Drought tolerance

WGIN-2 SG meeting

Limagrain Woolpit 6 December 2013

The University of Nottingham

John Innes Centre

defra
Department for Environment Food and Rural Affairs

Wheat Genetic Improvement Network

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*)**

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

- $^{13}C\ \Delta$ grain
- senescence kinetic
- stem WSC

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 Δ 13C (unirrigated)**
- **NDVI**

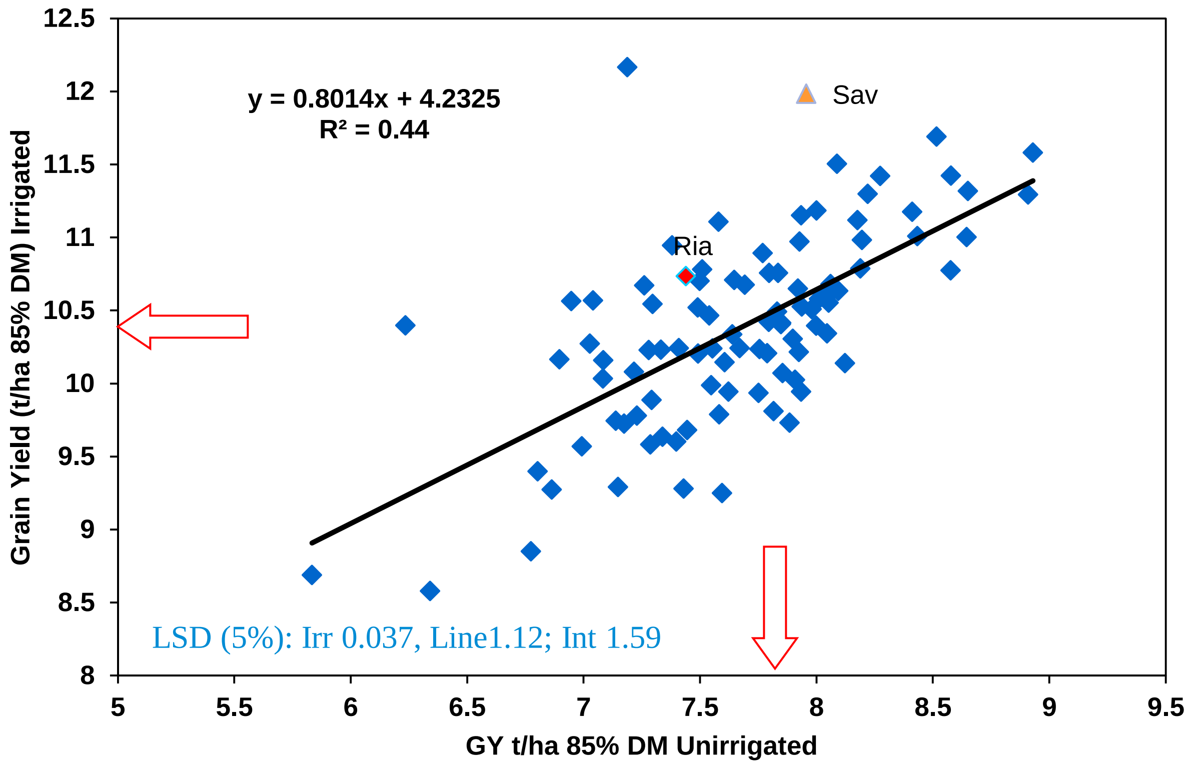
Drought effects 11 July 2011

L2

L39

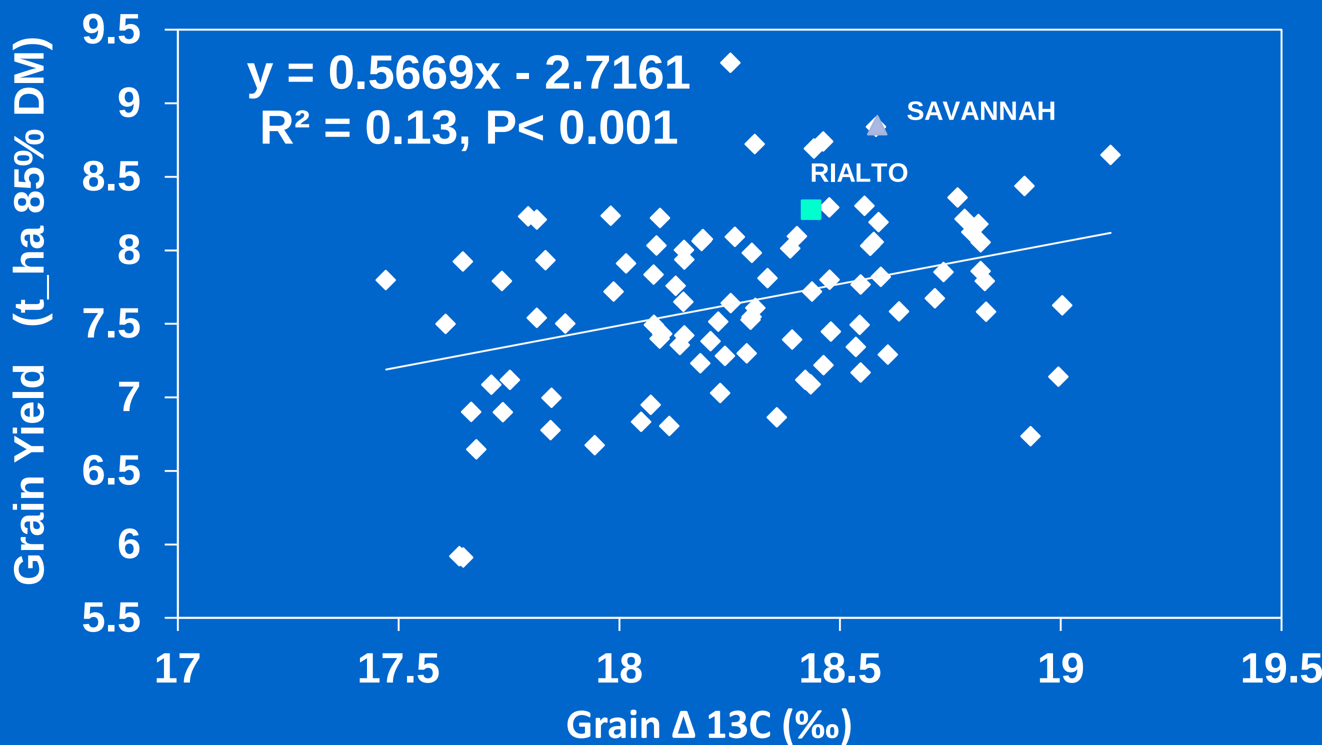
L47

Grain yield responses to irrigation



Sutton Bonington 2010-11

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



High WUE ← Low WUE

Drought effects 11 July 2011

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

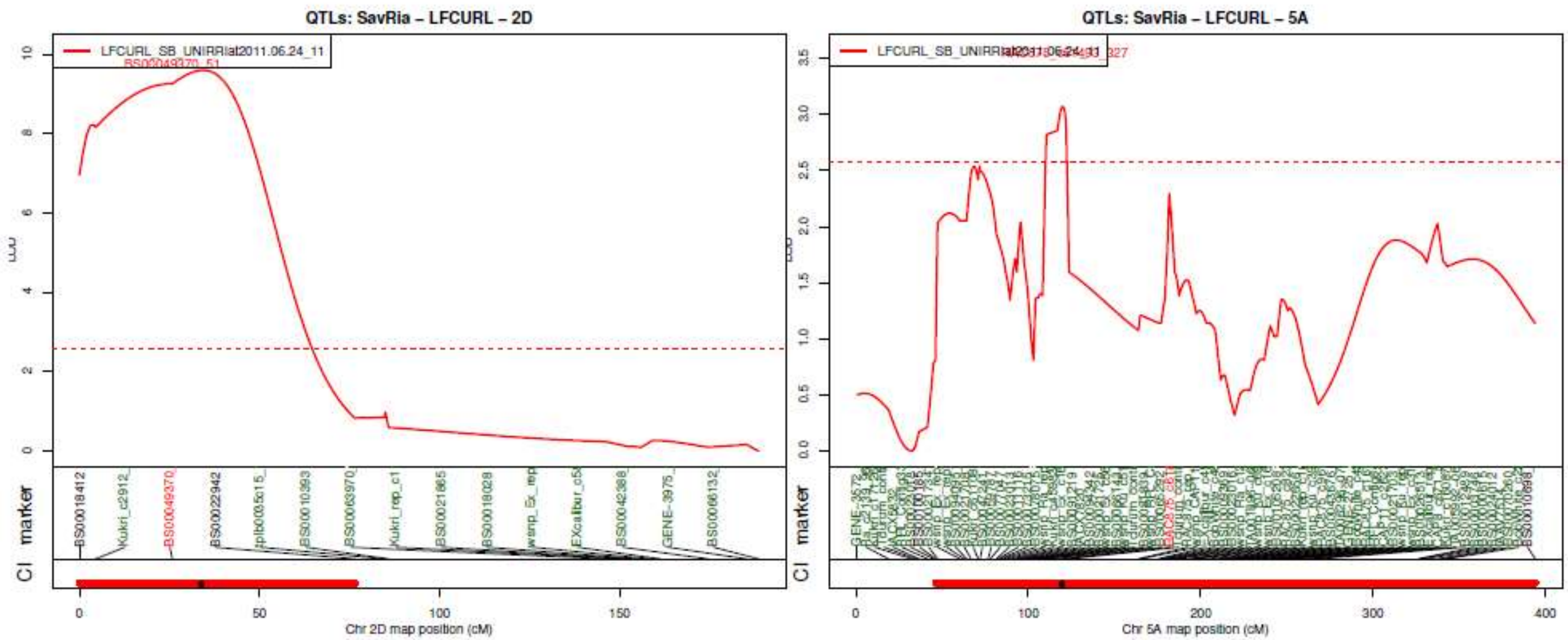
- both environments: TGRWT (5A)
- irrigated: HI (1D, 4D), TGRWT (4A,6A)
- unirrigated: EARpsqm (2D, 7A), GRpsqm (2D,3B), GRYLD (3B), LFCURL (2B, 2D, 5A), NDVI (5A), Cdelta (2A)
- no qtls: AGDM, CTEMP, StemWSC

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

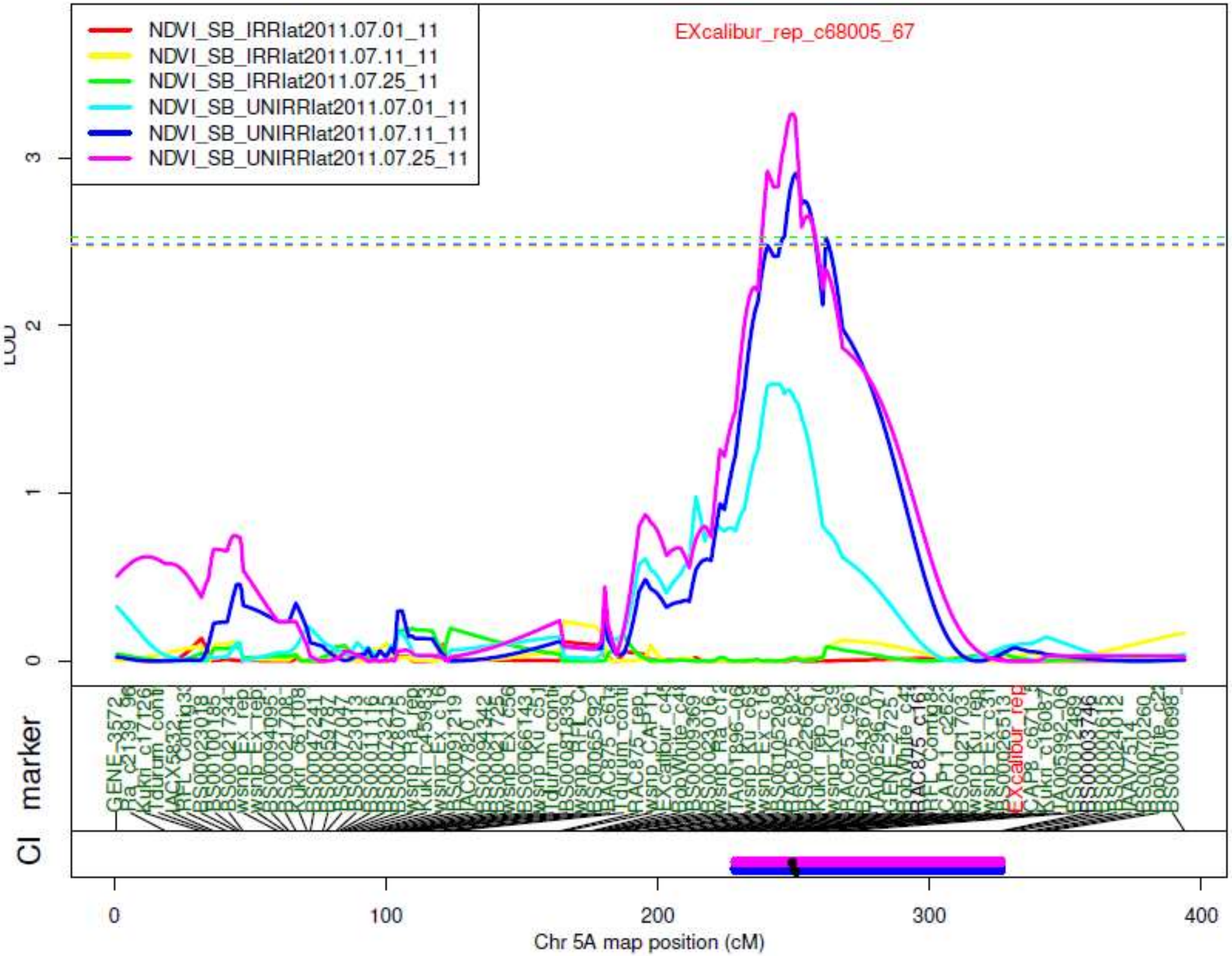
- both environments: TGRWT (5A)
- irrigated: HI (1D, 4D), TGRWT (4A,6A)
- unirrigated: EARpsqm (2D, 7A), GRpsqm (2D,3B), GRYLD (3B), LFCURL (2B, 2D, 5A), NDVI (5A), Cdelta (2A)
- no qtls: AGDM, CTEMP, StemWSC

QTLs for LFCURL



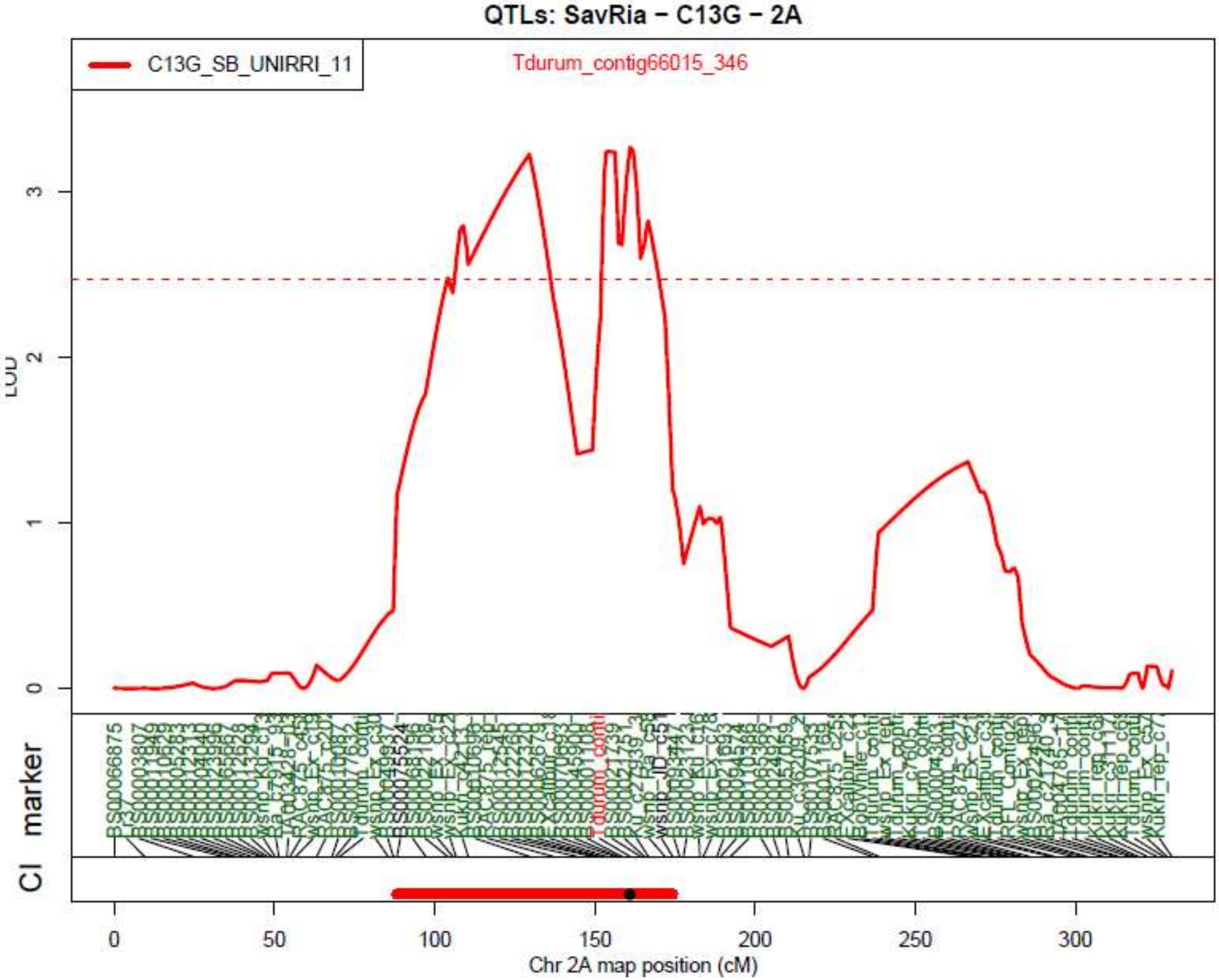
LEAFCURL QTL 2D coincides with GRpsqm, 5A NOT with NDVI.

QTL 5A for NDVI

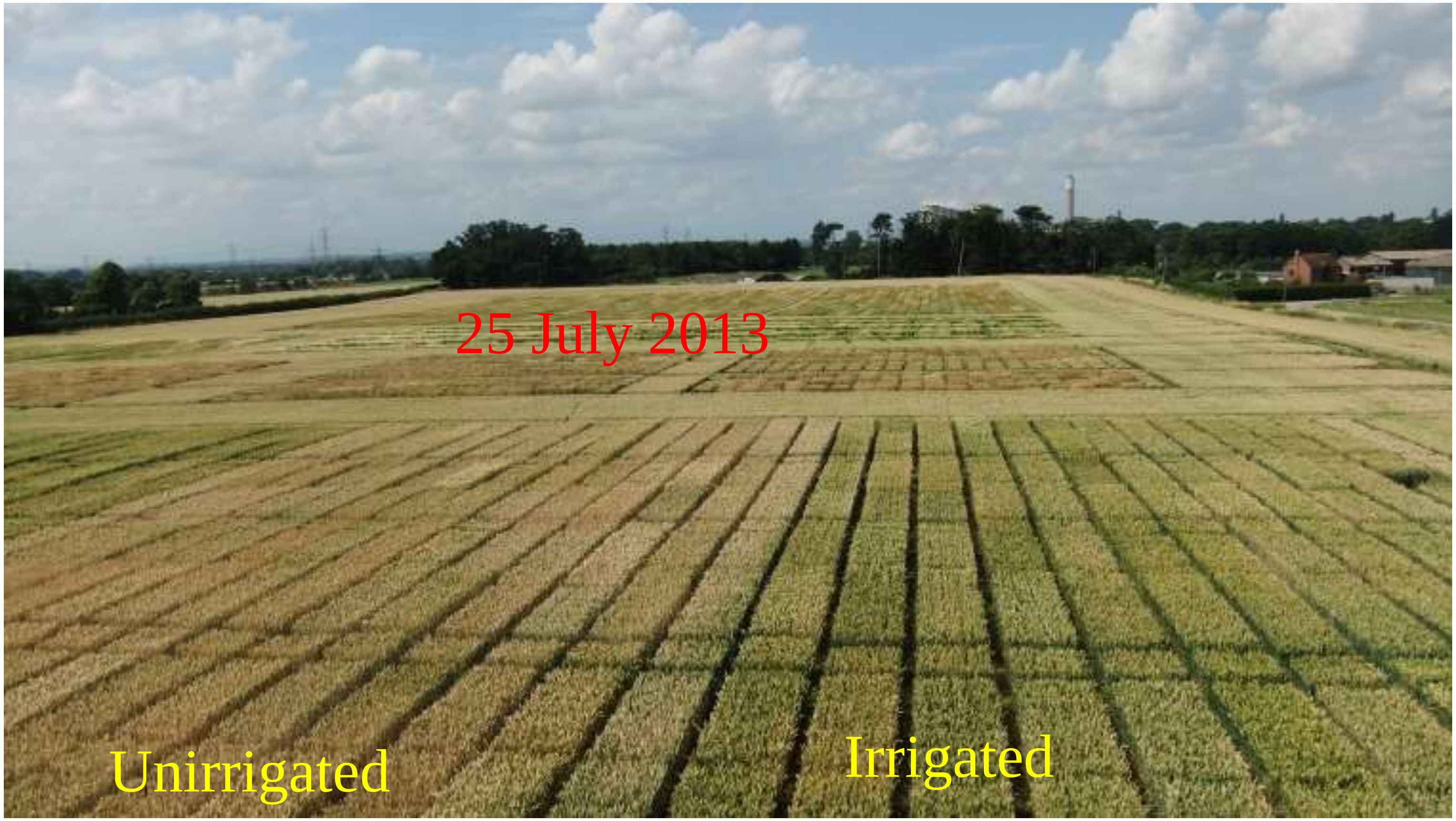


NDVI QTL 5A only under 'drought'.

QTLs for Cdelta



Rialto x Savannah DH pop 2012-13



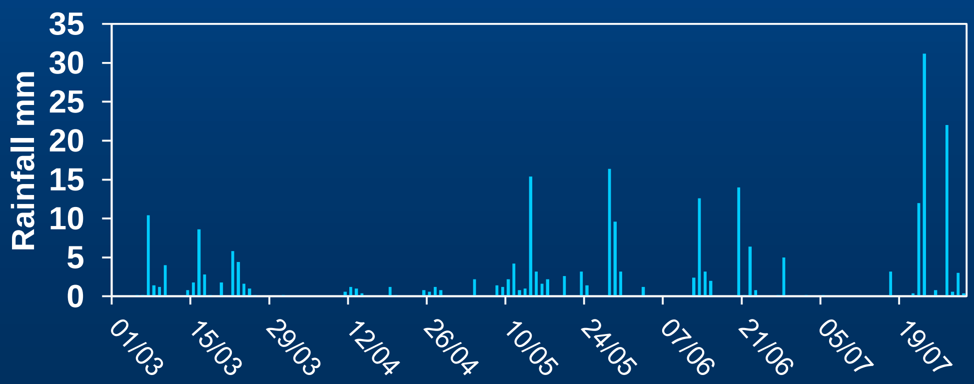
9.2 QTL Detection

2012-13 expt (Sown 16 October 2012)

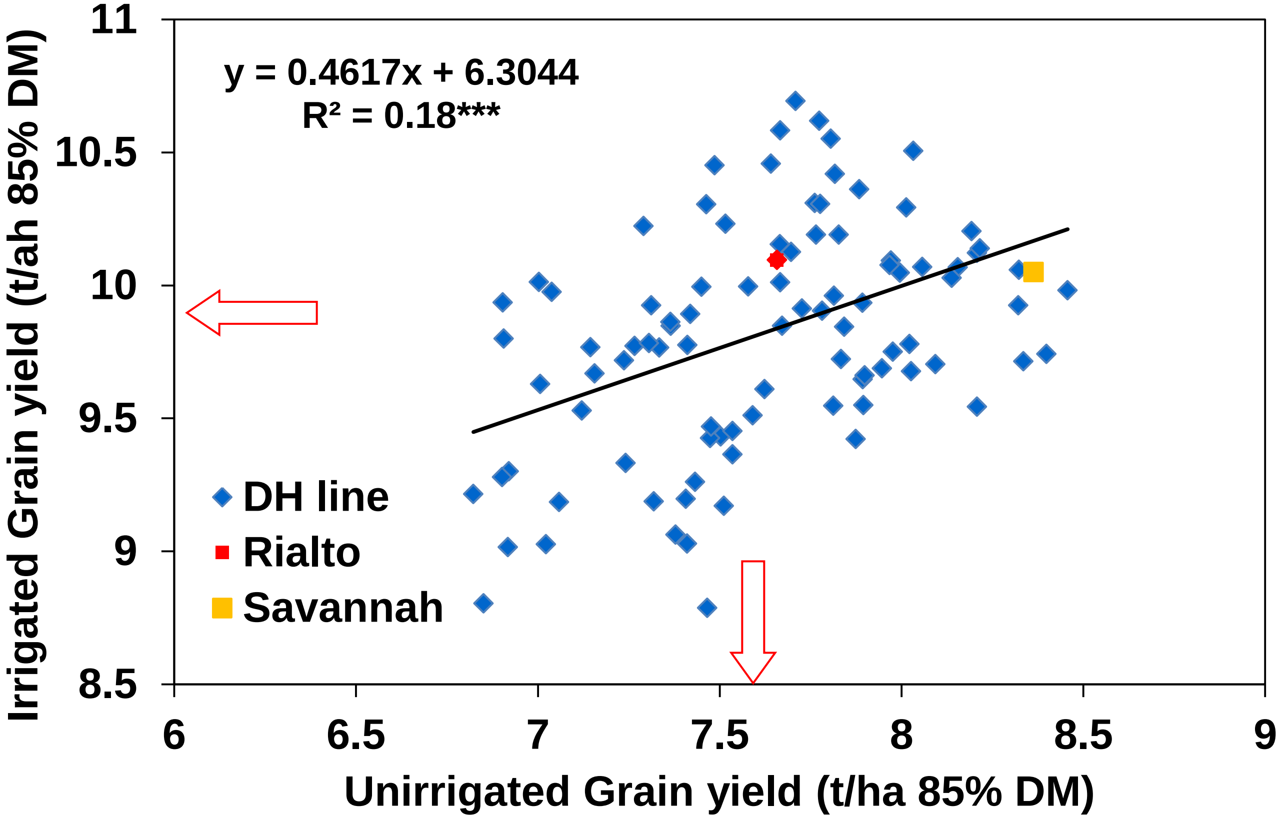
• Rialto x Savannah DH population (94 lines and 2 parents) - irrigated & unirrigated

• 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)



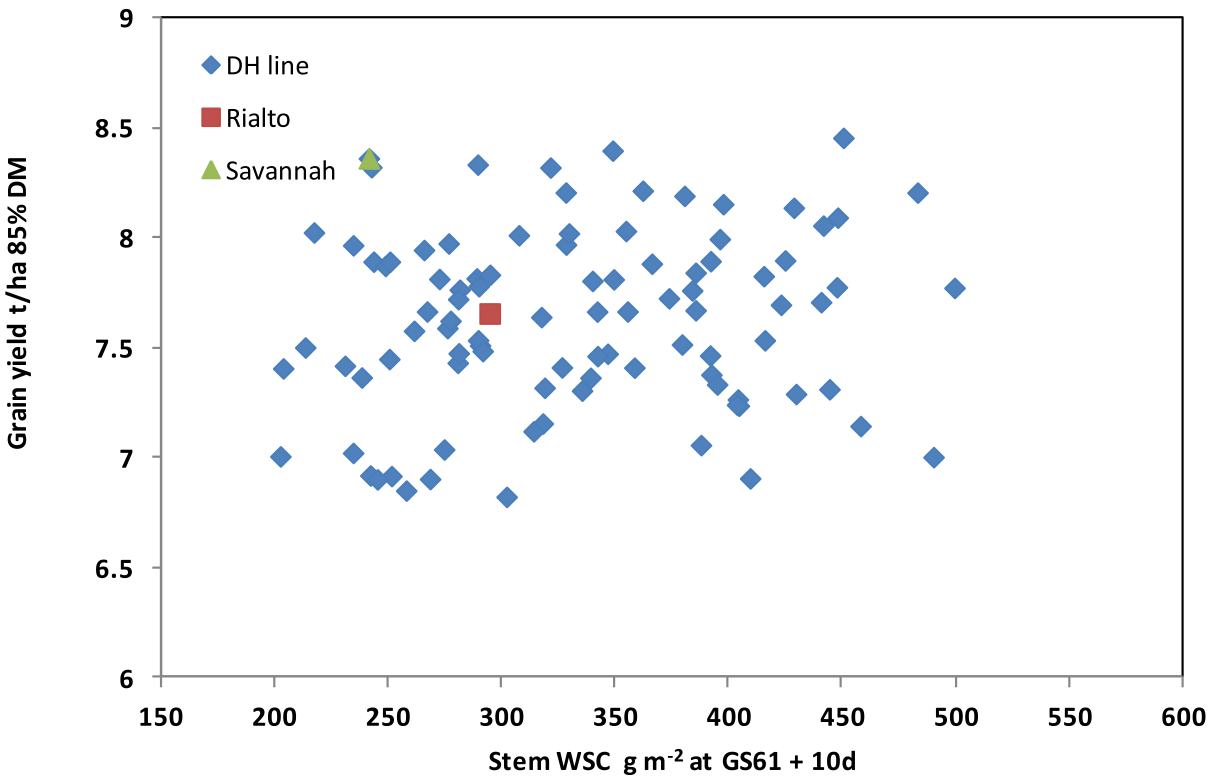
Savannah x Rialto DHs



LSD (5%): Irr 2.97 (P = 0.06) , Line 0.51 (P< 0.001) ; Int 0.95 (P< 0.01)

Sutton Bonington 2012-13

Grain Yield versus Stem water sol.CHO (Savannah x Rialto DHs)

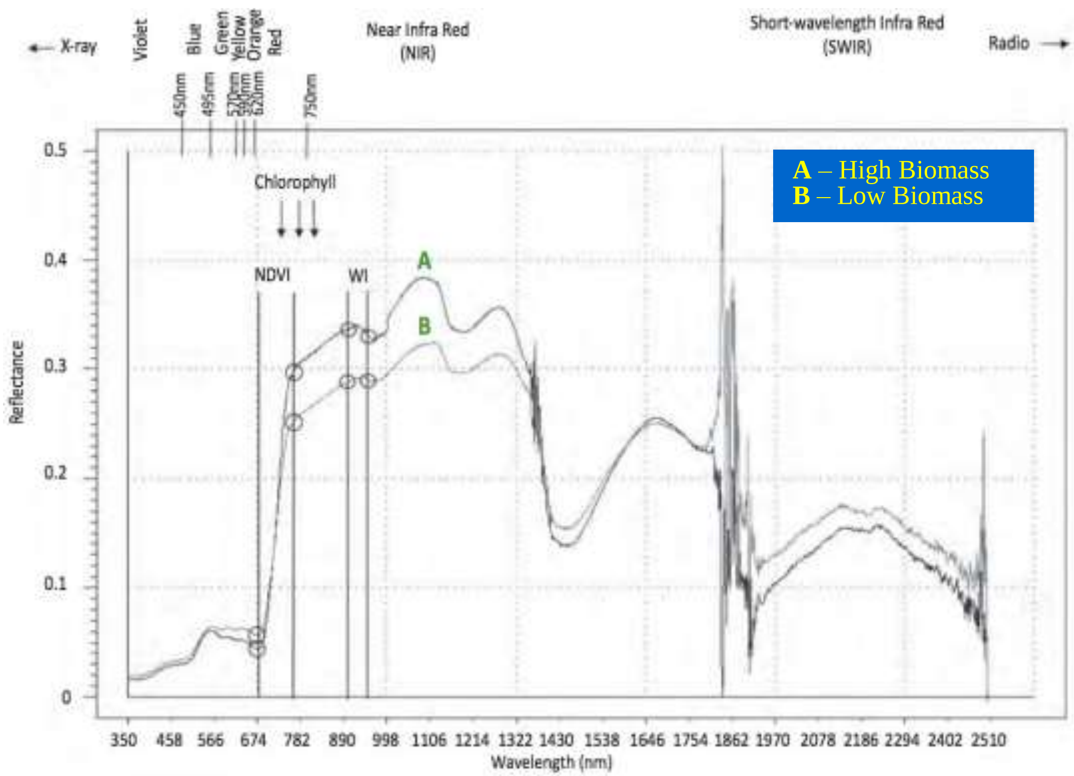


Sutton Bonington 2012-13 Unirrigated

Normalized Difference Vegetation Index (NDVI)

$$NDVI = \frac{R_{NIR} - R_{RED}}{R_{NIR} + R_{RED}} = \frac{R_{900} - R_{680}}{R_{900} + R_{680}}$$

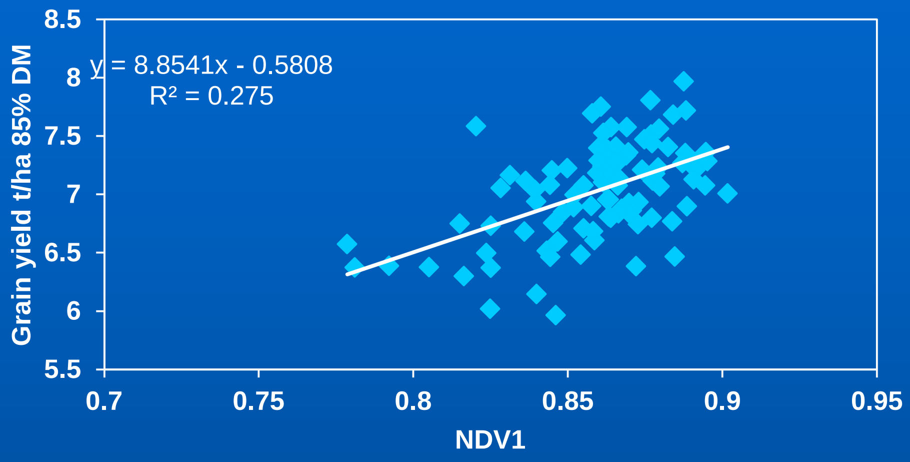
- Green area
- Photosynthetic capacity
- N status



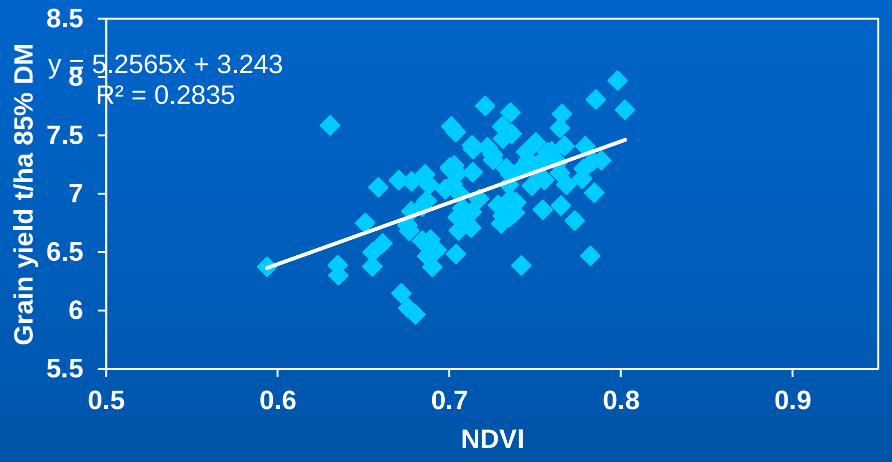
Adapted from: Reynolds M, Pask A, Mullan D (2012) Physiological breeding I: Interdisciplinary approaches to improve crop adaptation.

Grain Yield versus NDVI (Savannah x Rialto DHs)

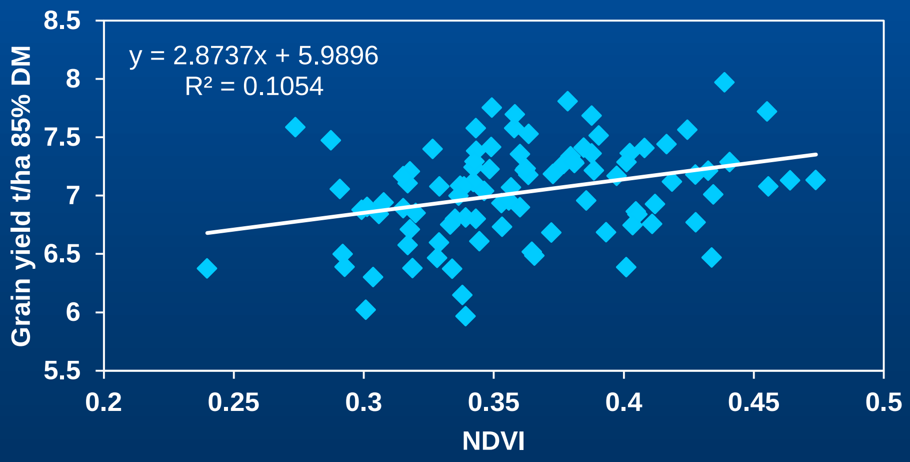
9 July Unirr



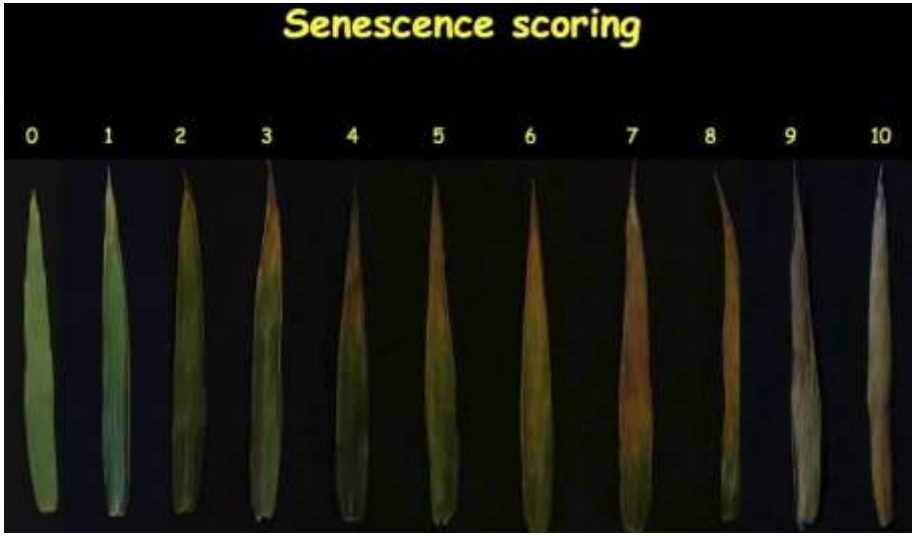
16 July Unirri

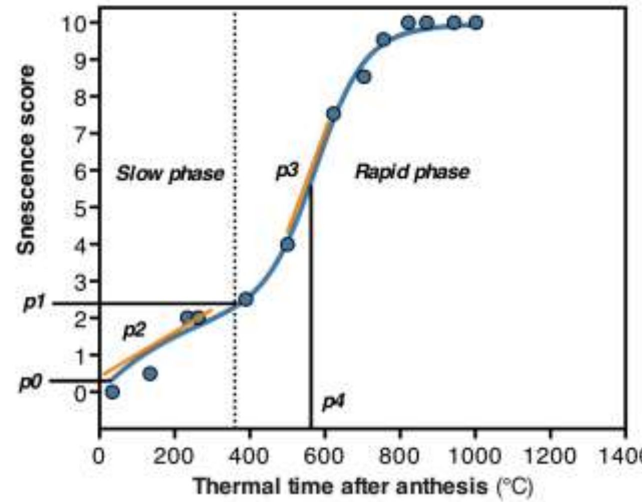


26 July Unirri



Flag Leaf Senescence Kinetics





Fitting the senescence data

$$score = p0 + p1 \times (1 - exp((-p2 \times STA/ p1)) + (10 - p1 - p0/ (1 + exp(-4 \times p3 (STA - p4)/ (10 - p1 - p0)))$$

Score: visual senescence score

STA: thermal time after anthesis (° C days)

p0: score at anthesis

p1: score at the end of the slow phase

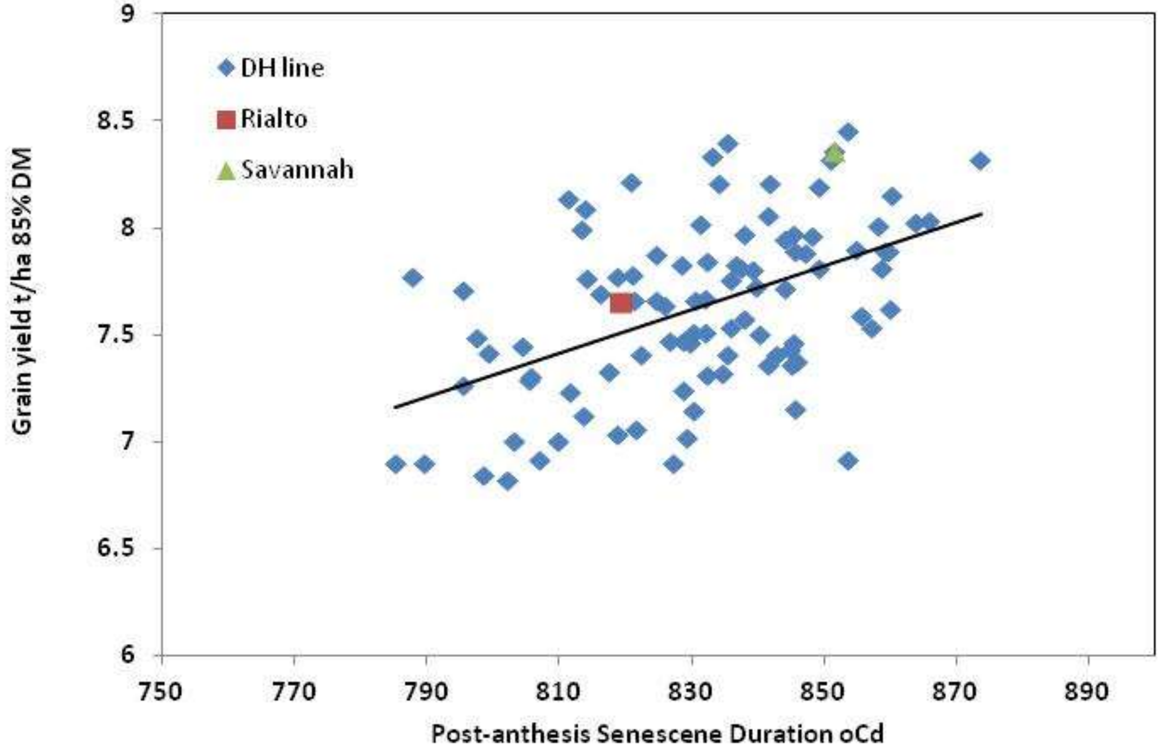
p2: maximum rate of the slow phase

p3: maximum rate at rapid phase

p4: date at which ***p3*** is reached

Stay-green associated with ***p4***.

Grain yield versus Flag leaf senescence duration (Savannah x Rialto DHs)



Sutton Bonington 2012-13 Unirrigated

Complete phenotyping data set for 2012/13 to be sent to SG/LW at JIC for QTL analysis (2nd week Jan 2014)

Geno	HD	AD	ADTT	GY	TGW	NGM2	NEarM2	AGDM	HI	NDVI-01 July	NDVI-11 July	NDVI-25 July	StemWSC_Ant	LR_24 June	Delta 13C	CT_24 June
site	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB
year and treatment	11IRRI	11IRRI	11IRRI	11IRRI	11IRRI	11IRRI	11IRRI	11IRRI	11IRRI	11IRRI	11IRRI	11IRRI	11IRRI	11IRRI	11IRRI	11IRRI
mean phenotypes	HD	AD	ADTT	GY	TGW	NGM2	NEarM2	AGDM	HI	NDVI-01 July	NDVI-11 July	NDVI-25 July	StemWSC_A	LR_24 June	G Δ 13C	CT_24 June
var	days	days	$^{\circ}$ Cd	t ha^{-1}	g	m^{-2}	m^{-2}	g m^{-2}		%	%	%	gm^{-2}		$^{o}/_{oo}$	$^{\circ}$ C
RIALTO	#N/A	#N/A	#N/A	10.74	47.68	22529	417	2110	0.51	0.89	0.83	0.56	#N/A	#N/A	#N/A	#N/A
SAVANNAH	#N/A	#N/A	#N/A	11.98	54.32	22070	436	2191	0.547	0.88	0.86	0.63	#N/A	#N/A	#N/A	#N/A
SXR001	#N/A	#N/A	#N/A	9.74	48.96	19898	358	1892	0.516	0.86	0.82	0.54	#N/A	#N/A	#N/A	#N/A
SXR002	#N/A	#N/A	#N/A	9.68	53.4	18114	337	1775	0.545	0.89	0.84	0.51	#N/A	#N/A	#N/A	#N/A
SXR003	#N/A	#N/A	#N/A	10.59	48.96	21642	412	2176	0.487	0.88	0.86	0.58	#N/A	#N/A	#N/A	#N/A
SXR005	#N/A	#N/A	#N/A	10.03	48.88	20515	407	1919	0.522	0.87	0.78	0.39	#N/A	#N/A	#N/A	#N/A
SXR006	#N/A	#N/A	#N/A	10.07	51.52	19650	367	1977	0.51	0.89	0.84	0.60	#N/A	#N/A	#N/A	#N/A
SXR007	#N/A	#N/A	#N/A	10.52	51.76	20328	385	1998	0.527	0.90	0.87	0.61	#N/A	#N/A	#N/A	#N/A
SXR008	#N/A	#N/A	#N/A	10.24	52.34	19553	373	1970	0.52	0.90	0.85	0.60	#N/A	#N/A	#N/A	#N/A
SXR009	#N/A	#N/A	#N/A	10.68	46.02	23233	381	1978	0.54	0.89	0.84	0.50	#N/A	#N/A	#N/A	#N/A
SXR010	#N/A	#N/A	#N/A	10.63	49.52	21475	384	1993	0.534	0.88	0.84	0.49	#N/A	#N/A	#N/A	#N/A
SXR011	#N/A	#N/A	#N/A	10.23	51.2	19963	395	2051	0.499	0.88	0.83	0.46	#N/A	#N/A	#N/A	#N/A
SXR012	#N/A	#N/A	#N/A	10.34	49.02	21113	406	2092	0.495	0.88	0.83	0.52	#N/A	#N/A	#N/A	#N/A
SXR013	#N/A	#N/A	#N/A	10.89	45.94	23726	470	2055	0.53	0.88	0.84	0.54	#N/A	#N/A	#N/A	#N/A
SXR014	#N/A	#N/A	#N/A	10.24	50.54	20264	394	1970	0.52	0.89	0.87	0.69	#N/A	#N/A	#N/A	#N/A
SXR016	#N/A	#N/A	#N/A	10.57	50.12	21086	443	2006	0.527	0.89	0.86	0.65	#N/A	#N/A	#N/A	#N/A
SXR017	#N/A	#N/A	#N/A	10.65	50.88	20941	390	1984	0.537	0.89	0.85	0.62	#N/A	#N/A	#N/A	#N/A
SXR018	#N/A	#N/A	#N/A	10.39	55.18	18839	455	2338	0.446	0.88	0.86	0.70	#N/A	#N/A	#N/A	#N/A
SXR019	#N/A	#N/A	#N/A	10.40	52.86	19667	410	1995	0.521	0.89	0.84	0.66	#N/A	#N/A	#N/A	#N/A
SXR020	#N/A	#N/A	#N/A	11.32	53.58	21122	422	2122	0.533	0.88	0.82	0.54	#N/A	#N/A	#N/A	#N/A
SXR021	#N/A	#N/A	#N/A	10.21	44.98	22773	493	2117	0.482	0.89	0.84	0.55	#N/A	#N/A	#N/A	#N/A
SXR023	#N/A	#N/A	#N/A	10.56	54.08	19532	355	1974	0.536	0.88	0.83	0.49	#N/A	#N/A	#N/A	#N/A
SXR024	#N/A	#N/A	#N/A	9.73	47.58	20447	421	2028	0.483	0.90	0.86	0.58	#N/A	#N/A	#N/A	#N/A
SXR025	#N/A	#N/A	#N/A	11.58	53.64	21701	479	2282	0.508	0.89	0.85	0.54	#N/A	#N/A	#N/A	#N/A

Geno	HD	AD	ADTT	GY	TGW	NGM2	NEarM2	AGDM	HI	NDVI-01 July	NDVI-11 July	NDVI-25 July	StemWSC_Ant	LR_24 June	Delta 13C	CT_24 June
site	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB
year + treatment	11UNIRRI	11UNIRRI	11UNIRRI	11UNIRRI	11UNIRRI	11UNIRRI	11UNIRRI	11UNIRRI	11UNIRRI	11UNIRRI	11UNIRRI	11UNIRRI	11UNIRRI	11UNIRRI	11UNIRRI	11UNIRRI
mean phenotypes	HD	AD	ADTT	GY	TGW	NGM2	NEarM2	AGDM	HI	NDVI-01 July	NDVI-11 July	NDVI-25 July	StemWSC_A	LR_24 June	G Δ 13C	CT_24 June
var	days	days	$^{\circ}$ Cd	t ha^{-1}	g	m^{-2}	m^{-2}	g m^{-2}		%	%	%	gm^{-2}		$^{o}/_{oo}$	$^{\circ}$ C
RIALTO	#N/A	37	907	7.44	49.16	15136	316	1467	0.508	0.77	0.53	0.31	495.5	3	17.75	24.8
SANANNAH	#N/A	36	900	7.63	52.8	14452	307	1434	0.532	0.75	0.53	0.30	536.6	5	17.76	25.4
SXR001	#N/A	37	907	7.14	42.38	16856	333	1478	0.484	0.78	0.59	0.33	#N/A	5	19.00	25.8
SXR002	#N/A	37	907	7.45	51.62	14434	322	1482	0.502	0.74	0.47	0.30	557.1	4	18.23	25.2
SXR003	#N/A	36	900	8.03	49.38	16268	353	1633	0.492	0.81	0.63	0.34	560.5	5	18.57	25.3
SXR005	#N/A	36	900	7.91	45.48	17414	358	1563	0.506	0.78	0.53	0.29	537.9	5	17.97	26.1
SXR006	#N/A	39	929	7.86	44.46	17652	363	1573	0.499	0.80	0.63	0.34	#N/A	4	18.60	24.8
SXR007	#N/A	37	907	7.49	48.7	15379	342	1607	0.47	0.79	0.58	0.34	377.9	5	18.27	24.7
SXR008	#N/A	37	907	7.76	45.8	16931	350	1510	0.515	0.77	0.55	0.31	546.8	5	18.13	25.4
SXR009	#N/A	38	915	8.06	44.34	18178	356	1540	0.524	0.80	0.64	0.31	514.1	5	18.02	24.5
SXR010	#N/A	38	915	8.09	49.14	16471	322	1455	0.558	0.80	0.58	0.31	444.9	5	18.32	26.1
SXR011	#N/A	38	915	7.28	48.92	14892	318	1496	0.487	0.79	0.62	0.34	486.4	5	18.24	25.6
SXR012	#N/A	36	900	7.64	48.06	15886	355	1625	0.471	0.78	0.59	0.31	578.9	5	18.12	25.7
SXR013	#N/A	37	907	7.77	44.68	17420	346	1493	0.521	0.77	0.50	0.29	436.7	5	17.90	25.5
SXR014	#N/A	36	900	7.67	46.38	16534	344	1525	0.503	0.79	0.67	0.34	473.9	5	18.72	24.7
SXR016	#N/A	38	915	7.04	47.32	14892	330	1373	0.513	0.75	0.52	0.31	378.8	5	18.42	25.4
SXR017	#N/A	37	907	7.92	49.7	15932	335	1510	0.525	0.75	0.57	0.29	#N/A	4	17.22	26.5
SXR018	#N/A	38	915	8.00	50.5	15823	321	1596	0.502	0.79	0.68	0.37	387.3	4	17.90	24.9
SXR019	#N/A	37	907	6.24	51.8	12049	281	3023	0.307	0.73	0.52	0.30	433.8	5	17.56	24.8
SXR020	#N/A	39	929	8.65	48.66	17811	347	1651	0.525	0.80	0.57	0.31	#N/A	5	18.22	24.9
SXR021	#N/A	37	907	7.79	39.2	19861	402	1609	0.484	0.75	0.59	0.30	539.2	5	17.74	24.7
SXR023	#N/A	37	907	6.95	49.98	13965	306	1395	0.498	0.75	0.51	0.30	#N/A	5	18.07	23.9
SXR024	#N/A	38	915	7.51	42.82	17501	302	1427	0.526	0.82	0.67	0.36	624	4	18.23	24.3
SXR025	#N/A	36	900	8.93	48.24	18581	393	1763	0.51	0.83	0.68	0.34	760	4	18.17	24.9

Preliminary Conclusions

- **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?**
- **Work is ongoing to:**
  - **develop high-throughput screens for breeding**
  - **Understand the genetic basis of drought tolerance and WUE traits (QTL detection)**

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

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?

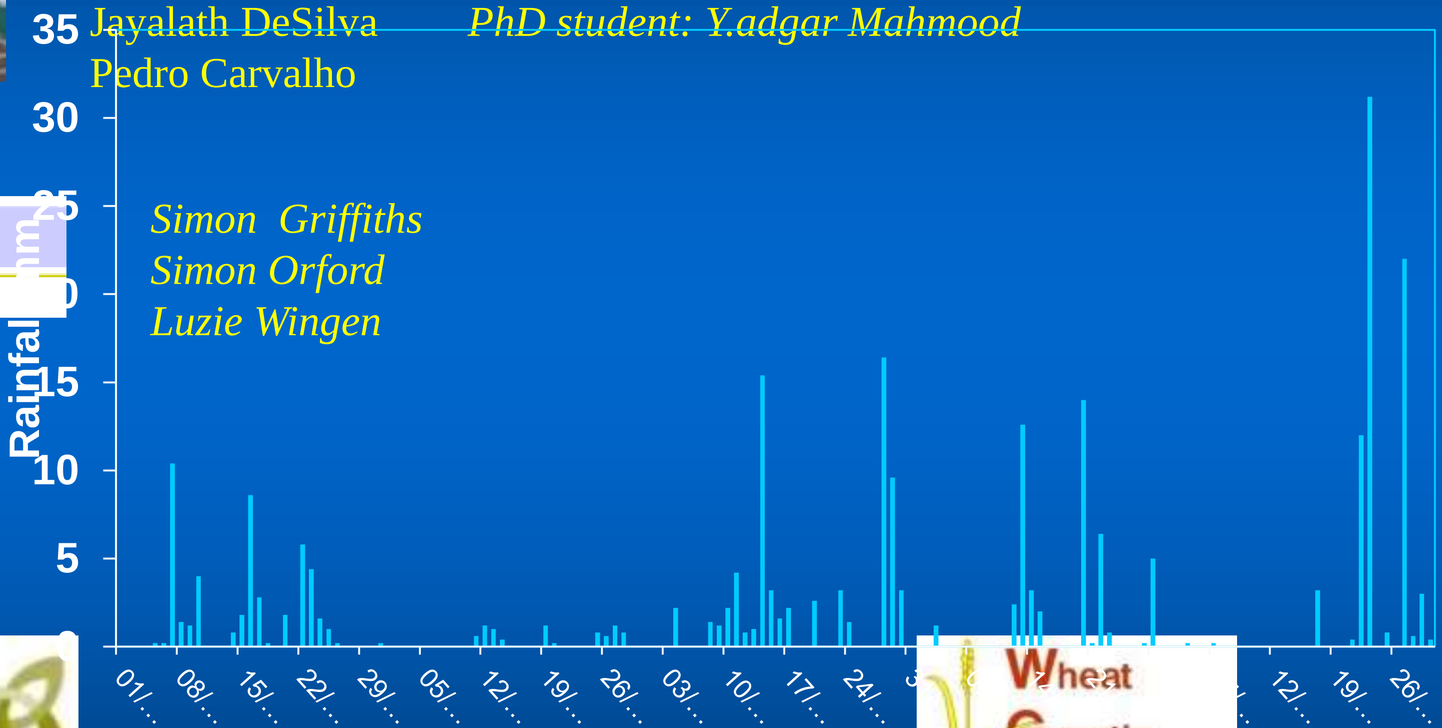
The University of Nottingham

Jayalath DeSilva
Pedro Carvalho

PhD student: Y.adgar Mahmood

Simon Griffiths
Simon Orford
Luzie Wingen

JOHN INNES CENTRE



BRITISH WHEAT BREEDERS

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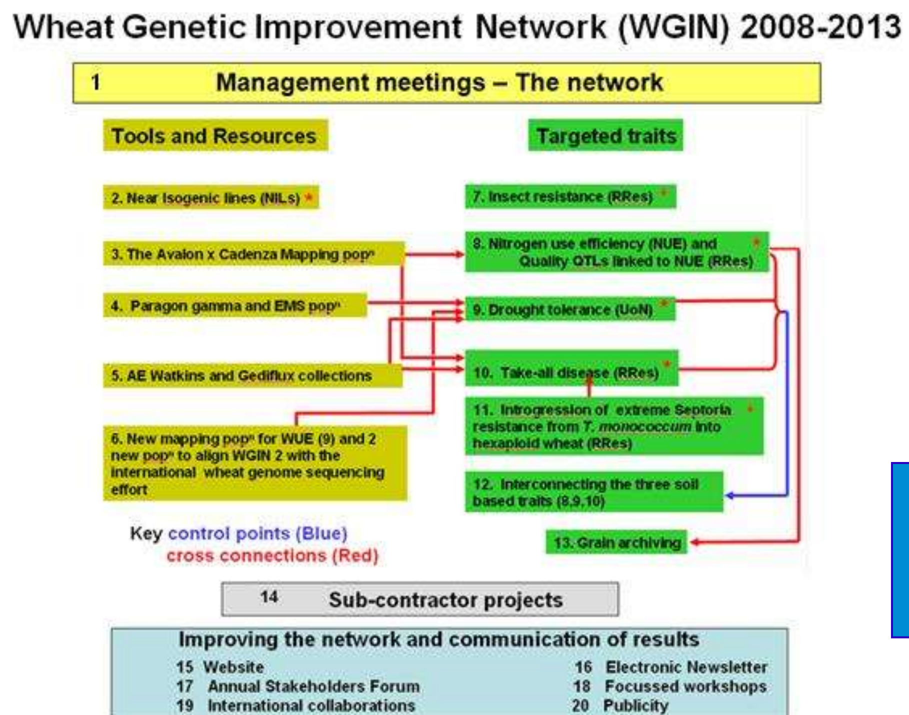
Department for Environment Food and Rural Affairs

Wheat Genetic Improvement Network



ncy: definitio urement

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

Traits associated with main drivers of yield under drought

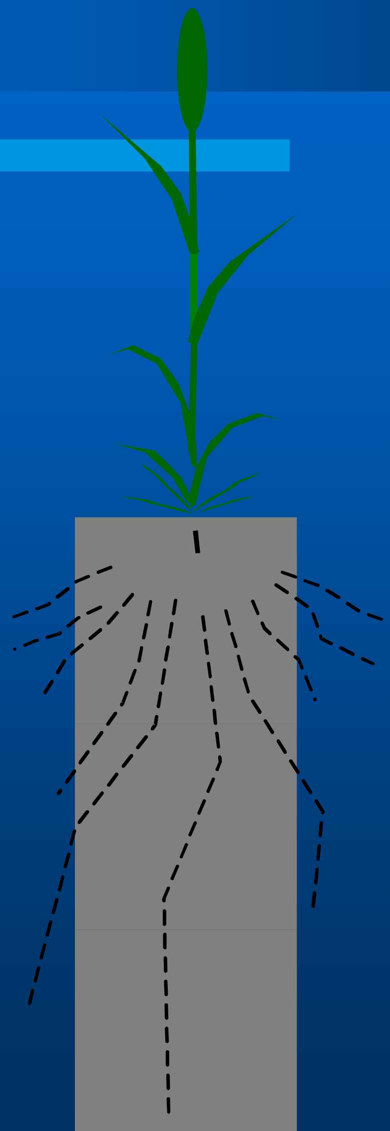
Yield = WU x WUE x HI

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

Optimised ABA root signalling

EARLINESS

- Extend stem elongation phase
- Early onset GS31

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

on.

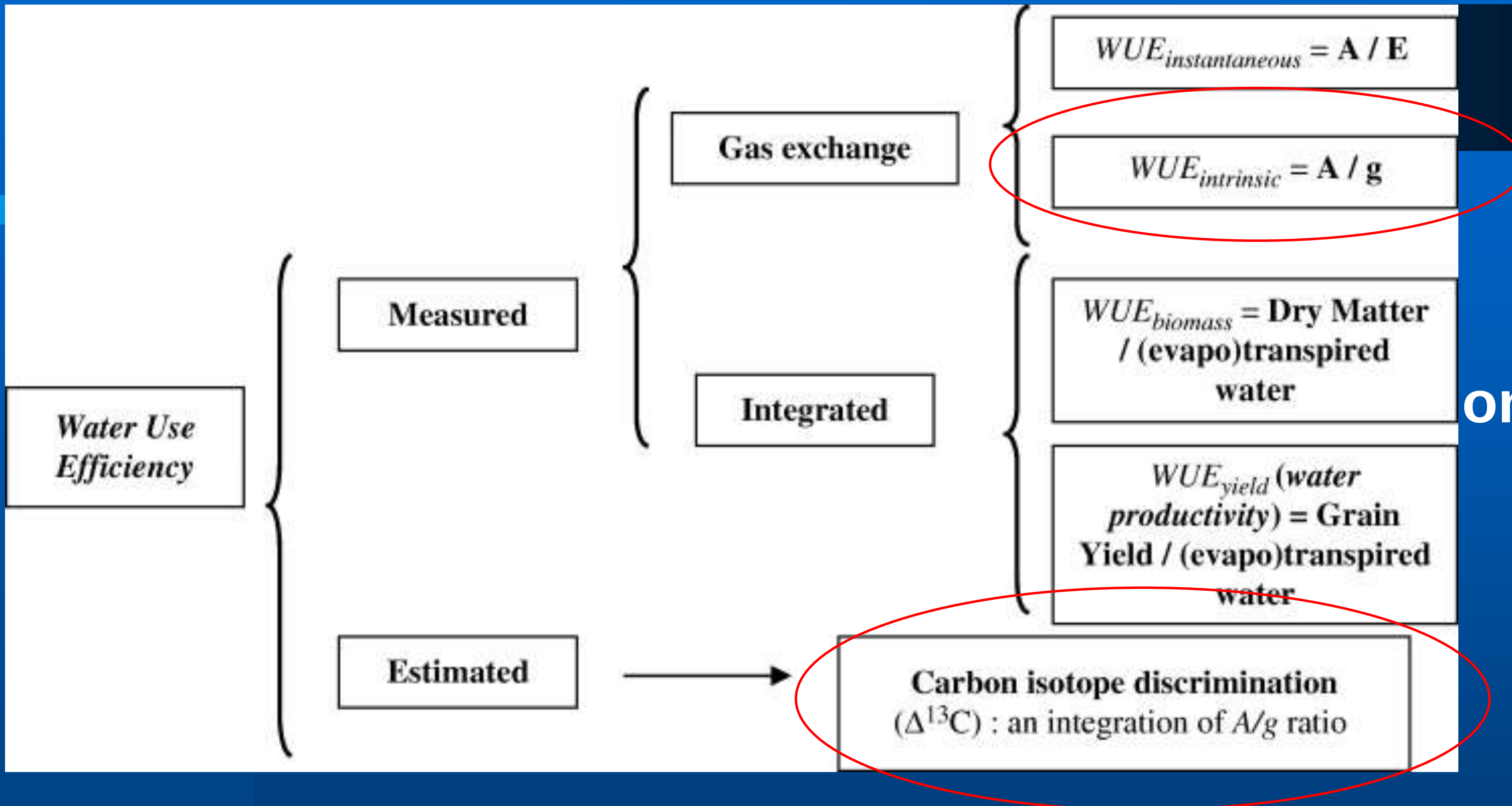
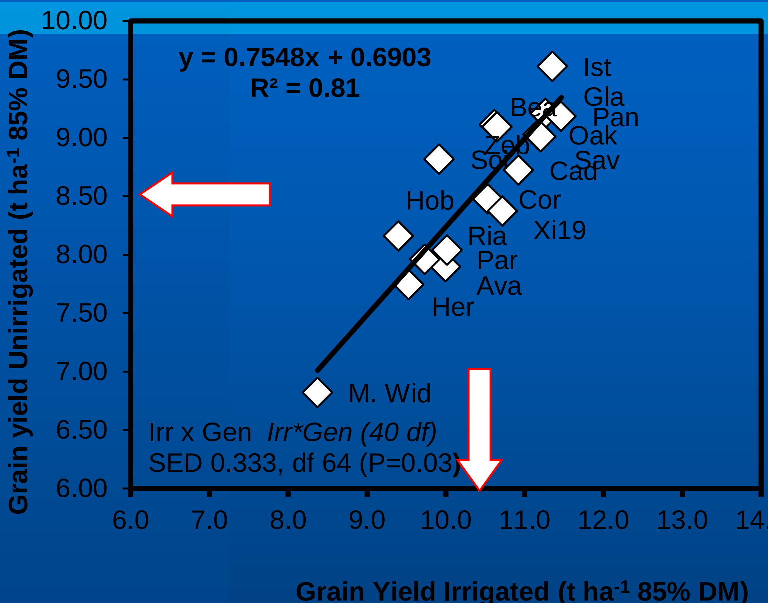
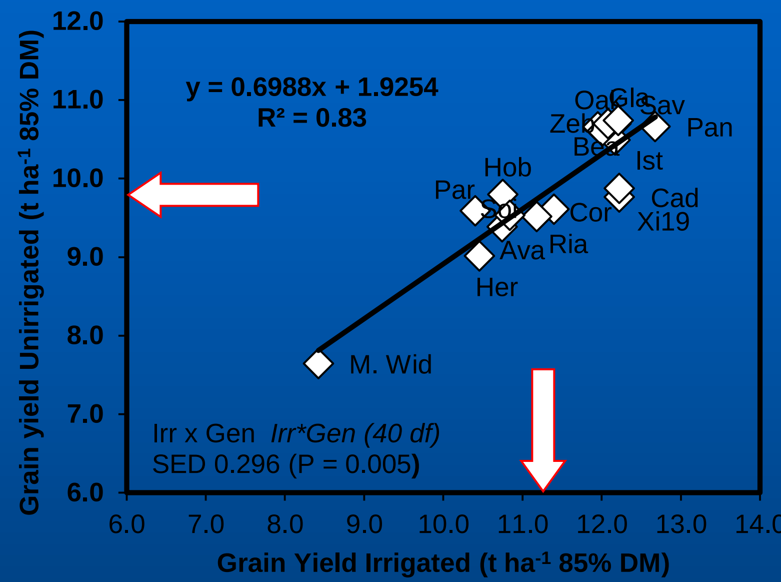


Figure 1. Definitions of 'water use efficiency'. The scheme represents the several definitions of water use efficiency (WUE) used in the text. *A*, net photosynthetic rate expressed as μmol CO_2 m^{-1} s^{-1}; E, transpiration rate expressed as mmol H_2O m^{-2} s^{-1}; $\Delta^{13}C$, carbon isotope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

Tambussi et al. 2007 Field Crops Res

Grain yield responses to Drought

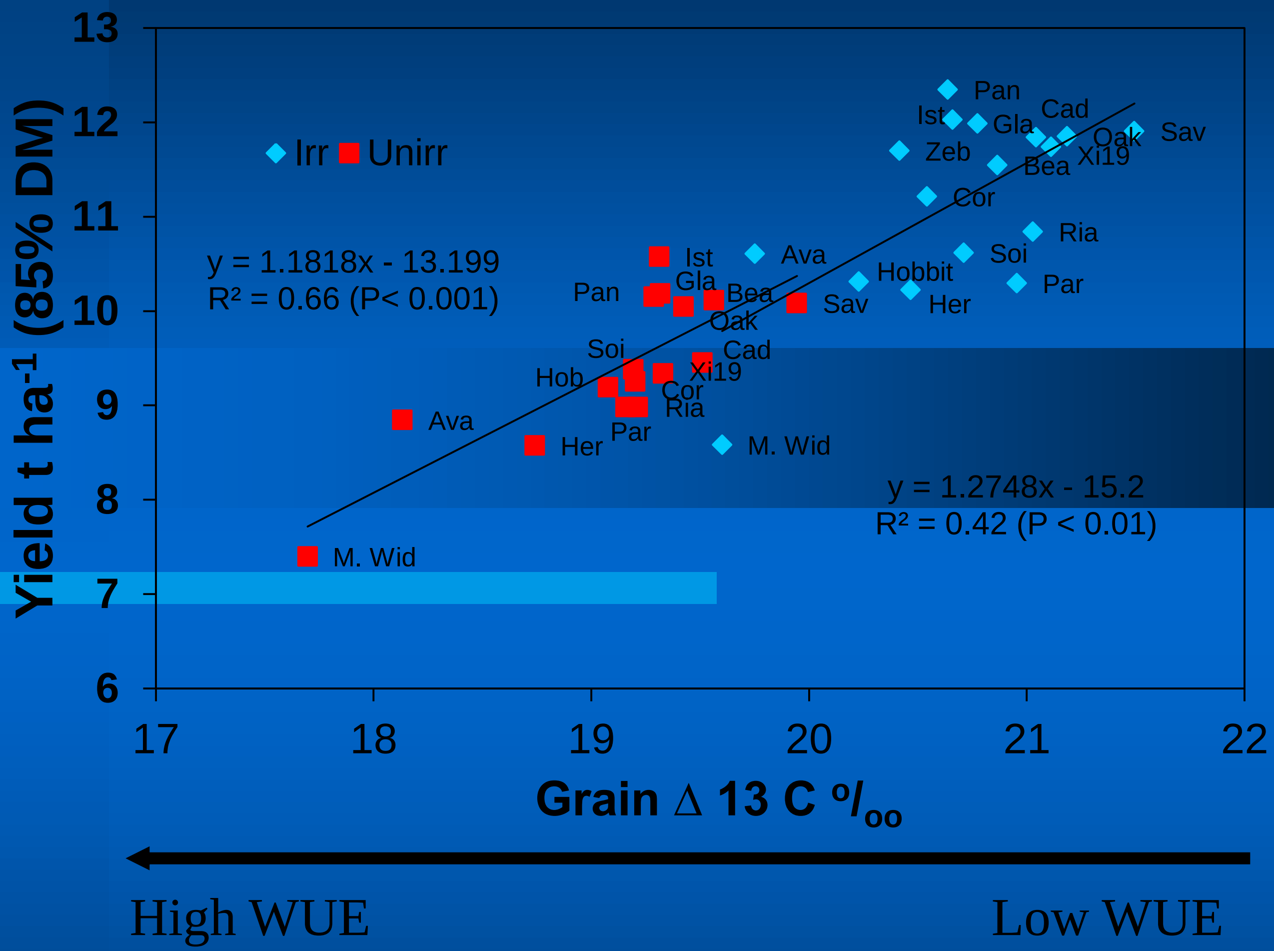




	Rainfall mm (% LTM)	
	2010	2011
January	33.0 (62)	33.2 (62)
February	41.6 (95)	44.6 (101)
March	36 (67)	1.2 (2)
April	24 (55)	23 (53)
May	16.2 (35)	27.8 (61)
June	69.2 (152)	45.4 (100)
July	42.6 (86)	17.8 (36)

Irrigated vs Unirrigated 19 July

Δ ^{13}C vs grain yield in 18 wheat cultivars



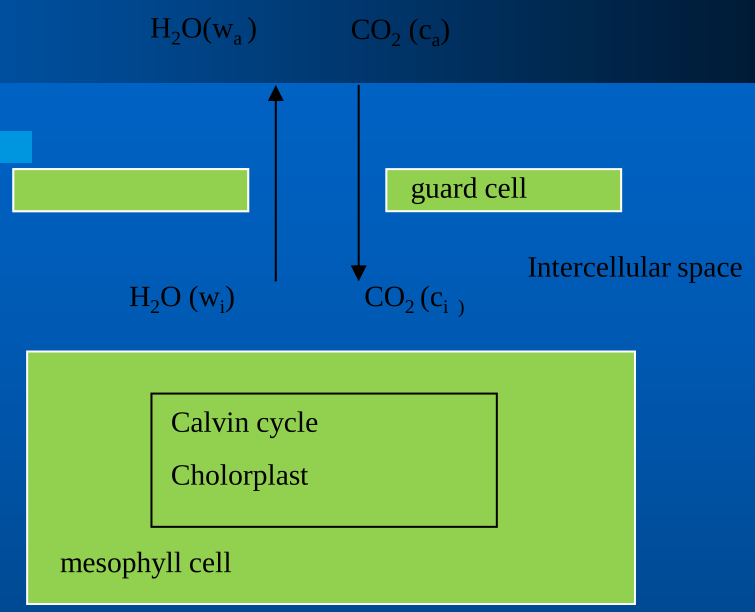
- *Grain $^{13C}\Delta$ positively associated with yield under drought – indicator of ability to access water*
- *Trade-off between WUE and season-long water use*

Sutton Bonington Mean 2009-10 & 2010-11

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

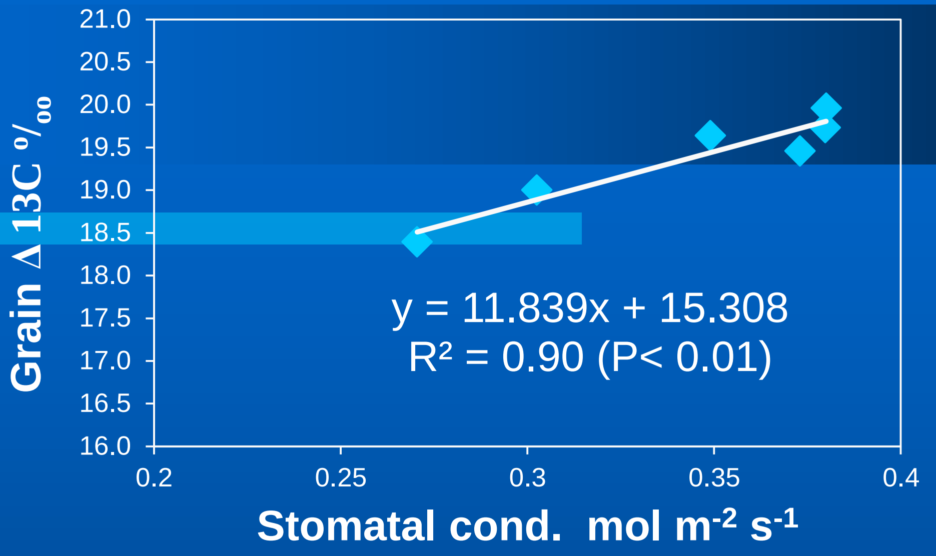
- ***N or Rubisco content per unit leaf area:*** Greater photosynthetic activity ↓ c_i , hence ↑ TE.

Condon et al. (2002). Crop Science

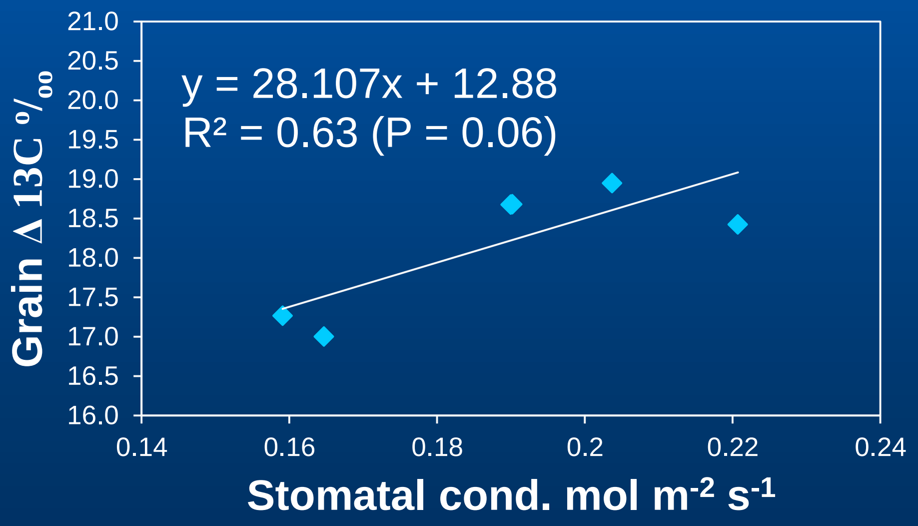


Grain Δ13C versus stomatal conductance (Unirrigated)

2009-10



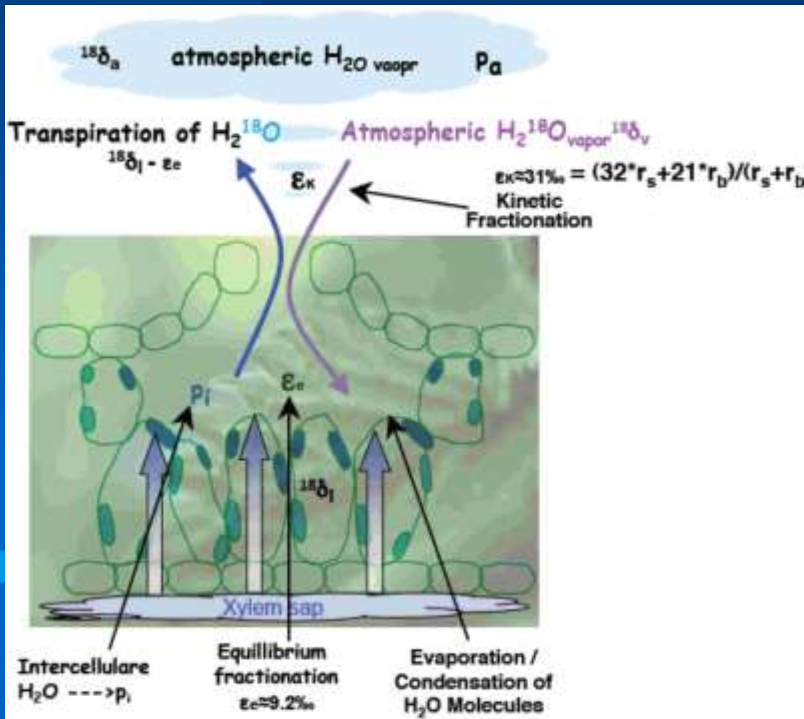
2010-11



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

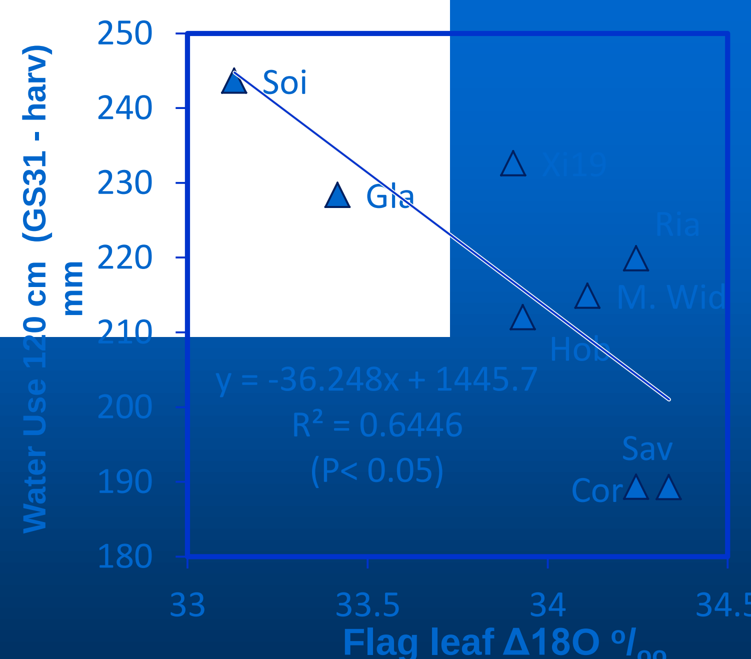
Oxygen isotope ratio technique ~ leaf transpiration



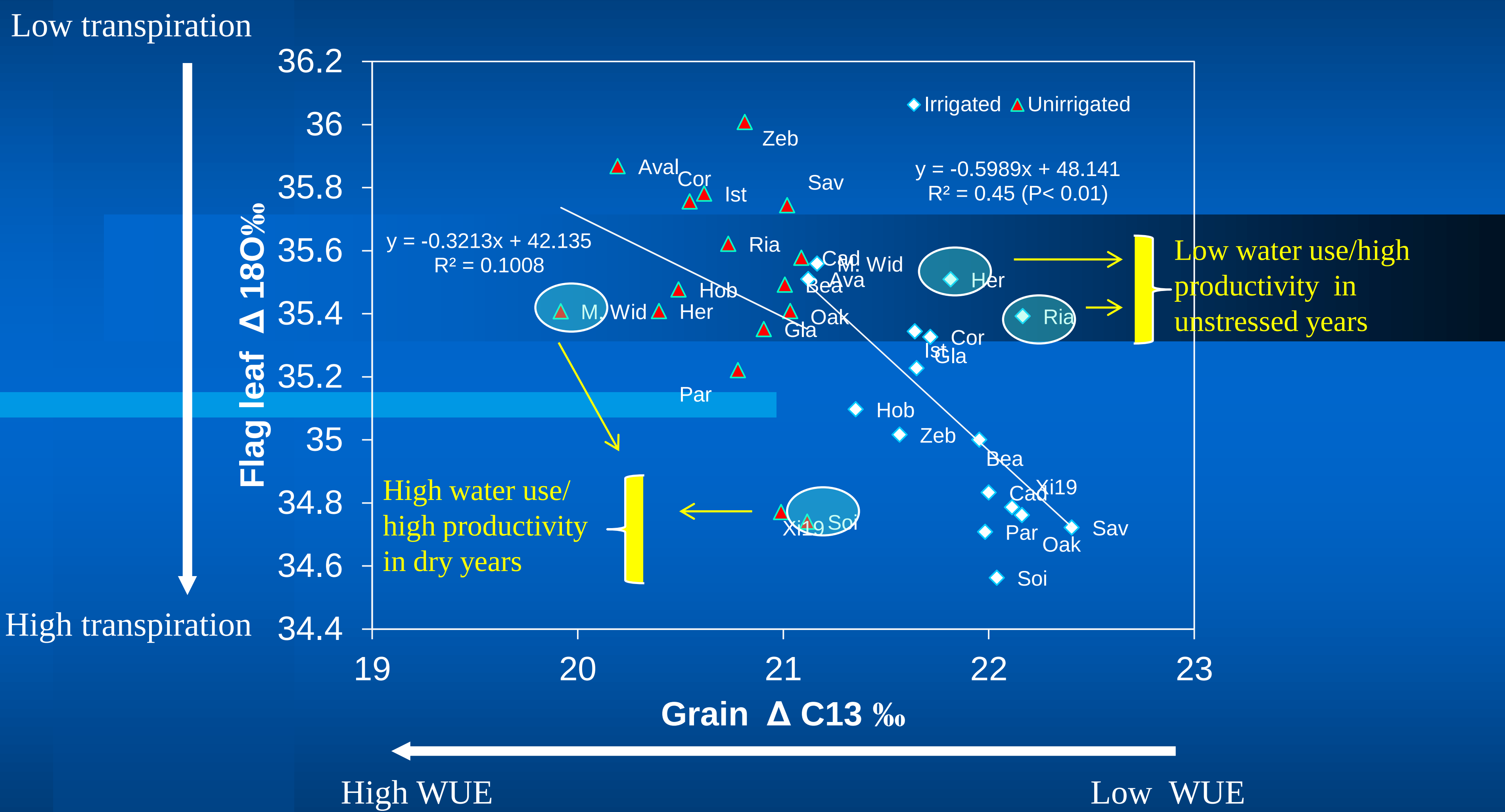
- $^{18}O/^{16}O$ ratio determined by enrichment in the leaf water due to transpiration.

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

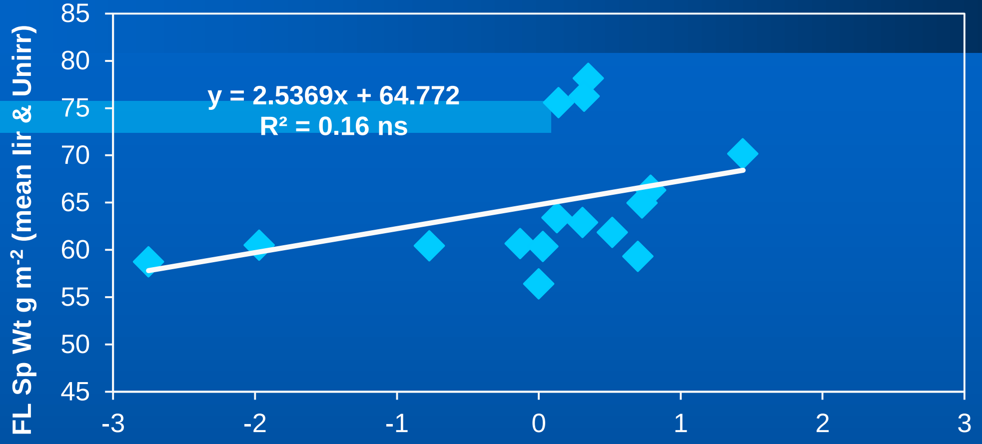
- An increase in leaf transpiration decreases leaf T°C (hence intercellular vapour pressure) resulting in less $H_2{}^{18}O$ enrichment at the evaporating site.



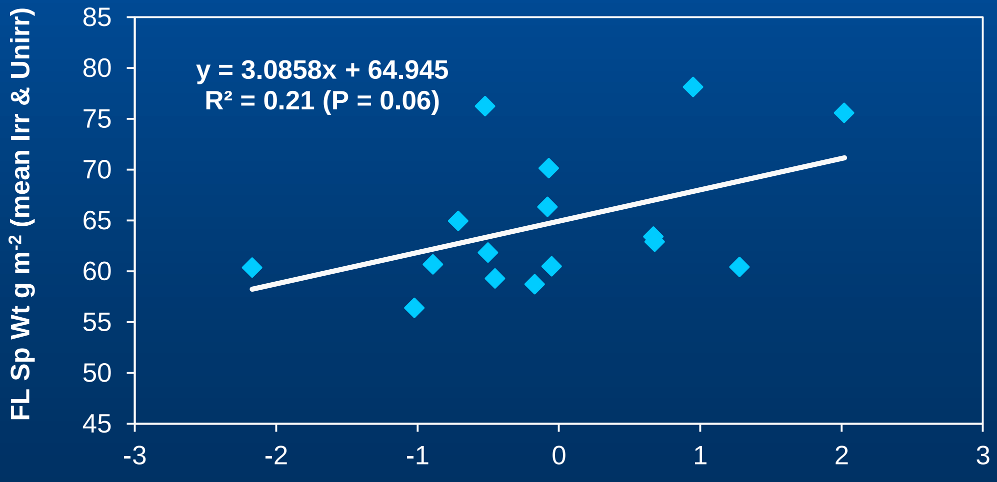
Relationship between $\Delta^{13}C$ and $\Delta^{18}O$ in 18 wheat cultivars (mean 2010 and 2011)



Residual flag leaf Δ¹⁸O vs grain Δ¹³C relationship versus flag leaf specific weight at GS61



Residual FL Δ 18O versus grain Δ 13 C **Unirrigated**



Residual FL 18O versus grain 13C **Irrigated**

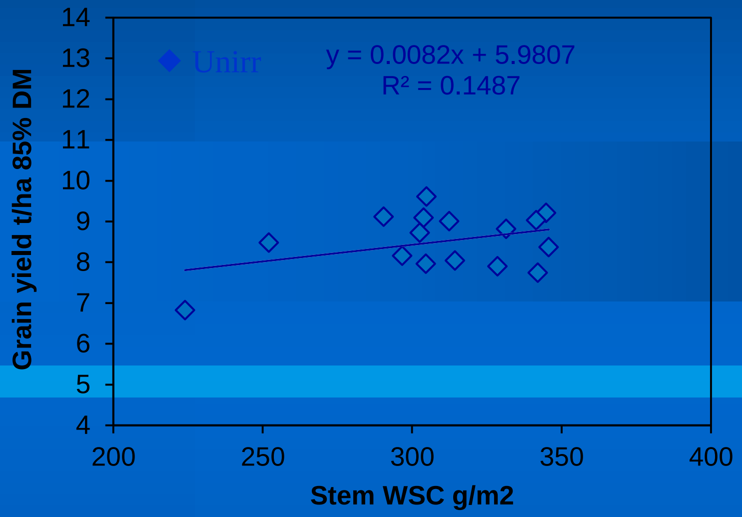
WGIN 2 (9.2 QTL Detection)

2010-11 and 2011-12 expts

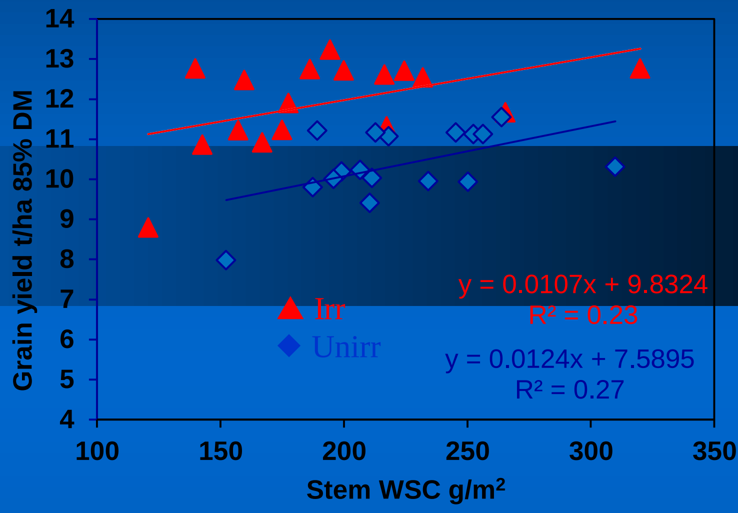
- Rialto x Savannah DH population for phenotying for yield physiological traits (94 lines and 2 parents)
- 2 sites: Nottingham - irrigated & unirrigated; JIC - unirrigated
- Target traits
  - ^{13}C Δ grain
  - senescence kinetics
  - canopy temperature
  - stem WSC

Other traits correlations: Stem WSC @ GS61+9d

Grain yield versus stem WSC reserves

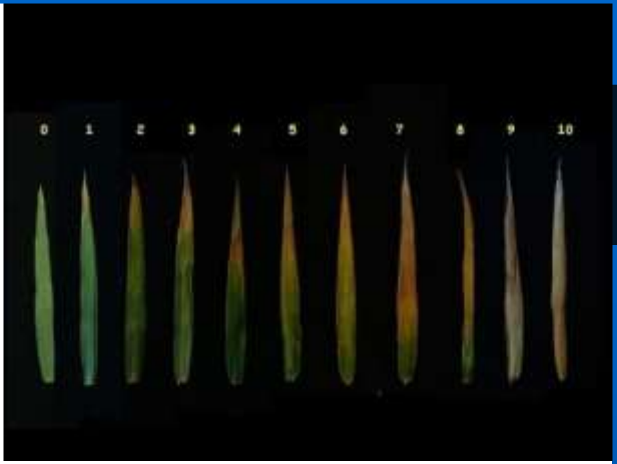


Sutton Bonington 2009-10



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)

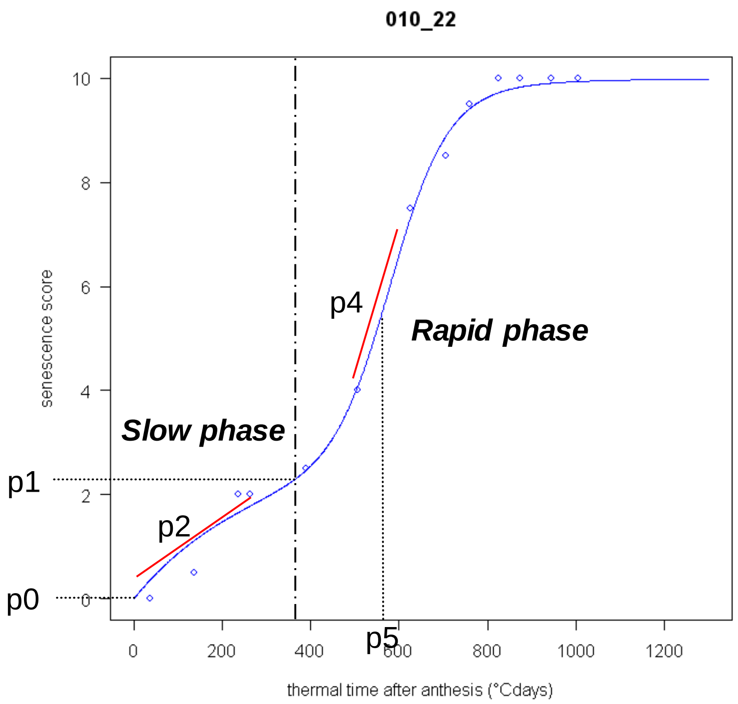
p0 : score at anthesis

p1 : score at the end of the slow phase

p2 : max rate of the slow phase

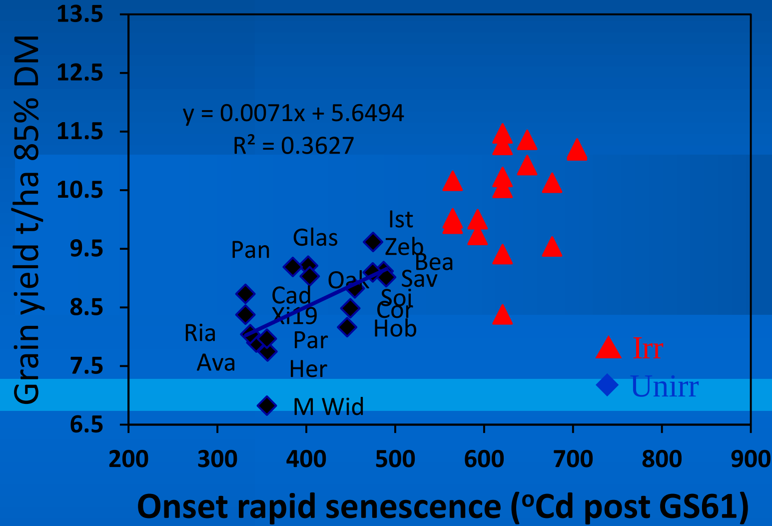
p4 : max rate of the rapid phase

p5 : date at which p4 is reached

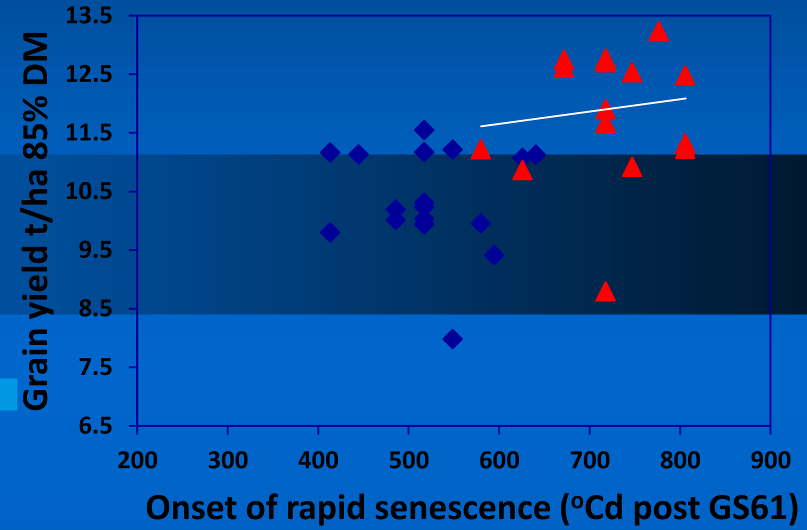


Other traits correlations: Flag leaf senescence

Grain yield versus Onset of Senescence

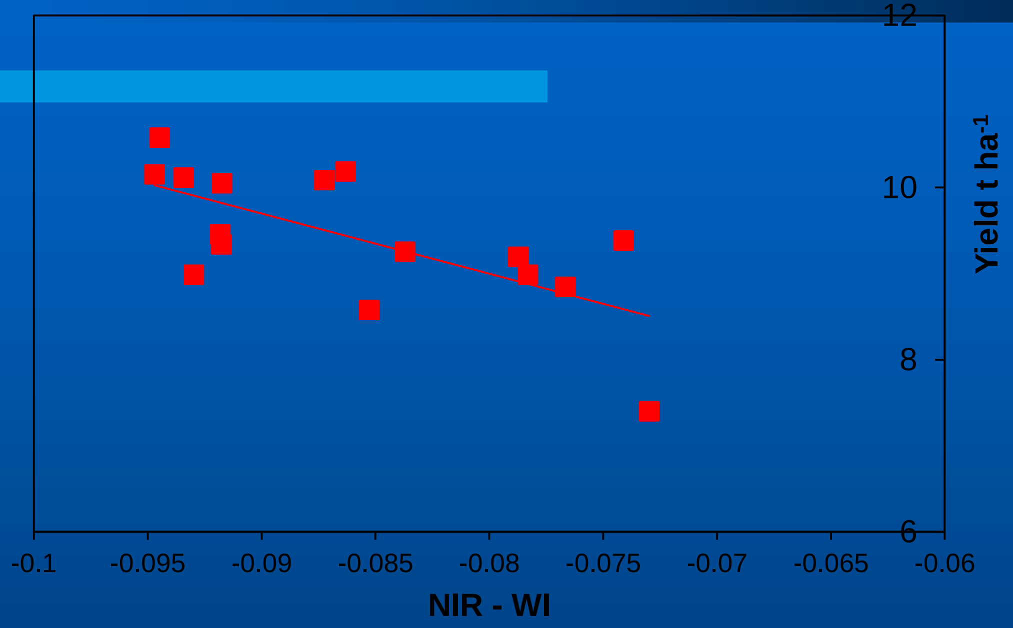


Sutton Bonington 2009-10



Sutton Bonington 2010-11

Spectral reflectance: Water index at GS61+14 d



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

Sutton Bonington Mean 2009-10 & 2010-11

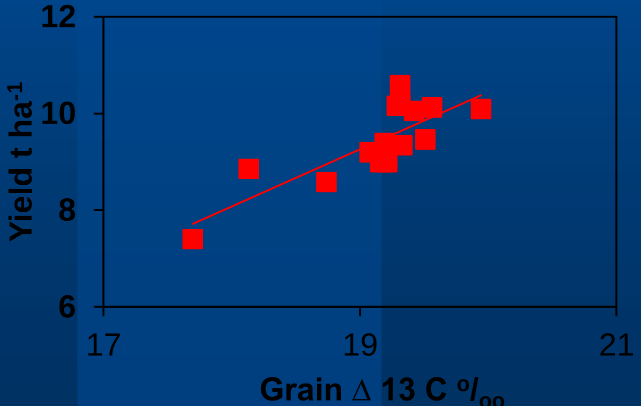
Drought tolerant plant ideotype

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

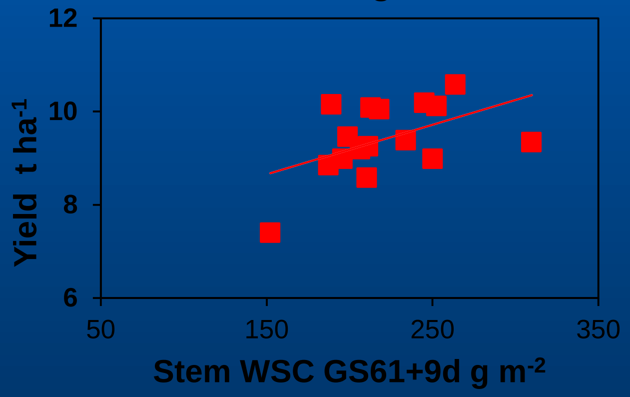
$$GY = -41.9\ x_1 + 0.08\ x_2 + 12.3\ x_3$$

Unirr

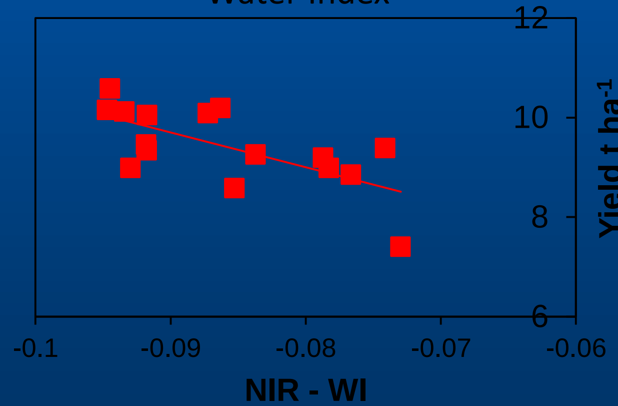
GY increases with increasing Δ 13 C (↓WUE) :



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 Δ grain	Captures extra water	High
Flag leaf 'stay-green'	Extends grain filling during late drought	High
Low canopy T°C/ 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

Rothamsted Research
where knowledge grows

NUE stuff

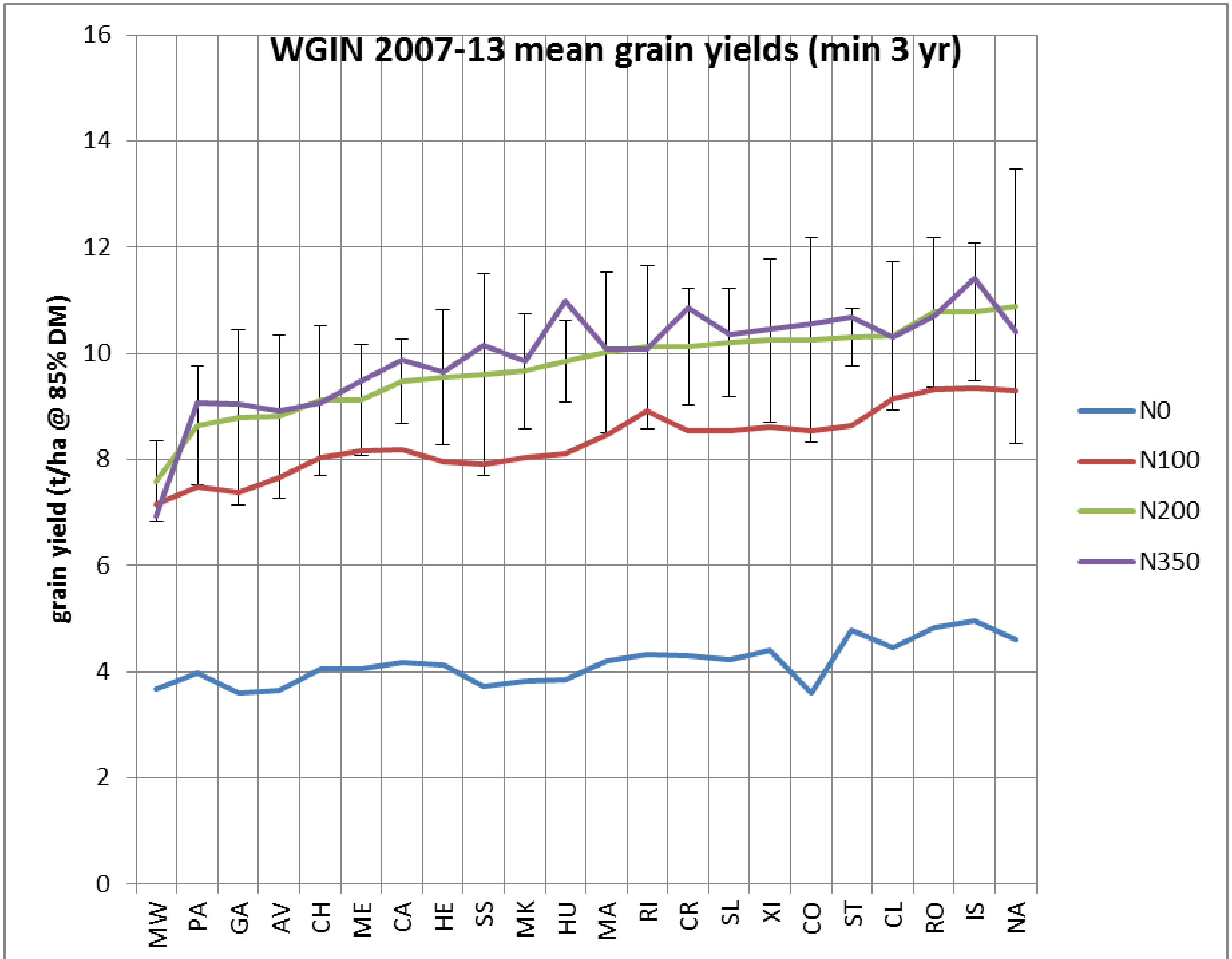
Malcolm J. Hawkesford

Current activities (nitrogen)

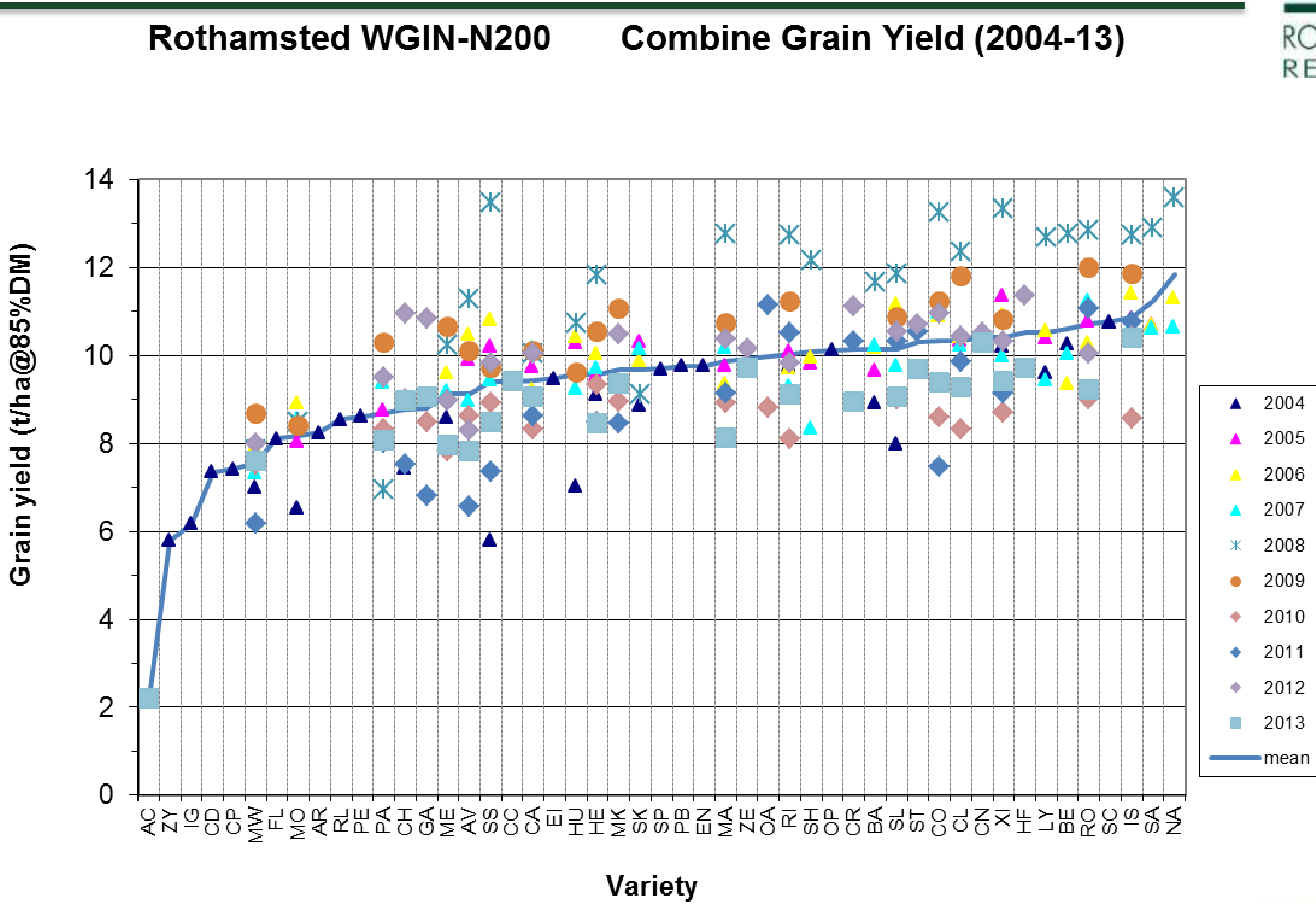
- 2014 Diversity trial drilled
- Avalon x cadenza full field trial – to be use in root phenotyping + yield etc (but hestitation on line purity….)
- Rebulking A x C
- Using Diversity for UAV testing
- NIRS for N analysis of past Diversity samples
- Data collation…….

Rothamsted 2013

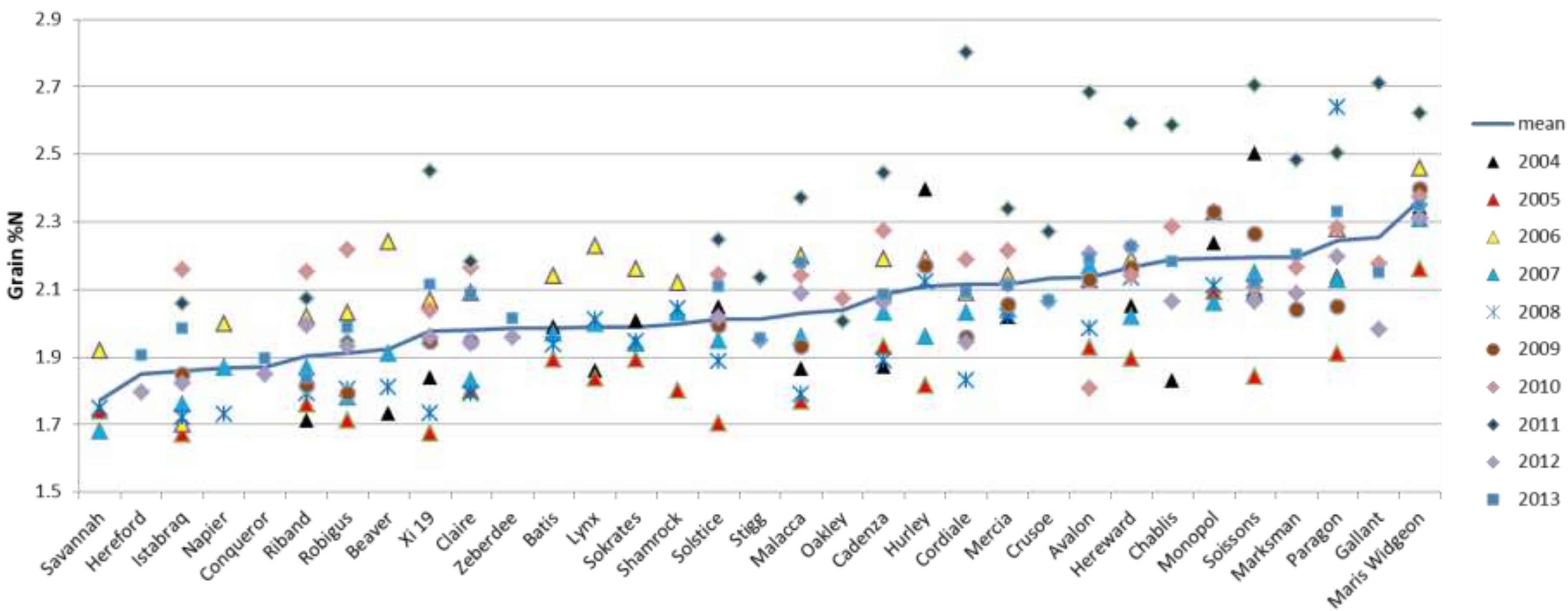
Grain yields core set



Rothamsted WGIN Trials – yield stability



Grain %N (2004-13)



NB only for varieties with more than single year data

Uptake and partitioning

Field Crops Research xxx (2013) xxx–xxx

Contents lists available at ScienceDirect

Field Crops Research

journal homepage: www.elsevier.com/locate/fcr

Genotypic variation in the uptake, partitioning and remobilisation of nitrogen during grain-filling in wheat☆

Peter B. Barraclough*, Rafael Lopez-Bellido[1], Malcolm J. Hawkesford

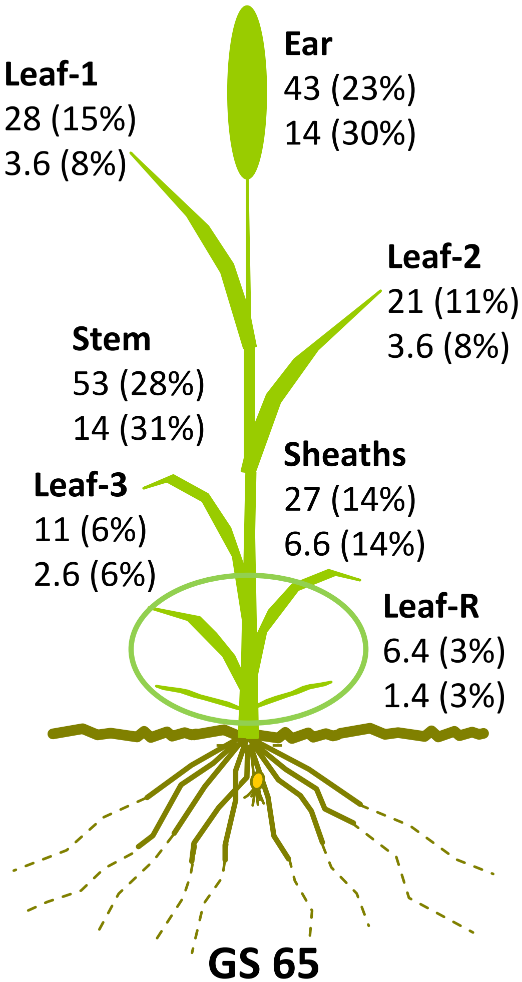
Plant Biology and Crop Science Department, Rothamsted Research, West Common, Harpenden, Hertfordshire AL5 2JQ, UK

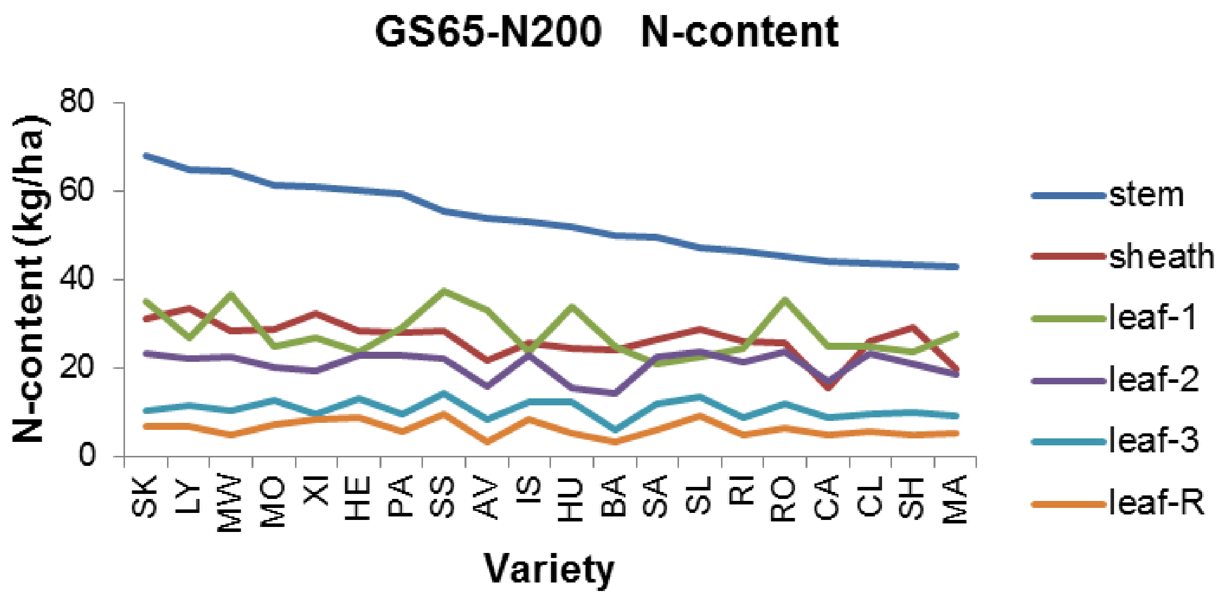
ROTHAMSTED RESEARCH

BBSRC bioscience for the future

Partitioning at anthesis, N200

Shoot total
N200 - 189 kg/ha (100%)
N0 - 46 kg/ha (100%)



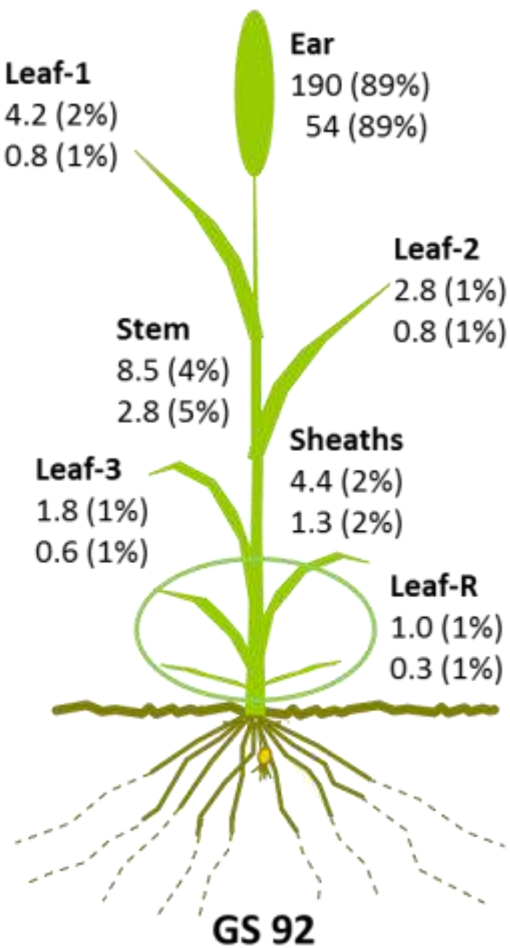


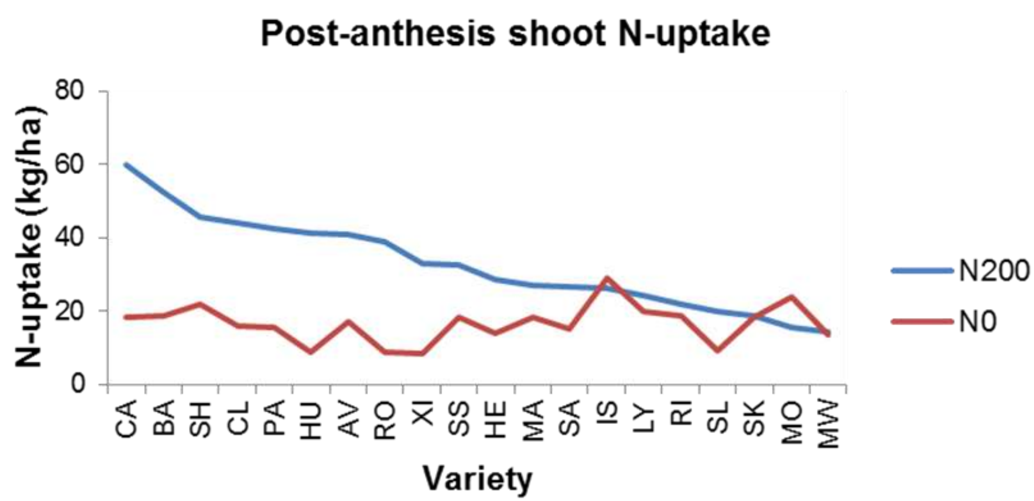
ROTHAMSTED RESEARCH

BBSRC bioscience for the future

Post anthesis N uptake

Shoot total
N200 - 213 kg/ha (100%)
N0 - 61 kg/ha (100%)

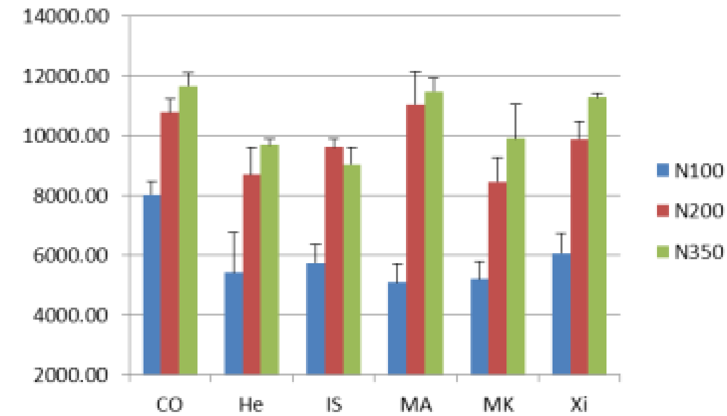




Grain protein N response

ROTHAMSTED RESEARCH

- Part of BBSRC-HGAC GPD project
- See HGCA report number 521
- Papers on gamma and omega gliadins
  - J. Exp Bot
  - Anal Bot (in press)



Annals of Botany Page 1 of 9
doi:10.1093/aob/mct291, available online at www.aob.oxfordjournals.org
ANNALS OF BOTANY

Effects of nitrogen nutrition on the synthesis and deposition of the ω-gliadins of wheat

Yongfang Wan, Cristina Sanchis Gritsch, Malcolm J. Hawkesford and Peter R. Shewry*
Department of Pla

Recei

October 2013

HGCA

Project Report No. 521

›ility of UK-grown wheat for breadmaking

by

Wan[1], G. Chope[2], S. Penson[2], E. F.Mosleth[3] and M. J. Hawkesford[1]

Journal of Experimental Botany Advance Access published November 16, 2012
Journal of Experimental Botany
doi:10.1093/jxb/ers318
This paper is available online free of all access charges (see http://jxb.oxfordjournals.org/open_access.html for further details)
Journal of Experimental Botany

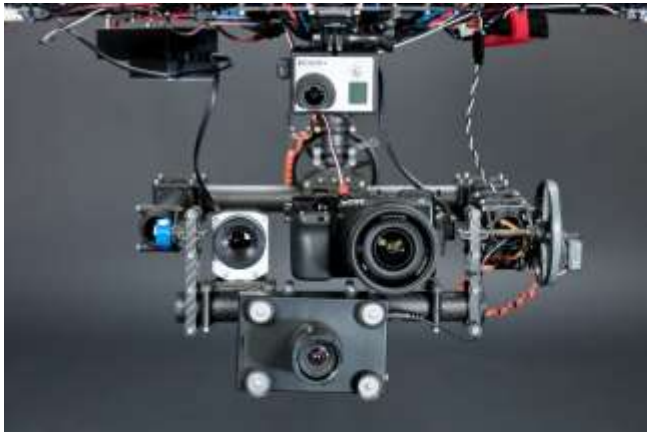
RESEARCH PAPER

A novel family of γ-gliadin genes are highly regulated by nitrogen supply in developing wheat grain

Yongfang Wan, Peter R. Shewry* and Malcolm J. Hawkesford
Department of Plant Biology and Crop Science, Rothamsted Research, Harpenden, Hertfordshire AL5 2JQ, UK

BBSRC
bioscience for the future

UAV NDVI



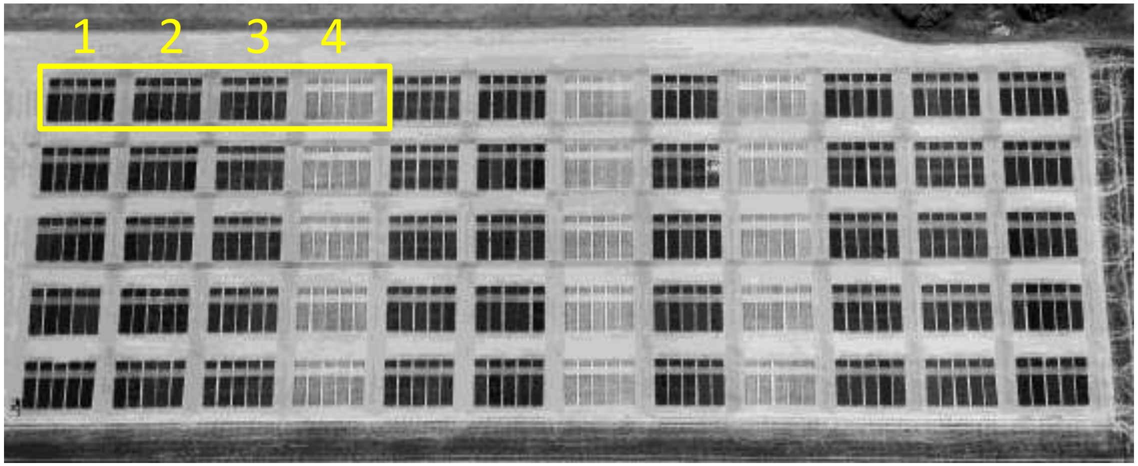
UAV NDVI

ROTHAMSTED RESEARCH

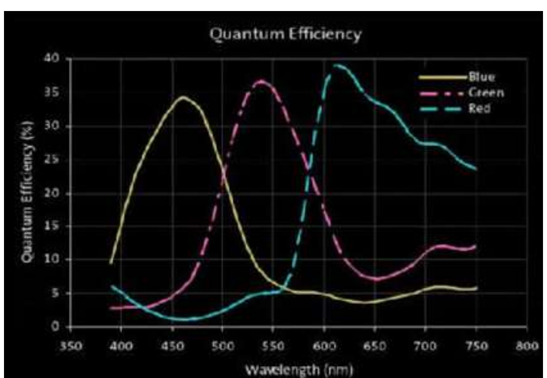
BBSRC bioscience for the future

UAV NDVI

ROTHAMSTED RESEARCH



Plot	Nitrogen	Crop density index
1	350	105
2	200	100
3	100	66
4	0	29



BBSRC bioscience for the future

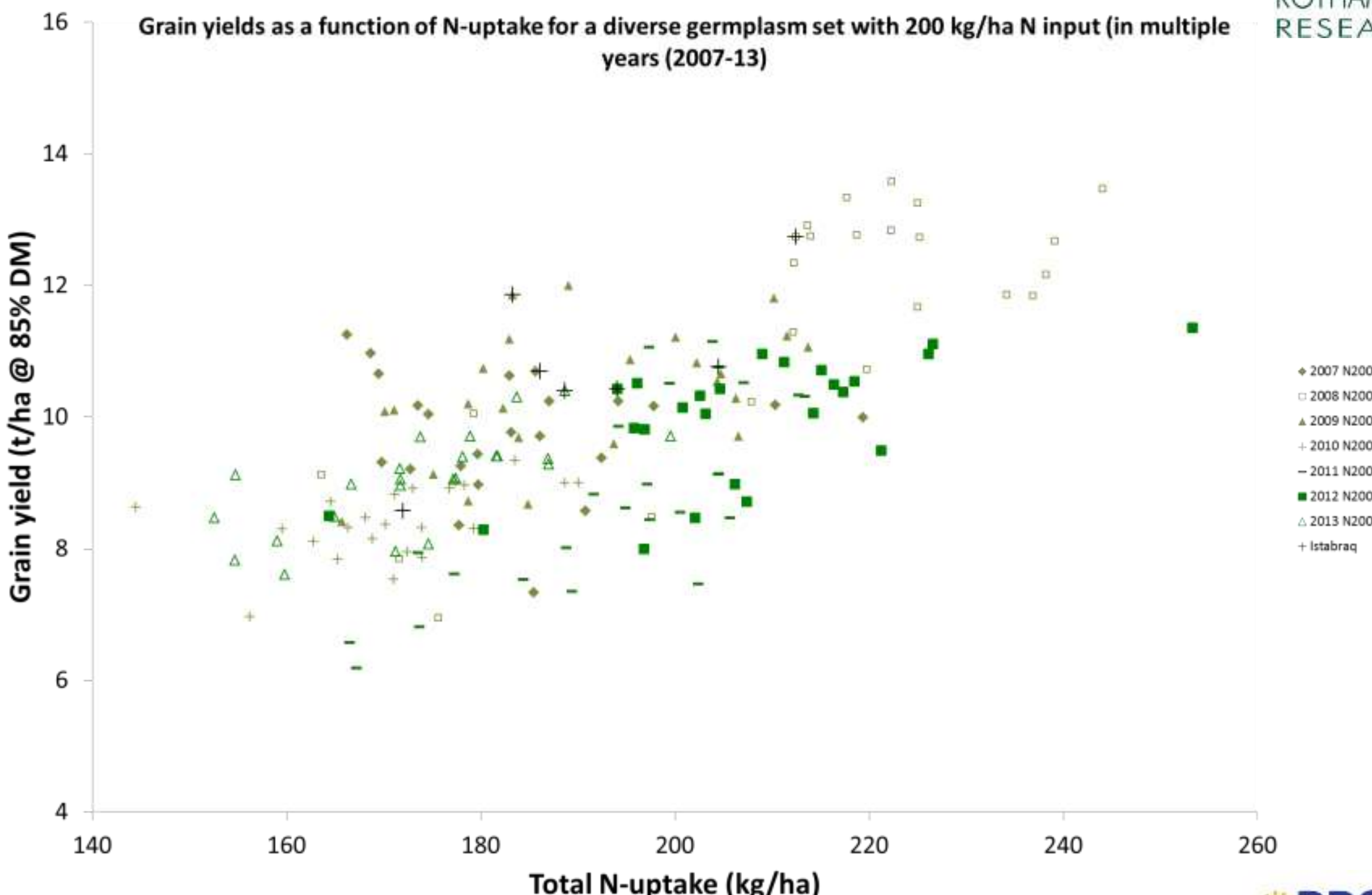
Summary

- Large data set
- Multiple years
- Trait breakdown
- Spin off projects
- More publications in the pipeline
- Trial continuing in 2014

Thanks

- RRes Farm staff
- Peter Buchner, Saroj Parmar, Andrew Riche, Yongfang Wan,Peter Barraclough
- PhD students: Adinda Derkx, Caihong Bai, Astrid Grün, Nick Evens
- Visitors: Xiaochang Dong, Deyong Zhao. Kasra Sabermenesh
- Summer students and casuals
- Peter Shewry
- WISP, WGIN and 20:20 teams

Yield and N-uptake at N200

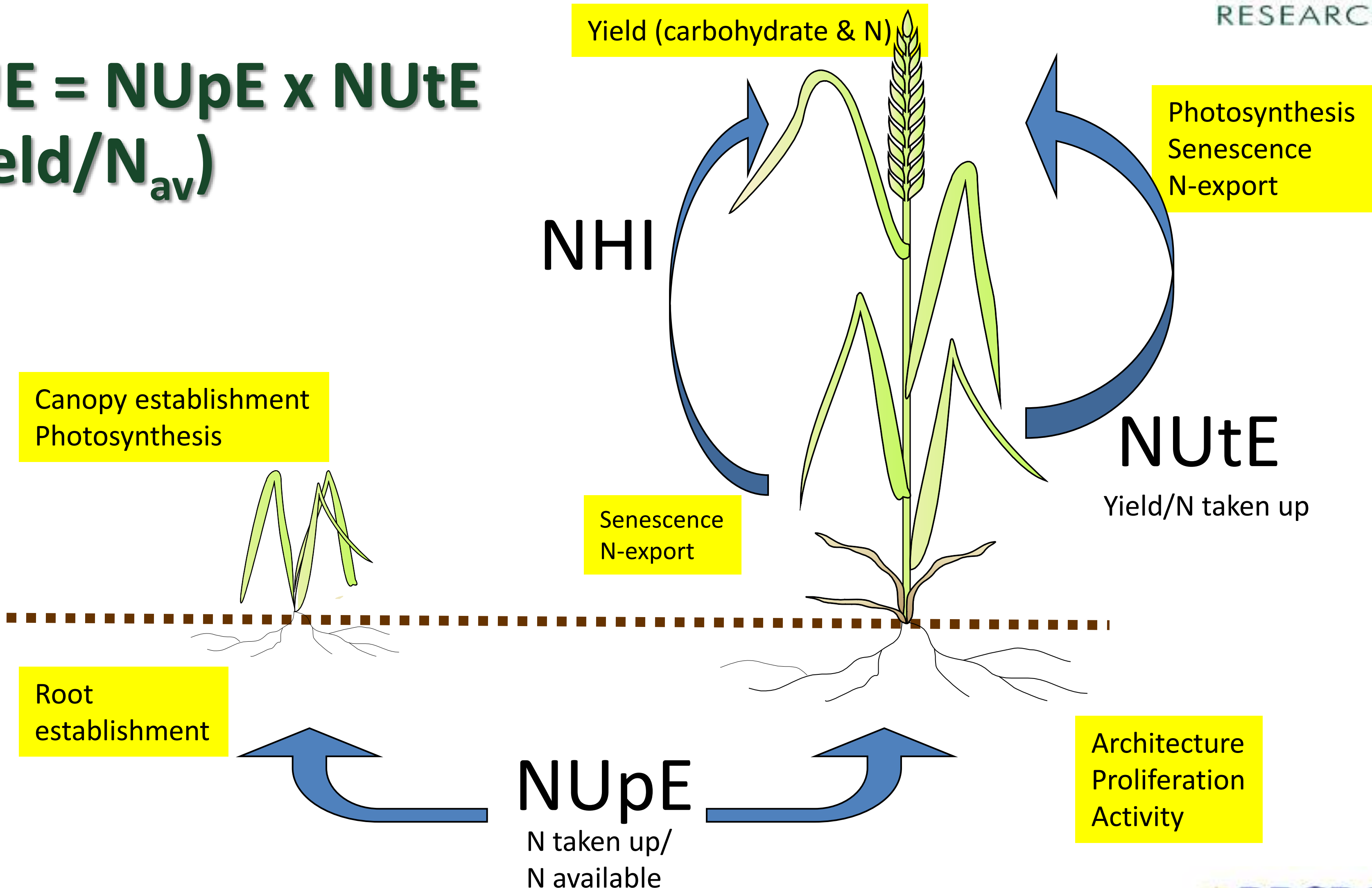


ROTHAMSTED RESEARCH

BBSRC bioscience for the future

Definitions

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



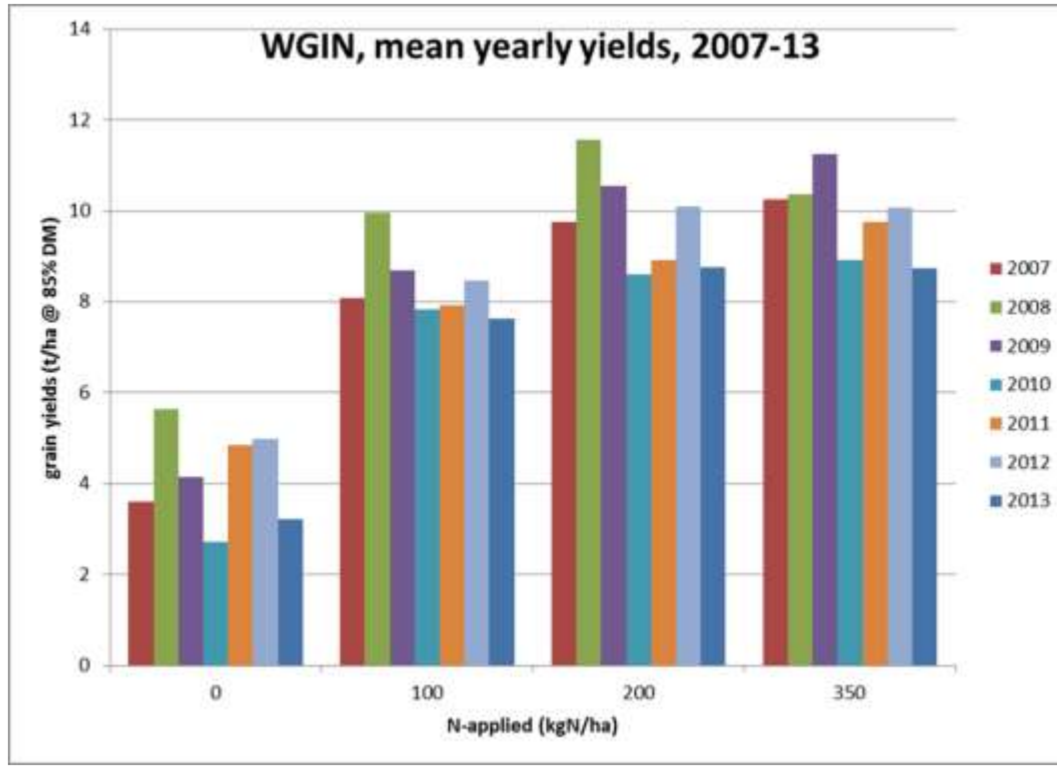
Overview

- The trials
- WGIN Diversity Trial: example data on yield, stability, N uptake, GPD project
- Spin-off projects
- High throughput field phenotyping

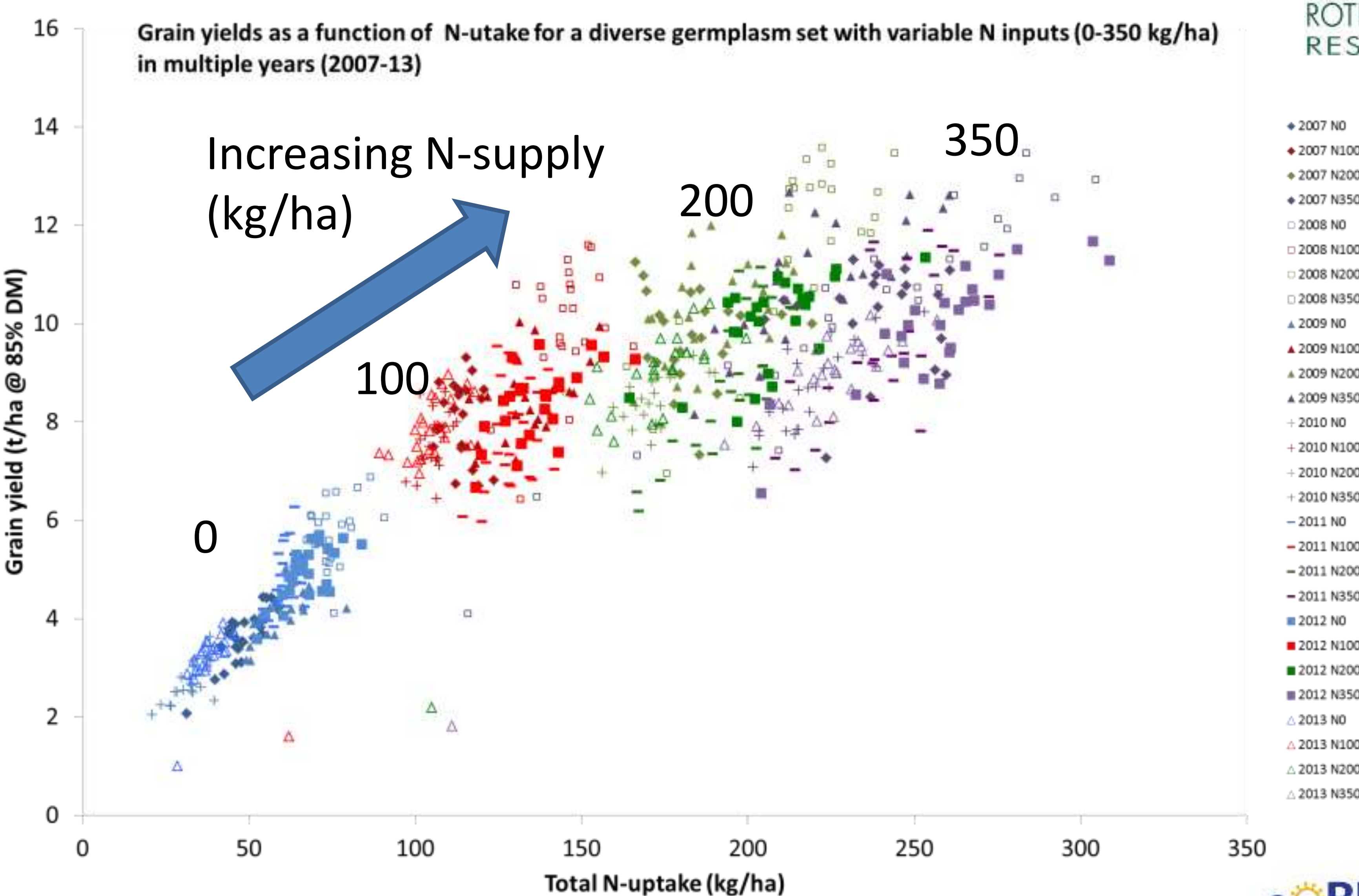



WGIN: The Nitrogen-Diversity trial

- 2004-13
- 51 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
- Many spin-off projects



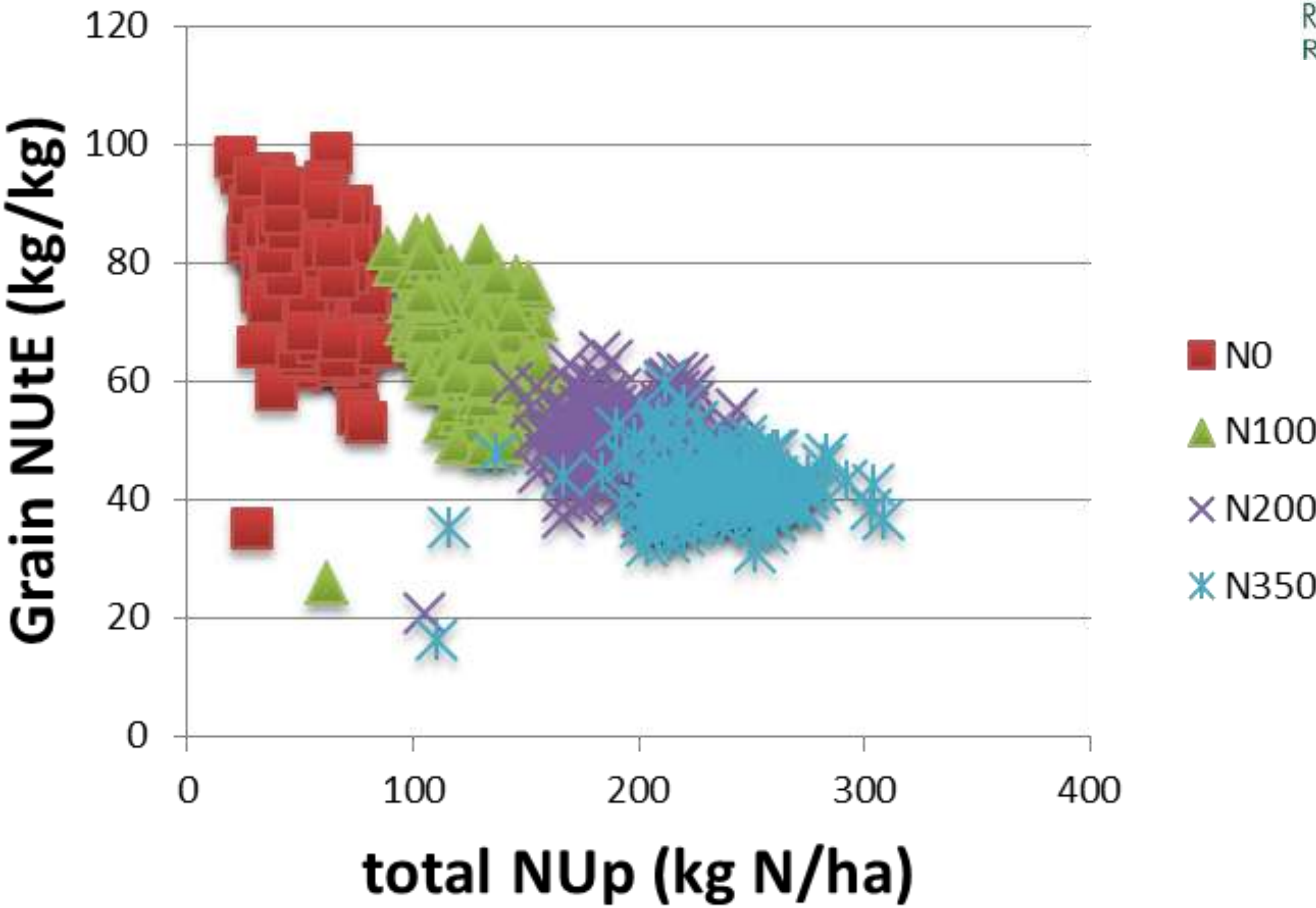
N-supply impacts on yields and quality



ROTHAMSTED RESEARCH

BBSRC bioscience for the future

Do NUtE and NUp correlate?

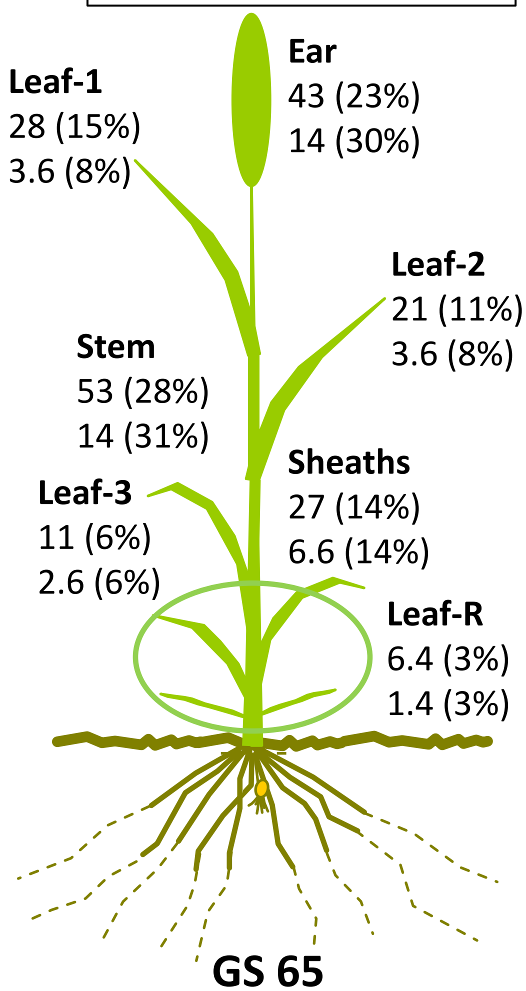


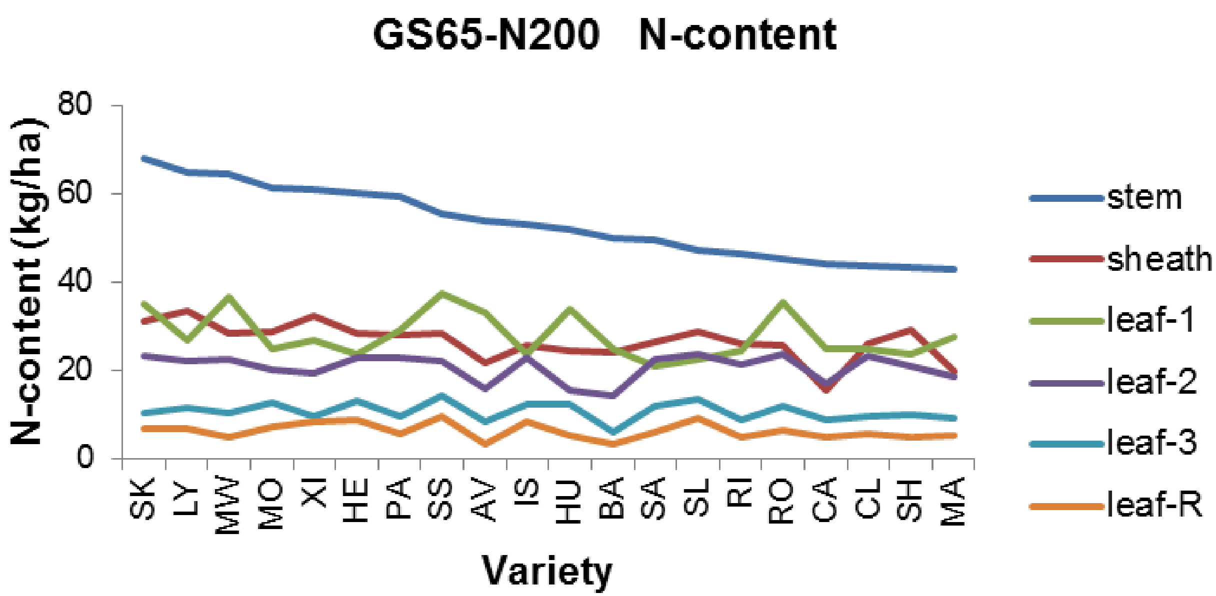
ROTHAMSTED RESEARCH

BBSRC bioscience for the future

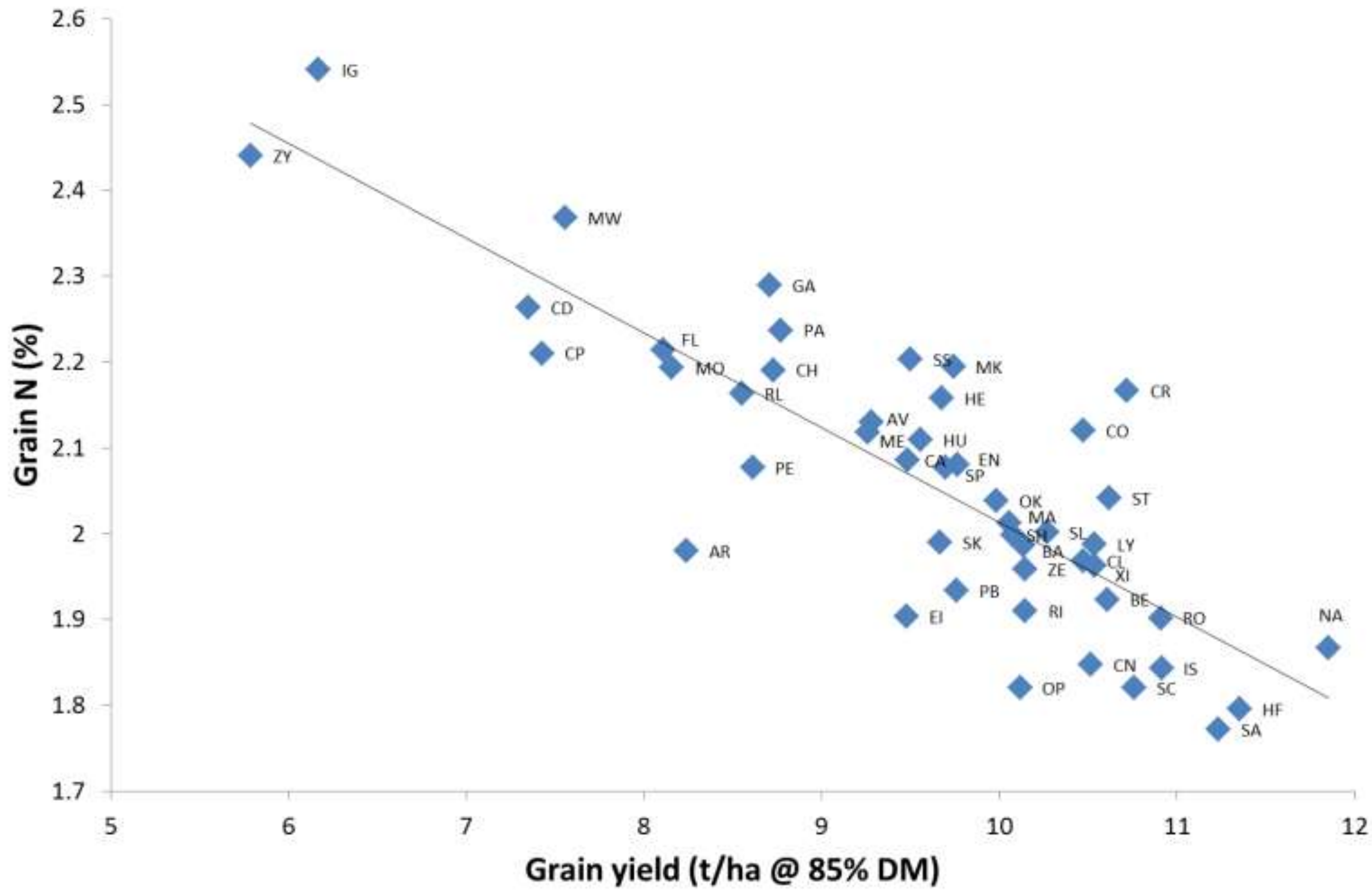
Partitioning at anthesis

Shoot total
N200 - 189 kg/ha (100%)
N0 - 46 kg/ha (100%)





GPD, WGIN trials, 2004-12



ROTHAMSTED RESEARCH

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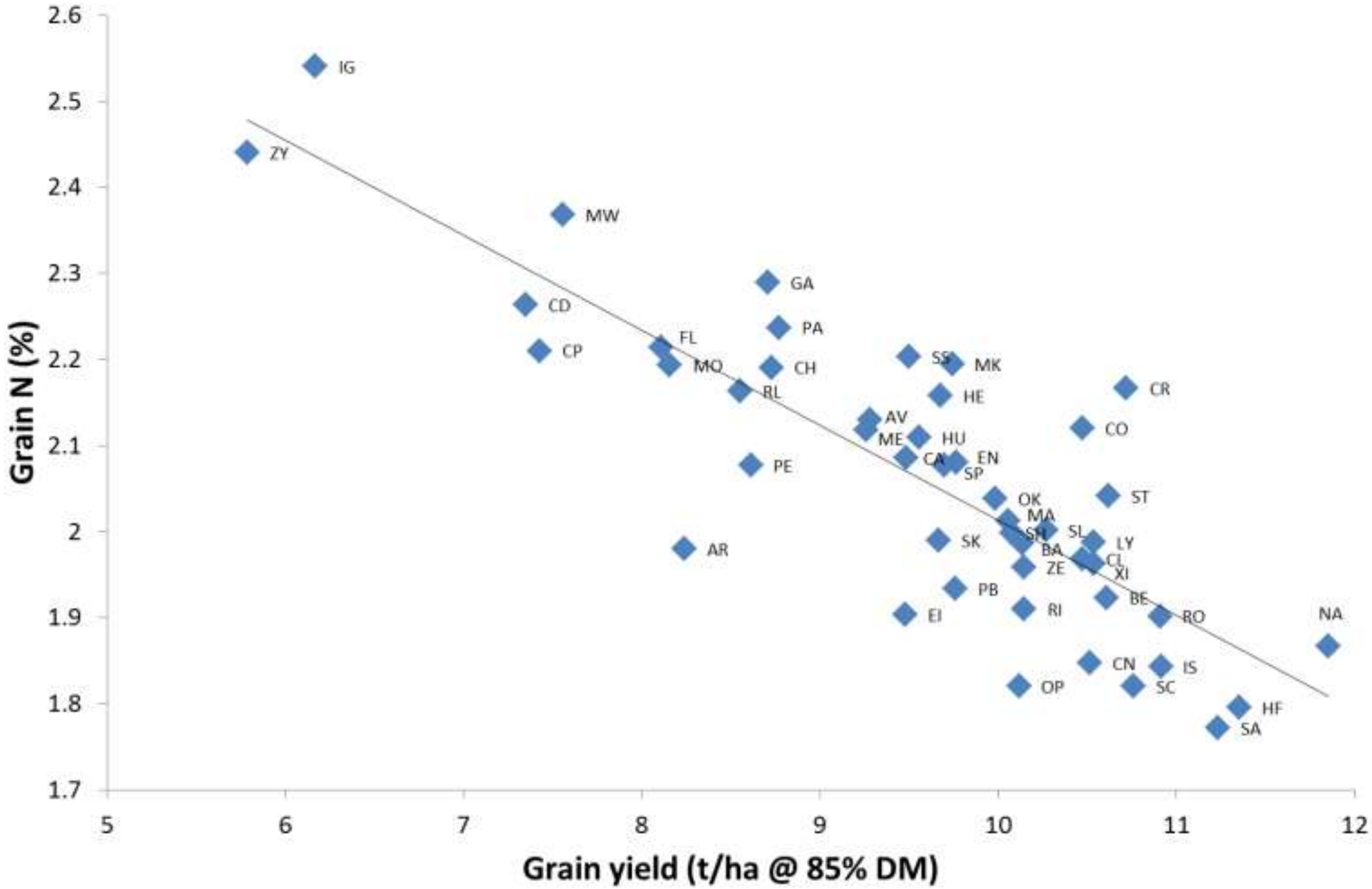
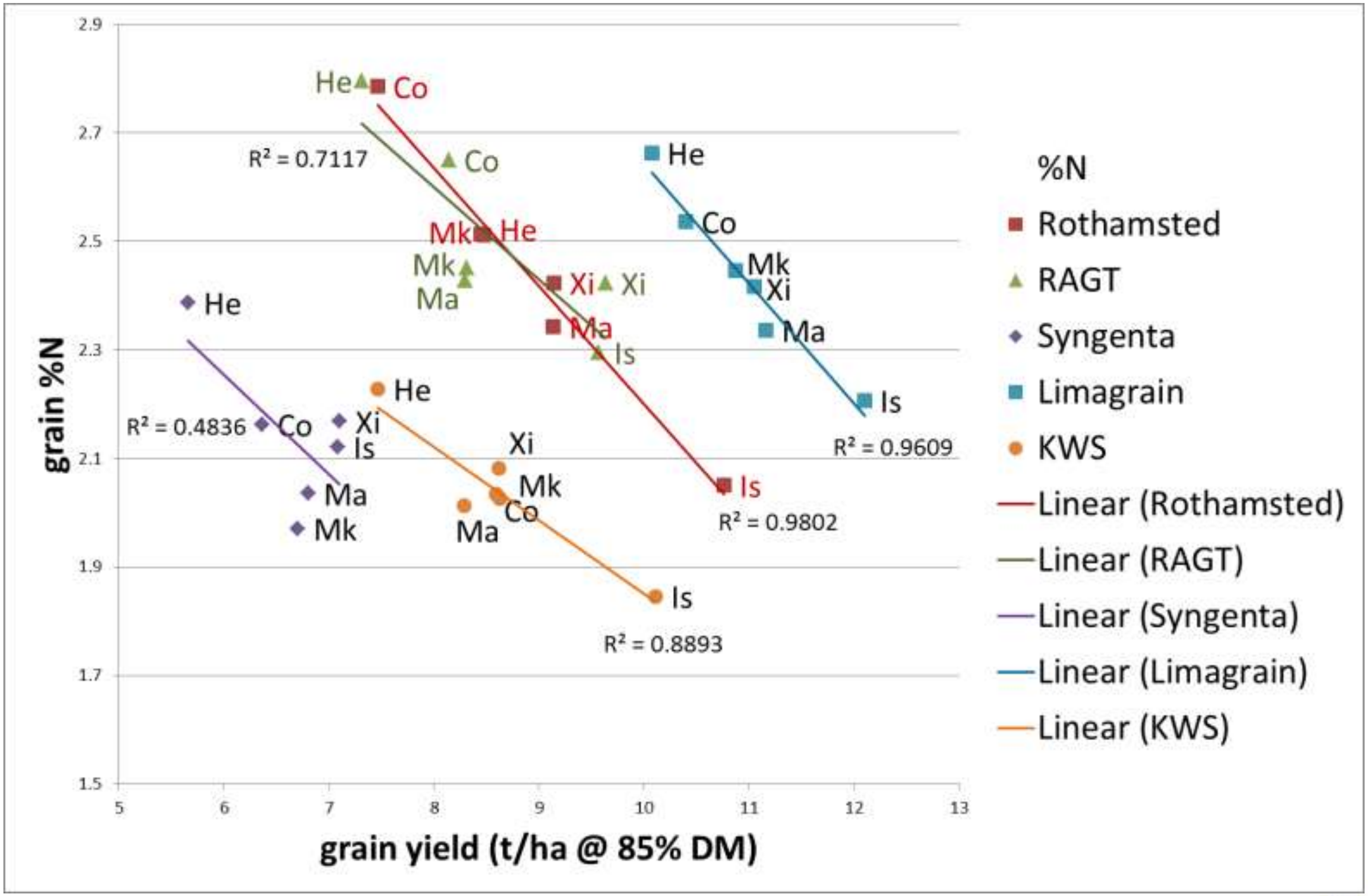
GPD, WGIN trials, 2004-12



GPD, different sites



ROTHAMSTED RESEARCH

BBSRC bioscience for the future

No 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	Inter-Q (orange)	Inter-Q (orange)	Upper-Q	Inter-Q (yellow)
Flanders	FL	1	1	Lower-Q	Upper-Q	Inter-Q (yellow)	Lower-Q
Hereward	HE	1	5	Inter-Q (yellow)	Inter-Q (orange)	Upper-Q	Inter-Q (yellow)
Hurley	HU	1	5	Inter-Q (yellow)	Inter-Q (orange)	Inter-Q (orange)	Inter-Q (yellow)
Malacca	MA	1	5	Inter-Q (orange)	Inter-Q (yellow)	Inter-Q (yellow)	Inter-Q (orange)
Mercia	ME	1	4	Inter-Q (yellow)	Inter-Q (orange)	Inter-Q (yellow)	Inter-Q (yellow)
Maris Widgeon	MW	1	5	Lower-Q	Upper-Q	Lower-Q	Lower-Q
Shamrock	SH	1	4	Inter-Q (yellow)	Inter-Q (yellow)	Inter-Q (orange)	Inter-Q (orange)
Solstice	SL	1	5	Inter-Q (orange)	Inter-Q (yellow)	Inter-Q (yellow)	Upper-Q
Spark	SP	1	1	Inter-Q (orange)	Inter-Q (orange)	Inter-Q (orange)	Inter-Q (yellow)
Xi 19	XI	1	5	Upper-Q	Lower-Q	Inter-Q (orange)	Upper-Q
Cadenza	CA	2	5	Inter-Q (yellow)	Inter-Q (orange)	Upper-Q	Inter-Q (orange)
Cordiale	CO	2	3	Upper-Q	Inter-Q (orange)	Upper-Q	Inter-Q (orange)
Einstein	EI	2	1	Inter-Q (yellow)	Lower-Q	Lower-Q	Inter-Q (orange)
Lynx	LY	2	5	Upper-Q	Inter-Q (yellow)	Upper-Q	Inter-Q (orange)
Rialto	RL	2	1	Inter-Q (yellow)	Upper-Q	Inter-Q (yellow)	Lower-Q
Scorpion	SC	2	1	Upper-Q	Lower-Q	Inter-Q (orange)	Upper-Q
Soissons	SS	2	5	Inter-Q (yellow)	Upper-Q	Inter-Q (orange)	Lower-Q
Beaver	BE	3	4	Inter-Q (orange)	Inter-Q (yellow)	Inter-Q (yellow)	Inter-Q (orange)
Claire	CL	3	4	Upper-Q	Inter-Q (yellow)	Upper-Q	Upper-Q
Riband	RI	3	5	Inter-Q (orange)	Lower-Q	Inter-Q (yellow)	Upper-Q
Robigus	RO	3	4	Upper-Q	Lower-Q	Upper-Q	Upper-Q
Istabraq	IS	4	4	Upper-Q	Lower-Q	Inter-Q (orange)	Upper-Q
Napier	NA	4	3	Upper-Q	Inter-Q (yellow)	Upper-Q	Inter-Q (orange)
Savannah	SA	4	4	Upper-Q	Lower-Q	Inter-Q (orange)	Upper-Q
Paragon (spring)	PA	1	5	Inter-Q (yellow)	Upper-Q	Inter-Q (orange)	Inter-Q (yellow)
Chablis (spring)	CH	2	1	Lower-Q	Lower-Q	Lower-Q	Upper-Q
Arche	AR	F	1	Lower-Q	Inter-Q (yellow)	Lower-Q	Inter-Q (yellow)
Batis	BA	G	5	Inter-Q (orange)	Inter-Q (yellow)	Upper-Q	Inter-Q (yellow)
Caphorn	CP	F	1	Lower-Q	Upper-Q	Lower-Q	Lower-Q
Cappelle Desprez	CD	F	1	Lower-Q	Upper-Q	Lower-Q	Lower-Q
Enorm	EN	G	1	Inter-Q (orange)	Inter-Q (orange)	Upper-Q	Inter-Q (yellow)
Isengrain	IG	F	1	Lower-Q	Upper-Q	Lower-Q	Lower-Q
Monopol	MO	G	5	Lower-Q	Upper-Q	Inter-Q (yellow)	Lower-Q
Opus	OP	G	1	Upper-Q	Lower-Q	Lower-Q	Upper-Q
PBis	PB	G	1	Inter-Q (orange)	Inter-Q (yellow)	Inter-Q (yellow)	Inter-Q (orange)
Petrus	PE	G	1	Inter-Q (yellow)	Inter-Q (orange)	Inter-Q (yellow)	Inter-Q (yellow)
Sokrates	SK	G	5	Inter-Q (orange)	Inter-Q (orange)	Inter-Q (orange)	Inter-Q (orange)
Zyta	ZY	P	1	Lower-Q	Upper-Q	Lower-Q	Lower-Q

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

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

EJA (2010) 33, 1-11

Europ. J. Agronomy 33 (2010) 1–11

Contents lists available at ScienceDirect

European Journal of Agronomy

journal homepage: www.elsevier.com/locate/eja

ELSEVIER

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

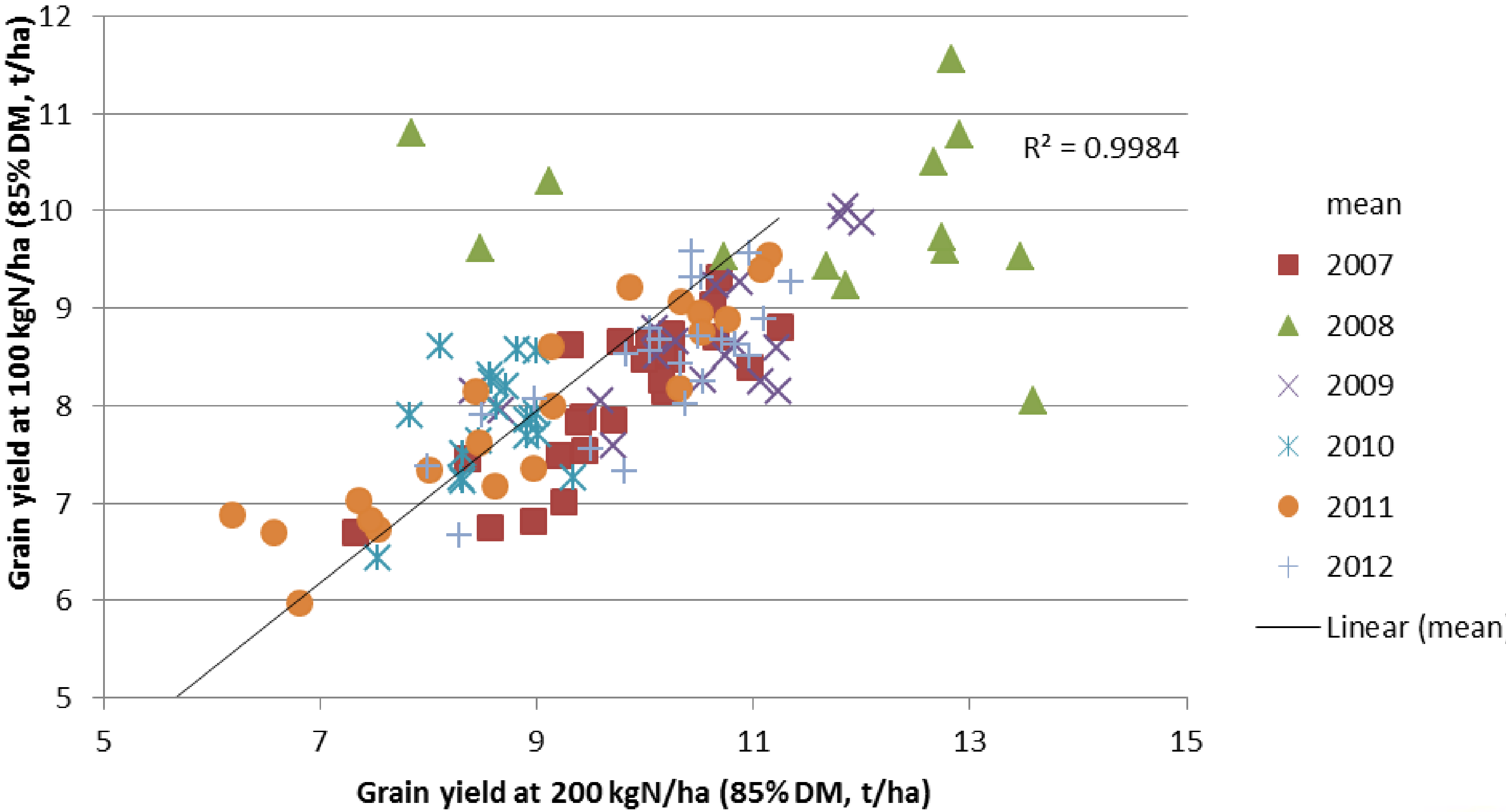
Peter B. Barraclough[a,*], Jonathan R. Howarth[a], Janina Jones[a], Rafael Lopez-Bellido[b], Saroj Parmar[a], Caroline E. Shepherd[a], Malcolm J. Hawkesford[a]

BBSRC bioscience for the future

High v low inputs

ROTHAMSTED RESEARCH

WGIN Comparative low N v high N performance (2007-12)



BBSRC bioscience for the future

Diversity trial history

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

WGIN MM
6th December2013
@Limagrain

Reducing the risk of take-all disease in wheat

Vanessa McMillan

Richard Gutteridge

Kim Hammond-Kosack

Wheat Genetic Improvement Network

defra
Department for Environment Food and Rural Affairs

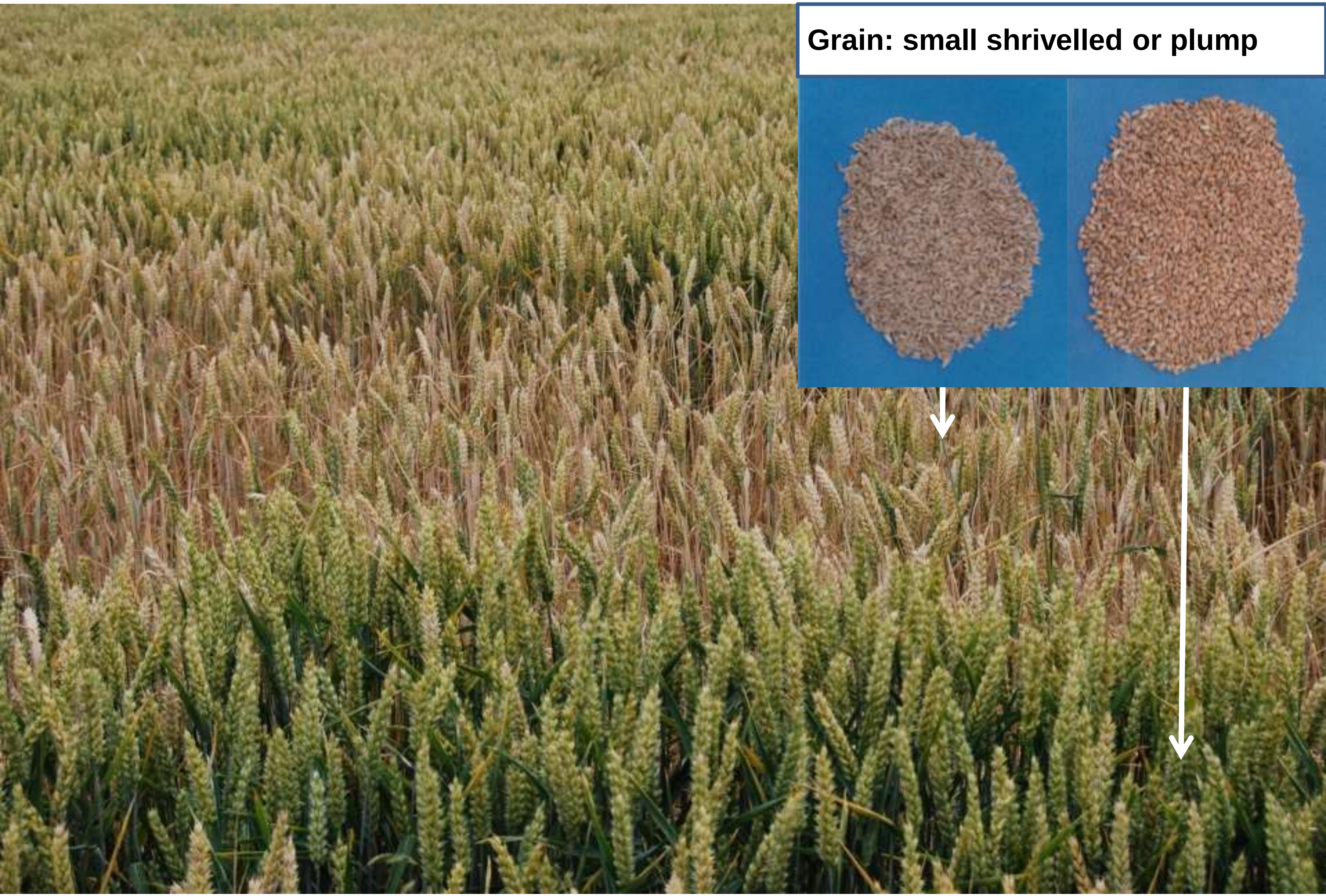
ROTHAMSTED RESEARCH

Take-all disease

- *Gaeumannomyces graminis* var. *tritici* (*Ggt*)
- ascomycete soil-borne fungus
- *Ggt* infects the roots
- No genetic solution to the control of take-all disease available

Severely infected plant

Typical take-all patch showing stunting and premature ripening of the crop



Disease development

- **1st wheat crop-** very little disease provided break crop is free from take-all carriers

- **2nd – 4th wheat crop-** severe disease can occur during this period

- **5th wheat crop onwards-** take-all severity decreases compared to a crop at its peak. This is known as Take-all Decline (TAD)

WGIN2 Cultivar Rotation trial

Hypothesis: 1st wheat genetics can be used to improve 2nd wheat crop yield performance

1st wheat
Inoculum build–up in the soil at harvest

→

2nd wheat
Grain Yield
Straw Yield

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

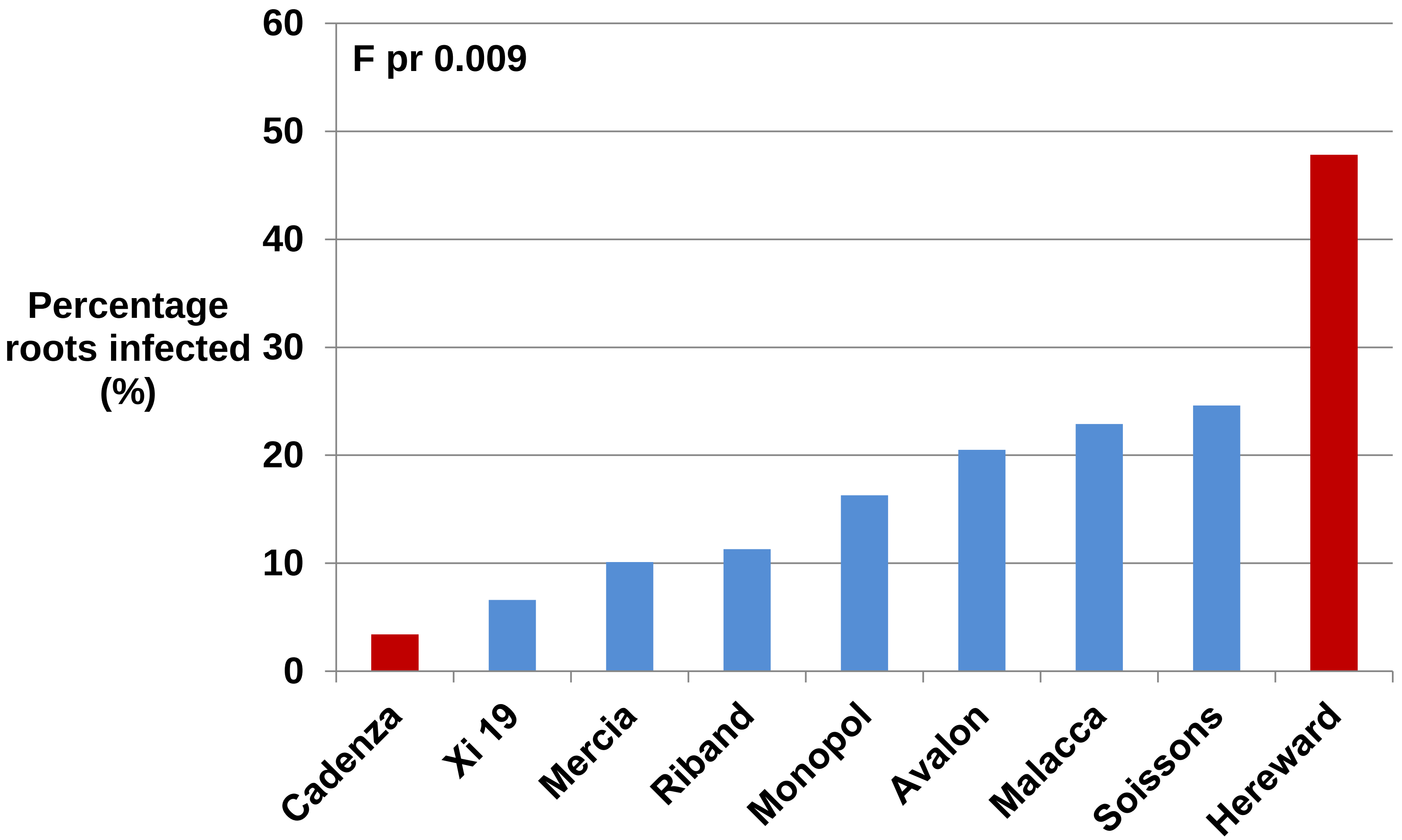
Soil core bioassay plants

Severe take-all infection

Slight take-all infection

Soil infectivity post harvest is influenced by variety (WGIN1 Diversity 4 year means)

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

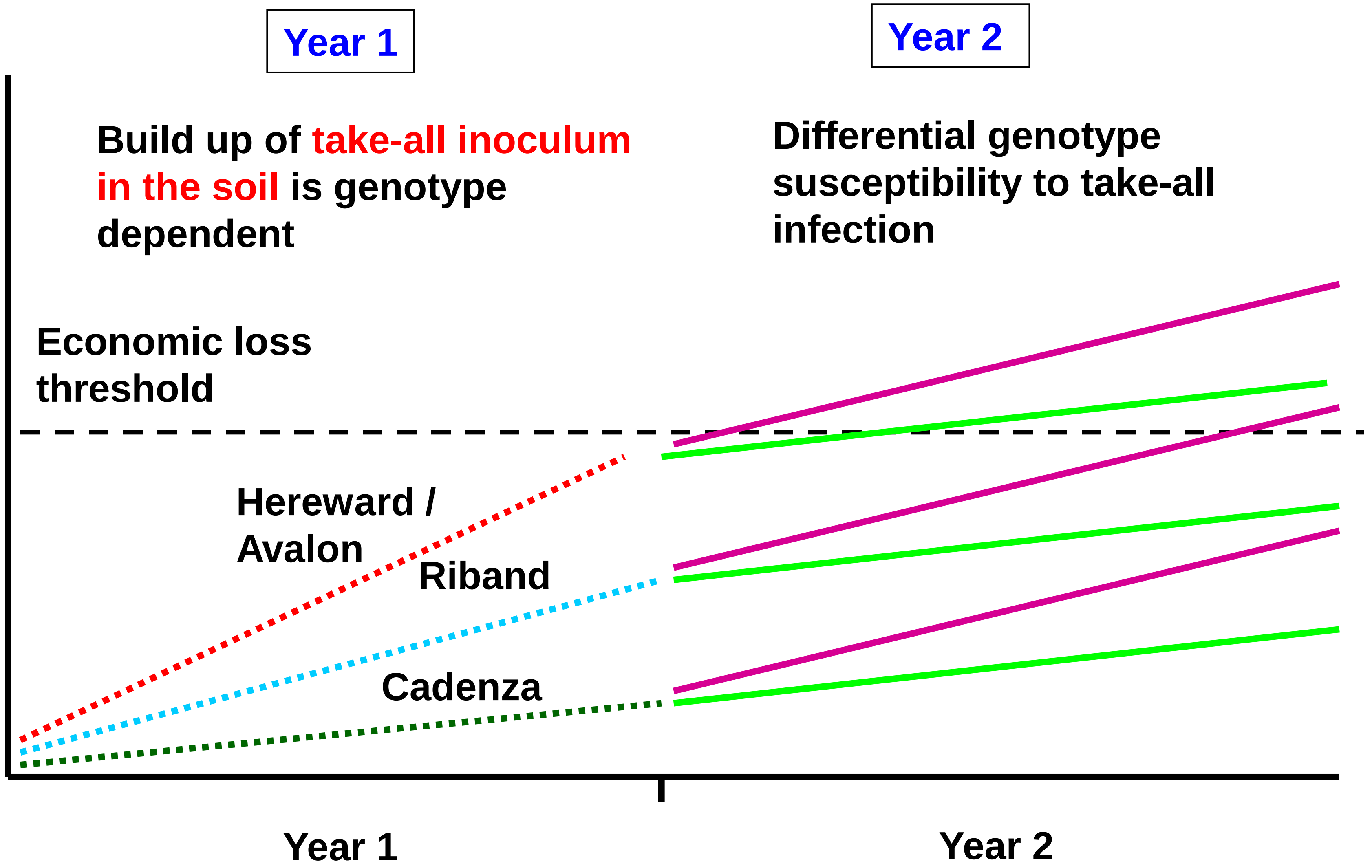


McMillan *et al*. 2011, Plant Pathology, **60**, 200-206

1st wheats

Cultivar rotation trials

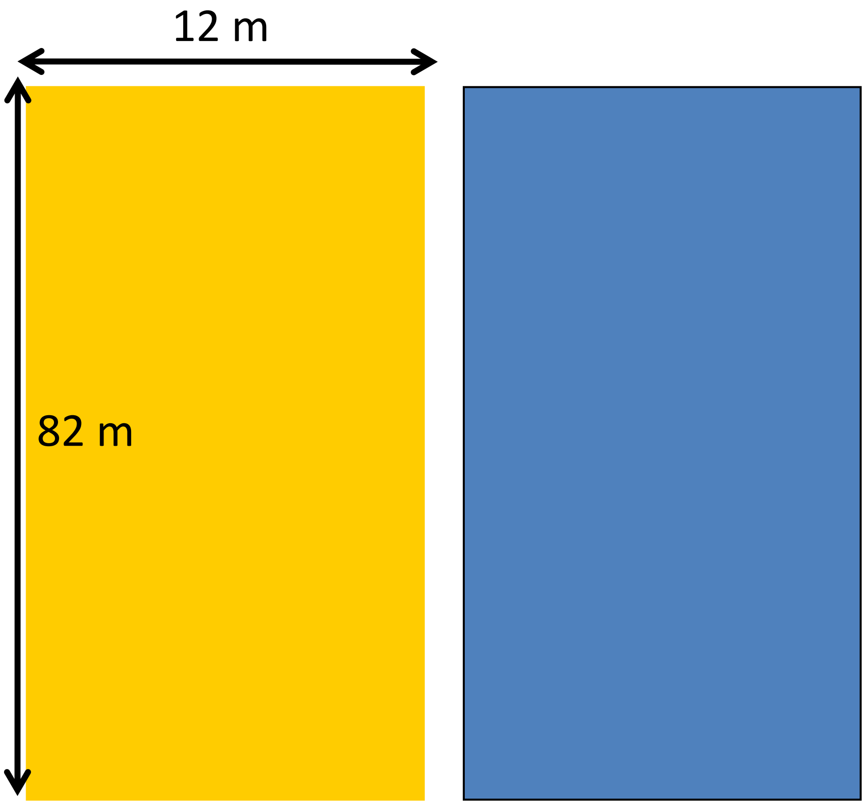
Overall objective: **Explore the effect of sowing different sequences of cultivars on take-all disease pressure**



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)

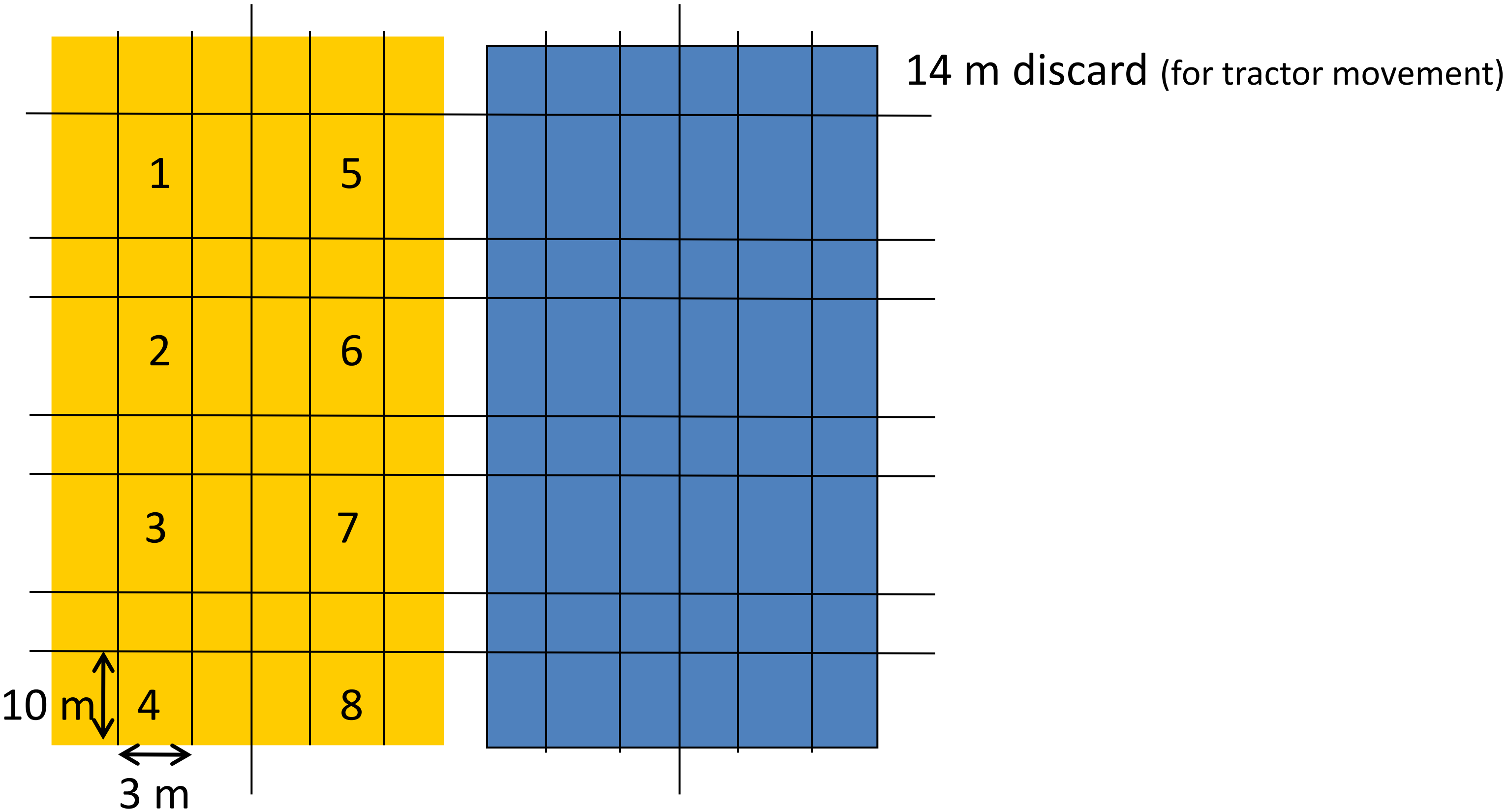


12m x 82m, of each variety
4 replicates of each

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.

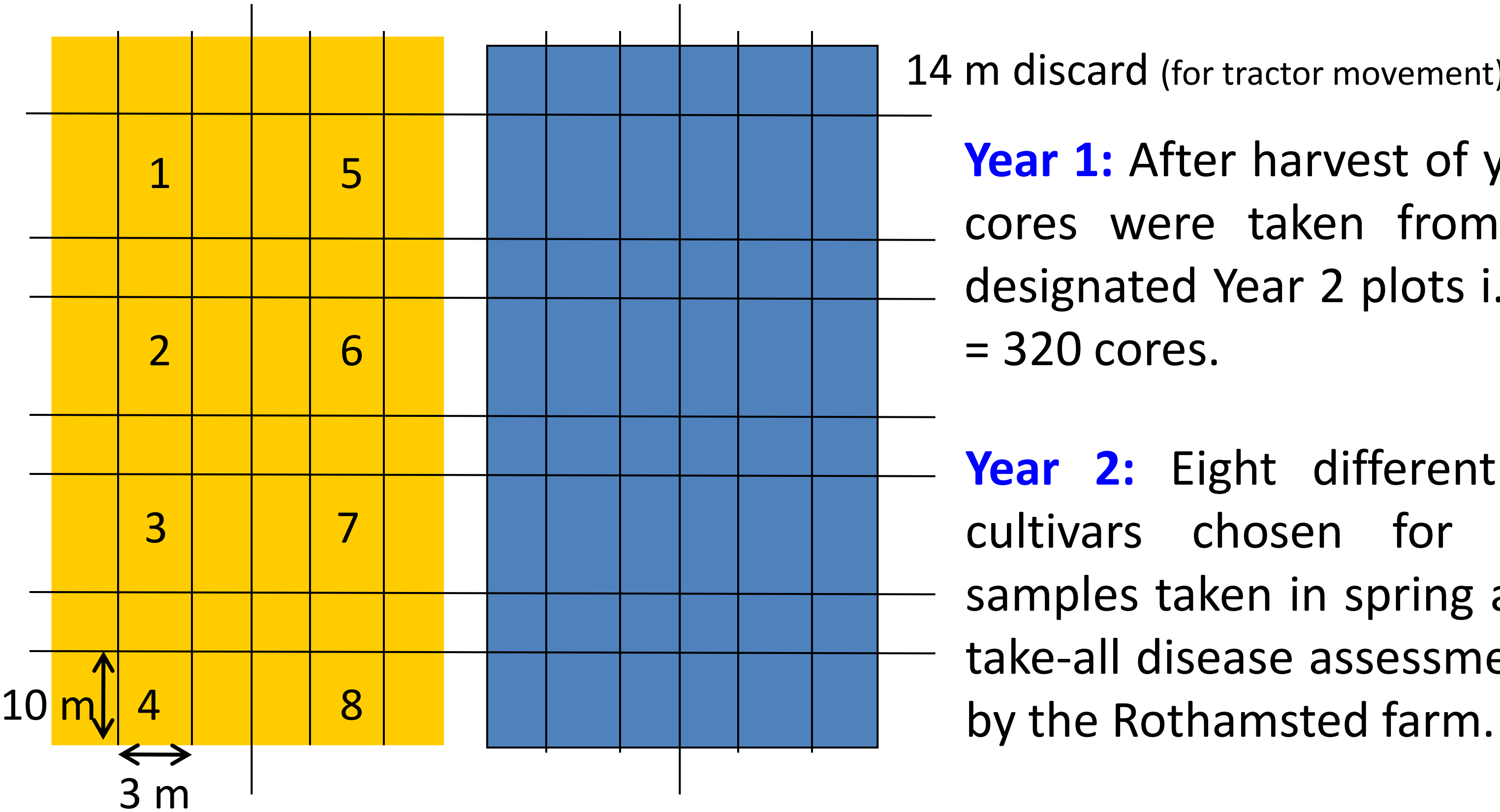


Plan NOT drawn to scale

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

The WGIN Cultivar Rotation Trial
Field: Drapers (October 2011 to August 2013)

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 % roots infected (Back-transformed means)
Cadenza	-0.94 (**12.8%**)
Hereward	-0.24 (**37.6%**)
d.f.	3
SED	0.15
F Pr	**0.019**
Grand mean	-0.59 (25.2%)

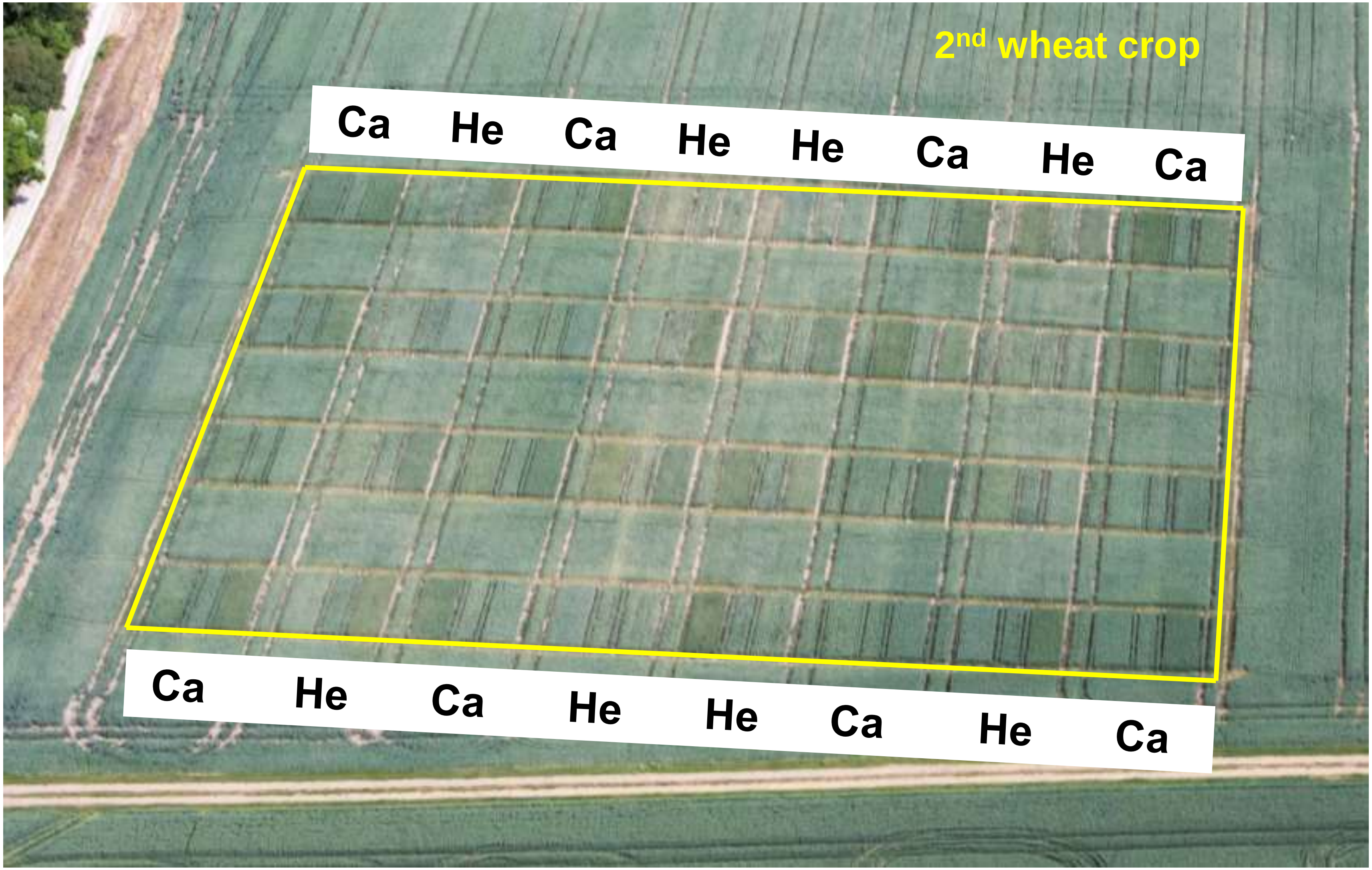
The WGIN Cultivar Rotation Trial
Field: Drapers (2011 - 2013)

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)	Year 2 (2012-2013)	
	Soil bioassay after harvest of 1st wheat plots	Over-sow **Spring** plant samples (24th April 2013, GS 24-27)	
Source variety	Logit % roots infected (Back-transformed means)	Logit % plants with take-all (Back-transformed means)	Take-all roots per plant
Cadenza	-0.94 (**12.8%**)	-0.48 (**27.6%**)	**0.55**
Hereward	-0.24 (**37.6%**)	0.65 (**78.9%**)	**1.95**
d.f.	3	3	3
SED	0.15	0.08	0.029
F Pr	**0.019**	**<.001**	**<.001**
Grand mean	-0.59 (25.2%)	0.09 (53.3%)	1.25

The WGIN 2 Cultivar Rotation Trial – 2nd year over sown with 8 cultivars

Field: Drapers July 2013



The current WGIN Cultivar Rotation Trial
Field: Drapers   July 17th 2013

Solstice after Cadenza

Solstice after Hereward

The WGIN Cultivar Rotation Trial
Field: Drapers (October 2011 to August 2013)

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)		
	Oversow Summer measurements		Oversow Summer plant samples
Source variety	Take-all patch score (% area)	Canopy height pre-harvest (cm)	TAI (0-100)
Cadenza	38	59.05	Still to be assessed
Hereward	65	53.61	
d.f.			
SED			
F Probability			

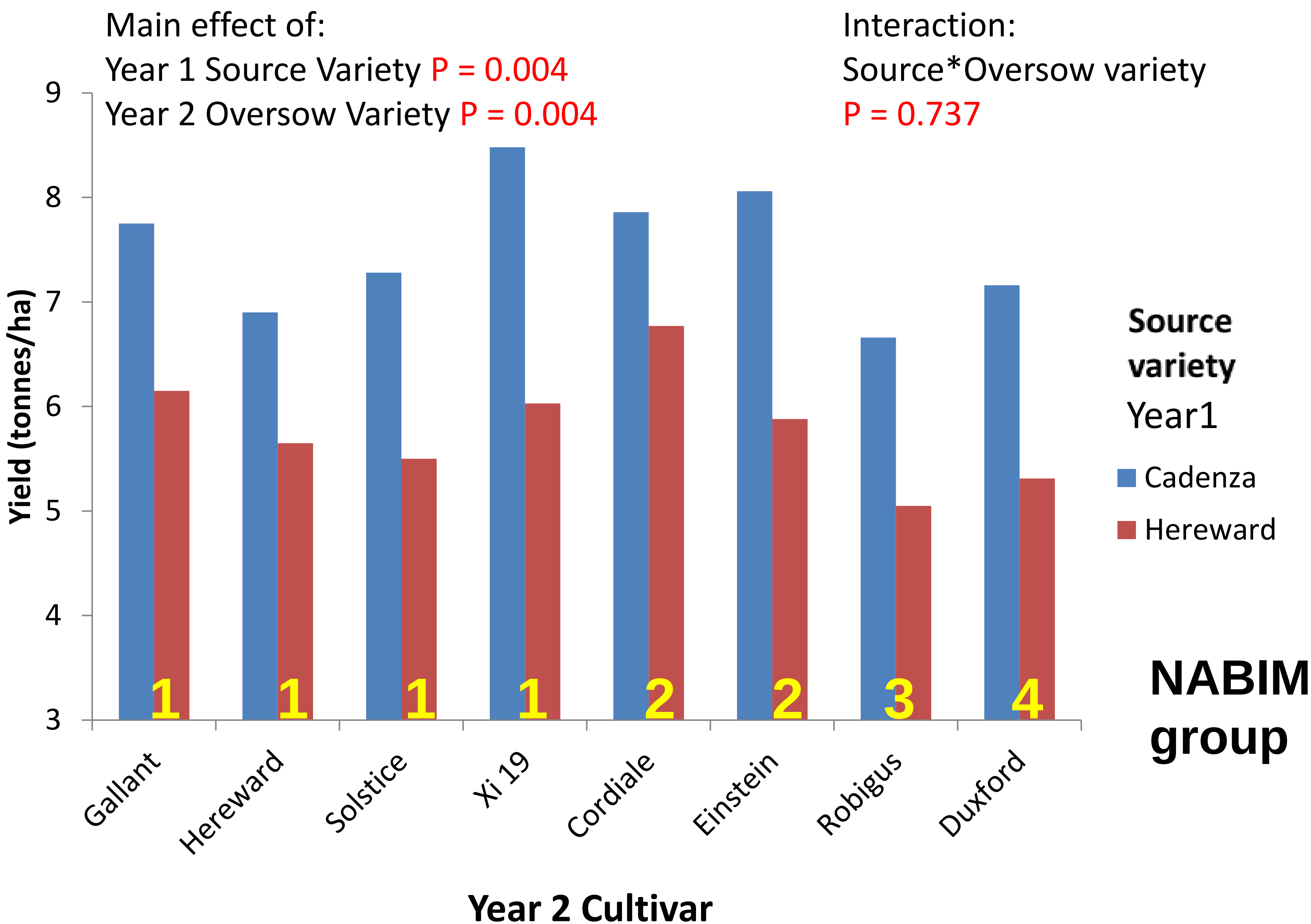
The WGIN Cultivar Rotation Trial
Field: Drapers (October 2011 to August 2013)

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)				
	Oversow Summer measurements		Oversow Summer plant samples	Oversow Yield	
Source variety	Take-all patch score (% area)	Canopy height pre-harvest (cm)	TAI (0-100)	Grain yield (tonnes/ha)	Straw yield (tonnes/ha)
Cadenza	38	59.05	Still to be assessed	7.52	3.21
Hereward	65	53.61		5.79	2.25
d.f.				3	3
SED				0.217	0.155
F Probability				0.004	0.009

Rotation trial: harvest years 2012 and 2013

Second wheat yields



Rotation trial: harvest years 2011 and 2012
Great Harpenden 2

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 oversow.

	Year 1 (2010-2011)
	Soil bioassay after harvest of 1st wheat plots
Source variety	Logit % roots infected (Back-transformed means)
Cadenza	-0.73 (**18.4%**)
Hereward	-0.31 (**34.7%**)
d.f.	3
SED	0.115
F Probability	**0.034**
Grand mean	-0.52 (26.6%)

Rotation trial: harvest years 2011 and 2012
Great Harpenden 2

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 oversow.

	Year 1 (2010-2011)	Year 2 (2011-2012)	
	Soil bioassay after harvest of 1st wheat plots	Oversow **Spring** plant samples (Xi 19 & Hereward plots sampled)	
Source variety	Logit % roots infected (Back-transformed means)	Logit % plants with take-all (Back-transformed means)	Take-all roots per plant
Cadenza	-0.73 (**18.4%**)	0.56 (**75.5%**)	**2.18**
Hereward	-0.31 (**34.7%**)	1.82 (**97.9%**)	**4.29**
d.f.	3	3	3
SED	0.115	0.216	0.268
F Probability	**0.034**	**0.010**	**0.004**
Grand mean	-0.52 (26.6%)	1.19 (86.7%)	3.23

Rotation trial: harvest years 2011 and 2012
Great Harpenden 2

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 oversow.

	Year 2 (2011-2012)		
	Oversow **Summer** measurements		Oversow **Summer** plant samples
Source variety	Take-all patch score (% area)	Canopy height pre-harvest (cm)	TAI (0-100)
Cadenza	**49.4**	**63.55**	**72.98**
Hereward	**81.3**	**57.75**	**93.62**
d.f.	3	3	3
SED	3.72	0.818	1.79
F Probability	**0.003**	**0.006**	**0.001**
Grand mean	65.4	60.65	83.30

Rotation trial: harvest years 2011 and 2012
Great Harpenden 2

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 oversow.

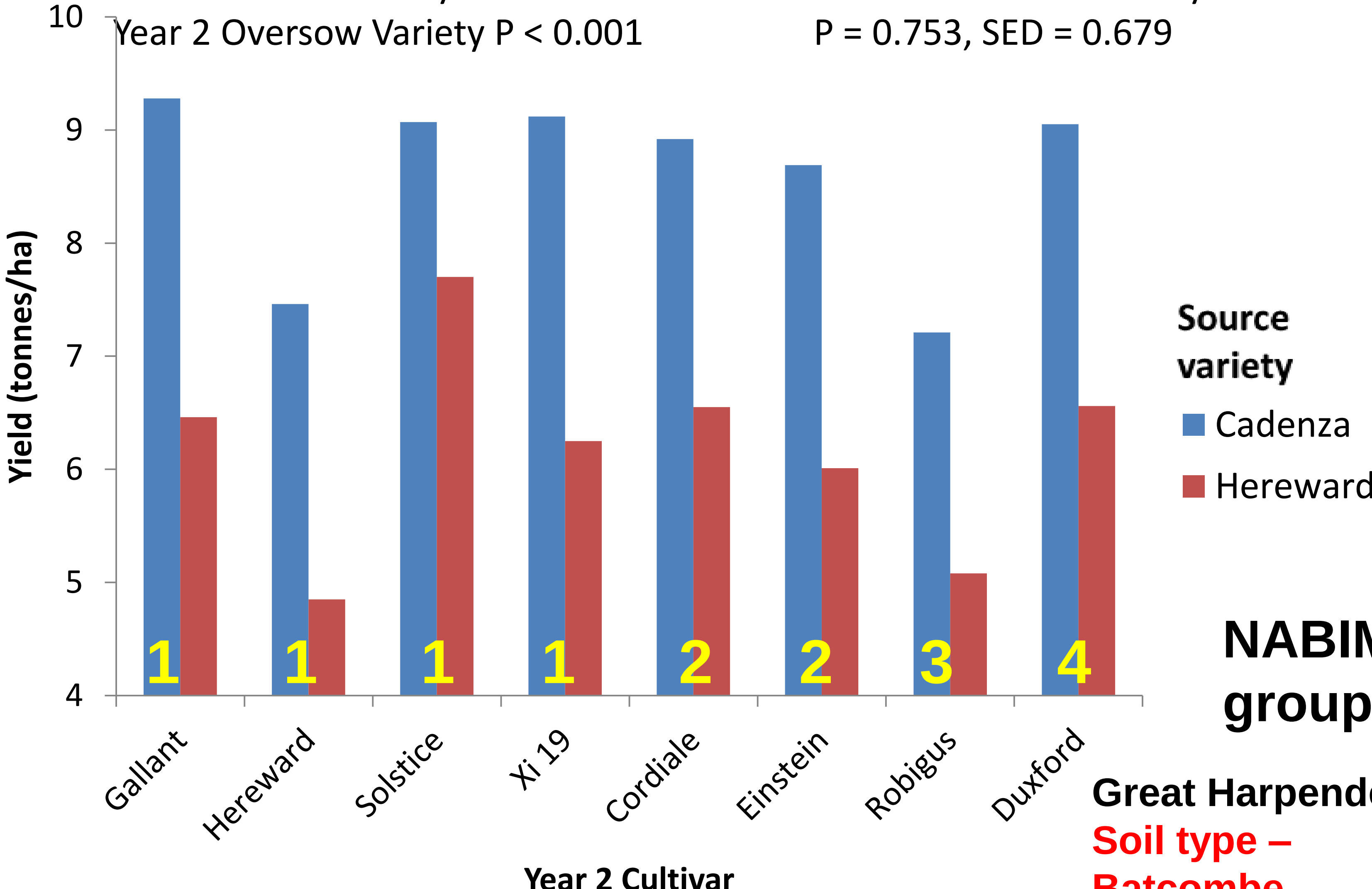
	Year 2 (2011-2012)				
	Oversow Summer measurements		Oversow Summer plant samples	Oversow Yield	
Source variety	Take-all patch score (% area)	Canopy height pre-harvest (cm)	TAI (0-100)	Grain yield (tonnes/ha)	Straw yield (tonnes/ha)
Cadenza	**49.4**	**63.55**	**72.98**	**8.60**	**5.57**
Hereward	**81.3**	**57.75**	**93.62**	**6.18**	**4.25**
d.f.	3	3	3	3	3
SED	3.72	0.818	1.79	0.338	0.167
F Probability	**0.003**	**0.006**	**0.001**	**0.006**	**0.004**
Grand mean	65.4	60.65	83.30	7.39	4.91

Rotation trial: harvest years 2011 and 2012

Second wheat yields

Main effect of:
Year 1 Source Variety P = 0.006
Year 2 Oversow Variety P < 0.001

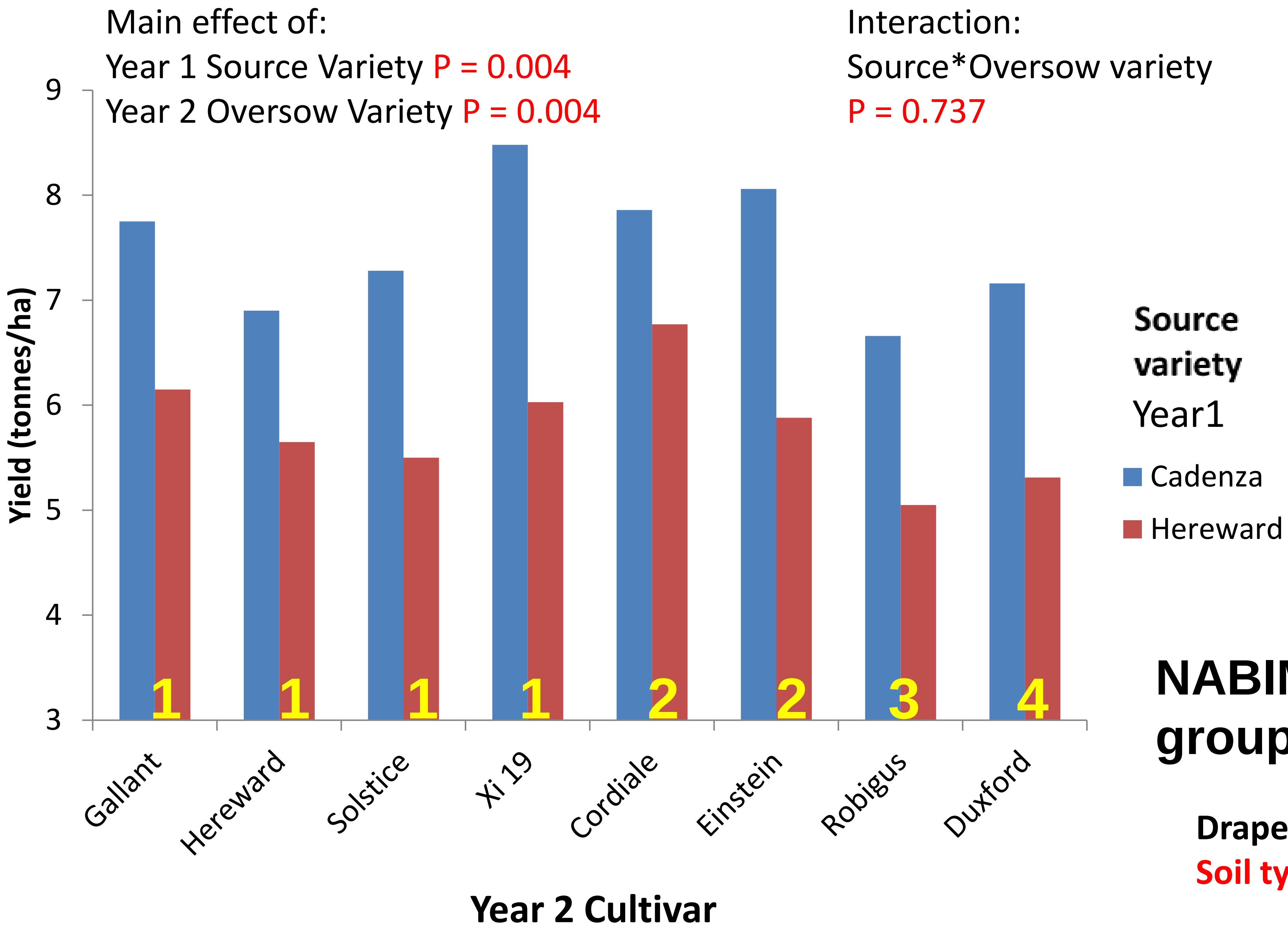
Interaction:
Source*Oversow variety
P = 0.753, SED = 0.679



NABIM group

Great Harpenden 2
Soil type – Batcombe

Rotation trial: harvest years 2012 and 2013
Second wheat yields



NABIM group

Drapers
Soil type

Results Summary : Cultivar rotation trials
Take-all inoculum build-up trait

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 (2011)
2.42 t /ha (2012)
1.73 t /ha (2013)

Results Summary : Cultivar rotation trials
Take-all inoculum build-up trait

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

- **Yield advantage in the 2nd wheat crop**

Grain	Straw
0.2 t /ha (2011)	not measured
2.42 t /ha (2012)	1.32 t /ha
1.73 t /ha (2013)	0.96 t /ha

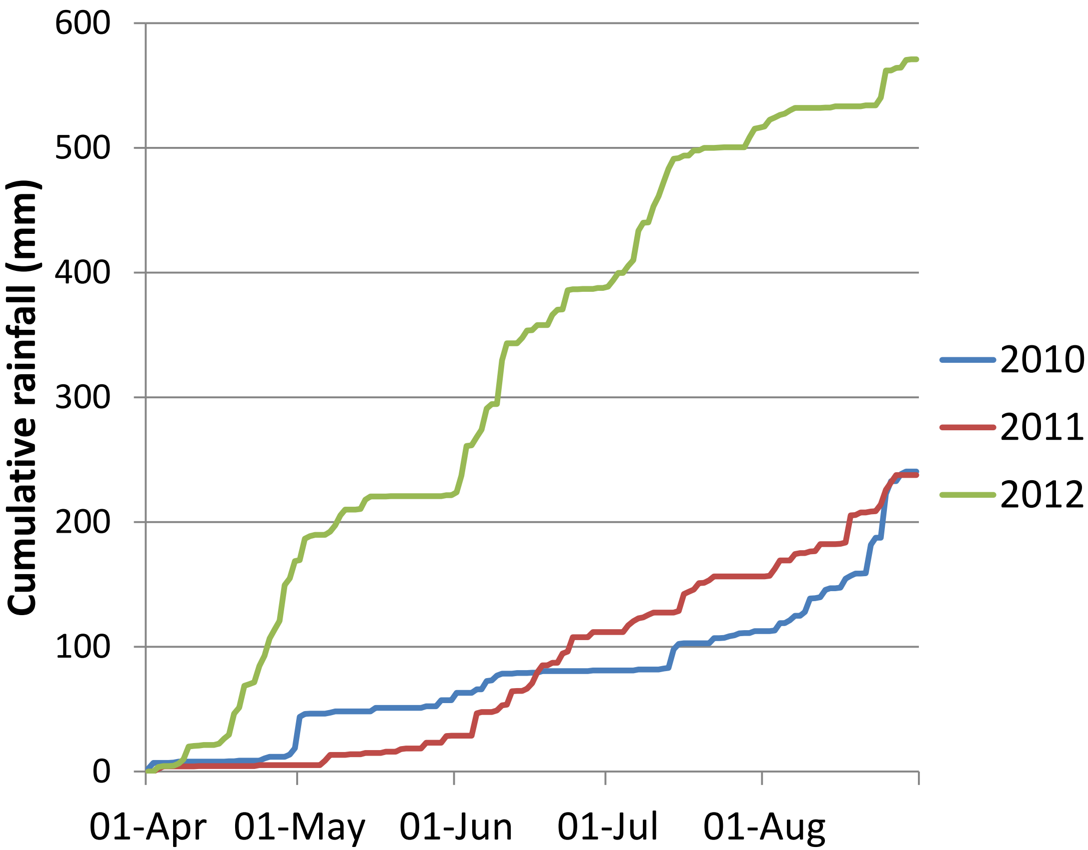
- **Occurs on 2 different soil types@Rothamsted**

Batcombe (2012) - Fine silty /fine loamy over clayey soils with slowly permeable subsoils and slight seasonal water logging

Panholes (2013) - Well drained calcareous fine silty soils over chalk

Why is the effect on yield increase variable between years?

Harvest years	Year 1 TAB % roots infected	Year 2 Yield advantage tonnes/ha
2010-2011	2.2	0.2
2011-2012	26.6	2.42
2012-2013	25.2	1.73



- **Year 1 differences in the amount of take-all inoculum that built up in the soil**
- Summer 2010 was very dry - unfavourable for take-all inoculum build-up
- Summer 2012 was very wet, waterlogging – reduced inoculum build-up?

Why is the effect on yield increase variable between years?

Harvest years	Year 1 TAB % roots infected	Year 2 Spring % plants infected	Year 2 Summer Take-all Index (0-100)	Yield advantage tonnes/ha
2010-2011	2.2	4.7	17.3	0.2
2011-2012	**26.6**	**86.7**	83.3	**2.42**
2012-2013	**25.2**	**53.3**	currently being assessed	**1.73**

- Year 1 TAB very similar for 2011 and 2012 but the amount of take-all disease in the spring is different

- Length of intercrop period?

2011-2012
Year 1 Harvested 31st Aug
Year 2 Sown 29th Sept (**29 days**)

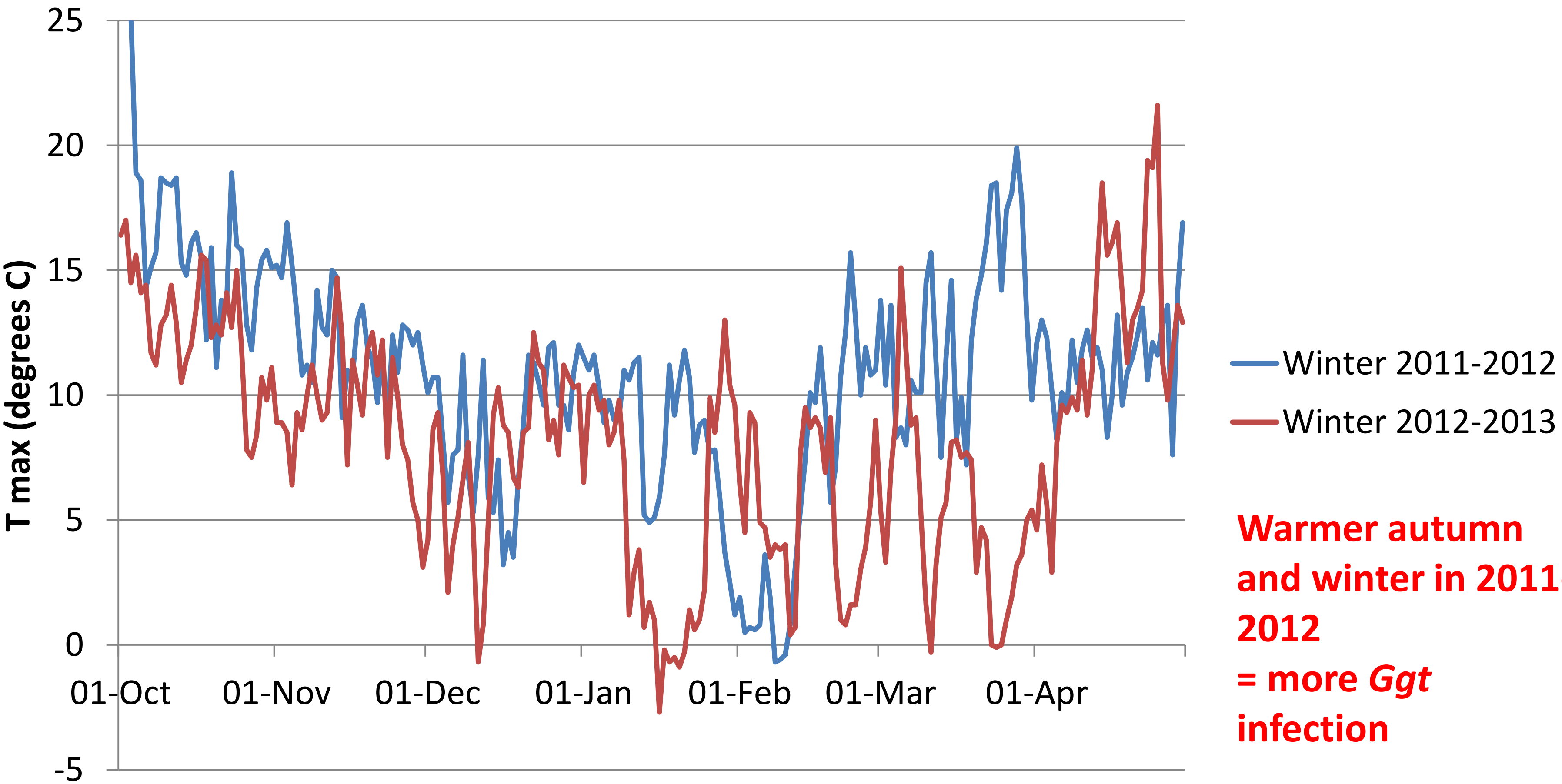
2012-2013
Year 1 Harvested 14th Aug
Year 2 Sown 03rd October (**49 days**)

Longer intercrop period = inoculum declines

- Autumn weather after sowing 2nd wheat crop?

Why is the effect on yield increase variable between years?

Harvest years	Year 1 TAB % roots infected	Year 2 Spring % plants infected	Year 2 Summer Take-all Index (0-100)	Yield advantage tonnes/ha
2010-2011	2.2	4.7	17.3	0.2
2011-2012	**26.6**	**86.7**	83.3	**2.42**
2012-2013	**25.2**	**53.3**	currently being assessed	**1.73**



Warmer autumn and winter in 2011-2012 = more *Ggt* infection

WGIN Take-all inoculum build-up trait - What else ?

- Diploid wheat (*T. monococcum*) – Does the Take-all inoculum build-up (TAB) phenotype exist?

YES

Eight *T. monococcum* genotypes
All build-up take-all inoculum in the soil

Many thanks to

RRes Farm staff

Vanessa McMillan
Richard Gutteridge
Kostya Kanyuka
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Nicola Phillips (HGCA)
Joseph Whittaker (BBSRC)
Adrian Czaban (WGIN)
Marcin Czaban (WGIN)
James Bruce (HGCA-BBSRC)
Steve Freeman (WGIN)
Carl Halford (WGIN)
Daniela Izera (WGIN)
Mike Hammond-Kosack (TSB)
Mike Hall (TSB-WGIN)
Aisling Clifford (WGIN)