Plant Ontologies for Agronomic Traits Workshop

December 2011

Examples of Trait Descriptions for Breakout Sessions

Example	Description	Source
1	HGCA Recommended List® winter wheat 2012/13	http://www.hgca.com/
2	HGCA Recommended List® spring wheat 2012	http://www.hgca.com/
3	HGCA Recommended List® late autumn sown wheat 2012/13	http://www.hgca.com/
4	James Cockram, Supplementary Data Table S2, Barley GWAS	http://www.pnas.org/content/early/2010/11/24/1010179107
5	JIC, INRA, Nottingham, NUE QTL Trial, Rialto x Savannah. Qualitative Traits	Luzie Wingen (JIC)
6	JIC, INRA, Nottingham, NUE QTL Trial, Rialto x Savannah. Environmental – Soil and Management Factors	Luzie Wingen (JIC)
7	Trait names and from the JIC WGIDB (John Innes Centre Wheat Genetic Improvement Database)	Luzie Wingen (JIC)
8	Photosynthetic Traits	Martin Parry (RRes)

Example 1a

HGCA Recommended List® winter wheat 2012/13

MARKET OPTIONS AND GRAIN QUALITY

	New										New									New										New	New								
	Crusoe	Gallant	Solstice	KWS Sterling	Ketchum	Panorama	KWS Podium	Cordiale	Battalion	Einstein	Torch	Cocoon	Invicta	Tuxedo	KWS Target	Warrior €	Scout	Claire	Gravitas	Horatio	Beluga	Denman	Viscount	Alchemy	KWS Santiago	Conqueror	KWS Gator	Relay	JB Diego	Duxford	Stigg	Grafton	Humber	Average LSD (5%)
End-use group	nabim Group 1			nabim Group 2							nabim Group 3								Soft Group 4						Hard Group 4									
Scope of recommendation	UK	UK	UK	UK	UK	UK	UK	UK	UK	UK	UK	E&W	UK	UK	UK	Sp	UK	UK	UK	UK	UK	UK	UK	UK	E&W	UK	UK	E&W	UK	UK	UK	UK	UK	
UK treated yield (% control 10.3 t/ha)	99	99	97	103	102	101	99	98	98	97	105	104	104	103	102	101	99	98	105	105	104	104	103	100	108	107	106	105	104	102	102	101	100	2.5
Main market options (The specific attributes of varieties are different so, whenever possible, varieties should not be mixed in store)																																		
UK bread-making	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
UK biscuit, cake-making	-	-	-	-	-	-	-	-	-	-	Y	Y	Y	Y	Y	Y	Y	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
UK distilling	-	-	-	-	-	-	-	-	-	-	-	-	[Y]	[Y]	-	-	-	[Y]	[Y]	[Y]	Y	Y	Y	[Y]	-	-	-	-	-	-	-	-	-	
ukp bread wheat for export	[Y]	Y	Y	[Y]	-	[Y]	[Y]	Y	-	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
uks soft wheat for export	-	-	-	-	-	-	-	-	-	-	[Y]	[Y]	[B]	[Y]	[Y]	-	Y	Y	[Y]	[B]	[Y]	-	[B]	B	-	-	-	-	-	-	-	-	-	
Grain quality																																		
Endosperm texture	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Soft	Soft	Soft	Soft	Soft	Soft	Soft	Soft	Soft	Soft	Soft	Soft	Soft	Soft	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	
Protein content (%)	12.2	12.0	11.9	11.1	11.3	11.4	12.2	12.2	12.1	11.9	10.6	10.9	10.8	10.9	11.2	11.2	11.4	11.2	10.4	10.9	10.7	10.7	10.7	11.0	10.8	10.6	10.6	11.0	11.0	10.8	11.3	11.5	11.5	0.3
Hagberg falling number	266	307	266	280	261	257	279	318	219	278	248	234	243	283	214	207	234	244	214	238	159	212	172	246	146	200	182	269	305	274	306	287	308	17
Specific weight (kg/hl)	78.1	77.9	78.0	76.4	78.0	77.7	78.7	79.5	75.6	77.8	76.4	76.2	75.7	75.4	76.9	75.5	78.7	77.1	77.0	76.4	75.7	75.9	76.1	77.5	75.0	75.5	75.6	77.1	77.8	76.7	74.7	78.8	77.2	0.7
1000 grain weight (g)	-	54.0	50.0	[49.5]	53.1	49.2	-	46.4	[48.3]	51.2	-	-	[46.9]	-	-	[45.2]	46.6	46.6	-	-	[55.7]	-	49.6	49.2	-	46.6	-	-	50.5	47.5	-	50.4	47.0	2.3
Chopin alveograph W	232	242	200	223	208	210	[266]	[269]	[178]	176	98	107	80	104	99	134	100	102	93	[78]	95	[69]	90	[71]	-	-	-	-	-	[182]	-	[146]	-	27
Chopin alveograph P/L	[0.6]	0.7	0.6	0.8	0.8	0.7	[0.6]	[0.7]	[0.7]	0.5	0.5	[0.4]	0.3	[0.4]	[0.3]	0.4	0.3	0.3	[0.4]	[0.3]	0.4	[0.3]	0.3	[0.6]	-	-	-	-	-	[0.8]	-	[0.8]	-	0.2
Status in RL system																																		
Year first listed	12	09	02	10	09	09	11	04	07	03	12	11	10	11	11	10	09	99	11	12	10	11	09	06	11	10	12	12	08	08	11	09	07	
RL status	P1	-	C	-	*	-	P2	-	*	C*	P1	P2	-	P2	P2	-	C	-	P2	P1	-	P2	-	C	P2	-	P1	P1	-	-	P2	-	*	

P1, P2 = first and second year of recommendation * = variety no longer in trials [ ] = limited data

C = yield control (Oakley was also a control but is no longer on the Recommended List)

Y = suited to that market [Y] = may be suited to that market B = suitable for blending into export cargoes [B] = may be suitable for blending into export cargoes

UK = recommended for the UK Sp = specific recommendation E&W = recommended for the East and West regions

Average LSD (least significant difference) 5%. Varieties that are more than one LSD apart are significantly different at the 5% confidence level

€ = Warrior is a specific recommendation for growers wanting a variety with good disease resistance

Varieties no longer listed: Cassius, Gladiator, Glasgow, Istabraq, Kingdom, Oakley and Robigus

Example 1b

HGCA Recommended List® winter wheat 2012/13

YIELD, AGRONOMY AND DISEASE RESISTANCE

	New																		New															
	Crusoe	Gallant	Solstice	KWS Sterling	Ketchum	Panorama	KWS Podium	Cordiale	Battalion	Einstein	Torch	Cocoon	Invicta	Tuxedo	KWS Target	Warrior €	Scout	Claire	Gravitas	Horatio	Beluga	Denman	Viscount	Alchemy	KWS Santiago	Conqueror	KWS Gator	Relay	JB Diego	Duxford	Stigg	Grafton	Humber	Average LSD (5%)
End-use group	nabim Group 1			nabim Group 2							nabim Group 3								Soft Group 4						Hard Group 4									
Scope of recommendation	UK	UK	UK	UK	UK	UK	UK	UK	UK	UK	UK	E&W	UK	UK	UK	Sp	UK	UK	UK	UK	UK	UK	UK	UK	E&W	UK	UK	E&W	UK	UK	UK	UK	UK	
Fungicide treated grain yield (% treated control)																																		
United Kingdom (10.3 t/ha)	99	99	97	103	102	101	99	98	98	97	105	104	104	103	102	101	99	98	105	105	104	104	103	100	108	107	106	105	104	102	102	101	100	2.5
East region (10.4 t/ha)	99	99	96	104	101	102	99	99	98	97	106	105	105	104	103	103	98	99	105	105	104	103	104	100	108	108	105	105	104	103	102	101	100	1.8
West region (10.3 t/ha)	101	100	97	103	103	102	97	98	99	97	103	104	104	103	101	101	99	97	104	104	105	104	102	101	108	106	106	106	106	101	103	102	100	2.9
North region (10.3 t/ha)	-	97	96	102	100	99	99	97	95	99	[101]	100	102	102	102	98	98	98	104	[104]	103	104	104	100	106	108	[106]	[103]	101	101	96	102	96	3.5
Untreated grain yield (% treated control in comparable trials)																																		
United Kingdom	89	83	79	84	87	89	83	83	88	84	85	87	90	90	87	94	88	82	91	92	85	90	90	87	87	87	90	91	91	84	98	90	83	4.7
Agronomic features																																		
Resistance to lodging without PGR	7	7	8	7	6	8	8	7	7	6	7	5	7	8	8	7	8	7	5	6	9	5	7	7	7	6	7	7	7	8	8	9	9	1.6
Resistance to lodging with PGR	7	8	8	8	7	9	8	8	8	7	8	7	7	8	8	8	8	7	7	8	8	7	7	7	7	7	9	8	8	9	8	9	9	1.1
Height without PGR (cm)	85	84	93	79	93	90	82	80	85	86	91	96	91	84	84	84	88	89	90	89	80	83	83	93	88	86	87	83	89	91	82	77	81	1.8
Ripening (days +/- Solstice, -ve = early)	+1	-2	0	0	+1	+2	0	-2	0	-1	0	+5	+3	+2	+1	+1	+2	0	+2	+1	0	0	+1	+3	+2	+2	+2	+1	0	+2	+2	-2	0	0.9
Resistance to sprouting	-	6	7	5	7	7	-	6	5	6	-	-	6	-	-	5	6	5	-	-	4	-	4	6	-	6	-	-	7	7	-	5	6	1.4
Disease resistance																																		
Mildew	9	5	4	7	8	7	6	6	8	6	3	7	4	7	4	8	6	4	7	7	4	5	7	7	5	3	6	6	6	6	8	7	5	1.1
Yellow rust	9	5	4	9	5	9	7	7	7	6	4	8	8	9	9	8	9	9	7	8	9	7	4	8	6	7	9	9	8	5	9	8	8	[1.2]
Brown rust	7	4	4	8	5	5	6	3	8	5	9	9	7	8	5	8	9	5	7	6	4	5	8	5	5	6	3	5	4	3	9	3	5	[2.1]
Septoria nodorum	-	5	5	6	5	6	5	5	7	6	[6]	6	6	8	7	6	8	6	6	[6]	5	7	7	6	[6]	7	[6]	[6]	6	5	6	6	5	2.9
Septoria tritici	7	5	5	4	6	6	5	5	5	5	6	5	5	6	6	7	5	5	6	6	5	5	5	6	5	4	5	6	5	5	7	5	6	0.7
Eyespot	5	5	4	6	5	4	4	4	7@	5	5	6	4	6	6	6	8	5	6	5	7	5	6	6	3	4	4	5	4	5	6	8@	7	1.8
Fusarium ear blight	6	5	6	6	6	7	6	6	6	6	5	7	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	6	6	6	5	6	-
Orange wheat blossom midge	-	-	-	-	-	-	R	-	-	-	R	-	-	-	R	R	R	-	R	R	-	R	R	-	R	R	R	-	-	-	-	-	-	

[ ] = limited data

Average LSD (least significant difference) 5%. Varieties that are more than one LSD apart are significantly different at the 5% confidence level

UK = recommended for the UK Sp = specific recommendation

E&W = recommended for the East and West regions

€ = Warrior is a specific recommendation for growers wanting a variety with good disease resistance

R = believed to be resistant to orange wheat blossom midge (OWBM) but this has not been verified in RL tests

@ Battalion and Grafton are believed to carry the Rendezvous resistance gene to eyespot but this has not been verified in RL tests

Comparisons of varieties across regions are not valid

On the 1-9 scales high figures indicate that a variety shows the character to a high degree (e.g. high resistance)

Example 1c

HGCA Recommended List® winter wheat 2012/13

SUPPLEMENTARY DATA

	New										New									New										New	New							
	Crusoe	Gallant	Solstice	KWS Sterling	Ketchum	Panorama	KWS Podium	Cordiale	Battalion	Einstein	Torch	Cocoon	Invicta	Tuxedo	KWS Target	Warrior €	Scout	Claire	Gravitas	Horatio	Beluga	Denman	Viscount	Alchemy	KWS Santiago	Conqueror	KWS Gator	Relay	JB Diego	Duxford	Stigg	Grafton	Humber	Average LSD (5%)
End-use group	nabim Group 1			nabim Group 2							nabim Group 3								Soft Group 4						Hard Group 4									
Scope of recommendation	UK	UK	UK	UK	UK	UK	UK	UK	UK	UK	UK	E&W	UK	UK	UK	Sp	UK	UK	UK	UK	UK	UK	UK	UK	E&W	UK	UK	E&W	UK	UK	UK	UK	UK	
Breeder/ UK contact																																		
Breeder	Lim	Syn	Lim	KWS	Syn	Lim	KWS	KWS	RAGT	Lim	RAGT	Sec	Lim	RAGT	KWS	RAGT	Sen	Lim	Lim	Lim	Sen	Syn	KWS	Lim	KWS	KWS	KWS	RAGT	Bruen	Syn	Lim	KWS	KWS	
UK contact	Lim	Syn	Lim	KWS	Syn	Lim	KWS	KWS	RAGT	Lim	RAGT	Mas	Lim	RAGT	KWS	RAGT	Sen	Lim	Lim	Lim	Sen	Syn	KWS	Lim	KWS	KWS	KWS	RAGT	Sen	Syn	Lim	KWS	KWS	
Annual yield (% control)																																		
2007 (9.8 t/ha)	-	103	96	102	98	100	-	98	[91]	98	-	-	102	-	-	98	99	97	-	-	105	-	104	99	-	104	-	-	104	100	-	102	96	3.8
2008 (11.6t/ha)	-	102	98	103	101	102	100	101	98	99	-	100	102	102	104	101	98	99	104	-	105	106	102	100	108	106	-	-	105	103	104	103	99	2.9
2009 (10.7 t/ha)	98	93	96	101	102	101	101	95	99	96	105	106	104	106	104	101	99	[100]	106	105	[104]	103	103	100	110	106	105	107	102	102	103	101	100	3.2
2010 (9.8 t/ha)	100	99	97	103	104	102	100	[98]	[100]	98	106	104	102	102	101	103	99	[96]	104	104	105	103	103	99	106	108	107	106	104	102	101	101	[103]	2.7
2011 (9.5 t/ha)	100	97	96	106	-	[99]	97	98	-	95	104	108	107	105	102	102	98	[99]	107	105	103	103	105	102	110	111	106	105	105	103	101	99	-	3.2
Rotational position																																		
First cereal (10.7 t/ha)	99	99	96	103	101	101	99	98	97	97	105	104	104	103	103	101	98	98	105	105	104	104	103	100	108	107	105	105	104	101	102	101	99	2.6
Second and more (9.0 t/ha)	98	98	98	103	104	102	98	99	101	99	103	105	102	103	100	101	99	96	103	103	105	101	104	99	108	106	108	106	104	103	100	103	100	3.4
Sowing date (most trials were sown during October)																																		
Before 6 Oct (10.6 t/ha)	100	99	96	103	101	101	100	98	97	97	105	102	104	103	102	102	99	99	105	104	104	104	104	101	108	108	104	105	104	102	103	102	99	2.5
Late autumn (8.9 t/ha)	-	100	96	[102]	[105]	101	-	[96]	100	-	-	-	[104]	-	-	[101]	99	-	-	-	[103]	-	104	100	-	109	-	-	105	101	-	[96]	104	6.9
Soil type (about 50% of trials are on medium soils)																																		
Light soils (10.0 t/ha)	-	97	96	102	100	100	99	98	95	98	[102]	103	103	103	101	100	99	96	104	[107]	104	103	104	100	105	108	[108]	[105]	105	101	99	101	100	3.8
Heavy soils (10.7 t/ha)	100	99	97	103	101	102	99	99	99	97	106	105	105	103	103	102	99	98	105	104	105	103	104	100	109	107	105	105	104	102	103	103	99	2.8
Agronomic features																																		
Lodging % without PGR	4.2	4.6	2.0	2.9	12.3	2.2	2.5	3.3	5.1	13.2	4.6	17.9	4.3	2.4	2.5	3.4	1.7	4.9	15.6	8.7	0.4	17.9	5.0	4.5	6.0	10.8	3.7	4.6	4.9	1.1	2.4	0.4	0.8	
Lodging % with PGR	7.2	4.5	2.2	1.9	10.2	1.4	3.5	2.7	2.5	10.7	2.1	12.2	5.3	2.5	2.5	4.3	1.9	6.3	8.2	4.4	2.4	5.5	8.7	5.4	6.7	5.4	1.4	3.4	5.0	1.5	1.8	0.6	1.3	
Latest safe sowing date #	-	End Jan	End Jan	End Jan	End Feb	End Feb	[Mid Feb]	End Jan	End Jan	End Jan	-	[End Jan]	Mid Feb	[Mid Feb]	[Mid Feb]	Mid Feb	End Jan	End Feb	[End Feb]	-	End Jan	[Mid Feb]	End Jan	End Jan	[End Jan]	Mid Feb	-	-	End Jan	End Feb	[End Jan]	End Jan	End Jan	-
Speed of development to growth stage 31 (days +/- average)																																		
Early Sep sown	-	-4	+1	+1	-4	-2	-2	-4	-1	-6	-	+5	0	+2	-3	-1	+4	+6	-1	-	0	+2	0	0	+8	-3	-	-	0	-3	0	+3	-3	7.2
Early Oct sown	-	-7	-2	-5	0	-2	-9	-9	0	-7	-	+7	0	0	-4	+3	-1	+4	-7	-	-1	0	+1	+3	+1	-5	-	-	-1	+1	-5	+1	-2	8.6
Early Nov sown	-	-4	-1	-2	+1	0	-1	-3	-1	-2	-	+4	+2	+1	-3	+3	+2	+4	+3	-	+1	+1	+3	+3	+0	-2	-	-	+1	+2	-1	+1	-1	4.0

All yields on this table are taken from treated trials receiving a full fungicide and PGR programme

[ ] = limited data

Key to Breeder and UK contact codes

Breun = Saatzucht Josef Breun, Germany
KWS = KWS UK (www.kws-uk.com)
Lim = Limagrain UK (www.limagrain.co.uk)
Mas = Masstock Arable (www.masstock.co.uk)
RAGT = RAGT Seeds (www.ragt.co.uk)
Sec = Secobra, France
Sen = Senova (www.senova.uk.com)
SU = Saaten Union UK (www.saaten-union.co.uk)
Syn = Syngenta Seeds (www.newfarmcrops.co.uk)

= Latest safe sowing date is the advised latest sowing time to give a sufficient cold period for flowering. A dash indicates that there is insufficient data to give a comment and NOT that the variety does not have a vernalisation requirement.

Example 2a

HGCA Recommended List® spring wheat 2012

	Mulika	Paragon	Tybalt	KWS Willow	Granary	Ashby	New KWS Alderon	Belvoir	Zircon $	Average LSD (5%)
End-use group	nabim Group 1		nabim Group 2				Group 4		Other	
Scope of recommendation	UK	UK	UK	UK	UK	UK	UK	UK	Sp	
UK yield as % control										
UK yield with fungicide (6.9 t/ha)	[103]	95	106	[105]	104	99	[108]	107	99	4.3
Grain quality										
Endosperm texture	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	
Protein content (%)	13.6	13.9	12.9	12.9	13.8	13.6	13.4	12.6	13.7	0.5
Hagberg falling number	294	273	280	224	228	282	309	208	169	40
Specific weight (kg/hl)	77.1	77.7	75.6	78.5	78.0	78.1	76.8	76.1	78.0	0.9
Agronomic features										
Resistance to lodging with PGR #	-	6	[3]	-	-	7	-	[7]	[6]	3.7
Straw height without PGR (cm)	80	86	77	79	81	80	[73]	77	80	2.7
Ripening (+/- Paragon, -ve = earlier) ~	-	-	-	-	-	-	-	-	-	-
Resistance to sprouting	[7]	6	7	[7]	7	7	-	7	3	1.1
Disease resistance										
Mildew	[7]	8	8	[8]	7	6	[5]	[7]	[7]	1.6
Yellow rust	9	9	7	6	6	9	8	9	9	[1.7]
Brown rust	9	8	9	7	6	6	8	8	7	[1.4]
Septoria tritici	6	6	6	6	7	5	6	5	6	1.0
Status in RL system										
Year first listed	11	99	03	11	09	03	12	03	07	
RL Status	P2	C	C	P2	*	C	P1	-	-	

C = yield control
P1 = first year of recommendation
P2 = second year of recommendation
[ ] = limited data
= historical data
~ = no data available for 2012
Average LSD (least significant difference) 5%. Varieties that are more than one LSD apart are significantly different at the 5% confidence level
On the 1-9 scales high figures indicate that a variety shows the character to a high degree (e.g. high resistance)
$ = Zircon is specifically recommended as a white-grained wheat. nabim do not classify it as a bread-making variety

Example 2b

HGCA Recommended List® spring wheat 2012

SUPPLEMENTARY DATA

	Mulika	Paragon	Tybalt	KWS Willow	Granary	Ashby	New KWS Alderon	Belvoir	Zircon	Average LSD (5%)
End-use group	nabim Group 1		nabim Group 2				Group 4		Other	
Scope of recommendation	UK	UK	UK	UK	UK	UK	UK	UK	Sp	
Breeder/ UK Contact										
Breeder	BA	RAGT	Wier	KWS	KWS	KWS	KWS	KWS	KWS	
UK contact	Sen	RAGT	Lim	KWS	KWS	KWS	KWS	KWS	KWS	
Annual yields										
2007 treated (7.8 t/ha)	-	[94]	[108]	-	[103]	[98]	-	[107]	[103]	7.3
2008 treated (6.9 t/ha)	[103]	[95]	[105]	[107]	[107]	[100]	-	[110]	[100]	7.7
2009 treated (7.8 t/ha)	[103]	[96]	[105]	[109]	[103]	[99]	[110]	[107]	[99]	5.5
2010 treated (6.1 t/ha)	[105]	[95]	[105]	[100]	[104]	[100]	-	[101]	[100]	20.1
2011 treated (6.5 t/ha)	[102]	[96]	[106]	[105]	-	[98]	[103]	[108]	[94]	7.4

All yields are taken from treated trials receiving a full fungicide and PGR programme

Key to Breeder and UK contact codes

BA= Blackman Agriculture
KWS = KWS UK (www.kws-uk.com)
Lim = Limagrain (www.limagrain.co.uk)
RAGT = RAGT Seeds (www.ragt.co.uk)
Sen = Senova Ltd (www.senova.uk.com)
Wier = Wiersum BV, Germany

Example 3a

HGCA Recommended List® late autumn sown wheat 2012/13

	Gallant	Mulika +	Solstice	Paragon +	KWS Willow +	Ketchum	KWS Sterling	Panorama	Tybalt +	Battalion	Einstein	Cordiale	Ashby +	Invicta	Warrior	Scout	Viscount	Beluga	Alchemy	Conqueror	New KWS Alderon +	JB Diego	Belvoir +	Humber	Duxford	Grafton	Zircon + $	Average LSD (5%
Recommendation	nabim Group 1				nabim Group 2									nabim Group 3			Soft Group 4			Hard Group 4								
Scope of recommendation	UK	UK	UK	UK	UK	UK	UK	UK	UK	UK	UK	UK	UK	UK	Sp	UK	UK	UK	UK	UK	UK	UK	UK	UK	UK	UK	Sp	
UK yield as % treated control																												
UK yield with fungicide (9.0 t/ha)	104	[102]	100	95	[110]	108	[105]	104	104	102	[101]	[101]	100	[108]	[105]	103	107	[106]	102	113	[[110]]	107	106	106	104	100	100	7.7
Grain quality																												
Endosperm texture	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Soft	Soft	Soft	Soft	Soft	Soft	Hard	Hard	Hard	Hard	Hard	Hard	Hard	Hard	
Protein content (%)	[11.7]	[12.2]	[11.9]	12.4	[11.6]	[11.5]	[11.4]	[11.7]	11.8	[12.1]	[12.3]	[12.1]	12.4	[10.7]	[11.6]	[11.9]	[11.3]	[10.6]	11.3	[11.1]	[12.0]	[11.1]	11.1	[11.3]	[11.2]	[11.6]	12.3	0.8
Hagberg falling number	[287]	[301]	[246]	293	[251]	[210]	[259]	[213]	288	[204]	[283]	[343]	272	[214]	[174]	[230]	[147]	[132]	237	[200]	[302]	[298]	222	[313]	[246]	[251]	169	70
Specific weight (kg/hl)	[77.0]	[77.6]	[76.0]	78.3	[79.3]	[76.5]	[75.5]	[75.8]	76.3	[73.6]	[76.3]	[78.5]	78.5	[74.3]	[73.8]	[77.1]	[74.4]	[73.6]	75.4	[73.8]	[77.5]	[75.6]	76.9	[75.6]	[73.6]	[76.6]	79.1	1.9
Agronomic features																												
Lodging %	-	-	-	8.1	-	-	-	-	10.7	2.8	-	-	13.5	-	-	-	-	-	8.2	-	-	4.5	11.2	1.3	2.8	-	4.5	1.6
Straw height with PGR (cm)	76	[94]	81	100	[92]	[81]	[76]	[80]	89	[77]	[79]	[73]	88	[84]	[78]	78	74	[75]	81	75	[81]	80	81	[76]	81	[68]	85	5.5
Ripening (+/- Paragon, -ve = earlier)	[-1]	-	[-1]	[0]	-	[-1]	[-1]	[0]	[-1]	[-1]	-	[-1]	[0]	[+1]	[0]	[+2]	[0]	[0]	[+1]	[+1]	-	[-1]	[-1]	[0]	[0]	[-1]	[0]	2.4
Latest safe sowing date #	End Jan	-	End Jan	-	-	End Feb	End Jan	End Feb	-	End Jan	End Jan	End Jan	-	Mid Feb	Mid Feb	End Jan	End Jan	End Jan	End Jan	Mid Feb	-	End Jan	-	End Jan	End Feb	End Jan	-	
Disease resistance																												
Mildew	5	7	4	8	8	8	7	7	8	8	6	6	6	4	8	6	7	4	7	3	5	6	7	5	6	7	7	-
Yellow rust	5	9	4	9	6	5	9	9	7	6	6	7	9	8	8	9	4	9	8	7	8	8	9	8	5	8	9	-
Brown rust	4	9	4	8	7	5	8	5	9	8	5	3	6	7	8	9	8	4	5	6	8	4	8	5	3	3	7	-
Septoria tritici	5	6	5	6	6	6	4	6	6	5	5	5	5	5	7	5	5	5	6	4	6	5	5	6	5	5	6	-
Orange wheat blossom midge	-	R	-	-	-	-	-	-	-	-	-	-	-	-	R	R	R	-	-	R	-	-	R	-	-	-	-	
Staus in RL System																												
Year first listed	09	11	02	99	11	09	10	09	03	07	03	04	03	10	10	09	09	10	06	10	12	08	03	07	08	09	07	
RL Status	-	P2	-	C	P2	*	-	-	C	*	*	-	C	-	-	-	-	-	-	-	P1	-	-	*	-	-	*	

P1, P2 = first and second year of listing * = variety no longer sown in late autumn sown trials C = yield control Sp = Specific recommendation

$ = Zircon is specifically recommended as a white-grained wheat. nabim do not class it as a bread-making variety + = spring wheat

[ ] = limited data [[ ]] = very limited data

Average LSD (least significant difference) 5%. Varieties that are more than one LSD apart are significantly different at the 5% confidence level

On the 1-9 scales high figures indicate that a variety shows the character to a high degree (e.g. high resistance)

Data for winter wheat varieties is given for comparison only and do not constitute a Recommended List but the data are directly comparable with those for spring wheat

There are insufficient data to provide late autumn listings for newer winter wheat varieties and their absence from the table does not imply that they are unsuitable for late-autumn sowing

= latest safe sowing date is the advised latest date to give sufficient cold for flowering. Spring wheats have no vernalisation requirement

R = believed to be resistant to orange wheat blossom midge (OWBM), but this has not been verified in RL tests

Example 3b

HGCA Recommended List® late autumn sown wheat 2012/13

SUPPLEMENTARY DATA

	Gallant	Mulika +	Solstice	Paragon +	KWS Willow +	Ketchum	KWS Sterling	Panorama	Tybalt +	Battalion	Einstein	Cordiale	Ashby +	Invicta	Warrior	Scout	Viscount	Beluga	Alchemy	Conqueror	New KWS Alderon +	JB Diego	Belvoir +	Humber	Duxford	Grafton	Zircon + $	Average LSD (5'
Recommendation	nabim Group 1				nabim Group 2									nabim Group 3			Soft Group 4			Hard Group 4								
Scope of recommendation	UK	UK	UK	UK	UK	UK	UK	UK	UK	UK	UK	UK	UK	UK	Sp	UK	UK	UK	UK	UK	UK	UK	UK	UK	UK	UK	Sp	
Breeder/ UK contact																												
Breeder	Syn	BA	Lim	RAGT	KWS	Syn	KWS	Lim	Wier	RAGT	Lim	KWS	KWS	Lim	RAGT	Sen	KWS	Sen	Lim	KWS	KWS	Bruen	KWS	KWS	Syn	KWS	KWS	
UK contact	Syn	Sen	Lim	RAGT	KWS	Syn	KWS	Lim	Lim	RAGT	Lim	KWS	KWS	Lim	RAGT	Sen	KWS	Sen	Lim	KWS	KWS	Sen	KWS	KWS	Syn	KWS	KWS	
Annual yield as % control																												
2007 treated (8.1 t/ha)	-	-	-	[93]	-	-	-	-	[108]	[96]	-	-	[99]	-	-	-	-	-	[92]	-	-	[97]	[100]	[96]	[88]	-	[102]	8.0
2008 treated (10.5 t/ha)	[112]	[98]	[109]	[96]	[112]	[110]	-	[110]	[102]	[105]	[109]	-	[102]	-	-	[106]	[111]	-	[107]	[116]	-	[116]	[111]	[111]	[112]	[107]	[102]	9.5
2009 treated (8.9 t/ha)	[103]	[105]	[102]	[95]	[112]	[113]	[109]	[108]	[103]	[106]	-	[103]	[102]	[111]	[106]	[108]	[111]	[109]	[105]	[113]	[109]	[110]	[109]	[113]	[110]	[99]	[98]	6.4
2010 treated (7.3 t/ha)	[103]	[106]	[92]	[96]	[105]	[109]	[101]	[105]	[105]	-	[97]	[93]	[99]	[105]	[104]	[101]	[106]	[108]	[101]	[114]	[113]	[103]	[104]	-	[102]	[98]	[96]	8.9
2011 treated (10.2 t/ha)	[101]	-	[98]	-	-	-	[104]	-	-	-	[98]	[100]	-	[105]	[103]	[100]	[104]	[101]	[101]	[112]	-	-	-	-	-	-	-	11.1

All yields are taken from treated trials receiving a full fungicide and PGR programme

Key to Breeder and UK contact codes

BA= Blackman Agriculture
Breun = Saatzucht Josef Breun, Germany
KWS = KWS UK (www.kws-uk.com)
Lim = Limagrain (www.limagrain.co.uk)
RAGT = RAGT Seeds (www.ragt.co.uk)
Sen = Senova (www.senova.uk.com)
Syn = Syngenta Seeds (www.newfarmcrops.co.uk)
Wier = Wiersum BV, Netherlands

Example 4

Trait (number of varieties with data)	Character states	Character description	h^2
Aleurone colour (526) *	1,2,3	none to strong	0.72
Auricle anthocyanin coloration (469) *	1,9	present or absent	0.57
Auricle anthocyanin intensity (459) *	1,2,3,4,5,6,7,8,9	absent to very strong	0.45
Awn anthocyanin coloration (504) *	1,9	present or absent	0.58
Awn anthocyanin intensity (459) *	1,2,3,4,5,6,7,8,9	absent to very strong	0.35
Awn length (537)	3,4,5,6,7	short to long	0.23
Awn margin spiculation (434)	1,5,9	absent, reduced, present	0.01
Collar type (230)	1,2,3,4,5,6,7	recurrent - platform - cup	0.09
Ear attitude (536) *	1,2,3,4,5,6,7,8,9	erect to recurved	0.23
Ear emergence (537)	1,2,3,4,5,6,7,8,9	very early to very late	0.27
Ear glaucosity (540)	1,2,3,4,5,6,7,8,9	absent to very strong	0.34
Ear grain density (536)	1,2,3,4,5,6,7,8,9	very lax to very dense	0.19
Ear length (522)	1,2,3,4,5,6,7,8,9	very short to very long	0.16
Ear row-number (577) *	1,2	2-row, 6-row	0.80
Ear shape (535)	3,4,5,6,7	tapering-parallel-fusiform	0.16
Flag leaf-sheath glaucosity (538)	1,2,3,4,5,6,7,8,9	absent to very strong	0.34
Grain furrow hair (573) *	1,5,9	absent, sharkskin, present	0.55
Grain husk (535)	1,9	absent or present	0.01
Grain lateral nerve spiculation (541) *	1,2,3,4,5,6,7,8,9	absent to very strong	0.63
Grain rachilla hair type (578) *	1,2	short or long	0.58
Growth Habit (533)	1,2,3,4,5,6,7,8,9	erect to prostrate	0.29
Hairiness of leaf sheath (569) *	1,9	absent or present	0.61
Lemma nerve anthocyanin intensity (529) *	1,2,3,4,5,6,7,8,9	absent to very strong	0.59
Plant height (534)	1,2,3,4,5,6,7,8,9	very short to very tall	0.12
Rachis first segment curvature (531)	1,2,3,4,5,6,7,8,9	absent to very strong	0.22
Rachis first segment length (534)	3,4,5,6,7	short to long	0.34
Recurved leaf frequency (512)	1,2,3,4,5,6,7,8,9	absent to very high	0.14
Seasonal growth habit (530)*	1,2,3	spring, alternative, winter	0.80
Spikelet glume and awn length (528)	3,5,7	short to long	0.14
Sterile spikelet attitude (475) *	1,2,3	parallel to divergent	0.48
Sterile spikelet development (486) *	1,2	none or full	0.70
Sterile spikelet tip shape (406)	1,2,3	pointed, rounded, squared	0.07

Table S2. Traits for which phenotypic data is available for ≥ 200 cultivars within the association panel. * Phenotypes for which significant associations were identified by GWA analysis ($-\log_{10} p \geq 4.35$, ≥ 2 significant markers within a 4 cM window). Estimates of trait heritability (h^2) are indicated.

Example 5a

Growth stage	Trait	Definition	Units	Symbol
GS61	Anthesis date	Date of 50% shoots reaching GS61	Days after 1 May (1 May = 1)	AD
	Thermal time to anthesis	TT of 50% shoots reaching GS61	°Cd after sowing	ADTT
GS61+250°Cd	A250 date	Sampling date	Days after 1 May	A250D
	Aboveground dry matter at GS61+250°Cd	Gram (aboveground dry mass) per square meter (ground) at GS61+250°Cd	g m^{-2}	AGDMA250
	Straw dry matter at GS61+250°Cd	Gram (straw dry mass) per square metre (ground) at GS61+250°Cd	g m^{-2}	DMStrawA250
	Ear dry matter at GS61+250°Cd	Gram (ear dry mass) per square metre (ground) at GS61+250°Cd	g m^{-2}	DMEarA250
	Grain dry matter at GS61+250°Cd	Gram (grain dry mass) per square metre (ground) at GS61+250°Cd	g m^{-2}	DMGrainA250
	N uptake at GS61+250°Cd	Gram (aboveground N) per square metre (ground) at GS61+250°Cd	g m^{-2}	QNUptakeA250
	N uptake in straw at GS61+250°Cd	Gram (aboveground straw N) per square metre (ground) at GS61+250°Cd	g m^{-2}	QNStrawA250
	N uptake in ear at GG61+250°Cd	Gram (aboveground ear N) per square metre (ground) at GS61+250°Cd	g m^{-2}	QNEarA250
	N uptake in grain at GG61+250°Cd	Gram (aboveground grain N) per square metre (ground) at GS61+250°Cd	g m^{-2}	QNGA250
	Aboveground N concentration at GG61+250°Cd	Gram (aboveground N) per gram (aboveground dry mass) x 100 at GS61+250°Cd	%	%NA250
	Straw N concentration at GG61+250 °Cd	Gram (straw N) per gram (straw dry mass) at GS61+250°Cd x 100	%	%NStrawA250
	Ear N concentration at GG61+250°Cd	Gram (ear N) per gram (ear dry mass) x 100 at GS61+250°Cd	%	%NEarA250
	Grain N concentration at GG61+250°Cd	Gram (grain N) per gram (ear dry mass) x 100 at GS61+250°Cd	%	%NGA250

Example 5b

Harvest	Crop height	Height to tip of ear from ground level at harvest	cm	CHT
	Lodging score	Lodging score (1=no lodging, 9=fully lodged) at harvest (?)		LODGS
	Combine grain yield	Tonne (grain dry mass) per hectare (ground) at harvest	t ha^{-1}	GY
	Harvest index	Kilogram (grain dry mass) per kilogram above ground dry mass at harvest	kg kg^{-1} (unitless)	HI
	Aboveground dry matter at harvest	Gram (aboveground dry mass) per square meter (ground) at harvest	g m^{-2}	AGDM
	Straw (stem + leaves + chaff) dry matter at harvest	Gram (straw dry mass) per square meter (ground) at harvest	g m^{-2}	DMStraw
	Ears per m^2	Number ears per square meter (ground) at harvest	m^{-2}	NeearM2
	Grains per ear	Number grains per ear at harvest	grains ear^{-1}	NGEear
	Thousand grain weight	Dry mass of 1,000 grains at harvest	g	TGW
	Grains per m^2	Number grains per m^2 (ground) at harvest	m^{-2}	NGM2
	Grain N concentration	Gram (grain N) per gram (grain dry mass) x 100 at harvest	%	%NG
	Straw (stem + leaves + chaff) N concentration at harvest	Gram (straw N) per gram (straw dry mass) x 100 at harvest	%	%Nstraw
	Grain Protein concentration	Gram (grain protein) per gram (grain dry mass) x 100 at harvest	%	%PG
	Nitrogen-use efficiency	Kilogram (grain dry mass) at harvest per kilogram available N (from soil plus fertilizer)	kg kg^{-1} (unitless)	NUE
	Nitrogen-uptake efficiency	Kilogram (above-ground N) at harvest per kilogram available N (from soil plus fertilizer)	kg kg^{-1} (unitless)	NupE
	Nitrogen-utilization efficiency	Kilogram (grain dry mass) per kilogram (aboveground N) at harvest	kg kg^{-1} (unitless)	NutE
	Biomass production efficiency	Kilogram (aboveground dry mass) per kilogram (aboveground N) at harvest	kg kg^{-1} (unitless)	BPE
	Nitrogen harvest index	Proportion of aboveground N in the grain at harvest	unitless	NHI
	N uptake in grain	Gram (grain N) per square metre (ground) at harvest	g m^{-2}	QNG
	N uptake in straw at harvest	Gram (straw N) per square metre (ground) at harvest	g m^{-2}	QNStraw
	Aboveground N uptake at harvest	Gram (aboveground N) per square metre (ground) at harvest	g m^{-2}	QNUptake
	Ear N uptake at harvest	Gram chaff N = (Dmchaff *%Nstraw) per square metre (ground) at harvest	g m^{-2}	QNChaff
	Chaff N uptake at harvest	Gram (grain N + chaff N) per square metre (ground) at harvest	g m^{-2}	QNEar

Example 5c

Calculations	Grain Protein Deviation	Residual of linear regression of %PG vs N		GPD
	Nitrogen Nutrition Index at CG61+250°Cd	%NA250 / (5.35*(AGDMA250/100)^0.442)	unitless	NNIA250
	Nitrogen Nutrition Index	%NA250 / (5.35*(AGDMA250/100)^0.442)	unitless	NNI
	Post-anthesis N uptake	QNUptake - QNUptakeA250	$g\ m^{-2}$	PANU
	N grain from post-A250 N uptake	QNG/PANU	%	PANUG
	Post-A250 N remobilization	QNStrawA250 – QNStraw	$g\ m^{-2}$	PANR
	Post-A250 N remobilization efficiency	(PANR/QNStrawA250) x 100	%	PANRE
	N grain from post-A250 remobilisation	QNG/PANR	%	PANRG
	Senescence initial phase, max rate	Parameter of function fitted to senescence score vs TT	$^oC^{-1}$	SenP2
	Senescence rapid phase, max rate	Parameter of function fitted to senescence score vs TT	$^oC^{-1}$	SenP4
	Timing of max rate of senescence rapid phase	Parameter of function fitted to senescence score vs TT	°C	SenP5
	Duration of the slow phase of senescence	Parameter of function fitted to Senescence score vs TT	°C	SenDurSP
	Duration of the rapid phase of senescence	(End of rapid phase of senescence) – (Duration of the slow phase of senescence)	°C	SenDurRP
	End of rapid phase of senescence	Parameter of function fitted to senescence score vs TT	°C	SenEndRP

Abbreviations of Lines, Treatments and Sites				
	Names	**Treatment**	**Year**	**Symbol**
Lines	Savannah X Rialto DH lines			SXR001, SXR002
Controls	Savannah			CHKSAV
	Rialto			CHKRIA
Environments	Mons	low nitrogen fertiliser	2009	MS9LN
	Mons	high nitrogen fertiliser	2009	MS9HN
	Sutton-Bonington	low nitrogen fertiliser	2009	SB9LN
	Sutton-Bonington	high nitrogen fertiliser	2009	SB9HN
	Clermont-Ferrand	low nitrogen fertiliser	2009	CF9LN
	Clermont-Ferrand	high nitrogen fertiliser	2009	CF9HN
	Norwich	low nitrogen fertiliser	2009	NO9LN
	Norwich	high nitrogen fertiliser	2009	NO9HN

Example 6a

Environment	<site>8HN	<site>8LN
Year		
Site		
Latitude		
Longitude		
Elevation		
Design		
Plot size		
Plot number of rows		
Plot row spacing		
Sowing date		
Sowing density		
Previous crop		
Harvest date		
Silt (%) 0-30		
Fine sand (%) 0-30		
Coarse sand (%) 0-30		
Bulk density 0-30		
OM (%) 0-30		
pH 0-30		
CaCO3 (%) 0-30		
Clay (%) 30-60		
Silt (%) 30-60		
Fine sand (%) 30-60		
Coarse sand (%) 30-60		
Bulk density 30-60		
OM (%) 30-60		
pH 30-60		
CaCO3 (%) 30-60		
Clay (%) 60-90		
Silt (%) 60-90		
Fine sand (%) 60-90		
Coarse sand (%) 60-90		
Bulk density 60-90		
OM (%) 60-90		
pH 60-90		
CaCO3 (%) 60-90		
Clay (%) 90-120		
Silt (%) 90-120		
Fine sand (%) 90-120		
Coarse sand (%) 90-120		
Bulk density 90-120		
OM (%) 90-120		
pH 90-120		
CaCO3 (%) 90-120		
Treatment type 1		
Treatment molecule 1		
Treatment dose 1		
Treatment date 1		
Treatment type 2		
Treatment molecule 2		

Example 6b

Treatment dose 2		
Treatment date 2		
Treatment type 3		
Treatment molecule 3		
Treatment dose 3		
Treatment date 3		
Treatment type 4		
Treatment molecule 4		
Treatment dose 4		
Treatment date 4		
Treatment type 5		
Treatment molecule 5		
Treatment dose 5		
Treatment date 5		
Fertilisation P&K date		
Fertilisation P&K formulation		
Fertilisation P&K rate		
Fertilisation N date 1		
Fertilisation N formulation 1		
Fertilisation N Zadoks 1		
Fertilisation N rate 1		
Fertilisation N date 2		
Fertilisation N formulation 2		
Fertilisation N Zadoks 2		
Fertilisation N rate 2		
Fertilisation N date 3		
Fertilisation N formulation 3		
Fertilisation N Zadoks 3		
Fertilisation N rate 3		
Fertilisation N date 4		
Fertilisation N formulation 4		
Fertilisation N Zadoks 4		
Fertilisation N rate 4		
Soil N sowing sampling date		
Soil N sowing variety		
Soil NO3 sowing 0-30		
Soil NH4 sowing 0-30		
Soil water sowing 0-30		
Soil NO3 sowing 30-60		
Soil NH4 sowing 30-60		
Soil water sowing 30-60		
Soil NO3 sowing 60-90		
Soil NH4 sowing 60-90		
Soil water sowing 60-90		
Soil NO3 sowing 90-120		
Soil NH4 sowing 90-120		
Soil water sowing 90-120		
Soil N winter sampling date		
Soil N sowing variety		
Soil NO3 winter 0-30		
Soil NH4 winter 0-30		

Example 6c

Soil water winter 0-30		
Soil NO3 winter 30-60		
Soil NH4 winter 30-60		
Soil water winter 30-60		
Soil NO3 winter 60-90		
Soil NH4 winter 60-90		
Soil water winter 60-90		
Soil NO3 winter 90-120		
Soil NH4 winter 90-120		
Soil water winter 90-120		
Soil N sowing sampling date		
Soil N sowing variety		
Soil NO3 anthesis 0-30		
Soil NH4 anthesis 0-30		
Soil water anthesis 0-30		
Soil NO3 anthesis 30-60		
Soil NH4 anthesis 30-60		
Soil water anthesis 30-60		
Soil NO3 anthesis 60-90		
Soil NH4 anthesis 60-90		
Soil water anthesis 60-90		
Soil NO3 anthesis 90-120		
Soil NH4 anthesis 90-120		
Soil water anthesis 90-120		
Soil N harvest sampling date		
Soil N sowing variety		
Soil NO3 harvest 0-30		
Soil NH4 harvest 0-30		
Soil water harvest 0-30		
Soil NO3 harvest 30-60		
Soil NH4 harvest 30-60		
Soil water harvest 30-60		
Soil NO3 harvest 60-90		
Soil NH4 harvest 60-90		
Soil water harvest 60-90		
Soil NO3 harvest 90-120		
Soil NH4 harvest 90-120		
Soil water harvest 90-120		

Example 7

Collection of trait names and abbreviations used in the JIC WGIDB (John Innes Centre Wheat Genetic Improvement Database) – collated by Luzie U. Wingen

trait_name	short_name	unit abbreviation	description
Plot Description			
canopy cover	CC	%	A visual score in percent of the ground/soil coverage of the canopy measured at GS23-25 (early tillering).
plot length	PLOTLG	m	The length, measured in meters, of the plot.
number of replicates in trial	NBREPL		number of replicates in trial
Growth and Developmental Trait			
sowing date	SD	date	The date when seed was put into the ground.
booting date	BD	date	The date when plants have 2-3 productive tillers (Zadoks stage 4).
days to booting	DTBT	day	The number of days required half of the plants in a study.
heading date	HD	date	The date when the inflorescence (ear) emerges from the flag leaf of the plant (Zadoks stage 5).
days to heading	DTHD	day	The number of days required for the inflorescence (head/cob/panicle) to emerge from the flag leaf of a plant or a group of plants in a study.
ear emergence date	EM	date	The date when in half of the plot half of the ear has emerged from the flag leaf of the plant. This is a way to measure flowering time or heading date.
days to ear emergence	DTEM	day	The number of days required for half of the ear to emerge from the flag leaf in half of the plants in a study.
days to ear emergence from May 1st	DTEMfM	day	The number of days required for half of the ear to emerge from the flag leaf in half of the plants in a study from May 1st of that year (1. May=1).
anthesis date	AD	date	The date of anthesis, the first visible emergence of anthers (Zadoks stage 6 or growth stage 65 GS65).
anthesis date difference	ADDIF	days	The difference of date of anthesis between the two trial treatments
days to harvest	DTHAR	day	The number of days until harvest.
days to maturity	DTMA	day	The number of days until maturity.
grain milk date	GRMD	date	The first date when grain will produce a milky solution when squeezed (Zadoks stage 7).
grain dough date	GRDD	date	The first date when grain will still deform when squeezed, but no liquid is apparent (Zadoks stage 8).
harvest date	HARD	date	The day of harvest.
ripeninge date	RD	date	The first date when grain is hard and firm and ready for harvest.(Zadoks stage 9).
days to anthesis	DTAD	day	The number of days required for the first visible emergence of anthers.
days after earliest anthesis	DAEAD	day	The number of days after the first anthesis date in the population.
short days	SHTD	day	The number of short days after sowing.
date at growth stage 55	GS55	date	The date when plant is in growth stage 55 or ear emergence.
vegetative period	VgP	days	duration of vegetative period
grain filling period	GFP	days	Average duration of the grain filling period.
spike growth period	SGP	%	Spike grow period, it is from booting to anthesis. SGP commonly defined from terminal spikelet to anthesis.
thermal time to anthesis	ADTT	Ddays	Thermal temperature of 50 percentage shoots reaching GS61.
A250 date	A250D	Ddays	Sampling date in degree days after 1 May (1 May = 1).
leaf visual senescence	LFVS		A visual score measure the aging of leaf (senescence) from 1 to 10 (0=no senescence and 10= completely senescent).
leaf senescence rate	LFSENRATE		The rate of leaf senescence calculated by linear regression from the LFVS or the SPAD score.
senescence initial phase, initial flow	SenP0		Parameter of function fitted to senescence score vs TT
senescence initial phase, min score	SenP1		Parameter of function fitted to senescence score vs TT
senescence initial phase, max rate	SenP2	oC-1	Parameter of function fitted to senescence score vs TT
senescence rapid phase, max rate	SenP4	oC-1	Parameter of function fitted to senescence score vs TT
timing of max rate of senescence rapid phase	SenP5	oC	Parameter of function fitted to senescence score vs TT
duration of the slow phase of senescence	SenDurSP	oC	Parameter of function fitted to senescence score vs TT
duration of the rapid phase of senescence	SenDurRP	oC	(End of rapid phase of senescence) â€“ (Duration of the slow phase of senescence)
end of rapid phase of senescence	SenEndRP	oC	Parameter of function fitted to senescence score vs TT
overall rate of senescence	SenRgSlope	oC-1	slope of linear regression on senescence score vs TT
senescence base level	SenRgInt		Y-axis intercept of linear regression on senescence score vs TT
mean temperature of GFP	TEMPGFP	Ddays	The mean canopy temperature of the grainfilling period.
mean temperature of vegetative period	TEMPVgP	Ddays	The mean canopy temperature of the vegetative period.
days to carbohydrate sampling	DTCHOS	days	Days from anthesis to stem carbohydrate sampling. Used as a covariate in analysis. Perhaps measured in degree days, not days (?)
Shoot Anatomy And Morphology Trait			
plant height	Ht	cm	The actual measurement of plant height from soil surface to the highest point in plant as identified in the study in centimeters.
peduncle length	PEDLLG	cm	The average length of the peduncle, measured in centimeters.
internode1 length	INTN1LG	cm	The average length of internode1, measured in centimeters.
internode2 length	INTN2LG	cm	The average length of internode2, measured in centimeters.
internode3 length	INTN3LG	cm	The average length of internode3, measured in centimeters.
viridescent index	VIRIDS		A measurement of the presence of viridescence (bright green colour of leaves and spikes) of either 0,1 or 2 (?).
leaf curl	LFCURL		A visual assesment of the leaf curl on a scale from 1 to 5 (1=straight and 5=curled).
ear curlyness	EARCURL		A visual assesment of the earl curl on a scale from 1 to 5 (1=straight and 5=curled or bent) scored after anthesis (GS69+).
ear type	EARTYPE		A measurement of the wheat ear type on a scale from 1 to 5 (1=lax and 5=comp).

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winter damage	WTDMG		A measurement of the degree of winter damage on a scale from 0 - ? (0=no damage, ?=100 percent damage)
lodging	LODG		A measurement of the degree of lodging of the plants on a scale from 0 - 5 (0=no lodging, 5=100percent lodging)
leaf waxiness	LFWXN		A visual assesment of a plot of the waxiness of the leaves on a scale from 1 - 5 (1=no wax, 5=waxy). Waxy leaves have a white tinge.
erectness	ERCTN		A visual score of erectness of the plant on a scale from 1 to 10 (1=prostrate, 10=erect) at the pre-stem elongation growth stage (before GS30).
tip necrosis	TIPNC		A measurement of the necrosis of the plant leaf tip on a scale from 0 to 5 (0=none and 5=complete)
spike necrosis	SPNC		A measurement of the necrosis of the plant spike tip.
hybrid necrosis	HYBNC		A visual assesment of a plot of the necrotic lesions on plant, leaves and stems on a scale from 0 to 10 (0=none and 10=whole plant showing necrosis).
winter necrosis	WINTNC		A visual assesment of a plot in percent of the necrotic lesions on plant, leaves and stems (0=none and 100=whole plant showing necrosis).
leaf hybrid necrosis	LFHYBNC		A visual assesment of a plot of the necrotic lesions on leaves on a scale from 0 to 10 (0=none and 10=whole plant showing necrosis).
straw diameter	STRDIAM	cm	The average diameter of a straw stem, measured in centimeters.
straw wall thickness	STRWALL	cm	The average thickness of the straw wall, measured in centimeters.
straw fill	STRFILL	%	The average percentage of straw wall of the straw cross section, measured in percentages.
tetrastichon sessile spikelets	TSS		Measure of spike morphology (1 means TSS is present).
awns	AWNS		Absence/presence of awns coded as 0/1.
width of flag leaf	FLLFWD	cm	Average width of flag leaf.
flag leaf length	FLLFLN	cm	Average length of flag leaf. Measured after ear emergence at GS 60+.
flag leaf erectness	FLLFERCTN		A visual assesment per plot of the flag leaf characteristics measuring the degree of erectness of the flag leaf on a scale from 1 - 3 (1=erect, 3=floppy). Measured after ear emergence at GS 60+.

Yield Traits

plot grain yield	PlGRYLD	g	The grain yield, measured in grams, of a trial plot.
grain yield per plot adjusted for canopy cover and plot size	PlGRYLDaCP	g	The grain yield, measured in grams per plot, adjusted for canopy cover and plot size.
grain yield per plot adjusted for plot size	PlGRYLDaP	g	The grain yield, measured in grams per plot, adjusted for plot size.
grain yield per plot adjusted for canopy cover	PlGRYLDaC	g	The grain yield, measured in grams per plot, adjusted for canopy cover.
grain yield per square meter	GRYLDpsqm	g/sqm	The grain yield, measured in grams per square meter.
grain yield	GRYLD	t/ha	The grain yield, measured in tonnes per hectare.
grain yield adjusted for canopy cover	GRYLDaCC	t/ha	The grain yield, measured in tonnes per hectare adjusted for canopy cover.
grain yield adjusted for canopy cover and plot size	GRYLDaCP	t/ha	The grain yield, measured in tonnes per hectare adjusted for canopy cover and plot size.
1000-dehulled grain weight	TGRWT	g	The weight, measured in grams, of 1000 well-developed whole grains (without hull).
200-dehulled grain weight	200GRWT	g	The weight, measured in grams, of 200 well-developed whole grains (without hull).
grain per square meter	GRpsqm	1/sqm	The number of grains per square meter soil.
grain yield per ear	GRYLDpEAR	g	The grain yield measured in g per spike/ear.
grain yield per spikelet	GRYLDpSPT	g	The grain yield measured in g per spikelet (ear).
grain per spike	GRpSP		The number of grains per spike (ear).
grain per spikelet	GRpSPT		The number of grains per spikelet (ear).
grain length	GRLG	mm	The average length, measured in millimeters, of the grain (without hull).
grain width	GRWD	mm	The average width, measured in millimeters, of the grain (without hull).
grain surface area	GRSA	sqmm	The average surface area, measured in square millimeter, of the grain (without hull).
plant fresh weight	PLFWT	g	The average fresh weight, measured in grams, of a plant.
grain fresh weight	GRFWT	g	The fresh grain weight, measured in grams, of a sample of grains. Used to calculate PERGRBM
grain biomass	GRBM	g	The grain biomass (dry weight, 48h 80 degree C), measured in grams, of a sample of grains. Used to calculate PERGRBM.
percentage grain biomass	PERGRBM		The ratio of GRBM and GRFWT.
plant biomass	PLBM	g	The average above ground biomass (dry weight, 48h 80 degree C), measured in grams, of a plant.
total plant biomass	tPLBM	g	The average total biomass including the roots (dry weight, 48h 80 degree C), measured in grams, of a plant.
percent plant biomass	PERPLBM	g	The biomass divided by the fresh weight of a plant.
plant biomass at anthesis	PLBMANT	g	The average plant biomass (dry weight, 48h 80 degree C), measured in grams, of a plant at or shortly after anthesis date.
normalised plant biomass at anthesis	nPLBMANT	g	The average normalised plant biomass (dry weight, 48h 80 degree C), measured in grams, of a plant at or shortly after anthesis date.
straw biomass	STRBM	g	The average biomass (dry weight, 48h 80 degree C), measured in grams, of the straw, the plant without ear.
stem biomass	STBM	g	The average biomass (dry weight, 48h 80 degree C), measured in grams, of the stem.
spike biomass	SPBM	g	The average biomass (dry weight, 48h 80 degree C), measured in grams, of a spike.
straw biomass per area	STRBMpa	g	The average biomass (dry weight, 48h 80 degree C), measured in grams, of the straw, the plant without ear. on a specified area of the plot (e.g. a 60cm wide row).
plant biomass per area	PLBMpa	g	The biomass (dry weight, 48h 80 degree C), measured in grams, of a plant on a specified area of the plot (e.g. a 60cm wide row).
plant biomass per square meter	PLBMpsqm	g/sqm	The biomass (dry weight, 48h 80 degree C), measured in grams, of the above ground plants on a square meter.
plant biomass per tiller	PLBMpTI	g	The average biomass (dry weight, 48h 80 degree C), measured in grams, of a plant per tiller.
tiller biomass per area	TIBMpa	g	The biomass (dry weight, 48h 80 degree C), measured in grams, of tillers on a specified area of the plot (e.g. a 60cm wide row).
tiller biomass per square meter	TIBMpsqm	g/sqm	The biomass (dry weight, 48h 80 degree C), measured in grams, of tillers on a square meter.
tiller biomass	TIBM	g	The average biomass (dry weight, 48h 80 degree C), measured in grams, of a tiller.
tiller biomass at anthesis	TIBMANT	g	The average biomass (dry weight, 48h 80 degree C), measured in grams, of a tiller at anthesis.
twelve tiller biomass	12TIBM	g	The biomass of twelve tillers (dry weight, 48h 80 degree C), measured in grams.
twelve tiller biomass	12TIBMANT	g	The biomass of twelve tillers (dry weight, 48h 80 degree C), measured in grams at anthesis.
stem and leaf biomass	STLEBM	g	The average biomass (dry weight, 48h 80 degree C), measured in grams, of stem and leaves of a plant.
straw biomass per tiller	STRBMpTI	g	The average biomass (dry weight, 48h 80 degree C), measured in grams, of the straw of a tiller.
stem and leaf biomass per tiller	STLEBMpTI	g	The average biomass (dry weight, 48h 80 degree C), measured in grams, of stem and leaves of a tiller.

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stem and leaf biomass per area	STLEBMpa	g	The biomass (dry weight, 48h 80 degree C), measured in grams, of stem and leaves on a specified area of the plot (e.g. a 60cm wide row).
stem and leaf biomass per square meter	STLEBMpsqm	g/sqm	The biomass (dry weight, 48h 80 degree C), measured in grams, of stem and leaves on a square meter.
spike biomass at anthesis	SPBMANT	g	The average biomass (dry weight, 48h 80 degree C), measured in grams, of a tiller at anthesis.
ear biomass	EARBM	g	The average biomass (dry weight, 48h 80 degree C), measured in grams, of an ear.
ear biomass at anthesis	EARBMANT	g	The average biomass (dry weight, 48h 80 degree C), measured in grams, of an ear at anthesis.
twelve ear biomass	12EARBM	g	The biomass (dry weight, 48h 80 degree C) of 12 ears, measured in grams, of an ear.
twelve ear biomass	12EARBMANT	g	The biomass (dry weight, 48h 80 degree C) of 12 ears, measured in grams, of an ear at anthesis.
ear biomass per tiller	EARBMpTI	g	The average biomass (dry weight, 48h 80 degree C), measured in grams, of the ears on a tiller.
ear biomass per area	EARBMpa	g	The biomass of the ears, measured in grams, on a tiller on a specified area of the plot (e.g. a 60cm wide row).
ear biomass per square meter	EARBMpsqm	g	The biomass of the ears, measured in grams, on a square meter.
ear biomass at anthesis per square meter	EARBMApsqm	g	The biomass of the ears at anthesis, measured in grams, on on a square meter.
grain biomass per spike	GRBMpTI	g	The average biomass (dry weight, 48h 80 degree C) of grains (or yield) of a spike.
grain biomass per tiller	GRBMpTI	g	The average biomass (dry weight, 48h 80 degree C) of grains (or yield) of a tiller.
grain biomass per ear	GRBMpEAR	g	The average biomass (dry weight, 48h 80 degree C) of grains (or yield) of an ear.
grain biomass per area	GRBMpa	g	The biomass (dry weight, 48h 80 degree C) of grains on a specified area of the plot (e.g. a 60cm wide row).
harvest index	HI	%	Proportion of usable (economically significant) biomass over total (biological) biomass, expressed as a percentage.
harvest index seven days after anthesis	HIANT	%	Proportion of spike weigth over total culm weight, expressed as a percentage seven days after anthesis.
grain number per tiller	GRNBpTI	g	The average number of grains on a tiller.
grain number per ear	GRNBpEAR	g	The average number of grains on an ear.
grain number per spikelet	GRNBpSPT	g	The average number of grains in a spikelet.
ear number per area	EARNBpa		The number of ears on a specified area of the plot (e.g. a 60cm wide row).
ear number per square meter	EARNBpsqm	1/sqm	The number of ears on a square meter.
head count	HDCT		The number of heads (ears) on a specified number of plants.
tiller number	TINB		The number of tillers on a specified number of plants.
tiller number per area	TINBpa		The number of tillers on a specified area of the plot (e.g. a 60cm wide row).
tiller number per square meter	TINBpsqm	1/sqm	The number of tillers on a square meter.
fertile spikelet number per spike	ftSPTpS		The number of fertile spikelets on one or a given number of spikes.
sterile spikelet number per tiller	stSPTpT		The number of sterile spikelets on one or a given number of tillers.
fertile spike number per area	ftSPNBpa		The number of fertile spikes on a specified area of the plot (e.g. a 60cm wide row).
sterile spike number per area	stSPNBpa		The number of sterile spikes on a specified area of the plot (e.g. a 60cm wide row).
fertile tiller number per area	ftTINBpa		The number of fertile tillers on a specified area of the plot (e.g. a 60cm wide row).
sterile tiller number per area	stTINBpa		The number of sterile tillers on a specified area of the plot (e.g. a 60cm wide row).
sterile tiller number per square meter	stTINBpsqm		The number of sterile tillers per square meter.
spike number per square meter	SPNBpsqm	1/sqm	The number of spikes on a square meter.
sterile spike number per square meter	stSPNBpsqm		The number of sterile spikes per square meter.
fertile spike number per square meter	ftSPNBpsqm		The number of fertile spikes per square meter.
ear number per plant	EARNBpP		The average number of ears per plant.
ear number per tiller	EARNBpT		The average number of ears on a tiller.
tiller number per plant	TINBpP		The average number of tillers per plant.
fertile tiller number per plant	ftTINBpP		The average number of fertile tillers per plant.
sterile tiller number per plant	stTINBpP		The average number of sterile tillers per plant.
spike number per plant	SPNBpP		The average number of spikes per plant.
fertile spike number per plant	ftSPNBpP		The average number of fertile spikes per plant.
sterile spike number per plant	stSPNBpP		The average number of sterile spikes per plant.
spikelet number per spike	SPTNBpSP		The average number of spikelets per spike.
spikelet number per tiller	SPTNBpTI		The average number of spikelets per tiller.
spikelet number per ear single count	SPTNBpESC		The number of spikelets per ear in a single count.
sterile spikelet number per ear single count	sSPTNBpESC		The number of sterile spikelets per ear in a single count.
fertile spikelet number per ear single count	fSPTNBpESC		The number of fertile spikelets per ear in a single count.
spikelet number per ear	SPTNBpEAR		The average number of spikelets per ear.
sterile spikelet number per ear	sSPTNBpEAR		The average number of sterile spikelets per ear.
fertile spikelet number per ear	fSPTNBpEAR		The average number of fertile spikelets per ear.
grain number per spike	GRNBpSP	g	The average number of grains on a tiller.
grain spike ratio	GRSPR		Grams of grains per grams of spike (structure). A coefficient of fertility
carbohydrate content at anthesis	CHOCANT		Watersoluble carbohydrate content at anthesis.
chlorophyll content	ChlC		Amount of chlorophyll in a leave measured by SPAD chlorophyll meter.
chlorophyll content difference	ChlCD		Difference of chlorophyll content, measured by SPAD, in a leaf in a specified period.
chlorophyll content GFP	ChlCGFP		Chlorophyll content, measured by SPAD, in a leaf during the grain filling period.
proportion of grain filling	GFPRO		Proportion of grain fill of maturity to anthesis. GF=maturity-anthesis/maturity.
grain filling rate	GFR	g/day	Average rate of grain filling.
grain number per spikelet	GRNBpSPT	g	The average number of grains in an spikelet.
NDVI of GFP	NDVIGFP		Mean NDVI of grain filling period.

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NDVI of VgP	NDVIVgP		Mean NDVI of vegetative period.
tiller per ear ratio	TIEARR		The ratio of average TINB and EARNB.
normalised tiller per ear ratio	nTIEARR		The normalised ratio of average TINB and EARNB.
N related traits			
seed protein content	GRPRC	%	The amount of protein, measured in percent, in the seed/grain.
ear protein content	EARPRC	%	The amount of protein, measured in percent, in the ear.
straw protein content	STRPRC	%	The amount of protein, measured in percent, in the straw.
stem protein content	STMPRC	%	The amount of protein, measured in percent, in the stem.
seed nitrogen content	GRNC	%	The amount of nitrogen, measured in percent, in the seed/grain.
seed sulphur content	GRSC	%	The amount of sulphur, measured in percent, in the seed/grain.
seed nitrogen to sulphur ratio	GRNSR		The ratio of nitrogen over sulphur, measured in percent, in the seed/grain.
stem nitrogen content	STMNC	%	The amount of nitrogen, measured in percent, in the stem.
straw nitrogen content	STRNC	%	The amount of nitrogen, measured in percent, in the straw.
ear nitrogen content	EARNC	%	The amount of nitrogen, measured in percent, in the ear.
ear length	EARLG	cm	The average length of an ear, measured in centimeters.
ear length with awn	EARLGWA	cm	The average length of an ear including the awn, measured in centimeters.
aboveground dry matter at GS61+250 degree days	AGDMA250	g/sqm	Gram (aboveground dry mass) per square meter (ground) at GS61+250 degree days
straw dry matter at GS61+250 degree days	DMSTRA250	g/sqm	Gram (straw dry mass) per square metre (ground) at GS61+250 degree days
ear dry matter at GS61+250 degree days	DMEarA250	g/sqm	Gram (ear dry mass) per square metre (ground) at GS61+250 degree days
grain dry matter at GS61+250 degree days	DMGRA250	g/sqm	Gram (grain dry mass) per square metre (ground) at GS61+250 degree days
N uptake at GS61+250 degree days	QNUpA250	g/sqm	Gram (aboveground N) per square metre (ground) at GS61+250 degree days
N uptake in straw at GS61+250 degree days	QNSTRA250	g/sqm	Gram (aboveground straw N) per square metre (ground) at GS61+250 degree days
N uptake in ear at GG61+250 degree days	QNEarA250	g/sqm	Gram (aboveground ear N) per square metre (ground) at GS61+250 degree days
N uptake in grain at GG61+250 degree days	QNGA250	g/sqm	Gram (aboveground grain N) per square metre (ground) at GS61+250 degree days
aboveground N concentration at GG61+250 degree days	NA250C	%	Gram (aboveground N) per gram (aboveground dry mass) x 100 at GS61+250 degree days
straw N concentration at GG61+250 degree days	NSTRA250C	%	Gram (straw N) per gram (straw dry mass) at GS61+250 degree days x 100
ear N concentration at GG61+250 degree days	NEarA250C	%	Gram (ear N) per gram (ear dry mass) x 100 at GS61+250 degree days
grain N concentration at GG61+250 degree days	NGA250C	%	Gram (grain N) per gram (ear dry mass) x 100 at GS61+250 degree days
aboveground dry matter at harvest	AGDM	g/sqm	Gram (aboveground dry mass) per square meter (ground) at harvest
straw (stem + leaves) dry matter at harvest	DMSTR	g/sqm	Gram (straw dry mass) per square meter (ground) at harvest
chaff dry matter at harvest	DMChaff	g/sqm	Gram (chaff dry mass) per square meter (ground) at harvest
grain N concentration	NGRC	%	Gram (grain N) per gram (grain dry mass) x 100 at harvest
straw (stem + leaves) N concentration at harvest	NSTRC	%	Gram (straw N) per gram (straw dry mass) x 100 at harvest
nitrogen-use efficiency	NUE		Kilogram (grain dry mass) at harvest per kilogram available N (from soil plus fertilizer)
nitrogen-uptake efficiency	NupE		Kilogram (above-ground N) at harvest per kilogram available N (from soil plus fertilizer)
nitrogen-utilization efficiency	NutE		Kilogram (grain dry mass) per kilogram (aboveground N) at harvest
biomass production efficiency	BPE		Kilogram (aboveground dry mass) per kilogram (aboveground N) at harvest
nitrogen harvest index	NHI		Proportion of aboveground N in the grain at harvest
aboveground N uptake at harvest	QNUp	g/sqm	Gram (aboveground N) per square metre (ground) at harvest
N uptake in grain	QNG	g/sqm	Gram (grain N) per square metre (ground) at harvest
N uptake in straw at harvest	QNSTR	g/sqm	Gram (straw N) per square metre (ground) at harvest
N uptake in chaff at harvest	QNChaff	g/sqm	Gram chaff N = (Dmchaff*NstrawC) per square metre (ground) at harvest
N uptake in ear at harvest	QNEar	g/sqm	Gram (grain N + chaff N) per square metre (ground) at harvest
grain protein deviation	GPD		Residual of linear regression of %PG vs N
grain size grain number deviation	GsGnD		Residual of linear regression of %GRpsqm vs TGRWT
nitrogen nutrition index at CG61+250 degree days	NNIA250		NA250C / (5.35*(AGDMA250/100)^0.442)
nitrogen nutrition index	NNI		NA250C / (5.35*(AGDMA250/100)^0.442)
post-anthesis N uptake	PANU	g/sqm	QNUpHar - QNUpA250
n grain from post-A250 N uptake	PANUG	%	QNG/PANU
post-A250 N remobilization	PANR	g/sqm	QNSTRA250 - QNSTRHar
post-A250 N remobilization efficiency	PANRE	%	(PANR/QNSTRA250) x 100
n grain from post-A250 remobilisation	PANRG	%	QNG/PANR
Flour amino acid content			
Alanine content	AlaC		A amino acid content or composition (g/100g flour).
Arginine content	ArgC		R amino acid content or composition (g/100g flour).
Asparagine content	AsnC		N amino acid content or composition (g/100g flour).
Aspartic acid content	AspC		D amino acid content or composition (g/100g flour).
Cysteine content	CysC		C amino acid content or composition (g/100g flour).
Glutamic Acid content	GluC		E amino acid content or composition (g/100g flour).
Glutamine content	GlnC		Q amino acid content or composition (g/100g flour).
Glycine content	GlyC		G amino acid content or composition (g/100g flour).

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Histidine content	HisC		H amino acid content or composition (g/100g flour).
Isoleucine content	IleC		I amino acid content or composition (g/100g flour).
Leucine content	LeuC		L amino acid content or composition (g/100g flour).
Lysine content	LysC		K amino acid content or composition (g/100g flour).
Methionine content	MetC		M amino acid content or composition (g/100g flour).
Phenylalanine content	PheC		F amino acid content or composition (g/100g flour).
Proline content	ProC		P amino acid content or composition (g/100g flour).
Serine content	SerC		S amino acid content or composition (g/100g flour).
Threonine content	ThrC		T amino acid content or composition (g/100g flour).
Tryptophan content	TrpC		W amino acid content or composition (g/100g flour).
Tyrosine content	TyrC		Y amino acid content or composition (g/100g flour).
Valine content	ValC		V amino acid content or composition (g/100g flour).
3-Aminoadipic acid content	AadC		Aad amino acid content or composition (g/100g flour).
2-Aminobutyric acid content	AbuC		Abu content or composition (g/100g flour).
4-Aminobutyric acid content	GABAC		GABA content or composition (g/100g flour).
3-Aminopimelic acid content	ApmC		Apm content or composition (g/100g flour).
2,4-Diaminobutyric acid content	DbuC		Dbu content or composition (g/100g flour).
2,2'-Diaminopimelic acid content	DpmC		Dpm content or composition (g/100g flour).
2,3-Diaminopropionic acid content	DprC		Dpr content or composition (g/100g flour).
N-EthylAA content	EtAAC		EtAA amino acid content or composition (g/100g flour).
Hydroxylysine content	HylC		Hyl amino acid content or composition (g/100g flour).
allo-Hydroxylysine content	aHylC		aHyl content or composition (g/100g flour).
3-Hydroxyproline content	3HypC		3Hyp content or composition (g/100g flour).
4-Hydroxyproline content	4HypC		4Hyp content or composition (g/100g flour).
allo-Isoleucine content	aIleC		aIle amino acid content or composition (g/100g flour).
N-Methylglycine (aka sarcosine) content	MeGlyC		MeGly amino acid content or composition (g/100g flour).
N-MethylAA content	MeAAC		MeA amino acid content or composition (g/100g flour).
Norvaline content	NvaC		Nva amino acid content or composition (g/100g flour).
Norleucine content	NleC		Nle amino acid content or composition (g/100g flour).
Ornithine content	OrnC		Orn amino acid content or composition (g/100g flour).
total amino acid content	tAAC		total amino acid content (g/100g flour).
Wheat Quality measures			
specific weight	SPWT	kg/hl	The weight of the grains per hectoliter. Should be above 76 kg/hl for good quality wheat.
Hagberg falling number	HFN		Alpha-amylase activity in grain is measured by the Hagberg-Perten Falling Number, a test to assess sprout damages.
loaf volume	LoafV	ml	Volume of the bread loaf in ml. Wheat quality measure.
L*	LStar		L*. Wheat quality measure.
day 1 TPA firmness	D1TPA		Day 1 TPA firmness (sometimes just Day 1 in wheat functionality project). Wheat quality measure.
day 3 TPA firmness	D3TPA		Day 3 TPA firmness (sometimes just Day 3 in wheat functionality project). Wheat quality measure.
no cells	CELLNB		Number_of_Cells or Number of cells (per slice?). Wheat quality measure.
no cells/slice area	CELLNBpSA		also Cells/unit area. Wheat quality measure.
wall thickness	WALLTH		Wheat quality measure.
loaf height	LoafHt	px	In the Wheat functionality project: Average Height_Max. Wheat quality measure.
cell diameter	CellD	px	Wheat quality measure.
coarse cell Volume	CCellV		Wheat quality measure.
firmness1	FIRM1		Day 1 TPA firmness or Firmness @25% compression (Day 1), N. Wheat quality measure.
firmness3	FIRM3		Day 3 TPA firmness or Firmness @25% compression (Day 3), N. Wheat quality measure.
firmness3-Fmrmness1	FIRM31D		Firmness @25% compression (Day 3-1), N. Wheat quality measure.
firmness3/loaf volume	FIRM3pLV		Firmness (DOP3)/loaf vol. Wheat quality measure.
firmness3-firmness1/loaf Volume	FIRM31DpLV		Firmness @25% compression (Day 3-1)/loaf vol. Wheat quality measure.
firmness3/loaf volume	FIRM3pLV		Wheat quality measure.
left+right concavity	LRCon		Wheat quality measure.
left+right concavity/loaf volume	LRConpLV		Wheat quality measure.
left+right concavity/max height	LRConpHT		left+right concavity/max slice height. Wheat quality measure.
dough consistency ex mixer	DoughCEx	BU	Wheat quality measure.
dough consistency ex 10 mins	DoughCEx10	BU	Wheat quality measure.
degree of softening	DEGRSOFT		Wheat quality measure.
mix time	MIXTIME	s	Wheat quality measure.
temp ex mixer	TEMPEX	DegrC	Wheat quality measure.
temp ex 10 minutes	TEMPEX10	DegrC	Wheat quality measure.
gross water to 410BU	GROSSH20		Wheat quality measure.
manual stickiness	MANUSTICK		Wheat quality measure.

Collection of trait names and abbreviations used in the JIC WGIDB (John Innes Centre Wheat Genetic Improvement Database) – collated by Luzie U. Wingen

grain moisture content	GRH2OC		Wheat moisture content, % NIR. Wheat quality measure.
hardness Index	HARDI		Hardness Index (NIR). Wheat quality measure.
straight run extraction rate	STRRUNEX	%	Straight run extraction rate (white). Wheat quality measure.
bran finisher flour	BRANFF	%	Bran finisher flour. Wheat quality measure.
offal finisher flour	OFFALFF	%	Offal finisher flour. Wheat quality measure.
flour moisture content	FLH2OC	%	White flour Moisture content. Wheat quality measure.
flour protein content	FLPRC	%	White flour protein content (N x5.7) @14%mc. Wheat quality measure.
flour water absorption 600 line	FLH2OABS	%	White flour absorption 600 line. Wheat quality measure.
flour water absorption 14 PERC mb	FLH2OABS14	%	White flour Water absorption 14%mb. Wheat quality measure.
flour development time	FLDEVT	min	White flour development time in minutes. Wheat quality measure.
flour stability	FLSTAB	min	White flour stability. Wheat quality measure..
flour degree of softening	FLDEGRSOFT		White flour degree of softening. Wheat quality measure..
wholemeal flour water absorption 600 line	WMFH2OABS	%	Wholemeal flour absorption 600 line. Wheat quality measure.
wholemeal flour Hagberg falling number	WMFHFN	min	Wholemeal flour Alpha-amylase activity in grain is measured by the Hagberg-Perten Falling Number, a test to assess sprout damages. Wheat quality measure..
white flour protein content DMB	WIFPRCDMB	%	White flour Protein content (N x5.7) DMB. Wheat quality measure.
white flour protein loss	WIFPRLOSS		White flour Protein loss. Wheat quality measure.
grain sodium dodecylsulphate sedimentation volumn	GRSDS		A rapid measure of potential breadmaking performance.
Disease Traits			
mildew disease score	MILDS		A measurement of the degree of disease on the leaves or of the plant on a scale from 0 - 10 (0=0% of leaf area diseased, 10=100% diseased)
yellow rust disease score	YRTDS		A measurement of the degree of disease on the leaves or of the plant on a scale from 0 - 10 (0=0% of leaf area diseased, 10=100% diseased)
brown rust disease score	BRTDS		A measurement of the degree of disease on the leaves or of the plant on a scale from 0 - 10 (0=0% of leaf area diseased, 10=100% diseased)
septoria disease score	SPTDS		A measurement of the degree of disease on the leaves or of the plant on a scale from 0 - 10 (0=0% of leaf area diseased, 10=100% diseased)
Chile Physiology Traits			
booting to anthesis period	ADBDDIFF	days	Days from booting to anthesis.
emergence to anthesis Dday period	EDADTT	Ddays	TT from emergence to anthesis.
booting to anthesis Dday period	BDADTT	Ddays	TT from booting to antheis.
grain filling Dday period	GFPTT	Ddays	TT of grain filling period (anthesis to physiological maturity).
carpel weight	CARWT	mg	Carpel weight of carpel position two from the central spikelets of the mainstem spike at anthsis of Control treatment.
grain water content	GRWC	mg	stabilized value of water content of grain position two from the central spikelets of the mainstem spike at 20 days after anthesis of Control treatment.
grain dry weight at position	GRBMP	mg	Grain dry weight of grain at specified position (e.g. 1, 2, 3, 4) from the central spikelets of the main stem spike at harvest.
grain length at position	GRLGP	mm	Grain length of grain at specified position (e.g. 1, 2, 3, 4) from the central spikelets of the mainstem spike at harvest.
grain width at position	GRWDP	mm	Grain width of grain at specified position (e.g. 1, 2, 3, 4) from the central spikelets of the mainstem spike at harvest.
grain length width ratio at position	GRLGWDRP	mm	Ratio of grain length and width of grain at specified position (e.g. 1, 2, 3, 4) from the central spikelets of the mainstem spike at harvest.
grain height at position	GRHtP	mm	Grain height of grain at specified position (e.g. 1, 2, 3, 4) from the central spikelets of the mainstem spike at harvest.
grain volume at position	GRVOLP	mm3	Grain volume of grain at specified position (e.g. 1, 2, 3, 4) from the central spikelets of the mainstem spike at harvest.
Wheat Ear Sterility Project			
mean Sterility as percentage of all florets	AVGSTERPF		
mean Sterility as percentage of outer florets	AVGSTERPOF		
all Years_GS on Date	AVGGS		Average growth stage of all trials on named date.
date of GS	GSD		The date when plant is in a particular growth stage. Needs a growth stage number.
days ahead-behind parent	DabP	days	Days a plant is ahead or behind a parent. Needs the parent as qualifier
days GS was ahead of date	dGSaD	days	Days a particular growth stage is ahead of a particular date. Needs growth stage and date as qualifier.
GS on date	GSoD		Growth stage at a particular date. Needs date as qualifier.
potential grain number	potGRNBpSP		What is this? Average potential grain number per spike?
sterile florets per ear	stFLNBpEAR		The average number of sterile florets per ear.
maturity	MATU		Overall maturity of the plant scored as early, moderate or late (e,m,l)
night Temp at GS	NTEMPGS	DegrC	Night temperatur at a particular growth stage. Needs a qualifier date.
percentage sterility	STERPER	%	Percentage of florets which are sterile of all florets.
percentage sterility excluding middle florets	STERPERNMF	%	Percentage of florets which are sterile of all florets but the middle florets.
percentage sterility outer florets	STERPEROF	%	Percentage of outer florets which are sterile of all florets but the middle florets.
sterility field score	STERFS		Sterility field score (1-9) at GS87.
sterility field score early sown plants	STERFSESP		Sterility field score (1-9) at GS87 of early sown plants.
sterility lab description	STERLD		Sterility initial lab description.
sterility lab score	STERLS		Sterility lab score (1-9).
sterility lab score JIC	STERLSJIC		Sterility lab score (1-9) JIC samples.
days after earliest growth stage	DAEGSD	day	The number of days after the date when the first plant or plot reached a specified growth stage in the population.

Example 8

Field trait measurements:

Weekly:
Height from March to start of senescence
SPAD (leaf chlorophyll) from May to nearly end of senescence)
Zadoks growth stage from tiller 1 to grain maturity
Senescence (from start to end of senescence)

Fortnightly:
LAI (from May to start senescence)
Fluorescence (from May to start senescence)

One off measurements:
Linear density – planting density, any time after plant emergence
Number of tillers (2 weeks after anthesis)
Flag leaf width (2 weeks after anthesis)
Peduncle length (2 weeks after anthesis)
FLiR thermal imaging (once)
Li-Cor photosynthesis analysis (within 2 weeks before and 2 weeks after anthesis, Stomatal conductance, Ci, Pmax, Compensation point, etc etc)
Rubisco activity (leaf samples taken at the same time as Li-Cor)

ABA leaf samples after good (>2 weeks dry weather)
Metabolite samples at leaf emergence, anthesis and 7 days after anthesis (7 DPA)

Soil measurements:
The amount of water each time irrigation was used
Water content of soil using PR probe, logged hourly or weekly depending on plot
Soil water tension at 4 depths, logged hourly
Penetrometer soil resistance (4-5 per year)
Electrical resistance (tomography) (4-5 per year, April onwards)
Soil surface profiles
Electromagnetic Induction (once)
Air permeability (once)
Soil acoustics (once)
Crop acoustics (once)

Post-Harvest measurements:
TGW
^{13}C grain
Grain nitrogen
Straw nitrogen
Grain yield ($t.ha^{-1}$)
Straw yield ($t.ha^{-1}$)
Grain and dry weight
Straw fresh and dry weight
Harvest index