ROTHAMSTED RESEARCH

Low Protein Wheat for Baking Quality

Till K Pellny ROTHAMSTED RESEARCH

BBSRC bioscience for the future

Lawes Agricultural Trust

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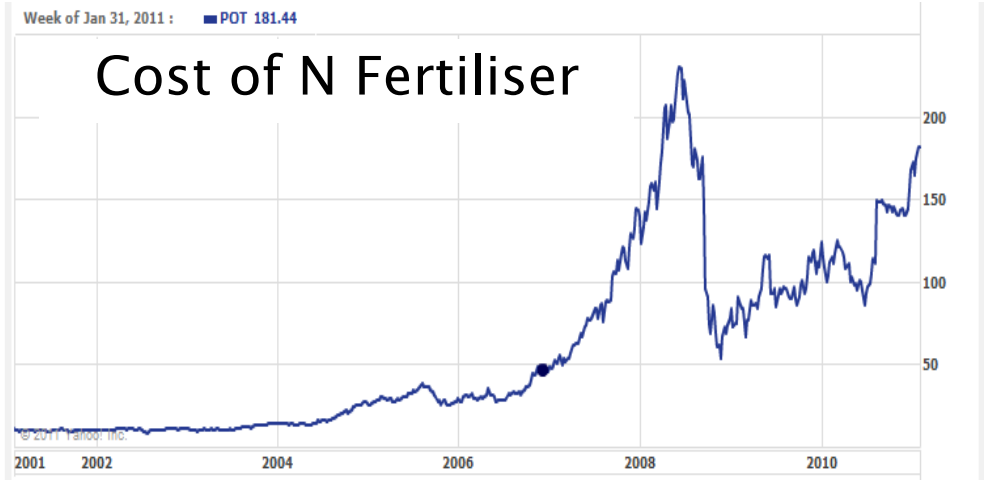
Challenges for Wheat Quality in Europe

ROTHAMSTED RESEARCH

Major priorities

- Yield
- Reduce N requirement for growing high yielding bread making wheats
- Increase stability of yield and quality



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Challenges for Wheat Quality in Europe

ROTHAMSTED RESEARCH

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Types of UK wheat used by flour millers

Group	Description	% of 2016 UK wheat crop*
nabim Group 1	Consistent bread making wheats. 13% protein, 250s HFN and specific weight 76kg/hl.	24
nabim Group 2	Bread making potential. Some are inconsistent, others suit specialist flours.	7
nabim Group 3	Soft wheats for biscuits, cakes etc. Low protein and an extensible but not elastic gluten.	5
nabim Group 4	Feed wheats.	58

** Varieties not in the Recommended List are not included.*

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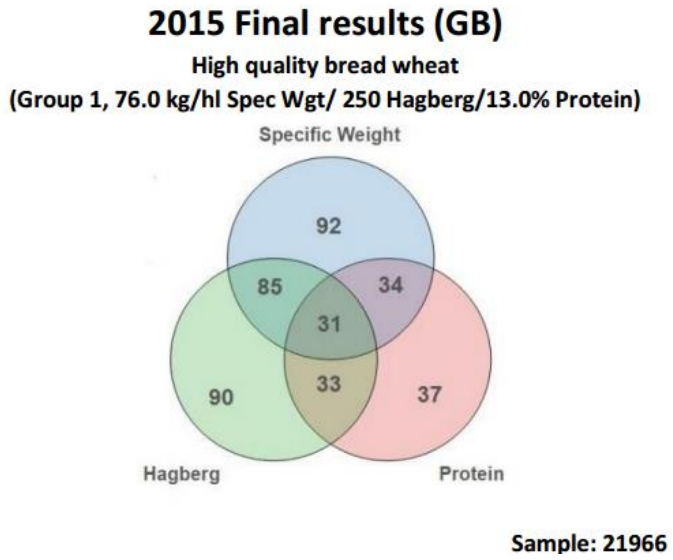

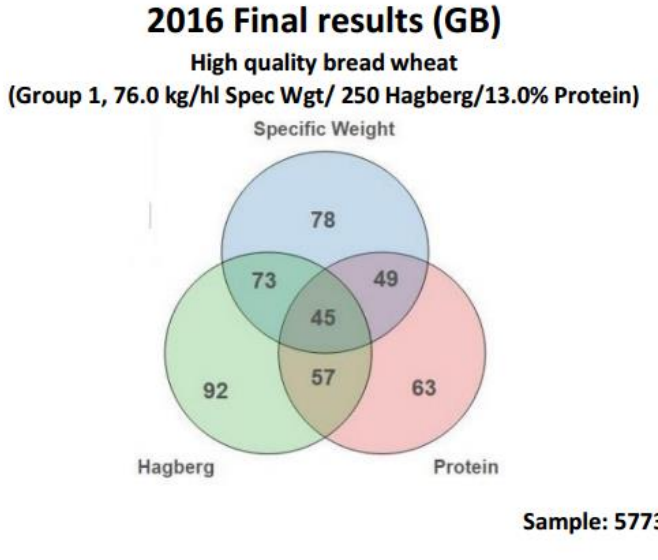

Source: AHDB Cereals & Oilseeds Quality Survey 2016

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Nitrogen (Protein) is Key

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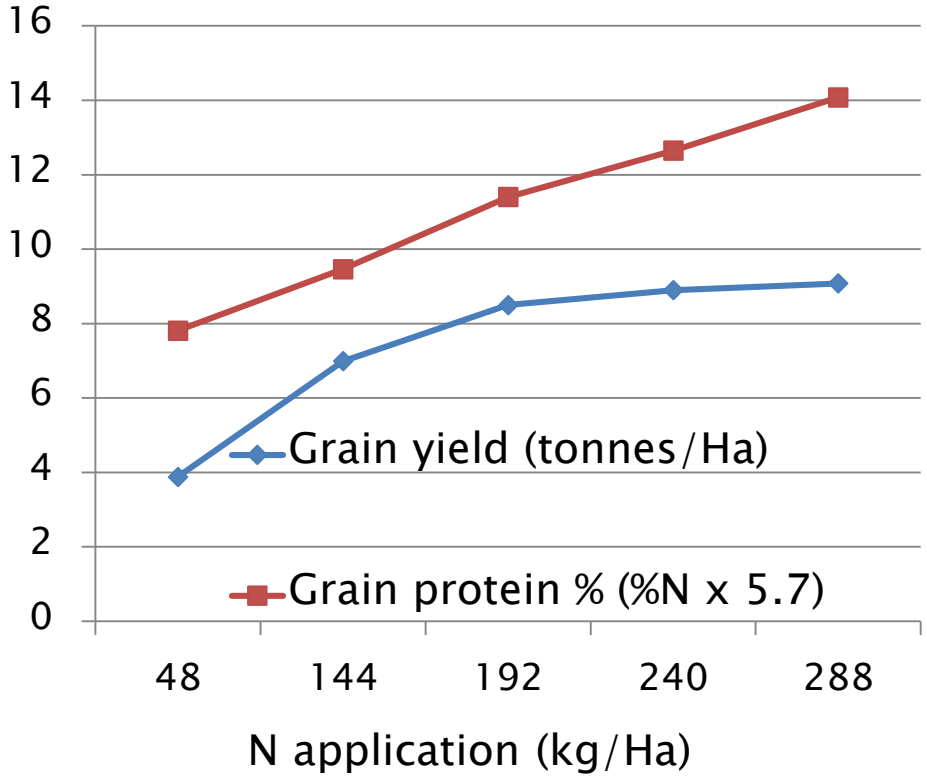

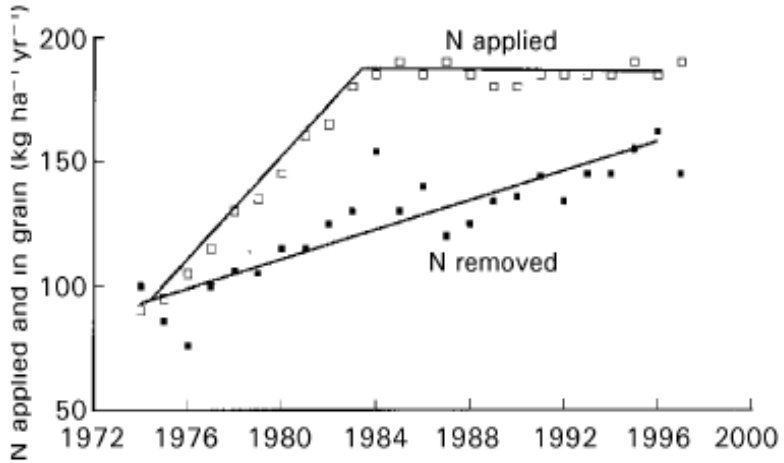

N applied vs N removed

- The high grain protein requirement for bread making results in N applications above the optima for yield and N use efficiency

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Nitrogen (Protein) is Key

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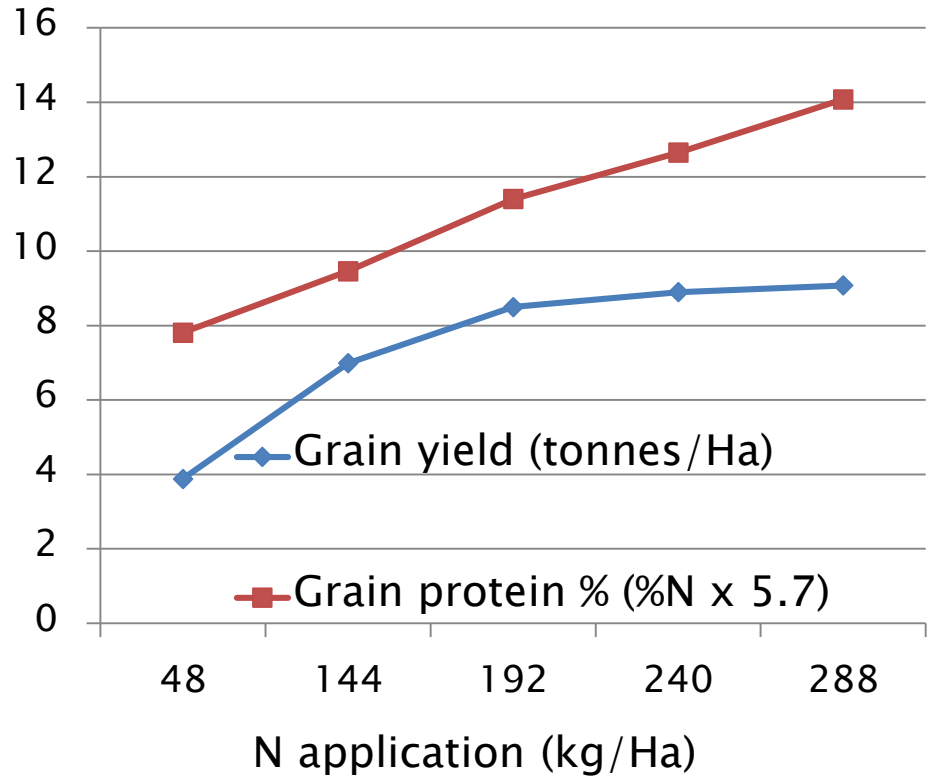

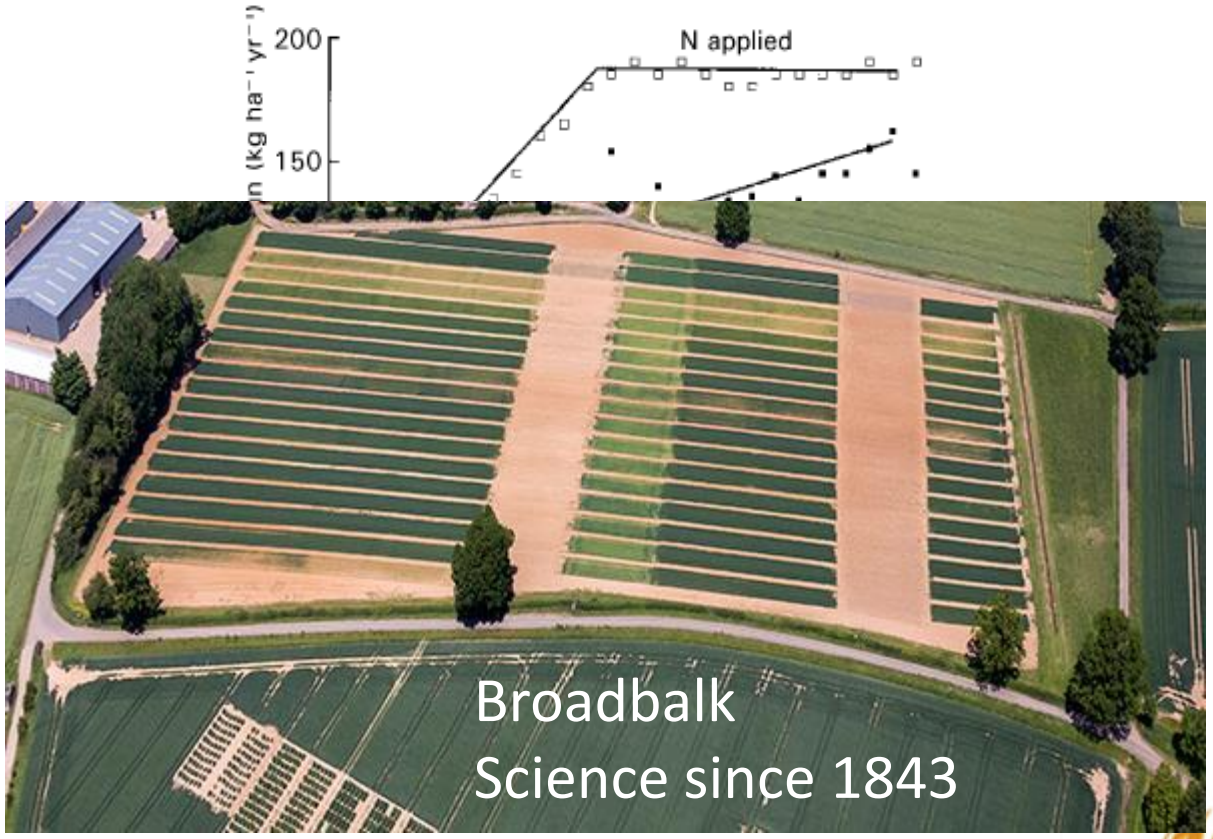

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Nitrogen (Protein) is Key

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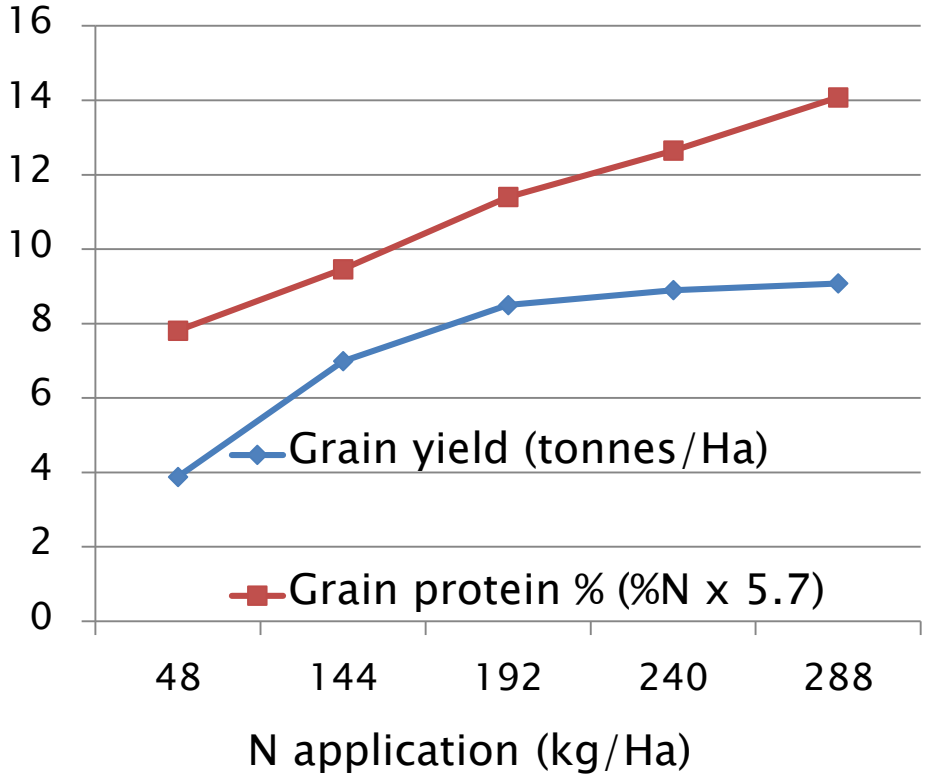

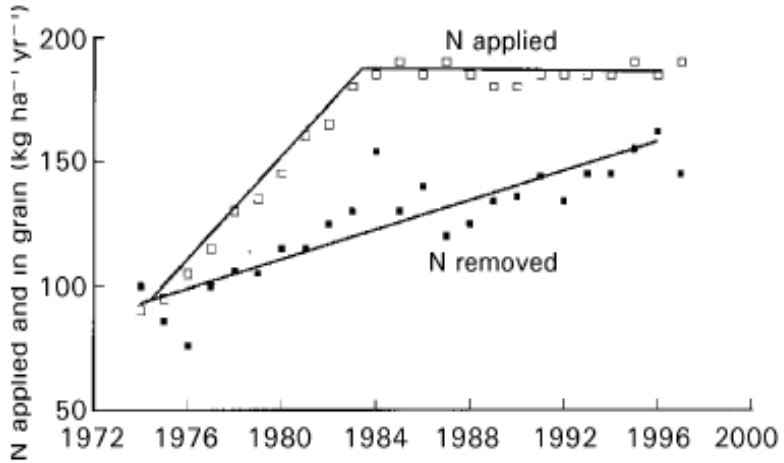

N applied vs N removed

- The high grain protein requirement for bread making results in N applications above the optima for yield and N use efficiency

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Nitrogen (Protein) is Key

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Improved quality with low N application

- Exploiting grain protein deviation (GPD)
- Stacking beneficial genes
- Developing low protein grain

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Cultivars vary in their grain N contents

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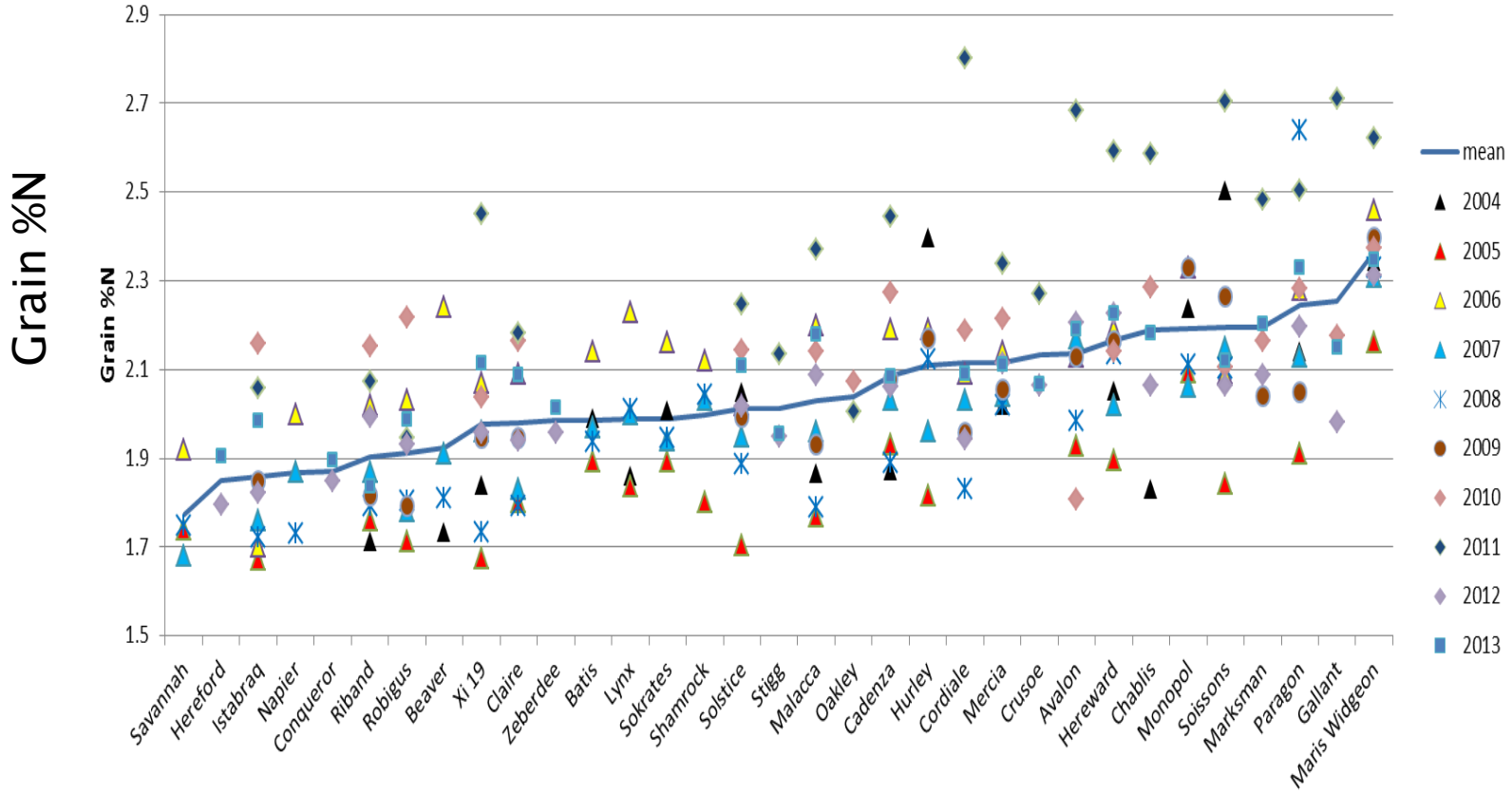

Data for 33 UK cultivars grown at least 2 years between 2004 and 2013 at 200 kg N/Ha varieties

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Grain protein content decreased with intensive breeding

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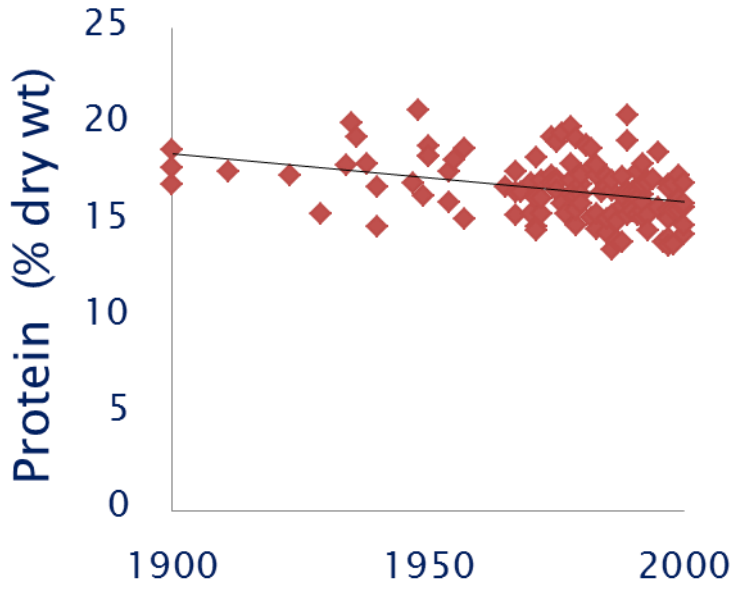
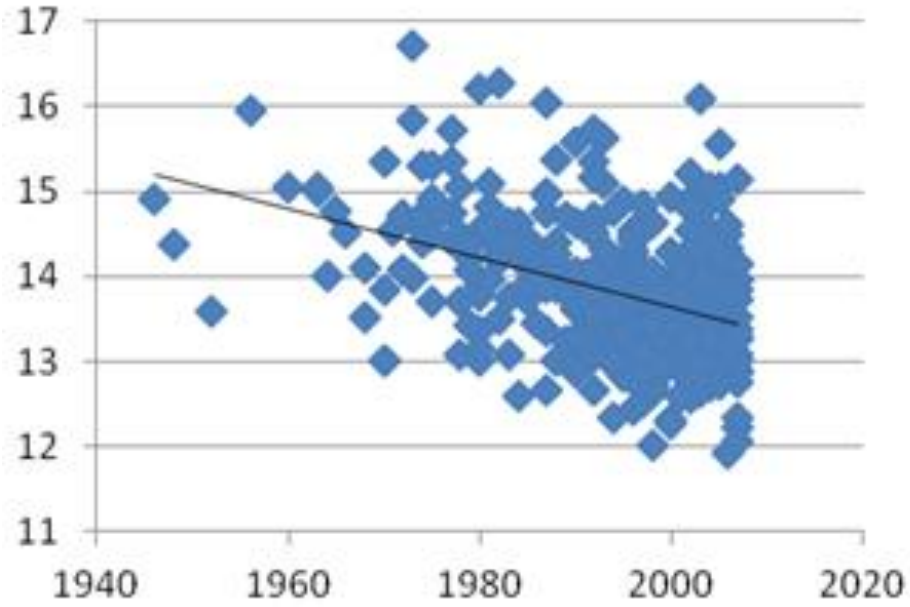
HEALTH·GRAIN

set of 145 wheat lines



Shewry et al, 2011, JAFC 59 928-933

European TriticeaeGenome panel of 376 elite winter wheat cultivars



Data provided by Ian Mackay from Bentley et al 2014,TAG 127: 2619-2633

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Grain protein deviation (GPD)

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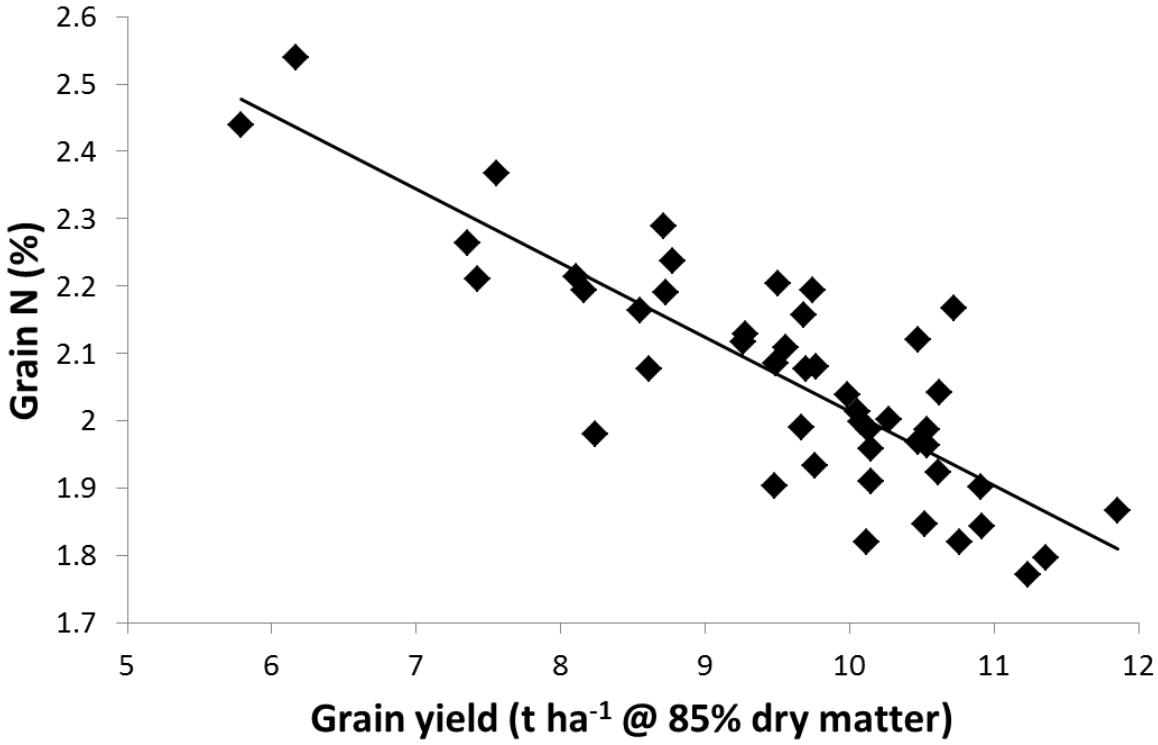

Mean grain N contents and yields for 47 wheat cultivars grown at Rothamsted Research between 2004 and 2012.

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Exploiting GPD

- Trials
  - Rothamsted in 2009
  - Rothamsted, Syngenta, Ragt, Limagrain and KWS in 2010 and 2011
- Analyses
  - Yield
  - Grain protein
  - Milling and baking
- Transcriptomics (21 dpa)
  - 2009 Rothamsted (all plots)
  - 2010 Rothamsted (all plots) + RAGT (all N200 plots)
  - 2011 Rothamsted and RAGT (200N at both sites only)

Six cultivars:

Hereward: Group 1, stable high protein, outclassed in yield

Xi 19: Group 1, medium protein

Malacca: Group 1, medium protein, outclassed in yield

Cordiale: Group 2, medium protein, *grain protein deviation*

Marksman: Group 2, medium protein, *grain protein deviation*

Istabraq: Group 4, low protein, suitable for feed and biofuel

Data integration: Ellen Mosleth (Oslo)

Nitrogen Field Trials

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Yield and grain N are corrected for effects of N fertilisation

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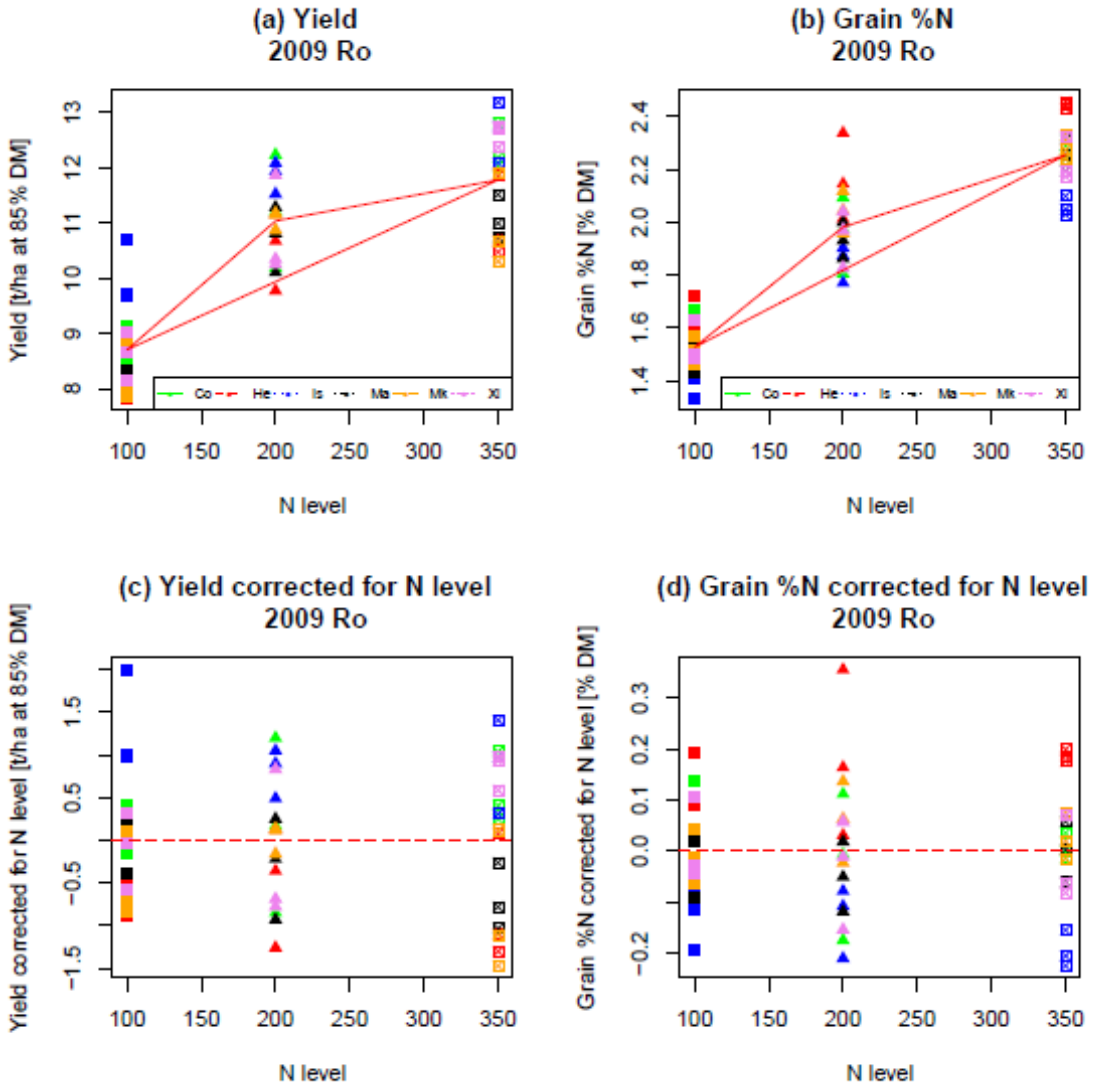

Her
Xi19
Mal
Cor
Mar
Ist

Data integration:
Ellen Mosleth (Oslo)

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This allows the calculation of GPD

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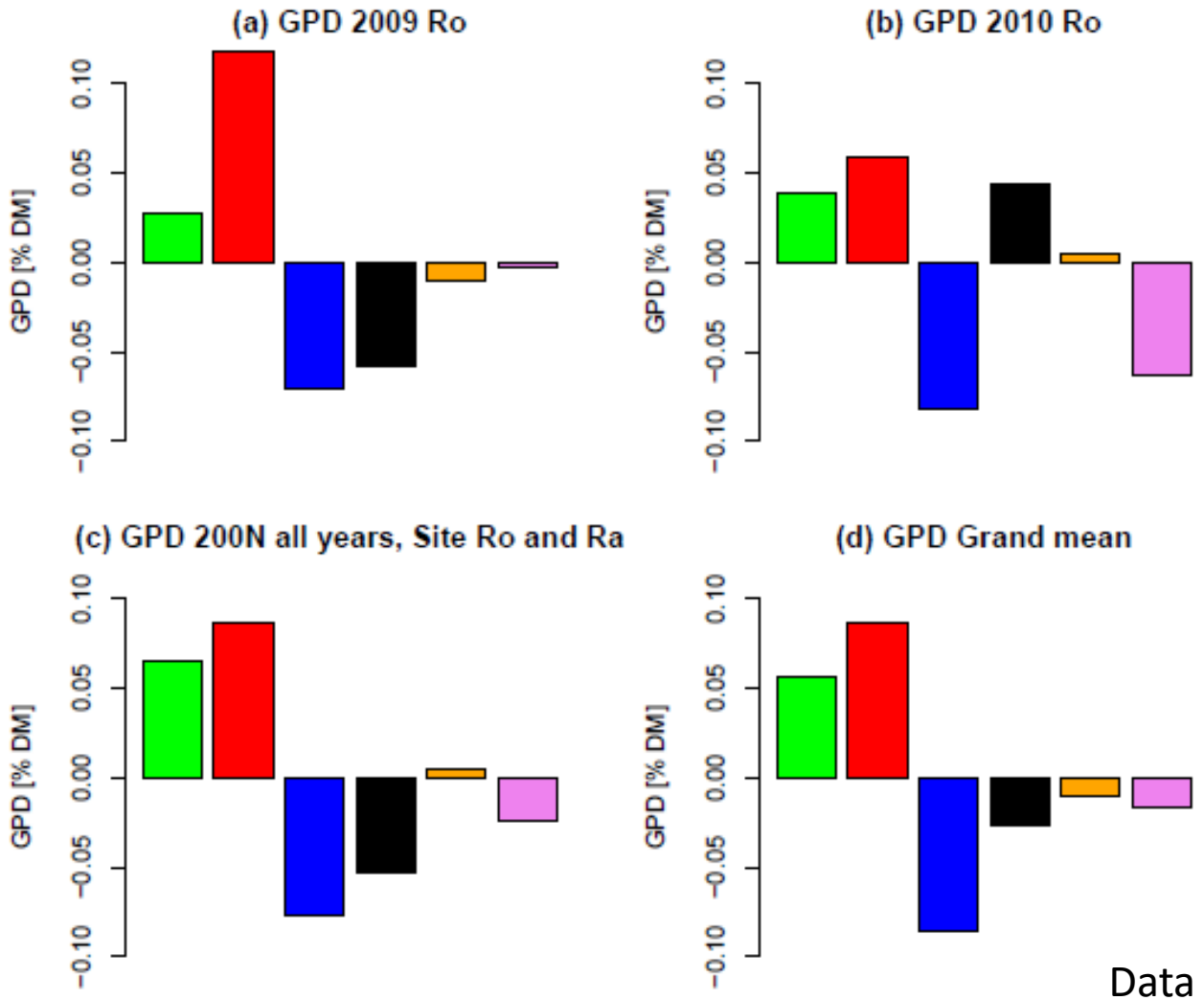

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Transcriptomics

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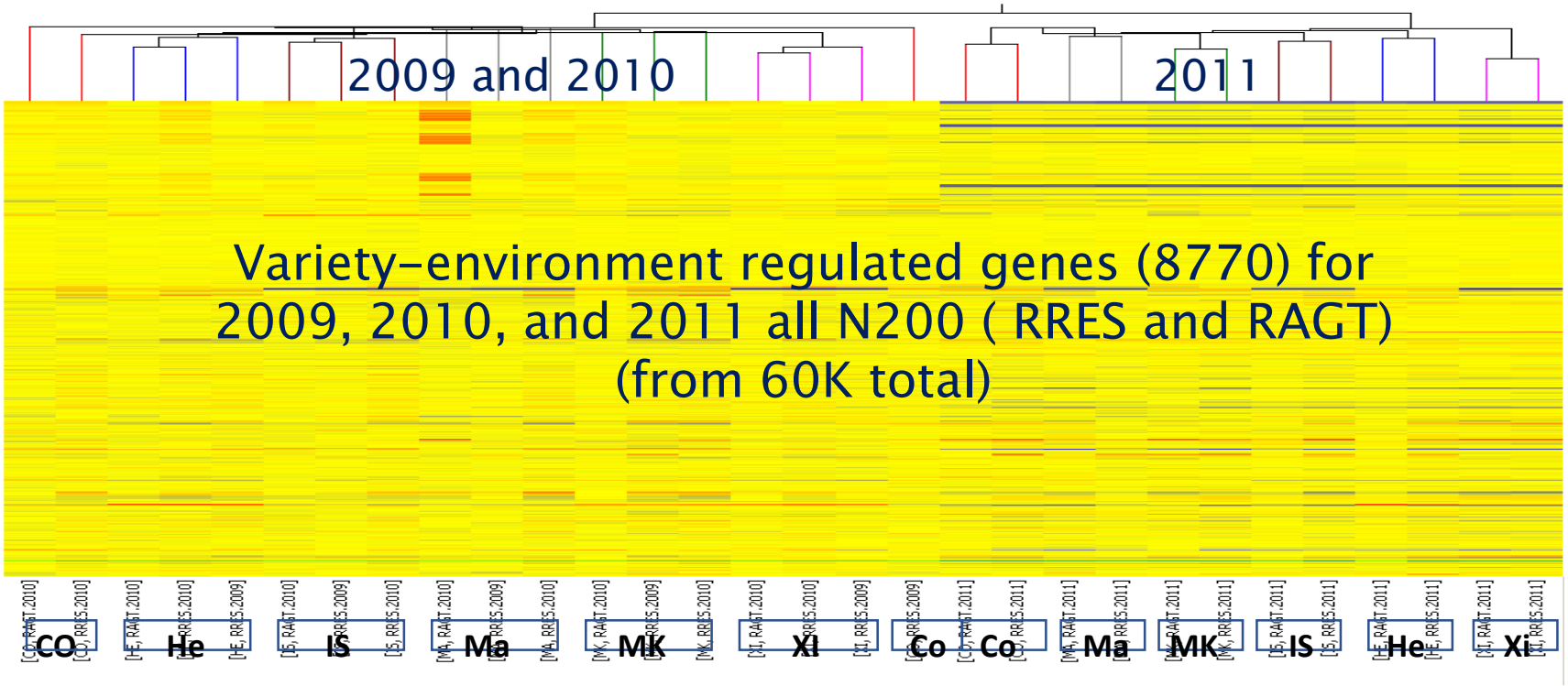

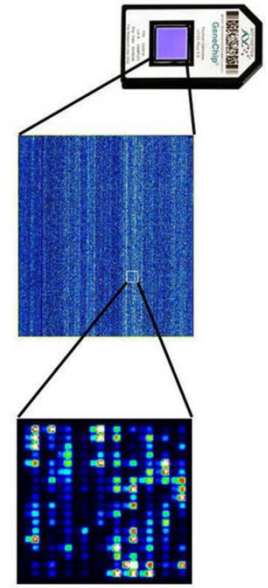

Expression data processed to remove effects of

1. Nitrogen fertilisation
2. Yield

Identified 136 transcripts related to cultivar differences in GPD

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Campden BRI food and drink innovation

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The challenge is to confirm gene function

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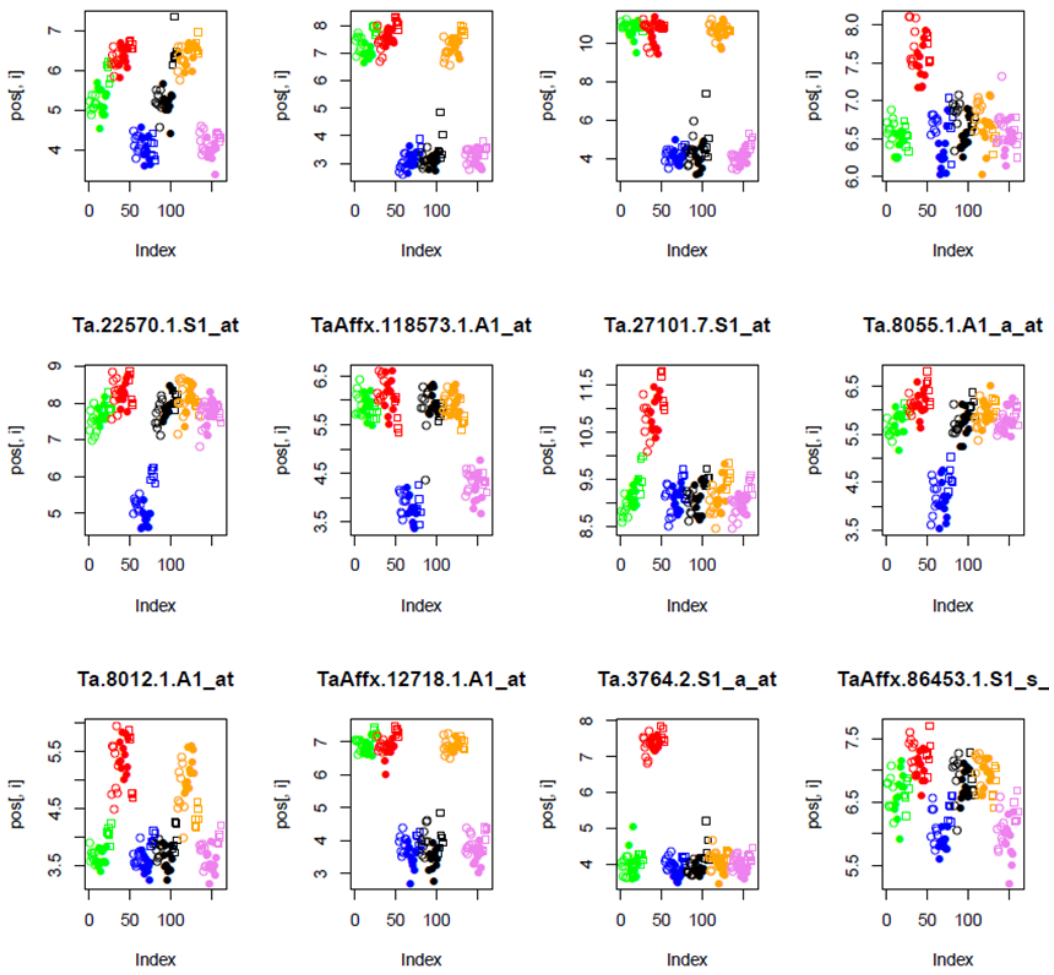
The samples are sorted along the x-axis according to the cultivar

Green: Cordiale
Red: Hereward,
Blue: Istabraq
Black: Malacca,
Yellow: Marksman
Purple: Xi19



Her
Xi19
Mal
Cor
Mar
Ist

Expression of genes positively related to GDP in 2009 (open circles), 2010 (closed circles) and 2011 (open squares)

Mosleth et al. (2015) Plant Biotechnology Journal 13 : pp.625-635

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Nitrogen (Protein) is Key

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Improved quality with low N application

- Exploiting grain protein deviation (GPD)
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The Hereward x Malacca population

ROTHAMSTED RESEARCH

- DH population of approx 100 lines (from RAGT)
- "Good x good" cross but neither cultivar has "good" HMW alleles:
  - Hereward: 1B7+9, 1D3+12
  - Malacca: 1B17+18, 1D 2+12
- Grown for 2 years (2005, 2006) on 2 sites
- Assessed for milling, baking (spiral white, wholemeal, CBP) and puff pastry making

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Traits Investigated

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Milling	
M1	Hardness
M2	Protein
M3	Water absorption
M4	Development time
M5	Stability
M6	Hagberg
M7	Wheat moisture content % NIR
M8	Straight run extraction rate (white)%
M9	Bran finisher flour
M10	Protein Content white flour
M11	Falling No (S)
M12	Protein Loss

Puff Pastry	
P1	Avg Height (avg)/px
P2	Avg No. of Cells
P3	Avg Cell Volume
P4	Avg Count >10
P5	Avg Calc Score
P6	Avg Tenderness
P7	Avg Breadth/px
P8	Avg Coarse/Fine Clustering
P9	Avg Cell Alignment
P10	Avg Non Uniformity
P11	Avg wall thickness/px
P12	Avg Layer Count
P13	Avg Height mm
P14	Avg Width mm
P15	Avg Depth mm
p16	Avg Calc% Shrinkage
p17	Avg Cell Elongation
p18	Avg Max bubble px

Wholemeal	CBP White	Spiral White	
B1			Loaf volume, ml
B2			L*
B3			Firmness (Day 1), N
B4			Firmness (Day 3), N
B5			Total_ Concavity
B6			Cell_ Contrast
B7			Number_ of_Cells
B8			Cell_ Diameter
B9			Non_ Uniformity
B10			Firmness (DOP3)/loaf volume
B11			Firmness @25%compression(day3-1)N
B12			Firmness @25% compression (day3-1)/loaf volume
B13			Average height max
B14			Cell / Unit area
B15			Wall Thickness/px
B16			Coarse cell volume
B17			L + R Concavity

B18	Dough Consistency Ex Mixer (BU's)
B19	Dough Consistency Ex 10 Mins (BU's)
B20	Degree of Softening
B21	Mix time (S)
B22	Temp Ex mixer (0C)
B23	Temp Ex 10 minutes (0C)
B24	Gross Water to 410BU's
B25	Manual Stickiness

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QTL for spiral white loaf volume in Malacca x Hereward

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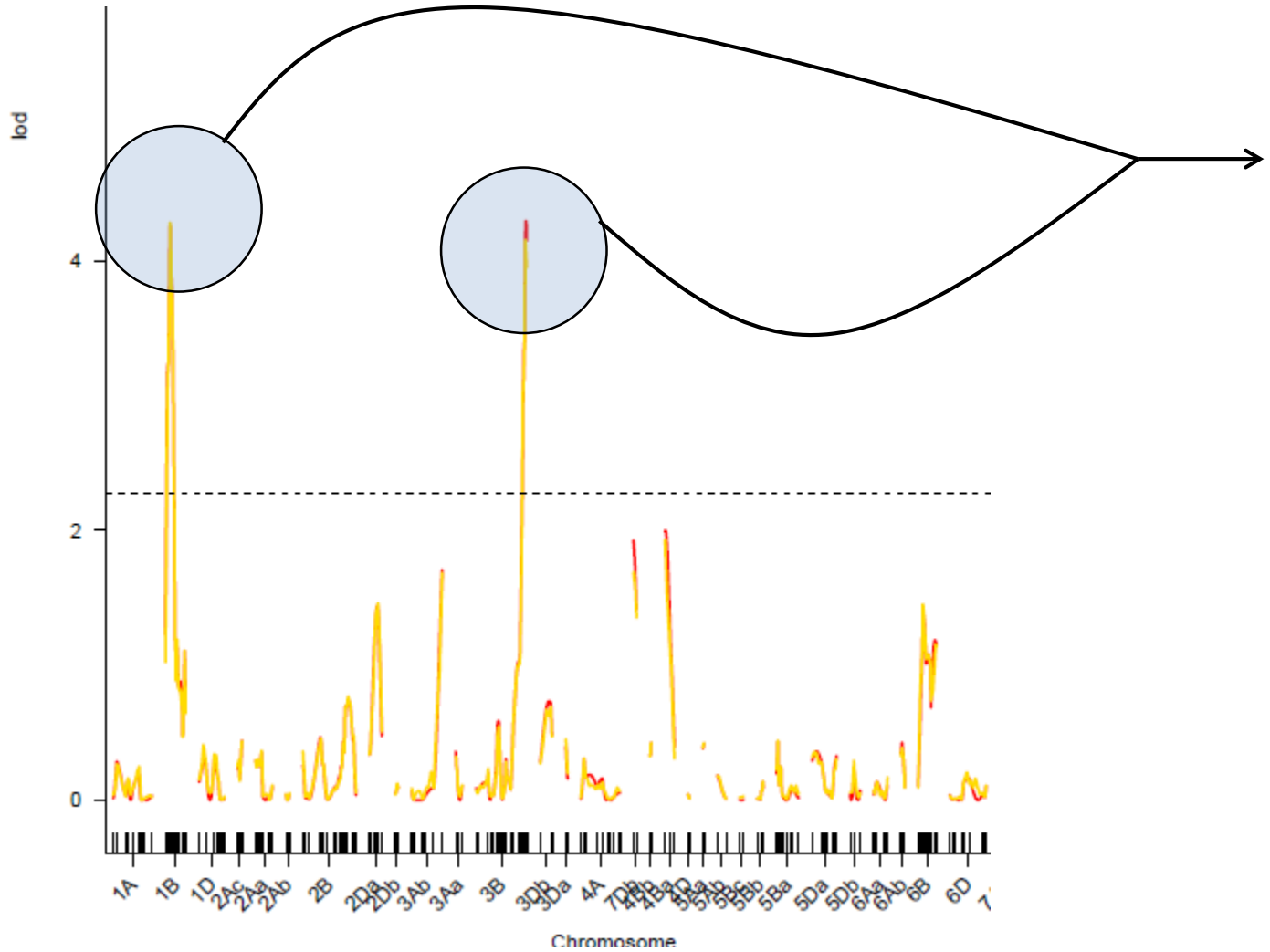

QTL represent genes

Different versions (alleles) of genes are present in Malacca and Hereward

Combining these alleles will increase loaf volume.

Simon Griffiths

John Innes Centre

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The Hereward x Malacca population

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-
- Assessed for milling, baking (spiral white, wholemeal, CBP) and puff pastry making

- Simon Griffiths (JIC) developed molecular maps and near-isogenic pairs differing in quality QTLs

Simon Griffiths

John Innes Centre

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Spiral white Quality QTL in Malacca x Hereward lines

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Donor line	Parent	Trait	Chromosome	Markers
MH100	Malacca	Cell number	1B	gwm264 and barc8
MH58	Hereward	Firmness	2B	wmc257 and wmc317
MH9	Malacca	Loaf volume	2D	whole linkage group
MH19	Hereward	L*	4D	barc98 and psp3103
MH1	Malacca	Cell number	4D	barc98 and psp3103
MH70	Malacca	Cell number	6A	gwm334-barc3
MH60	Malacca	Loaf volume	7A	psp3001-Wpt1259
MH39	Hereward	Loaf volume	7B	gwm357-barc182

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John Innes Centre

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- Assessed for milling, baking (spiral white, wholemeal, CBP) and puff pastry making
- Simon Griffiths (JIC) developed molecular maps and near-isogenic pairs differing in quality QTLs
- Currently stacking QTLs to assemble "ideal wheat"

Simon Griffiths

John Innes Centre

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Stacking functionality QTL

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Line 1	Line 2	Trait 1	Trait 2	Background
MH1/Mal4 161-1 7	MH100/Mal4 188-3 20	4D cell num/L*	1B cell num	Malacca
MH1/Mal4 161-2 16	MH100/Mal4 188-4 6	4D cell num/L*	1B cell num	Malacca
MH100/Mal4 188-6 6	MH9/Mal4 163-2 7	1B cell num	2D loaf vol	Malacca
MH100/Mal4 188-9-1	MH9/Mal4 163-2-18	1B cell num	2D loaf vol	Malacca
MH60/Mal4 186-5 3	MH1/Mal4 161-5 3	7A loaf vol	4D cell num/L*	Malacca
MH60/Mal4 186-8 4	MH1/Mal4 161-2 17	7A loaf vol	4D cell num/L*	Malacca
MH9/Mal4 163-2 22	MH60/Mal4 186-11 9	2D loaf vol	7A loaf vol	Malacca
MH9/Mal4 163-2 24	MH60/Mal4 186-12 7	2D loaf vol	7A loaf vol	Malacca
MH70/Mal4 168-1 4	MH1/Mal4 161-5 12	6A cell num	4D cell num/L*	Malacca
MH70/Mal4 168-3 7	MH1/Mal4 161-7 7	6A cell num	4D cell num/L*	Malacca
MH70/Mal4 168-9 2	MH100/Mal4 188-11 8	6A cell num	1B cell num	Malacca
MH70/Mal4 168-10 4	MH100/Mal4 188-14 11	6A cell num	1B cell num	Malacca
MH19/Her4 207-6-12	MH39/Her4 209-5-17	4D L*	2D/7B Loaf vol	Hereward
MH19/Her4 207-8-02	MH39/Her4 209-6-10	4D L*	2D/7B Loaf vol	Hereward
MH39/Her4 209-5-20	MH58/Her4 214-3-05	2D/7B Loaf vol	2B firmness	Hereward
MH39/Her4 211-7-13	MH58/Her4 214-9-11	2D/7B Loaf vol	2B firmness	Hereward

Simon Griffiths

John Innes Centre

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Nitrogen (Protein) is Key

ROTHAMSTED RESEARCH

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Determine genetic variation in commercial germplasm

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Type	Cultivar	Breeder	Type	Cultivar	Breeder
NABIM 4	JB Diego	Breun	Misc.	Cadenza	CPB/KWS
	Dickens	Secobra		Malacca	CPB/KWS
NABIM 1	Skyfall	RAGT		Shamrock	Advanta
	Crusoe	Limagrain	Hungarian	Mv Karisma	Martonvasar
	Gallant	Syngenta		Mv Lucilla	Martonvasar
	Solstice	Limagrain	German	Memory	Secobra
	KWS Trinity	KWS		Potenzial	DSV
NABIM 2	Einstein	Limagrain		Rumor	S Union
	KWS Cashel	KWS		Nelson	Secobra
	Cordiale	KWS	Hybrids	Hybery SU	S Union
	KWS Lili	KWS		Hystar	S Union
Spring	Mulika	Blackman	French	Tobak	Desprez
	Paragon	RAGT		Apache	Limagrain
	Granary	KWS		Arlequin	Limagrain
	Willow	KWS		Premio	RAGT
Misc.	KWS Siskin	KWS	Denmark	Genius	S Union
	Hereward	RAGT		Dacanto	KWS
	Soissons	Desprez	Paragon lines	Par Rht2	JIC
	Xi 19	Limagrain		Par Stay Green	JIC
	Avalon	PBI		Paragon LR19	JIC

40 Varieties

UK cultivars: current, recent, new

Parents of JIC mapping populations

Hungarian "strong" wheats

German and Danish "low protein" wheats

Hybrids

Model lines based on gluten composition (HMW subunits, Gli:Glu ratio etc

2 N levels

150kg/ha and 250kg/ha

6 Sites

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2016: Grain nitrogen contents (by NIRS)

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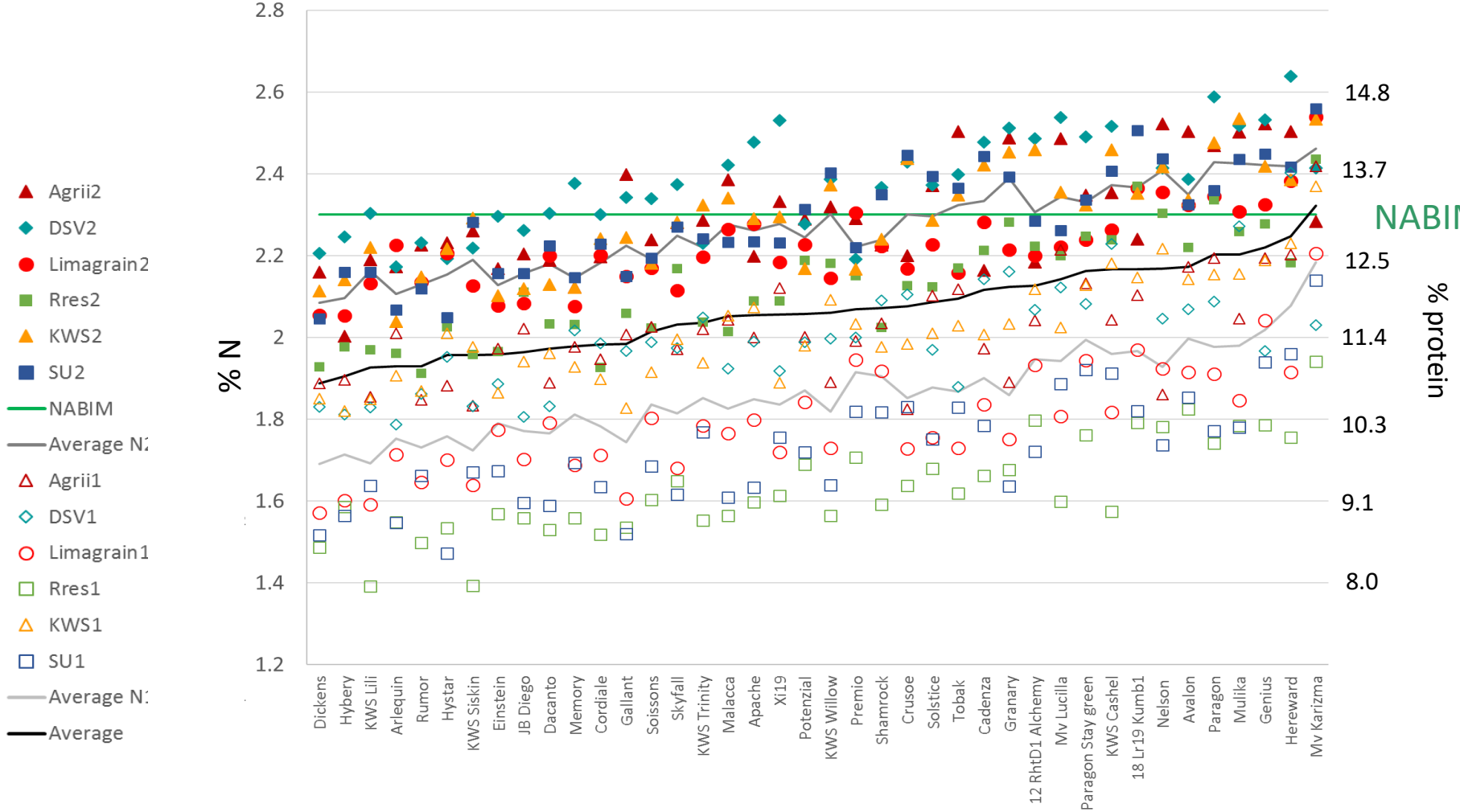

NABIM requirement

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2017: Grain nitrogen contents (by NIRS)

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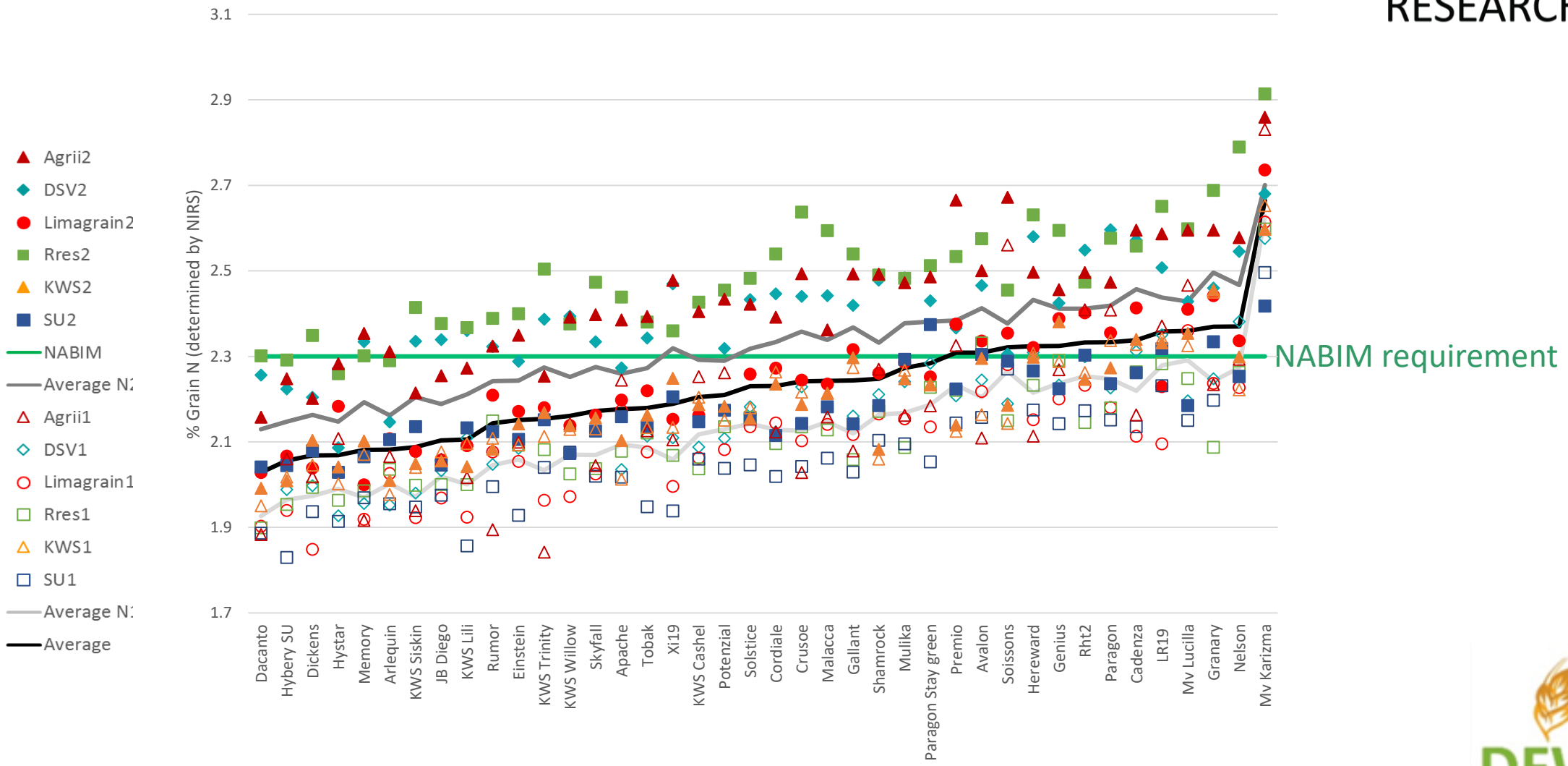

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Grain nitrogen 2016 v. 2017

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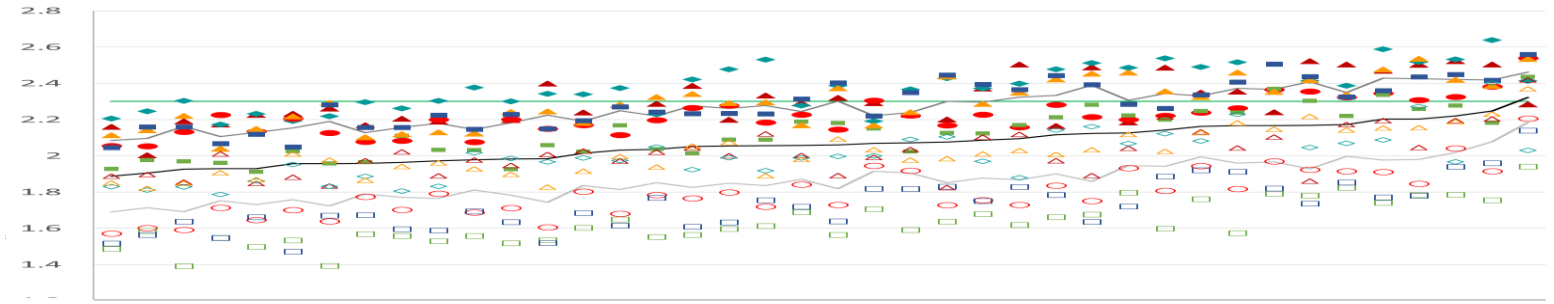
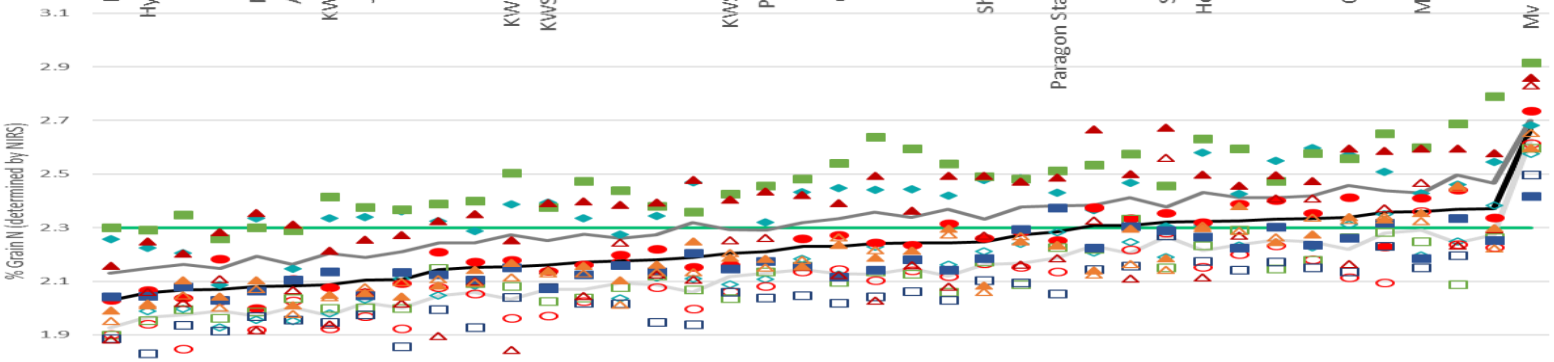
2016



2017



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Yield v Grain N % 2017 season

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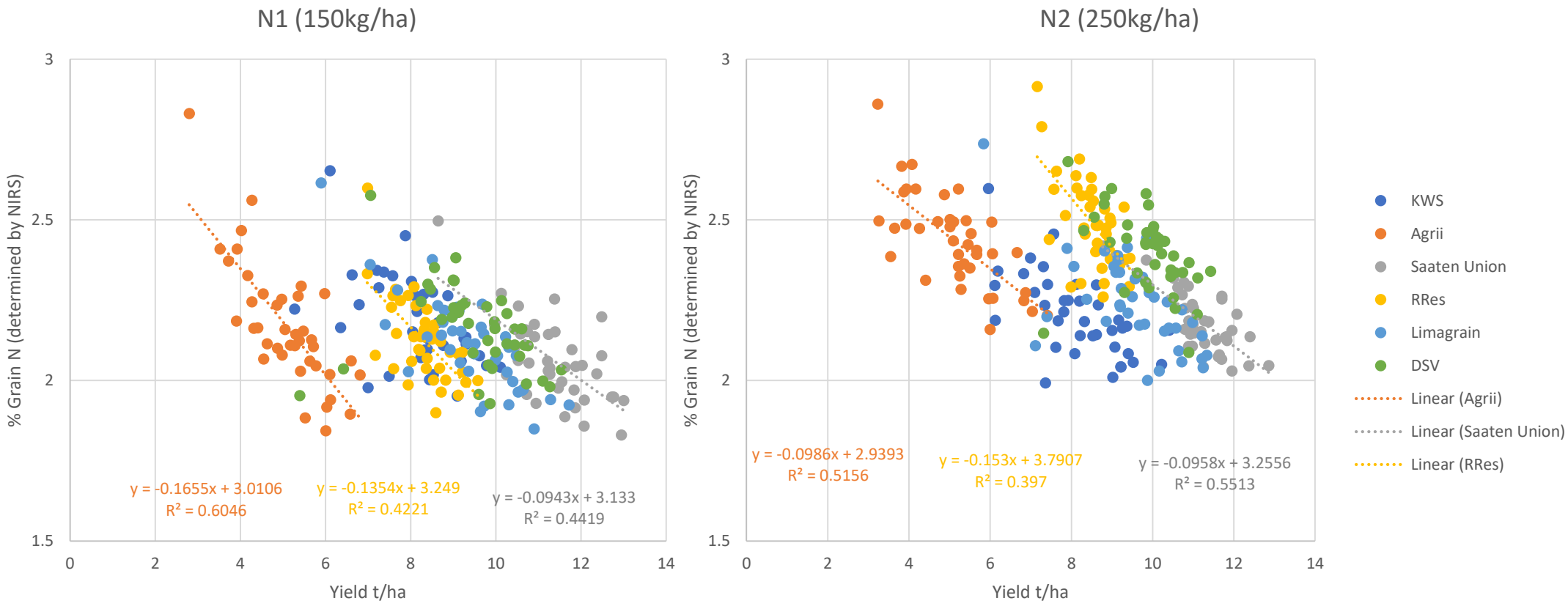

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Flour Quality Testing

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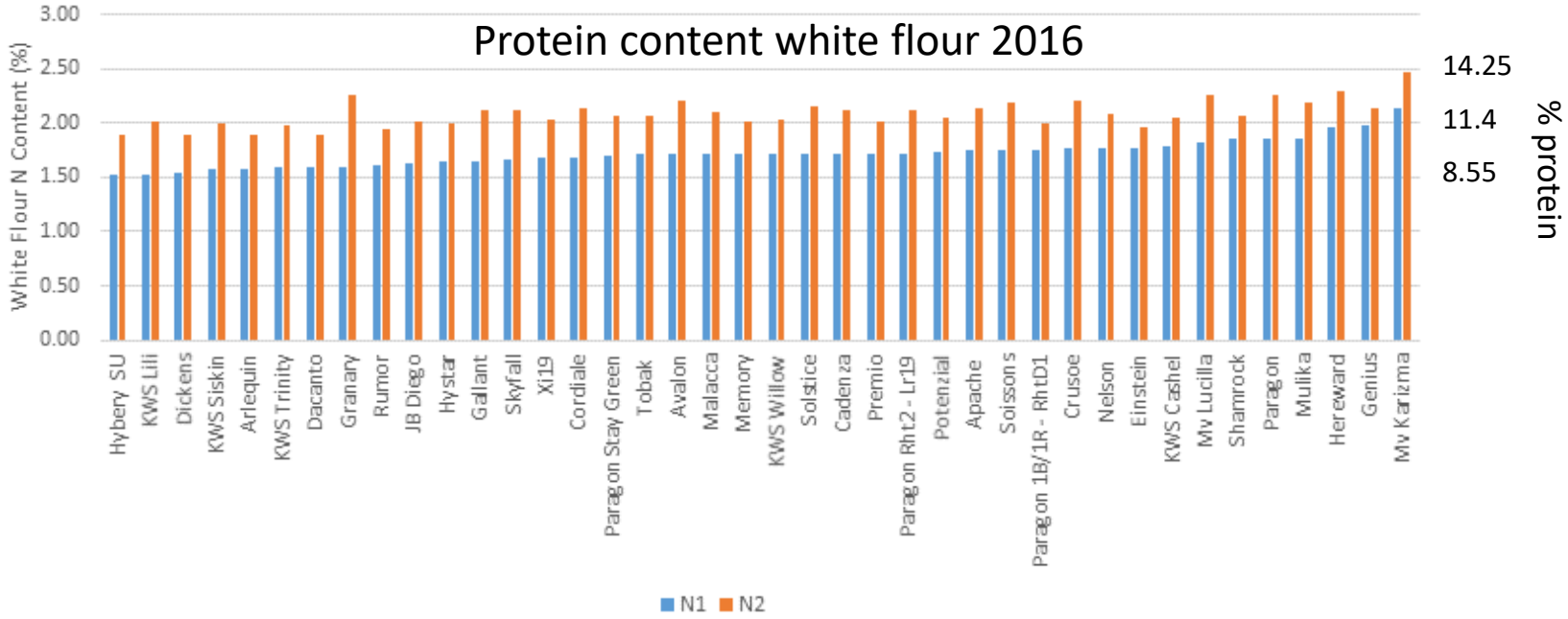
- Pooling of four sites
- Buhler milling
- Functionality Testing
- Test baking



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Gluten Performance Index determined by SRC

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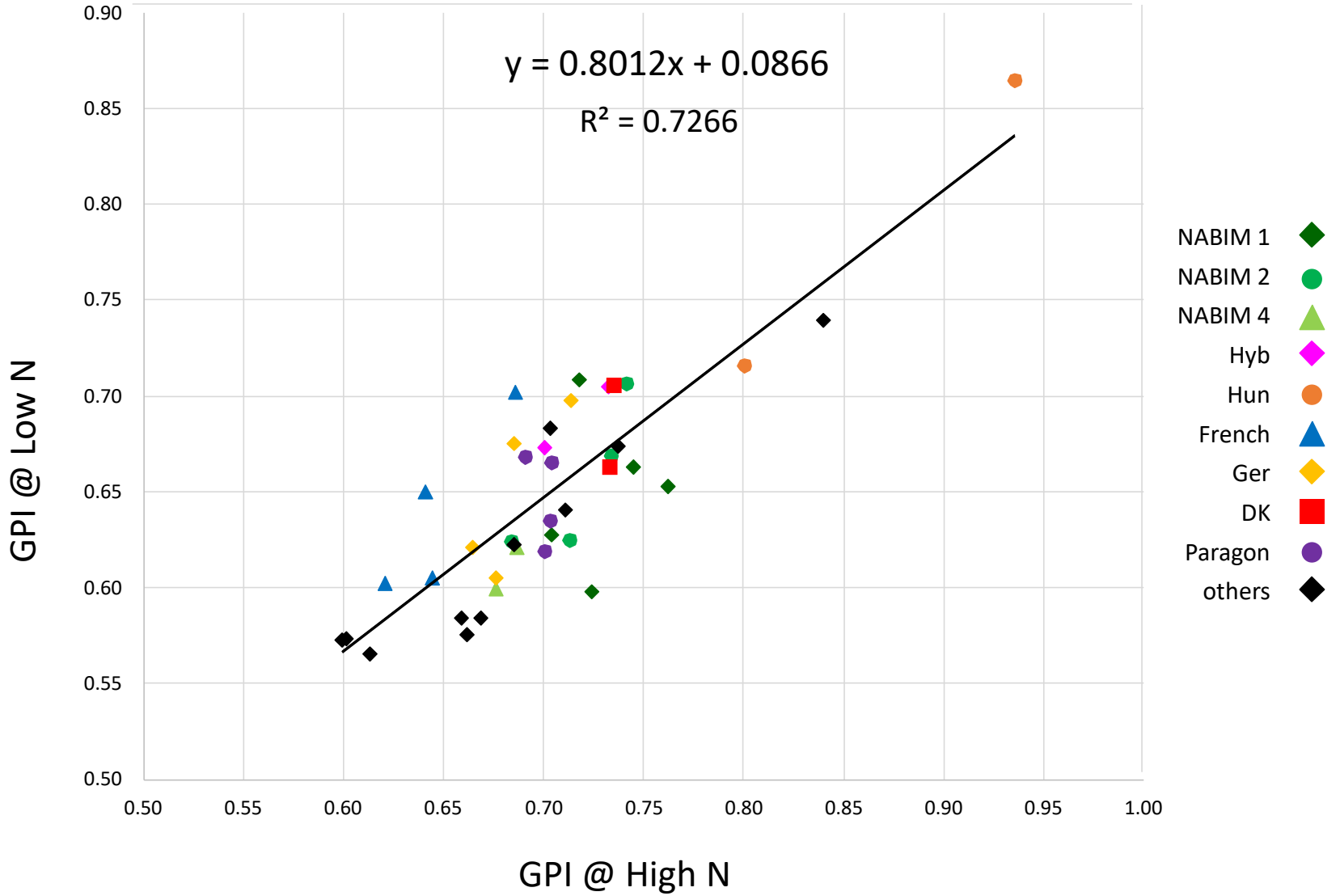

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Resistance, Extensibility and Water Absorption

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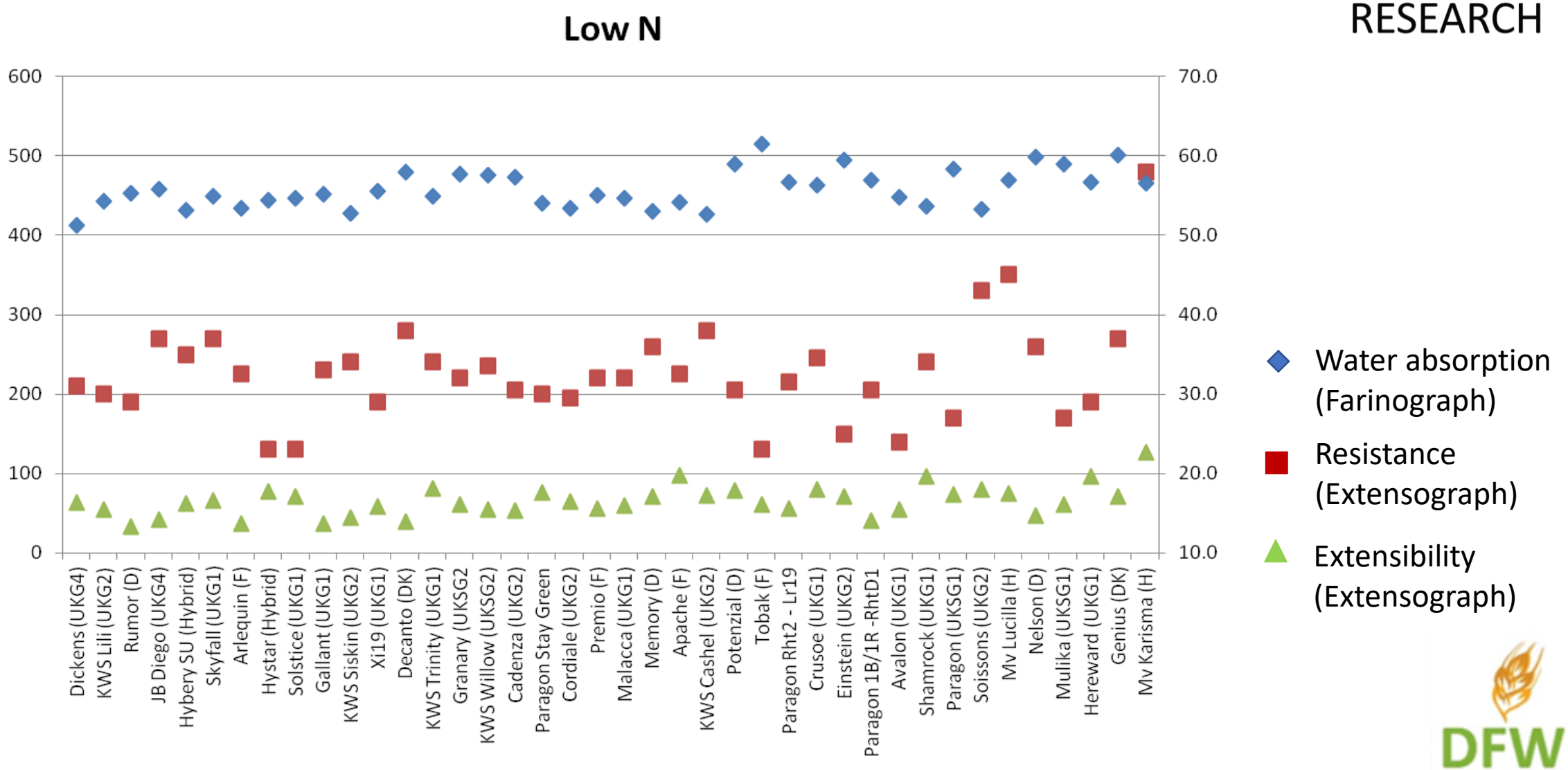

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Resistance, Extensibility and Water Absorption

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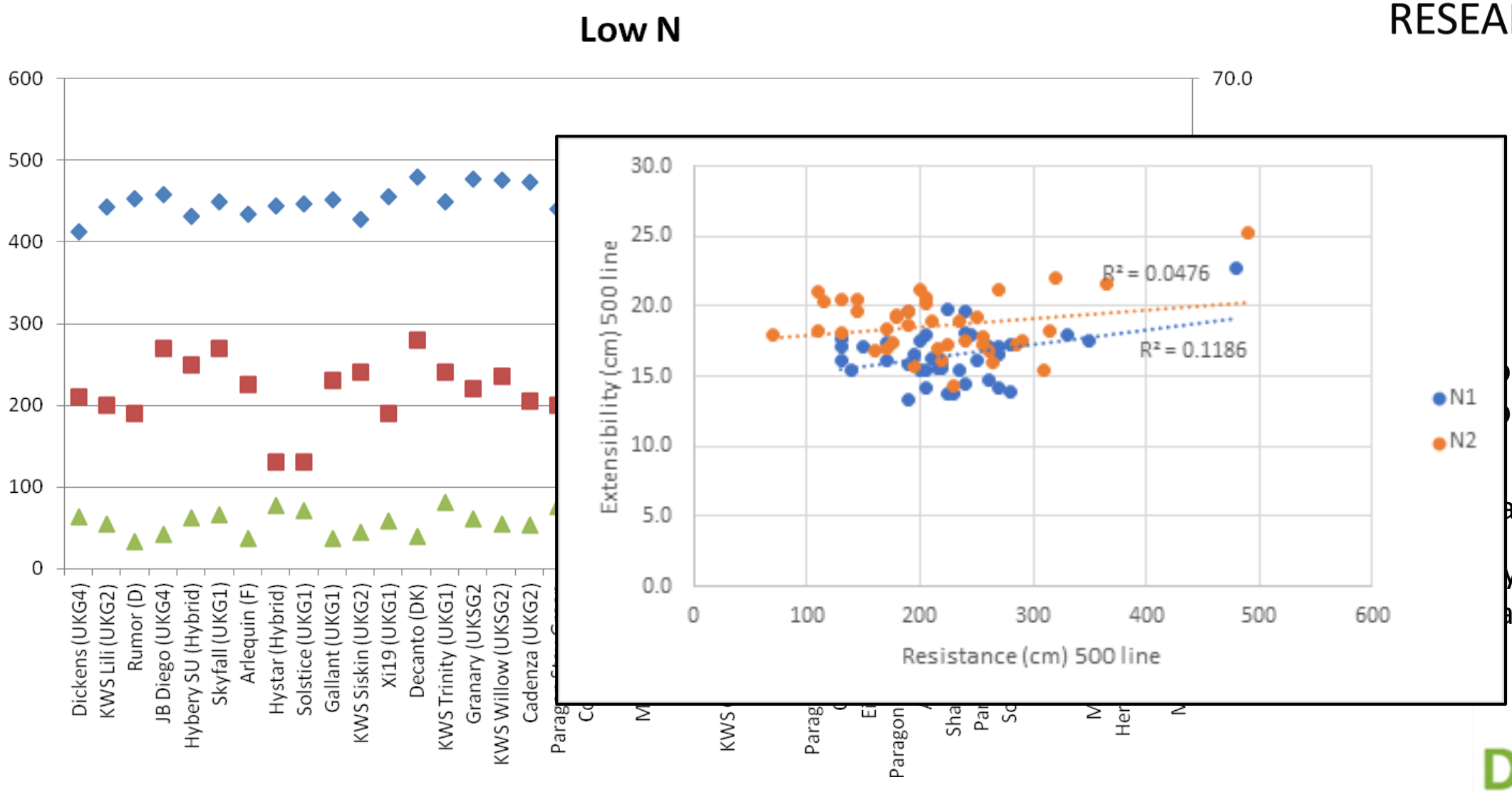

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Test Baking

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Data recorded by bakers

- Mixing time
- Dough temperature
- Dough strength
- Dough extensibility
- Dough handling
- Proof height
- Oven spring (except Warburtons)
- Loaf volume and/or baked height
- Crumb colour
- Crumb texture
- Crumb structure
- Crumb colour L*, a*, b* (except ADM)
- C-cell (except Hovis)

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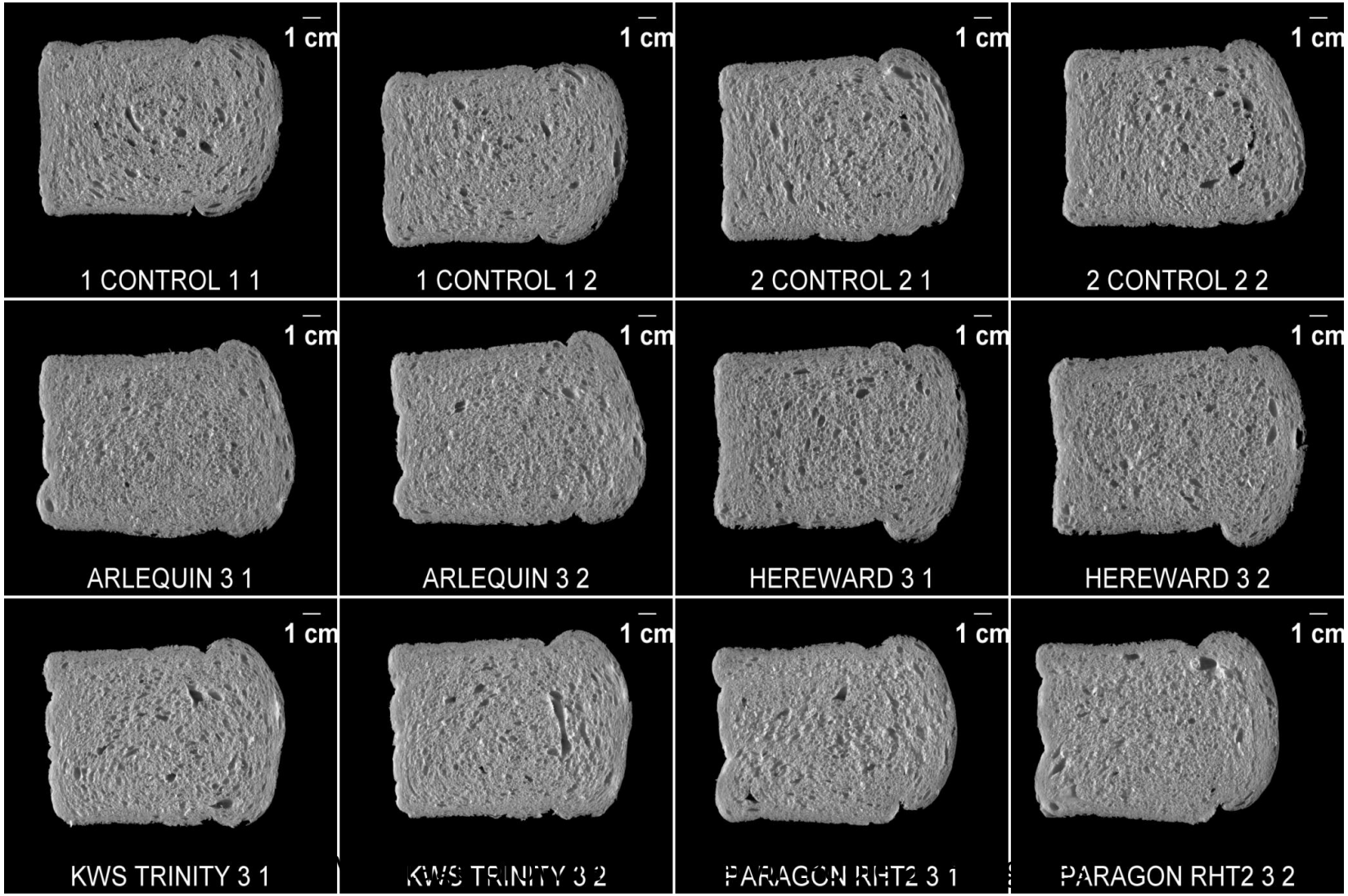
Test Baking

ROTHAMSTED RESEARCH



Montage provided by Mervin Poole at Heygates

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Progress

ROTHAMSTED RESEARCH

Integration of the large data sets

Second year analysis 30 varieties

Year three 20 varieties

microGWAS

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