Genetic Resource Development and Gene Discovery at the John Innes Centre

WGIN Management

RReS

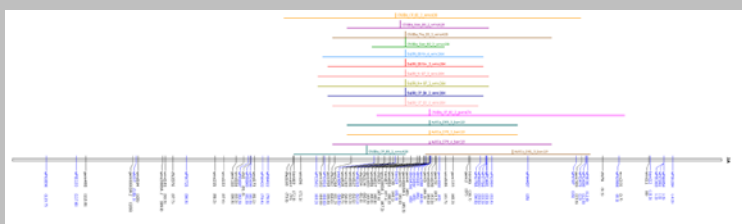
20th July 2011

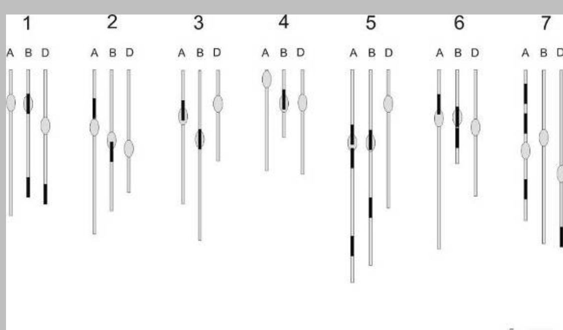
WGIN gene discovery strategy:

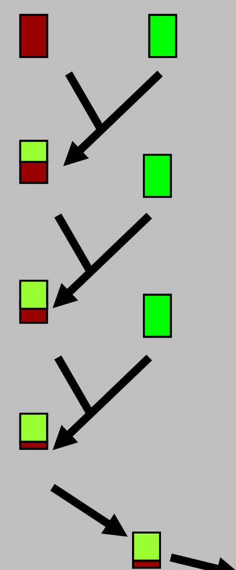
- Spark x Rialto
- Avalon x Cadenza
- Buster x Charger
- Charger x Badger
- Savannah x Rialto
- Shango x Shamrock

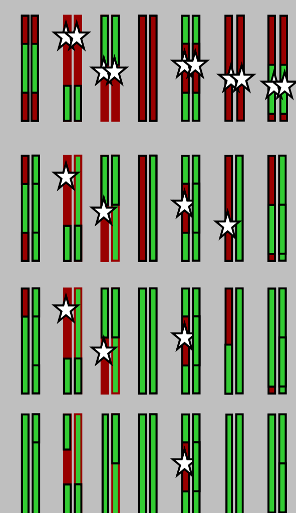
- Malacca x Charger
- Savannah x Renesansa
- Lynx x Cadenza
- Beaver x Soissons
- Weebil x Bacanora
- Milan x Catbird

Assess impact of genes



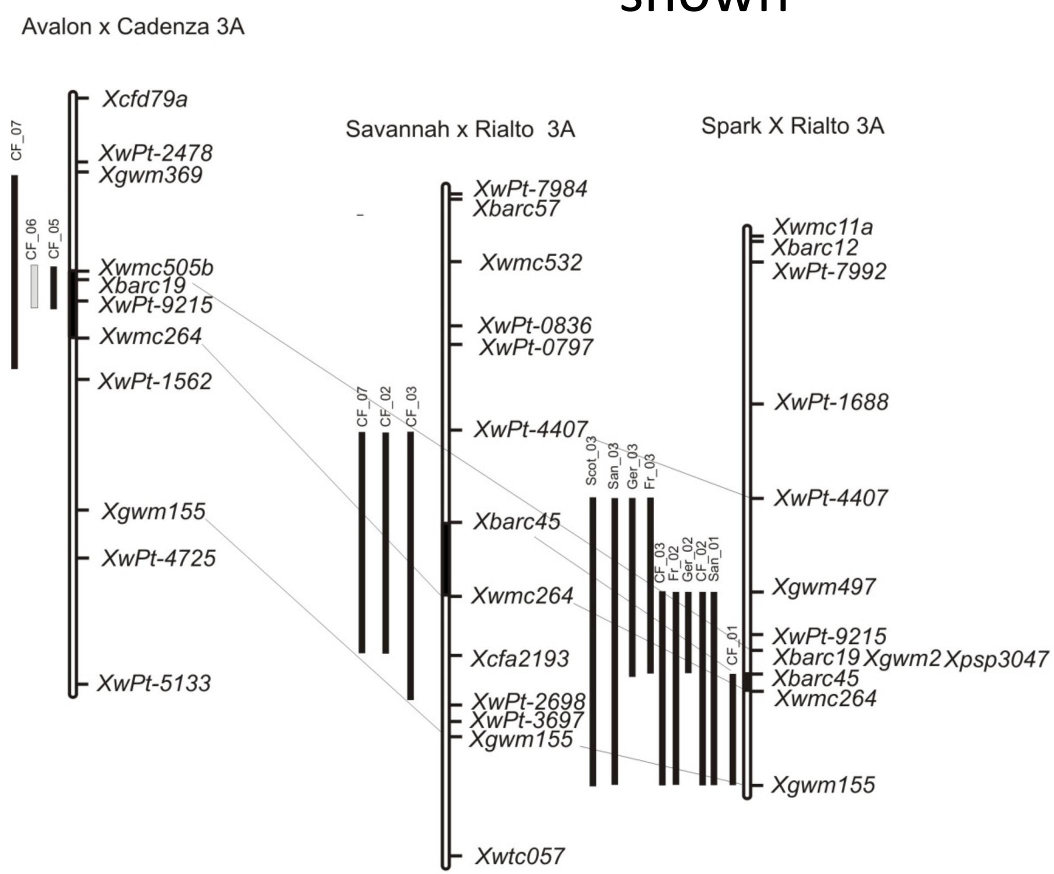






Pivotal role of Avalon x Cadenza mapping population through meta analysis

- Flowering time example
- QTL on 3A in AxC and Savannah x Rialto, Spark x Rialto, others not shown



QTL details for Avalon x Cadenza JIC data

	Chromosome	Nearest Marker	Position (cM on map)	LOD score	Additive Effect (days)	% variation
Church Farm 2006	3A	*Xwmc264*	33.21	10.10	-0.58	6.40
Church Farm 2007	3A	*Xwmc264*	33.21	3.50	-0.58	6.40
Church Farm 2005	3A	*XwPt9215*	29.11	10.10	-0.81	13.60

Validation of QTL using WGIN developed Near Isogenic Lines

2011 Field data for heading date

	line	t-stat	df	p-val	A mean	B mean	no A	no B	A	B	QTL
ac113-e113/10.a.b	ac113-e113/10	-3.31	28.6	0.0026	23.6	24.3	20	12	a	b	AxC 3A
ac113-e113/8.a.b	ac113-e113/8	-1.49	18.4	0.1533	24.8	25.3	13	18	a	b	AxC 3A
ac179-e27/2.a.b	ac179-e27/2	-5.06	8.1	9.00E-04	22.6	23.8	14	5	a	b	AxC 3A
ac179-e27/8.a.b	ac179-e27/8	-10.58	7	0	22	24	3	8	a	b	AxC 3A
ac69-e44/4.a.b	ac69-e44/4	-1.35	6.1	0.2251	27	27.7	6	3	a	b	AxC 3A
ac69-e44/6.a.b	ac69-e44/6	0.45	2.9	0.6828	27.3	27	3	5	a	b	AxC 3A
ac144-e32/1.a.b	ac144-e32/1	-4.79	11.5	5.00E-04	23.8	25.9	6	8	a	b	AxC 3A

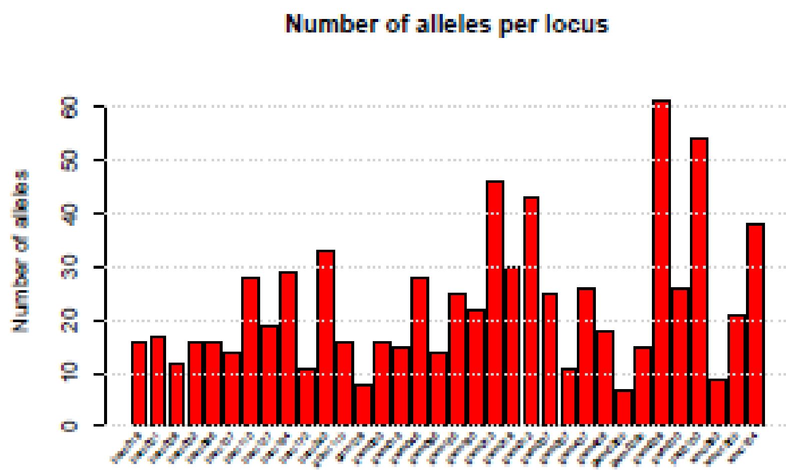
The validation strategy is proving successful, even for QTL with relatively small additive effects

Analysis of population structure the AE Watkins collection

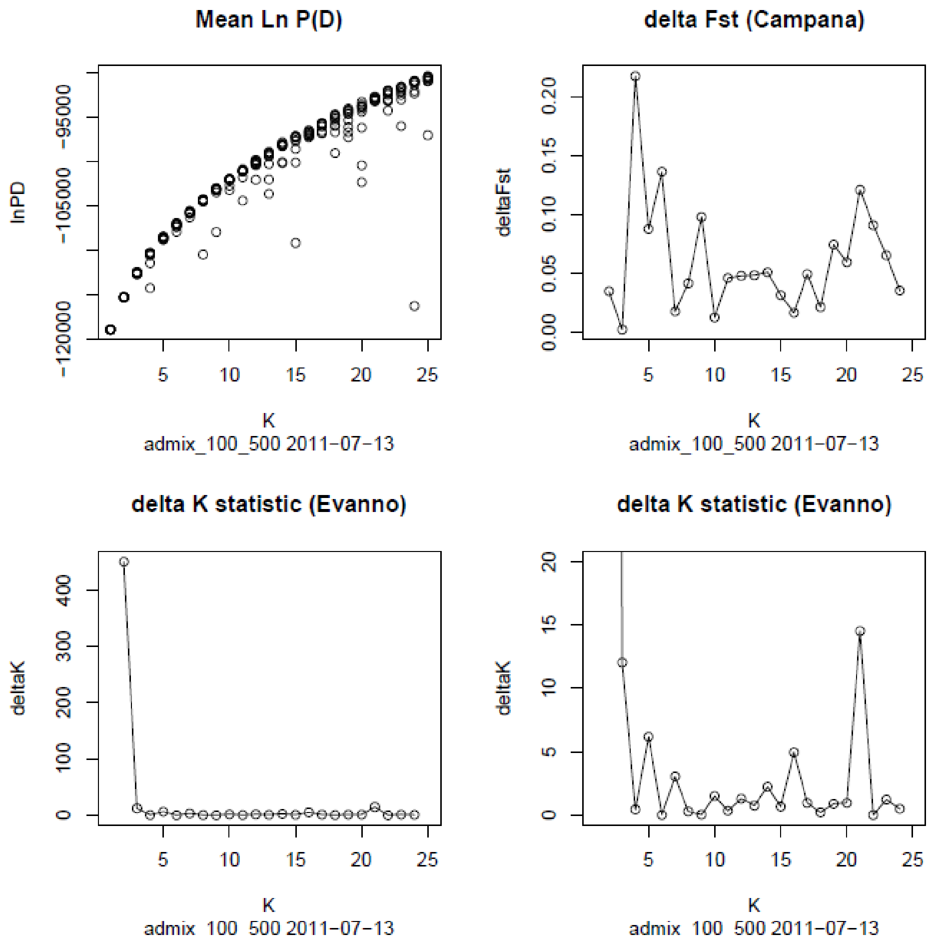
- Needed to
  - Define core sets
  - Measure diversity
  - QC accessions as they travel!
  - Facilitate association analysis
- 1088 accession included
- 50 molecular markers (4 monomorphic, 8 with greater than 10% nulls/missing)

Measures of genetic variation in AEW

material	number of accessions	number of markers	average allele number	range of allele number	PIC	Ref.
IPK landraces	998	24	18.1	4-46	0.77	[Huang et al., 2002]
modern wheat	502	20	10.5	4-22	0.647	[Röder et al., 2002]
Chinese LR	24	40	6.9	1-16	0.419	[Wei et al., 2005]
Eur. 1840-2000	480	39	16.4	4-40	0.65	[Roussel et al., 2005]
UK/USA/Aus 1845-2005	140	379	DArT	-	0.399	[White et al., 2008]
INRA landraces	3,942	38	23.9	7-45	0.74	[Balfourier et al., 2007]
modern + traditional	1,057	178	DArT	-	0.44	[Raman et al., 2010]
Gediflux 1945-2000	511	42	10.5	1-16	0.65	update statistics
AE Watkins landraces	1,088	46	18.4	2-65	0.73	update statistics



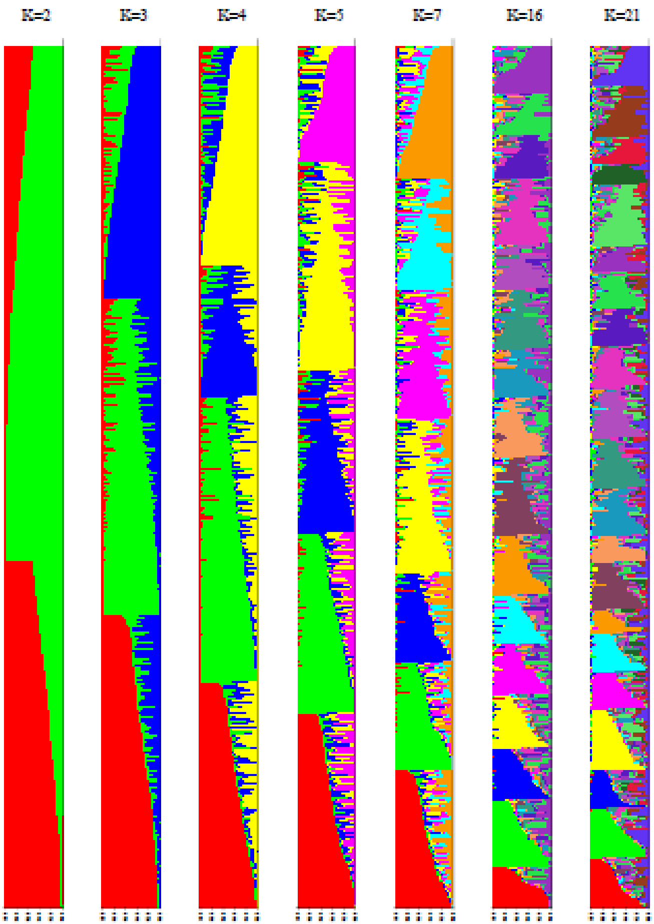
What groups can be identified using ?
Structure model based clustering (Pritchard et al 2000)



lnP(D) (posterior probability of the data)

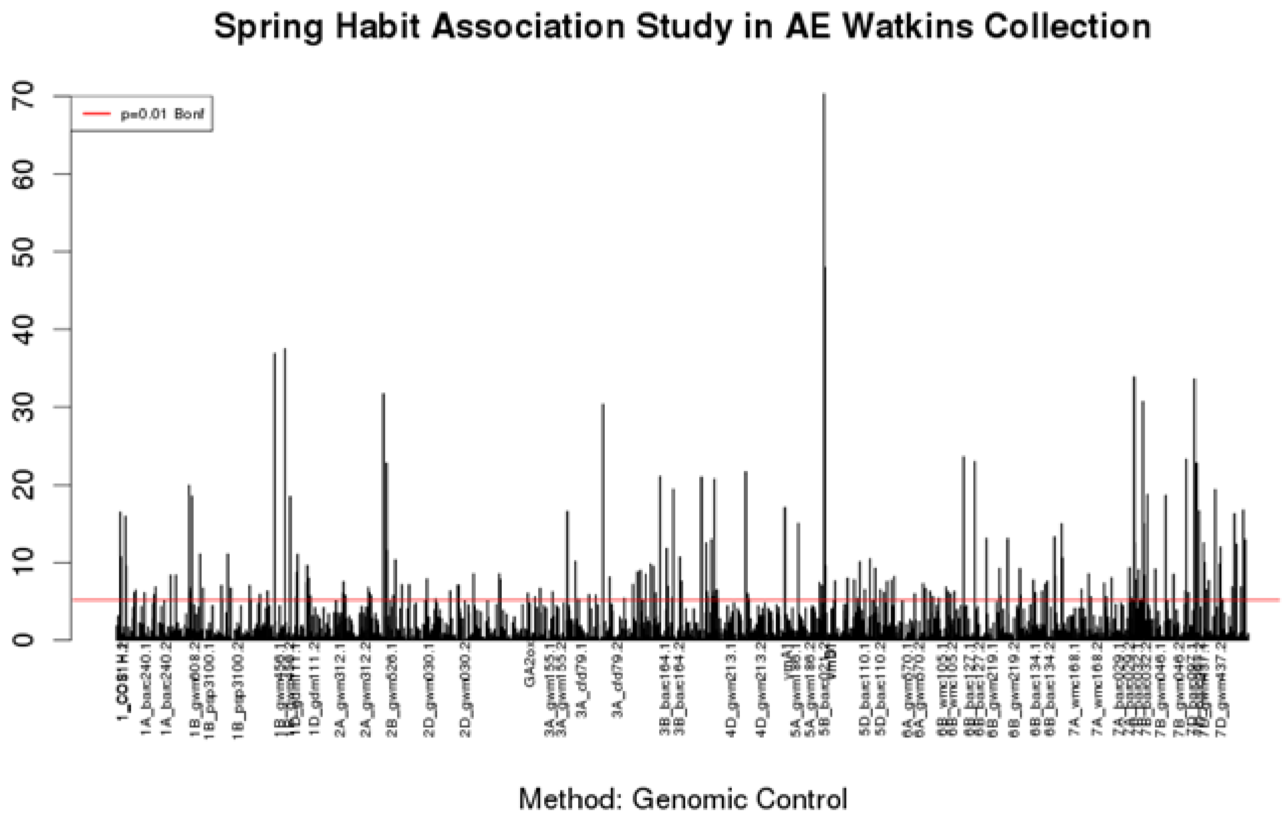
2 and 21 groups?

Representations of possible AE Watkins population structure

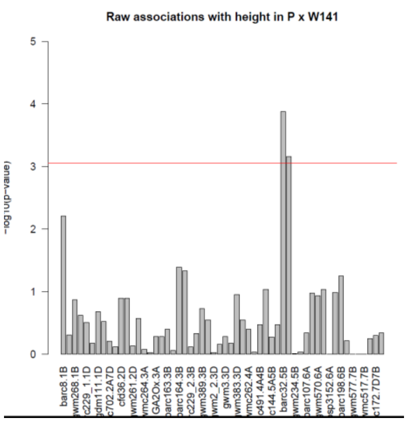


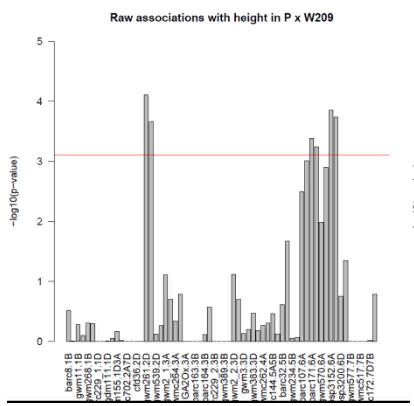
What patterns emerge within groups?

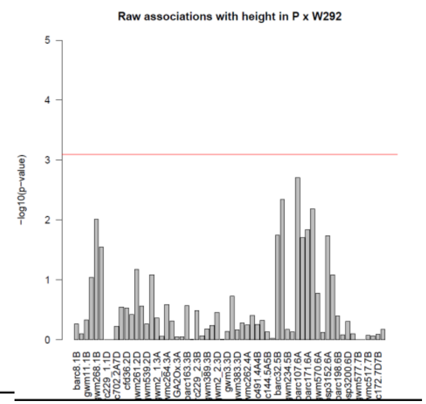
Is the collection useful for association mapping?

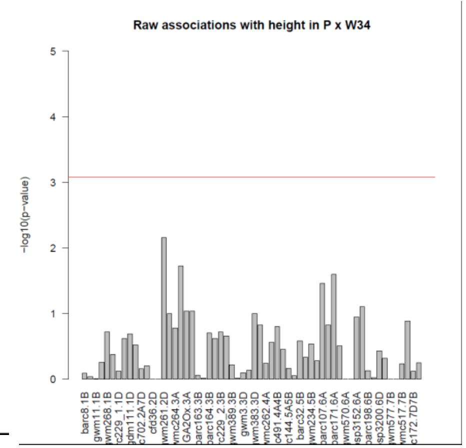


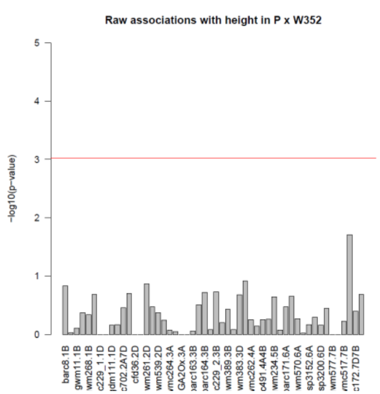
AEWatkins SSD populations-height QTL (Wheat pre-breeding LOLA data)

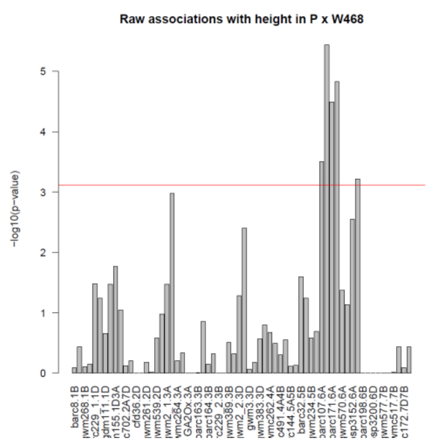


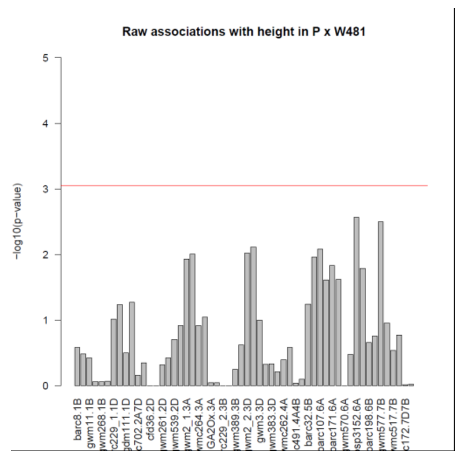


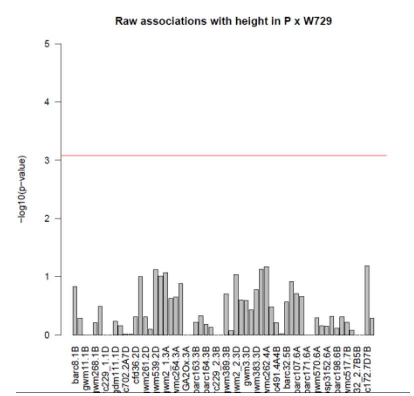












More population development in WGIN

- Segregating:
  - Paragon x Garcia (drought) F2
  - Paragon x Chinese Spring F7
  - Paragon x Synthetic F6
- Mutant:
  - Paragon gamma deletions
  - Paragon EMS (7000 F5 SSD derived)
- Collections
  - AEW and Gediflux

Jun Ma

Richard Goram

Lorelei Bilham

John Snape

Debora Gasperini

Michelle Leverington

Sue Freeman

Luzie Wingen

Meluleki Zikhali

Simon Orford

Abdul Aziz Al Homenei

Wheat Genetic Improvement Network

defra

Objective 8 – Nitrogen update

M J Hawkesford

WGIN Management Meeting

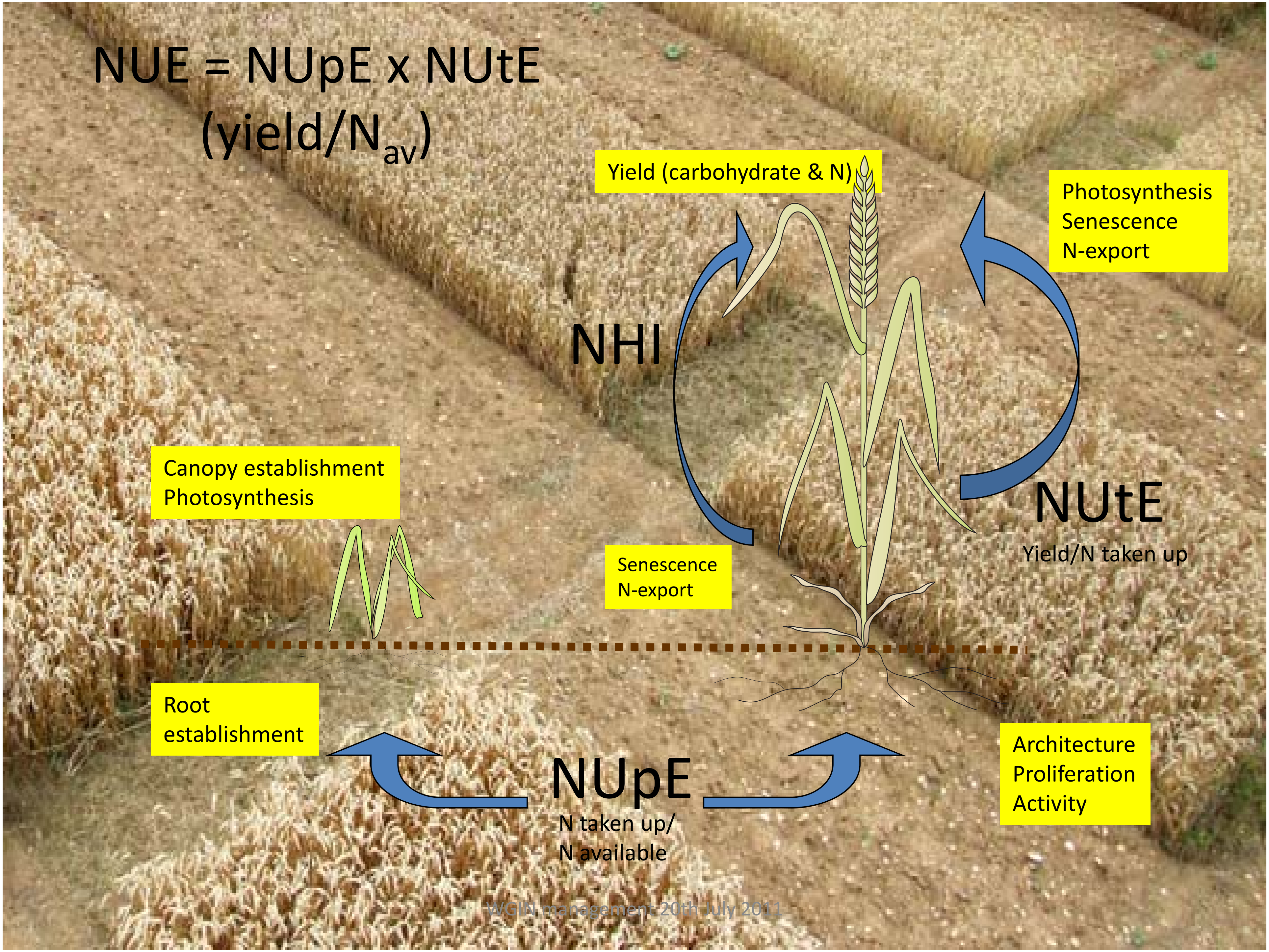
20th July 2011

Why nitrogen?

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

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


NUE = NUpE x NUtE
(yield/N_{av})
Yield (carbohydrate & N)
Photosynthesis
Senescence
N-export
NHI
Canopy establishment
Photosynthesis
NUtE
Yield/N taken up
Senescence
N-export
Root
establishment
NUpE
N taken up/
N available
Architecture
Proliferation
Activity
WGIN management 20th July 2011

Approaches

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

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 2009-2013

- Deeper phenotyping
  - Partitioning
  - Canopy longevity
  - Roots and uptake
- Stability data
- NUE – WUE – Take-all interactions
- Encourage spin off projects

Diversity Trial 2011

Example results

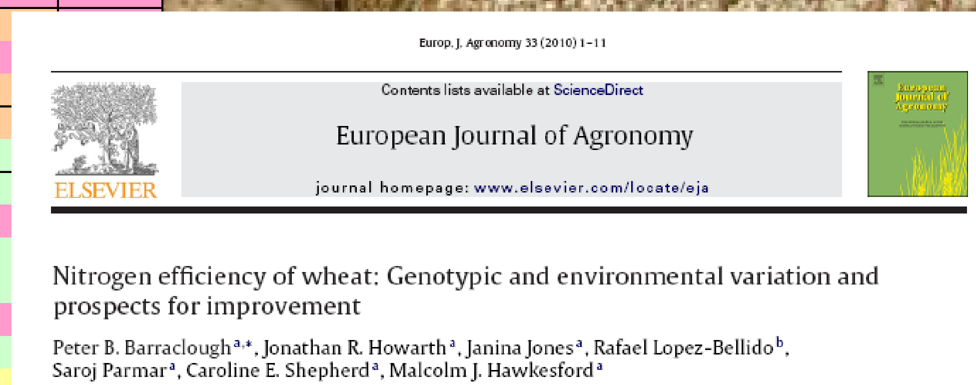
- Trait performance rankings
- Stability
- Yield plateauing
- Performance at low compared to high N input
- qtls

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

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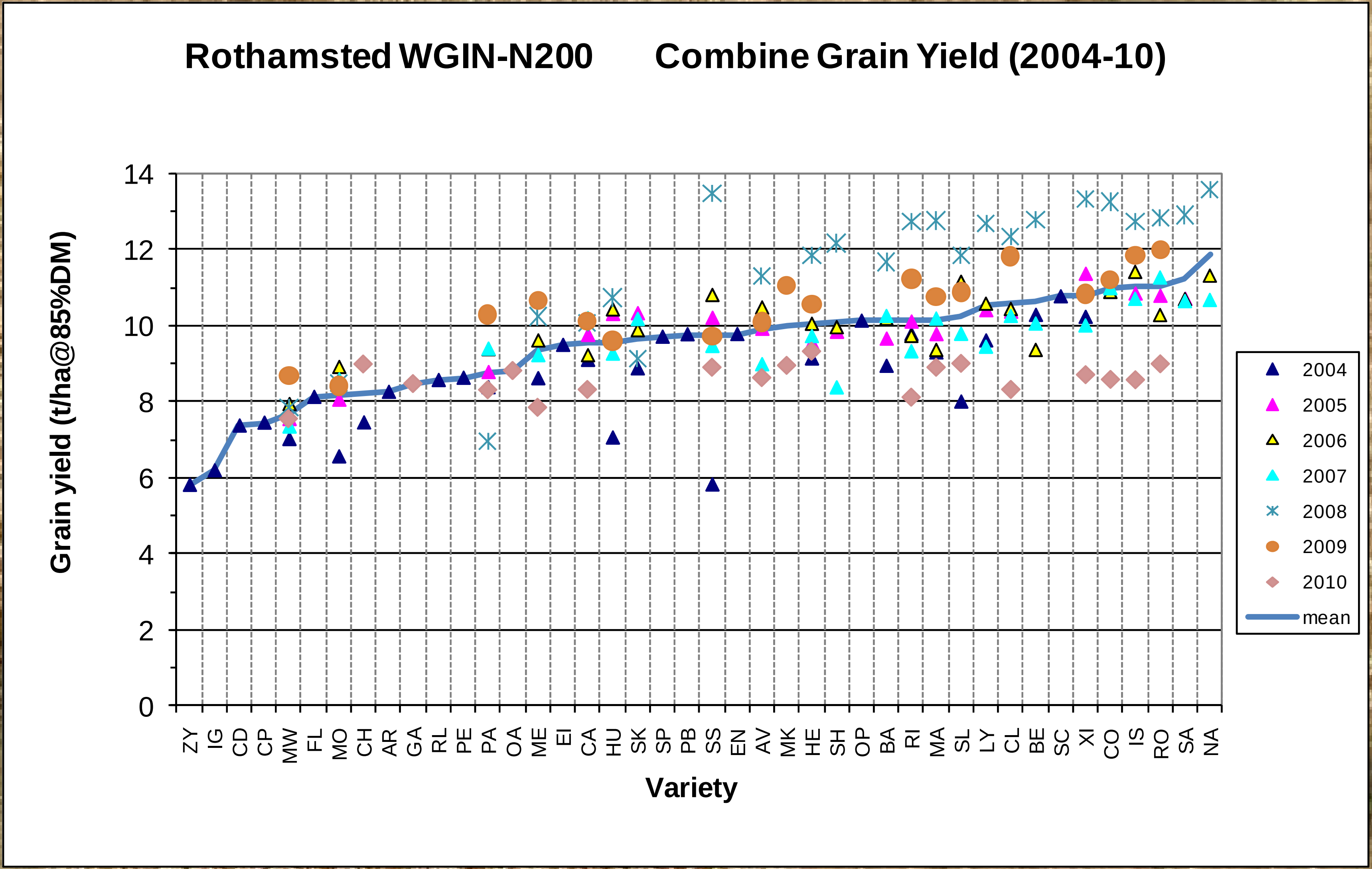
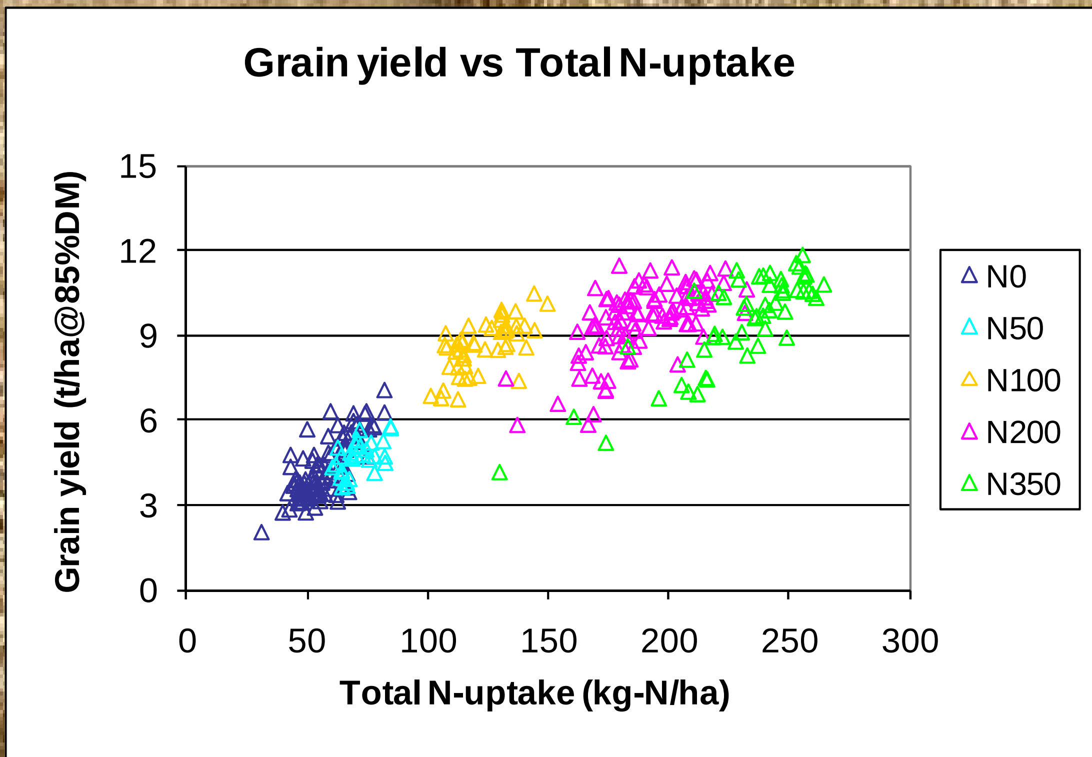
EJA (2010) 33, 1-11

Stability



Rothamsted WGIN-N200 Combine Grain Yield (2004-10)
Grain yield (t/ha@85%DM)
Variety
14
12
10
8
6
4
2
0
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
2004
2005
2006
2007
2008
2009
2010
mean

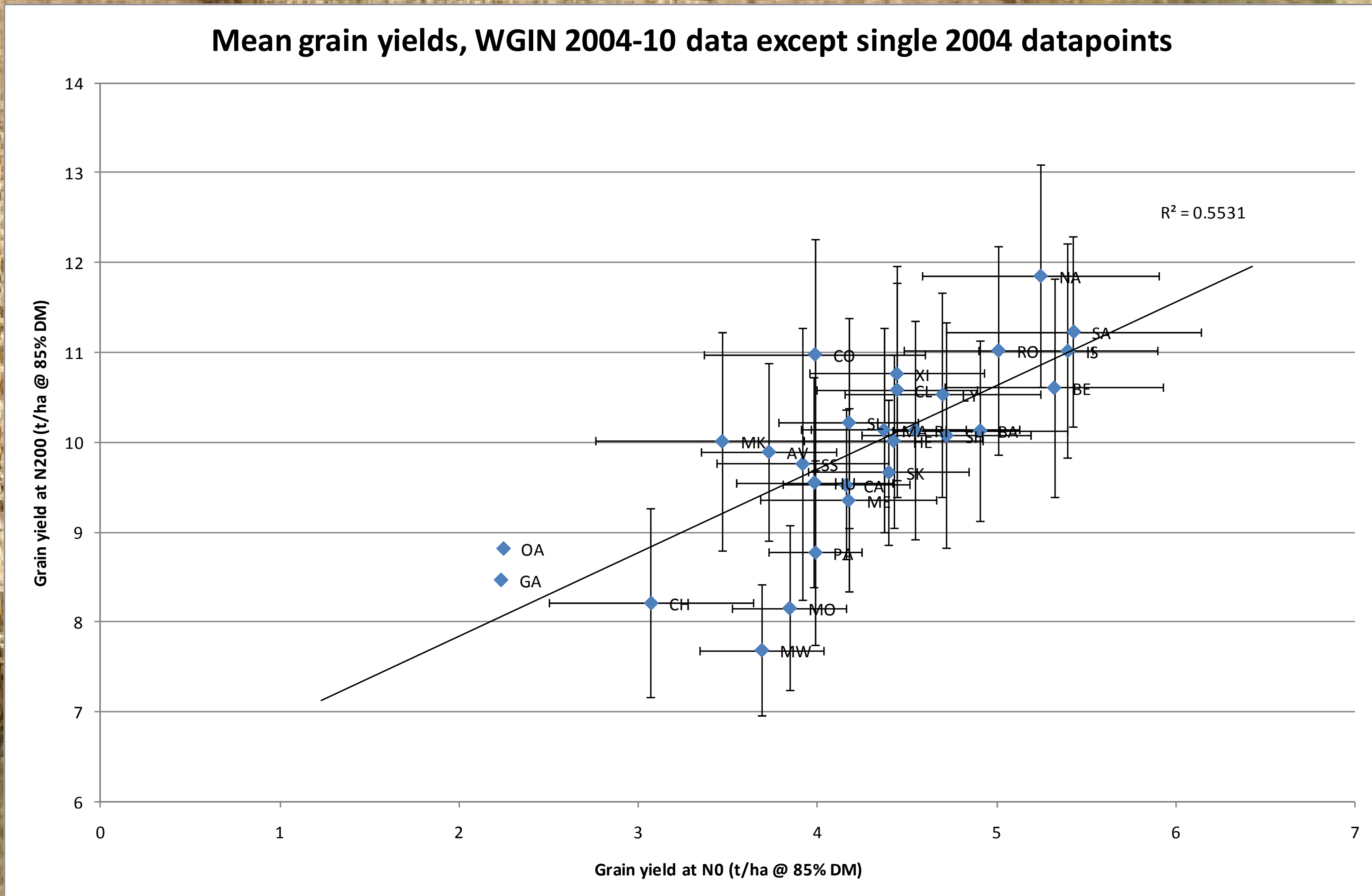
Grain yield plateau



(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

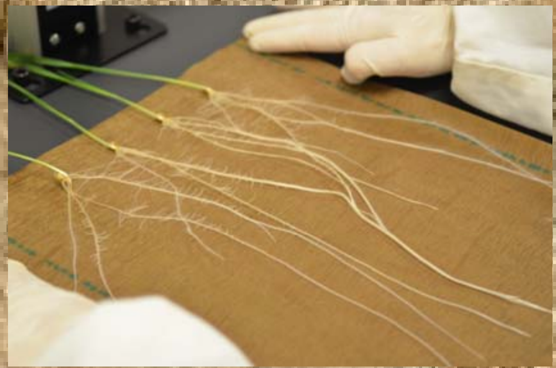
Performance at N200 compared to N0



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



Forward plans….

- 2 years Diversity – selection of varieties
- NUE/RUE/Take interaction
- Addition low N trial for Avalon x Cadenza
- Greenhouse N uptake trial for Avalon x Cadenza

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/

Thanks

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

Drought tolerance

WGIN-2 SG meeting

Rothamsted Research 20 July 2011

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*)**

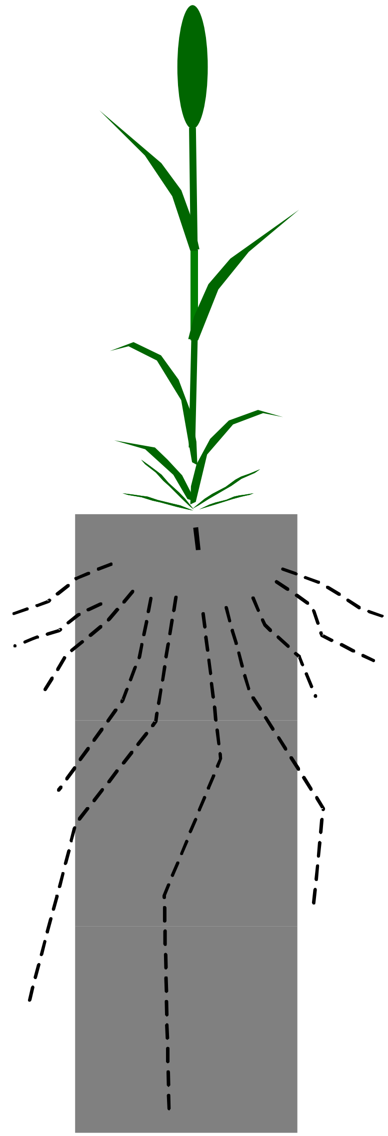
Obj 3. **Develop one new DH pop for drought research. (*Yrs 2-4*)**

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

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

Traits associated with main drivers of yield under drought

Yld = 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

WGIN 2 (9.1 Trait Identification)

WUE trial 2009-10

Split plot design (3 reps): plot size 1.6 x 12 m

Main plot:	Fully irrigated (trickle irrigation)
	Unirrigated

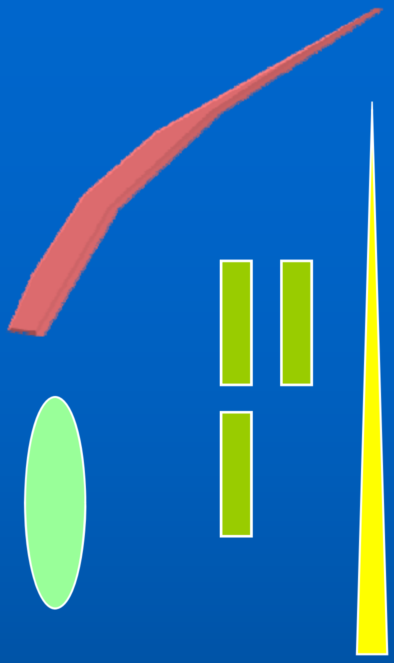
Split plot (variety):

1. Avalon *
2. Beaver
3. Cadenza *
4. Cappelle Deprez
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

* Common with NUE trial

Measurements

- Combine grain yield, yield components
- DM & partitioning at GS31, GS61, harvest
- % stem WSC at GS61+10d
- Leaf senescence kinetics for L1, L2 and L3.
- Stomatal conductance/photosynthetic rate using Licor 6400 (unirrigated)
- Canopy temperature
- Water use ~ gravimetric analysis of soil cores (unirrigated, 18 varieties)
- ^{13}C Δ grain ~ leaf WUE
- ^{18}O Δ flag leaf ~ leaf transpiration



Leaf gas exchange

Canopy temp.

Chemical analysis In WGIN drought tolerance trial in 2009/10 & 2010/11

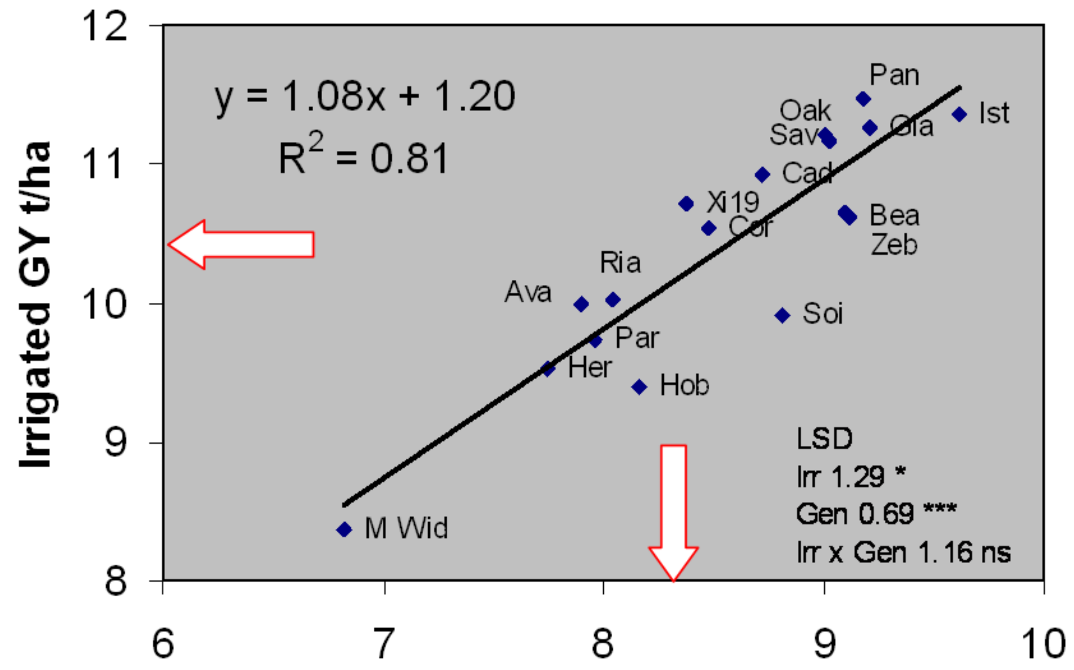
Samples (per year) on 18 cultivars x 2 Irr trts x 3 reps (=108 plots)

	Chemical analysis			Total
No. samples	**13C**	**18O**	**Ash%**	
Flag leaf @ GS61	**108**	***108***	***108***	**324**
Grain @ harvest	***108***		***108***	**216**

Core funding

Sub-contract funding

Grain yield responses to irrigation



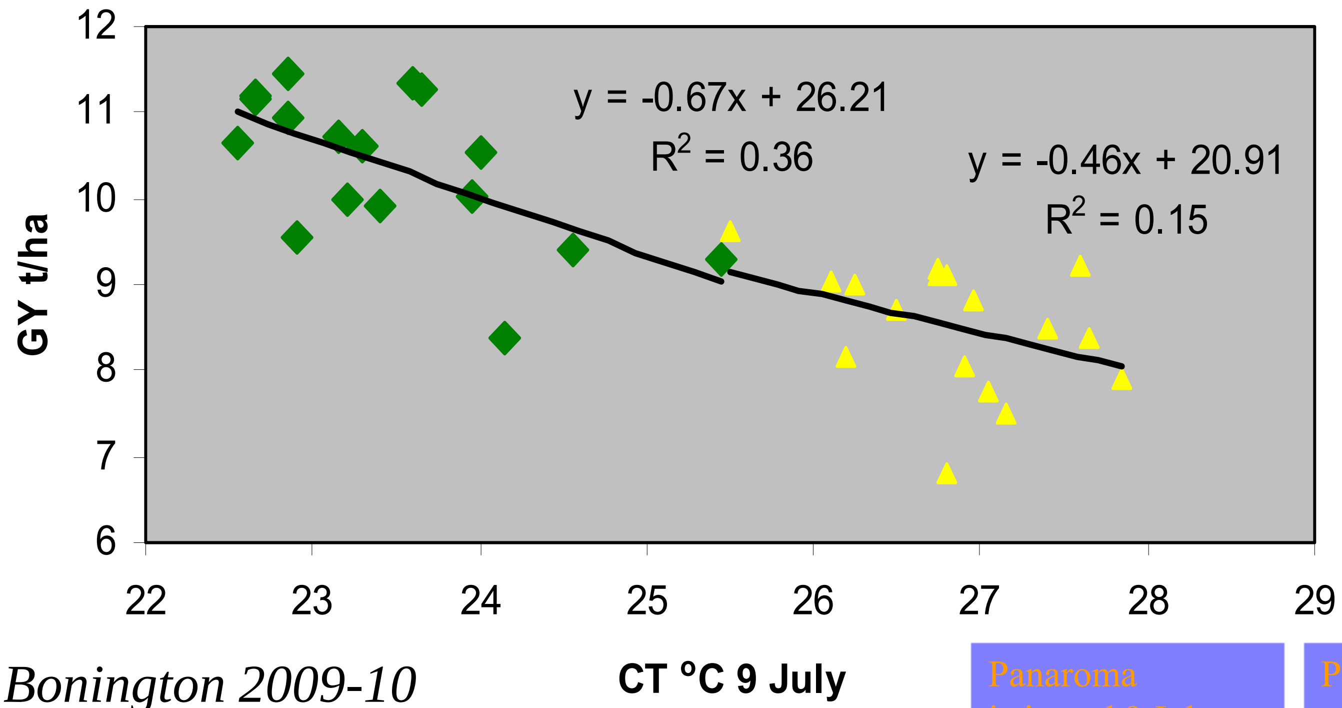
Sutton Bonington 2009-10

	Rainfall (mm)	
	2010	LTM 75-09
Jan	33	54.1
Feb	41.6	43.4
Mar	36	45.7
Apr	24	44.4
May	18.2	45.6
Jun	69.2	58.7
Jul	42.6	49.8

Glasgow Irrigated vs Unirrigated 19 July


Wheat Genetic Improvement Network

Canopy Temperature (indicative of access to water) post-anthesis vs grain yield

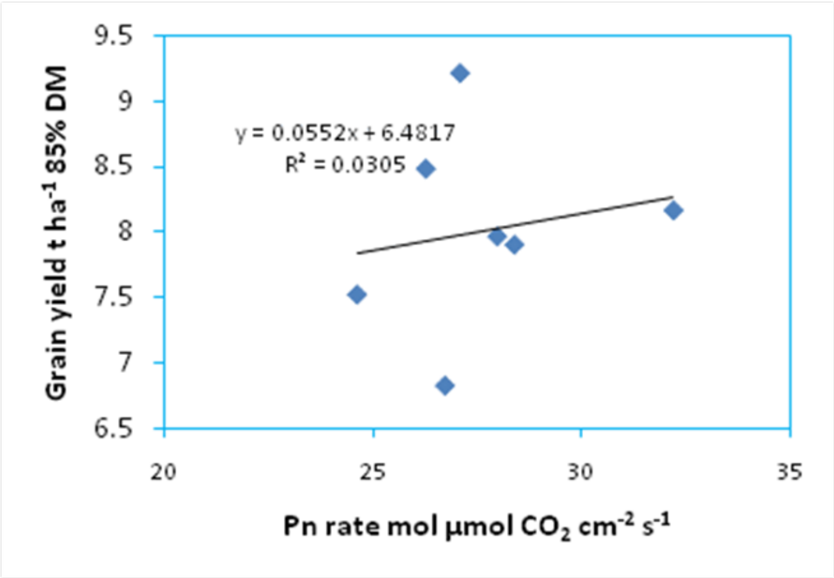


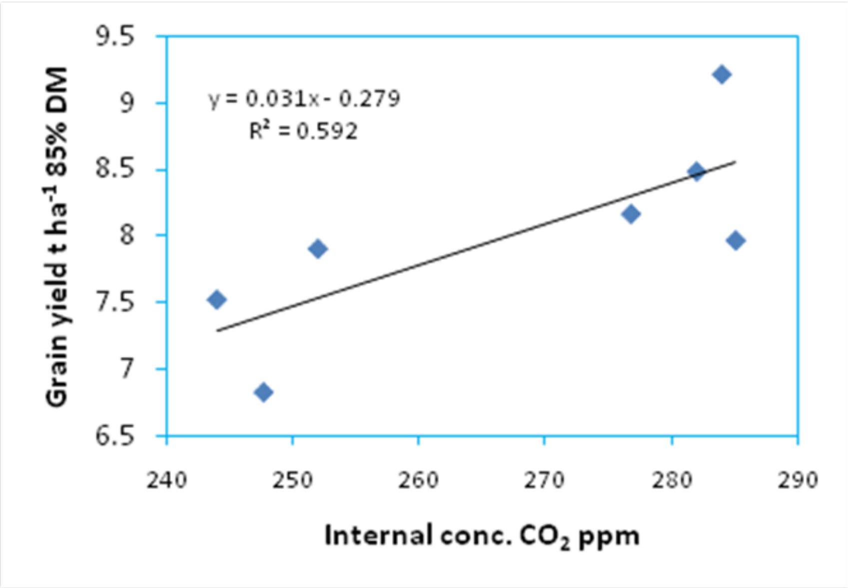
Sutton Bonington 2009-10

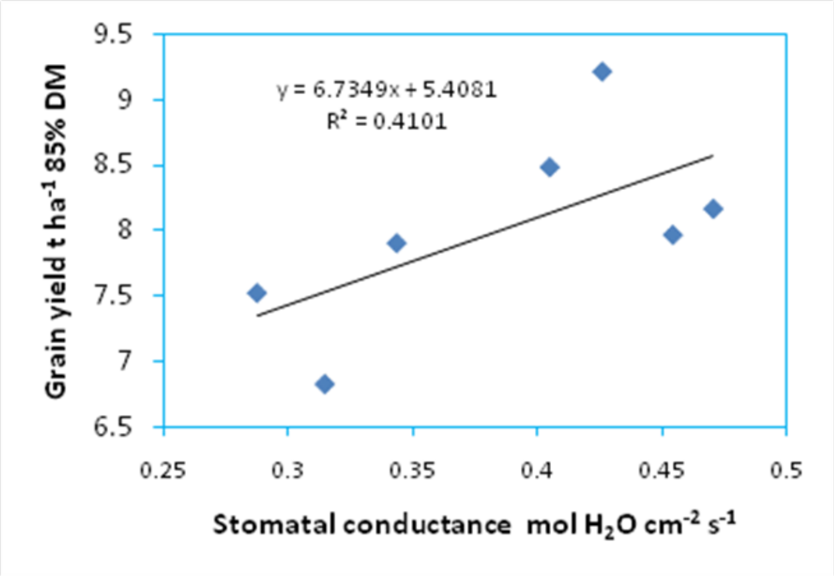
Drought tolerance index: (Y_{Dr}/Y_{Irr}) / (mean Y_{Dr} / mean Y_{Irr})

	R^2	Prob
Canopy T°C vs DTI	**0.16**	**0.11**
Anthesis date vs DTI	**0.04**	**0.43**
Plant height vs DTI	**0.01**	**0.81**

Relationship between leaf activity traits (24 June) and yield (unirrigated)





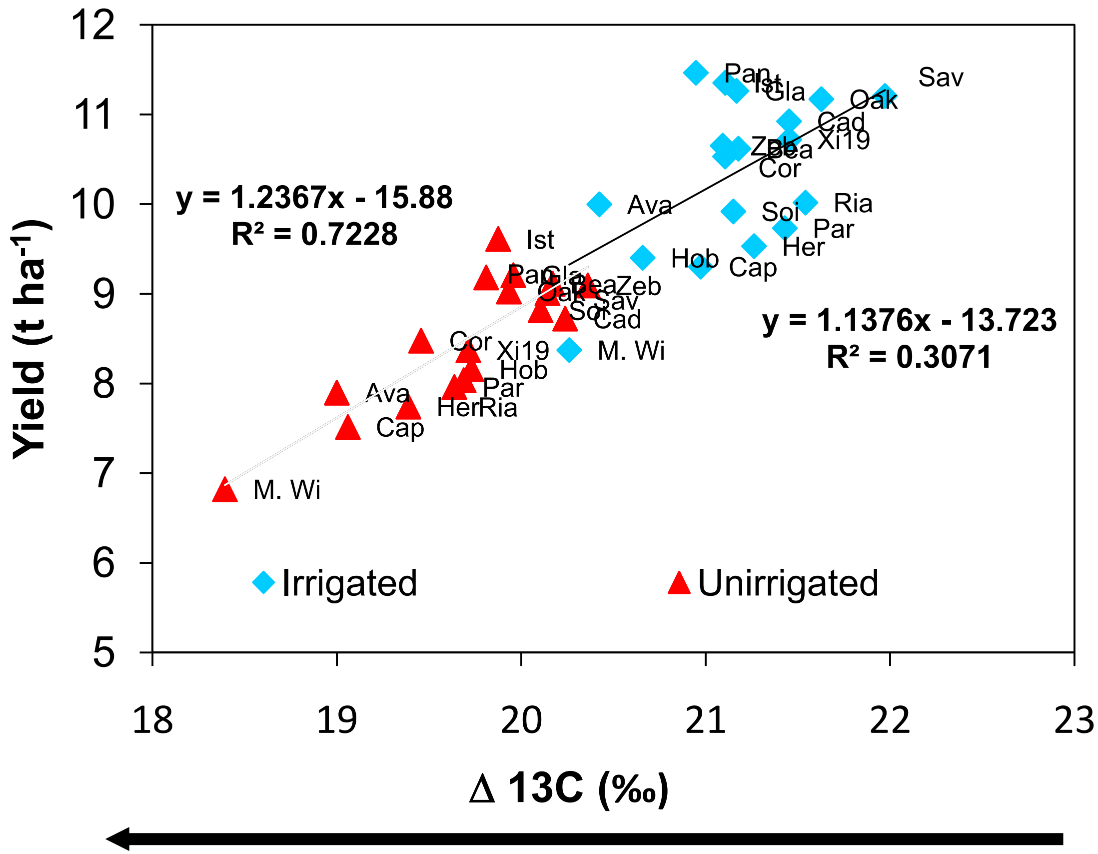


	02-Jun	24-Jun	28-Jun	13-Jul
Ps rate	0.22	0.03	0.26	0.00
Ci	0.18	0.59	0.20	0.36
Gs	0.31	0.41	0.25	0.37

Water use efficiency: definition and measurement

- **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 as an indicator of WUE**
- **Low discrimination against $^{13}CO_2$ → high WUE**

Δ [13]C vs grain yield in 18 wheat cultivars



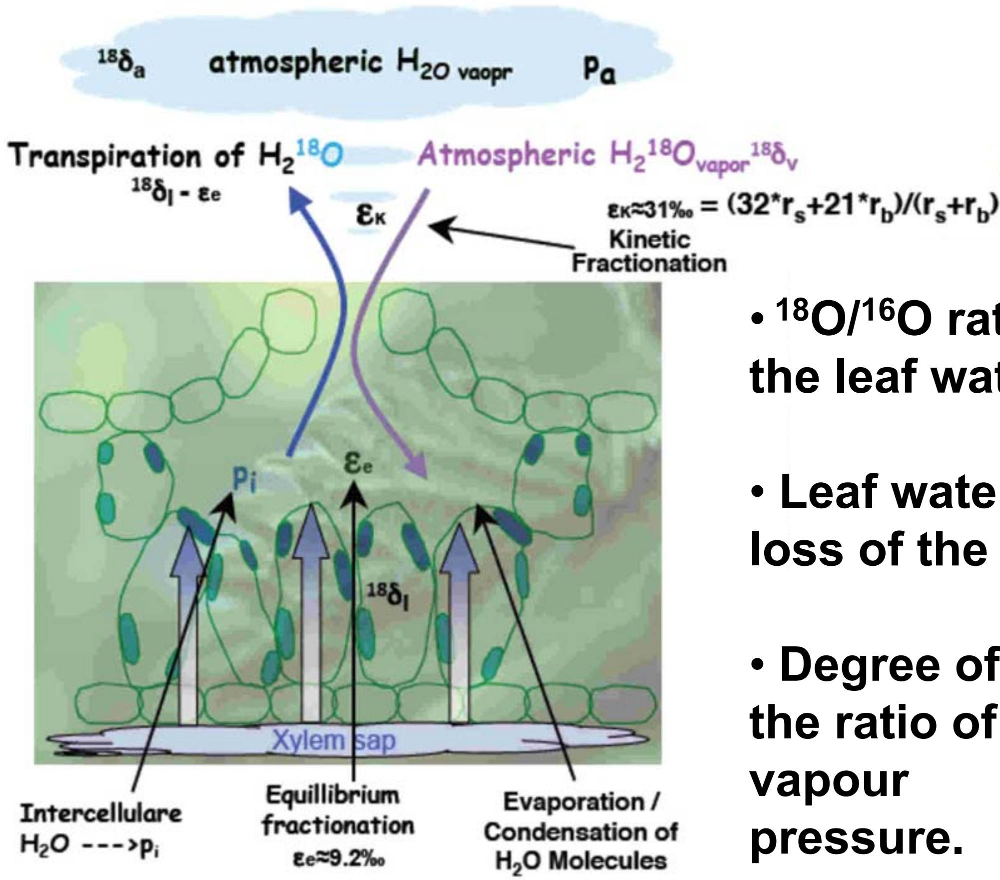
High WUE

Low WUE

Sutton Bonington 2009-10

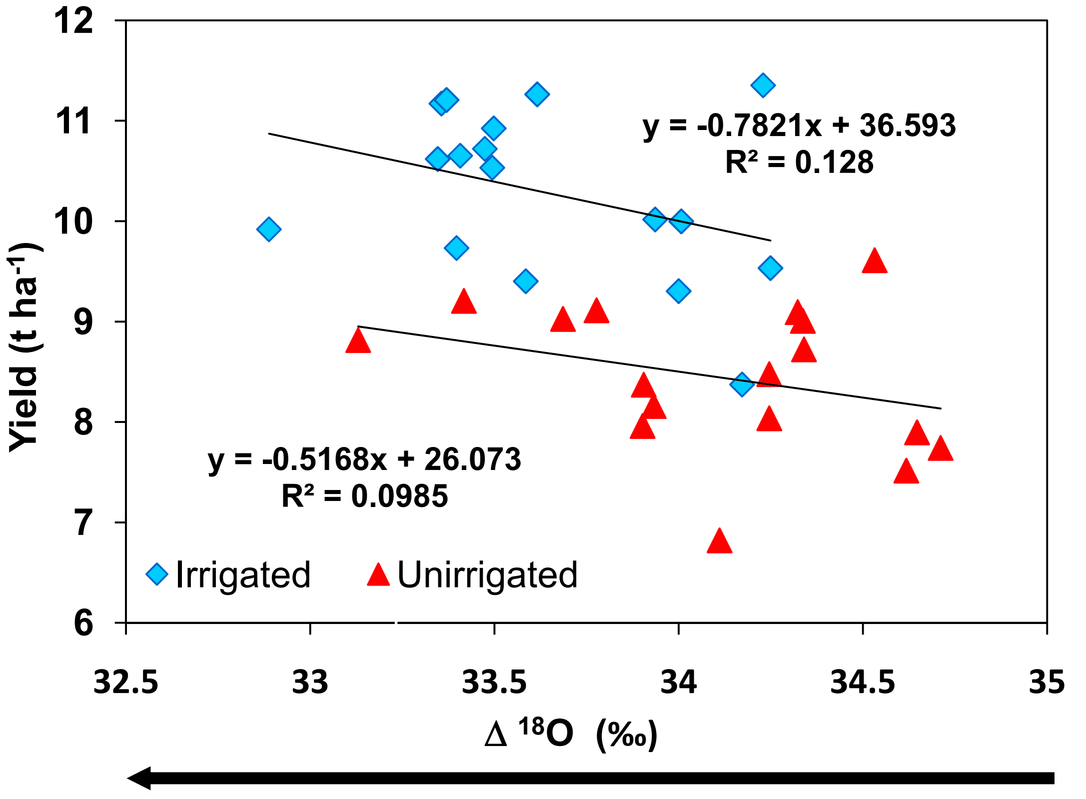
Wheat
Genetic
Improvement
Network

Techniques: Oxygen isotope ratio ~ leaf transpiration



- $^{18}O/^{16}O$ ratio determined by enrichment in the leaf water due to transpiration.
- Leaf water enriched due to the preferential loss of the lighter $H_2{}^{16}O$ during evaporation.
- Degree of $H_2{}^{18}O$ enrichment is related to the ratio of atmospheric to intercellular vapour pressure.
- An increase in stomatal conductance decreases leaf temp. hence intercellular vapour pressure, resulting in less $H_2{}^{18}O$ enrichment at the evaporating site.

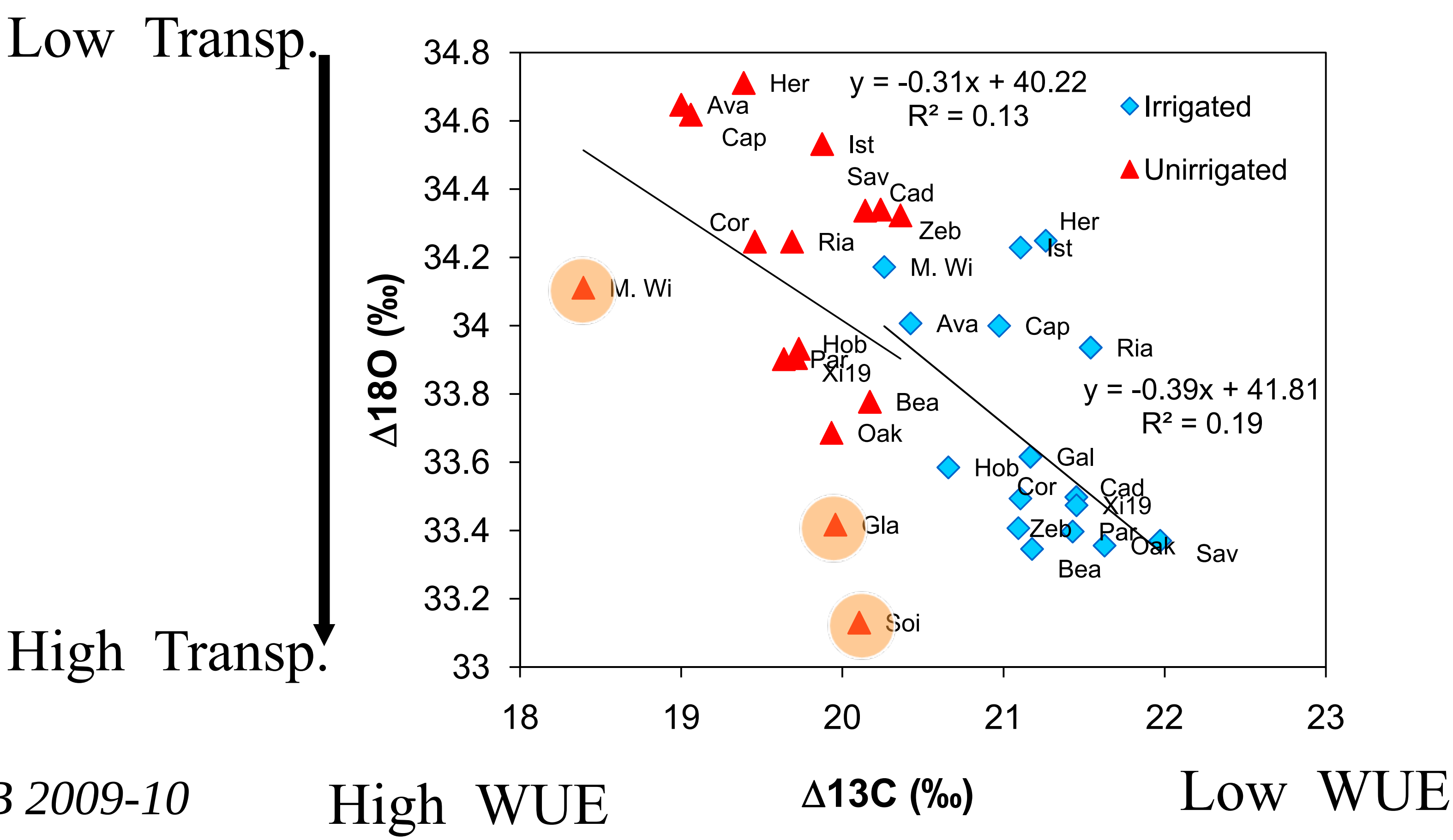
Δ [18]O enrichment vs grain yield in 18 winter wheat cultivars



High leaf transp. Low leaf transp.

Sutton Bonington 2009-10

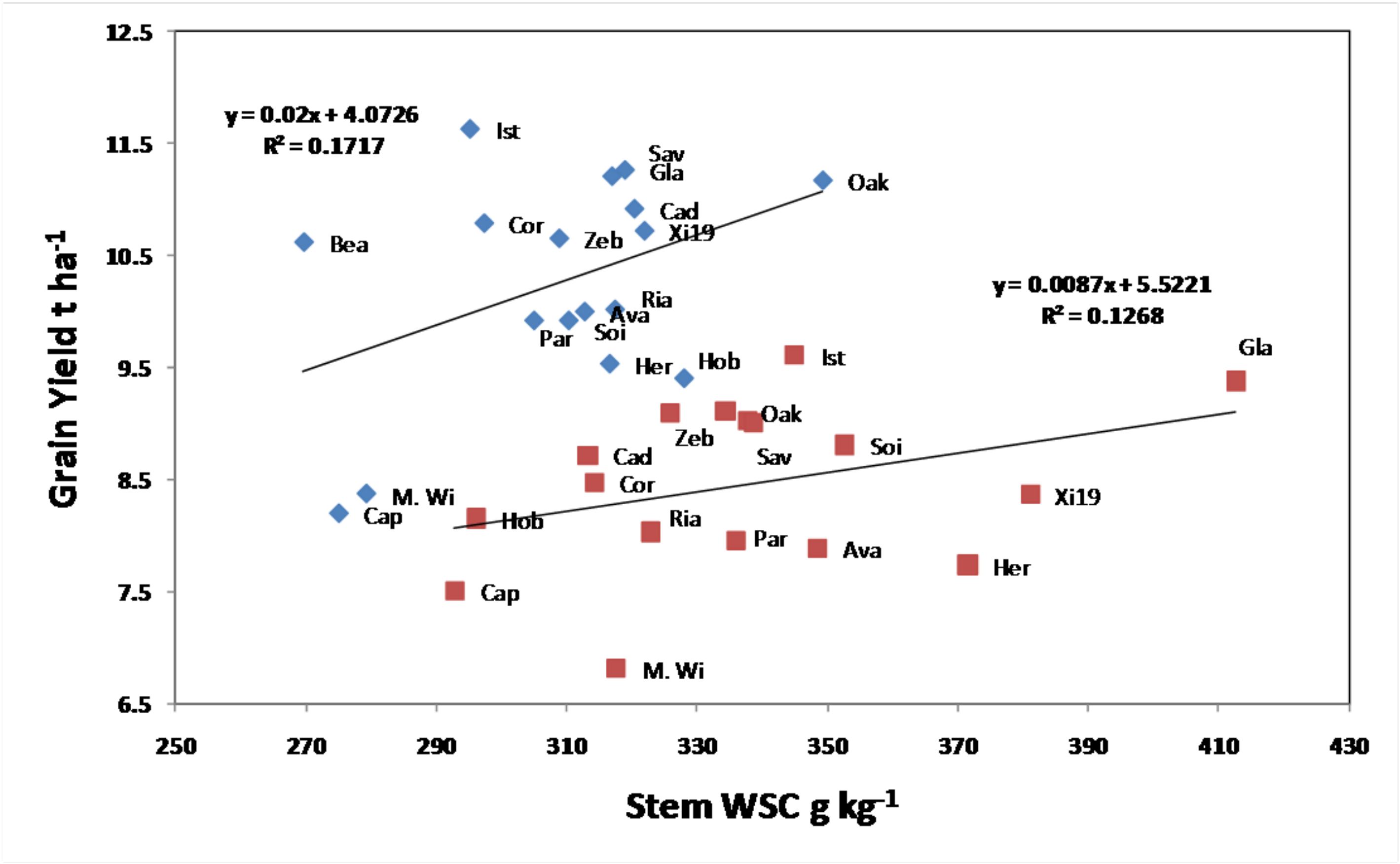
Relationship between $\Delta^{13}C$ and $\Delta^{18}O$ in 18 wheat cultivars



SB 2009-10

→$\Delta^{18}O$ is not strongly influenced by Ps rate, so measurement of $\Delta^{13}C$ and $\Delta^{18}O$ allows stomatal and Ps effects on Δ13C to be teased apart

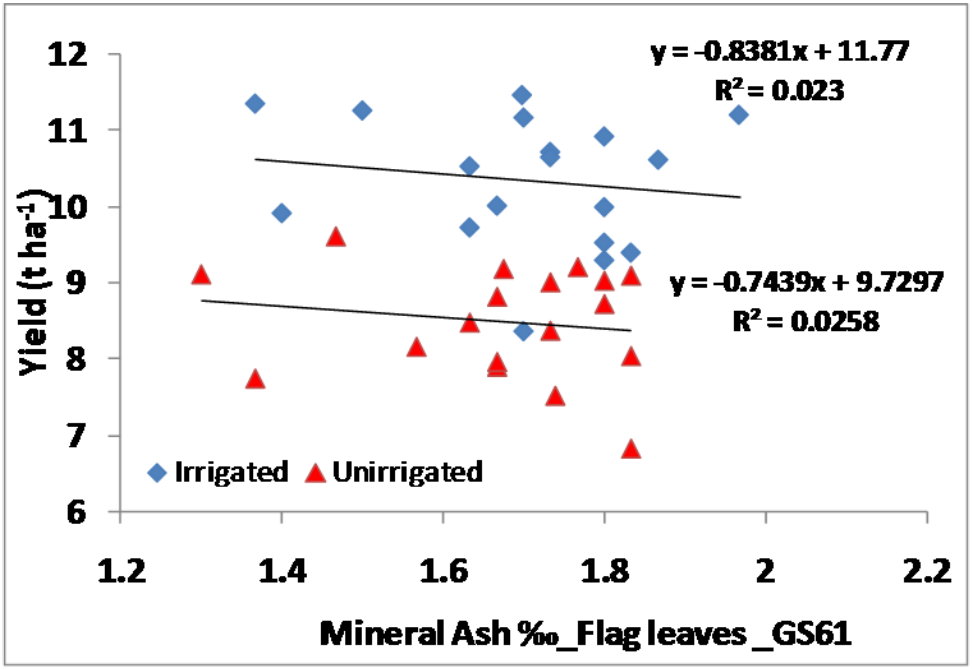
Stem soluble CHO at GS61 +9 d vs grain yield



SB 2009-10

Mineral ash content ~ **water use**

- Total leaf ash content of plant tissues is suggested as a useful tool to predict yield under drought.
- The mechanism of mineral accumulation in plant tissues appears to be explained through the passive transport of minerals via xylem driven by transpiration.
- Ash content measured provides an indicator of the total water transpired.
- Analysis of mineral ash content is less expensive than Δ13C or Δ18O.



SB 2009-10

WGIN 2 (Drought tolerance, 9.1)

2010-11 expt

Split plot design (3 reps): plot size 1.6 x 12 m
Main plot: Fully irrigated (trickle irrigation)
Unirrigated

Split plot (variety):

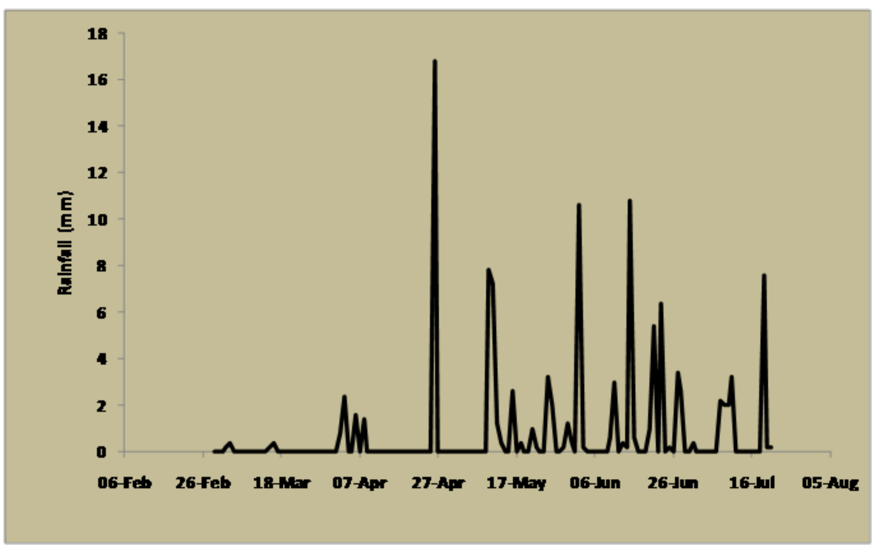
1. Avalon *
2. Beaver
3. Cadenza *
4. Sterling (Cap Desprez)
5. Cordiale
6. Glasgow
7. Hereward *
8. Hobbit
9. Istabraq
10. M. Widgeon *
11. Oakley *
12. Panorama
13. Paragon *
14. Rialto
15. Savannah
16. Soissons
17. Xi 19 *
18. Zebedee

Drought effects 11 July 2011

Panorama

Cadenza

Istabraq



	Rainfal (mm) 2011	LTM 75-09
March	1.2	54.1
April	23	43.4
May	27.8	45.7
June	45.4	45.6
July	17.8	49.8

WGIN 2 (9.2 QTL Detection)

<u>2010-11 and 2011-12 expts</u>

- 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 kinetics
  - canopy temperature
  - 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 △ 13C (unirrigated)**
- **NDVI**

Drought effects 11 July 2011

L2

L39

L47

WGIN 2 (9.3 Develop new DH pop)

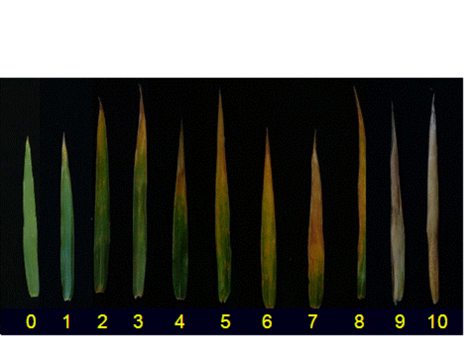
	Project Month	Milestone
31/03/2012	40	Act 9 Obj3. Complete development of one new DH population in an elite modern background segregating for drought-tolerance traits.

- Candidate F1(s) made at JIC crosses to maize informed by data analysis from LK0986 project
- F1 crossed with maize
- 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

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



WGIN 2 (Activity 9, Drought tolerance)

	Project Month	Milestone
30/11//2011	36	Act 9 Obj1: Complete phenotyping and data analysis for drought tolerance traits in elite winter wheat varieties in 2009/10 &10/11.
30/11/2012	48	Act 9 Obj2: QTL analysis to identify genome locations associated with WUE and drought tolerance traits completed.
31/03/2012	40	Act 9 Obj3. Complete development of one new DH population in an elite modern background segregating for drought-tolerance traits.
28/02/2013	51	Act 9 Obj4: Association genetics analysis of drought tolerance traits using AE Watkins & Gediflux collections completed.
28/02/2013	51	Act 9 Obj5: Collation of diverse germplasm collection (cultivars, advanced lines) from worldwide drought-tolerance wheat breeding programmes completed.

Conclusions

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

- **Canopy T°C correlated with grain yield under drought. Physiological basis ~ dehydration postponement, 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,)**

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L. Fish

ADAS
R. Sylvester-Bradley
R. Weightman

UK climate 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)

Effects of major breeding changes on grain $^{13}\Delta$ $^o/_{oo}$ (WUE)

Irrigated :

- - awns — no change
- + Rht2 — + 0.09* (WUE ↓)
- + 1BL.1RS — + 0.31 ** (WUE ↓)

Unirrigated :

- - awns — no change
- + Rht2 — + 0.22 * (WUE ↓)
- + 1BL.1RS — + 0.30 ** (WUE ↓)

→ modern UK wheat cultivars may have lower WUE during grain filling than their predecessors, and therefore may require more water to fulfil their yield potential.

Beaver x Soissons DH population

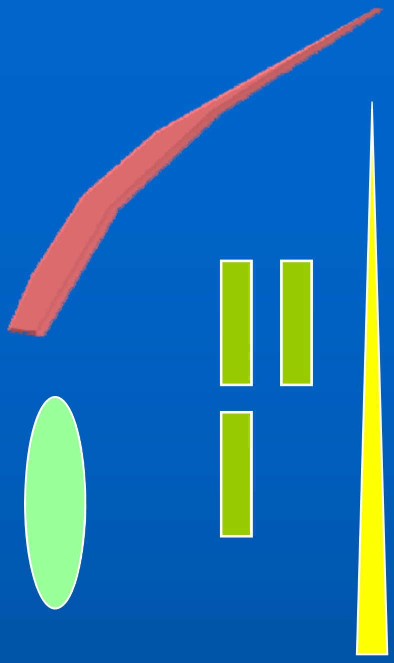
Gleadthorpe Mean 2000/1 and 2001/2

Traits for adaptation to heat stress

- Heat stress around flowering predicted to increase with climate change
  - > 31°C reduce grain number (Ferris et al. 1998 Ann Bot)
  - > 27°C reduce grain size (Wheeler et al. 1996 J Exp Bot)
- Warmer conditions could result in wheat flowering 3 weeks earlier by 2055 helping to avoid drought (Semenov et al. 2010 Nat. Prec.)
- Therefore increasing interest in development of wheat varieties which are tolerant to high temperature

Measurements

- **Combine grain yield, yield components**
- **DM & partitioning at GS31, GS61, harvest**
- **% stem WSC at GS61+10d**
- **Leaf senescence kinetics for L1, L2 and L3.**
- **Stomatal conductance/photosynthetic rate using Licor (unirrigated)**
- **Canopy temperature**
- **Water use ~ gravimetric analysis of soil cores (unirrigated, 18 varieties)**
- **^{13}C Δ grain ~ leaf WUE**
- **^{18}O Δ flag leaf ~ leaf transpiration**



Leaf gas exchange

Canopy temp.

Traits for adaptation to heat stress

- Many drought-adaptive traits also useful under heat stress:
  - Canopy T°C ~ evaporative cooling
  - Stay-green ~ photosynthesis/chlorosis
  - Leaf glaucousness ~ reduce heat load
  - Awns ~ maintain photosynthesis

- Some traits specific to heat tolerance
  - Membrane thermostability ~ maintain membrane integrity/reduce ion leakage from cell
  - Flowering window ~ reduce spikelet sterility
  - Starch synthase activity ~ reduce inhibition of SS

Sub-contract budget

Estimated costs	
Salaries	£3,512 (2 months Research technician)
Other expenses	£15,012 (Chemical analysis for $\Delta^{18}0$, $\Delta^{18}0$, ash content)
	£ 3,849 Indirect costs (OHs)
VAT	£2,627
Total	£25,000

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.	Slight
Early flowering	Advances grain filling before the drought risk period.	Neutral
Awns	Use less water per unit growth.	Slight

Sub-contract budget

Estimated costs	
Salaries	£3,512 (2 months Research technician)
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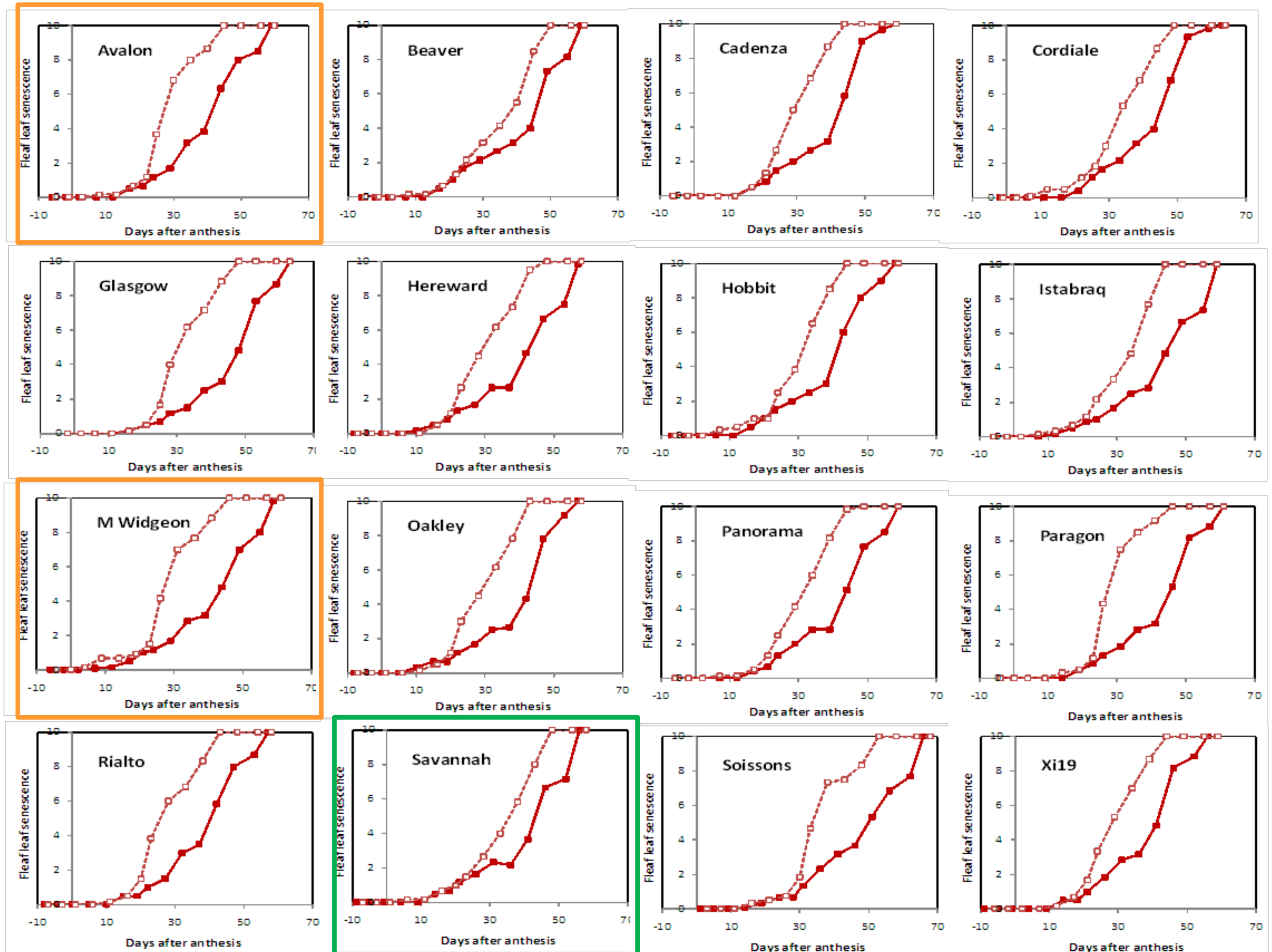
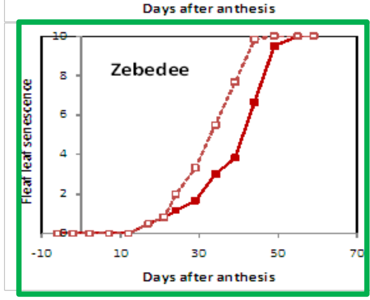
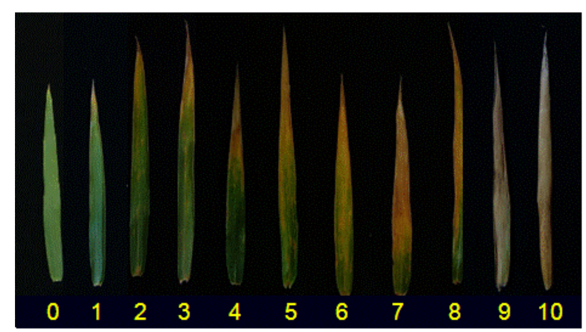




Flag leaf senescence



WGIN 2 (9.3 Develop New DH pop)

	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.

Candidate F1(s) made at JIC crosses to maize informed by data analysis from LK0986 project:

Timber
Gatsby
Consort
Clare
Zebedee
Garcia
Paragon

WGIN Management Meeting
Richard Gutteridge

July 20th 2011

Objective 10 – Take-all

1. Screen Watkins and improved Gediflux collections for take-all resistance under field conditions.
2. Explore the genetic basis for take-all inoculum build-up using the Avalon x Cadenza mapping population.

HGCA-BBSRC PhD

1st wheat variety trial 2009

Yield average 12.69t/ha

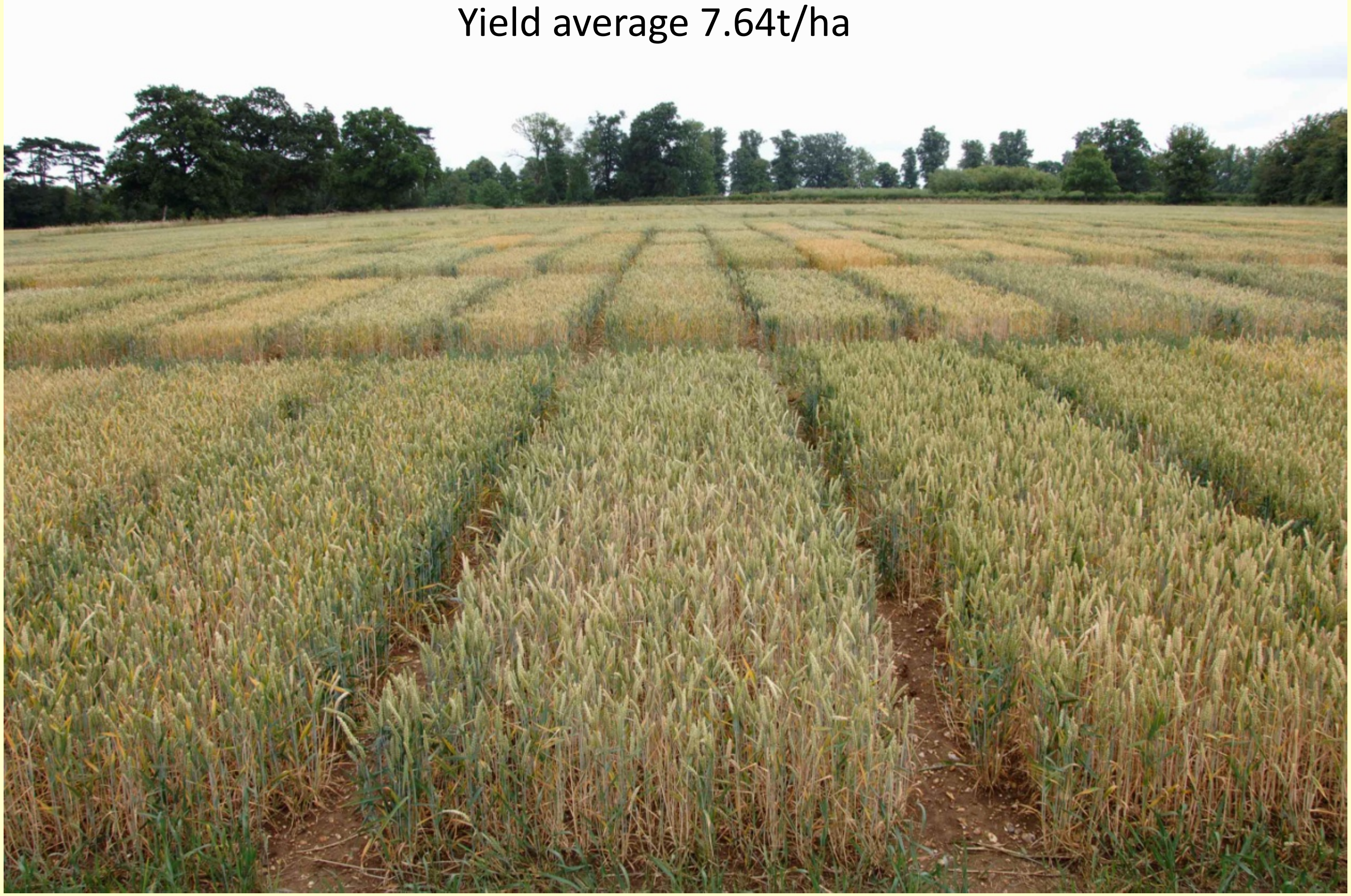
45 varieties x 4 reps

Variety trial sown on 09th October 2008 on Rothamsted Farm;

Photograph taken 08th July 2009

HGCA-BBSRC PhD

3rd wheat variety trial 2009

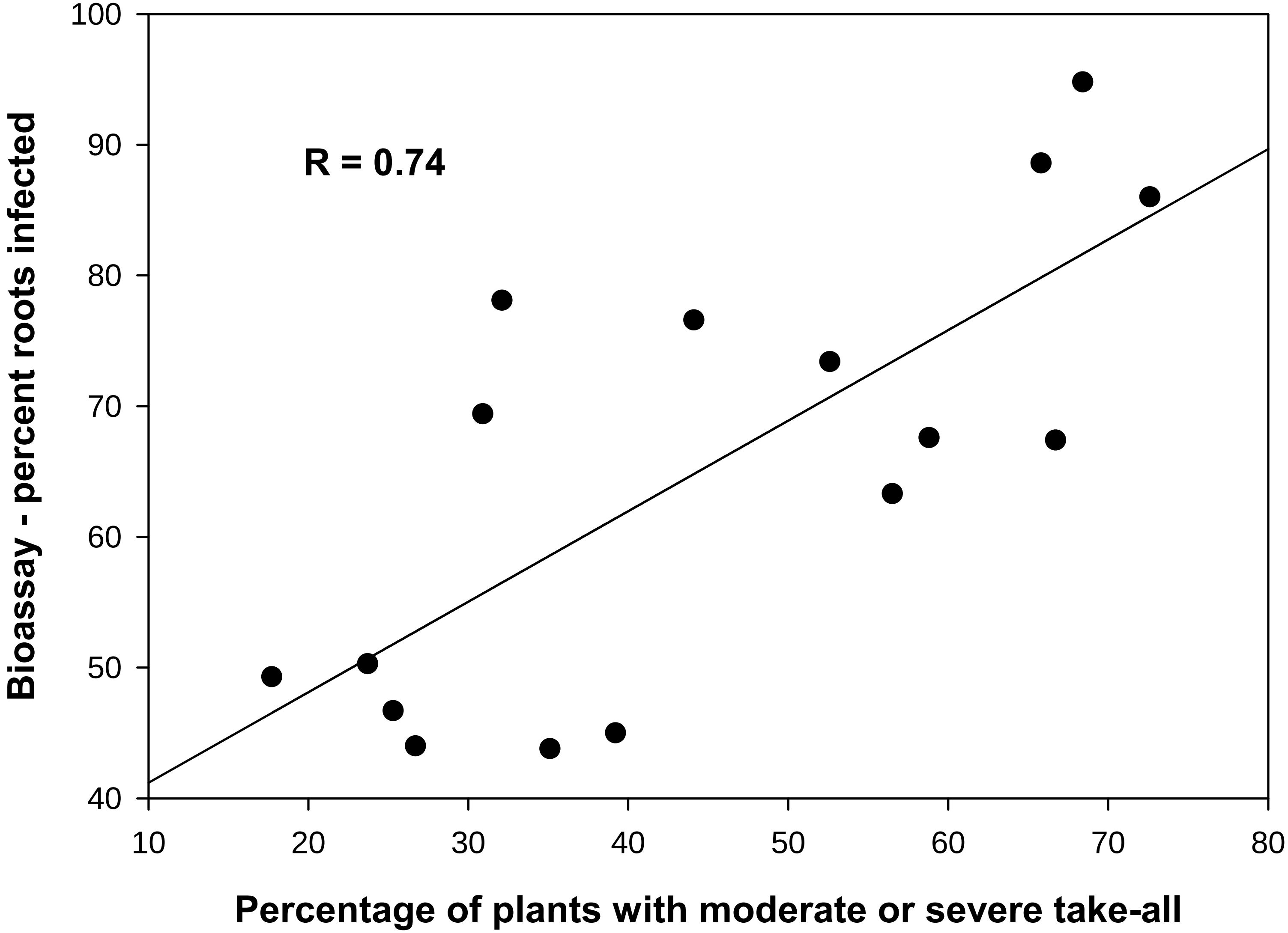


45 varieties x 4 reps

Variety trial sown on 09th October 2008 on Rothamsted Farm;

Photograph taken 08th July 2009

The relationship between percentage of roots infected in the autumn bioassay and the disease in the following crop



Take-all Assessment

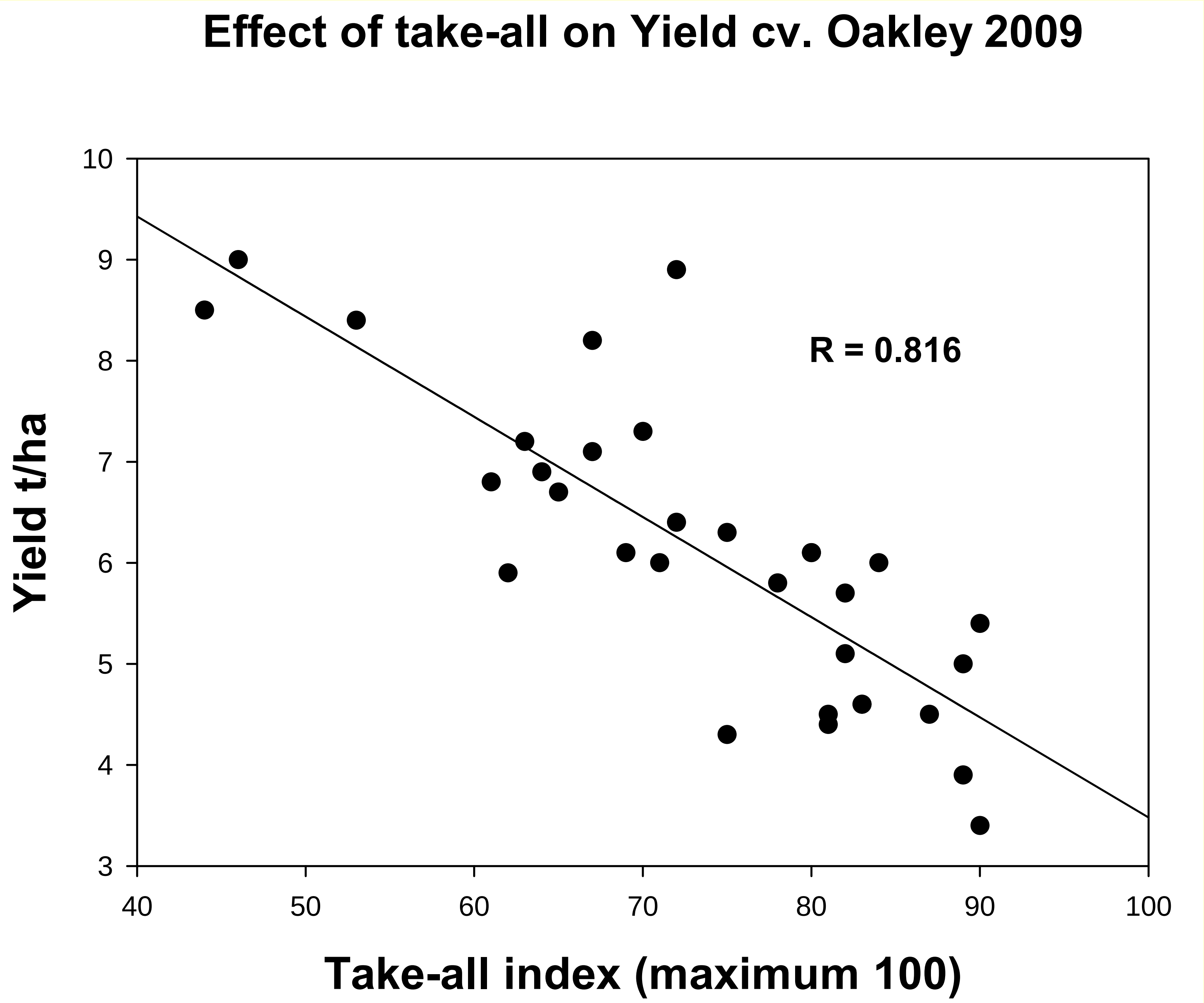
Whole plant root systems are assessed in a white dish under water and the proportion of roots affected by the disease graded as follows:

Slight 1: 1 – 12%; Slight 2: 13 – 25%; Moderate 1: 26 – 50%
Moderate 2: 51 – 75%; Severe >75%

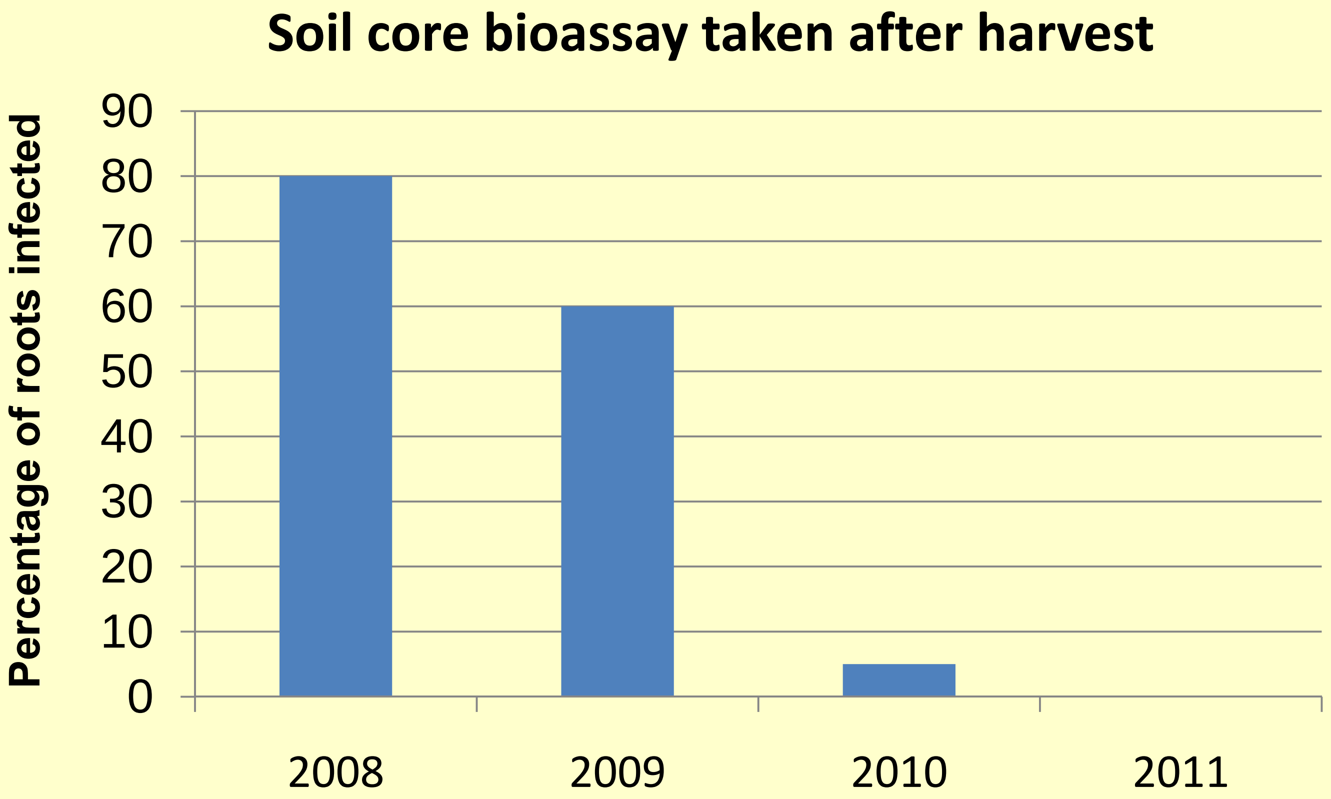
Take-all Index calculated by:

1 x %plants with slight 1; + 2 x %plants slight 2; + 3 x %plants moderate 1; + 4 x %plants moderate 2; + 5 x % plants severe

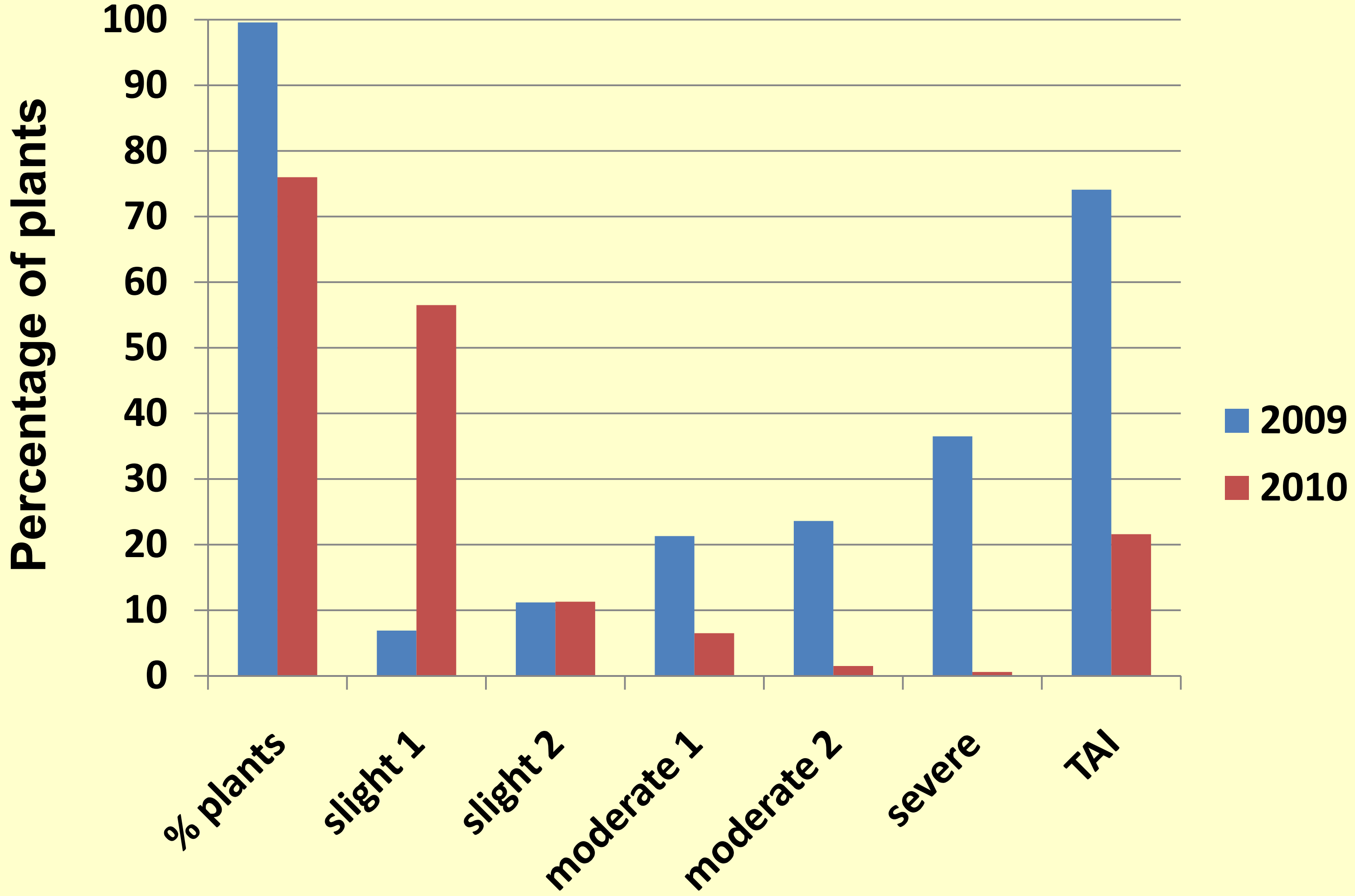
Divide by the number of categories (5) ; Maximum index = 100


Effect of take-all on Yield cv. Oakley 2009
R = 0.816
Yield t/ha
10
9
8
7
6
5
4
3
40
50
60
70
80
90
100
Take-all index (maximum 100)

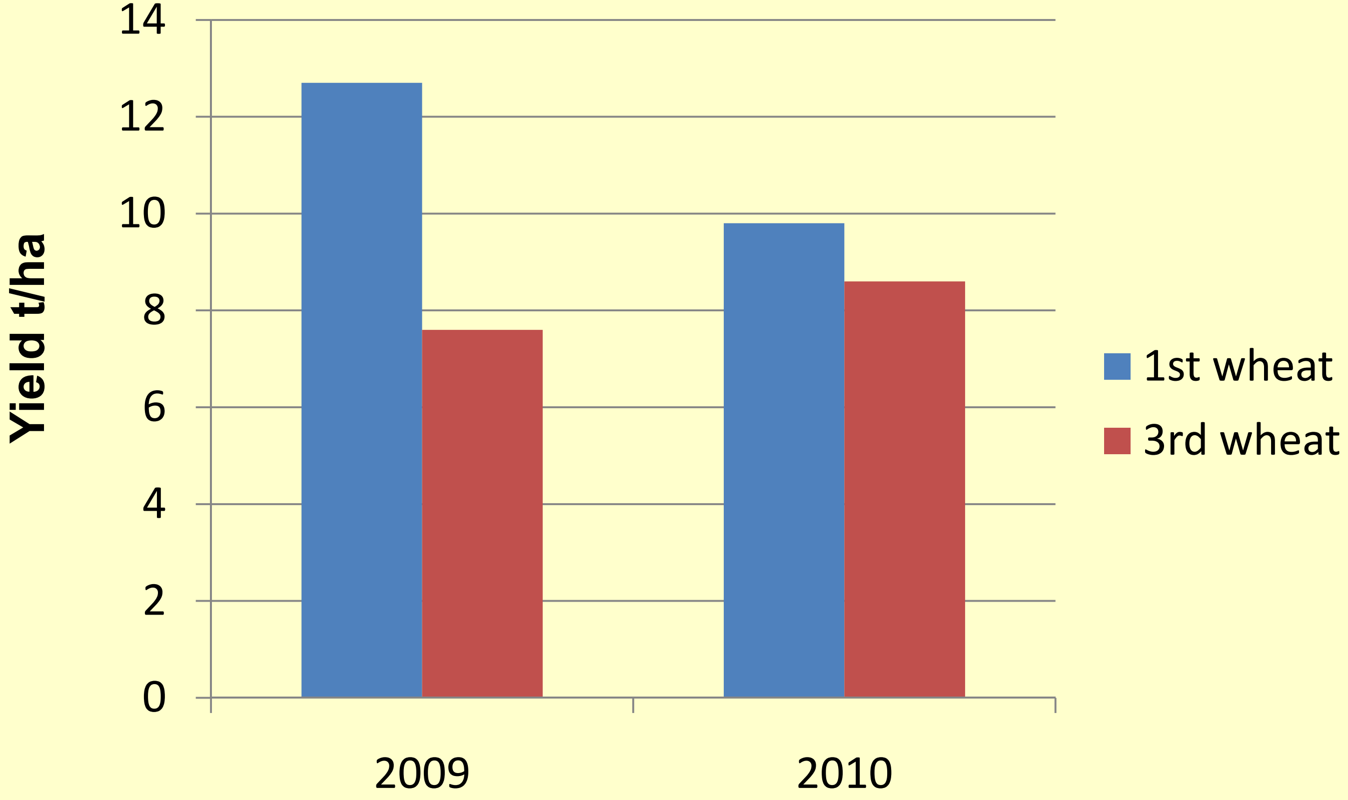
Take-all inoculum build-up between 2008- 2011



The differences in the severity of take-all in each disease category in 2009 and 2010 and the Take-all Index.



Yields of first and third wheat in 2009 and 2010



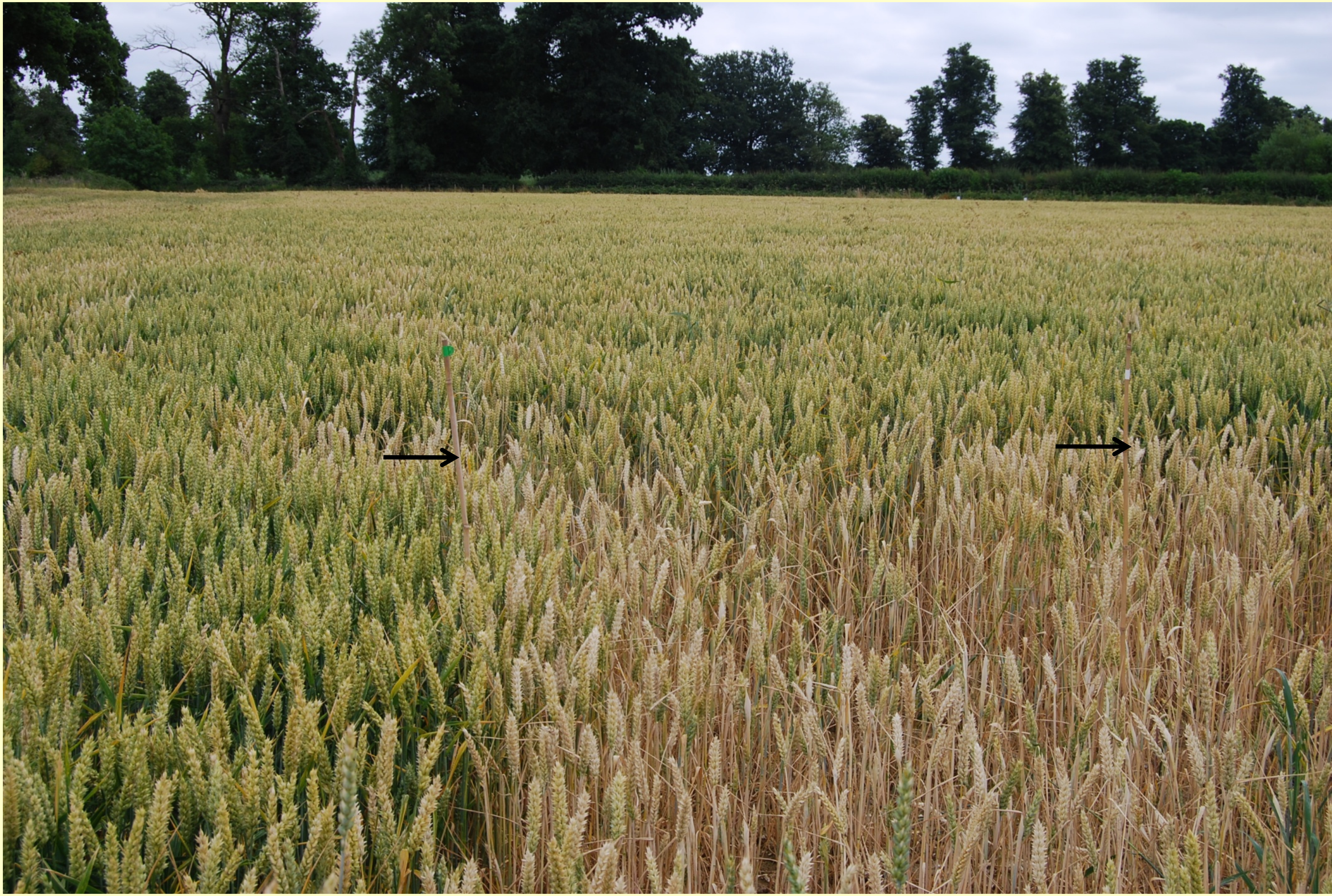
Average TAI 74.1

Average TAI 21.6

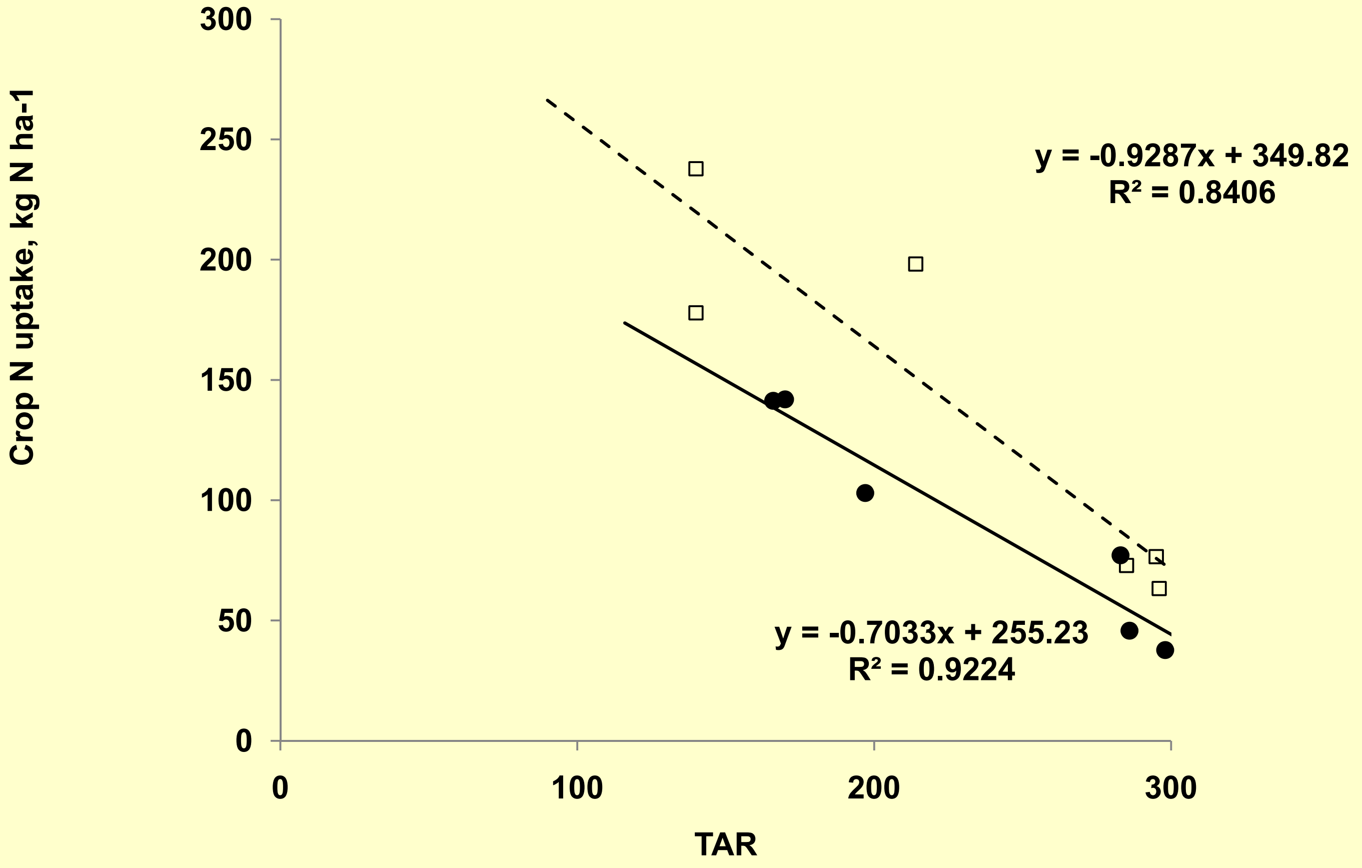
Effect of Take-all on Nitrogen uptake and the amount of mineral N in the soil after harvest when severe disease has occurred

Selecting ½ metre square good and poor areas

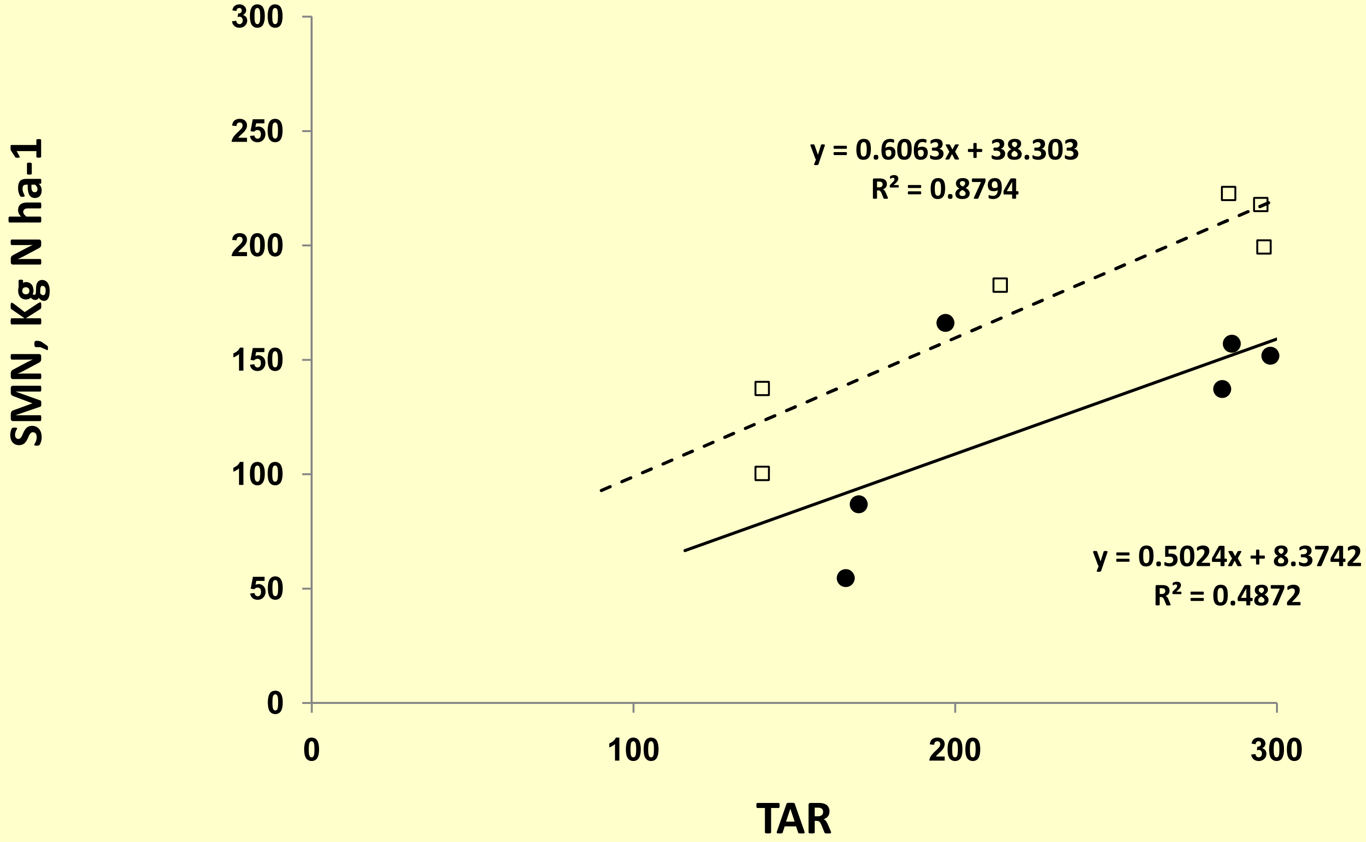
Areas selected are marked with canes



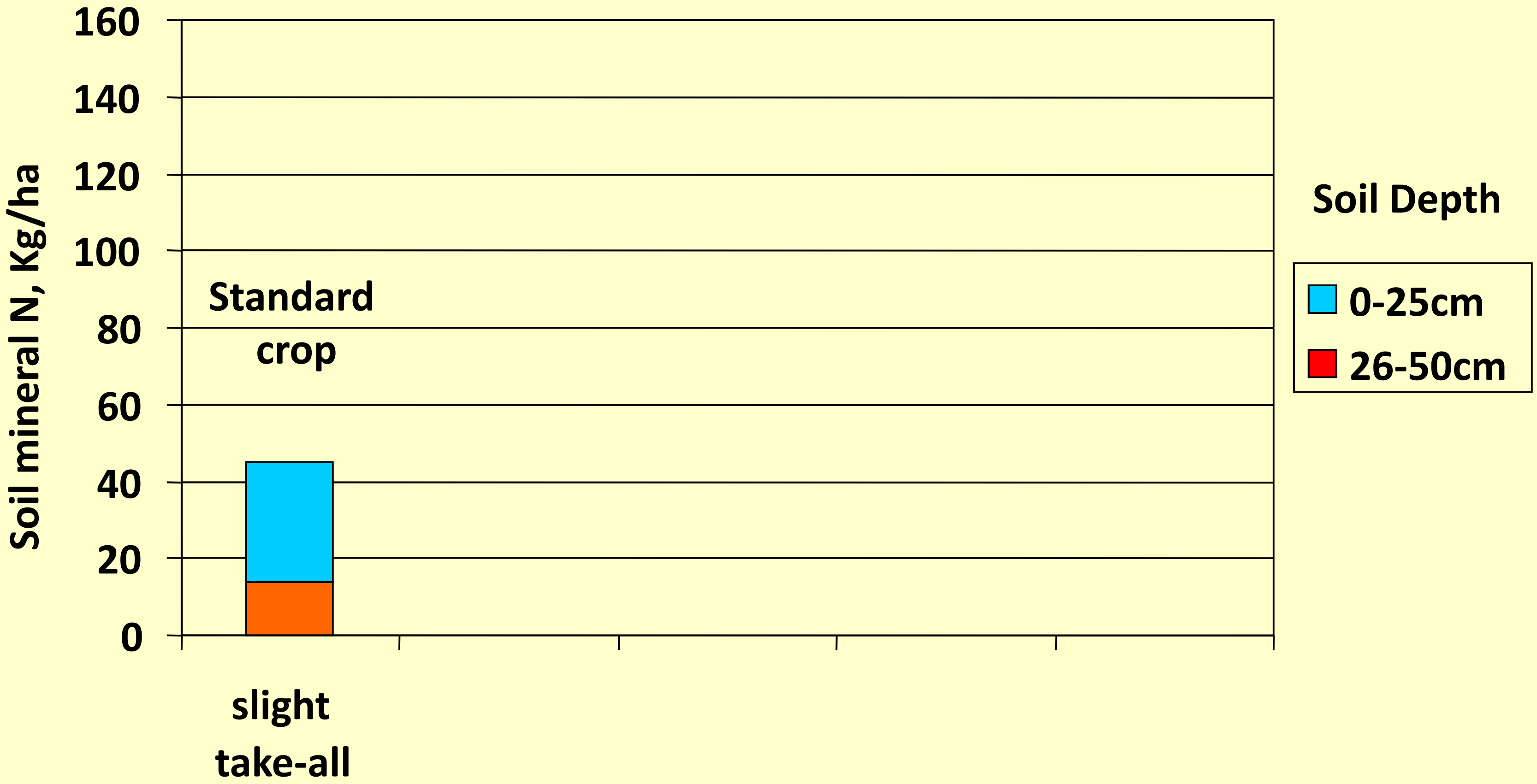
The relationship between Take-all infection (TAR) and whole crop N uptake by winter wheat at anthesis (□) and harvest (●)



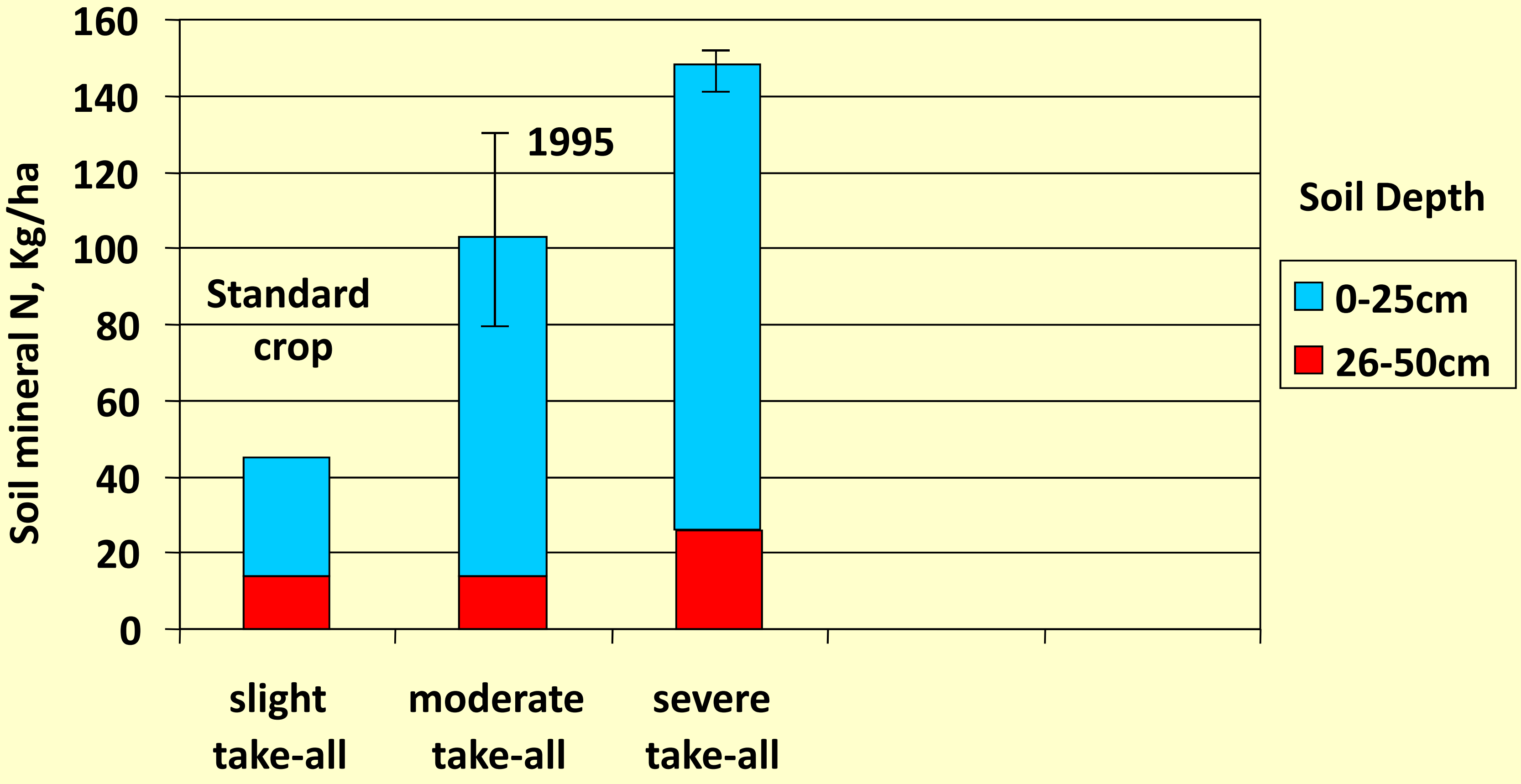
The relationship between Take-all infection (TAR) and Soil Mineral Nitrogen by winter wheat at anthesis (□) and harvest (●)



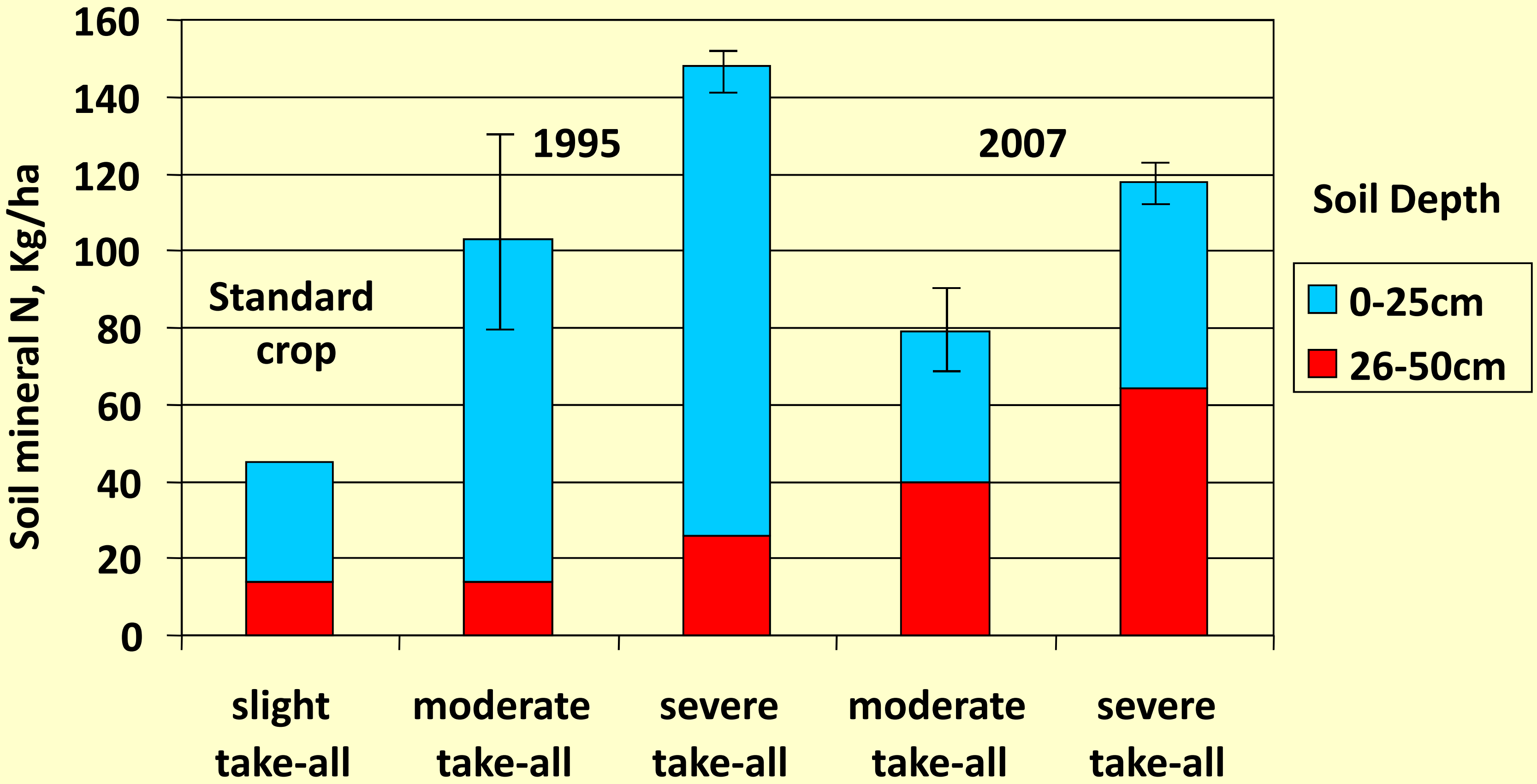
Effects of Take-all on soil mineral N at harvest



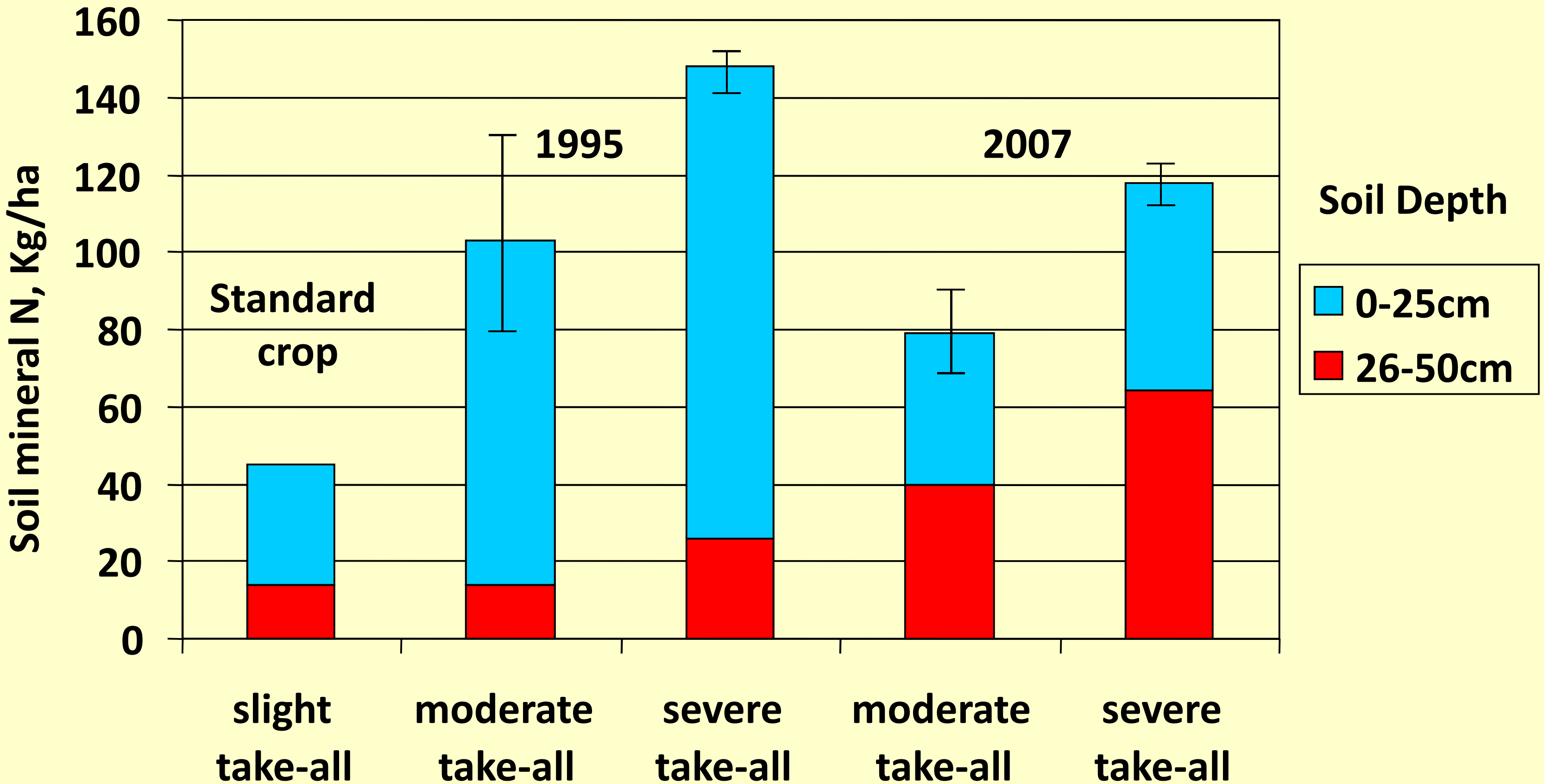
Effects of Take-all on the nitrogen left in the soil at harvest



Effects of Take-all on soil mineral N at harvest



Effects of Take-all on soil mineral N at harvest



Rainfall (mm)			
	April	11.3	2.8
	May	28.4	135.8
	June	28.2	72.4
	July	18.6	86.8

Conclusions

Severe take-all infection of winter wheat significantly decreased the crop's capacity to take up nitrogen, whether from fertiliser N or the soil reserves.

This substantially increased the amount of SMN (mostly nitrate) present in soil at harvest at risk to subsequent losses.

Severe take-all infection decreased the recovery of fertiliser N by about 33% of that applied.

Take-all increased the risk of nitrate leaching from severely infected patches of arable land in the autumn and winter following harvest, and almost certainly enhanced gaseous N losses to the atmosphere during the growing season.

Management practices which delay the onset of severe take-all infection until after anthesis may help maintain crop N uptake and minimise the risk of N losses.

A manuscript : Effects of take-all *(Gaeumannomyces graminis* var. *tritici)* on crop N uptake and residual mineral N in soils at harvest of winter wheat has been accepted by Plant and Soil and should appear later this year..

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