2} s^{-1}; $\Delta^{13}C$, carbon isotope discrimination.

Tambussi et al. 2007 Field Crops Res

Δ ¹³C vs grain yield in 18 wheat cultivars



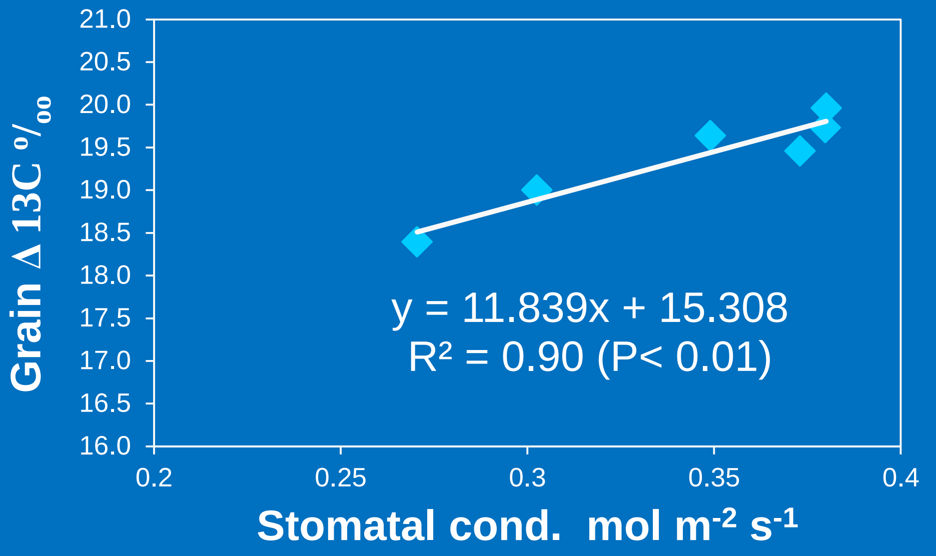
❖ ***Grain $^{13C}\Delta$ positively associated with yield under drought – indicator of ability to access water***

❖ ***Trade-off between WUE and season-long water use***

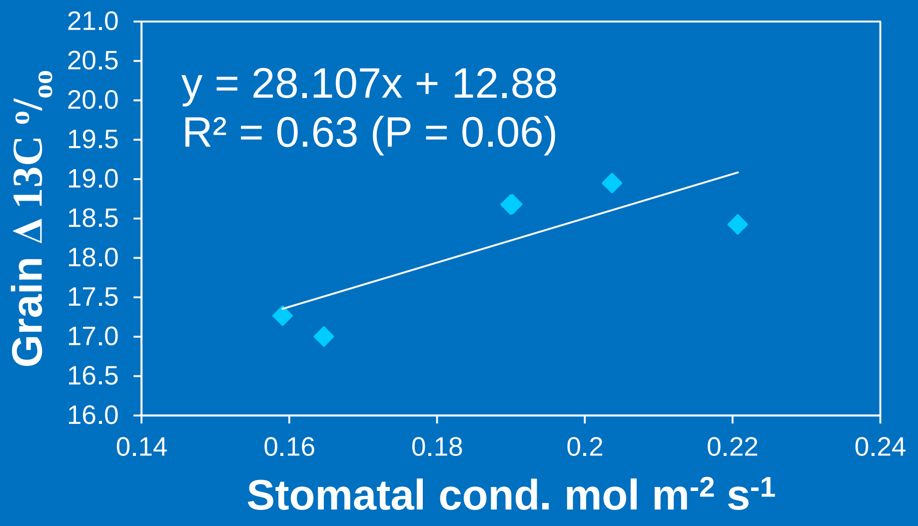
Sutton Bonington Mean 2009-10 & 2010-11

Grain Δ13C versus stomatal conductance (Unirrigated)

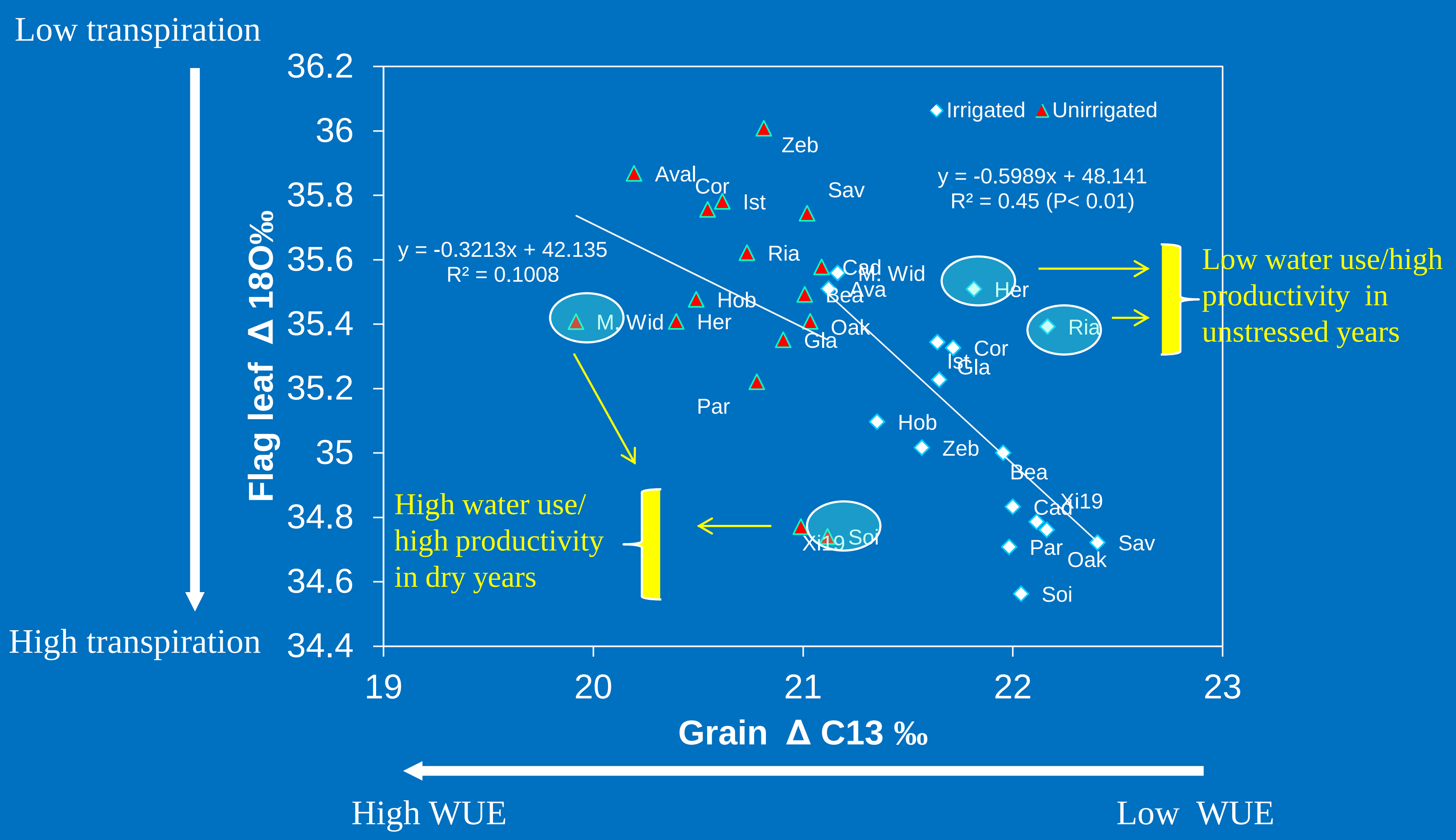
2009-10



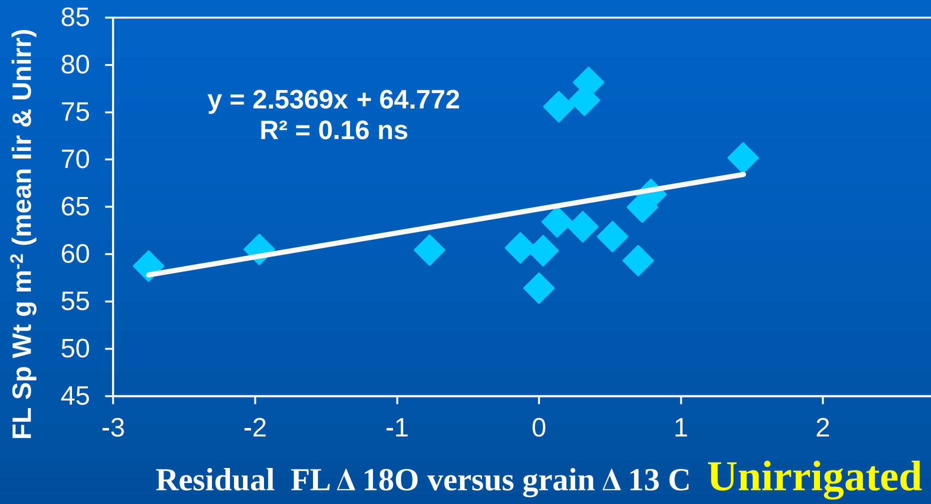
2010-11

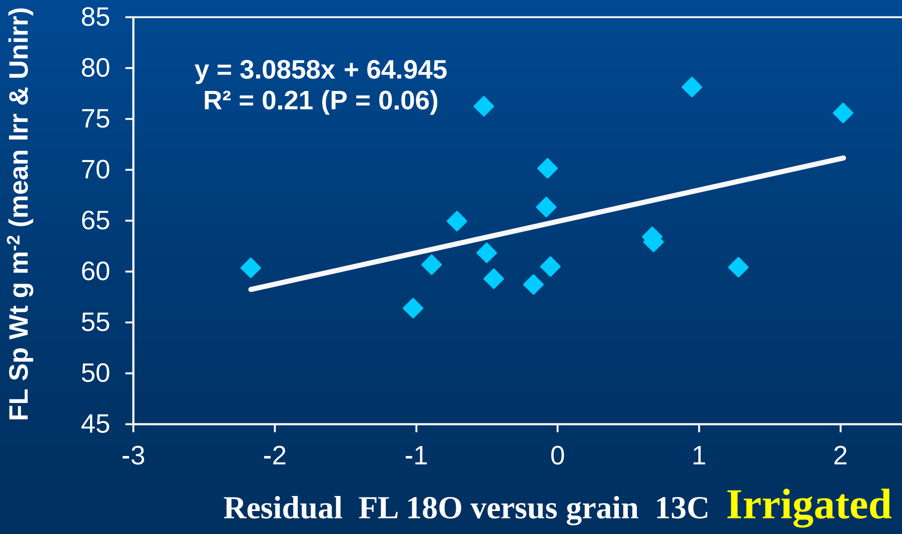


Relationship between $\Delta^{13}C$ and $\Delta^{18}O$ in 18 wheat cultivars (mean 2010 and 2011)



Residual flag leaf $\Delta^{18}O$ vs grain $\Delta^{13}C$ relationship versus flag leaf specific weight at GS61



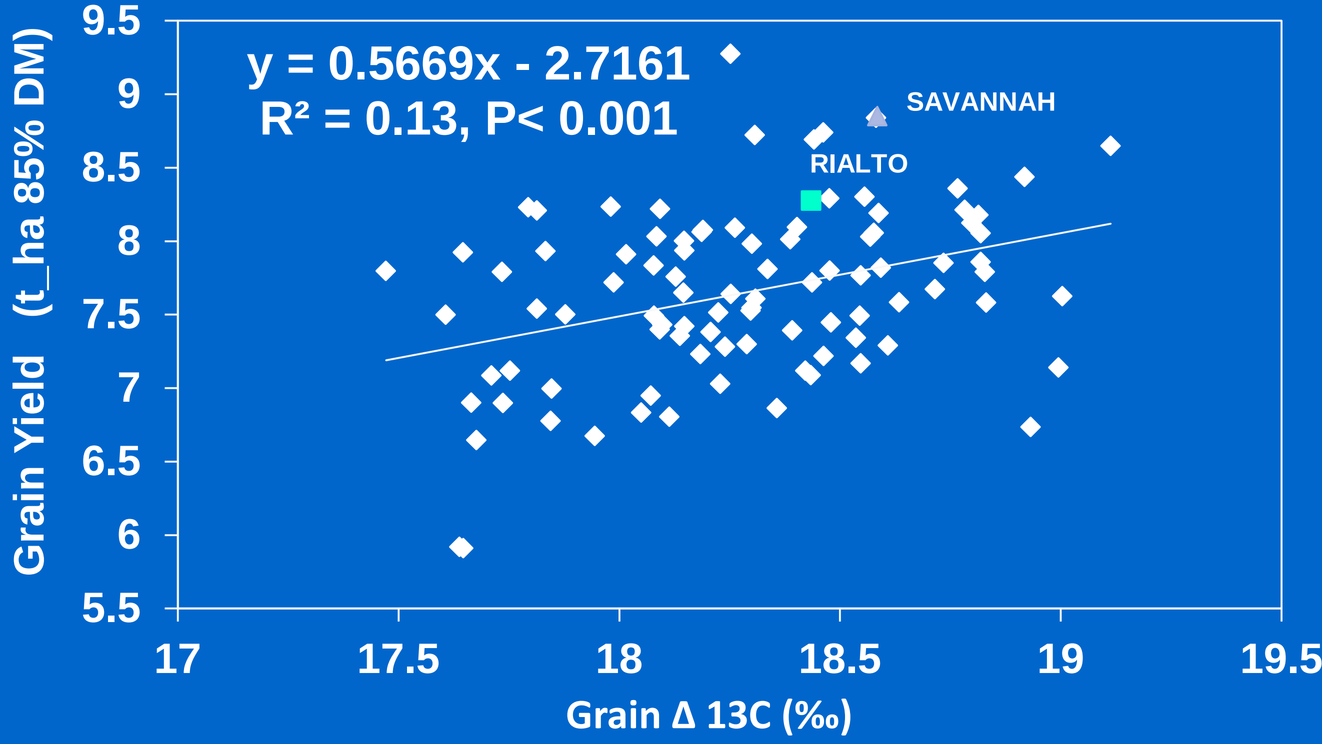


WGIN Objective 9.2 QTL Detection

2010-11, 2011-12 and 2012-13 expts

- Rialto x Savannah DH population for phenotying for yield physiological traits (94 lines and 2 parents)
- 2 sites: Nottingham - irrigated & unirrigated; JIC - unirrigated
- Target traits
  - ^{13}C Δ grain
  - senescence kinetic
  - stem WSC

Δ ^{13}C vs grain yield: Savannah x Rialto DH 2010-11



High WUE ← Low WUE

L2

L39

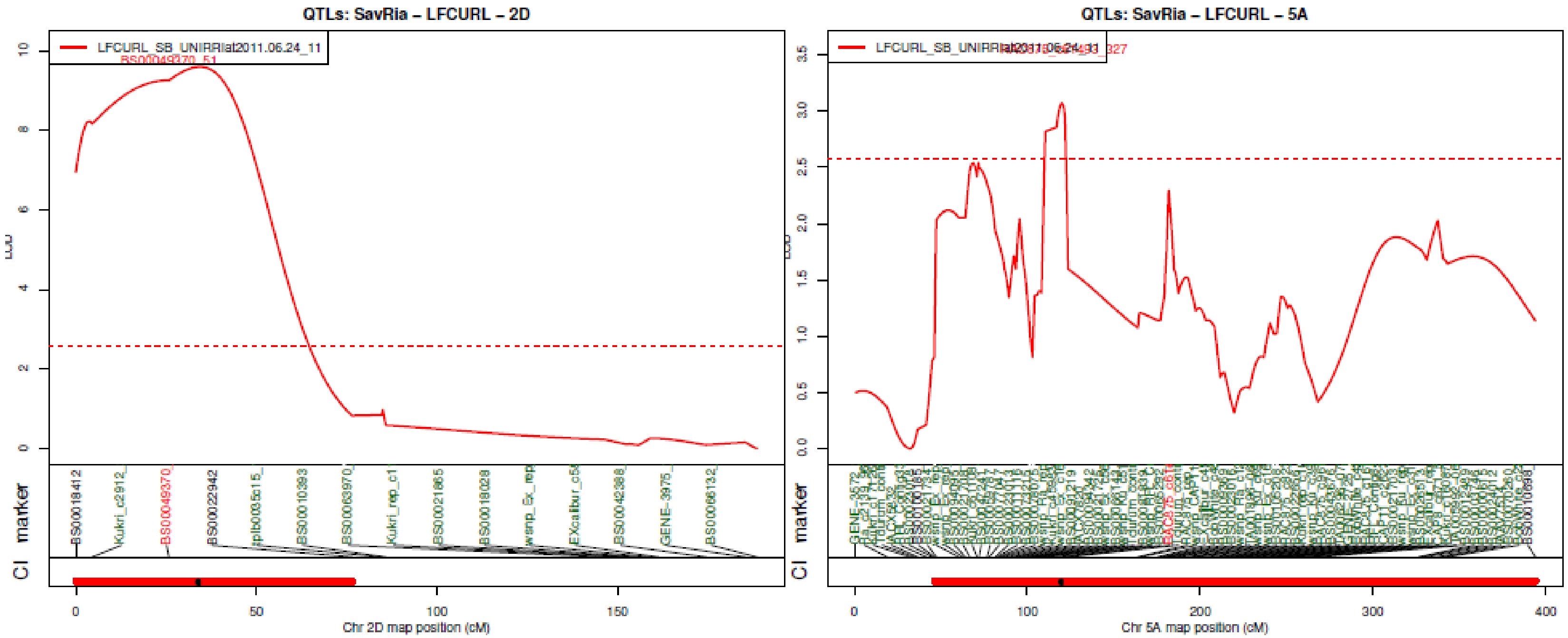
L47

SavXRia Sutton Bonnington QTLs 2010-11

chr	pos	LOD	var	mean	add eff	on	marker	trait	env
1D	28	3.1	12.9	0.5	-0.008	S	RAC875_c78062	HI	IRRI11
4D	17.8	2.7	11.1	0.5	0.008	R	GENE-2812	HI	IRRI11
4A	191.6	2.5	7.7	50.8	-0.8	S	BS00023164	TGRWT	IRRI11
5A	70.8	5.8	20.1	50.8	-1.35	S	Kukri_c61108	TGRWT	IRRI11
6A	129	4	13.1	50.8	-1.1	S	EXcalibur_c52196	TGRWT	IRRI11
2D	3	3	12	343	12.9	R	Kukri_c2912	EARNBpsqm	UNIRRI11
7A	0	3.9	16	343	15.1	R	EXcalibur_c48636	EARNBpsqm	UNIRRI11
2D	3	4.4	17.3	16267	703	R	Kukri_c2912	GRpsqm	UNIRRI11
3B	261	3	11.3	16266	-585	S	Ex_c14162_22093694	GRpsqm	UNIRRI11
3B	260	2.4	11.3	7.6	-0.19	S	Ex_c14162_22093694	GRYLD	UNIRRI11
3A	144.9	2.6	7.2	47	1.2	R	BS00110564	TGRWT	UNIRRI11
5A	337.3	2.8	7.7	47	-1.3	S	IAAV7514	TGRWT	UNIRRI11
7D	45	2.9	8.1	47.2	-1.1	S	Kukri_c48125	TGRWT	UNIRRI11
2D	34	8.2	30.3	4.4	0.28	R	BS00049370	LFCURL	UNIRRI11
2B		3.0	17.5	4.4	0.18	R	BS00098024	LFCURL	UNIRRI11
5A	119.8	1.4	4.2	4.4	0.18	R	RAC875_c61493	LFCURL	UNIRRI11
5A	249.8	3.2	15.1	0.32	-0.011	S	EXcalibur_rep_c68005	NDVI	UNIRRI11
2A	161	3.4	16.0	18.2	0.135	R	Tdurum_contig66015	DeltaC	UNIRRI11

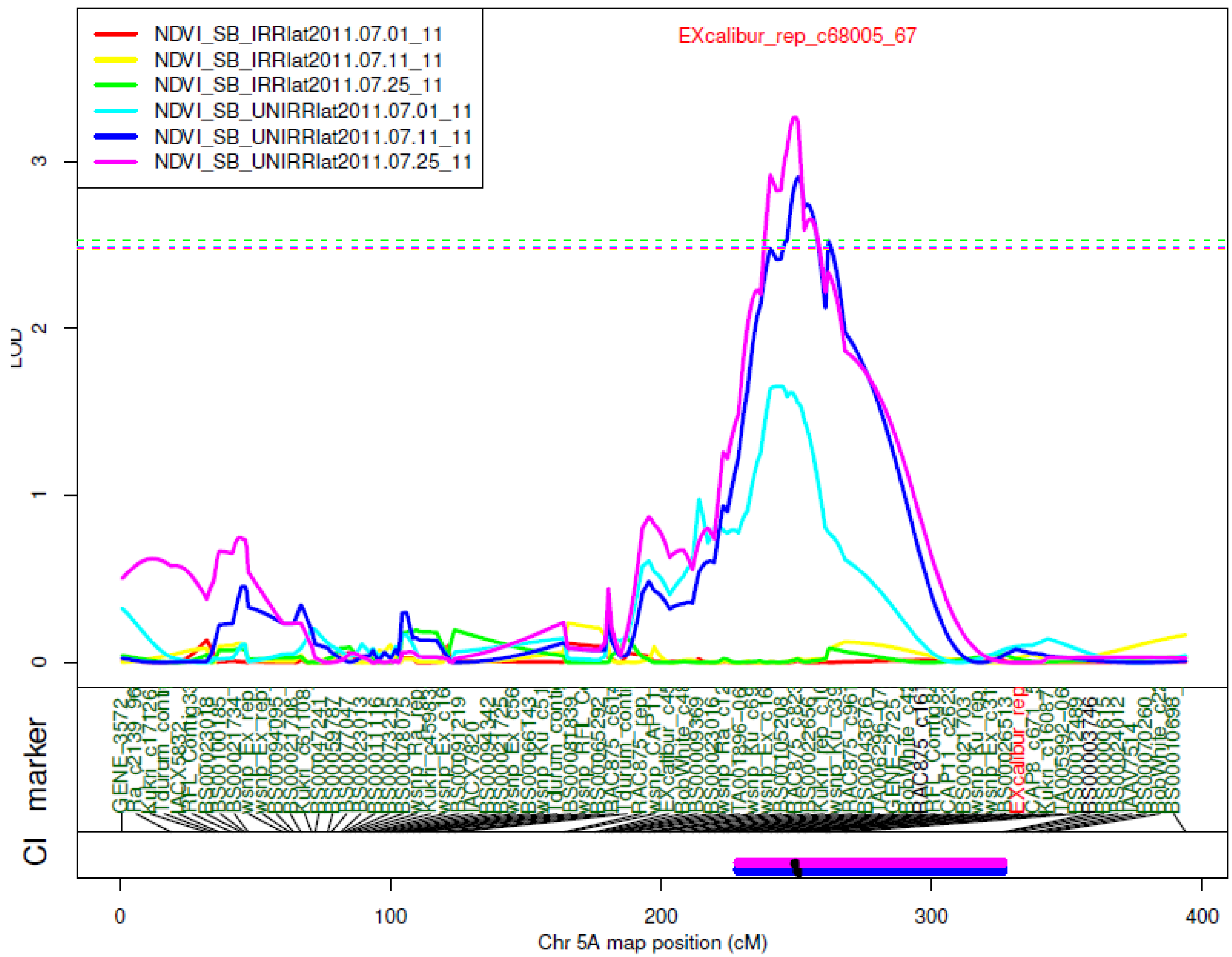
- both environments: TGRWT (5A)
- irrigated: HI (1D, 4D), TGRWT (4A,6A)
- unirrigated: EARpsqm (2D, 7A), GRpsqm (2D,3B), GRYLD (3B), LFCURL (2B, 2D, 5A), NDVI (5A), Cdelta (2A)
- no qtls: AGDM, CTEMP, StemWSC

QTLs for LFCURL



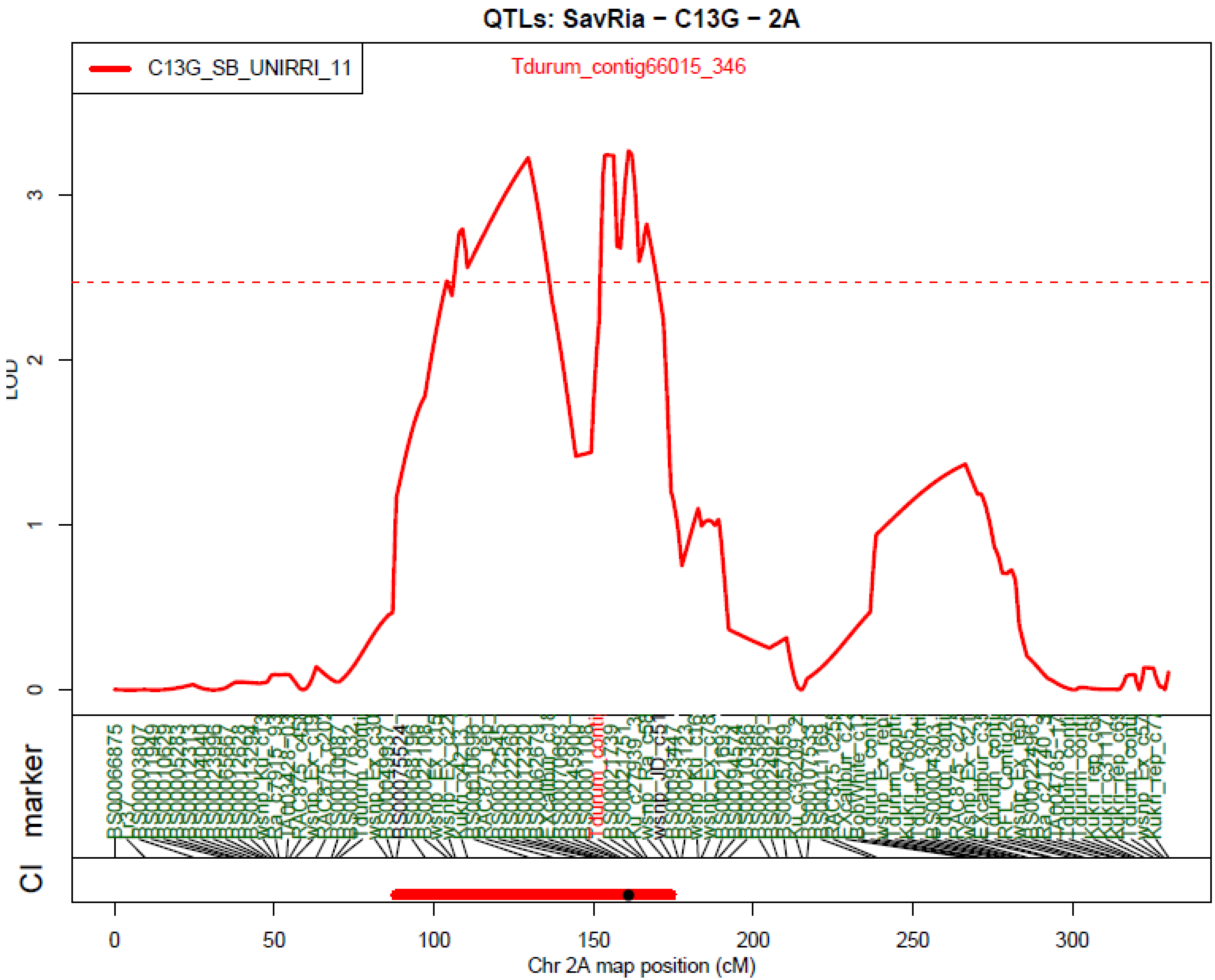
LEAFCURL QTL 2D coincides with GRpsqm, 5A NOT with NDVI.

QTL 5A for NDVI



NDVI QTL 5A only under 'drought'.

QTLs for Cdelta



9.2 QTL Detection

2012-13 expt (Sown 16 October 2012)

- Rialto x Savannah DH population for phenotying for yield physiological traits (94 lines and 2 parents) - irrigated & unirrigated

- Traits
  - $^{13}C\ \Delta$ grain (unirrigated)
  - senescence kinetics (flag leaf visual score,NDVI)
  - stem WSC at GS61+7d (unirrigated)
  - flag leaf Licor 6400 : Rialto, Savannah , 6 DH lines contrasting for $^{13}C\ \Delta$ grain (Licor 6400) (unirrigated)

SB Rainfall 2013	mm
January	29.80
February	27.40
March	46.40
April	8.00
May	71.80
June to 25th	45.40

Irrigation applied to 3 July : 60 mm

9.3 Develop SSD population

- Paragon x Garcia (contrasting for drought tolerance traits)
- Population segregating for *Ppd1a*:
  - use WGIN resource to select against *PpdD1a* - ie make the pop photoperiod sensitive.
  - keep the pop large, so we can have flowering time strata and perform analysis within them
- F3 sown in October 2012, population is in excess of 350 lines
  -

John Innes Centre

Obj 9.5. Collate germplasm (cvs, advanced lines) for genetics studies. (*Yrs 4 -5*)

CIMMYT Semi-arid Trials/Nurseries

Trial Name	Target environment	No Entries	No. Reps		
Semi-Arid Wheat Yield Trial (SAWYT)	Low rainfall environments	50	2	SAWYT*1 (Yield Trial with one 85g envelope/entry/rep, for machine sowing)	
Semi-Arid Wheat Screening Nursery (SAWSN)	Low rainfall environments	150	1	SAWSN (Screening Nursery with one 10g envelope/entry)	

- Standard Material Transfer Agreement (SMTA) signature

- Any additional declaration to be stated in the phytosanitary certificate issued by the Mexican phytosanitary authorities for the requested crop?

The University of Nottingham

Jayalath DeSilva
Pedro Carvalho

PhD student: Y.adgar Mahmood

John Innes Centre

Simon Griffiths
Simon Orford
Luzie Wingen

British Wheat Breeders

defra
Department for Environment Food and Rural Affairs

Wheat Genetic Improvement Network

Increasing the efficiency of water use of wheat by isotope screens indicative of water use, transpiration efficiency and drought tolerance

John Foulkes[1] , Simon Griffiths[2], Simon Orford[2],
Pedro Carvalho[1] & Jayalath DeSilva[1]

AAB "Crop Resource Use Efficiency and Field Phenotyping"

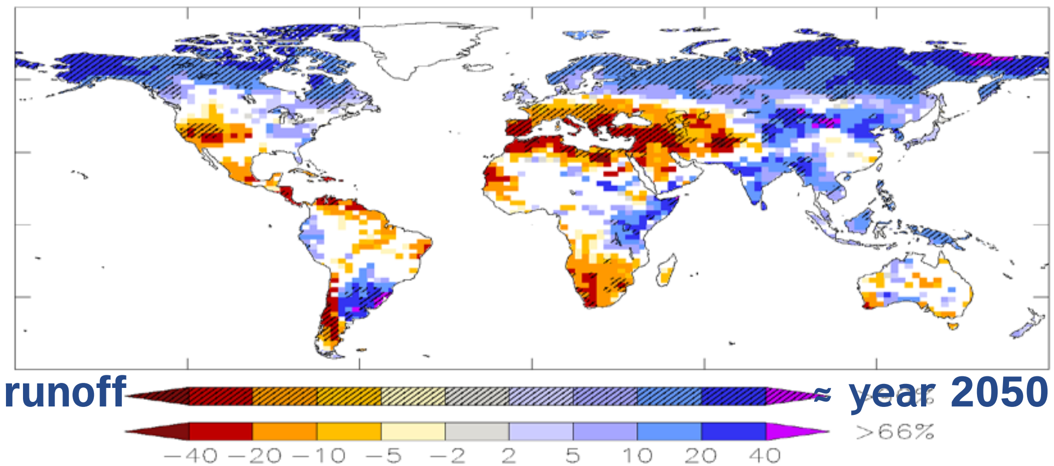
Belton Woods Hotel, Grantham 25-26 March 2013

1 The University of Nottingham

2 John Innes Centre

Background: Water supply and Productivity

Climate change & water supply:



The Wet gets wetter! - The Dry gets drier!

By 2025, two-thirds of the world population could be under "*stress conditions*" (500-1000 m³ per year per capita), and 1800 million people are expected to be living in countries or regions with "*absolute water scarcity*" (<500 m³ per year per capita)

The good news is that 1% of water productivity gain in agriculture means 10% increase of availability for other uses

Litres per day per person	
Drinking	2-4
Domestic	40-400
Food	1000-5000 (and more)

Drivers for increasing WUE and drought tolerance in UK

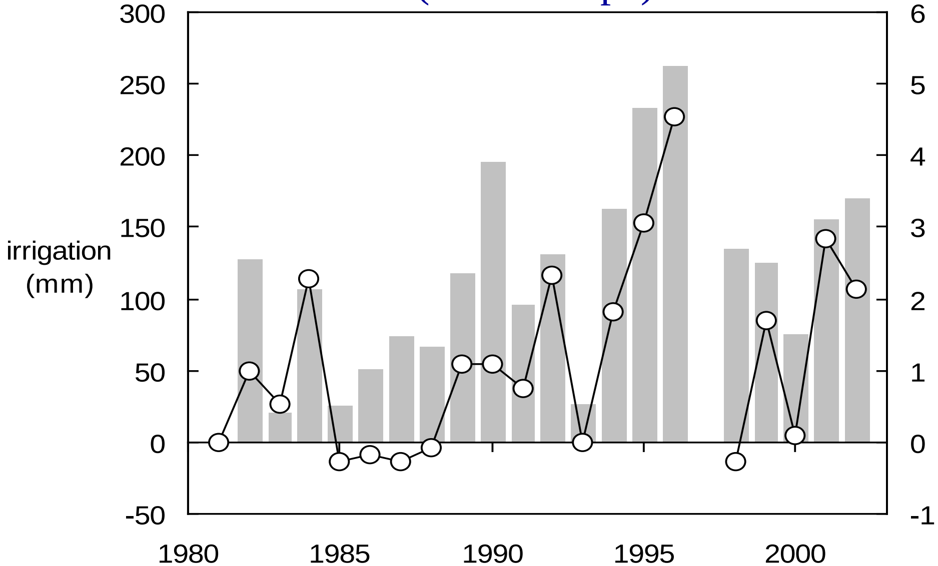
- **30% of UK wheat on drought-prone land, losses are 1-2 t ha^{-1} = >£50M per year.**
- **With climate change summer rainfall will decrease, potentially increasing these losses.**
- **Improving WUE will decrease crop water use in non-drought years, increasing water for:**
  - **use in irrigating other crops**
  - **increasing water flows in rivers and aquifer recharge.**

Impact of drought on UK wheat yields

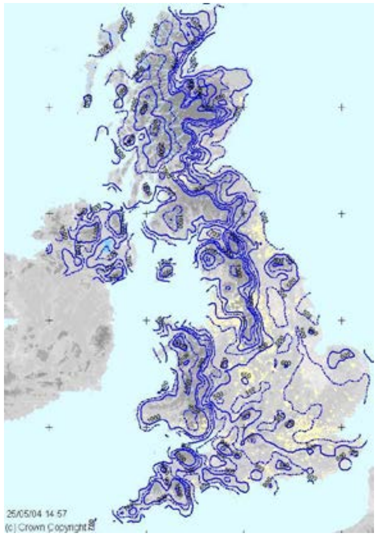
Distribution of available water to 1.2 m in UK wheat

Soil AWC mm	%
126-150	12
151-175	26
176-200	13
201-225	39
226-250	9

Yield response to irrigation on light soil (Gleadthorpe)



Rainfall contour map



Gleadthorpe Notts
AWC = 140 mm

Foulkes et al. 2001, 2002, JAg Sci; FCR 2007

How will UK weather change?

- Summer rainfall to decrease by 11- 27% by 2080s; decrease 40% in S. England, less change in N. Scotland.
- Average summer temp. to rise by 3-4° C by 2080s; changes greatest in S. England (2.2-6.8°C) and least in N. Scotland (1.2-4.1°C).
- Sea levels are expected to rise by 36 cm by the 2080s.
- Extreme weather events are likely to become more common.

Predictions based UK Climate Projections (UKCP09)

Traits associated with main drivers of yield under drought

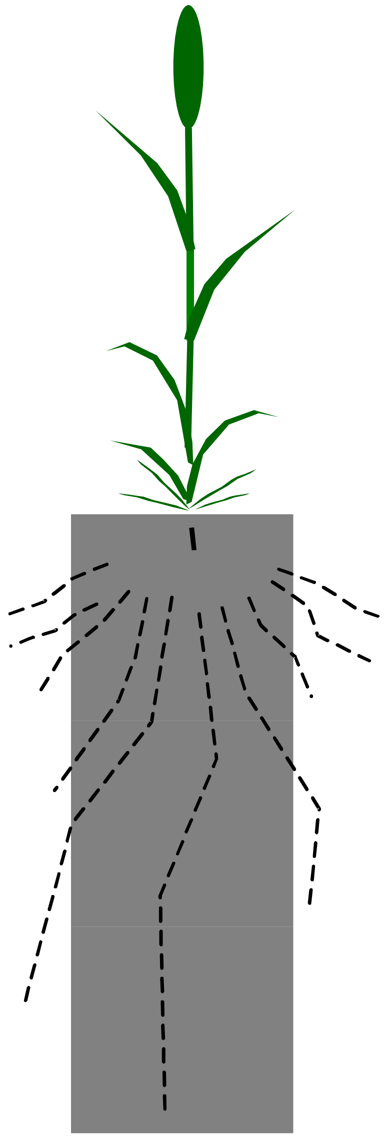
Yield = WU x WUE x HI

OPTIMIZE WUE

- WUE of leaf photosynthesis
- Low $^{13/12}$C discrimination

MAXIMIZE HARVEST INDEX

- Pre-antheis partitioning to stem CHO reserves
- Functional stay green



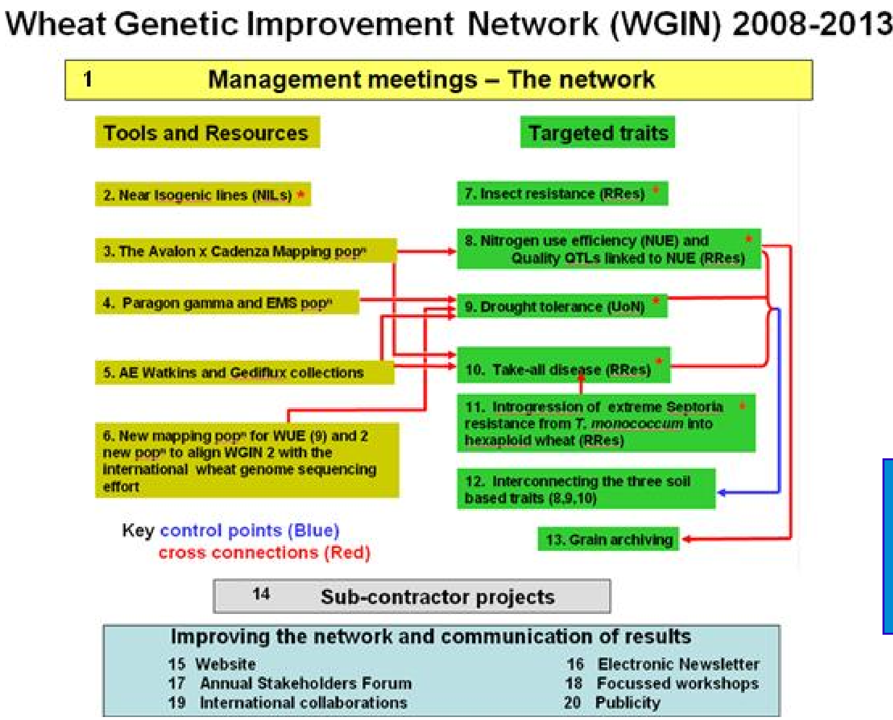
MAXIMIZE WATER CAPTURE

- Increase root density at depth
- Distribute roots deeper
- Access to water by roots indicated by cooler canopy

EARLINESS

- Extend stem elongation phase
- Early onset GS31

Wheat Genetic Improvement Network



Genetic Improvement of Drought Tolerance

Target physiological traits:

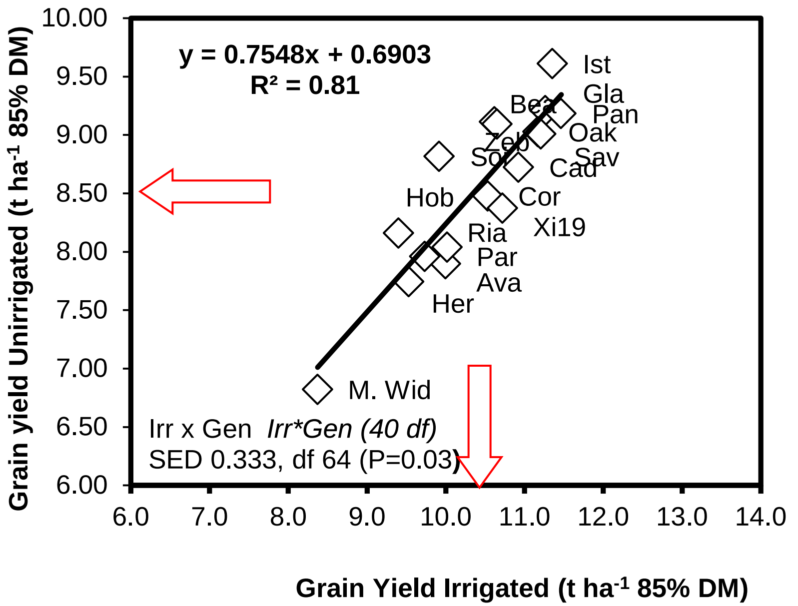
- Grain Δ 13 C (WUE)
- Flag Δ 18 O (Water Use)
- Stem WSC Reserves (HI)
- Canopy water status (NIR - WI)

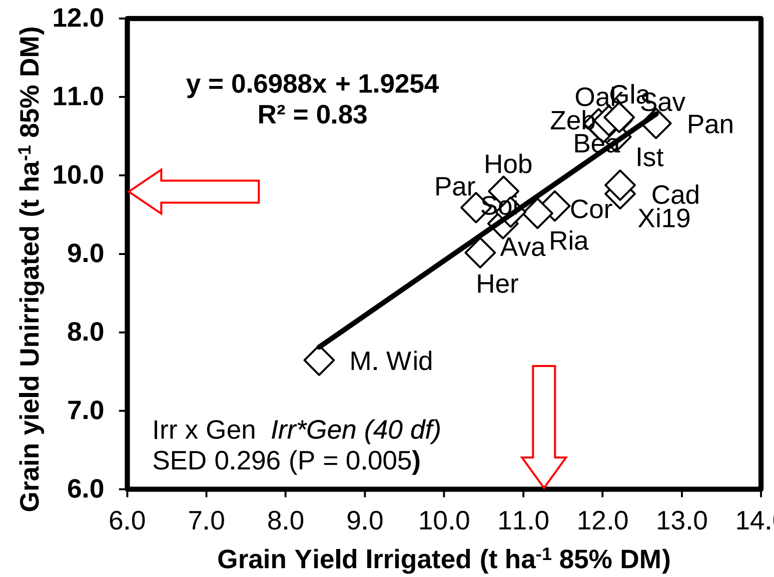
GY = Water Use x WUE x HI

Passioura 1977

Sutton Bonington 2009-10 and 2010-11

Grain yield responses to Drought

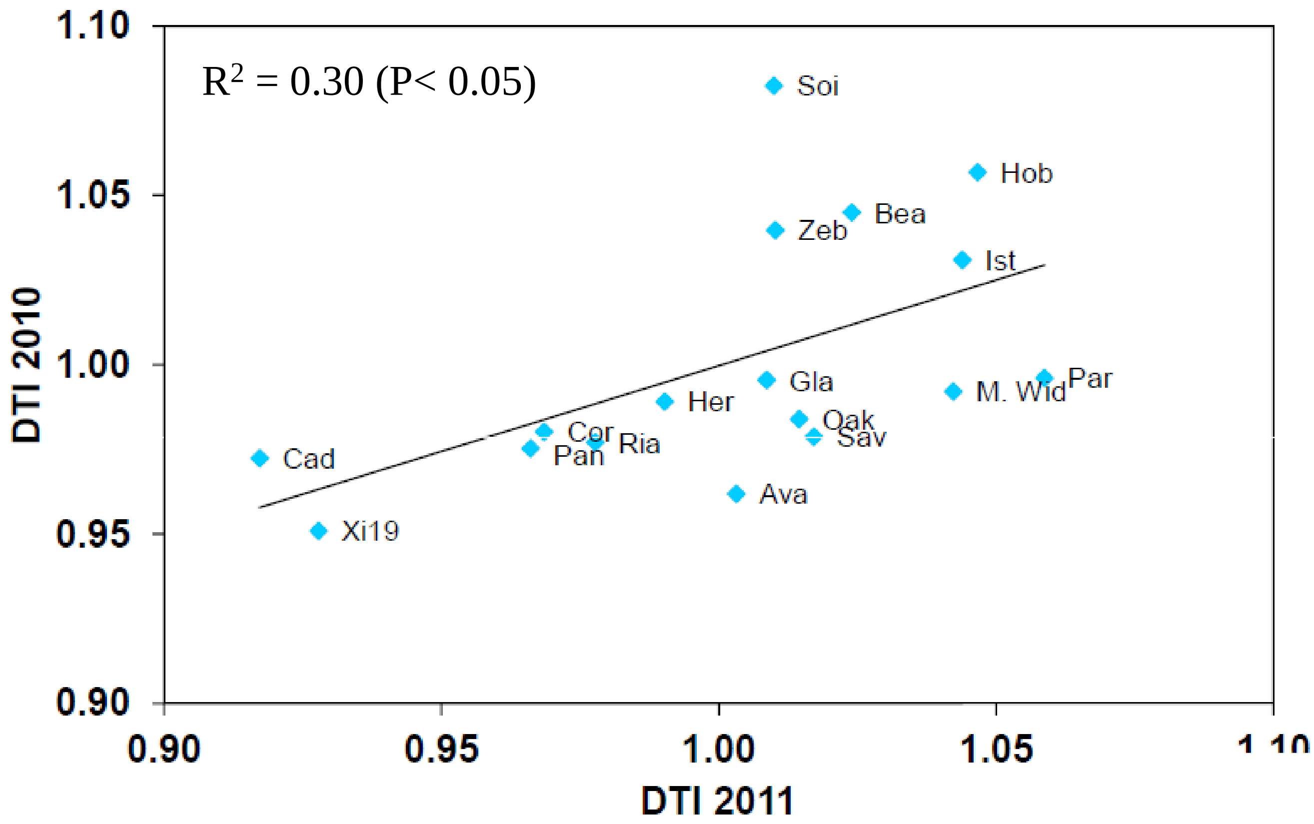




	Rainfall mm (% LTM)	
	2010	2011
January	33.0 (62)	33.2 (62)
February	41.6 (95)	44.6 (101)
March	36 (67)	1.2 (2)
April	24 (55)	23 (53)
May	16.2 (35)	27.8 (61)
June	69.2 (152)	45.4 (100)
July	42.6 (86)	17.8 (36)

Irrigated vs Unirrigated 19 July

Drought tolerance index: $(Y_{Dr}/Y_{Irr}) / (\text{mean } Y_{Dr} / \text{mean } Y_{Irr})$



Wheat Genetic Improvement Network

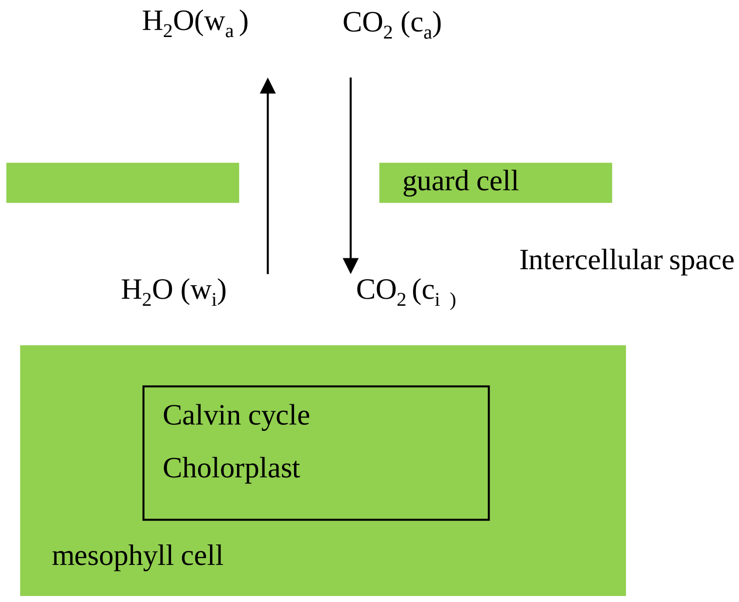
Water use efficiency: definition and estimation

- **Water-use efficiency (WUE) is the ratio of above-ground dry matter production to evapotranspiration.**
- **$^{13}C/^{12}C$ isotope ratio of fixed CO_2 can be used to estimate WUE**
- **Low discrimination against $^{13}CO_2$ → high WUE**

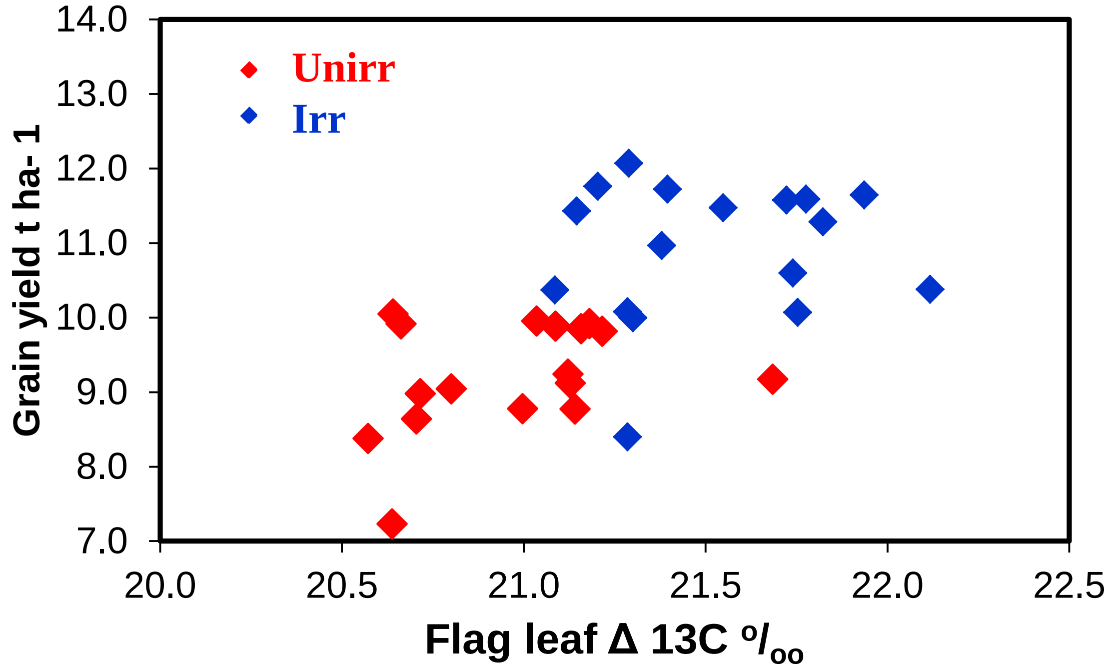
Relationship between c_i and leaf transpiration efficiency

- ***Stomatal conductance:***. Lower conductance ↓ ci hence ↑ TE.
- ***N or Rubisco content per unit leaf area:*** Greater photosynthetic activity ↓ c_i , hence ↑ TE.

Condon et al. (2002). Crop Science



Δ ^{13}C flag leaf vs grain yield



High WUE Low WUE

Sutton Bonington Mean 2009-10 & 2010-11

Trade off between water-use efficiency and water use

Use Δ18O as an indicator of transpiration to allow stomatal and Ps effects on Δ13C to be teased apart

WGIN Objective 9.2 QTL Detection

* Email:

2010-11, 2011-12, 2012-13 expts

July 2013

• Rialto x Savannah DH population for phenotying for yield physiological traits (94 lines and 2 parents)

*

Institution:

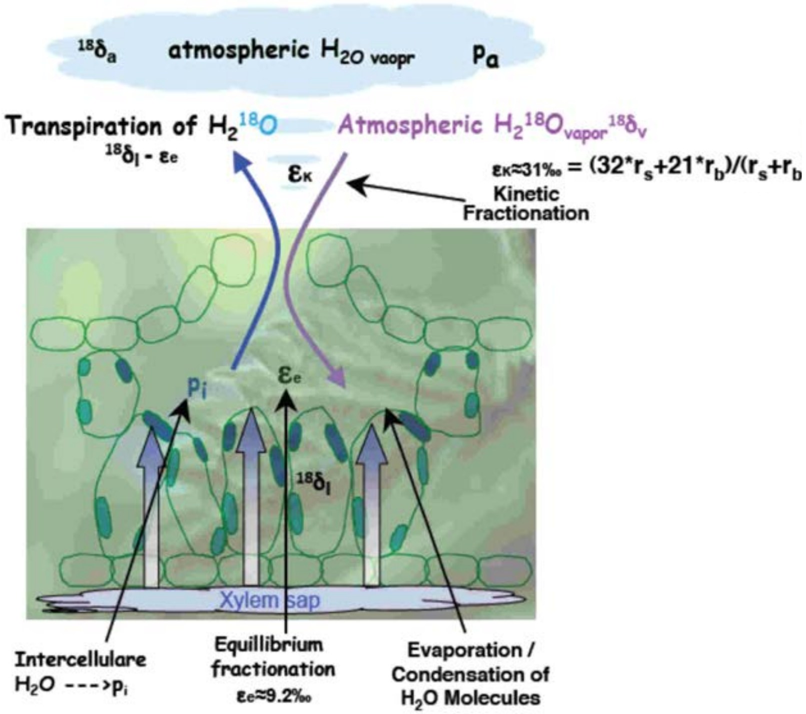
• 2 sites: Nottingham - irrigated & unirrigated; JIC - unirrigated

Su	Mo	Tu	We	Th	Fr	Sa
30	1	2	3	4	5	6
7	8	9	10	11	12	13

• Target traits

- ^{13}C Δ grain
- senescence kinetic
- stem WSC

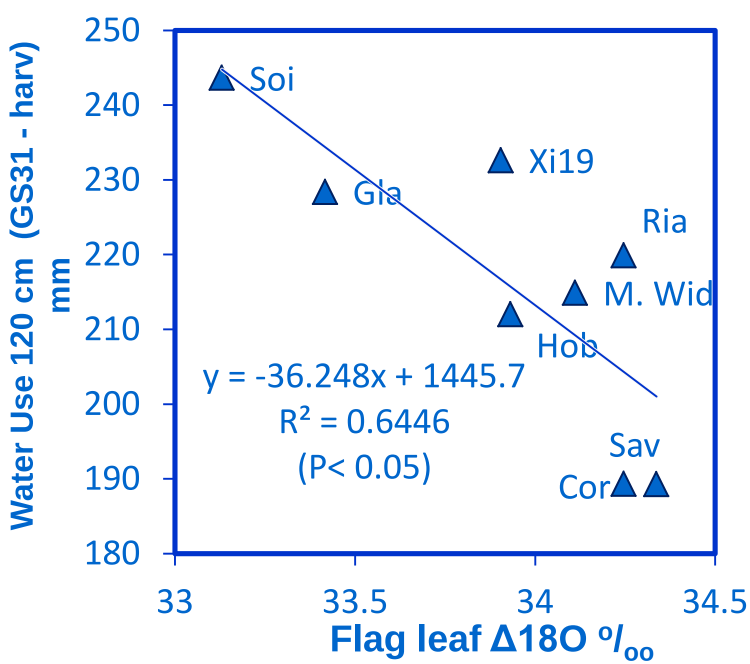
Oxygen isotope ratio technique ~ leaf transpiration



- $^{18}O/^{16}O$ ratio determined by enrichment in the leaf water due to transpiration.

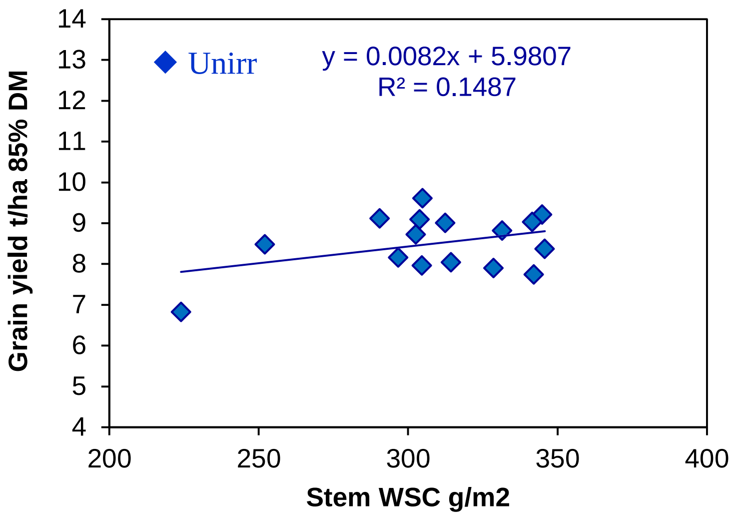
- Leaf water enriched due to preferential loss of the lighter $H_2{}^{16}O$ during evaporation.

- An increase in leaf transpiration decreases leaf T°C (hence intercellular vapour pressure) resulting in less $H_2{}^{18}O$ enrichment at the evaporating site.

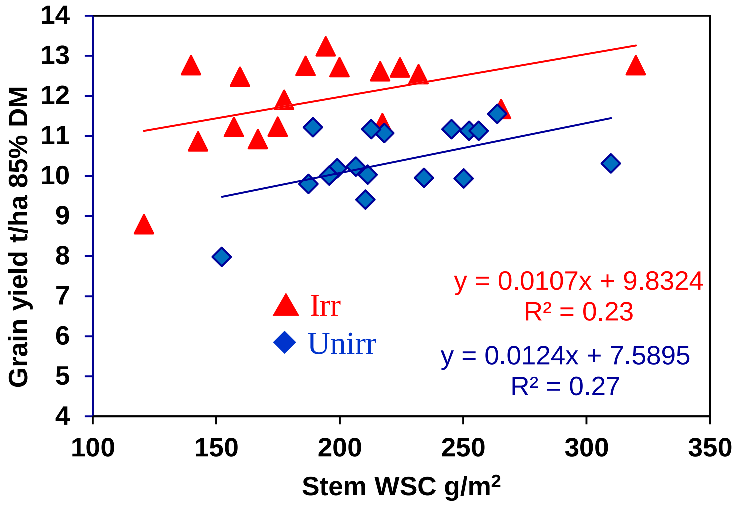


Other traits correlations: Stem WSC @ GS61+9d

Grain yield versus stem WSC reserves

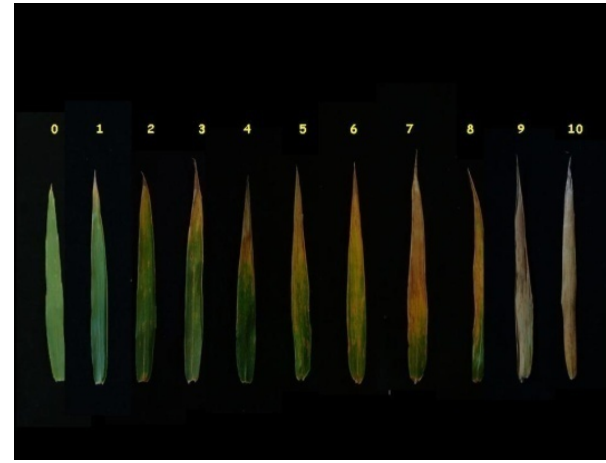


Sutton Bonington 2009-10



Sutton Bonington 2010-11

Flag leaf senescence score



Fitting the senescence data

$$score = p0 + p1 * (1 - \exp((-p2 * STA / p1)) + (10 - p1 - p0 / (1 + \exp(-4 * p4(STA - p5) / (10 - p1 - p0)))$$

score : visual senescence score

STA : thermal time after anthesis (°C.days)

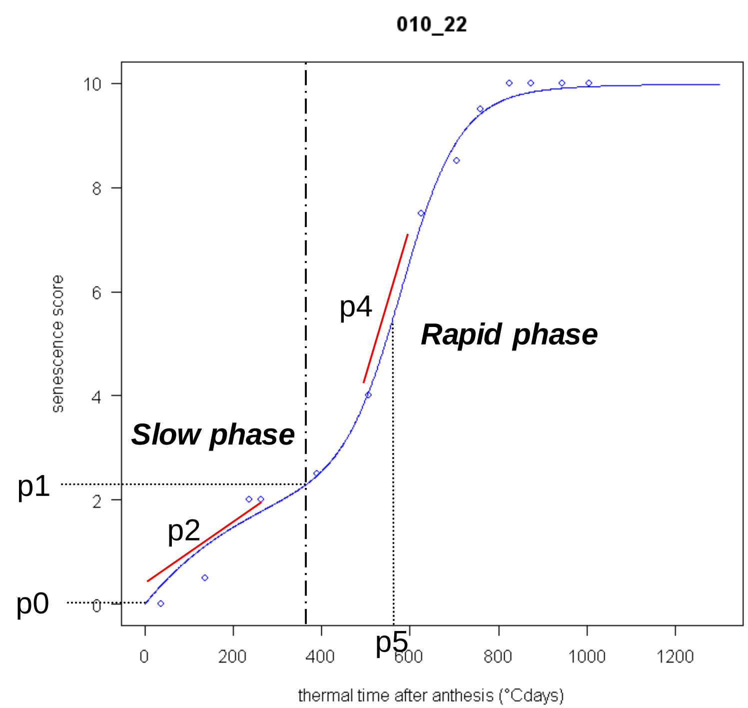
p0 : score at anthesis

p1 : score at the end of the slow phase

p2 : max rate of the slow phase

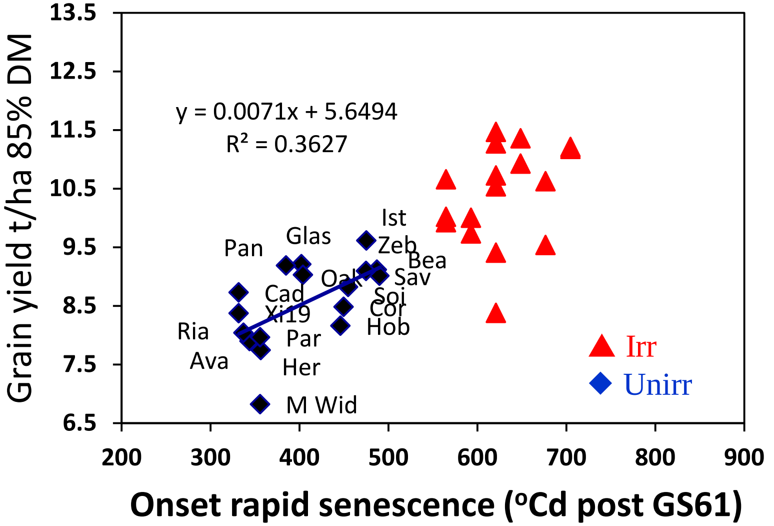
p4 : max rate of the rapid phase

p5 : date at which p4 is reached

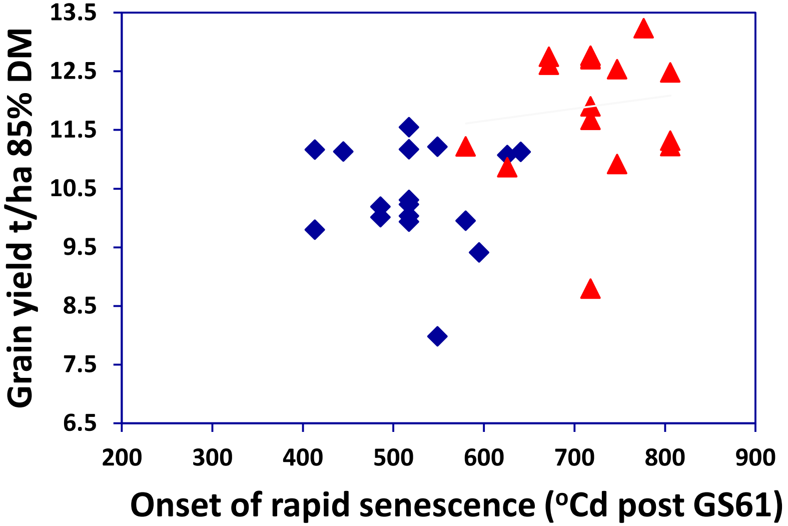


Other traits correlations: Flag leaf senescence

Grain yield versus Onset of Senescence

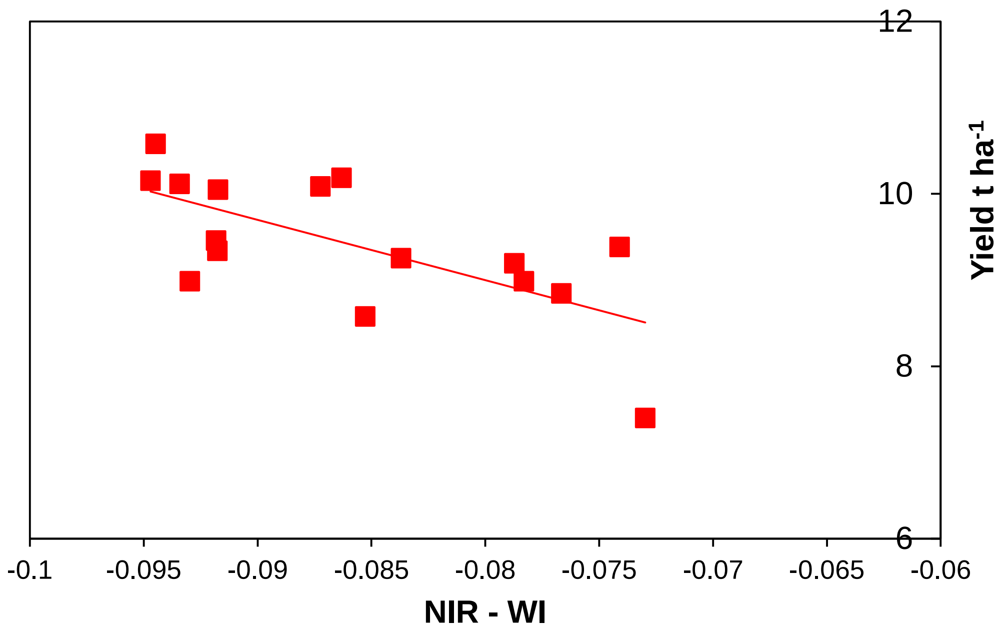


Sutton Bonington 2009-10



Sutton Bonington 2010-11

Spectral reflectance: Water index at GS61+14 d



WI = (R970-R900/)/(R970+R900)

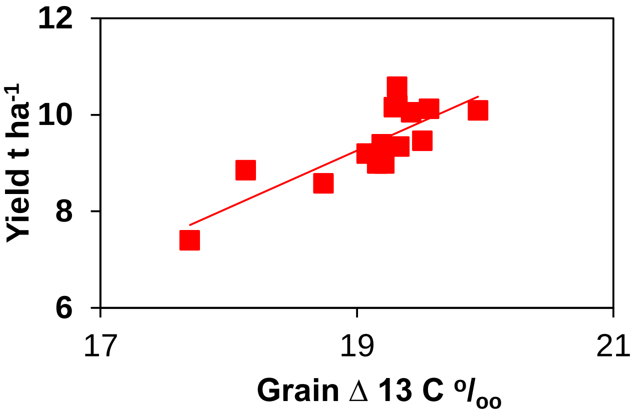
Sutton Bonington Mean 2009-10 & 2010-11

Drought tolerant plant ideotype

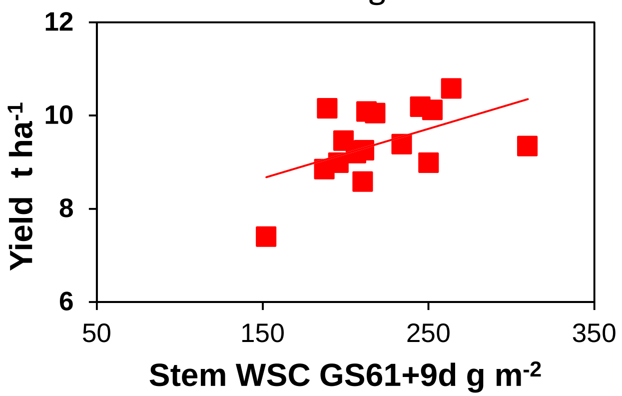
- **Multiple linear regression (P<0.001) accounted for 71% of the yield under drought and showed that:**

$$GY = -41.9\ x_1 + 0.08\ x_2 + 12.3\ x_3$$

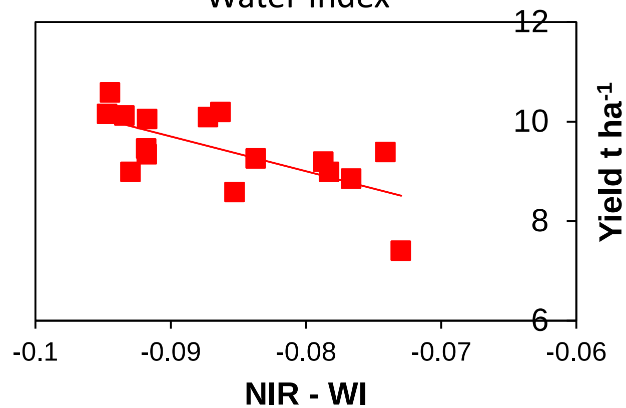
GY increases with increasing Δ 13 C (↓WUE) :



Grain yield increases with increasing stem WSC



GY increases with decreasing Water Index



WI = (R970-R900/)/(R970+R900)

Traits summary

Estimated value of traits to avoid or minimise effects of drought in UK

Variety character	How it might work	Value
High $^{13}C\ \Delta$ grain	Captures extra water	High
Flag leaf 'stay-green'	Extends grain filling during late drought	High
Low canopy T^oC/ deep roots	Captures extra water	High
High stem sugars	Buffers effects of post-flowering drought on grain filling.	Moderate
Early flowering	Advances grain filling before the drought risk period.	Neutral
Awns	Use less water per unit growth.	Slight

Measurements on DH pop

- **Combine grain yield, yield components**
- **% stem WSC at GS61+10d (unirrigated)**
- **Leaf senescence kinetics for flag-leaf, L2 and L3.**
- **Canopy temperature**
- **grain △ 13C (unirrigated)**
- **NDVI**

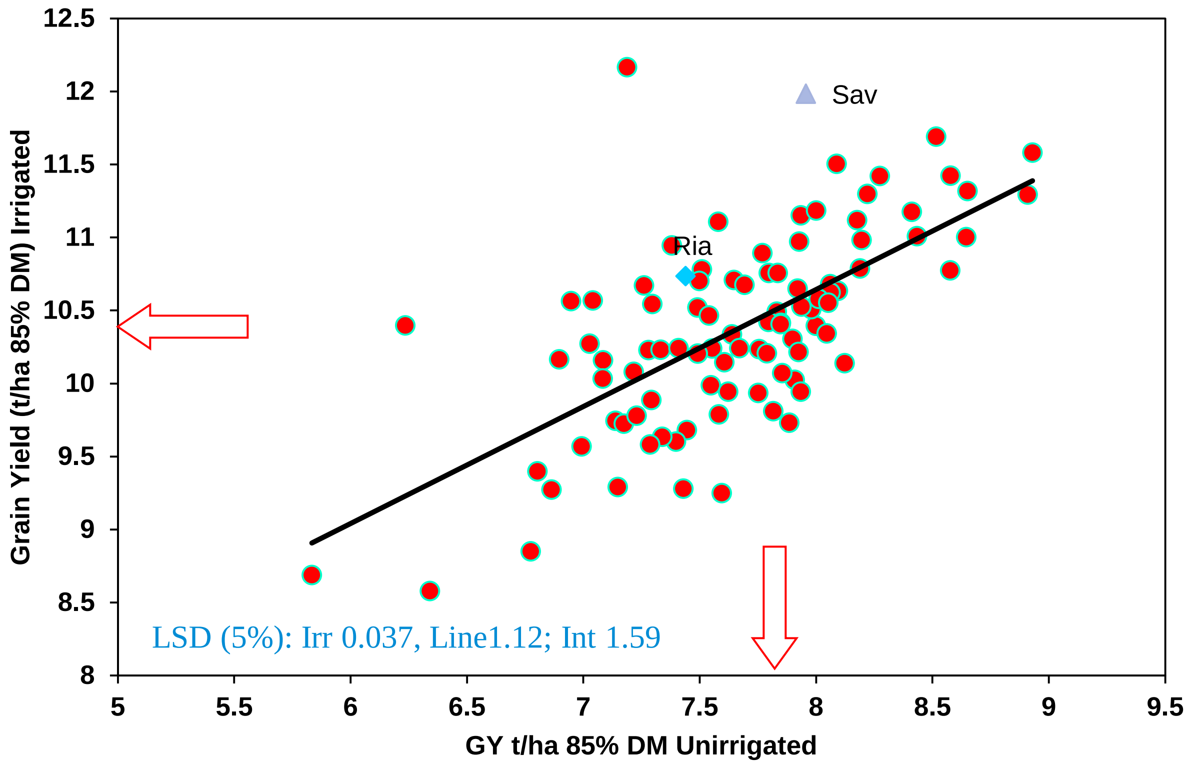
Drought effects 11 July 2011

L2

L39

L47

Grain yield responses to irrigation

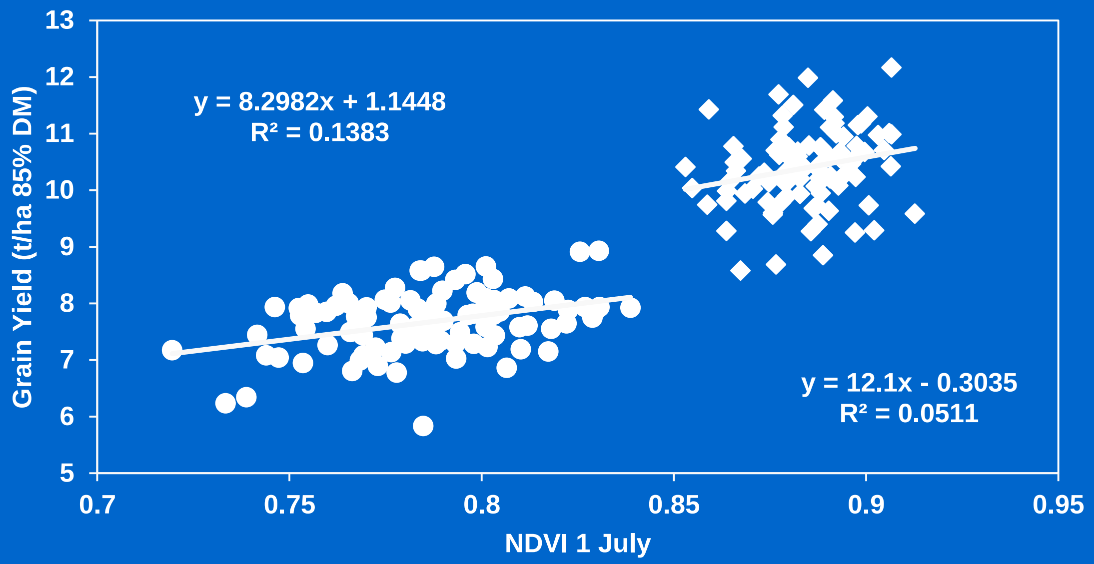


Sutton Bonington 2010-11

Spectral Reflectance Indices vs Grain Yield

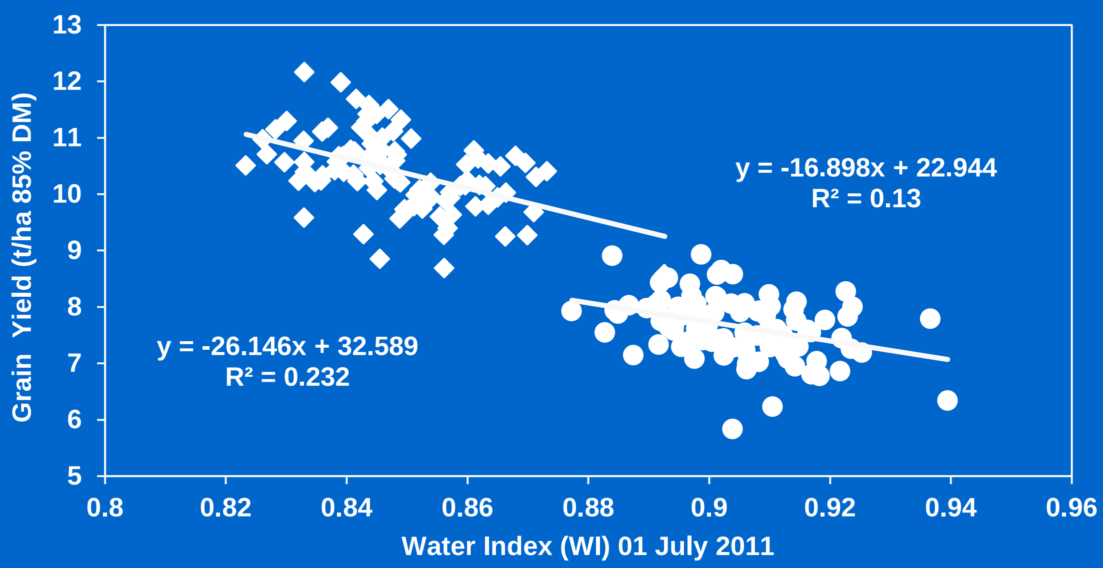
NDVI

LSD:
Irr 0.074 ***;
Line 0.061 ns
Int 0.042 ns

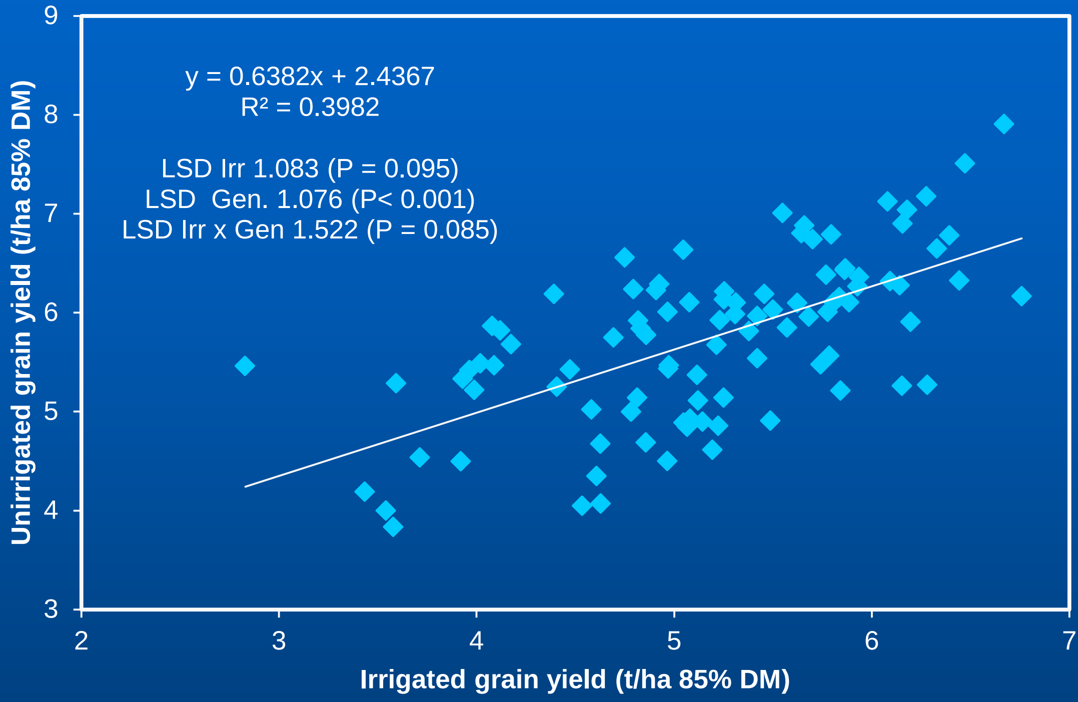


Water Index

LSD:
Irr 0.003 ***
Line 0.002 **
Int 0.004 ns

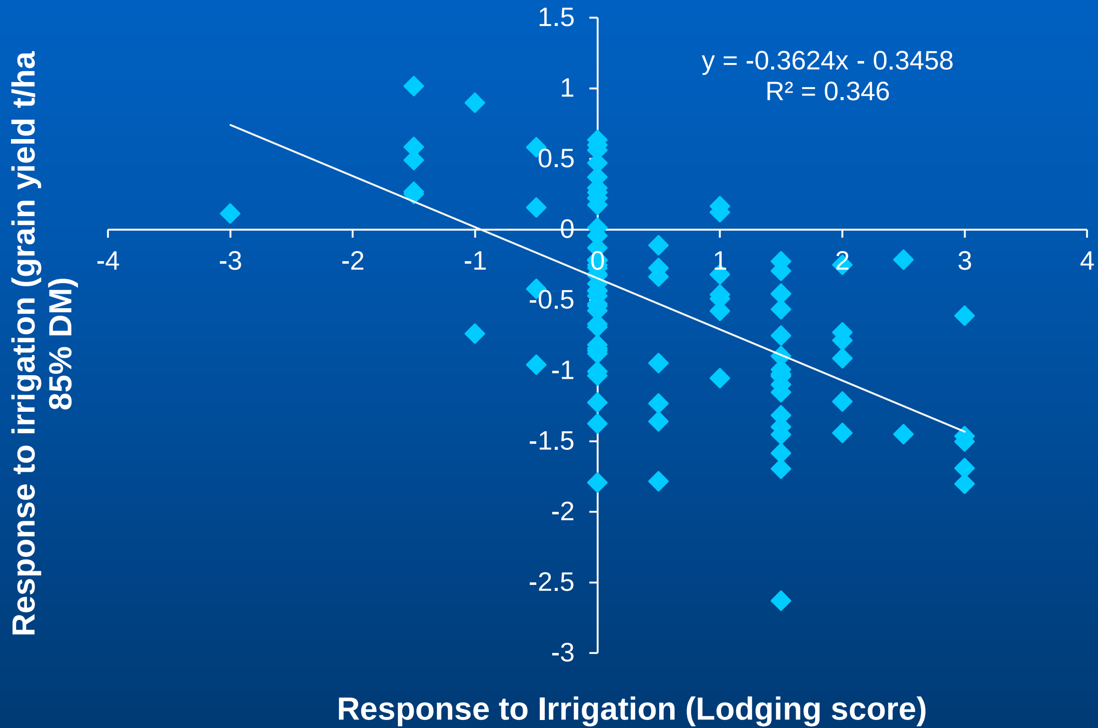


Rialto x Savannah DH exp 2011-12



	Rainfall (mm)	
	2012	LTM 75-09
January	54.2	54.3
February	13.2	44
March	24.4	46.2
April	111.4	46.8
May	26.2	44.3
June	110.6	58.7
July	107.1	49.8

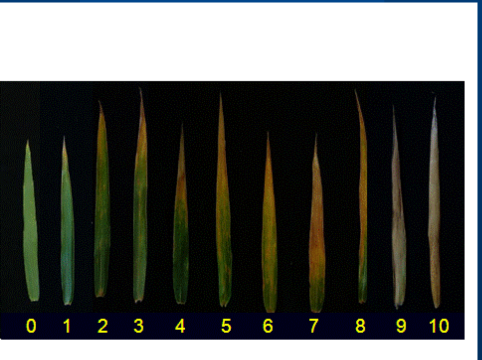
Rialto x Savannah DH exp 2011-12



WGIN 2 (9.4 Association Genetics)

	Project Month	Milestone
31/03/2012	40	Act 9 Obj3. Complete development of one new DH population in an elite modern background segregating for drought-tolerance traits.

120Watkins lines assessed for leaf Ps rate (quantum yield, fluorpen) and visual senescence scores (weekly post anthesis) in 2010-11 and 2011-12



Stomata open (irrigated conditions): Discrimination in favour of $12CO_2$ isotope form at high internal CO_2 concentration.

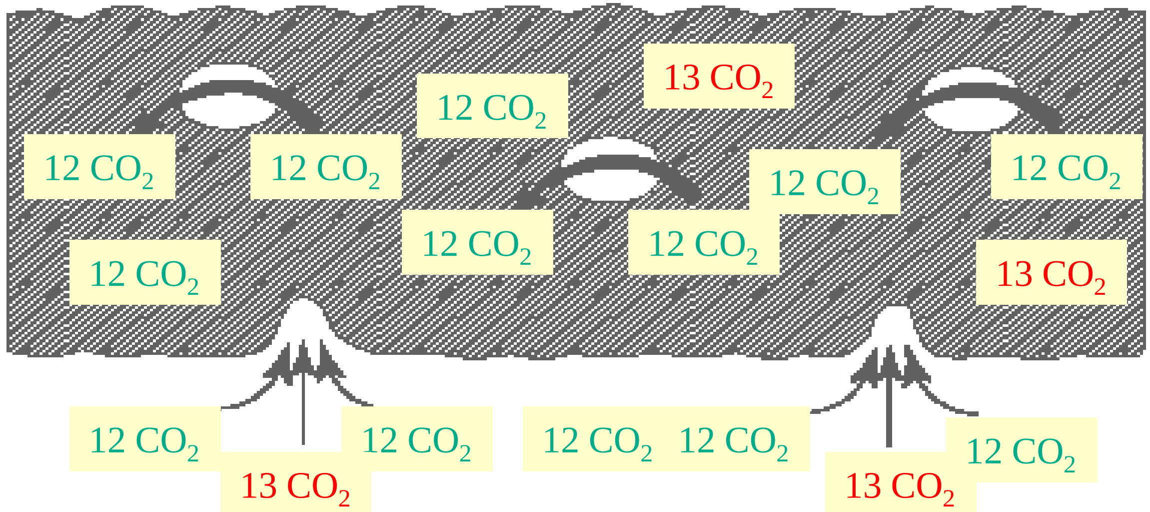
Irrigated conditions

Stomata open (high stomatal conductance)

↓

High Ci

High Discrimination against $^{13}CO_2$ → Low WUE



Stomata closed (moisture stress): Discrimination less favourably to $12CO_2$ as internal CO_2 concentration falling.

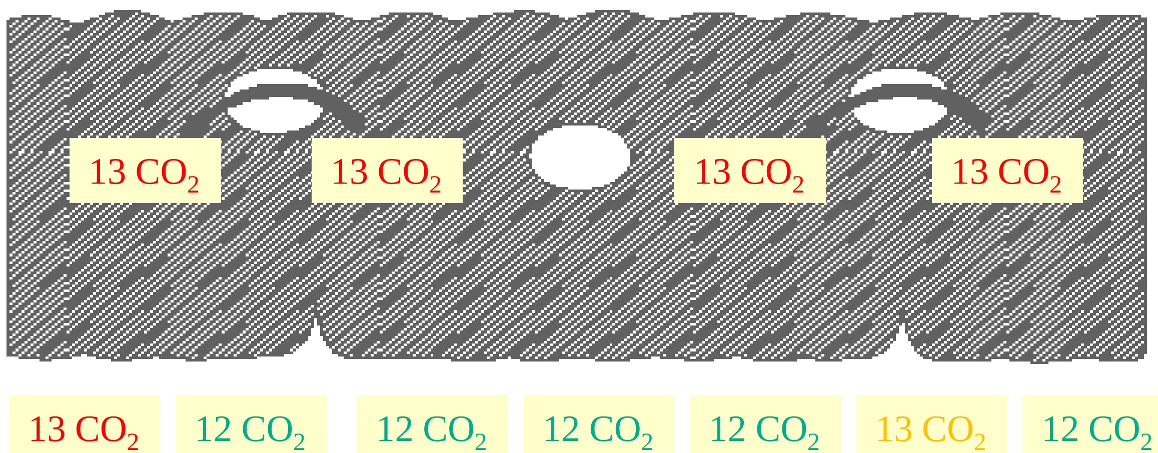
Drought conditions

Stomata close (low stomatal conductance)

↓

Low Ci

Low Discrimination against $^{13}CO_2$ → High WUE



Araus 2005

Diagram 1. Carbon isotope discrimination under irrigated and dry conditions.

Preliminary Conclusions

- **Consistent differences in Drought Tolerance Index identified amongst panel of 18 cultivars**

- **Ability to access water appears to be a key driver for productivity under UK drought.**

- **High 13C Δ correlated with grain yield under drought. Physiological basis ~ increased stomatal conductance, deeper roots?**

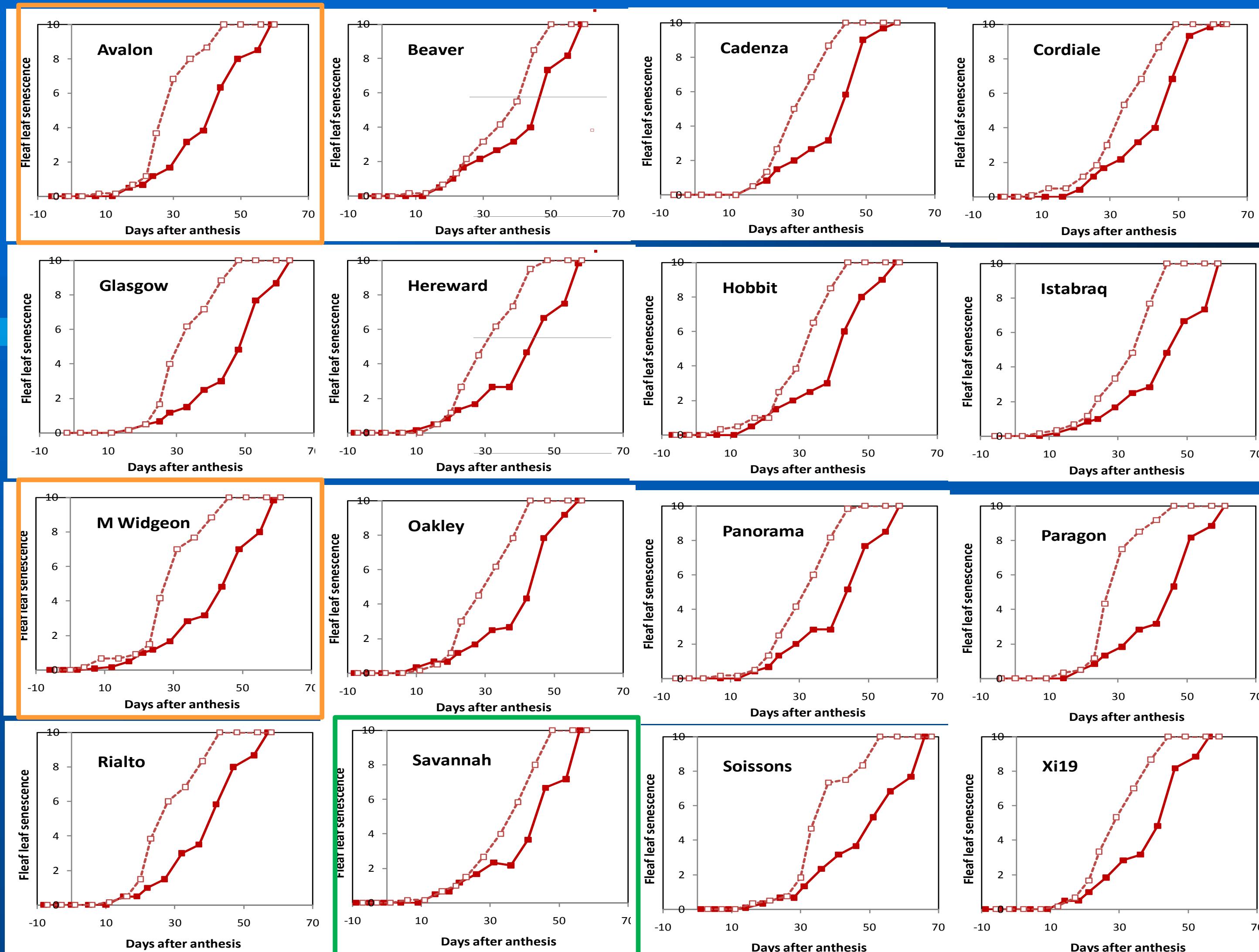
- **Measurement of stable isotopes in plant dry matter may a useful phenotypic tool for speeding up breeding**
  - **Grain ^{13}C Δ**
  - **Flag leaf Δ ^{18}O**

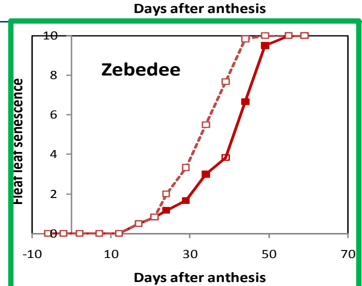
- **Work is ongoing to:**
  - **identify opportunities to break linkage between WU and WUE**
  - **develop high-throughput screens for breeding**
  - **Understand the genetic basis of drought tolerance and WUE traits (QTL detection)**

WGIN Drought tolerance (2009-14)

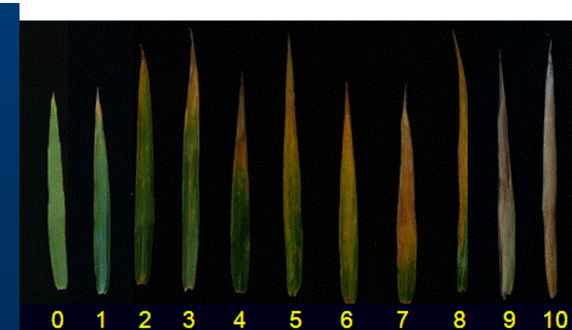
OBJECTIVES

- **Identify traits for WUE and drought tolerance (DT) in elite winter wheat varieties. (*Yrs 1-2*)**
- **Identify QTLs for WUE and DT traits using one DH pop in an elite background. (*Yrs 2-3*)**
- **Develop one new DH pop for UK drought research. (*Yrs 2-4*)**



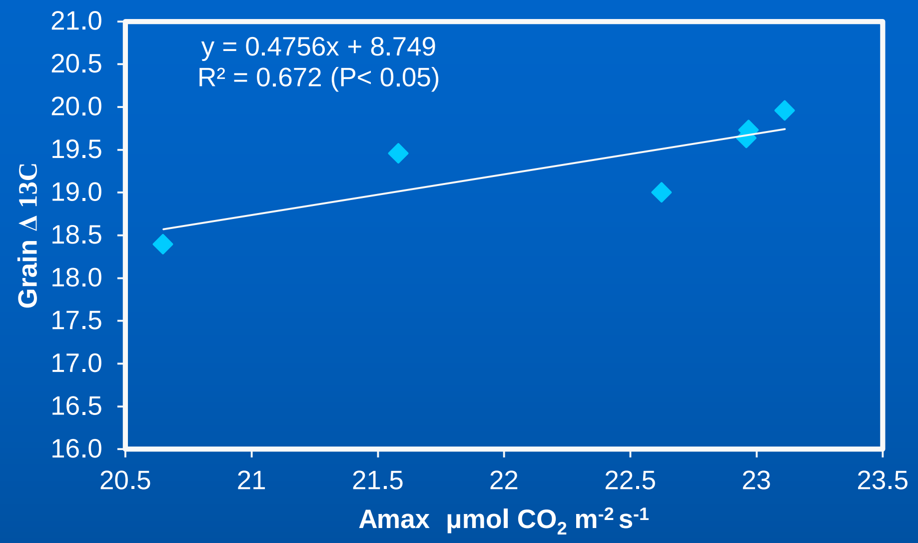


Flag leaf senescence



Grain Δ13C versus Pn rate (Amax) (Unirrigated)

2009-10



2010-11

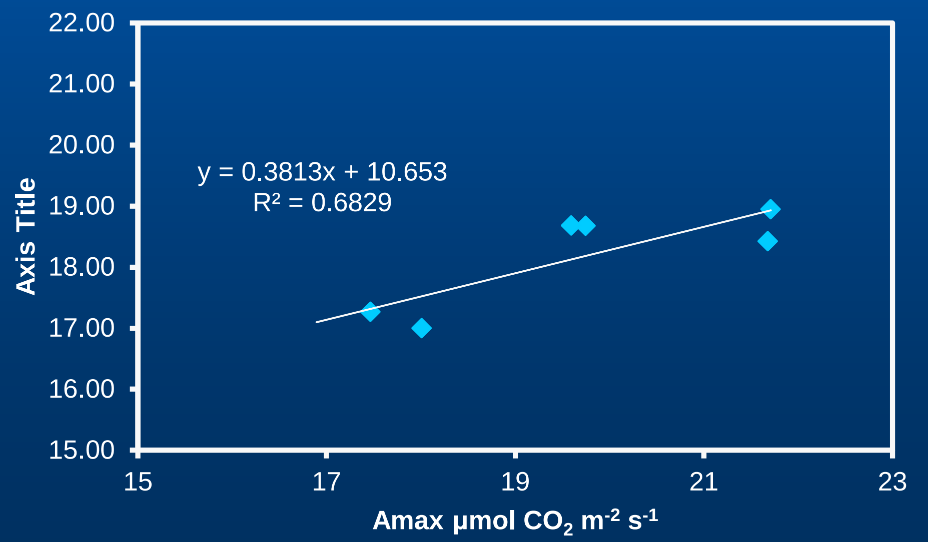
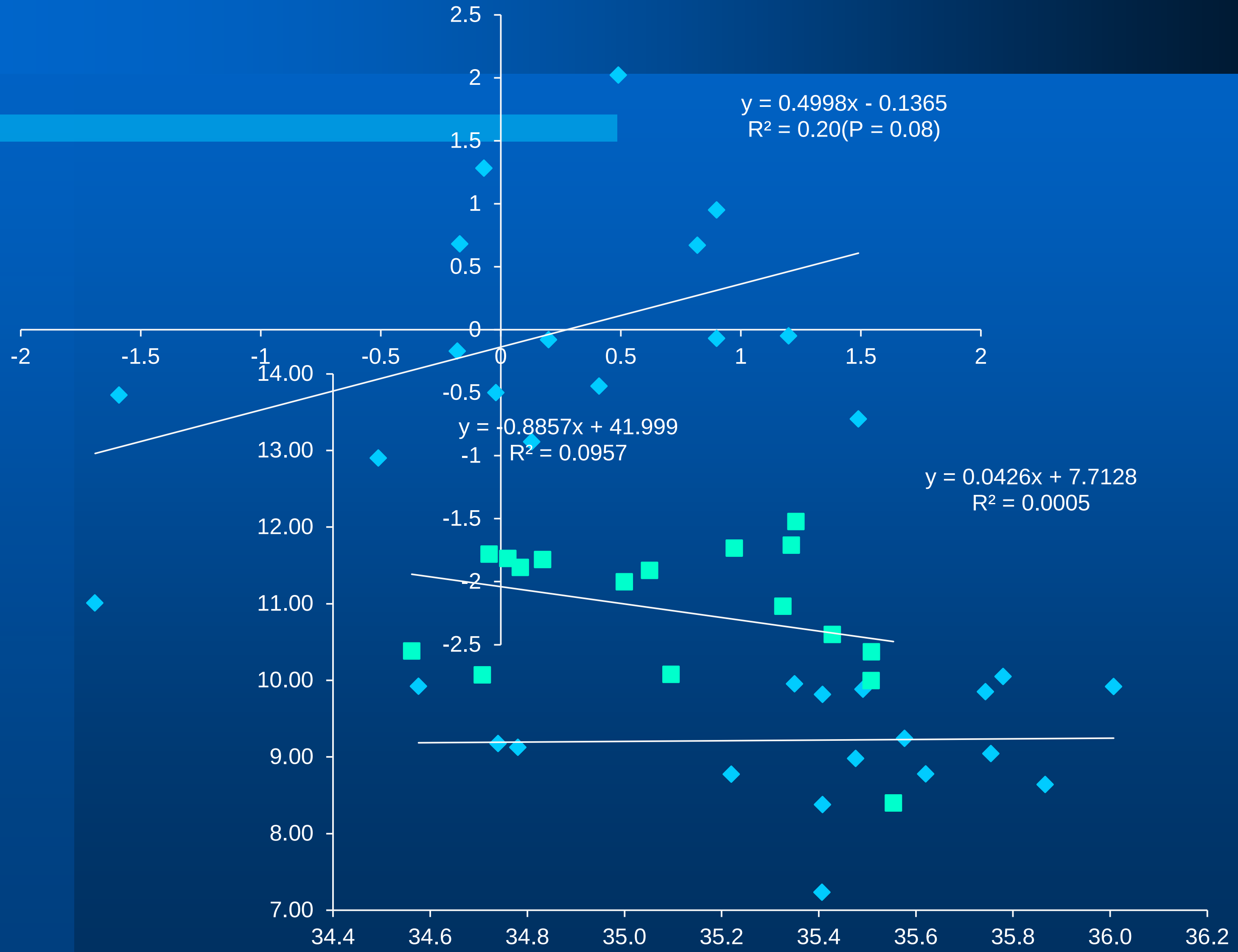


Table 7.1. Commonly used spectral reflectance indices (SRI) for wheat canopy analysis where index types are: VI – vegetation index; PI – pigment related index; WI – water index.

Index	Name	Physiological process	Type	Calculation
NDVI	Normalized difference vegetation index	Green area, photosynthetic capacity, N status	VI	$[R_{900}-R_{680}]/[R_{900}+R_{680}]$
R-NDVI	Red normalized difference vegetation index	Green area, photosynthetic capacity, N status	VI	$[R_{780}-R_{670}]/[R_{780}+R_{670}]$
G-NDVI	Green normalized difference vegetation index	Green area, photosynthetic capacity, N status	VI	$[R_{780}-R_{550}]/[R_{780}+R_{550}]$
SRa	Simple Ratio	Green biomass	VI	$[R_{800}/R_{680}]$ and $[R_{900}/R_{680}]$
$RARS_a$	Ratio analysis of reflectance spectra chlorophyll a	Chlorophyll a content	PI	$[R_{675}/R_{700}]$
$RARS_b$	Ratio analysis of reflectance spectra chlorophyll b	Chlorophyll b content	PI	$R_{675}/[R_{650}*R_{700}]$
$RARS_c$	Ratio analysis of reflectance spectra carotenoid	Carotenoid content	PI	$[R_{760}/R_{500}]$
NPQI	Normalized pheophytinization index	Normal chlorophyll degradation; can be used to estimate phenology, pest and diseases	PI	$[R_{415}-R_{435}]/[R_{415}+R_{435}]$
SIPI	Structural independent pigment index	Senescence related to stress	PI	$[R_{800}-R_{435}]/[R_{415}+R_{435}]$
PRI	Photochemical reflectance index	Dissipation of excess radiation	PI	$[R_{531}-R_{570}]/[R_{531}+R_{570}]$
WI	Water index	Plant water status	WI	$[R_{970}/R_{900}]$
NWI-1	Normalized water index 1	Plant water status	WI	$[R_{970}-R_{900}]/[R_{970}+R_{900}]$
NWI-2	Normalized water index 2	Plant water status	WI	$[R_{970}-R_{850}]/[R_{970}+R_{850}]$
NWI-3	Normalized water index 3	Plant water status	WI	$[R_{970}-R_{880}]/[R_{970}+R_{880}]$
NWI-4	Normalized water index 4	Plant water status	WI	$[R_{970}-R_{920}]/[R_{970}+R_{920}]$



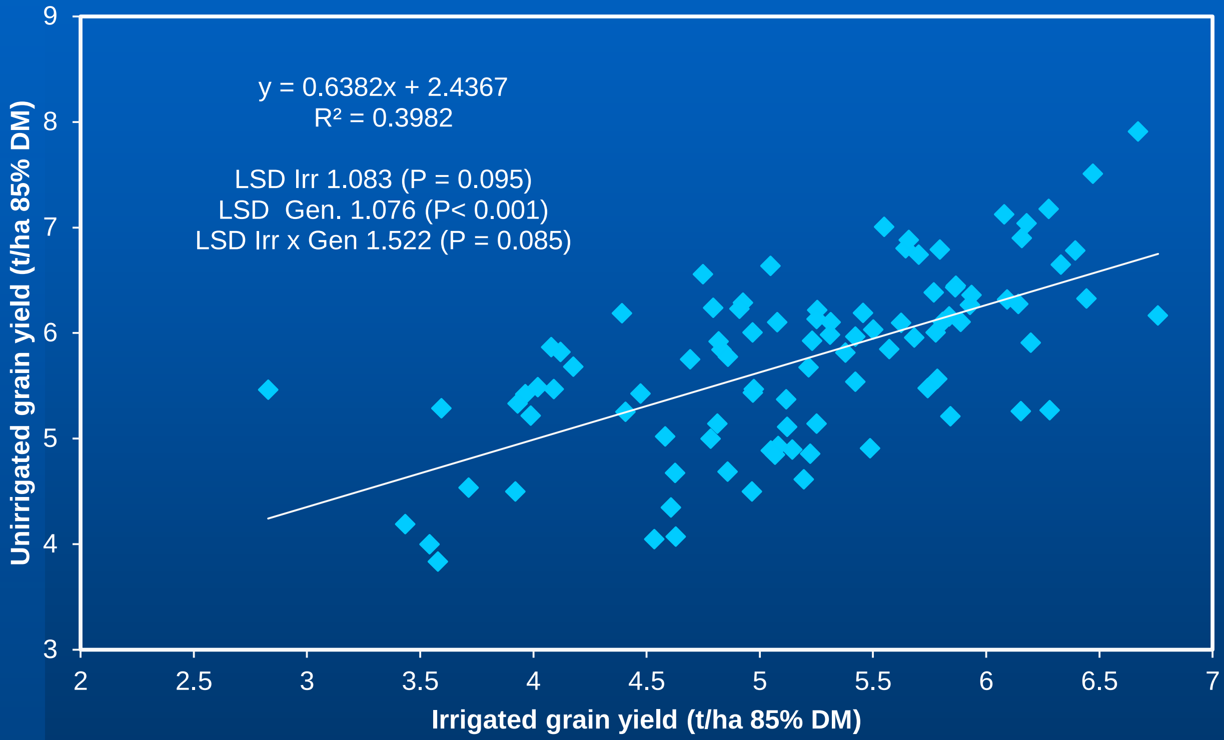
y = 0.4998x - 0.1365
R² = 0.20(P = 0.08)
y = -0.8857x + 41.999
R² = 0.0957
y = 0.0426x + 7.7128
R² = 0.0005
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
14.00
13.00
12.00
11.00
10.00
9.00
8.00
7.00
34.4
34.6
34.8
35.0
35.2
35.4
35.6
35.8
36.0
36.2

WGIN 2 (9.3 Develop new SSD pop)

	Project Month	Milestone
31/03/2012	40	Act 9 Obj3. Complete development of one new SSD population in an elite modern background segregating for drought-tolerance traits.

- Candidate F1(s) made at JIC informed by data analysis from LK0986 project
- Population segregating for *Ppd1a*:
  - use WGIN resource to select against *PpdD1a* - ie make the pop photoperiod sensitive.
  - keep the pop large, so we can have flowering time strata and perform analysis within them
- F3 sown in October 2012, population is in excess of 350 lines

Rialto x Savannah DH exp 2011-12



• Conflicting results obtained in various crops under different growing conditions on the association between 12/13C and yield - range from no relationship between delta and yield to negative or positive relationships, depending on the crop and the environment.

• Deep or dense root system which would promote soil moisture capture and WU is correlated across genotypes with low WUE (Pinheiro et al., 2005; Kobata et al., 1996) but high ability to

• Favorable genotypic plant waterstatus under drought stress as reflected in measurements of canopy temperature is correlated with lowWUE across genotypes (Araus et al., 1993; Frank et al., 1997; Read et al., 1991; Zong et al., 2008).

• Genotypic variation in WUE under limited water regimes is affected more by variation in the denominator (WU) rather than by variation in the nominator (biomass) (Blum, 2005).

• The successful and widely cited case for dryland wheat grain yield improvement with selection for high WUE (low carbon isotope discrimination) in NSW Australia (Condon et al., 2002) can be explained by the fact that wheat is grown there mainly on stored soil moisture. (Fig. 6 in Condon et al., 2002).

5. Drought resistance was found to be associated with low WUE when analyzed by delta under limited water supply (e.g.Araus et al., 2003; Morgan et al., 1993; Ngugi et al., 1994; Solomon and Labuschagne, 2004).

“water uptake (WU), water-use efficiency (WUE), and harvest index (HI) are drivers of yield.” Whereas HI is also largely influenced by WU and plant water status, it can be concluded that WU alone is the main (not the exclusive)

driver of yield under drought stress.

The $^{13}C/^{12}C$ ratios (R) of leaves grains analysed using an elemental analyser (Carlo Erba 2100) interfaced to an isotope ratio mass spectrometer.
Results expressed as $\delta^{13}C$ values, using a secondary standard calibrated against Vienna Pee Dee Belemnite calcium carbonate (VPDB).

$$\delta^{13}C = (R\text{sample} - R\text{standard}) - 1$$

The C isotope discrimination (Δ 13C) of plant parts is then calculated as:

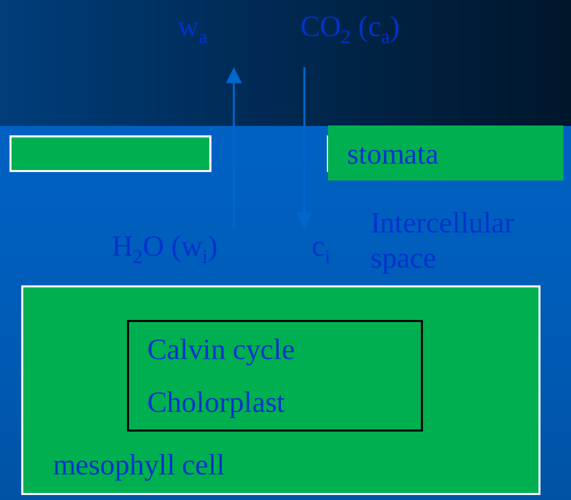
$$\Delta\, 13C = (\delta^{13}Ca - \delta^{13}Cp) /[1 +(\delta^{13}Cp/1000)]$$

where $\delta^{13}Ca$ and $\delta^{13}Cp$ refer to air and plant C isotope compositions, respectively.
d13C of free atmospheric CO_2 taken as -8‰ (Farquhar et al., 1989).

Effects of leaf activity traits on WUE

- ***Stomatal conductance:***. Lower conductance ↓ ci hence ↑ WUE.

- ***N or Rubisco content per unit leaf area:*** Greater photosynthetic activity ↓ c_i , hence ↑ WUE.



The $^{18}O/^{16}O$ ratios (R) of irrigation water were determined by the CO_2/H_2O equilibration technique and using an isotope ratio mass spectrometer

Results were expressed as $\delta^{18}O$ values, using two secondary standards (IAEA 601 and IAEA 602) calibrated against to the Vienna Standard Mean Oceanic Water (VSMOW)

$$\delta 18O = (\delta R_{sample} / \delta R_{standard} - 1)$$

Then, the 18O enrichment in grains ($\Delta 18O$) was calculated as:

$$\Delta 18O = (\delta 18O_p - \delta 18O_w) / [1 + \delta 18O_w/1000)]$$

where d18Op and d18Ow refer to the oxygen isotope compositions of plant sample and rain water, respectively (d18O rain water was approx. 210.78 ‰).

Objective 8 – Nitrogen update

M J Hawkesford

WGIN Management Meeting

3rd July 2013

2013 Diversity Trial

Diversity trial history

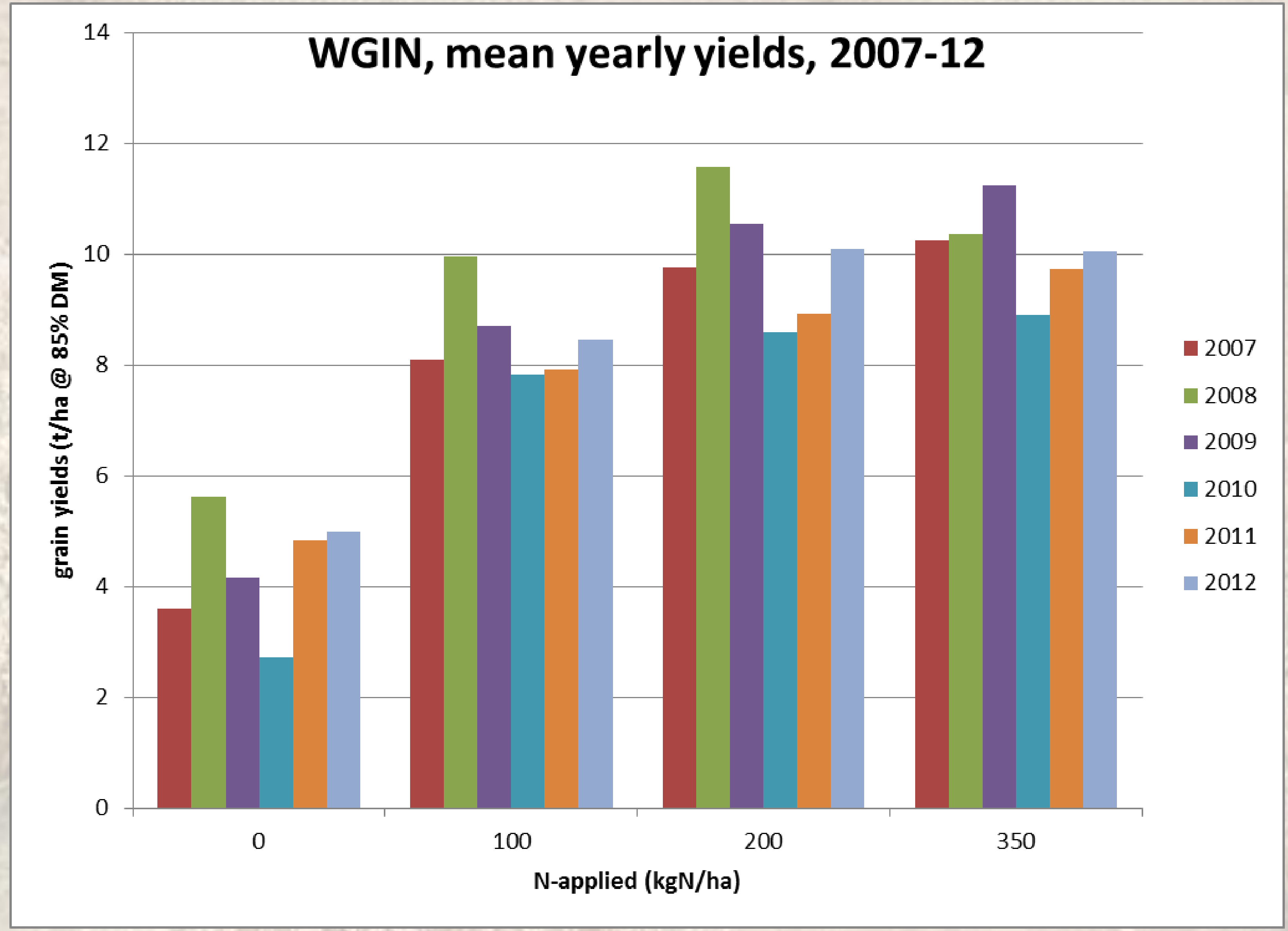
Trial	Year	Varieties (core of 9)	N-levels	kg N/ha	
1	2004	32	4	0,50,200,350	Blackhorse
2	2005	20	2	0,200	Fosters
3	2006	24	3	0,100,200	Meadow
4	2007	24	4	0,100,200,350	Blackhorse
5	2008	24	4	0,100,200,350	Meadow
6	2009	24 (include 6 x A x Cs)	4	0,100,200,350	Summadells
7	2010	25 (include 6 x A x Cs)	4	0,100,200,350	Blackhorse
8	2011	25 (include 4 x A x Cs)	4	0,100,200,350	Meadow
9	2012	25 (include WUE/take-all lines)	4	0,100,200,350	Summardell
10	2013	25 (include WUE/take-all lines)	4	0,100,200,350	Blackhorse
11	2014	25?			

WGIN 2004-08 & 2009-13

- 49 varieties
- 14 in at least 9 years
- All 4 groups
- 4 N levels in all except 2 years
- Grain and straw, yield and %N
- Archived fresh grain
- Archived dry milled grain and straw

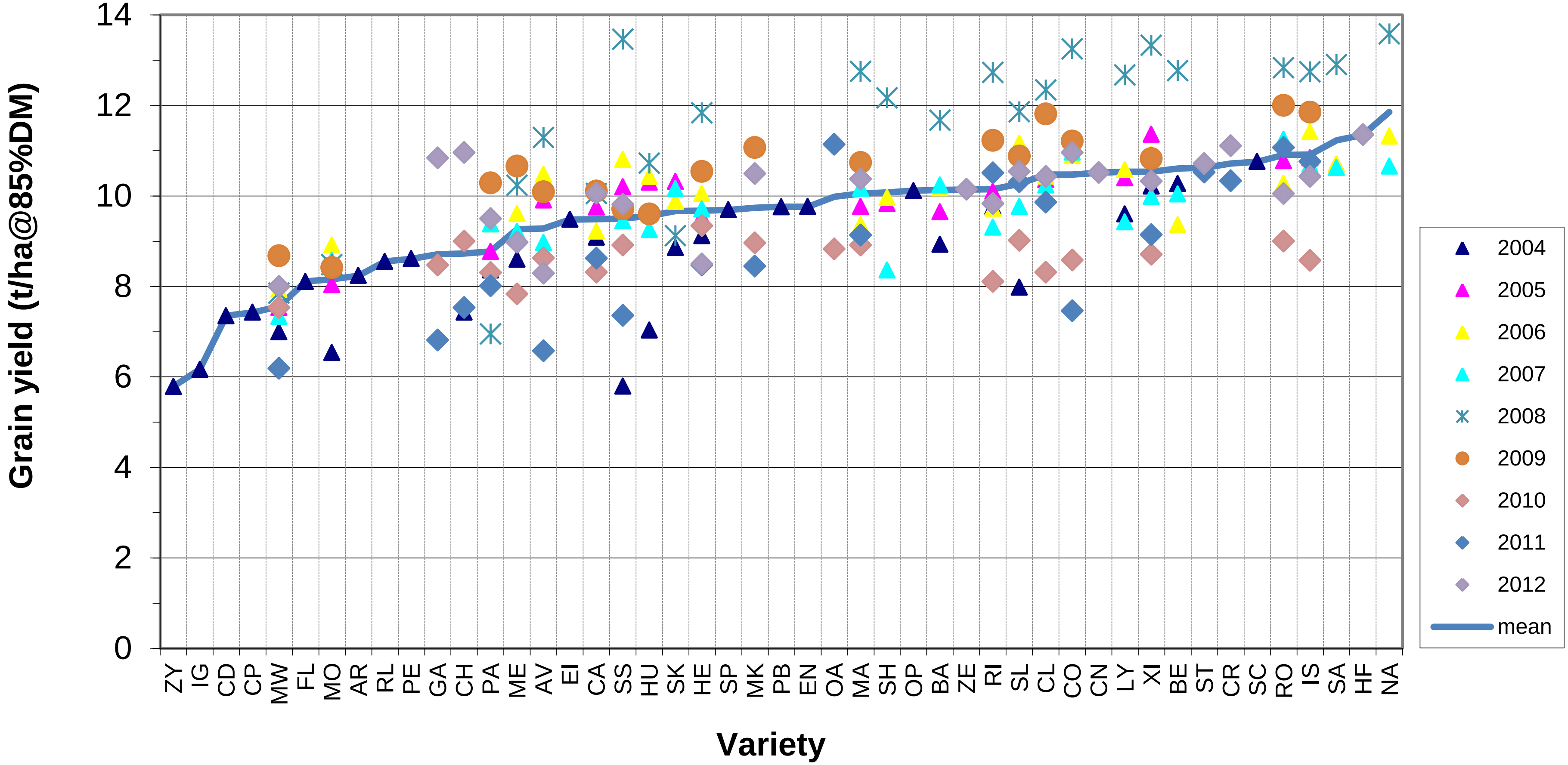
Varieties summary

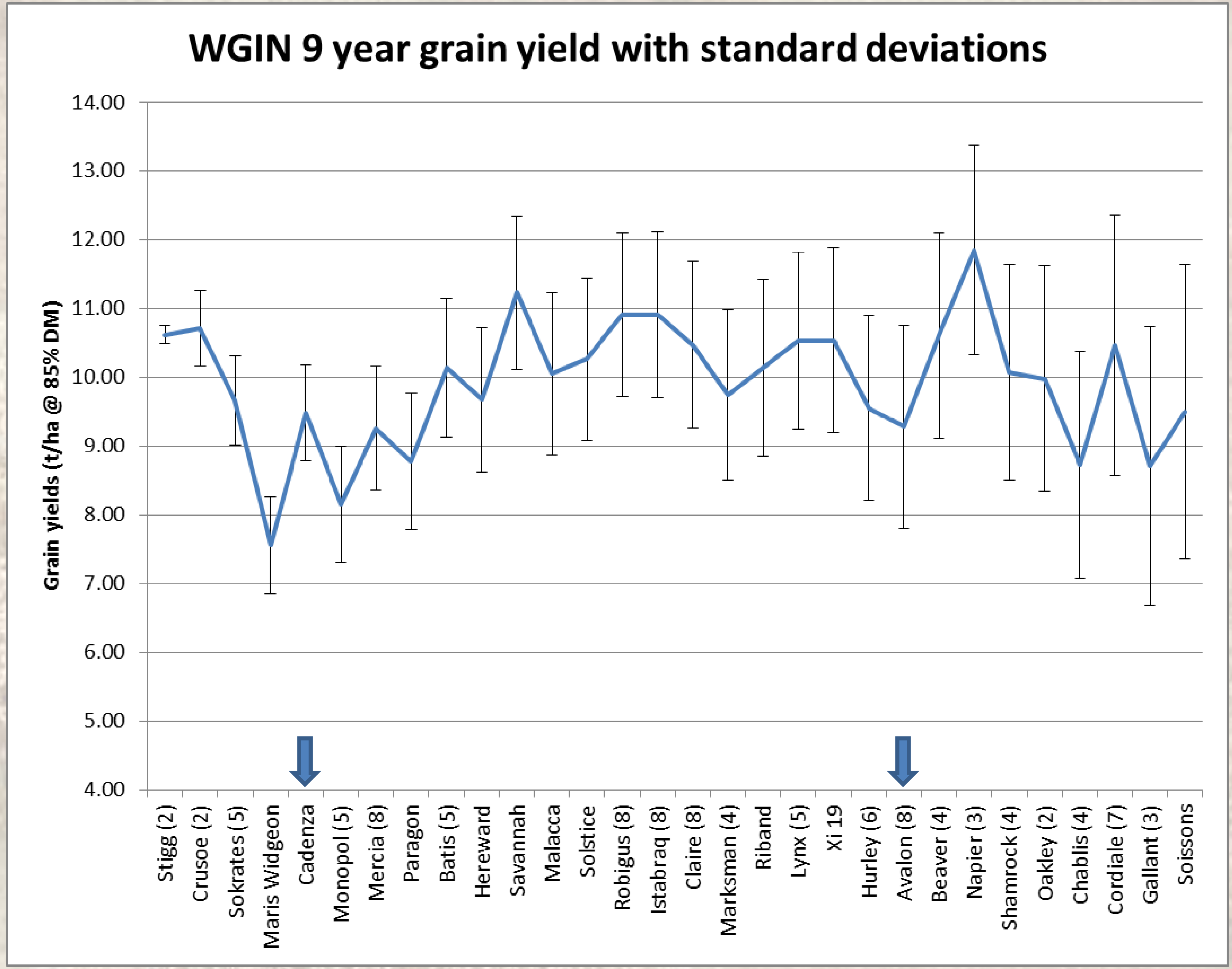
No.	Variety	Code	Years	WUE trial?
1	Arche	AR	1	
2	Avalon	AV	9	Y
3	Batis	BA	5	
4	Beaver	BE	4	
5	Cadenza	CA	10	Y
6	Caphorn	CP	1	
7	Cappelle Desprez	CD	1	
8	Chablis	CH	4	
9	Claire	CL	9	
10	Conqueror	CN	2	
11	Cordiale	CO	8	Y
12	Crusoe	CR	3	
13	Einstein	EI	1	
14	Enorm	EN	1	
15	Flanders	FL	1	
16	Gallant	GA	4	
17	Hereford	HF	2	
18	Hereward	HE	10	Y
19	Hurley	HU	6	
20	Isengrain	IG	1	
21	Istabraq	IS	9	Y
22	Lynx	LY	5	
23	Malacca	MA	10	
24	Maris Widgeon	MW	10	Y
25	Marksman	MK	5	
26	Mercia	ME	9	Y
27	Monopol	MO	6	
28	Napier	NA	3	
29	Oakley	OK	2	
30	Opus	OP	1	
31	Paragon	PA	10	
32	Pbis	PB	1	
33	Petrus	PE	1	
34	Rialto	RL	1	
35	Riband	RI	10	
36	Robigus	RO	9	Y
37	Savannah	SA	4	
38	Scorpion	SC	1	
39	Shamrock	SH	4	
40	Soissons	SS	10	Y
41	Sokrates	SK	5	
42	Solstice	SL	10	
43	Spark	SP	1	
44	Stigg	ST	3	
45	Xi 19	XI	10	Y
46	zeberdee	ZE	2	Y
47	Zyta	ZY	1	

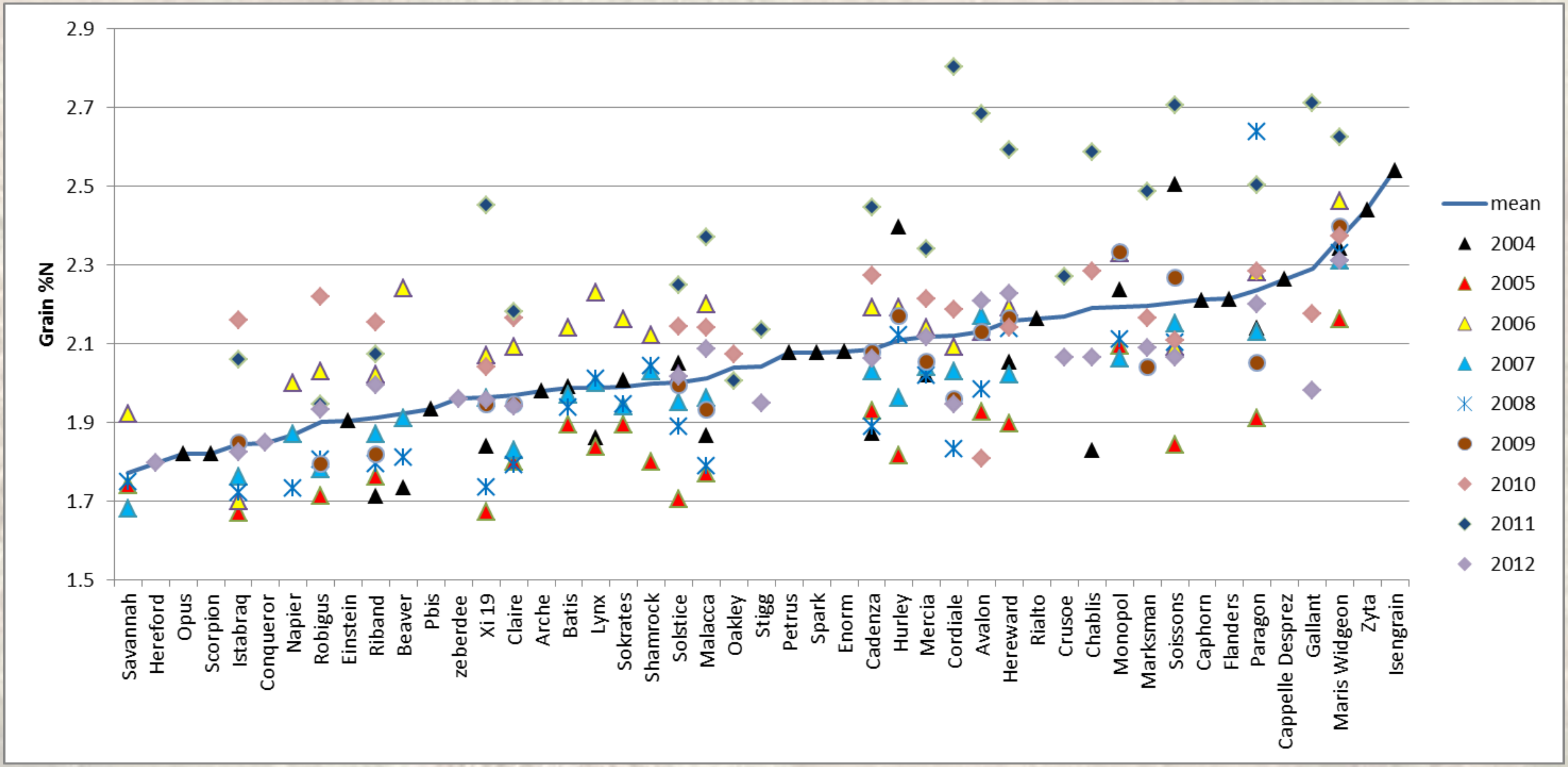


WGIN, mean yearly yields, 2007-12
grain yields (t/ha @ 85% DM)
0
2
4
6
8
10
12
14
0
100
200
350
N-applied (kgN/ha)
2007
2008
2009
2010
2011
2012

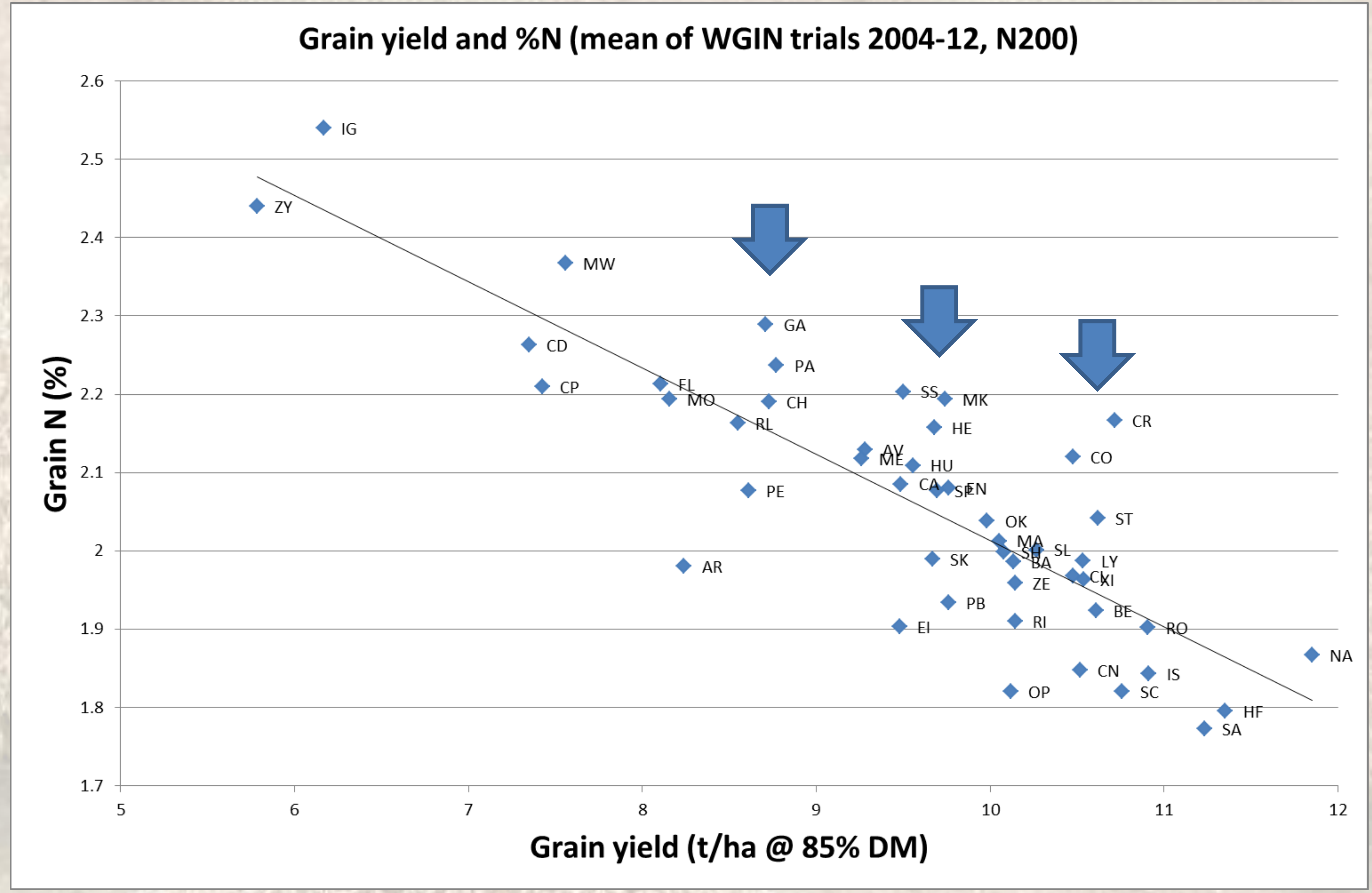
Rothamsted WGIN-N200 Combine Grain Yield (2004-12)




WGIN 9 year grain yield with standard deviations
Grain yields (t/ha @ 85% DM)
14.00
13.00
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
Stigg (2)
Crusoe (2)
Sokrates (5)
Maris Widgeon
Cadenza
Monopol (5)
Mercia (8)
Paragon
Batis (5)
Hereward
Savannah
Malacca
Solstice
Robigus (8)
Istabraq (8)
Claire (8)
Marksman (4)
Riband
Lynx (5)
Xi 19
Hurley (6)
Avalon (8)
Beaver (4)
Napier (3)
Shamrock (4)
Oakley (2)
Chablis (4)
Cordiale (7)
Gallant (3)
Soissons



Grain %N
2.9
2.7
2.5
2.3
2.1
1.9
1.7
1.5
Savannah
Hereford
Opus
Scorpion
Istabraq
Conqueror
Napier
Robigus
Einstein
Riband
Beaver
Pbis
zeberdee
Xi 19
Claire
Arche
Batis
Lynx
Sokrates
Shamrock
Solstice
Malacca
Oakley
Stigg
Petrus
Spark
Enorm
Cadenza
Hurley
Mercia
Cordiale
Avalon
Hereward
Rialto
Crusoe
Chablis
Monopol
Marksman
Soissons
Caphorn
Flanders
Paragon
Cappelle Desprez
Gallant
Maris Widgeon
Zyta
Isengrain
mean
2004
2005
2006
2007
2008
2009
2010
2011
2012

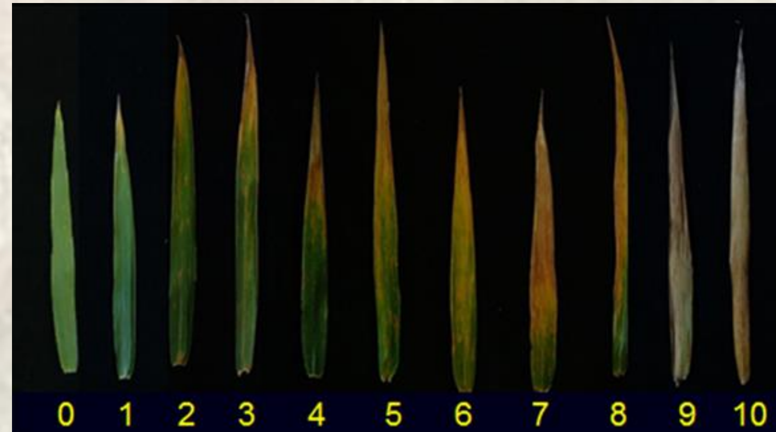


Grain yield and %N (mean of WGIN trials 2004-12, N200)
Grain N (%)
Grain yield (t/ha @ 85% DM)
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
5
6
7
8
9
10
11
12
IG
ZY
MW
GA
CD
PA
CP
FL
MO
CH
SS
MK
RL
HE
CR
AV
ME
HU
CO
PE
CA
SP
EN
OK
ST
MA
SH
SL
BA
LY
SK
AR
CL
XI
ZE
PB
BE
RI
EI
RO
NA
CN
IS
OP
SC
HF
SA

In use, 2013….

- Take-all samples (Vanessa)
- Root sampling – N transporters (Buchner)
- Grain development (Tosi)
- NDVI validations (Riche/lola)
- Aerial measurements
- Bionut training course (Malcolm)

Measuring growth and maturation



2013 harvest season (drilled 13th October)

Wheat varieties for WGIN-NUE 2012/13

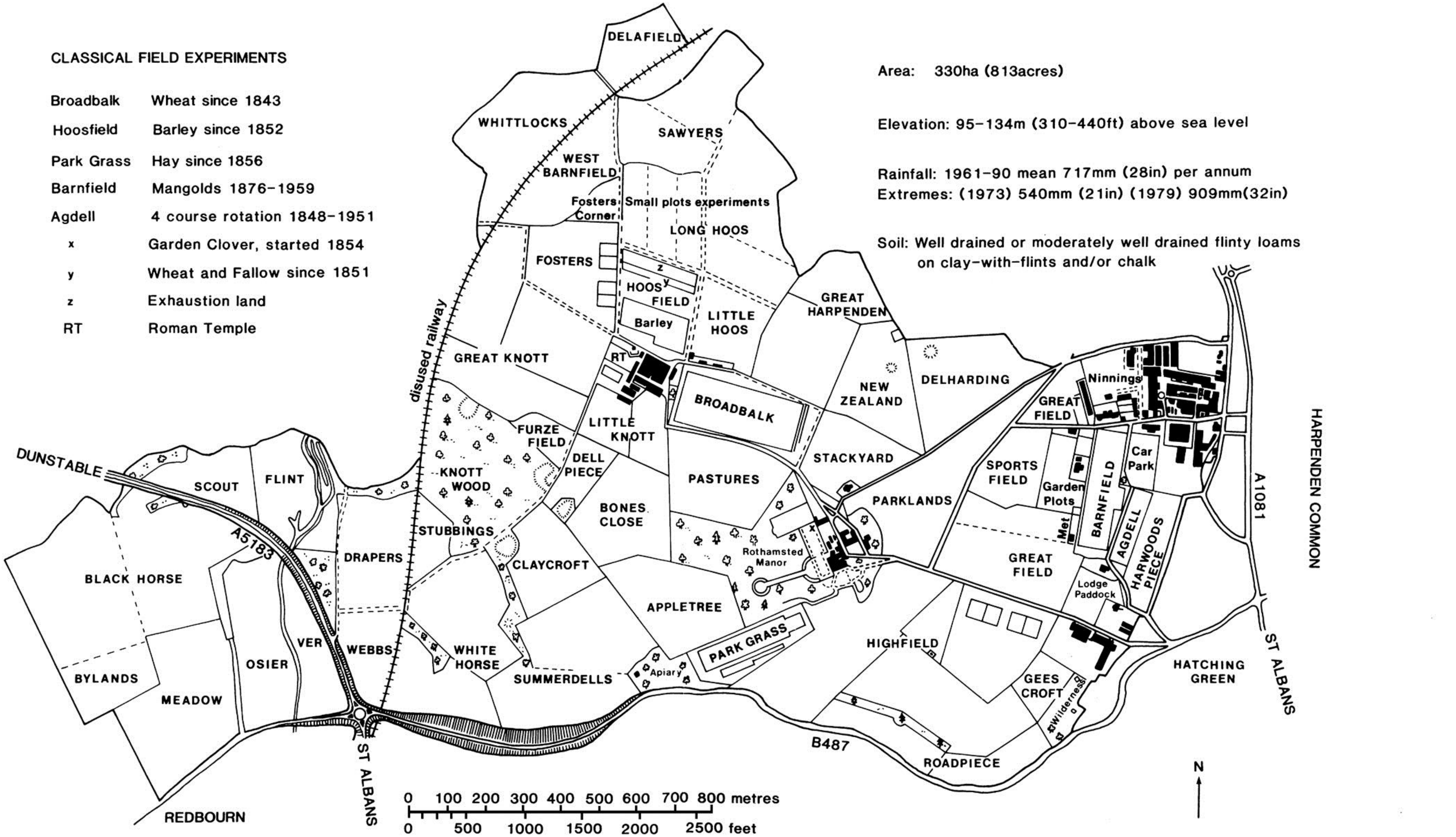
W=WGIN data, D=desk study

Variety	Source	Dressing	Code	Nabim	Rationale	inclusion in trial requested by	Previous years of trials (harvest year)
1. A C Barrie	Premium Crops		AB		Canadian re wheat. Disease sensitive. Tall. High grain N. Low yield. Spring type.	MH	new
2. Avalon		recleaned	AV	1	WGIN DH parent; Low NupE & NutE (D) WUE trial	PB, RG, MJH	05-12
3. Cadenza		recleaned	CA	2	WGIN DH parent; Best NupE (W) WUE trial	PB, RG, MJH	04-12
4. Chablis	KWS		CH	2	SPRING variety (previous grown in 2004 trial) as very N-responsive variety	MH	only in 04, 10, 11, 12
5. Claire	LIM	kinto	CL	3	Was biggest area on RL; WGIN DH parent; Good second wheat	PB,PS	05-12
6. Cocoon	Agrii/Secobra		CC	3	Tall variety. High yield. 2010 introduction. Eyespot and rust resistant.	MH	New
7. Conqueror	KWS		CN	4	New Grp 4, very high yielding	MH	12
8. Cordiale	KWS	redigo deter	CO	2	Good second wheat. BBSRC Quality project WUE trial	RG	06-12
9. Crusoe	LIM		CR	2	Carries dicoccoides. Shows the 'stay green' character		11, 12
10. Gallant	Syn		GA	1	new claimed high yield and high protein type	MH	10, 11, 12
11. Hereford	Syn		HF	4	Feed (not on RL), high yield, brown rust susceptible, possible low take-all build-up and good resistance. Multi trait.	KHK/RG	12
12. Hereward	RAGT	anchor	HE	1	Best protein on RL; benchmark bread variety. BBSRC Quality project WUE trial	PB,PS	04-12
13. Istabraq	LIM	kinto + lattitude	IS	4	Best yield on RL; Distilling cultivar; In LINK 'GREENgrain'; Good second wheat. BBSRC Quality project. WUE trial	PB,PS	05-12
14. Malacca	KWS	redigo deter	MA	1	Biggest Group 1 area; DH choice; Low NupE, high NutE (W). BBSRC Quality project	PS	04-12
15. Marksman	RAGT	redigo	MK	2	new for 2009, PRS request for BBSRC Quality project	PS	09-12
16. Maris Widgeon		sibutol	MW	1	Tall (rht), old cultivar WUE trial	PB, AM	04-12
17. Mercia		recleaned	ME	1	Low NupE & NutE (desk); Low Canopy N requirement; In IGF micro-array. WUE trial. RHT series	RG	04, 06-12
18. Paragon	RAGT	redigo twin	PA	1	Spring variety; WGIN mutagenesis population; High NupE (W)	PB	04-12
19. Riband	RAGT	recleaned	RI	3	WGIN DH parent; Distilling cultivar; In LINK 'GREENgrain'; High NutE (W)	RG	04-12
20. Robigus	KWS	redigo deter lattitude	+RO	3	Best Group 3 yield; Best NUE, high NupE & NutE (D); Good second wheat. WUE trial	PB, AM	05-12
21. Stigg	LIM		ST	?4	Carries dicoccoides. High disease resistance. Shows the 'stay green' character		11, 12
22. Soissons	Elsoms	redigo	SS	2	WGIN DH parent; Early maturing; High NupE, low NutE (W) WUE trial	PB,RG, AM	04-12
23. Solstice	LIM	beret gold lasttitude	+SL	2	Biggest Group 2 area; DH choice; Worst NupE (W)	RG	04-12
24. Xi19	LIM	redigo deter	XI	1	Best Group 1 yield; High NUE, NupE, NutE (D); Low NupE (W). BBSRC Quality project. WUE trial	PB,PS	04-12
25. Zebedee	LIM		ZE	3	High WUE, grp 3. Multi trait. WUE trial	JFoulkes	12

Thanks

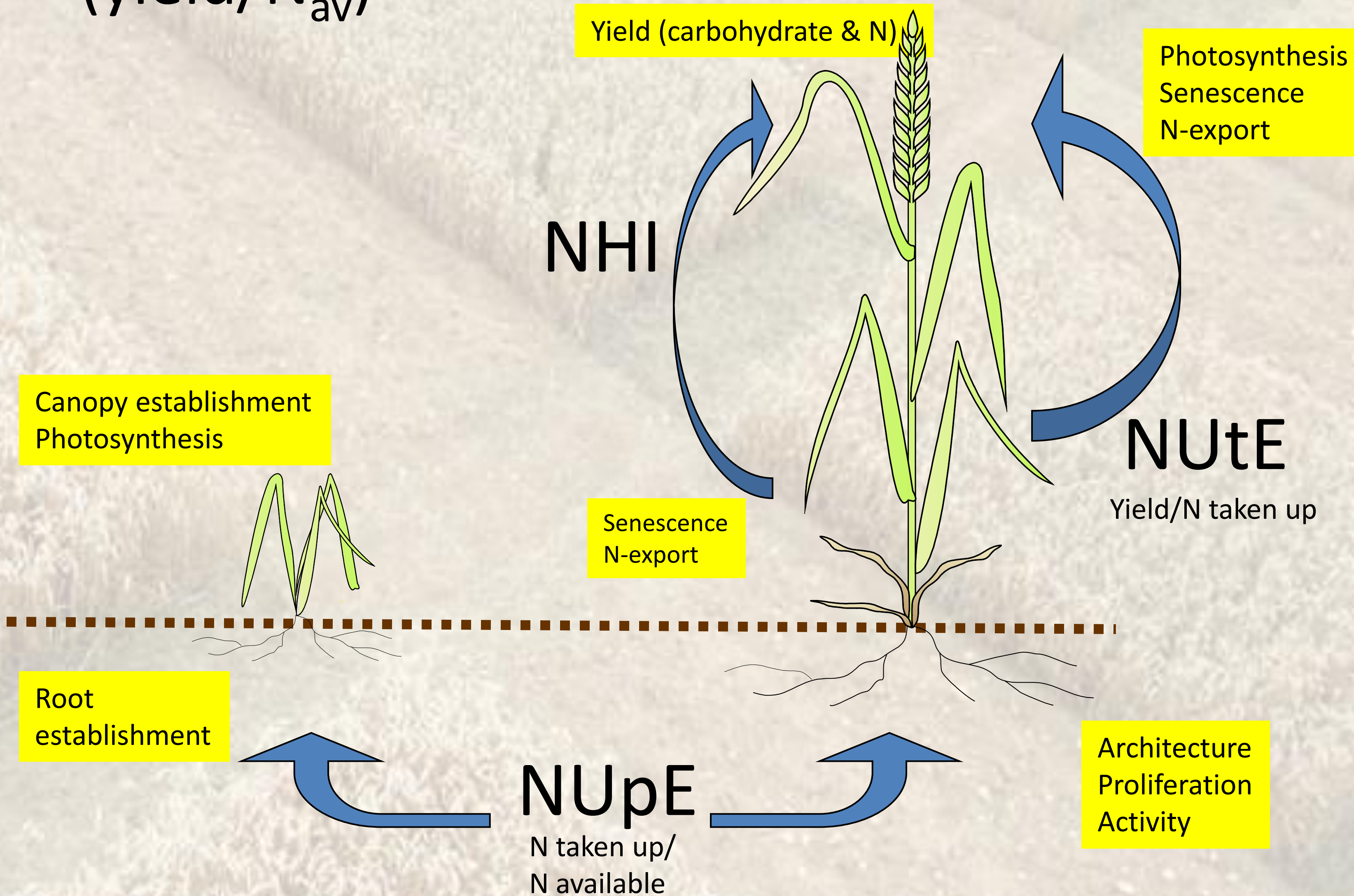
- RRes Farm staff
- Peter Barraclough
- Group and field team: Andrew Riche, Peter Buchner, Yongfan Wan, Jonathan Howarth, Mark Durenkamp, Saroj Parmar, Janina Jones, Dan Godfrey, Emmanuelle Cabannes, Adinda Derkx, Fumie Shinmachi, Astrid grun, Nick Evens, Deyong Zhao, Caihong Bai + many summer students

ROTHAMSTED EXPERIMENTAL STATION



2013 Diversity Trial

NUE = NUpE x NUtE
(yield/N_{av})

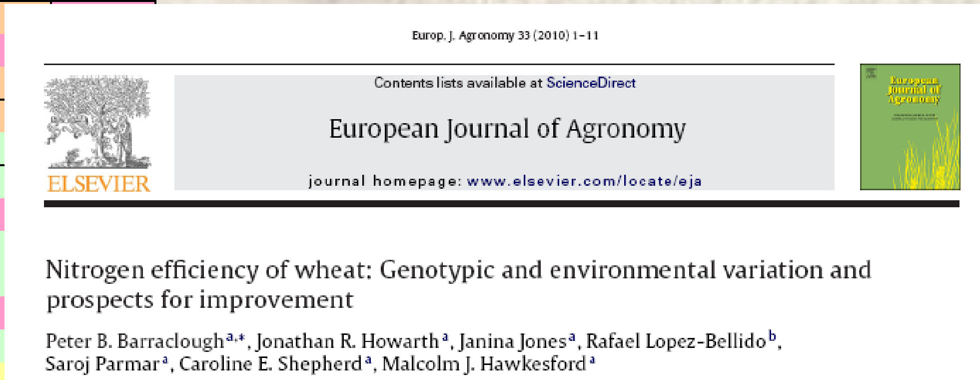


Variety Performance at 200 kg-N/ha (2004-08)

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


Europ. J. Agronomy 33 (2010) 1–11
Contents lists available at ScienceDirect
European Journal of Agronomy
journal homepage: www.elsevier.com/locate/eja

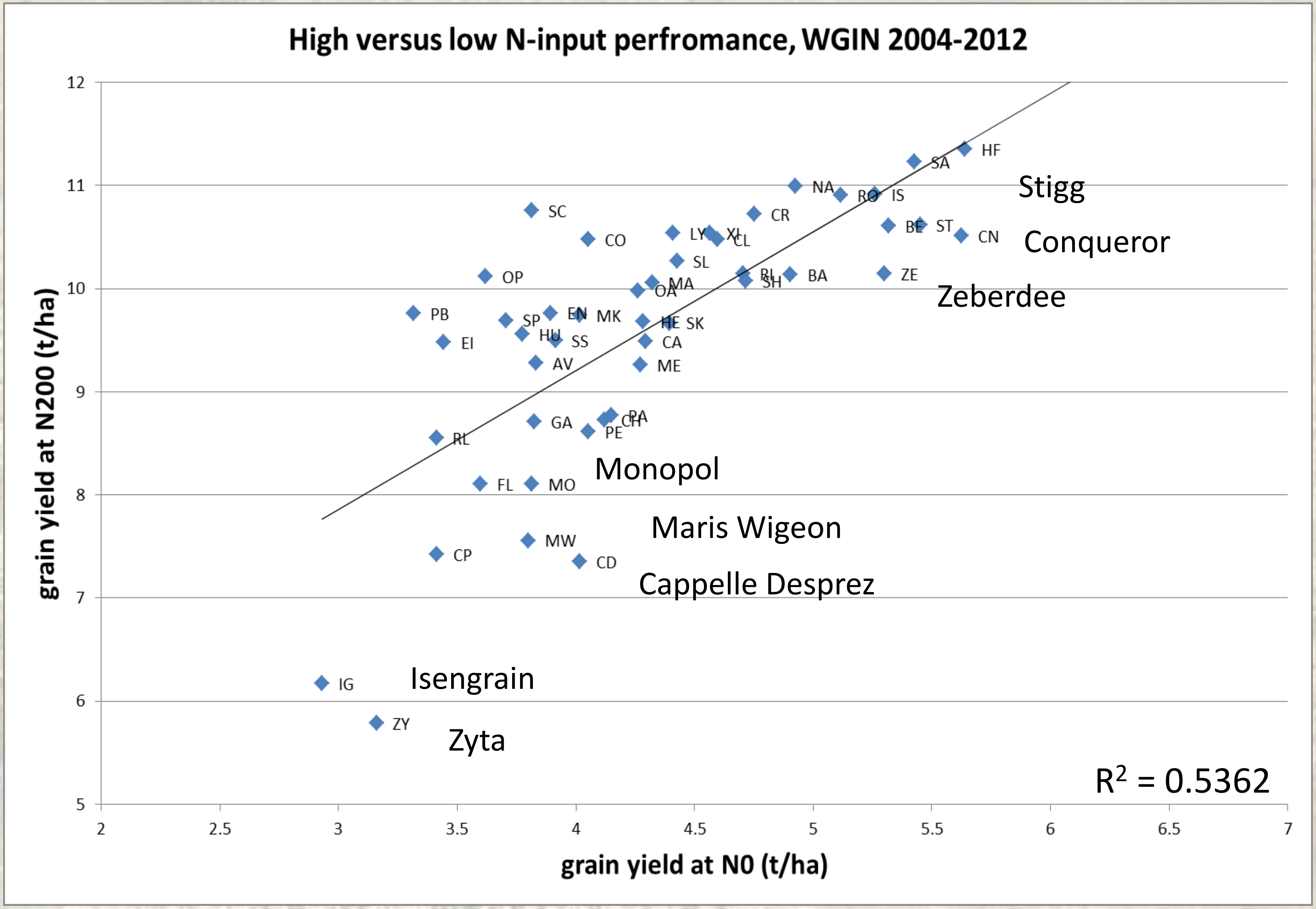
Nitrogen efficiency of wheat: Genotypic and environmental variation and prospects for improvement

Peter B. Barraclough[a,*], Jonathan R. Howarth[a], Janina Jones[a], Rafael Lopez-Bellido[b], Saroj Parmar[a], Caroline E. Shepherd[a], Malcolm J. Hawkesford[a]

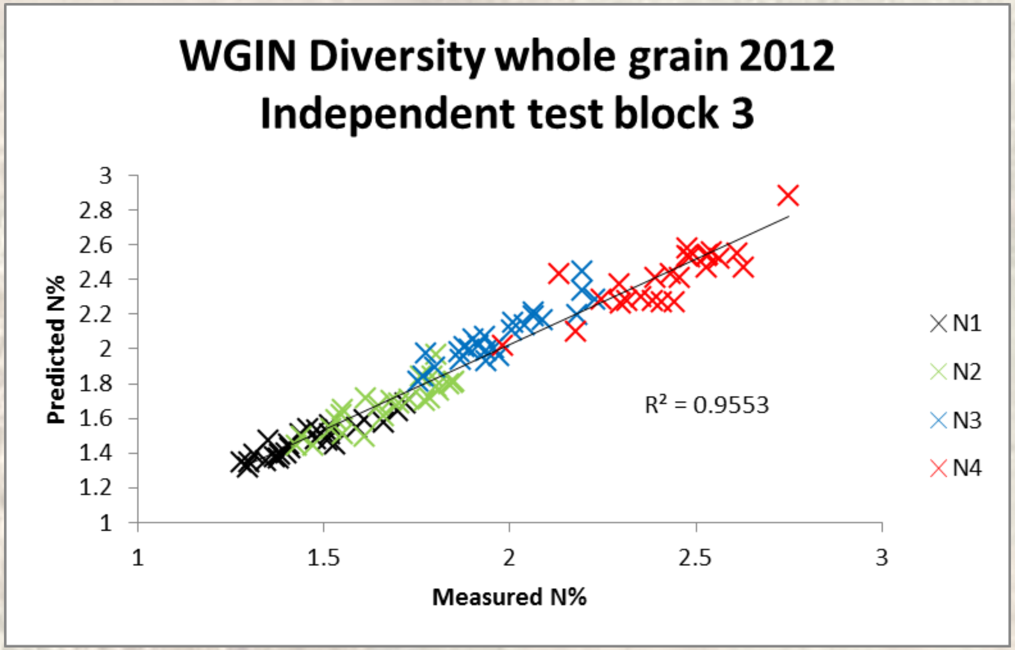
EJA (2010) 33, 1-11

2012 Diversity Trial

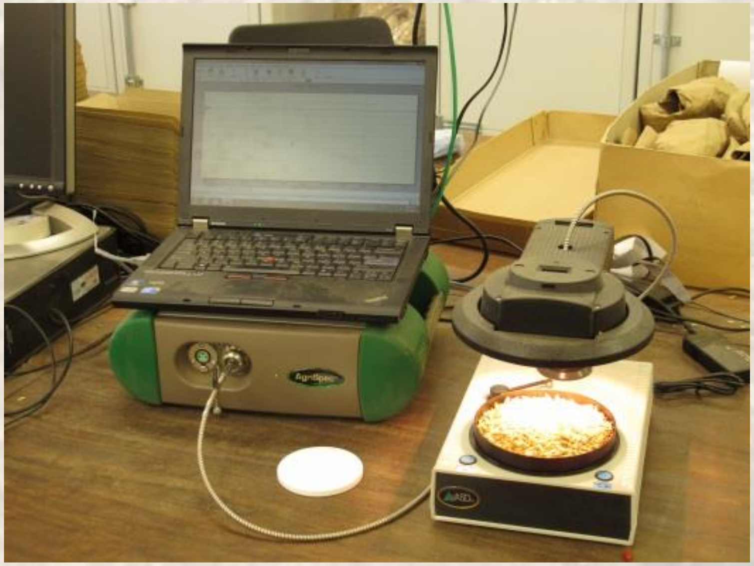
Grain yields, high v low N input performance, 2004-12



NIRS - Predicting Grain Nitrogen



The grain from 2 blocks was used to build a grain N prediction model, and the model was independently tested on the grain from block 3.



Whole grain is scanned on a sample turntable. Up to 240 samples can be scanned/day. Milling, weighing and measuring N conventionally would take about about 5 days per 240 samples, and be expensive.

Avalon x Cadenza 2012 trial

Avalon x Cadenza Trials

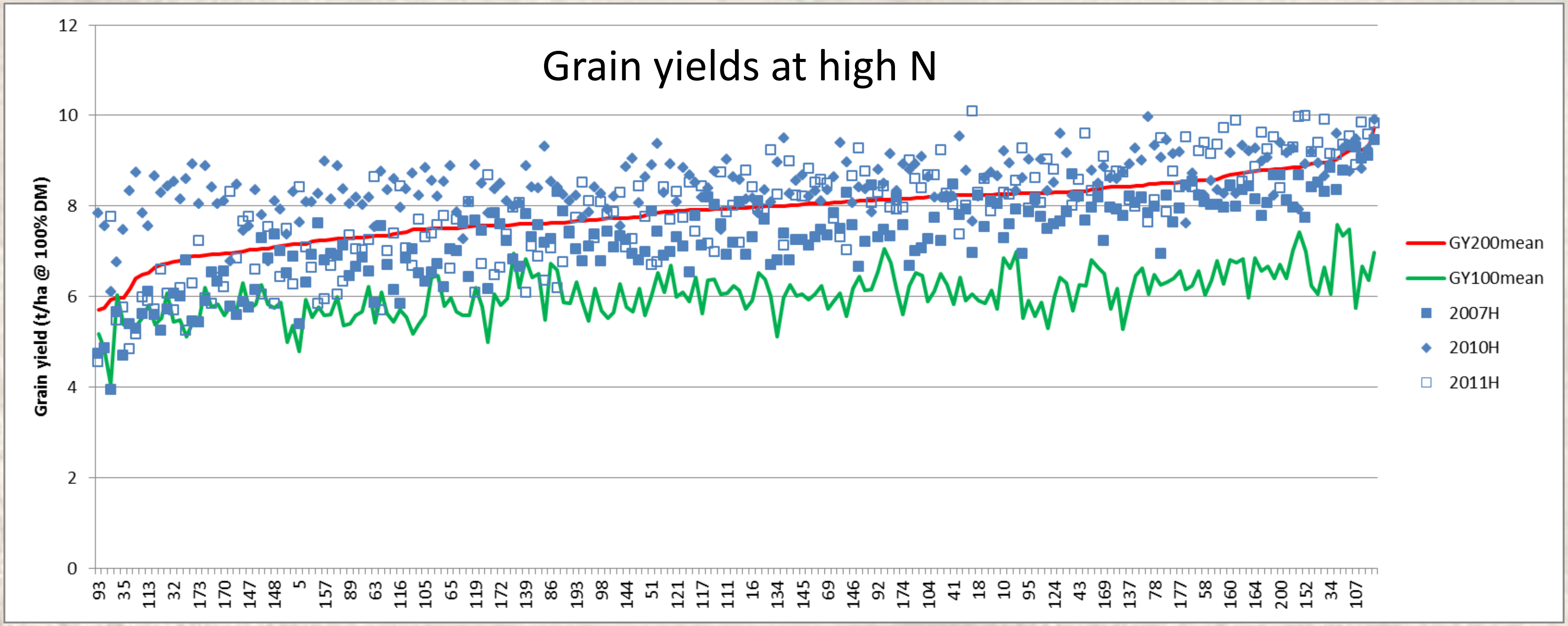
Trial	Harvest year	Sites	Notes	kg N/ha applied (+ c 50 kg/ha N_{min})	Soil N (kg/ha to 90 cm)
1 (719)	2007	Blackhorse		200	49.9
2, 3 (817; 851-3)	2008	Bones and Woburn	Woburn trial split	Both 100	78.3; 34.4,36.1, 36.7
4 (903, 904)	2009	Fosters/Summardells	Split over 2 fields (wet)	100	48.2; 40.7
5 (1035)	2010	Blackhorse	(very dry)	200	39.8
6(1103)	2011	Great Harpenden	(very dry)	200	44.0
7*(1202)	2012	Bones	(wet May/June)	50	69.5
8*(1319	2013	Blackhorse	Abandoned		

*= not directly WGIN funded

Avalon x Cadenza

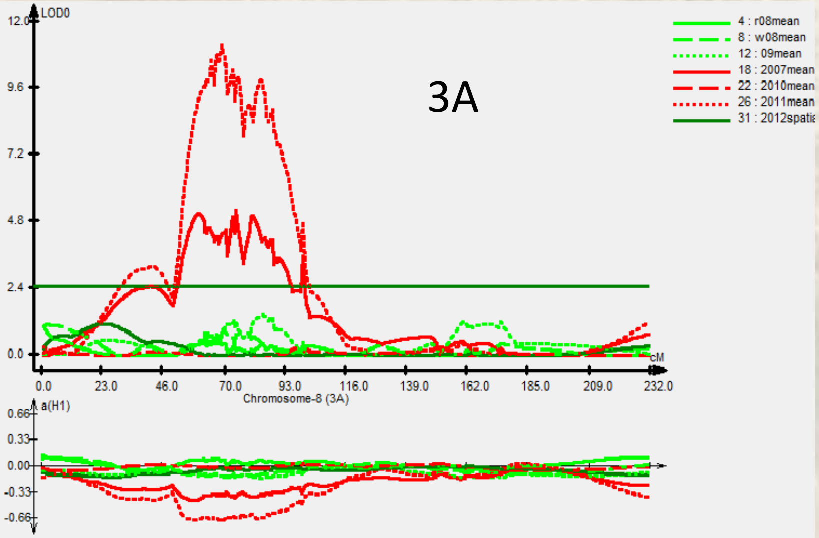
- # Traits being measured

- Flowering time and height
- Yield (grain and straw) and TGW
- Nitrogen (grain and straw)
- NUtE, N uptake (final)
- Leaf N and SPAD (anthesis and 21 dpa)
- Leaf size
- Canopy longevity, reflectance, rate of senescence
- Early N uptake
- Gene expression
- Roots

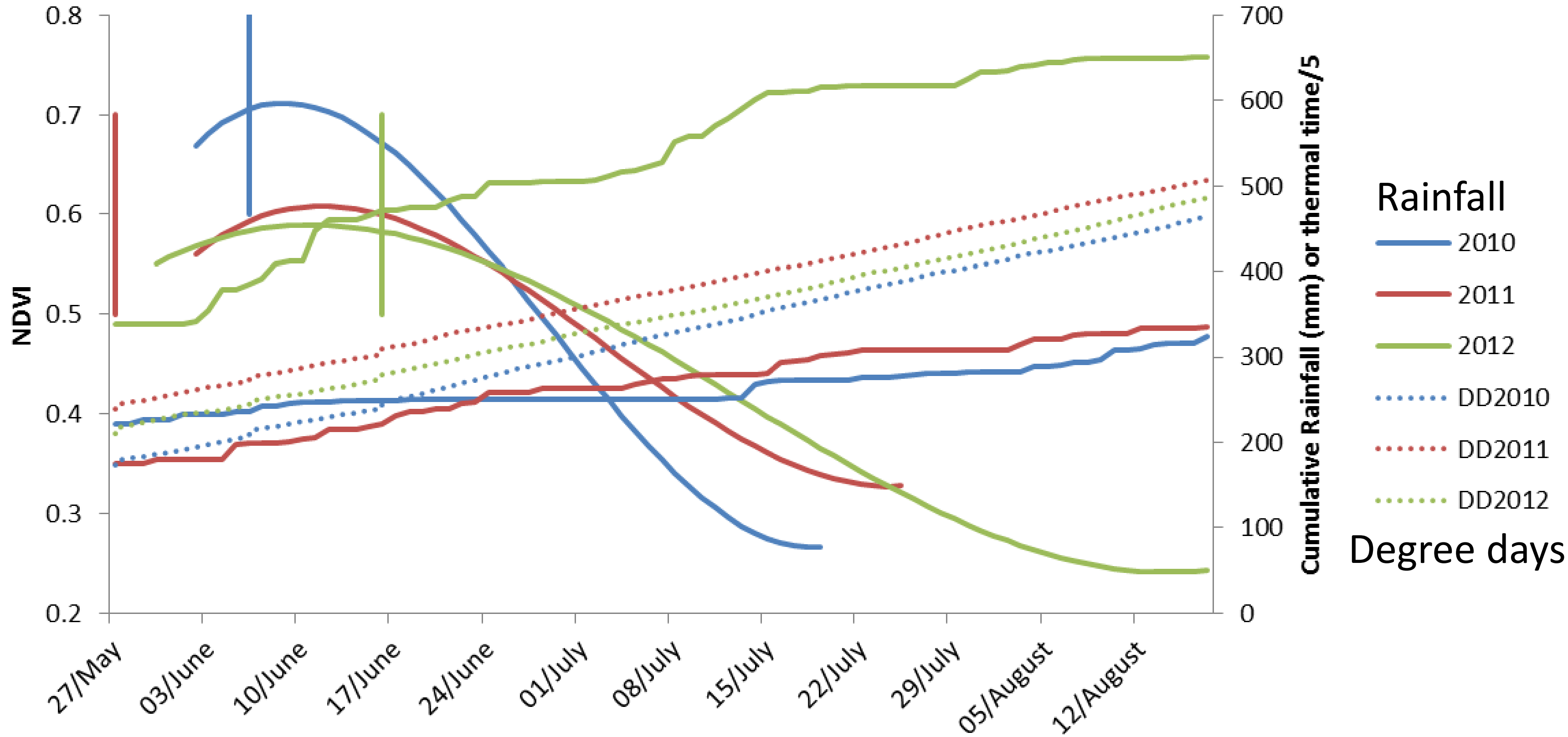


Monthly rainfall in spring and summer (mm) at Rothamsted in the years 2007-2011. Six-monthly totals and 30-year averages (1971-2000) are shown.

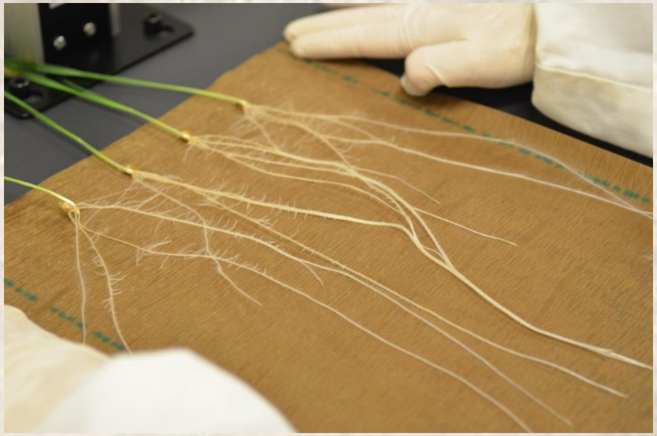
Year	Mar	Apr	May	Jun	Jul	Aug	Total
2007	57.6	2.8	135.8	72.4	86.8	64.4	**419.8**
2008	108.5	53.5	87	35.3	90.3	107.8	**482.4**
2009	37.3	46.7	24.8	68.1	73.3	63.4	**313.6**
2010	45.2	18.7	38.4	23.5	31.6	127.6	**285**
2011	10	5.2	23.6	83	44.6	81.2	**247.6**



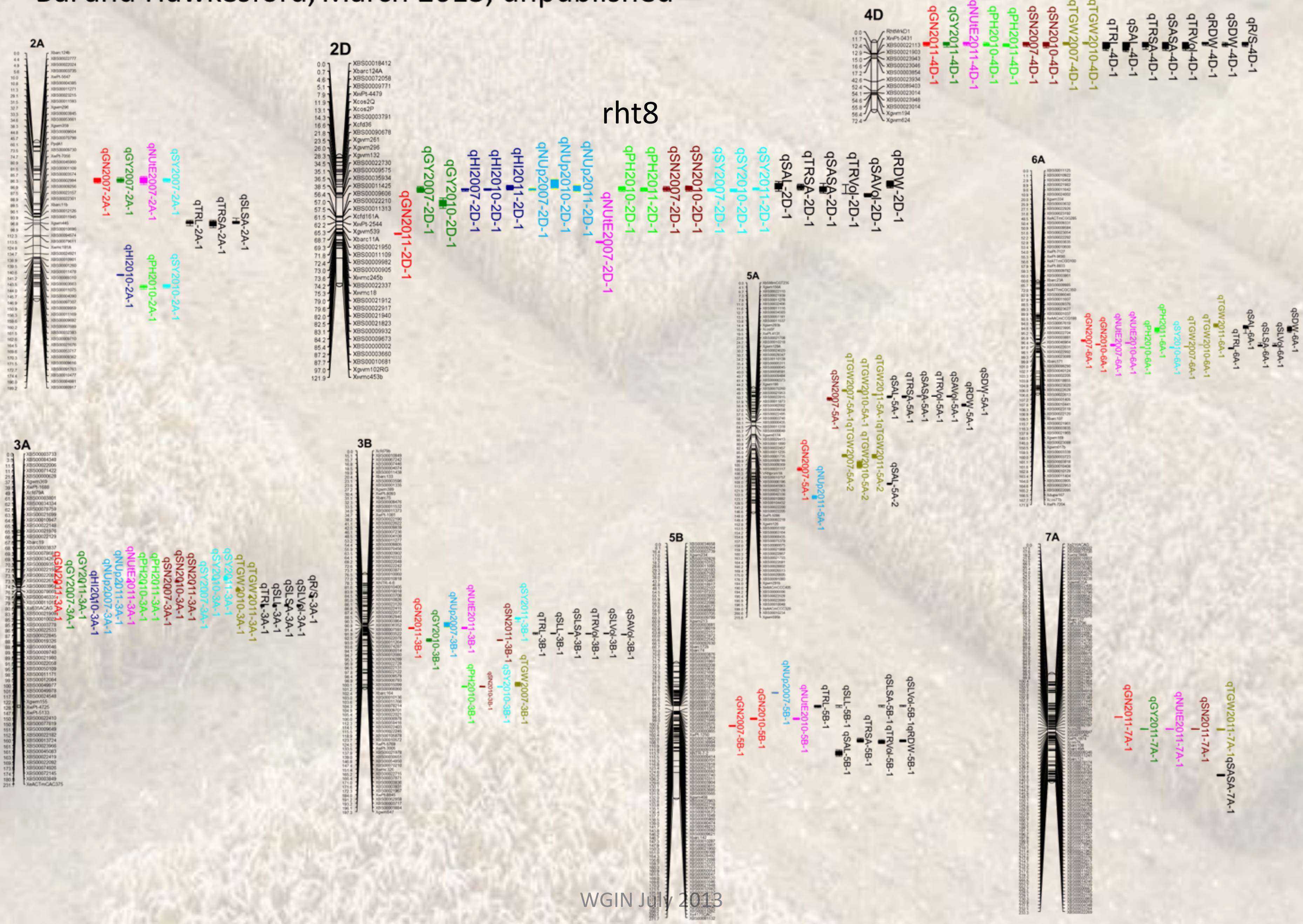
Mean senescence curves, cumulative rainfall, thermal time (Day degrees, dotted lines) and mean anthesis dates (vertical lines) for three years 2010-2012



Variation in root traits: mapping QTLs

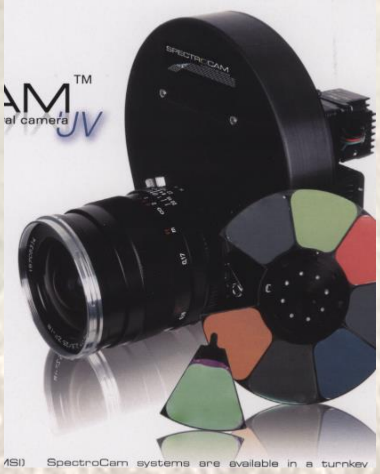


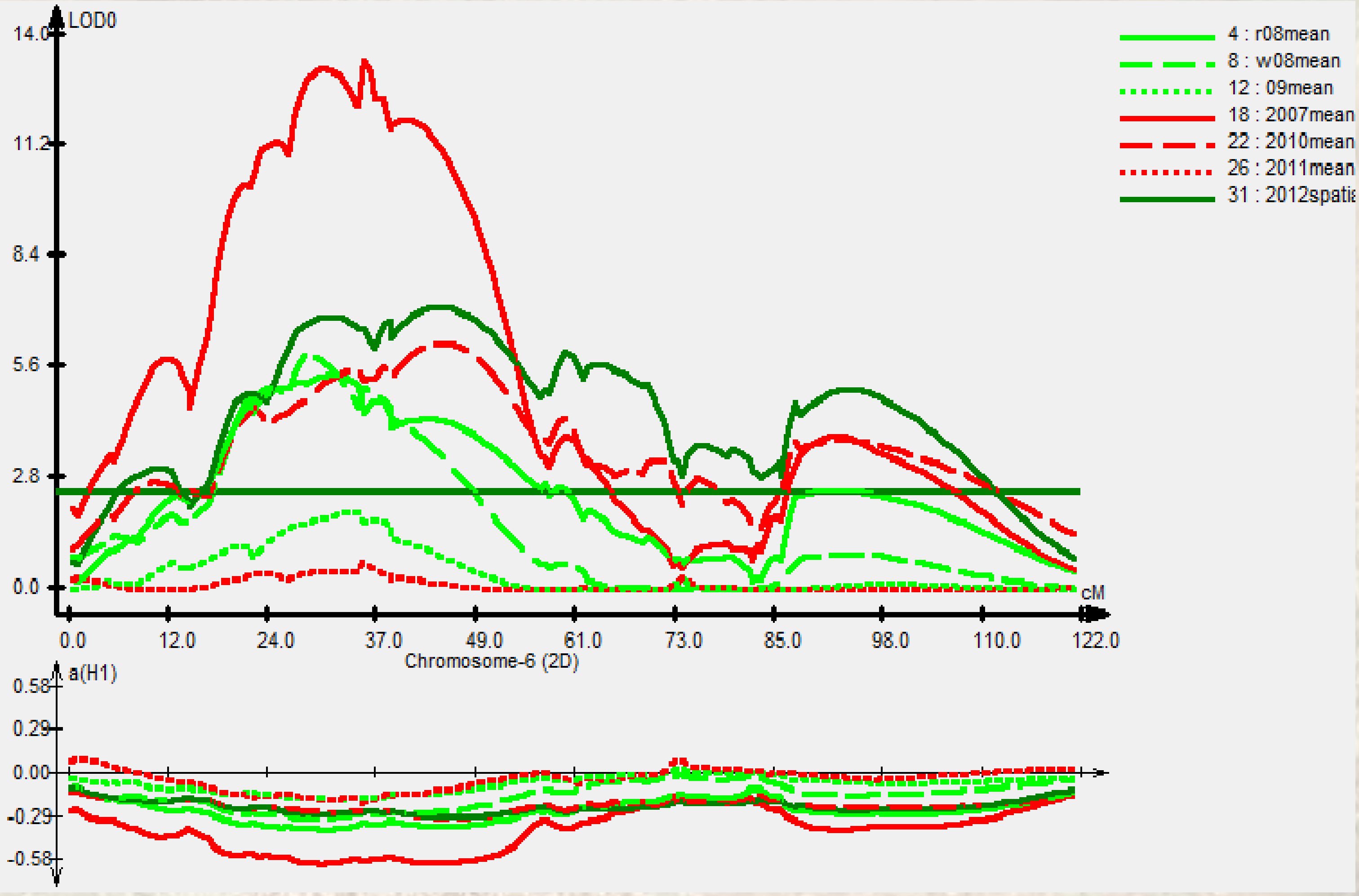
Bai and Hawkesford, March 2013, unpublished



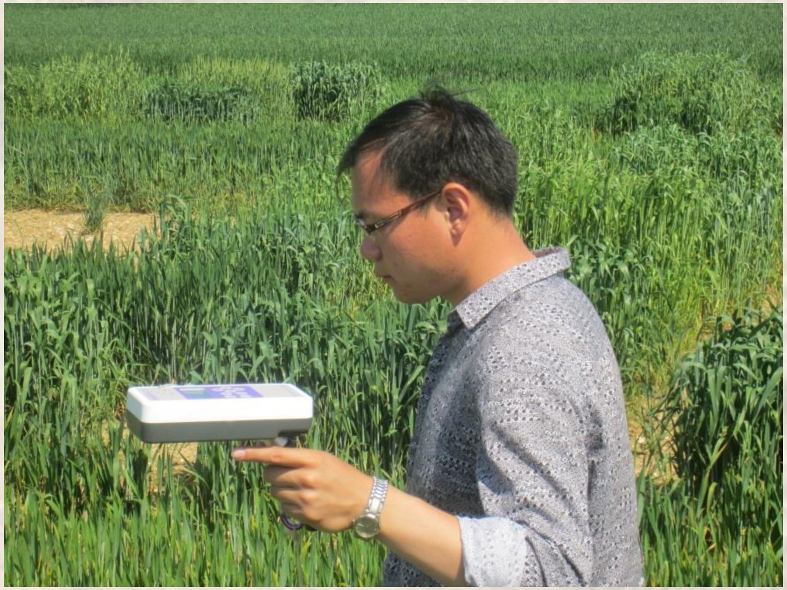
Forward plans….

- Final evaluation of modern diversity trial
- Evaluate field phenotype methodologies: NDVI, canopy multispectral data, NIRS and imaging
- Cross reference NUE/RUE/Take-all interactions

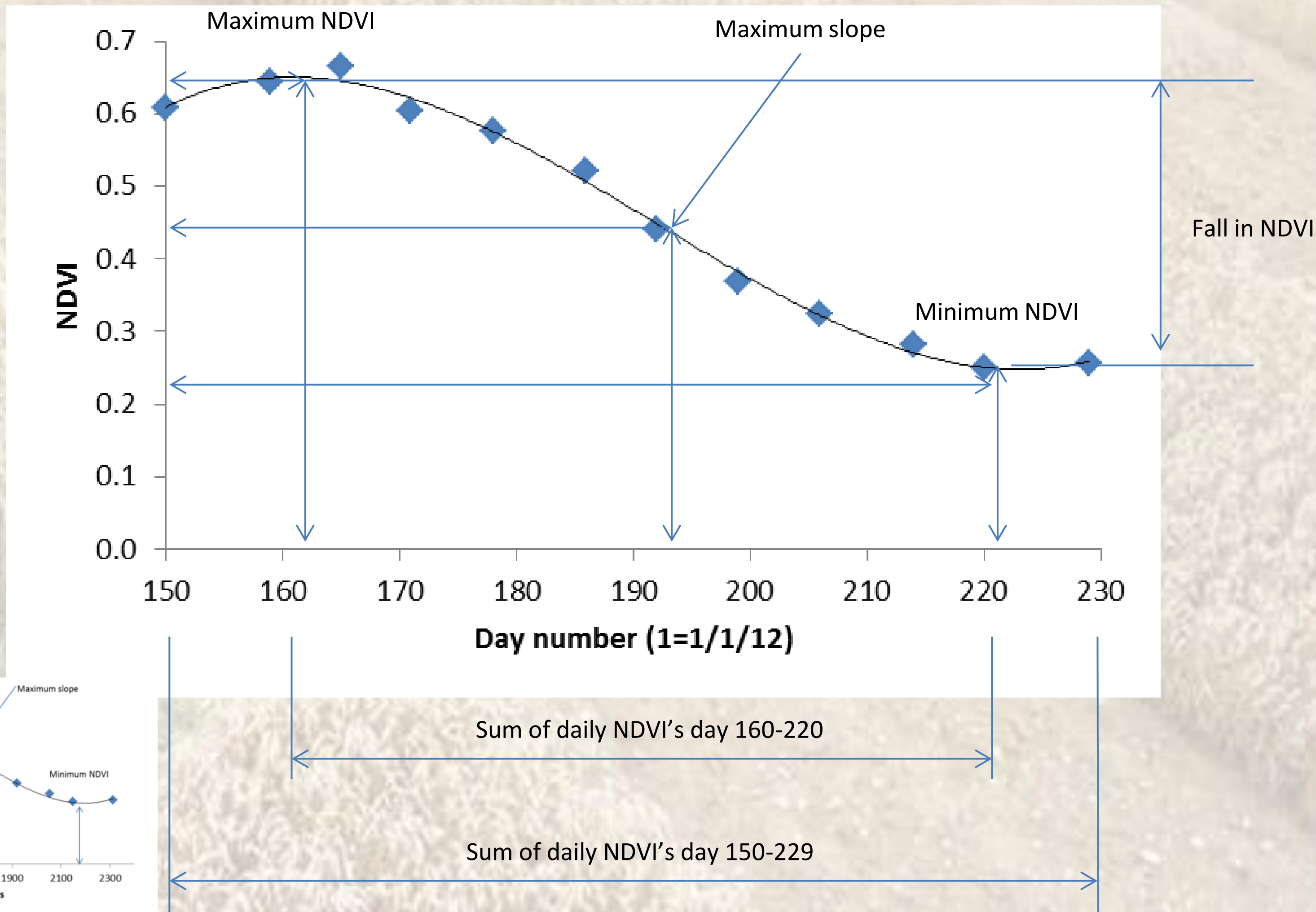


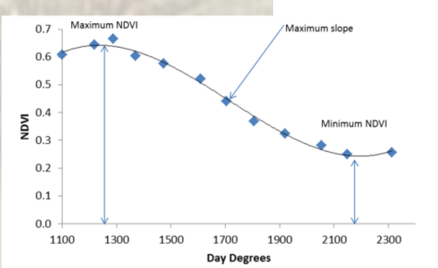

LOD0
14.0
11.2
8.4
5.6
2.8
0.0
4 : r08mean
8 : w08mean
12 : 09mean
18 : 2007mean
22 : 2010mean
26 : 2011mean
31 : 2012spatia
cM
0.0
12.0
24.0
37.0
49.0
61.0
73.0
85.0
98.0
110.0
122.0
Chromosome-6 (2D)
a(H1)
0.58
0.29
0.00
-0.29
-0.58

A x C and senescence

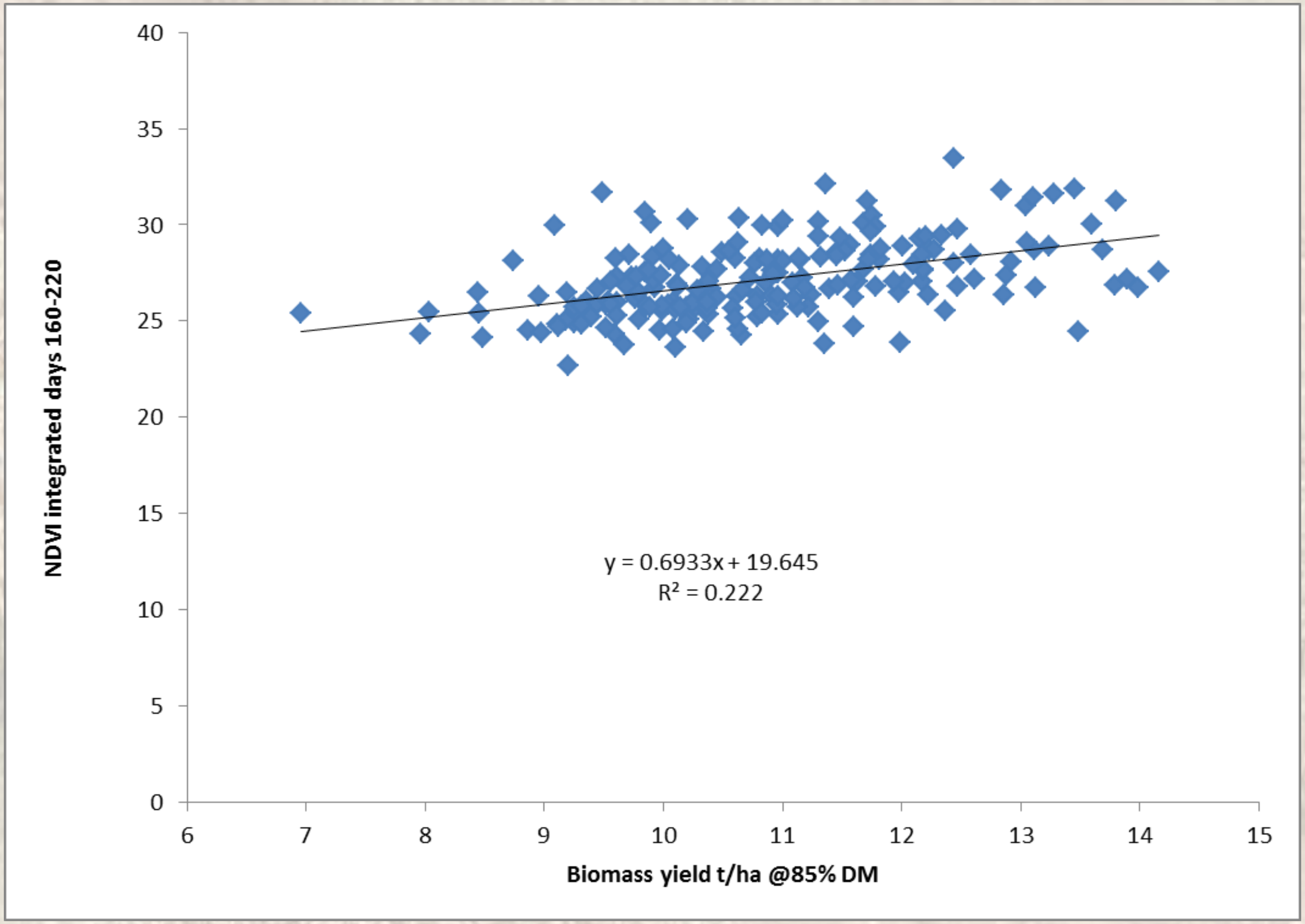


A x C senescence curve parameters

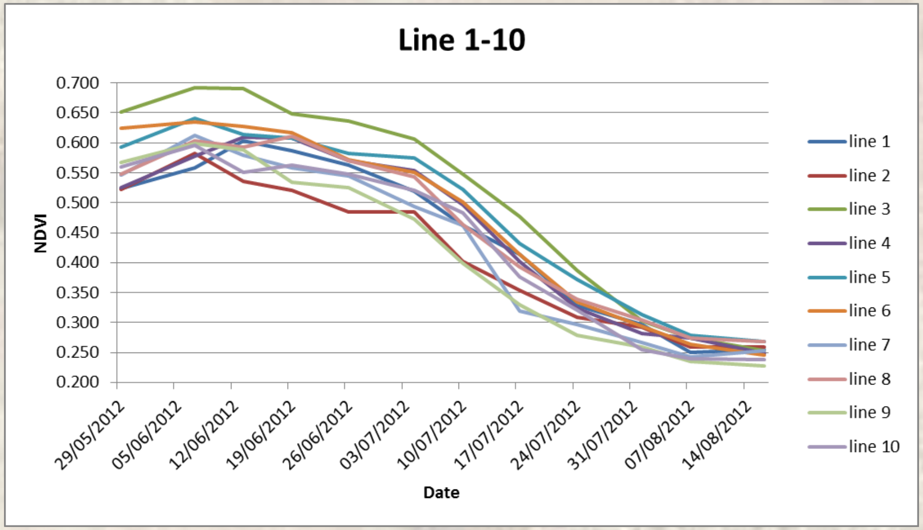




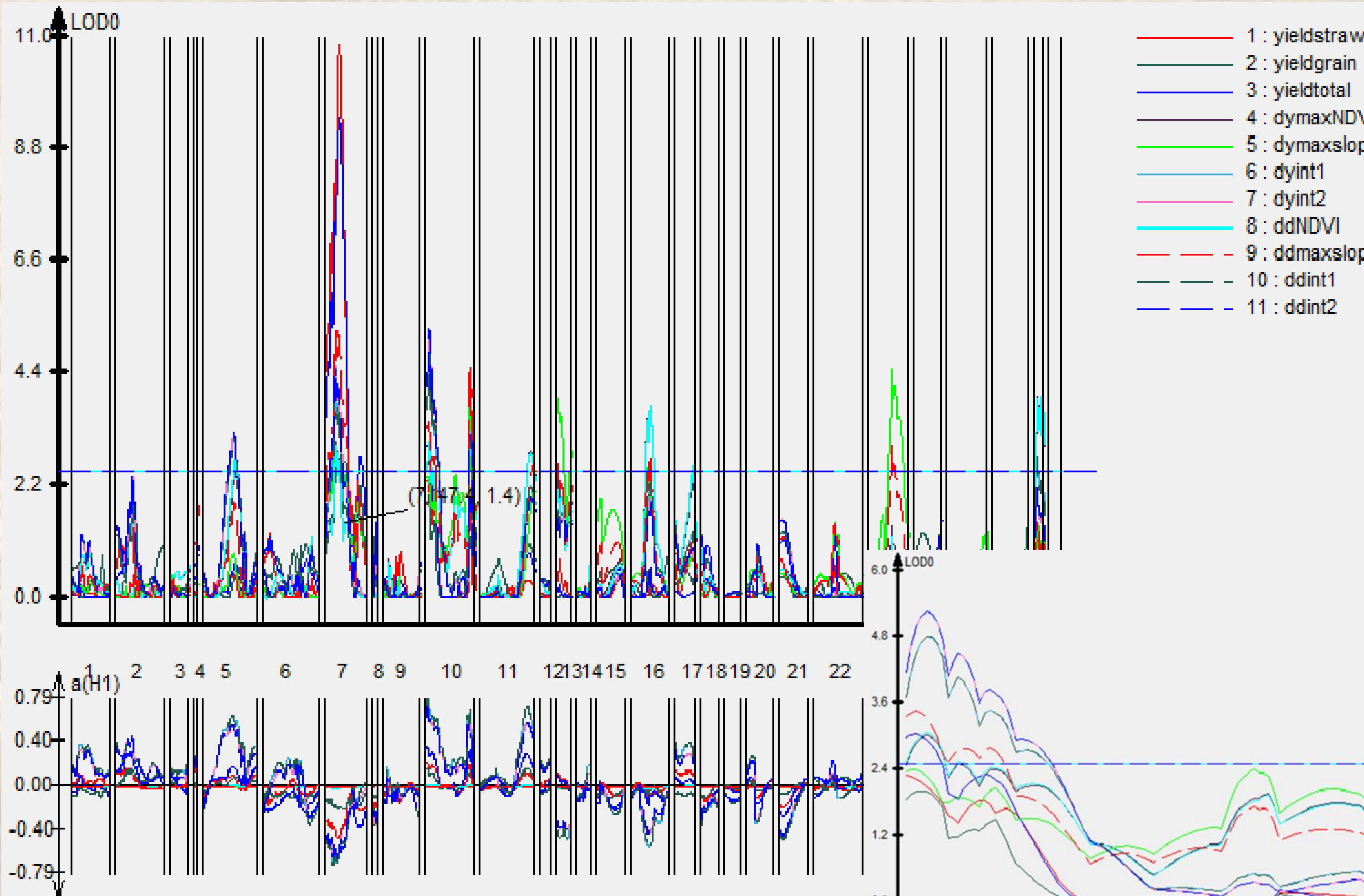
Integration relates to yield

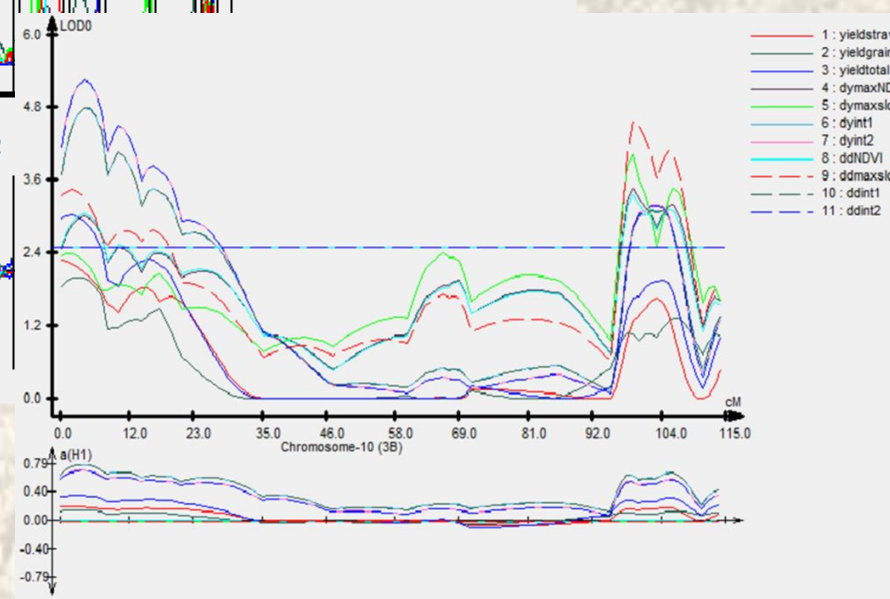


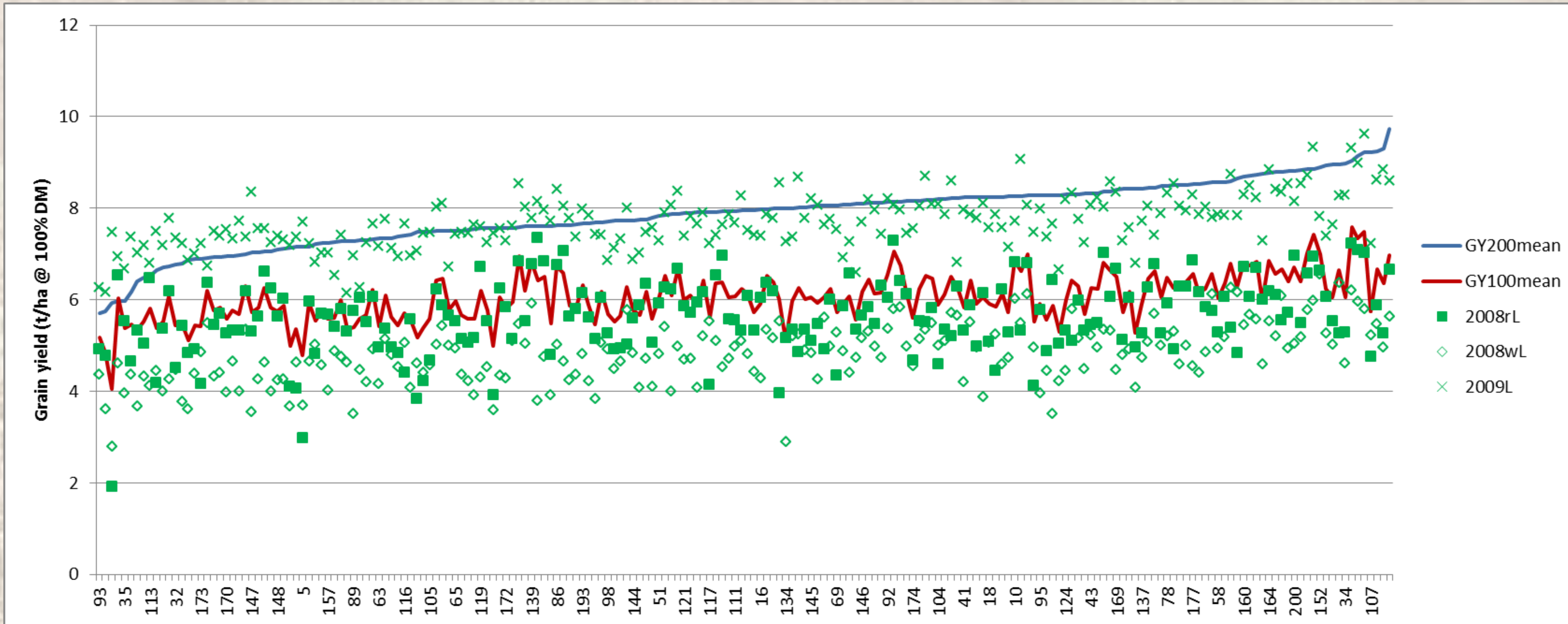
Quantifying senescence characteristics



Senescence and yield QTL



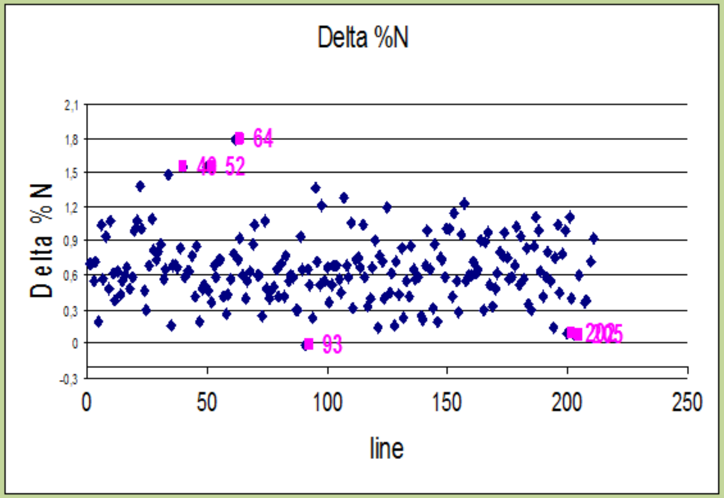


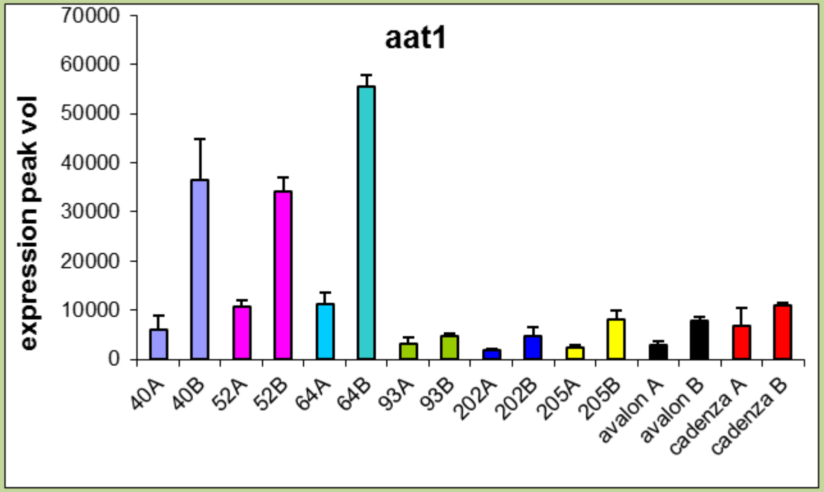


Grain yield (t/ha @ 100% DM)
12
10
8
6
4
2
0
93
35
113
32
173
170
147
148
5
157
89
63
116
105
65
119
172
139
86
193
98
144
51
121
117
111
16
134
145
69
146
92
174
104
41
18
10
95
124
43
169
137
78
177
58
160
164
200
152
34
107
GY200mean
GY100mean
2008rL
2008wL
2009L

Canopy longevity as a target

Wheat amino acid transporter TaAAT1 expression in leaf 2 of AxC double haploid lines (field grown) differing in their N-remobilisation capacity



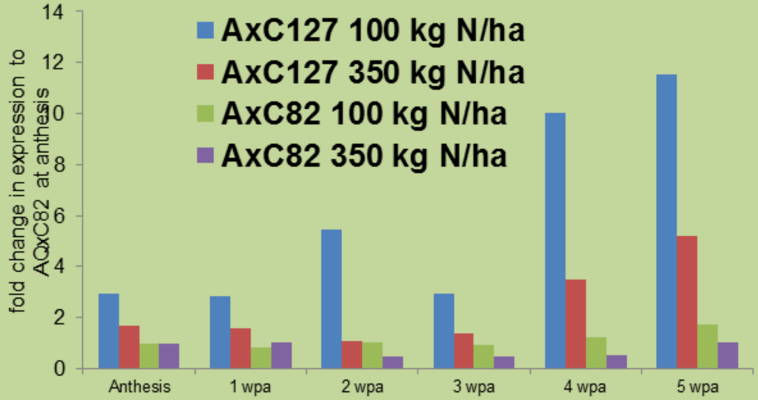


Lines 40, 52 and 64 with a high delta N and lines 93, 202 and 205 with a low delta N (red dots). Delta N was measured on leaf 2 between anthesis and day 21.

Positive correlation with increasing expression of TaAAT1 in AxC lines with high leaf 2 N-remobilisation capacity 3 weeks post anthesis compared to low expression in AxC lines with low N-remobilisation capacity.
A = anthesis; B = 3 wpa)

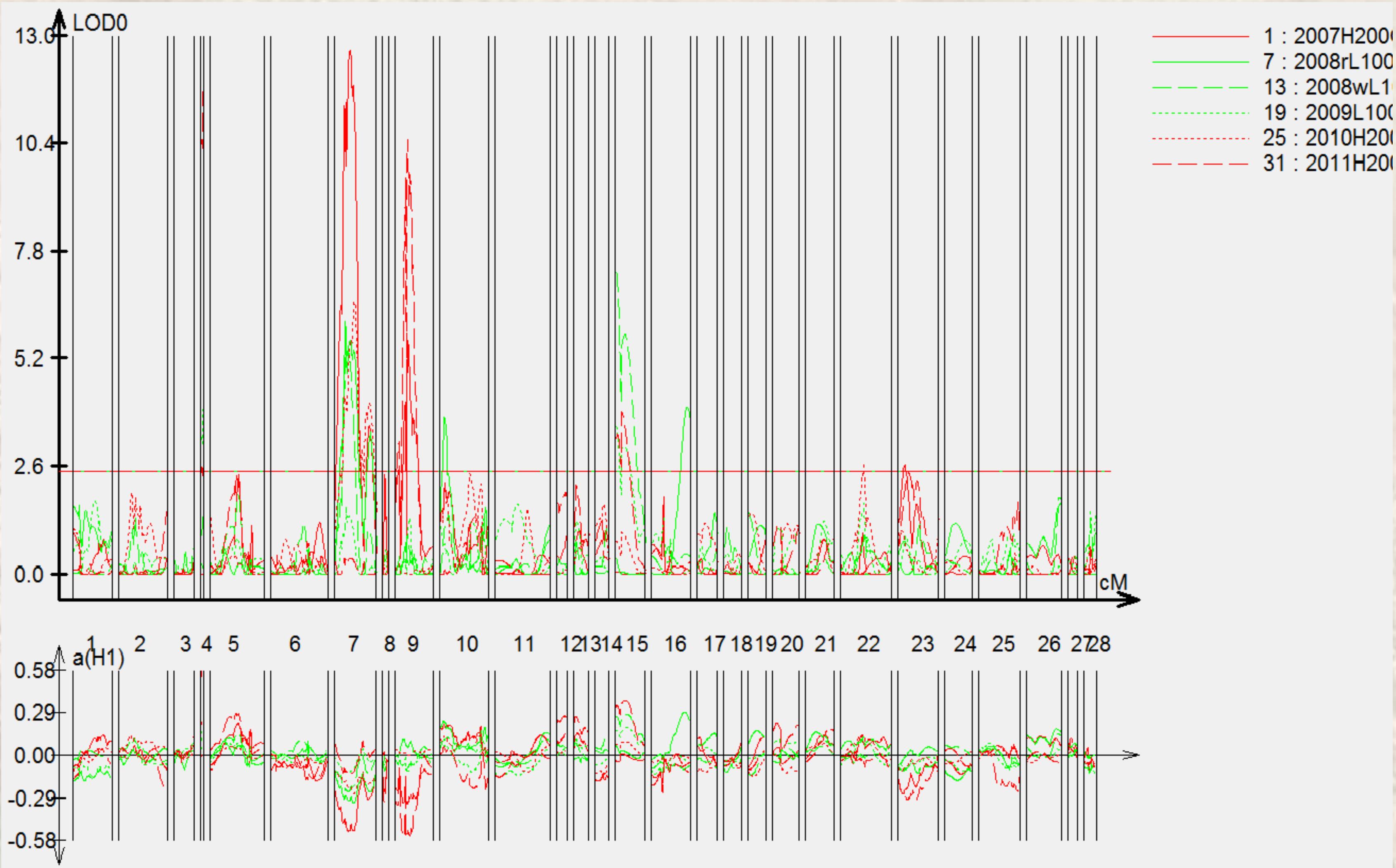
Field experiment (WGIN)

AxC lines 127 and 82 are characterised by early N export (127) compared to slow export (82). The lines where grown in the field under different nitrate fertilization (0, 100, 200, 350 kg/ha N). With anthesis leaf 2 were harvested every week until 5 weeks post-anthesis (wpa) and gene expression studies were performed.



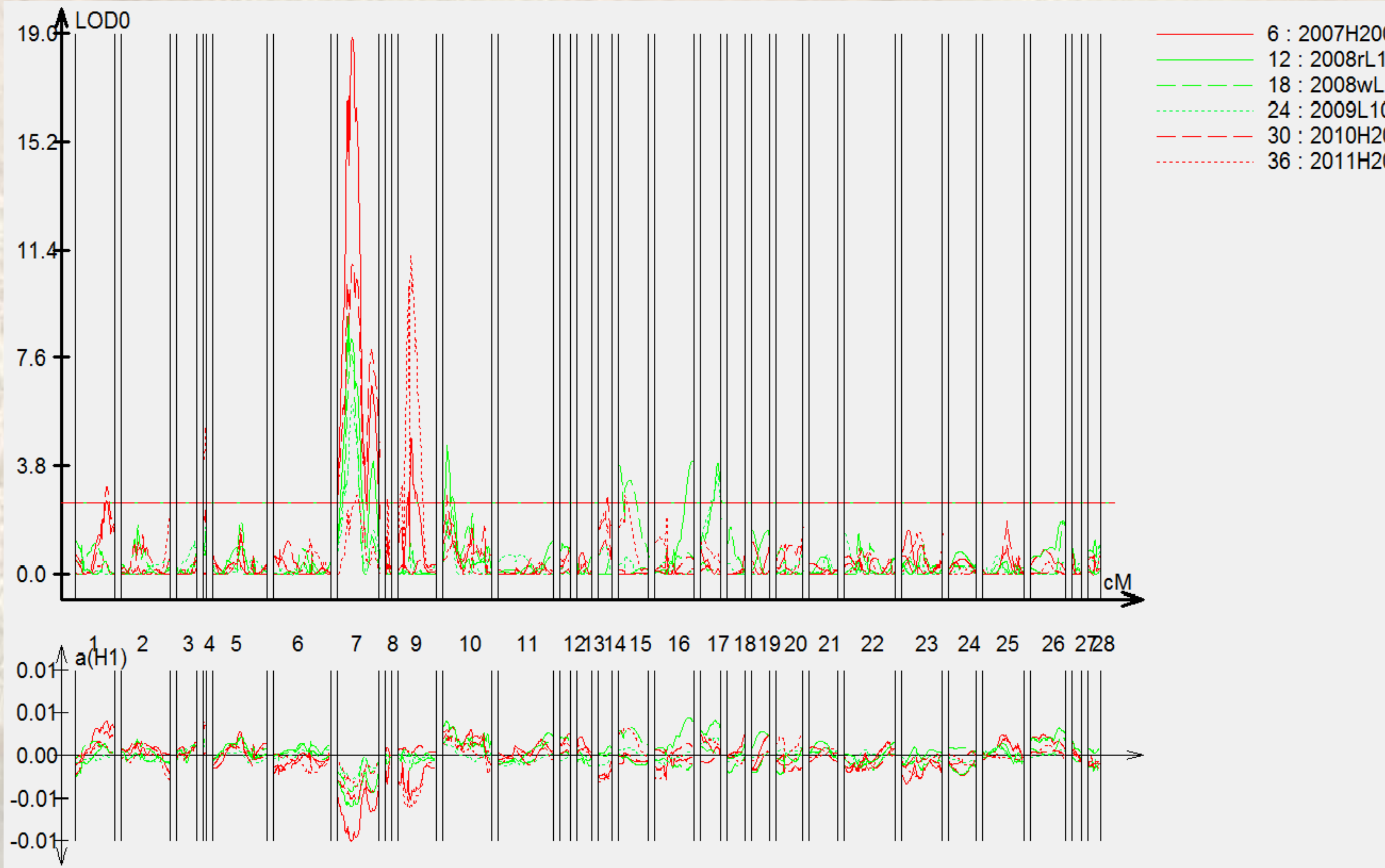
Under field conditions insufficient N-fertilization (100 kg N/ha) results already in an up-regulation of TaAAT1 gene expression in leaf 2 of AxC line 127 which further increases with more N-demand during remobilisation/grain filling compared to high 350 kg N/ha which shows only a small increase with ongoing senescence. There is a positive correlation of TaAAT1 expression to the early N export capacity of AxC line 127 compared to the much reduced TaAAT1 gene expression in the slow N exporter line AxC line 82 especially with increasing senescence.

Grain yield



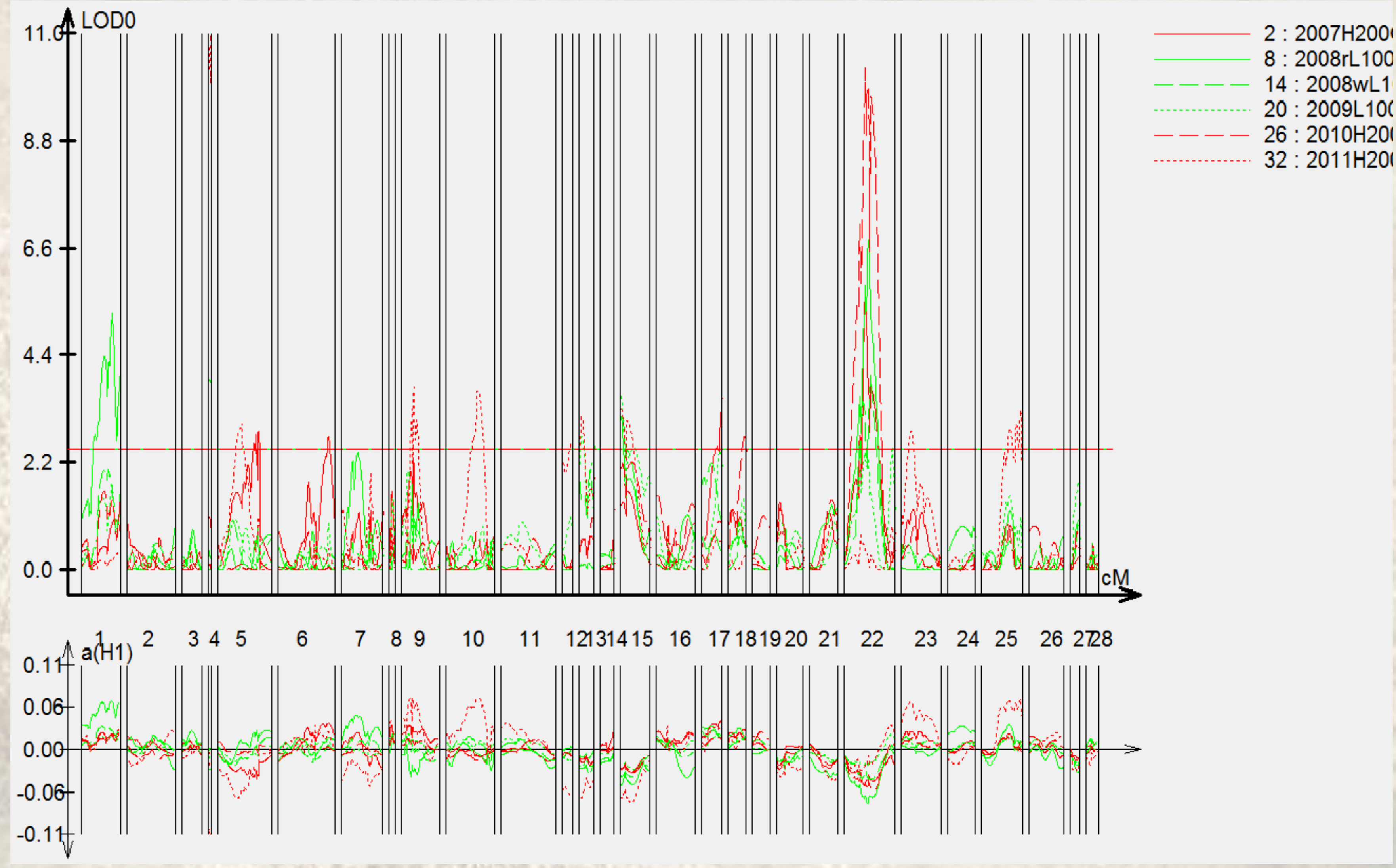
LOD0
13.0
10.4
7.8
5.2
2.6
0.0
cM
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
a(H1)
0.58
0.29
0.00
-0.29
-0.58
1 : 2007H200
7 : 2008rL100
13 : 2008wL1
19 : 2009L100
25 : 2010H200
31 : 2011H200

Total N



LOD0
19.0
15.2
11.4
7.6
3.8
0.0
cM
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
a(H1)
0.01
0.01
0.00
-0.01
-0.01
6 : 2007H2007
12 : 2008rL10
18 : 2008wL1
24 : 2009L10
30 : 2010H20
36 : 2011H20

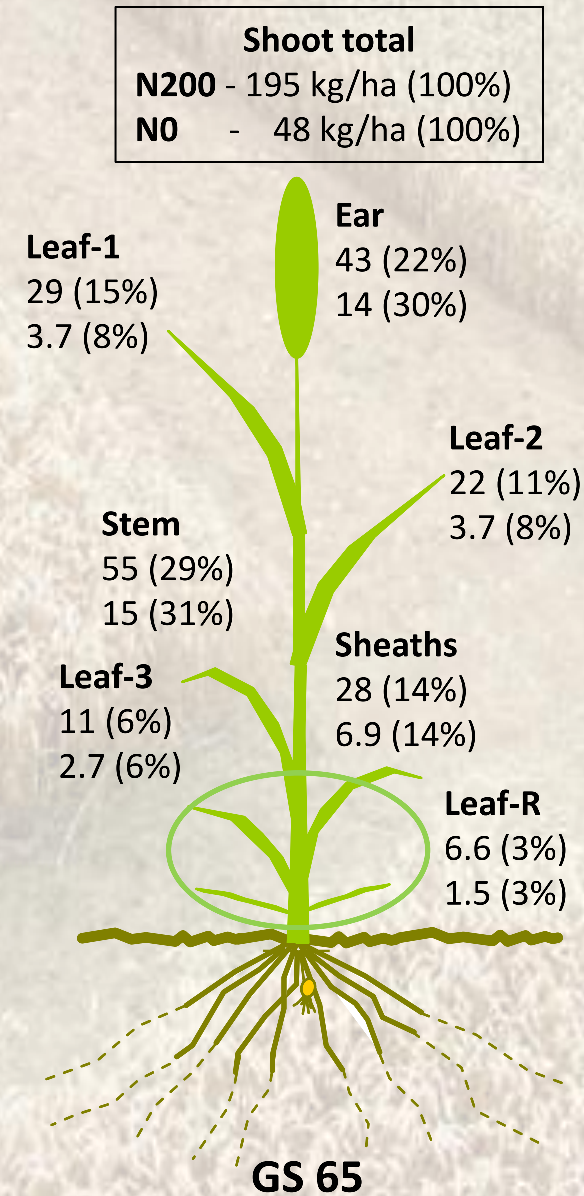
Grain %N

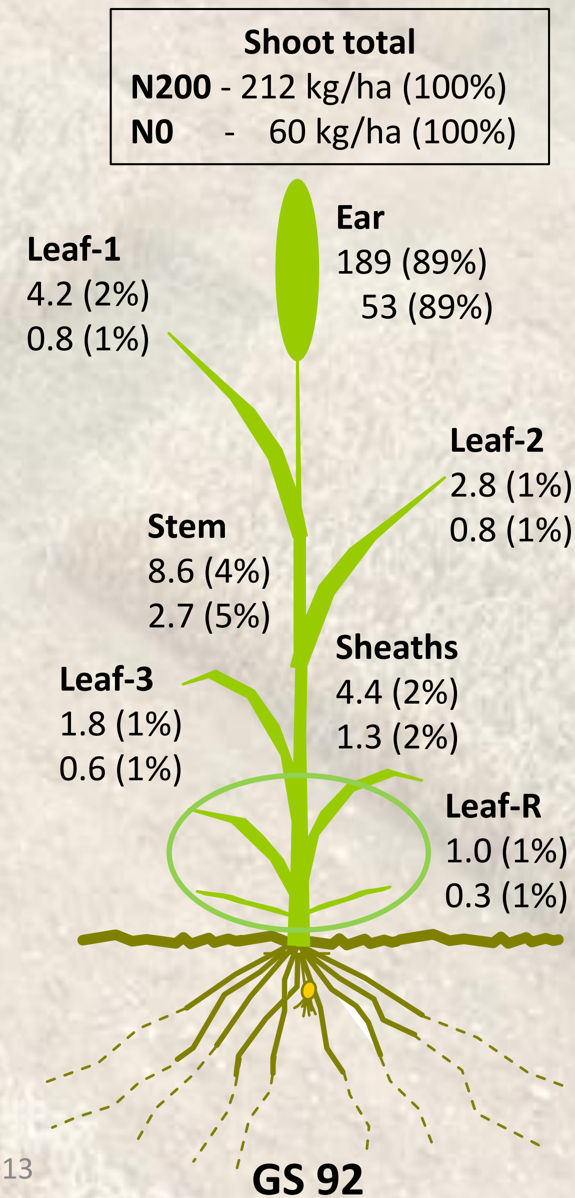

LOD0
11.0
8.8
6.6
4.4
2.2
0.0
cM
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
a(H1)
0.11
0.06
0.00
-0.06
-0.11
2 : 2007H200
8 : 2008rL100
14 : 2008wL1
20 : 2009L10
26 : 2010H20
32 : 2011H20

WGIN Diversity harvesting DH line 127 (D5) and line 82 (D6)

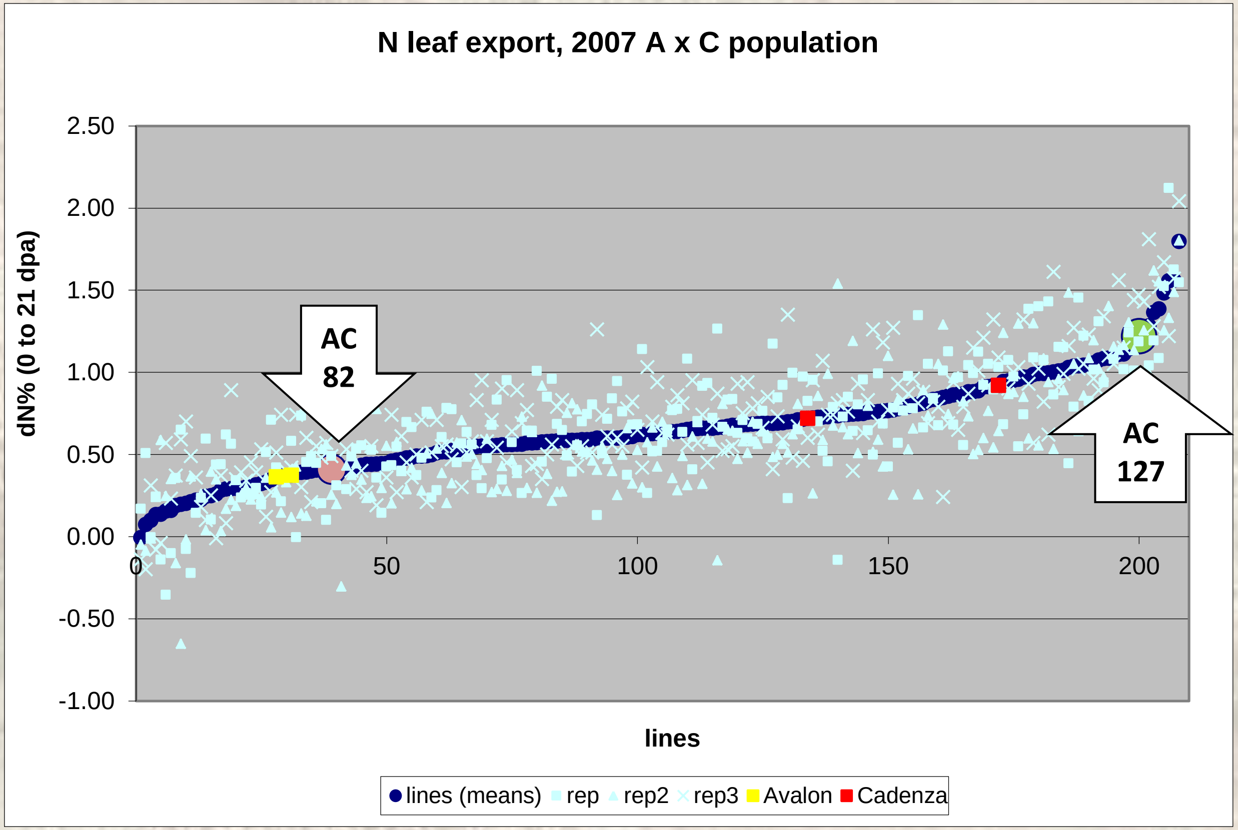
Avalon	AV	Gallant	GA	Mercia	ME	Xi19	XI		
Cadena	CA	Hereford	HF	Paragon	PA	Zebedee	ZE		
Chablis	CH	Hereward	HE	Riband	RI	AC 127	D5		
Claire	CL	Istabraq	IS	Robigus	RO	AC 82	D6		
Conqueror	CN	Malacca	MA	Stigg	ST				
Cordiale	CO	Marksman	MK	Soissons	SS				
Crusoe	CR	Maris Widgeon	MW	Solstice	SL				

N distribution in wheat main-stems at flowering and maturity

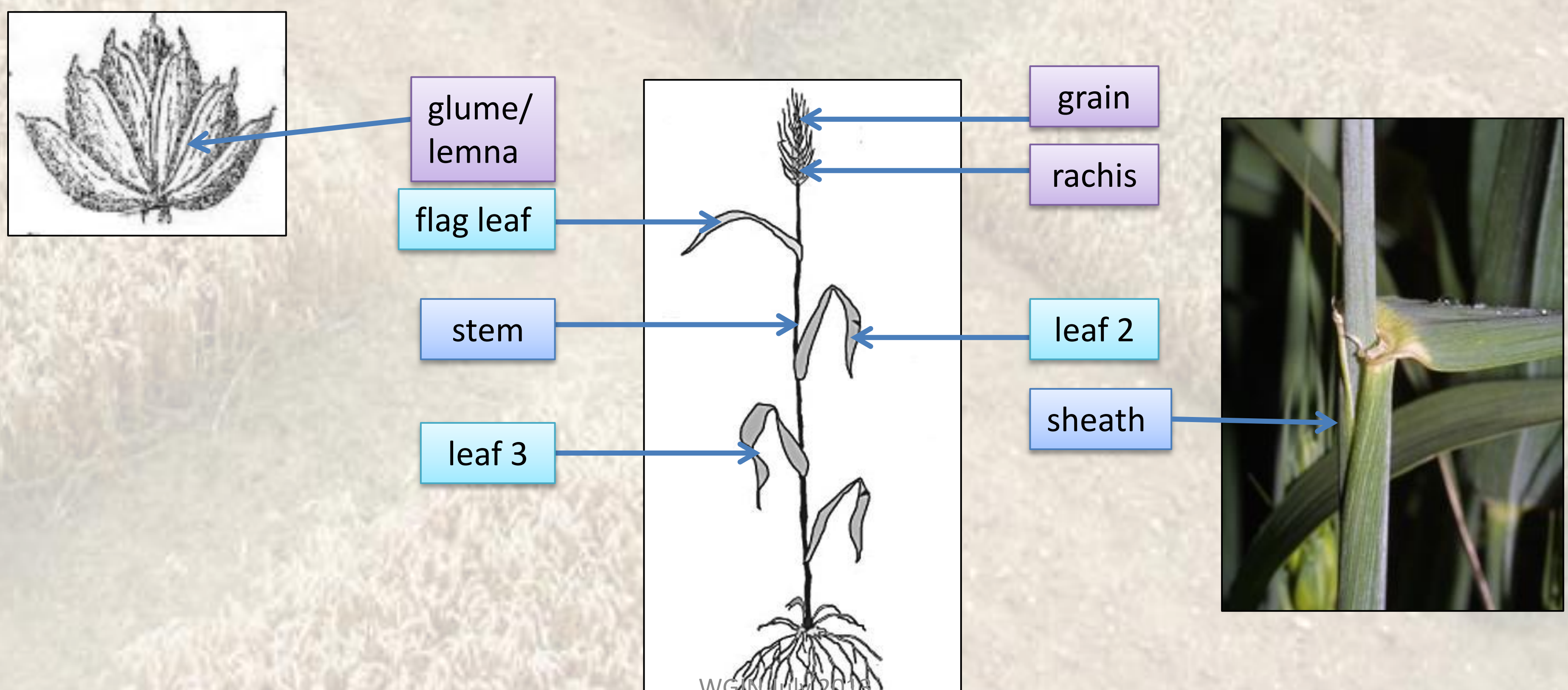




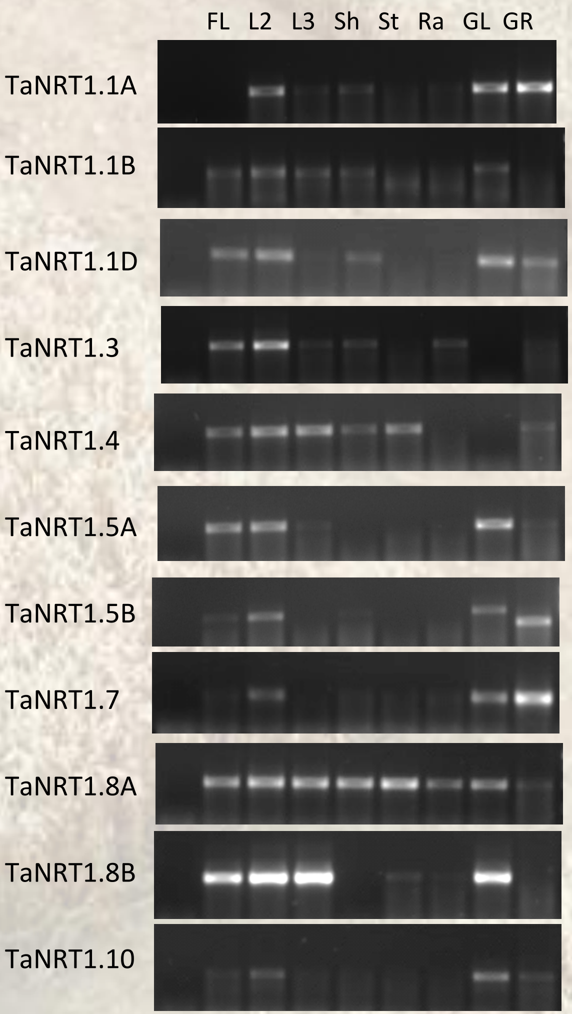
Double haploid lines 127 and line 82 were chosen from a Avalon/Cadenza double haploid mapping population because of their contrast characteristics in relation N leaf export (data 2007: early versus late leaf N-export).



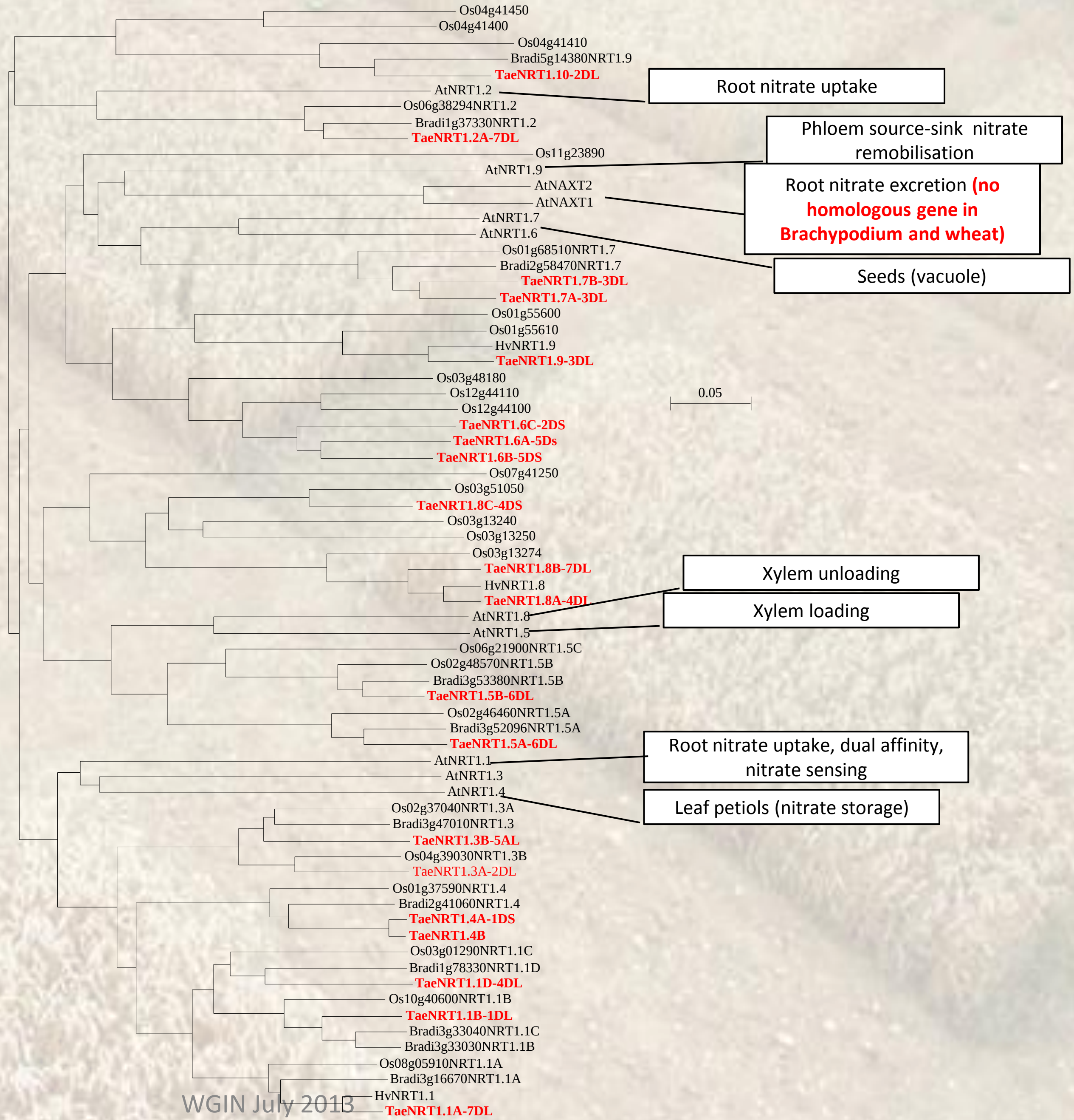
- Already observed differentially expression of specific target genes in the A xC lines 127 and 82 in leaves post anthesis
- In 2012 different tissues will be harvested at anthesis and weekly post-anthesis until complete senescence
- Extensive gene expression analysis of the different tissues will be performed to identify candidate genes involved in N-distribution and remobilisation in relation to post-anthesis grain N-filling.



Wheat low affinity Nitrate transporter in comparison to Barley, Brachypodium and Arabidopsis



Expression anthesis /
1 week post anthesis (grain/glume)



2012 varieties list (part 1)

Wheat varieties for WGIN-NUE 2010/11 W=WGIN data, D=desk study

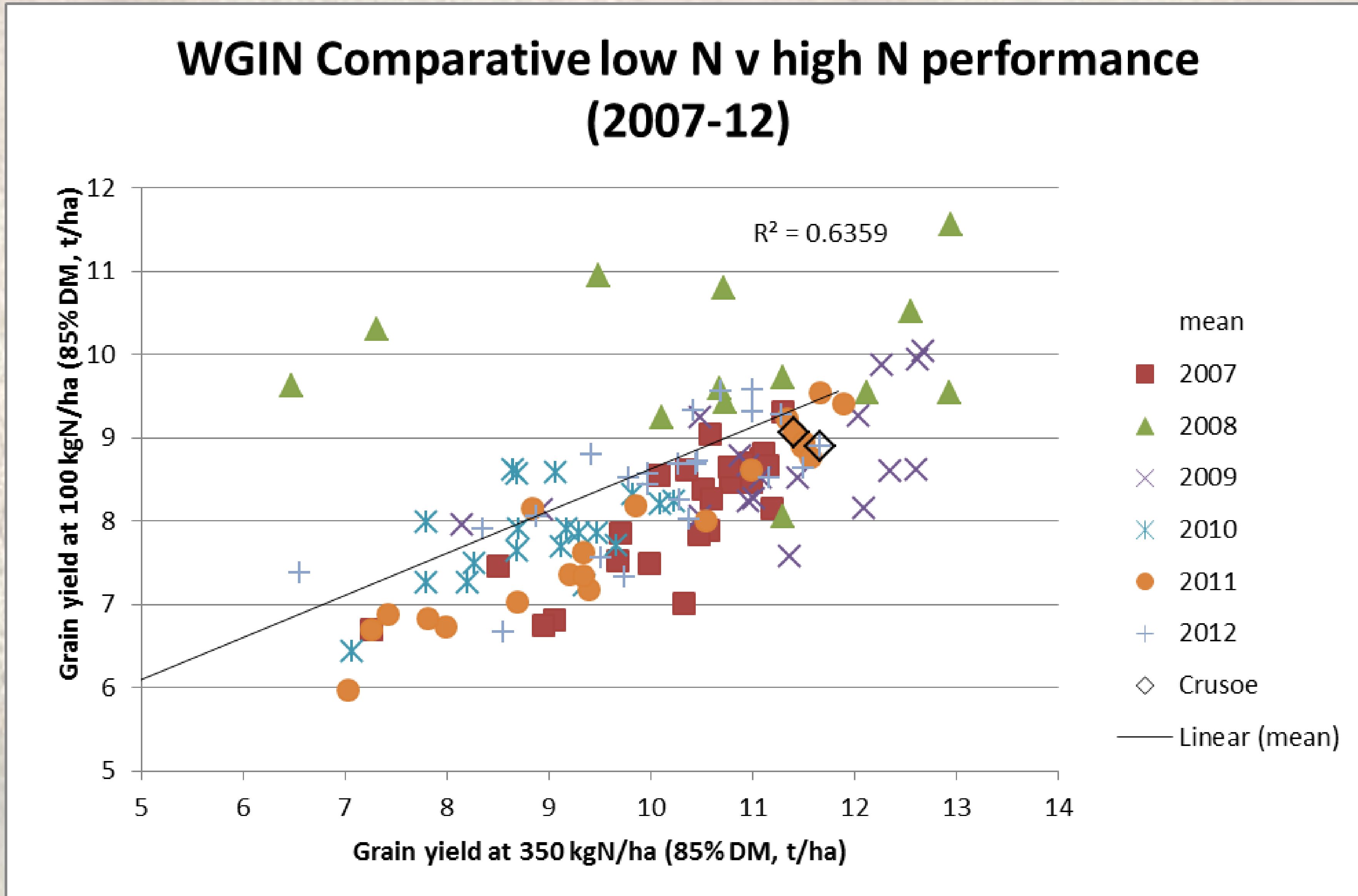
Variety	Source	Code	Nabim	Rationale	inclusion in trial requested by	Previous years of trials (harvest year)
1. Avalon	Av	AV	1	WGIN DH parent; Low NupE & NutE (D)	PB, RG, MJH	05-10
2. Cadenza	Ca	CA	2	WGIN DH parent; Best NupE (W)	PB, RG, MJH	04-10
3. Chablis NEW 09/10	KWS		2	SPRING variety (previous grown in 2004 trial) as very N-responsive variety	MH	only in 04 and 10
4. Claire NEW 2005	Nick	CL	3	Biggest area on RL; WGIN DH parent; Good second wheat	PB,PS	05-10
5. Conqueror	KWS	CN	4	New Grp 4, very high yielding	MH	new
6. Cordiale NEW 2006	KWS	CO	2	Good second wheat. BBSRC Quality project	RG	06-10
7. Crusoe NEW 10/11	Nick	CR	2	Carries dicoccoides. Shows the 'stay green' character		
8. Gallant NEW 09/10	Syn	GA	1	new claimed high yield and high protein type	MH	
9. Hereford	Syn	HF	4	Feed (not on RL), high yield, brown rust susceptible, possible low take-all build-up and good resistance.	KHK/RG	new
10. Hereward	RAGT	HE	1	Best protein on RL; benchmark bread variety. BBSRC Quality project	PB,PS	04-10
11. Istabraq NEW 2005	Nick	IS	4	Best yield on RL; Distilling cultivar; In LINK 'GREENgrain'; Good second wheat. BBSRC Quality project. WUE trial	PB,PS	05-10
12. Malacca	KWS	MA	1	Biggest Group 1 area; DH choice; Low NupE, high NutE (W). BBSRC Quality project	PS	04-10
13. Marksman	RAGT	MK	2	new for 2009, PRS request for BBSRC Quality project	PS	only 09 and 10

2012 varieties list (part 2)

W=WGIN data, D=desk study

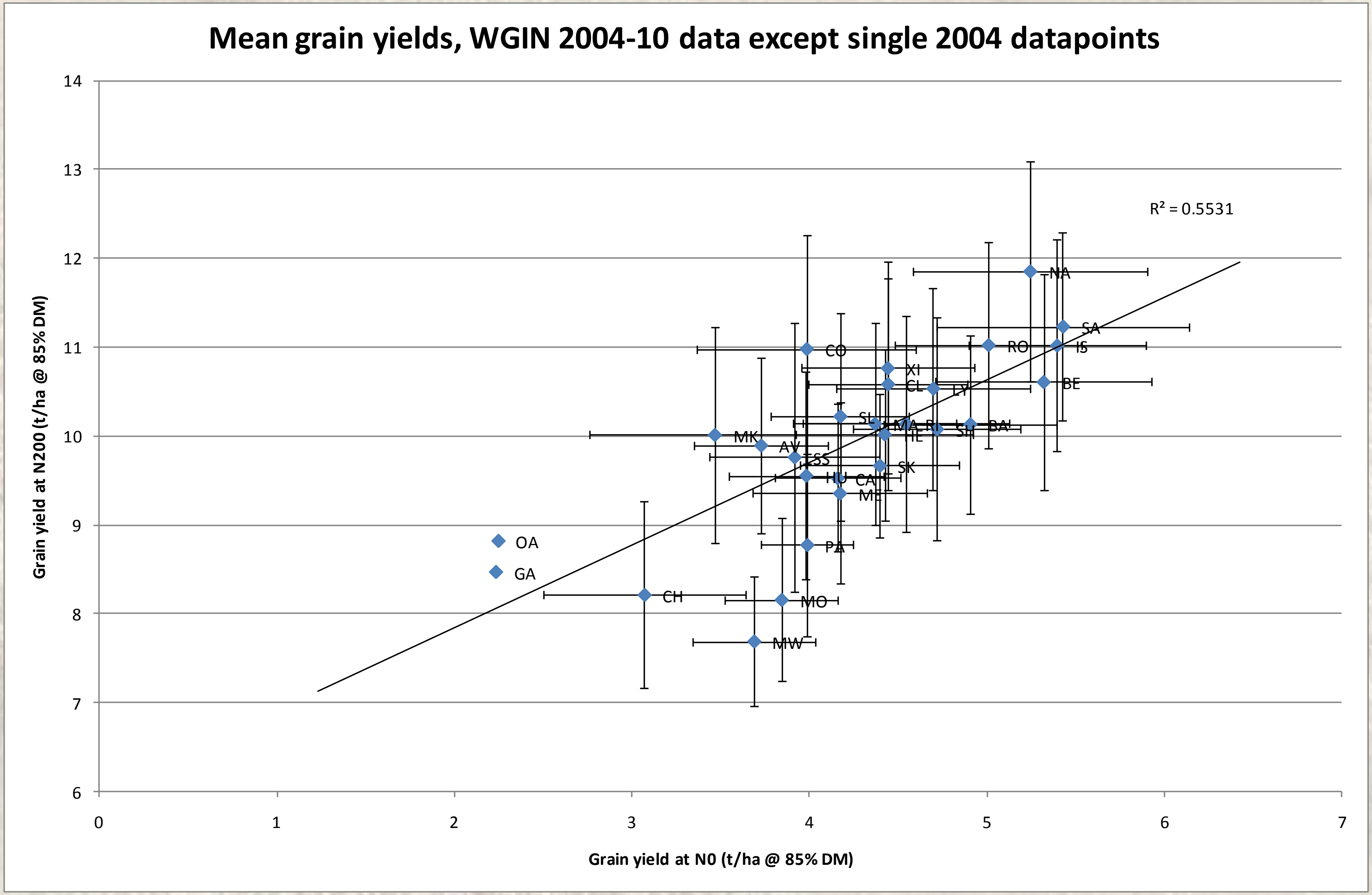
Variety	Source	Code	Nabim	Rationale	inclusion in trial requested by	Previous years of trials (harvest year)
14. Maris Widgeon		MW	1	Tall (rht), old cultivar	PB, AM	04-10
15. Mercia		ME	1	Low NupE & NutE (desk); Low Canopy N requirement; In IGF micro-array. WUE trial. RHT series	RG	04 and 06-10
16. Paragon	RAGT	PA	1	Spring variety; WGIN mutagenesis population; High NupE (W)	PB	04-10
17. Riband	RAGT	RI	3	WGIN DH parent; Distilling cultivar; In LINK 'GREENgrain'; High NutE (W)	RG	04-10
18. Robigus NEW 2005	KWS	RO	3	Best Group 3 yield; Best NUE, high NupE & NutE (D); Good second wheat. WUE trial	PB, AM	05-10
19. Stigg NEW 10/11	Nick	ST	?4	Carries dicoccoides. High disease resistance. Shows the 'stay green' character		
20 Soissons	Elsoms	SS	2	WGIN DH parent; Early maturing; High NupE, low NutE (W)	PB,RG, AM	04-10
21. Solstice	Nick	SL	2	Biggest Group 2 area; DH choice; Worst NupE (W)	RG	04-10
22. Xi19	Nick	XI	1	Best Group 1 yield; High NUE, NupE, NutE (D); Low NupE (W). BBSRC Quality project. WUE trial	PB,PS	04-10
23. Zebedee	LIM	ZE	3	High WUE, grp 3	JFoulkes	new
24. AxC line 127		D5		new in 2009 - good early export from leaves	MJH	09/10/
25. AxC line 82		D6		new in 2009 - slow early export from leaves	MJH	09/10/

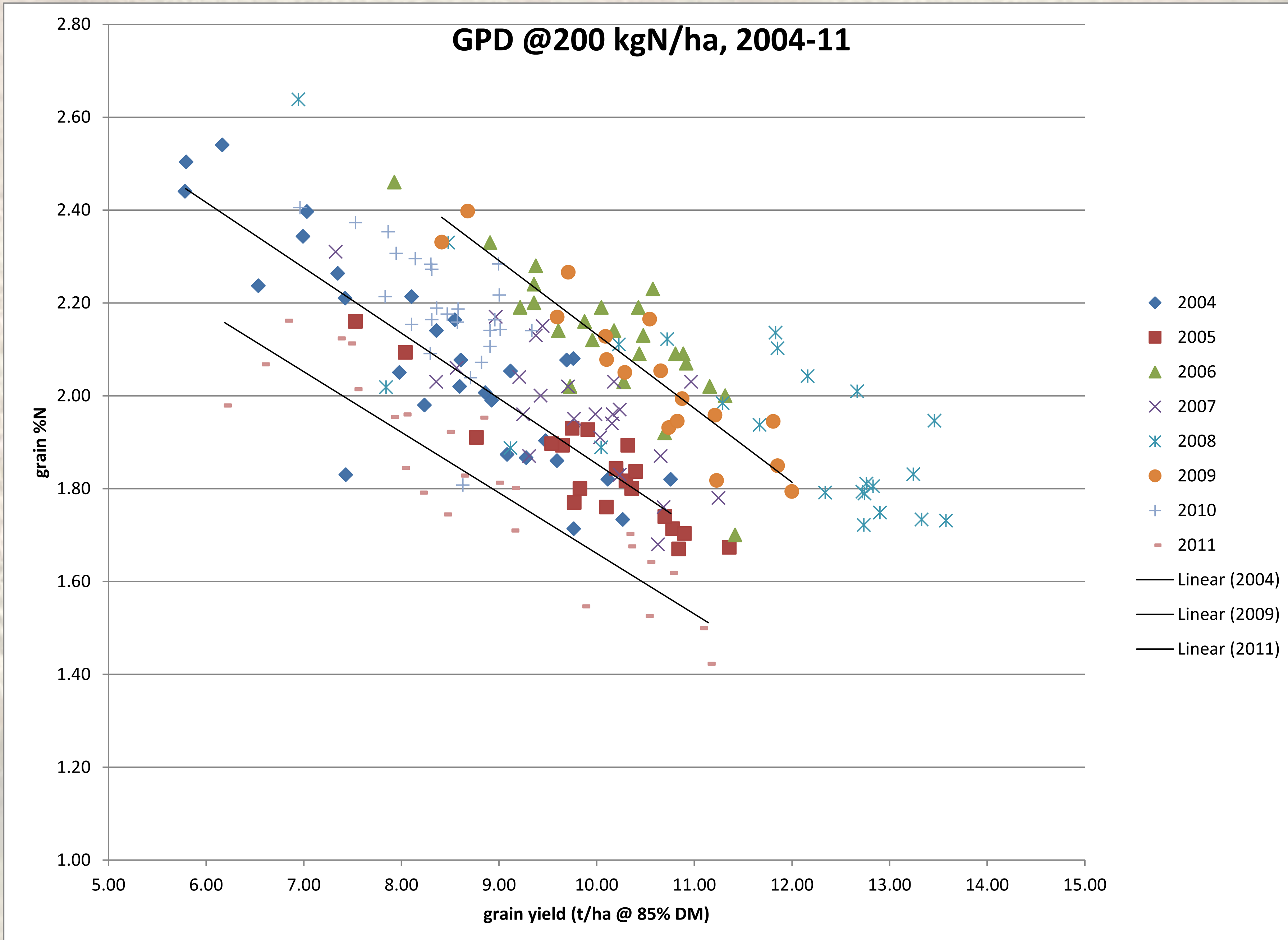
Removed from trial: 2 A x C lines and Oakley

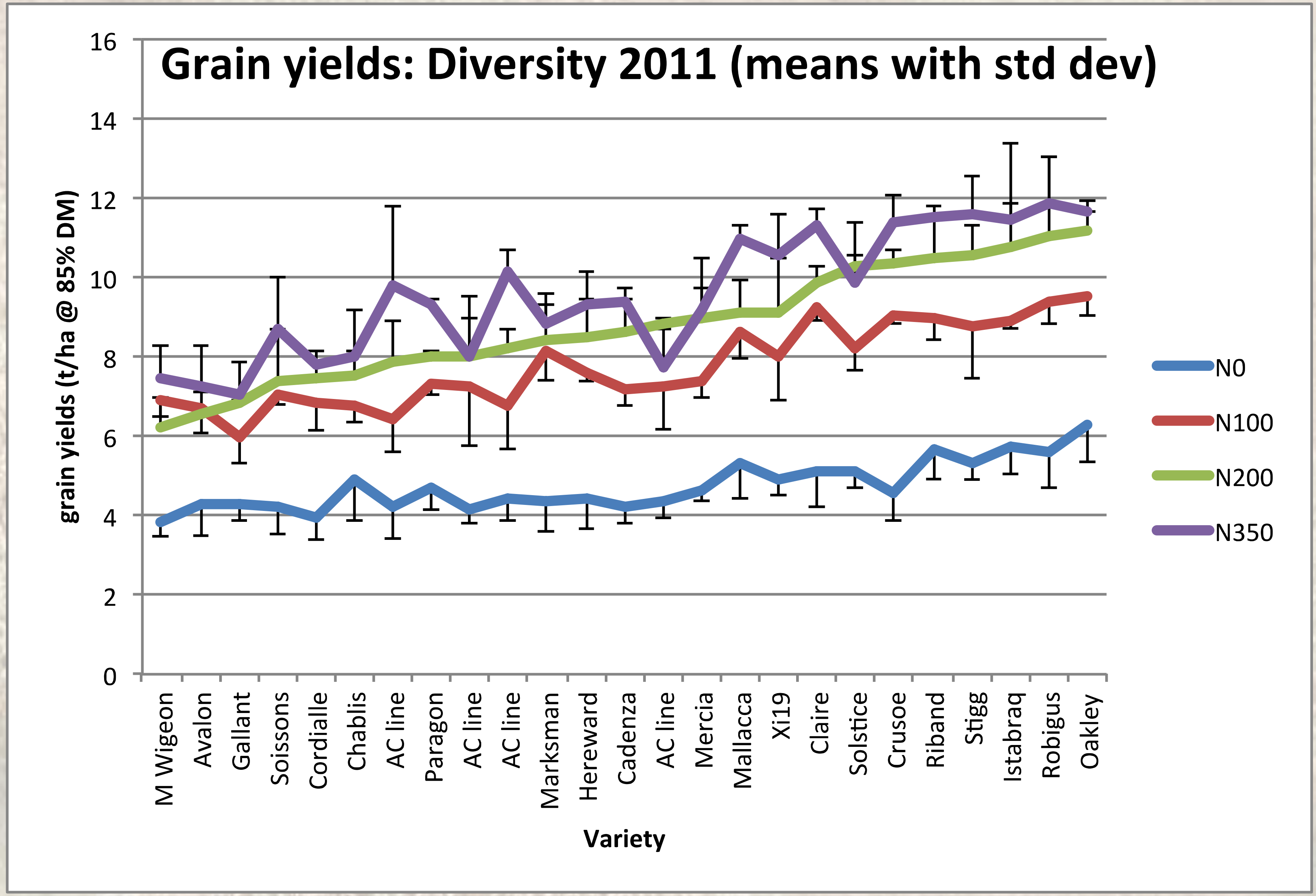


WGIN Comparative low N v high N performance (2007-12)
R^2 = 0.6359
Grain yield at 100 kgN/ha (85% DM, t/ha)
Grain yield at 350 kgN/ha (85% DM, t/ha)
5
6
7
8
9
10
11
12
13
14
mean
2007
2008
2009
2010
2011
2012
Crusoe
Linear (mean)

Performance at N200 compared to N0

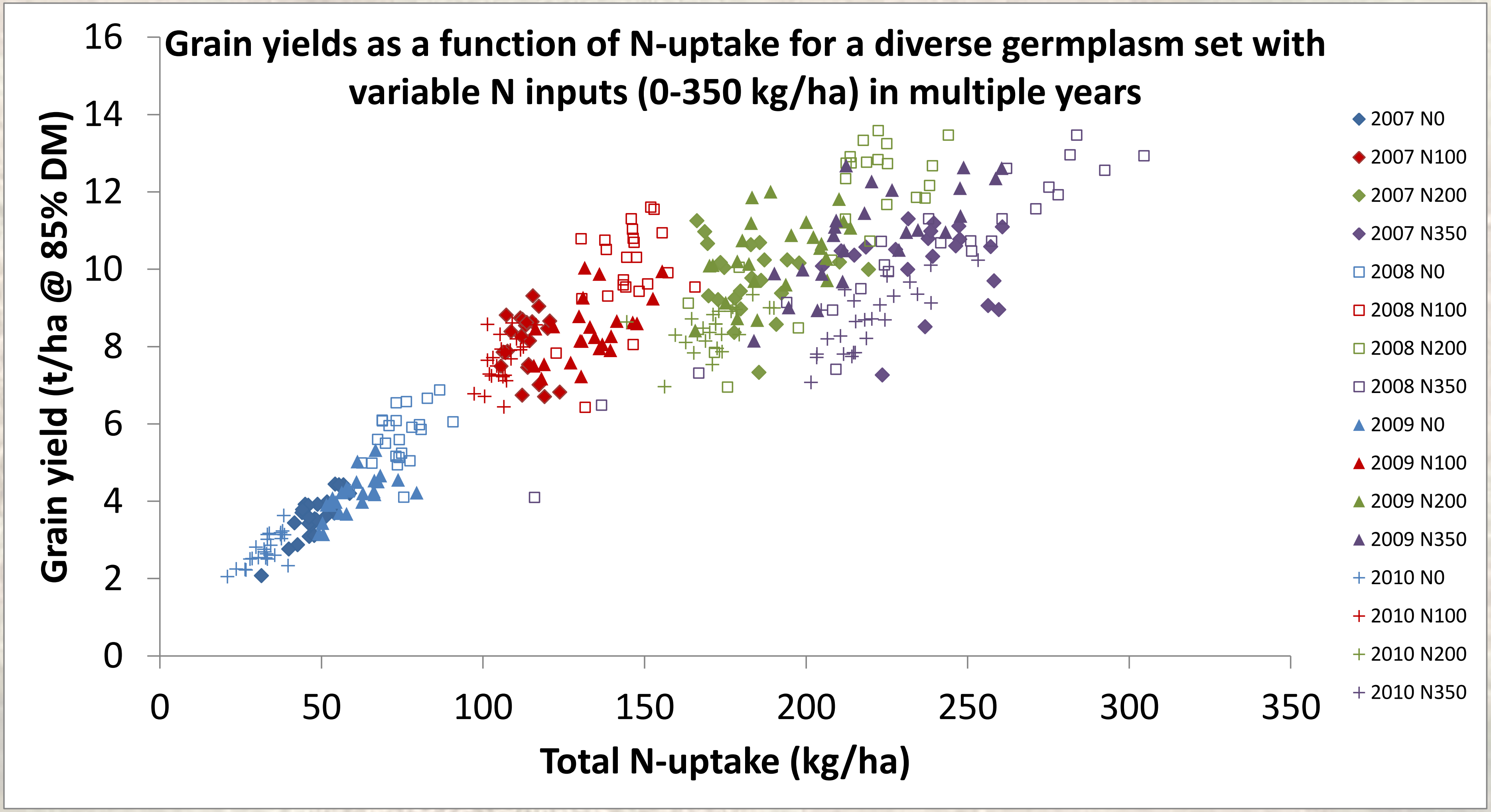



GPD @200 kgN/ha, 2004-11
grain %N
grain yield (t/ha @ 85% DM)
2.80
2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
13.00
14.00
15.00
2004
2005
2006
2007
2008
2009
2010
2011
Linear (2004)
Linear (2009)
Linear (2011)



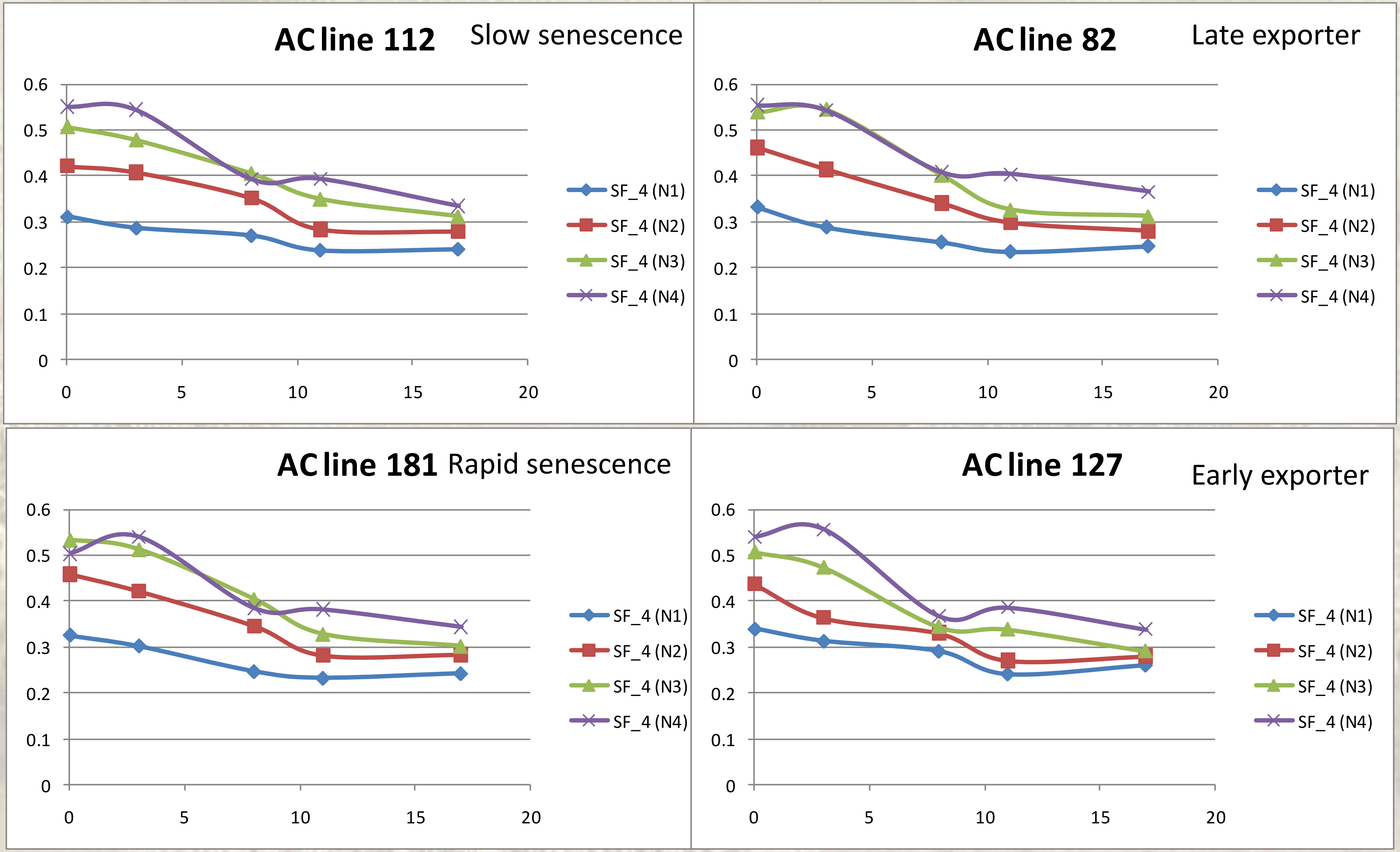
Grain yields: Diversity 2011 (means with std dev)
grain yields (t/ha @ 85% DM)
16
14
12
10
8
6
4
2
0
M Wigeon
Avalon
Gallant
Soissons
Cordialle
Chablis
AC line
Paragon
AC line
AC line
Marksman
Hereward
Cadenza
AC line
Mercia
Mallacca
Xi19
Claire
Solstice
Crusoe
Riband
Stigg
Istabraq
Robigus
Oakley
Variety
N0
N100
N200
N350

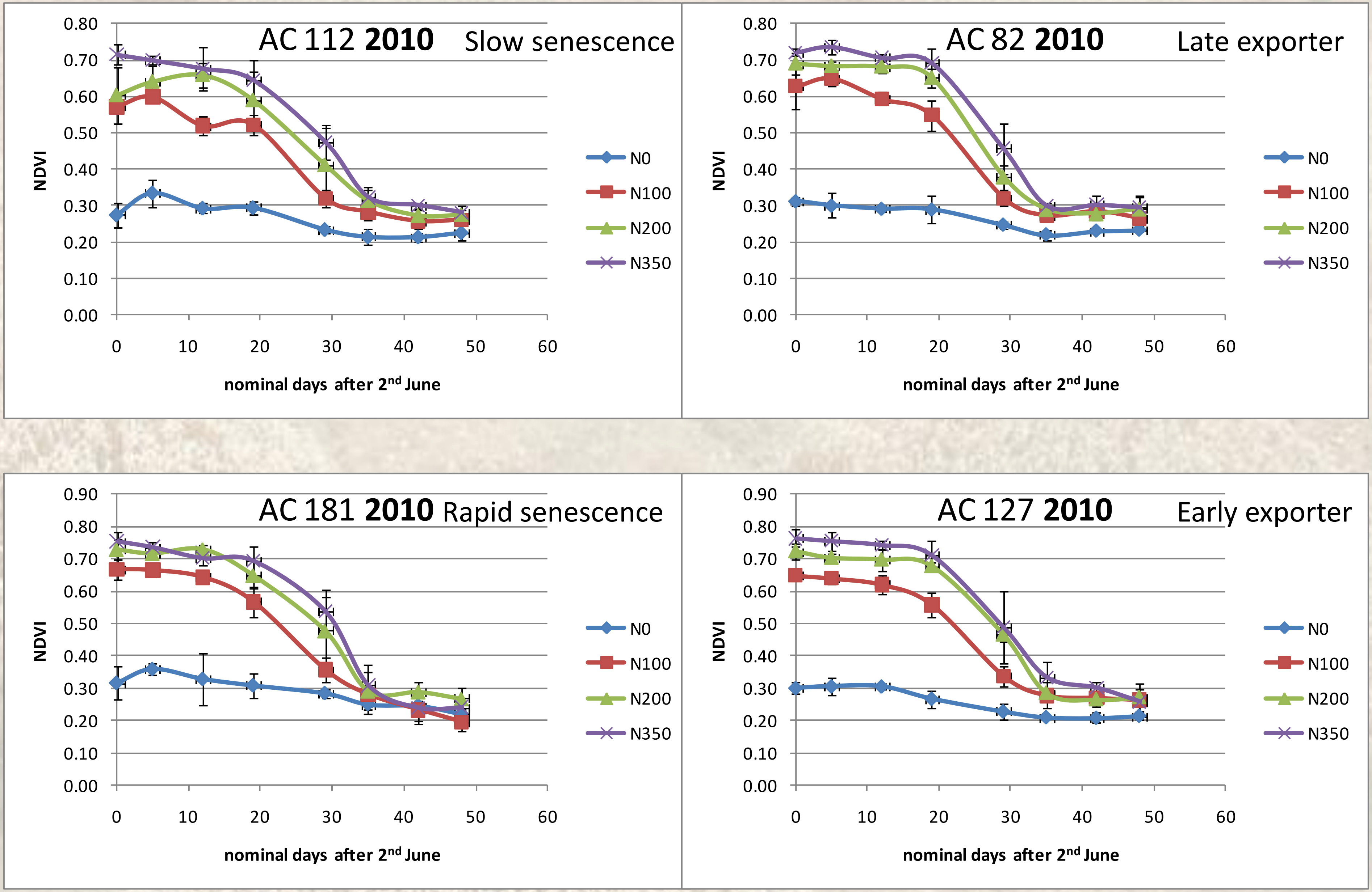
Avalon x Cadenza 2011


Grain yields as a function of N-uptake for a diverse germplasm set with variable N inputs (0-350 kg/ha) in multiple years
Grain yield (t/ha @ 85% DM)
Total N-uptake (kg/ha)
0
2
4
6
8
10
12
14
16
0
50
100
150
200
250
300
350
2007 N0
2007 N100
2007 N200
2007 N350
2008 N0
2008 N100
2008 N200
2008 N350
2009 N0
2009 N100
2009 N200
2009 N350
2010 N0
2010 N100
2010 N200
2010 N350

Diversity Trial 2011

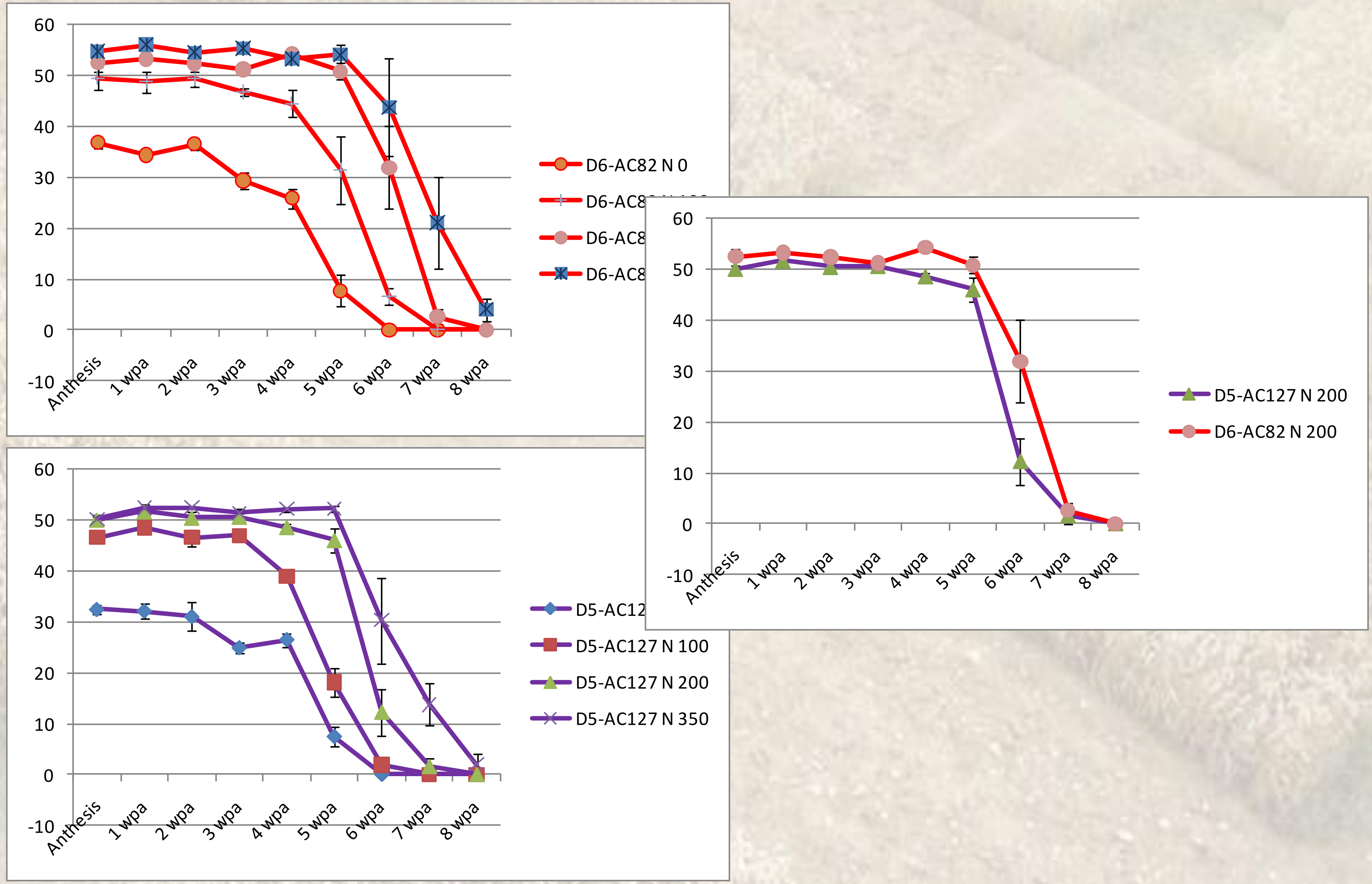
CropCircle (Holland Scientific), WGIN Diversity 2011





AC 112 2010 Slow senescence
AC 82 2010 Late exporter
AC 181 2010 Rapid senescence
AC 127 2010 Early exporter
NDVI
nominal days after 2nd June
N0
N100
N200
N350

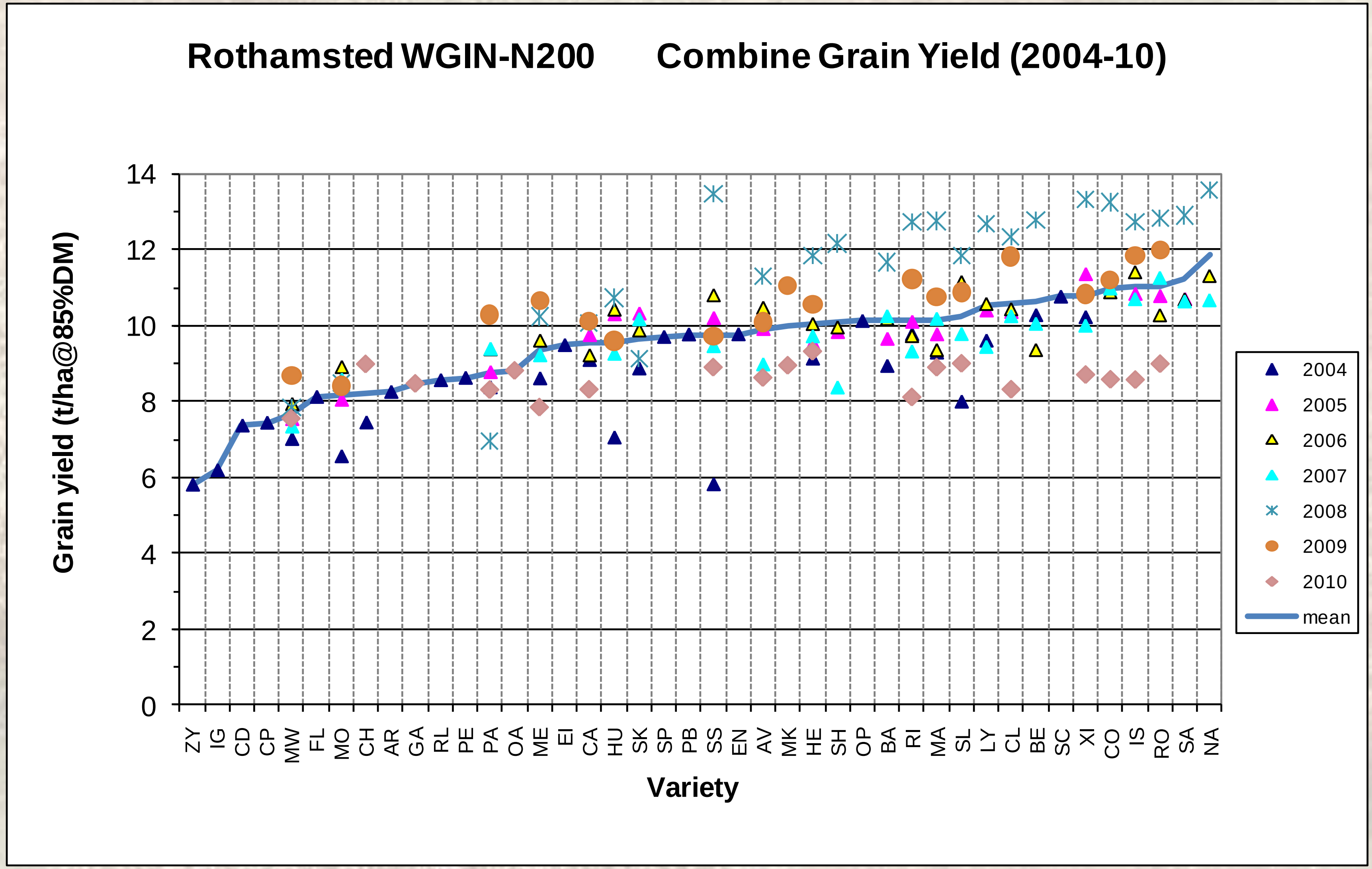
Spad data 2011 WGIN Diversity



Why nitrogen?

- Required for yield
- Required for protein
- Costs – financial/environmental
- Low efficiency on worldwide scale but higher in UK
- Management and genetic components

Stability


Rothamsted WGIN-N200 Combine Grain Yield (2004-10)
Grain yield (t/ha@85%DM)
0
2
4
6
8
10
12
14
ZY IG CD CP MW FL MO CH AR GA RL PE PA OA ME EI CA HU SK SP PB SS EN AV MK HE SH OP BA RI MA SL LY CL BE SC XI CO IS RO SA NA
Variety
2004
2005
2006
2007
2008
2009
2010
mean

WGIN NUE Objectives

- Define important NUE traits
- Identify and evaluate diversity
- Determine mechanisms
- Provide leads for markers and genes
- Examine trait stability over multiple years
- Trials and basic datasets

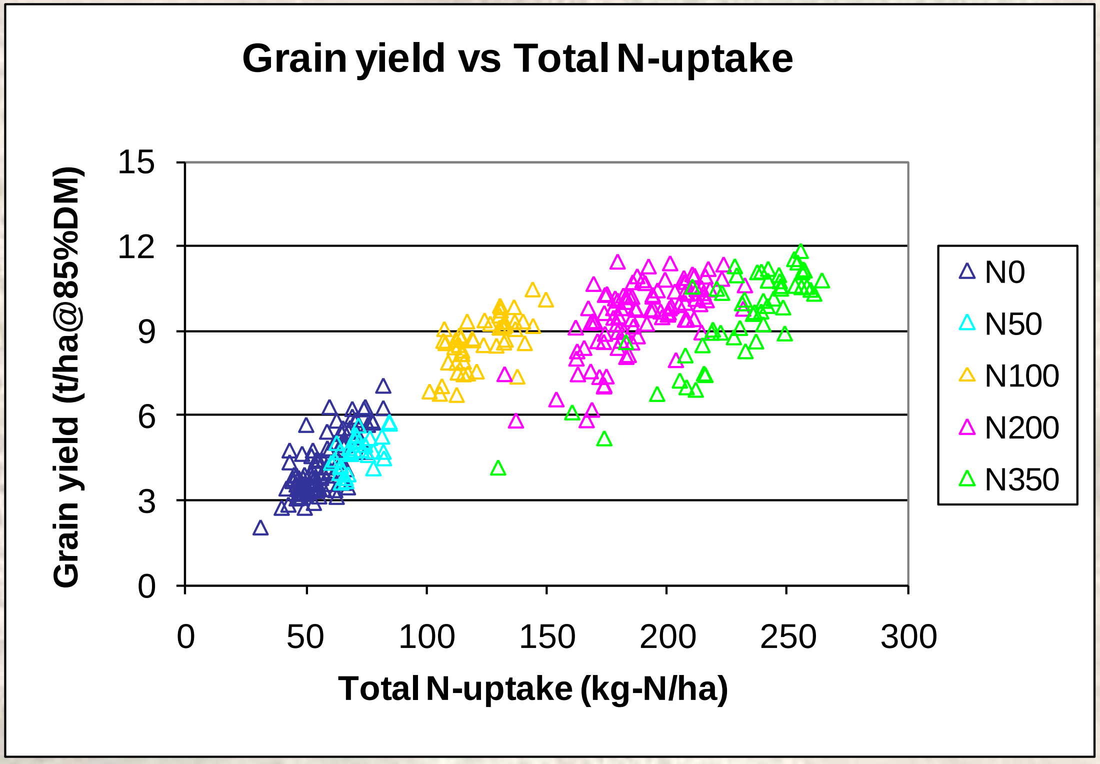
Approaches

- Modern commercial germplasm (Diversity) and mapping population (Avalon x Cadenza) trials
- Assessment of trial diversity in the field
- Identify QTL

Example results

- Trait performance rankings
- Stability
- Yield plateauing
- Performance at low compared to high N input
- qtls

Grain yield plateau



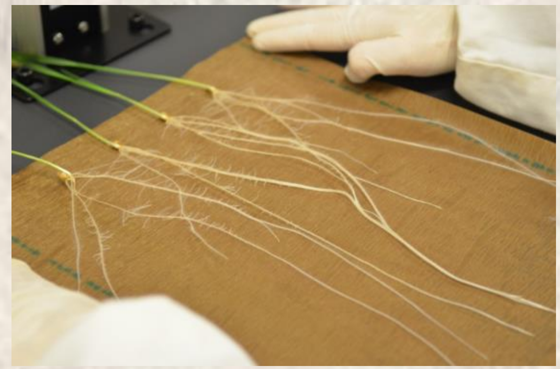
(mean data 2004-07)

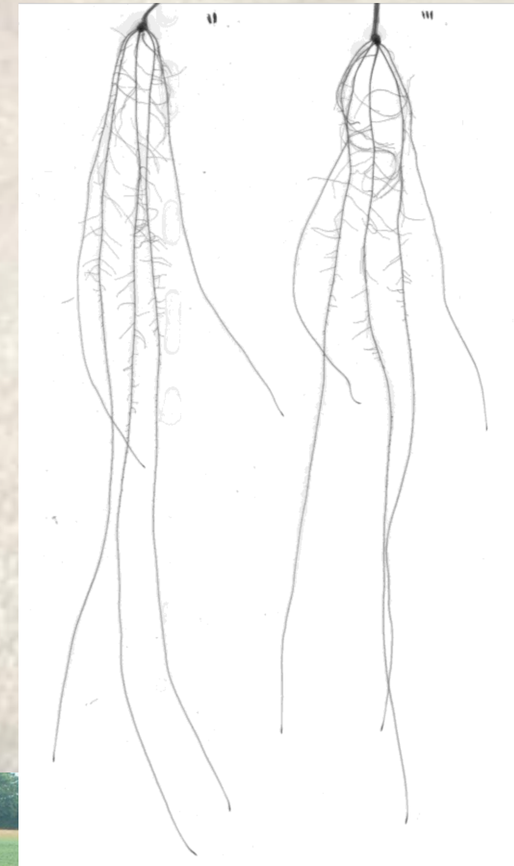
- Grain yield less strongly related to N uptake
- Plateau of yield although uptake increases with increasing N supply
- Cluster (no relationship between yield and uptake) at any one N supply both between treatments and between varieties
- Factors other than uptake limiting yield

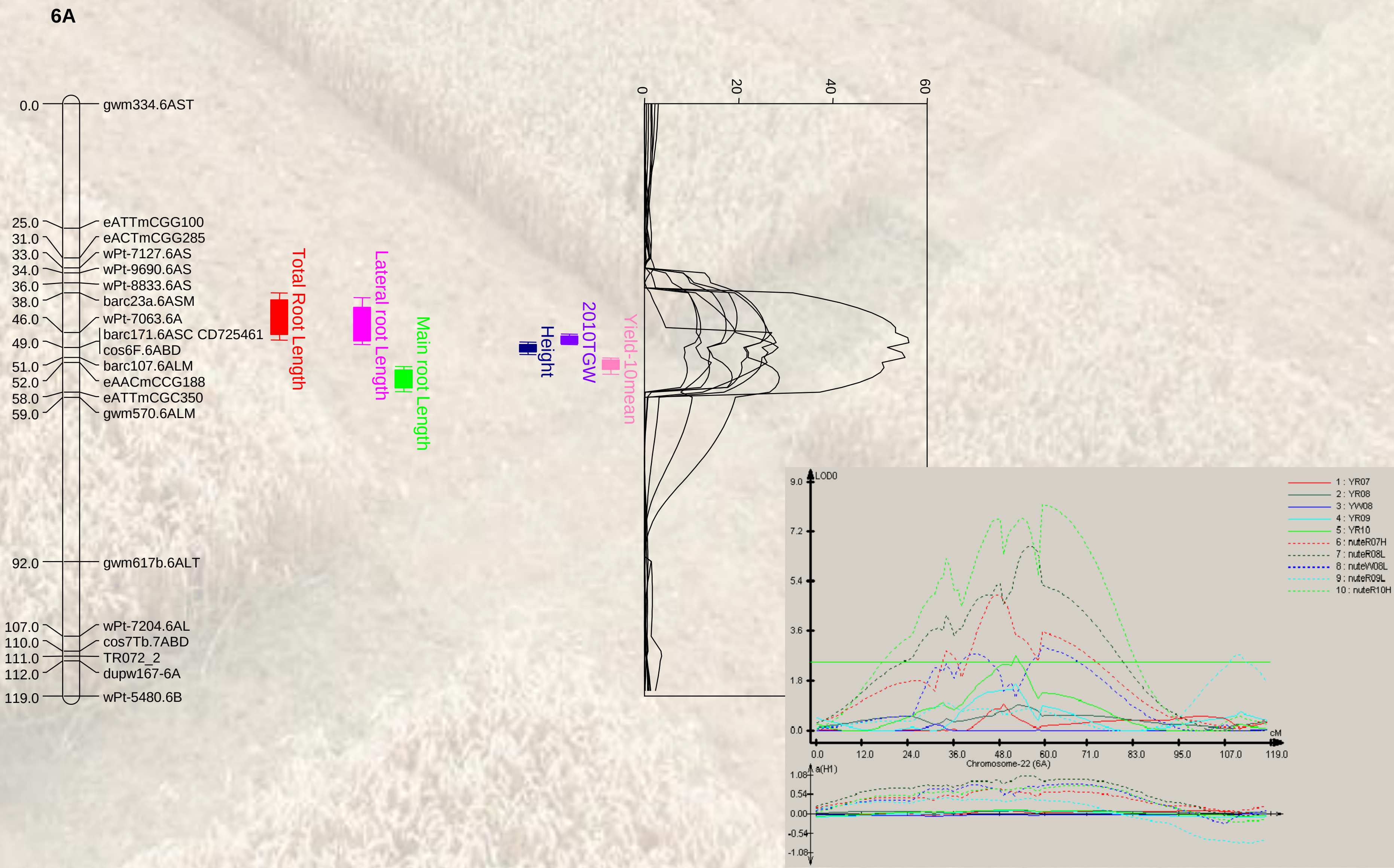
Avalon x Cadenza mapping population

- Traits for NUE – grain/straw yields/N uptake
- High and low N inputs
- Multiple years
- Analysis of post anthesis canopy dynamics and function
- Assessment of variability in uptake capabilities

Variation in root traits: mapping QTLs







6A
0.0 gwm334.6AST
25.0 eATTmCGG100
31.0 eACTmCGG285
33.0 wPt-7127.6AS
34.0 wPt-9690.6AS
36.0 wPt-8833.6AS
38.0 barc23a.6ASM
46.0 wPt-7063.6A
49.0 barc171.6ASC CD725461
cos6F.6ABD
51.0 barc107.6ALM
52.0 eAACmCCG188
58.0 eATTmCGC350
59.0 gwm570.6ALM
92.0 gwm617b.6ALT
107.0 wPt-7204.6AL
110.0 cos7Tb.7ABD
111.0 TR072_2
112.0 dupw167-6A
119.0 wPt-5480.6B
Total Root Length
Lateral root Length
Main root Length
Height
2010TGW
Yield-10mean
0
20
40
60
LOD0
9.0
7.2
5.4
3.6
1.8
0.0
1 : YR07
2 : YR08
3 : YW08
4 : YR09
5 : YR10
6 : nuteR07H
7 : nuteR08L
8 : nuteW08L
9 : nuteR09L
10 : nuteR10H
cM
0.0 12.0 24.0 36.0 48.0 60.0 71.0 83.0 95.0 107.0 119.0
Chromosome-22 (6A)
a(H1)
1.08
0.54
0.00
-0.54
-1.08

2011 varieties list (part 1)

Wheat varieties for WGIN-NUE 2010/11 W=WGIN data, D=desk study

Variety	Source	Code	Nabim	Rationale	inclusion in trial requested by	Previous years of trials (harvest year)
1. Avalon	Av	AV	1	WGIN DH parent; Low NupE & NutE (D)	PB, RG, MJH	05-10
2. Cadenza	Ca	CA	2	WGIN DH parent; Best NupE (W)	PB, RG, MJH	04-10
3. Chablis NEW 09/10	KWS		2	SPRING variety (previous grown in 2004 trial) as very N-responsive variety	MH	only in 04 and 10
4. Claire NEW 2005	Nick	CL	3	Biggest area on RL; WGIN DH parent; Good second wheat	PB,PS	05-10
5. Cordiale NEW 2006	KWS	CO	2	Good second wheat. BBSRC Quality project	RG	06-10
6. Crusoe NEW 10/11	Nick	CR	2	Carries dicoccoides. Shows the 'stay green' character		
7. Gallant NEW 09/10	Syn	GA	1	new claimed high yield and high protein type	MH	
8. Hereward	RAGT	HE	1	Best protein on RL; benchmark bread variety. BBSRC Quality project	PB,PS	04-10
9. Istabraq NEW 2005	Nick	IS	4	Best yield on RL; Distilling cultivar; In LINK 'GREENgrain'; Good second wheat. BBSRC Quality project. WUE trial	PB,PS	05-10
10. Malacca	KWS	MA	1	Biggest Group 1 area; DH choice; Low NupE, high NutE (W). BBSRC Quality project	PS	04-10
11. Marksman	RAGT	MK	2	new for 2009, PRS request for BBSRC Quality project	PS	only 09 and 10
12. Maris Widgeon		MW	1	Tall (rht), old cultivar	PB, AM	04-10
13. Mercia		ME	1	Low NupE & NutE (desk); Low Canopy N requirement; In IGF micro-array. WUE trial. RHT series	RG	04 and 06-10

2011 varieties list (part 2)

W=WGIN data, D=desk study

Variety	Source	Code	Nabim	Rationale	inclusion in trial requested by	Previous years of trials (harvest year)
14. Oakley NEW 09/10	KWS		4 (hard)	Hard milling type. Highest yielding wheat on RL.	MH	
15. Paragon	RAGT	PA	1	Spring variety; WGIN mutagenesis population; High NupE (W)	PB	04-10
16. Riband	RAGT	RI	3	WGIN DH parent; Distilling cultivar; In LINK 'GREENgrain'; High NutE (W)	RG	04-10
17. Robigus NEW 2005	KWS	RO	3	Best Group 3 yield; Best NUE, high NupE & NutE (D); Good second wheat. WUE trial	PB, AM	05-10
18. Stigg NEW 10/11	Nick	ST	?4	Carries dicoccoides. High disease resistance. Shows the 'stay green' character		
19 Soissons	Elsoms	SS	2	WGIN DH parent; Early maturing; High NupE, low NutE (W)	PB,RG, AM	04-10
20. Solstice	Nick	SL	2	Biggest Group 2 area; DH choice; Worst NupE (W)	RG	04-10
21. Xi19	Nick	XI	1	Best Group 1 yield; High NUE, NupE, NutE (D); Low NupE (W). BBSRC Quality project. WUE trial	PB,PS	04-10
22. AxC line 181		D3		new in 2010 - rapid canopy senescence	MJH	10/
23. AxC line 112		D4		new in 2010 - slow canopy senescence	MJH	10/
24. AxC line 127		D5		new in 2009 - good early export from leaves	MJH	09/10/
25. AxC line 82		D6		new in 2009 - slow early export from leaves	MJH	09/10/

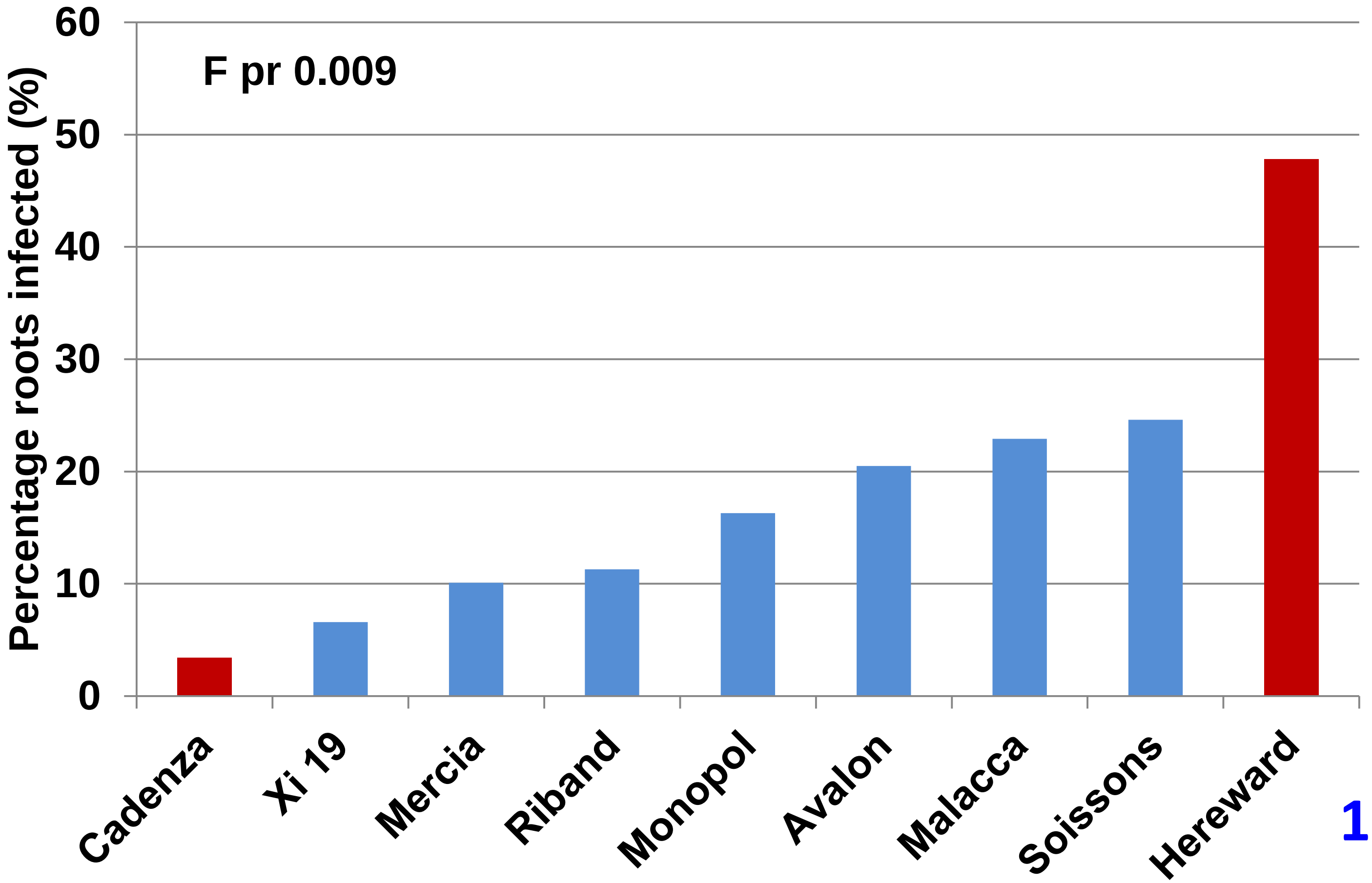
WGIN MM 3rd July 2013

Objective 10: Take-all disease Cultivar Rotation Trial Update

Vanessa McMillan
Richard Gutteridge
Kim Hammond-Kosack

WGIN winter wheat soil core bioassay (4 year means)

New trait is called **TAB** (**T**ake-**A**ll inoculum **B**uild-up)

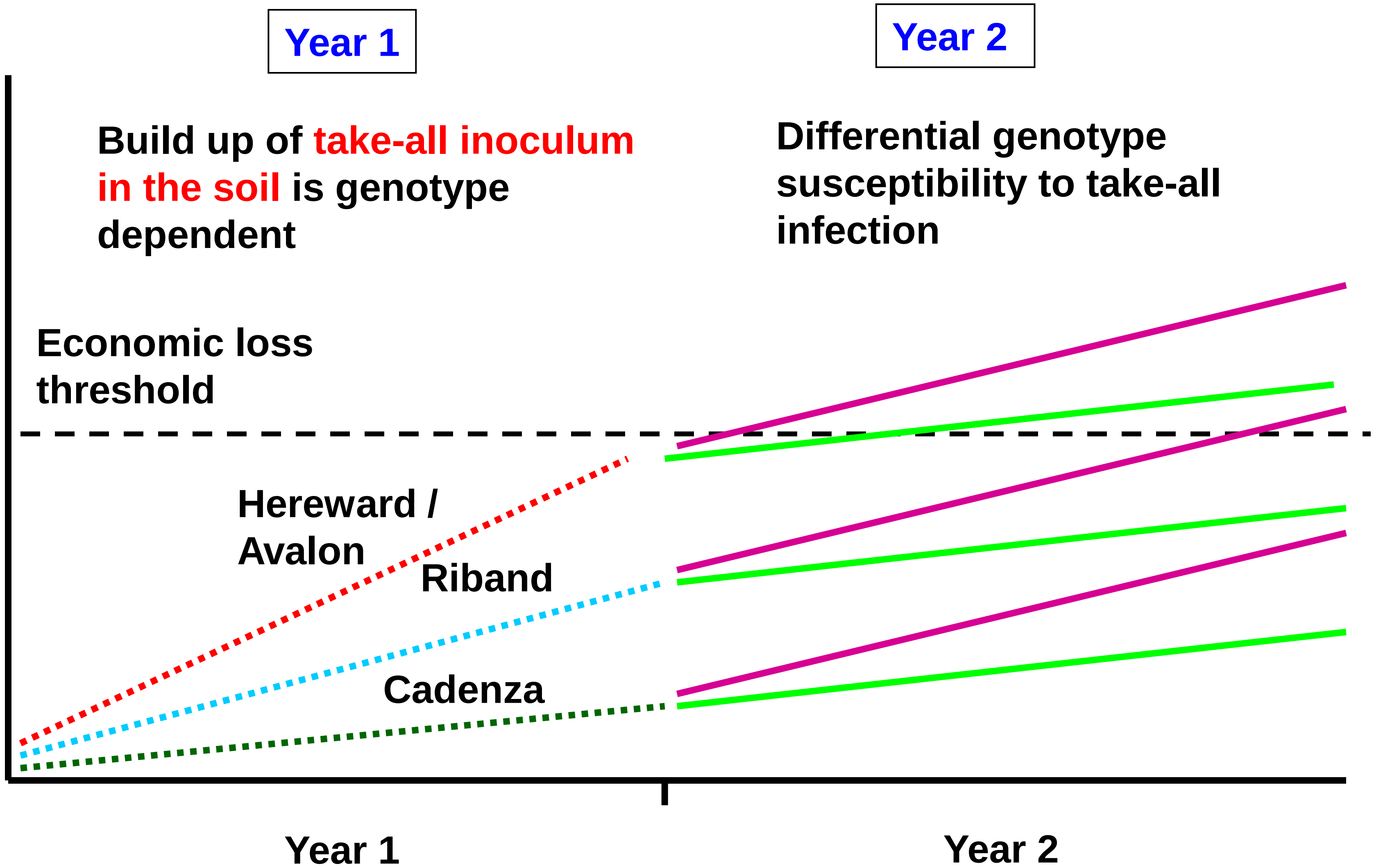


1st wheats

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

Cultivar rotation trials

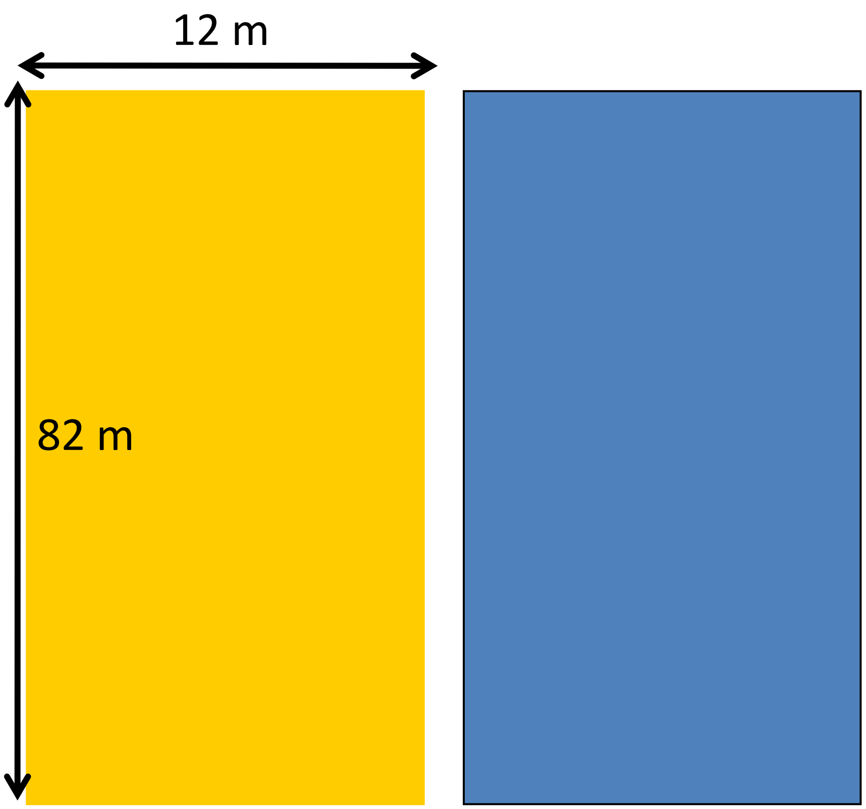
Overall objective: **Explore the effect of sowing different sequences of cultivars on take-all disease pressure**



Cultivar rotation trials

Overall objective: Explore the effect of different cultivar sequences on take-all disease pressure

Step 1: Year 1 To create different take-all disease pressures in the field using the varieties **Hereward** (high inoculum build up) and **Cadenza** (low inoculum build up)

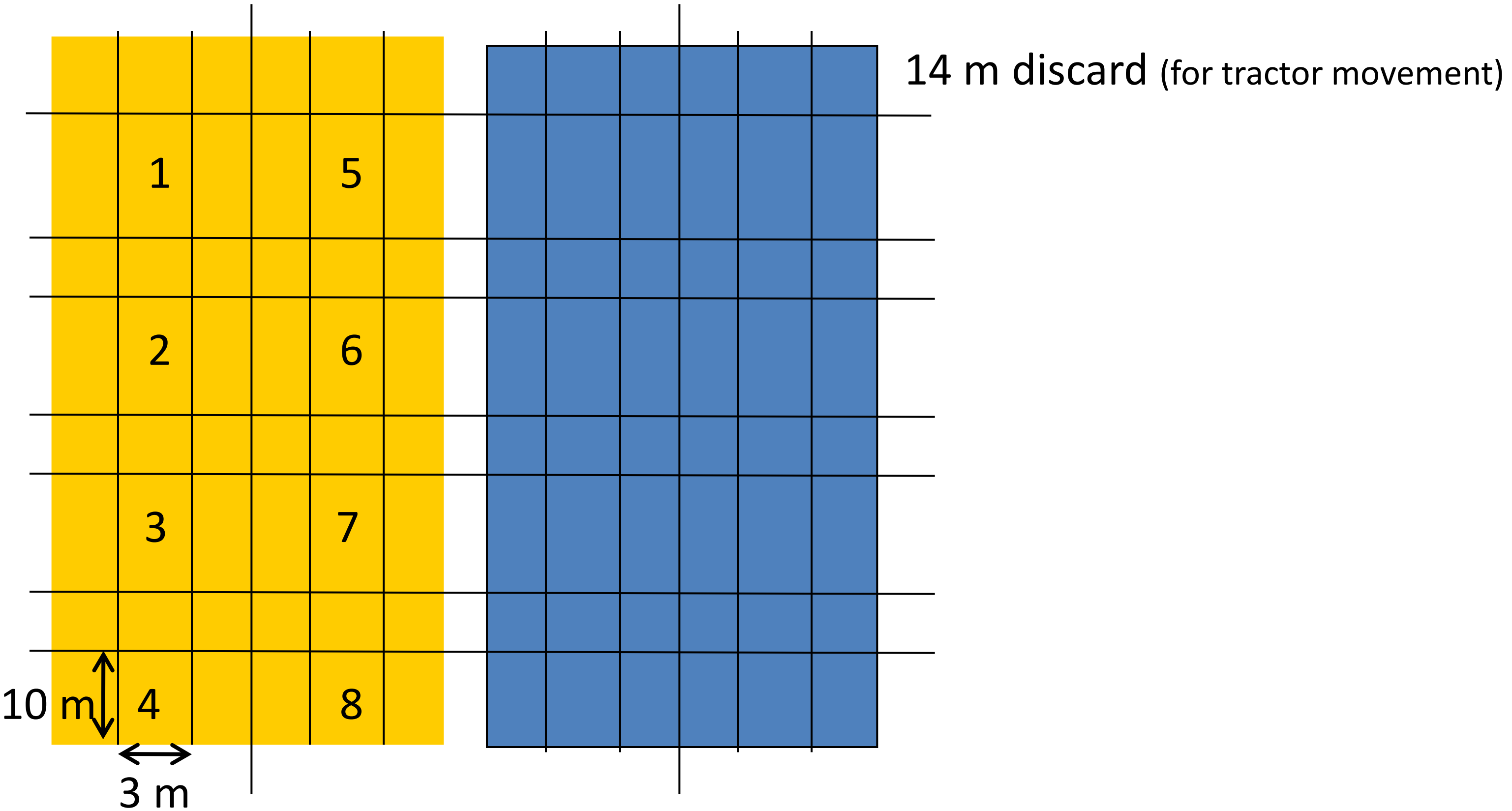


12m x 82m, of each variety
4 replicates of each

Cultivar rotation trials

Overall objective: Explore the effect of different cultivar sequences on take-all disease pressure

Step 2: Year 2 Each of the Year 1 large plots **divided into eight 10m x 3m** for the Year 2 field season.

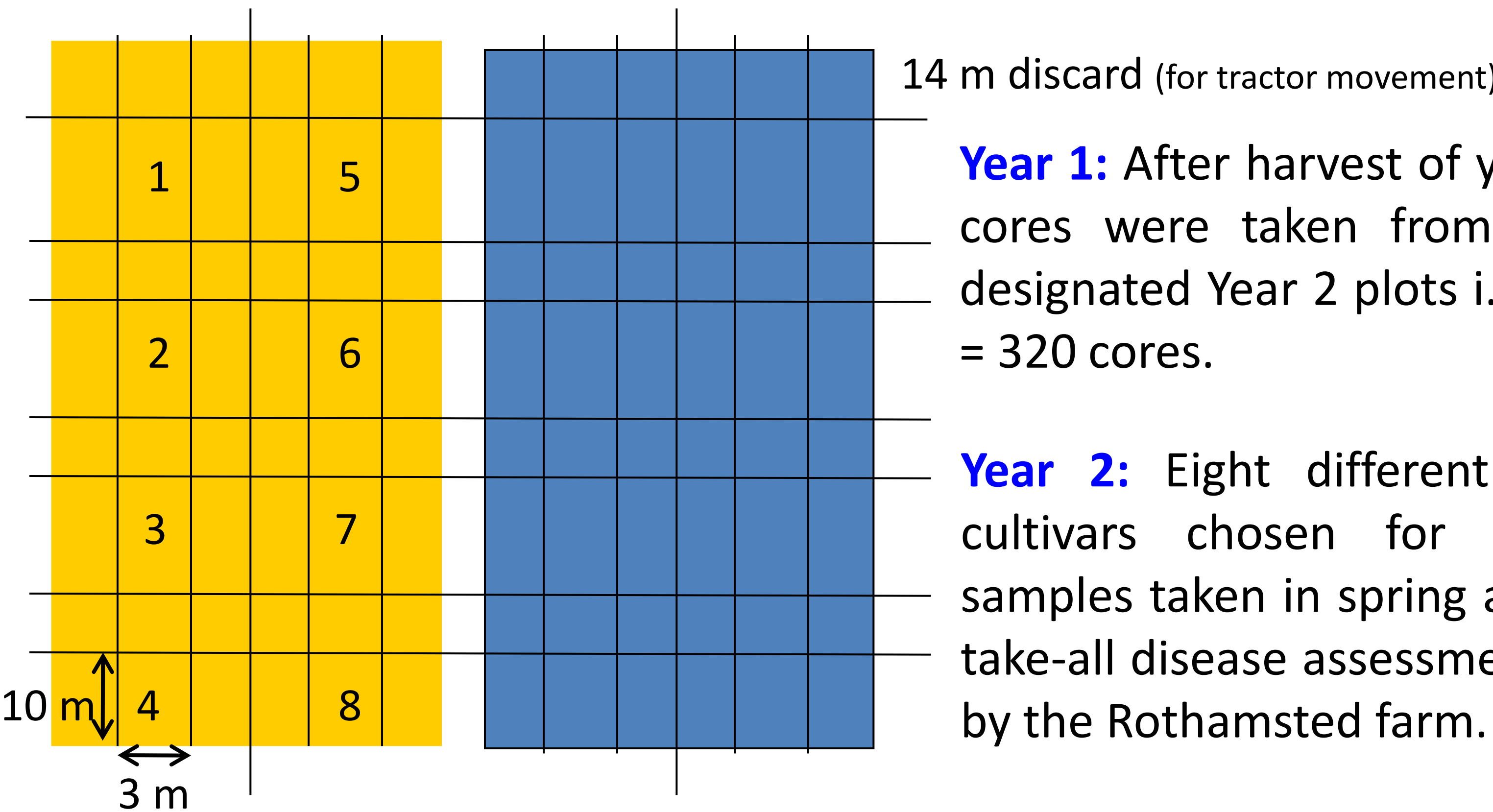


Plan NOT drawn to scale

Cultivar rotation trials

Overall objective: Explore the effect of different cultivar sequences on take-all disease pressure

Step 2: Year 2 Each of the Year 1 large plots **divided into eight 10m x 3m** for the Year 2 field season.



Plan NOT drawn to scale

Year 1: After harvest of year 1, five soil cores were taken from each of the designated Year 2 plots i.e. 64 plots x 5 = 320 cores.

Year 2: Eight different winter wheat cultivars chosen for Year 2. Plant samples taken in spring and summer for take-all disease assessment. Yields taken by the Rothamsted farm.

The eight selected cultivars for the rotation trial

Drilled as the 2nd wheat

Variety	Nabim group
Hereward	1
Gallant	1
Xi19	1
Solstice	1
Cordiale	2
Einstein	2
Robigus	3
Duxford	4

Results Summary : Cultivar rotation trials

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

- **Less take-all disease in a 2nd wheat crop when Cadenza is grown as the 1st wheat (n = 8 cultivars, 2nd wheats)**
- **Fewer plants infected and less severe root disease**
- **Grain yield advantage in the 2nd wheat crop**

0.2 t /ha (good growing season – 2011)
2.42 t /ha (difficult growing season – 2012)

The current WGIN Cultivar Rotation Trial
Field: Drapers

Take-all infectivity of the soil after the first wheat source varieties Cadenza and Hereward, and take-all disease and yield data in the subsequent second wheat over-sow.

	Year 1 (2011-2012)	
	Soil bioassay after harvest of 1st wheat plots	
Source variety	Logit % plants infected (Back-transformed means)	Logit % roots infected (Back-transformed means)
Cadenza	0.002 (**49.6%**)	-0.94 (**12.8%**)
Hereward	1.275 (**92.3%**)	-0.24 (**37.6%**)
d.f.	3	3
SED	0.186	0.15
F Pr	**0.006**	**0.019**
Grand mean	0.64 (71.0%)	-0.59 (25.2%)

The current WGIN Cultivar Rotation Trial
Field: Drapers

Take-all infectivity of the soil after the first wheat source varieties Cadenza and Hereward, and take-all disease and yield data in the subsequent second wheat over-sow.

	Year 2 (2012-2013)	
	Over-sow **Spring** plant samples (24th April 2013, GS 24-27)	
Source variety	Percentage plants infected with take-all	Number of take-all infected roots per plant
Cadenza	**28.8%**	**0.52**
Hereward	**75.1%**	**1.94**
d.f.		
SED		
F Pr		
Grand mean	52.0%	1.23

The current WGIN Cultivar Rotation Trial
Field: Drapers

Take-all infectivity of the soil after the first wheat source varieties Cadenza and Hereward, and take-all disease and yield data in the subsequent second wheat over-sow.

	Year 2 (2012-2013)	
	Over-sow **Spectral ratio meter** (26th June 2013, GS 64)	
Source variety	NDVI (Normalized Difference Vegetation Index)	Crop cover (%)
Cadenza	**0.90**	**86.1%**
Hereward	**0.84**	**72.0%**
d.f.		
SED		
F Pr		
Grand mean	0.87	79.05%