Wheat varietal differences in below ground biomass revealed by a semi-quantitative estimation of wheat root DNA in soil samples.

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Supplementary materials

Part 1 Supplementary Tables

Table 1: Varieties grown in trials 2012, 2014 and 2015. Additional data (including seasonality, *Rht*, 1B/1R and *Ppd*) for varieties included in the2014 and 2015 trials were provided by Alison Bentley (*pers. comm*).

Variety	2012 trial	2014 and 2015 trial	Spring growth habit	Rht status	Rye translocation	Photoperiod sensitivity
Alchemy	*	*	winter	Rht2	No Insertion	Photoperiod Sensitive
Avalon		*	winter	Rht2	No Insertion	Photoperiod Sensitive
Beaver		*	winter	Rht2	No Insertion	Photoperiod Sensitive
SHW Xi19 / (Xi19 // SHW-218) >18		*	No information	No information	No information	No information
SHW Xi19 / (Xi19 // SHW-218) >19		*	No information	No information	No information	No information
Buster		*	winter	Rht2	No Insertion	Photoperiod Sensitive
Cadenza		*	alternative	Tall	No Insertion	Photoperiod Sensitive
Cappelle Deprez		*	winter	Tall	No Insertion	*Ppd-A1b* (putative loss of function)
Glasgow		*	winter	Rht2	No Insertion	
Hereward		*	winter	Rht2	No Insertion	
Mercia		*	winter	Tall	No Insertion	*Ppd-D1b* (null allele)
Mercia Rht8		*	winter	Rht8	No Insertion	
Mercia Rht8 D1B		*	winter	Rht2	No Insertion	
Norman		*	winter	Rht2	No Insertion	
Oakley	*	*	winter	Rht1	No Insertion	
Paragon		*	spring	Tall	No Insertion	Photoperiod Sensitive
Rialto		*	winter	Rht2	1RS	Photoperiod Sensitive
Robigus		*	winter	Rht1	No Insertion	Photoperiod Sensitive
Savannah		*	winter	Rht2	1RS	
Soissons		*	winter	Rht1	No Insertion	PI (*Ppd-D1a*)
Spark		*	winter	Tall	No Insertion	Photoperiod Sensitive
Viscount	*					
Xi19		*	alternative	Rht2	No Insertion	

Table 2: Root Biomass Density from soil cores collected from the 2014 and 2015 trials.

Tables of means
Variate: ug/g dry soil

		Year	
Variety	OverAll	2014	2015
Alchemy	37.32	52.19	22.45
Avalon	58.02	31.71	84.33
Beaver	17.42	21.16	13.67
SHW Xi19 / (Xi19 // SHW-218) >18	27.02	24.31	29.73
SHW Xi19 / (Xi19 // SHW-218) >19	66.78	37.85	95.70
Buster	20.20	23.11	17.28
Cadenza	30.92	55.91	5.92
Cappelle D	26.30	23.87	28.72
Glasgow	14.98	16.84	13.12
Hereward	15.47	19.41	11.52
Mercia	12.99	19.32	6.67
Mercia Rht8	24.15	16.47	31.84
Mercia Rht8 D1B	15.87	15.55	16.19
Norman	46.68	46.70	46.66
Oakley	17.89	25.68	10.10
Paragon	44.37	40.55	48.19
Rialto	16.68	27.81	5.56
Robigus	11.61	12.29	10.93
Savannah	37.15	29.04	45.26
Soissons	30.27	23.71	36.83
Spark	36.45	61.49	11.41
Xi19	81.87	40.22	123.52
Mean	31.38	30.24	32.53

Table 2: (continued)

Tables of means

Variate: ug/g dry soil

	Depth			
Variety	0-250	250-500	500-750	750-1000
Alchemy	93.65	27.04	22.00	6.58
Avalon	116.83	69.76	35.05	10.44
Beaver	40.47	15.86	7.18	6.17
SHW Xi19 / (Xi19 // SHW-218) >18	77.07	28.01	6.26	3.25
SHW Xi19 / (Xi19 // SHW-218) >19	147.75	67.24	33.02	19.10
Buster	44.32	17.58	16.60	2.28
Cadenza	50.81	28.54	27.69	16.62
Cappelle D	68.64	22.93	11.79	1.82
Glasgow	32.39	17.38	5.41	4.74
Hereward	33.19	16.27	7.22	5.18
Mercia	32.10	11.95	5.78	2.16
Mercia Rht8	63.28	22.51	6.99	3.83
Mercia Rht8 D1B	44.11	21.51	0.56	2.71
Norman	110.30	46.19	19.69	10.54
Oakley	44.39	18.17	4.52	4.47
Paragon	106.52	48.62	20.39	1.95
Rialto	35.06	25.10	6.07	0.50
Robigus	36.44	9.04	2.33	1.37
Savannah	85.36	44.05	15.52	3.67
Soissons	44.89	40.00	28.18	8.03
Spark	91.68	42.47	7.77	3.87
Xi19	216.17	90.83	9.90	10.58
Mean	73.43	33.23	13.63	5.24

Table 2: (continued)

Tables of means

Variate: ug/g dry soil

	Year							
	Depth							
	2014				2015			
Variety	0-250	250-500	500-750	750-1000	0-250	250-500	500-750	750-1000
Alchemy	146.34	29.75	27.59	5.09	40.97	24.33	16.42	8.07
Avalon	76.65	31.74	10.79	7.66	157.00	107.78	59.30	13.22
Beaver	46.87	16.43	11.55	9.80	34.06	15.29	2.81	2.55
SHW Xi19 / (Xi19 // SHW-218) >18	68.86	18.36	8.92	1.11	85.28	37.65	3.60	7.61
SHW Xi19 / (Xi19 // SHW-218) >19	94.46	41.00	5.40	10.54	201.03	93.47	60.65	27.65
Buster	47.48	13.93	29.82	1.22	41.15	21.23	3.39	3.35
Cadenza	85.19	51.33	54.24	32.88	16.43	5.76	1.15	0.36
Cappelle D	58.12	18.09	13.34	5.93	79.15	27.77	10.25	2.28
Glasgow	31.99	18.61	8.75	8.01	32.79	16.14	2.07	1.47
Hereward	42.50	14.84	12.47	7.83	23.88	17.70	1.97	2.53
Mercia	43.23	14.82	10.72	8.51	20.97	9.07	0.83	4.20
Mercia Rht8	34.47	16.89	8.35	6.16	92.09	28.13	5.63	1.50
Mercia Rht8 D1B	35.58	17.24	6.82	2.58	52.65	25.78	5.70	7.99
Norman	97.19	37.83	31.70	20.07	123.42	54.54	7.68	1.00
Oakley	58.18	20.74	11.45	12.34	30.60	15.61	2.41	3.39
Paragon	101.76	45.13	11.02	4.29	111.27	52.12	29.76	0.39
Rialto	49.30	40.58	16.12	5.23	20.82	9.62	3.97	4.23
Robigus	31.70	8.81	8.01	0.65	41.19	9.28	3.35	3.40
Savannah	72.47	20.64	19.23	3.81	98.25	67.47	11.80	3.53
Soissons	28.74	35.67	18.46	11.99	61.03	44.33	37.90	4.06
Spark	172.25	58.31	8.23	7.16	11.11	26.62	7.31	0.59
Xi19	111.88	24.74	7.70	16.58	320.46	156.91	12.10	4.59
Mean	69.78	27.07	15.49	8.61	77.07	39.39	11.78	1.86

Table 3: Estimates for the soil depths (mm) containing 50 % and 95% of all roots (D_{50} and D_{95}) for each variety (Shenck & Jackson, 2005).

	2014 / 5		2014		2015	
Variety	**D_{50}**	**D_{95}**	**D_{50}**	**D_{95}**	**D_{50}**	**D_{95}**
Alchemy	-492	-936	-514	-926	-325	-963
Avalon	-597	-952	-617	-955	-589	-951
Beaver	-482	-872	-481	-835	-485	-919
SHW Xi19 / (Xi19 // SHW-218) >18	-274	-738	-359	-905	-233	-593
SHW Xi19 / (Xi19 // SHW-218) >19	-613	-976	-509	-928	-668	-980
Buster	-398	-961	-273	-976	-492	-831
Cadenza	-573	-953	-635	-964	-325	-695
Cappelle_D	-451	-827	-435	-951	-457	-735
Glasgow	-305	-907	-179	-945	-460	-855
Hereward	-392	-904	-328	-819	-510	-950
Mercia	-458	-759	-489	-815	-419	-690
Mercia_Rht8	-359	-887	-360	-913	-358	-873
Mercia_Rht8_D1	-567	-915	-528	-830	-606	-951
Norman	-380	-782	-476	-838	-316	-729
Oakley	-442	-844	-466	-926	-411	-672
Paragon	-514	-812	-521	-857	-510	-777
Rialto	-312	-903	-216	-859	-587	-937
Robigus	-448	-841	-535	-918	-364	-719
Savannah	-453	-695	-561	-918	-443	-672
Soissons	-486	-893	-601	-964	-452	-824
Spark	-488	-966	-464	-961	-662	-980
Xi19	-620	-948	-568	-911	-637	-955

Table 4: These regional (East Anglian) values use the latest available data from the UK climate network of observing stations. They show the Met Office's best assessment of the weather that was experienced across the UK. The columns headed 'Anom' (anomaly) show the differences from or percentages of the long-term averages.

Regional values compared with 1981 to 2010 averages

(Act=Actual, Anom=Anomaly)

	Max temp		Min temp		Mean temp		Sunshine		Rainfall		Days rain ≥1 mm		Days air frost	
	Act	Anom	Act	Anom	Act	Anom	Act	Anom	Act	Anom	Act	Anom	Act	Anom
	°C	°C	°C	°C	°C	°C	hours	%	mm	%	days	days	days	days
Nov-13	9.5	-0.7	3.5	-0.5	6.5	-0.6	75.8	111.0	53.0	86.0	11.6	0.5	2.9	-2.0
Dec-13	9.3	2.0	2.6	0.9	6.0	1.4	62.5	125.0	59.2	109.0	12.1	1.3	3.1	-6.9
Jan-14	8.8	1.8	2.8	1.4	5.8	1.6	65.4	111.0	102.3	192.0	22.5	11.2	4.8	-5.2
Feb-14	9.7	2.3	3.5	2.4	6.6	2.4	102.1	132.0	73.4	185.0	13.7	4.6	0.4	-10.1
Mar-14	13.1	2.7	3.3	0.4	8.2	1.6	157.8	143.0	21.7	50.0	5.9	-4.1	5.1	-1.0
Apr-14	15.2	2.1	6.3	2.2	10.7	2.1	156.0	97.0	19.5	44.0	6.3	-3.2	1.1	-2.2
May-14	17.3	0.8	8.5	1.3	12.9	1.1	186.1	95.0	93.1	191.0	12.7	3.9	0.4	-0.3
Jun-14	20.4	1.3	10.4	0.9	15.4	1.1	211.2	108.0	37.6	73.0	7.7	-0.7	0.0	0.0
Winter 13/14	9.3	2.0	2.9	1.5	6.1	1.8	229.9	123.0	234.9	159.0	48.4	17.1	8.4	-22.3
Spring 14	15.2	1.9	6.0	1.3	10.6	1.6	500.0	107.0	134.4	98.0	24.9	-3.4	6.6	-3.4
Nov-14	11.7	1.5	6.0	2.0	8.9	1.8	52.2	77.0	87.9	143.0	14.0	2.9	2.6	-2.3
Dec-14	8.3	0.9	2.4	0.6	5.3	0.8	79.7	159.0	50.3	92.0	9.2	-1.7	9.8	-0.2
Jan-15	7.6	0.5	1.0	-0.3	4.3	0.1	75.4	128.0	55.4	104.0	12.7	1.4	11.3	1.3
Feb-15	7.3	-0.1	1.0	0.0	4.2	-0.1	88.7	114.0	39.5	99.0	8.3	-0.8	8.8	-1.8
Mar-15	10.8	0.4	2.8	0.0	6.8	0.2	147.2	133.0	25.1	58.0	7.2	-2.8	4.2	-1.9
Apr-15	14.3	1.2	4.0	-0.1	9.2	0.6	224.5	139.0	21.8	49.0	6.5	-3.0	1.6	-1.6
May-15	16.4	-0.2	6.9	-0.2	11.6	-0.2	206.0	105.0	51.3	105.0	11.1	2.3	0.8	0.2
Jun-15	20.1	0.5	9.3	-0.7	14.7	0.0	228.3	120.0	22.0	42.0	6.1	-3.0	0.0	0.0
Winter 14/15	7.8	0.5	1.5	0.1	4.6	0.3	239.6	129.0	144.4	98.0	29.9	-1.3	30.6	0.0
Spring 15	13.8	0.5	4.5	-0.2	9.2	0.2	555.2	119.0	94.9	69.0	24.1	-4.3	7.1	-2.8

Supplementary Materials parts 2: Trial sites

ADAS Code	XAA1549
Trial title	NIAB rooting trial
ADAS site	Terrington
Host farmer/grower	Large
Field	Burkees
Grid ref.	TF 50061 18404
Year	2013/2014
Plot length (m)	12.00
Plot width (m)	2.00

Host farmer/grower:	Large
Contact number:	?

Plan created by:	AM
Plan version date:	02/12/2013
Plan checked by:	sm

N

Varieties

1 Alchemy
2 Avalon
3 Beaver
4 Buster
5 Cadenza
6 Cappelle D
7 Glasgow
8 Hereward
9 Mercia
10 Mercia-Rht8
11 Mercia-Rht8-D1b
12 Norman
13 Oakley
14 Paragon
15 Rialto
16 Robigus
17 Savannah
18 Soissons
19 Spark
20 Xi19
21 xs-218>D18-2 Bulk 18
22 xs-218>D19-3 Bulk 22

PLOT	DISCARD	DISCARD	66	67	68	69	70	71	72	73	74	75	76	77	78	DISCARD	DISCARD
BLOCK	DISCARD	DISCARD		3	3	3	3	3			3	3	3	3		DISCARD	DISCARD
VARIETY	DISCARD	DISCARD		4	16	13	20	11			14	22	2	17		DISCARD	DISCARD
PLOT	DISCARD	DISCARD	53	54	55	56	57	58	59	60	61	62	63	64	65	DISCARD	DISCARD
BLOCK	DISCARD	DISCARD	3	3	3	3	3	3	3	3	3	3	3	3	3	DISCARD	DISCARD
VARIETY	DISCARD	DISCARD	3	8	7	15	9	10	12	21	5	18	6	19	1	DISCARD	DISCARD
PLOT	DISCARD	DISCARD	40	41	42	43	44	45	46	47	48	49	50	51	52	DISCARD	DISCARD
BLOCK	DISCARD	DISCARD	2	2	2			2	2		2	2	2	2	2	DISCARD	DISCARD
VARIETY	DISCARD	DISCARD	13	16	15			9	11		21	14	5	1	17	DISCARD	DISCARD
PLOT	DISCARD	DISCARD	27	28	29	30	31	32	33	34	35	36	37	38	39	DISCARD	DISCARD
BLOCK	DISCARD	DISCARD	2	2	2	2	2	2	2	2	2	2	2	2		DISCARD	DISCARD
VARIETY	DISCARD	DISCARD	8	7	4	3	12	20	10	6	22	2	18	19		DISCARD	DISCARD
PLOT	DISCARD	DISCARD	14	15	16	17	18	19	20	21	22	23	24	25	26	DISCARD	DISCARD
BLOCK	DISCARD	DISCARD	1	1	1	1	1	1	1	1	1	1	1	1		DISCARD	DISCARD
VARIETY	DISCARD	DISCARD	4	15	8	7	11	9	20	2	18	5	14	17		DISCARD	DISCARD
PLOT	DISCARD	DISCARD	1	2	3	4	5	6	7	8	9	10	11	12	13	DISCARD	DISCARD
BLOCK	DISCARD	DISCARD		1	1	1	1	1			1	1	1	1	1	DISCARD	DISCARD
VARIETY	DISCARD	DISCARD		13	3	16	10	12			6	21	22	1	19	DISCARD	DISCARD

12.0m

2.0m

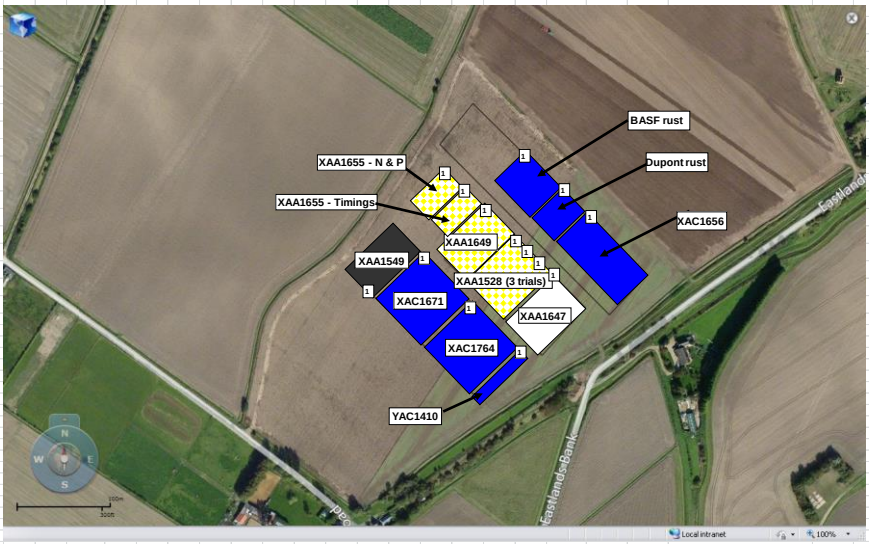


Figure 1

ADAS Code	XAA1549
Trial title	NIAB rooting trial
ADAS site	Terrington
Host farmer/grower	Ray Gadsby
Field	Willow Tree
Grid ref.	TF 53735 23887
Year	2014/2015
Plot length (m)	10.00
Plot width (m)	2.00

Host farmer/grower:	Ray Gadsby
Contact number:	?

Plan created by:	NIAB
Plan version date:	26/03/2015
Plan checked by:	sm

Discards = Crusoe

Drilled 26/09/14

N

PLOT	DISCARD	DISCARD	66	67	68	69	70	71	72	73	74	75	76	77	78	DISCARD	DISCARD
BLOCK			discard	3	3	3	3	3	discard	discard	3	3	3	3	discard		
VARIETY				4	16	13	20	11			14	22	2	17			
PLOT	DISCARD	DISCARD	53	54	55	56	57	58	59	60	61	62	63	64	65	DISCARD	DISCARD
BLOCK			3	3	3	3	3	3	3	3	3	3	3	3	3		
VARIETY			3	8	7	15	9	10	12	21	5	18	6	19	1		
PLOT	DISCARD	DISCARD	40	41	42	43	44	45	46	47	48	49	50	51	52	DISCARD	DISCARD
BLOCK			2	2	2	discard	discard	2	2	discard	2	2	2	2	2		
VARIETY			13	16	15			9	11		21	14	5	1	17		
PLOT	DISCARD	DISCARD	27	28	29	30	31	32	33	34	35	36	37	38	39	DISCARD	DISCARD
BLOCK			2	2	2	2	2	2	2	2	2	2	2	2	discard		
VARIETY			8	7	4	3	12	20	10	6	22	2	18	19			
PLOT	DISCARD	DISCARD	14	15	16	17	18	19	20	21	22	23	24	25	26	DISCARD	DISCARD
BLOCK			1	1	1	1	1	1	1	1	1	1	1	1	discard		
VARIETY			4	15	8	7	11	9	20	2	18	5	14	17			
PLOT	DISCARD	DISCARD	1	2	3	4	5	6	7	8	9	10	11	12	13	DISCARD	DISCARD
BLOCK			discard	1	1	1	1	1	discard	discard	1	1	1	1	1		
VARIETY				13	3	16	10	12			6	21	22	1	19		

12.0m

2.0m

Varieties

1	Alchemy
2	Avalon
3	Beaver
4	Buster
5	Cadenza
6	Cappelle D
7	Glasgow
8	Hereward
9	Mercia
10	Mercia-Rht8
11	Mercia-Rht8-D1b
12	Norman
13	Oakley
14	Paragon
15	Rialto
16	Robigus
17	Savannah
18	Soissons
19	Spark
20	Xi19
21	xs-218>D18-2 Bulk 18
22	xs-218>D19-3 Bulk 22

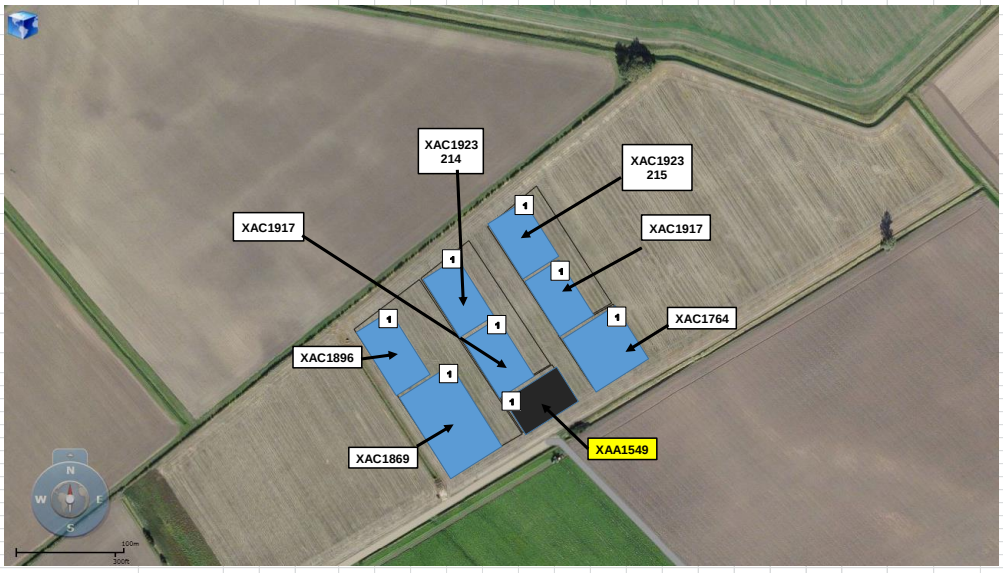


Figure 2

Supplementary Materials Part 3

Descriptions of soil found at the trial sites used in this study
Soil data for each site is taken from the LANDIS Land information system (Landis, 2014)

https://www.landis.org.uk/services/soilsguide/mapunit_list.cfm?sorttype_association=map_unit_name

0812b WISBECH (Terrington 2012 and 2014)

Soil and site characteristics
Deep stoneless calcareous coarse silty soils. Groundwater usually controlled by ditches or pumps. Flat land with low ridges. Risk of wind erosion locally.

Geology
Marine alluvium

Cropping and Land Use
Sugar beet, potatoes, field vegetables horticultural crops and cereals in the Fens; grassland and some cereals in moist districts.

Covers 898 km^2 in England and Wales

Soilscapes Classification

21 Loamy and clayey soils of coastal flats with naturally high groundwater

Detailed Description

The Wisbech association, on stoneless marine alluvium, covers 874 km^2 in England and Wales, of which 546 km^2 fringes the Wash. The remainder occurs on the Lancashire and Cumbrian coasts and in the Mersey, Ribble and Dee estuaries and near the mouth of the river Winster where it discharges into Morecambe Bay. It consists mainly of coarse silty calcareous alluvial gley soils, Wisbech series and gleyic brown calcareous alluvial soils belonging to the Romney series. Other soils include fine silty Agney and Blacktoft, and the silty over clayey Stockwith series. The association is restricted to the Dee estuary where about half the soils are coarse silty, some containing much fine sand. They were formerly mapped as Dee series. Romney soils are infrequent.

The association is extensive in the silt fenland around the Wash. It occurs mainly along present and former river courses and on ground reclaimed from saltings. Wisbech soils often occur on land reclaimed during the last century so they are less mature than Romney soils and have a less well developed subsoil structure with the depositional laminations often still recognizable below 50 cm depth. The association is frequently bounded to seaward by the Agney association and often passes inland to the Wallasea 2 association. The variation in soil texture across these three associations reflects depositional sequences in the marine alluvium. A discontinuous arc of higher ground, some 3 m above the general marsh level, called toft or townland, runs through the association from Wainfleet All Saints through Holbeach to West

Lynn. This land, 3 to 15 km inland from the present coastline of the Wash, contains more Romney soils than elsewhere. The earliest settlements were founded on this natural feature which was built up locally by the addition of silty waste from a medieval salt industry. Salt making sites often have disturbed soils containing ash and charcoal. Blacktoft soils, which chiefly occur on the fringes of the mapped areas, are uncommon in Lincolnshire.

The soils cover only 4 km² in Cumbria, along the lower reaches of the river Winster near Lindale where coarse silty alluvium overlies a raised beach. The Wisbech soils here, unlike those elsewhere, often have fine sandy horizons at 70 to 90 cm depth.

Soil Water Regime

The soils are waterlogged for long periods in winter (Wetness Class IV), where there has been little improvement in land drainage and the soil mottling reflects the current water regime. Where there are ditches, the soils are only occasionally waterlogged (Wetness Class II). Around the Wash, land drainage is controlled by an efficient system of main drainage channels, ditches and pumps which cope adequately with the naturally high groundwater. Because both Wisbech and Romney soils are very permeable they are well drained (Wetness Class I) and mottling in Wisbech and Romney soils is a relic feature reflecting the soil moisture regime prior to drainage. The soils are non-droughty for arable crops but Romney soils are slighty droughty for grass.

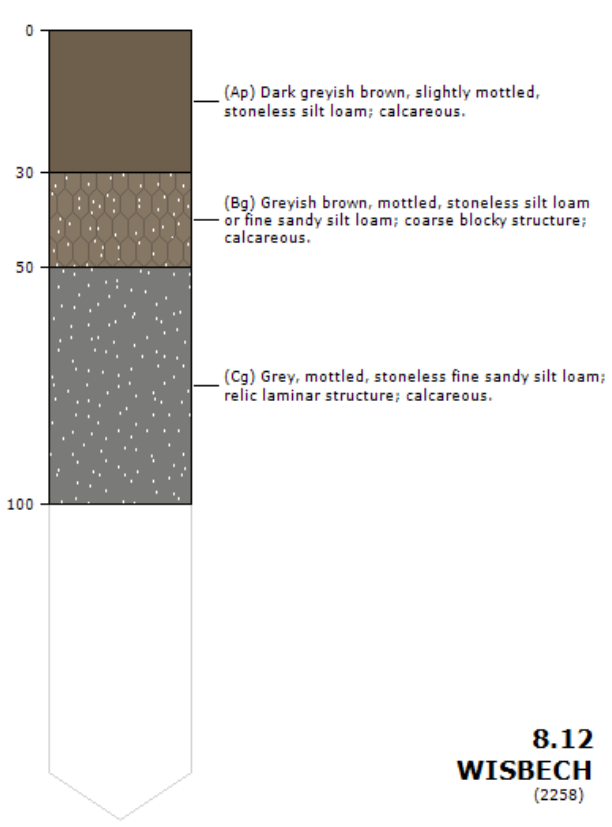
Cropping and Land Use

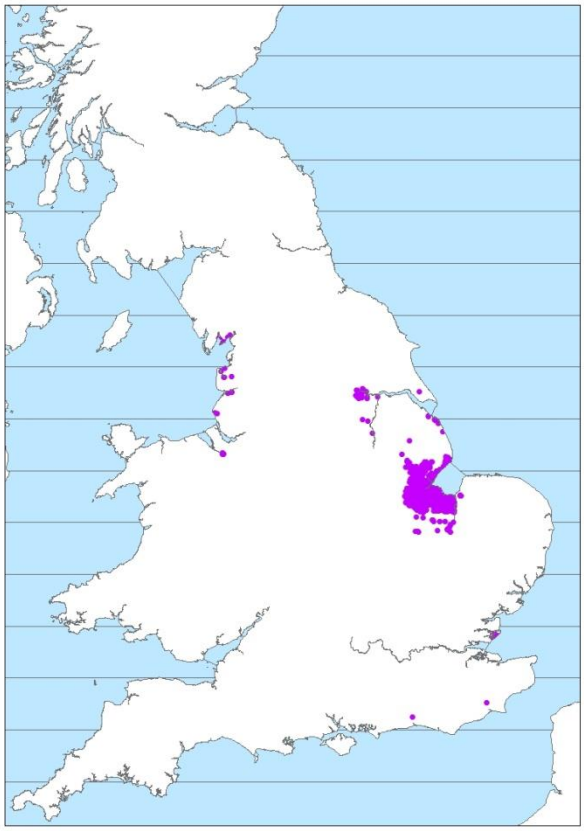
As most of the soils have not been effectively drained in the Dee estuary, they are under permanent grass but where drained are used mainly for winter cereals. The soils tend to erode easily when cultivated and seedbeds are often blown away, necessitating redrilling, or the seedlings are damaged by the abrasive sand particles, causing a reduction of yield. Where the soils have not long been reclaimed or have been in permanent grass for a long period phosphorus fertilizers are usually needed. Wisbech and Romney soils have permeable horizons throughout and are easily worked if groundwater levels are controlled by ditches and/or pumping. Surface capping, which causes delay in seedling emergence, is common, particularly when organic matter levels are low. Subsurface compaction can be caused by ploughing and sometimes by rotary cultivators, which are often used to produce fine seed beds, but is easily remedied by shallow subsoiling. However, because of compaction, the association is not suitable for direct drilling as there is substantial risk of yield loss, especially when crops are spring sown. The main crops are sugar beet, potatoes, brassicas, winter cereals, carrots, oilseed rape, peas and beans. Many different high value, often labour-intensive, crops are also grown including onions, celery, flower bulbs and spinach. The toft land between Wainfleet and West Lynn is very valuable and capable of producing two crops annually, or three crops in two years. These soils have had a long history of intensive cultivation and they have naturally high levels of available phosphorus and potassium. Most are naturally rich in calcium carbonate but the soils are sometimes limed to counteract club root in brassicas.

8.12 WISBECH (wT) (2258)

Major soil group:	08 ground-water gley soils	Seasonally waterlogged soils affected by a shallow fluctuating groundwater-table. They are developed mainly within or over permeable material and have prominently mottled or greyish coloured horizons within 40 cm depth Most occupy low-lying or depressional sites.
Soil Group:	1 alluvial gley soils	With distinct topsoil, in loamy or clayey recent alluvium more than 30 cm thick.
Soil Subgroup:	2 calcareous alluvial gley soils	(loamy with calcareous subsoil)
Soil Series:		light silty marine alluvium

Brief Profile Description





0532a BLACKTOFT (Terrington 2015)

Detailed Description

The Blacktoft association is dominated by calcareous fine silty soils in marine alluvium. It is widespread by the Humber in Northern England and occurs also in Eastern England in the Fens near King's Lynn and, in the South West, beside the Severn estuary in Somerset and Avon.

Blacktoft soils which cover two thirds of the land, are fine silty, gleyic brown calcareous alluvial soils with faint to distinct subsoil mottling. They are stoneless, usually moderately well structured and often pass downwards into laminated silt loam or clay. In other places they overlie peat or clay at about 1.5 m depth. The Romney series, also gleyic brown calcareous alluvial soils, rarely forms more than one sixth of the association. It often has weak structure, is usually coarse silty throughout and becomes increasingly mottled and laminated downwards. There is a small but variable proportion of clayey soils, the most common being the slowly permeable strongly mottled calcareous Newchurch series, pelo-calcareous alluvial gley soils. Others include the similar, but non-calcareous Wallasea seriesand the better-drained non-calcareous Dymchurch series. Minor associates include the Walkerith series, where peat occurs within 80 cm depth and the wetter, fine silty Agney series.

Between the Nene and the Great Ouse near King's Lynn the alluvial silts and clays were mainly deposited in Romano-British times. The land to the north of the Sea Bank has been laid down more recently and enclosed and reclaimed within sea walls. The earliest reclamation, the Sea Bank itself, is medieval, the rest dating from the 17th century to the present day. To the south of the Sea Bank the alluvium overlies thin peaty beds, part of the Upper Peat, and below this at depths of a few metres is the Fen Clay. This slightly higher ground at 2 to 3 m O.D. was settled by the Anglo Saxons. Further inland a series of embankments was built between the eleventh and thirteenth centuries to reclaim the land from the fens to the south. In all embanked areas there is a network of old creek courses forming low ridges called rodhams. In the Blacktoft association which covers 151 km² on both sides of the Sea Bank, rodhams formed of fine silty material predominate and alternate with clayey hollows. The land ranges from between 0 and 3 m O.D., the lowest sites being furthest from the old creek courses.

Near Gloucester and Bridgwater the Blacktoft series, fine silty gleyic brown calcareous alluvial soils are the main soils, with Romney series, coarse silty gleyic brown calcareous alluvial soils, on the raised levees of the river banks. The clayey Newchurch series, pelo-calcareous alluvial gley soils, and fine silty Agney series are found further from the rivers where formerly tidal silts thin out.

The Humber estuary is flanked by two distinct tracts of the association, which covers 164 km². In the Goole district the soils were formed largely by 19th century warping, an artificial flooding and sedimentation process (Heathcote 1951). Near Sunk Island however, much land was reclaimed during the 18th and 19th centuries by means of a series of embankments, built in stages around naturally aggrading banks of tidal sediment. By this means Sunk Island was eventually joined to the mainland. The Blacktoft association contains what is known locally as heavy warp, the light warp being the soils of the Romney association. The ground is flat except for slight levees, with differences in level of 1 to 2 m along some field boundaries or

ditches marking the limit of areas reclaimed or warped at different times. Altitude varies from 2 to 5 m O.D. along the whole 50 km length of the Humber estuary, the lowest ground often being furthest from the sea. Exposure is a limitation to agriculture on Sunk Island where gales sweep from the estuary across a treeless countryside.

The typical soil pattern is simple, with large expanses consisting only of the Blacktoft series, gleyic brown calcareous alluvial soils, and rare profiles of the Agney serie. The coarse silty Romney series, gleyic brown calcareous alluvial soils, is common only locally, as for instance around the mouths of the Trent and Ouse where the association adjoins the Romney association. The clayey Newchurch, pelo-calcareous alluvial gley soils, and Wallasea series are restricted mainly to the lower, wetter margins of warpland furthest from the river, particularly around Gilberdyke and Broomfleet. A few profiles of the Dymchurch series occur on better drained sites. The Wallasea series is also more common where the association passes into older natural marine alluvium at Walling Fen and the lower Hull and Ancholme valleys.

Soil Water Regime

In most places the groundwater level is kept low, even in winter, by a system of pumped dykes. Soils therefore have a drier regime than the subsoil mottling suggests, being well drained or only occasionally waterlogged (Wetness Classes I or II). Newchurch and Wallasea series are seasonally waterlogged (Wetness Class III). Soil compaction causes surface wetness in winter but otherwise the soils are permeable. The soils have a large silt content and are thus able to hold water at tensions which can be easily utilized by plants. Available water in the rooting zone may be augmented by a capillary rise from groundwater. In the Romney series available water is generally greater than the potential soil moisture deficit and droughtiness does not affect any crop except grass, for which these soils are slightly droughty. The more clayey Blacktoft soils hold less available water and are moderately droughty for grass and slightly droughty for potatoes in a normal year. The clayey Newchurch and Wallasea soils are more droughty still.

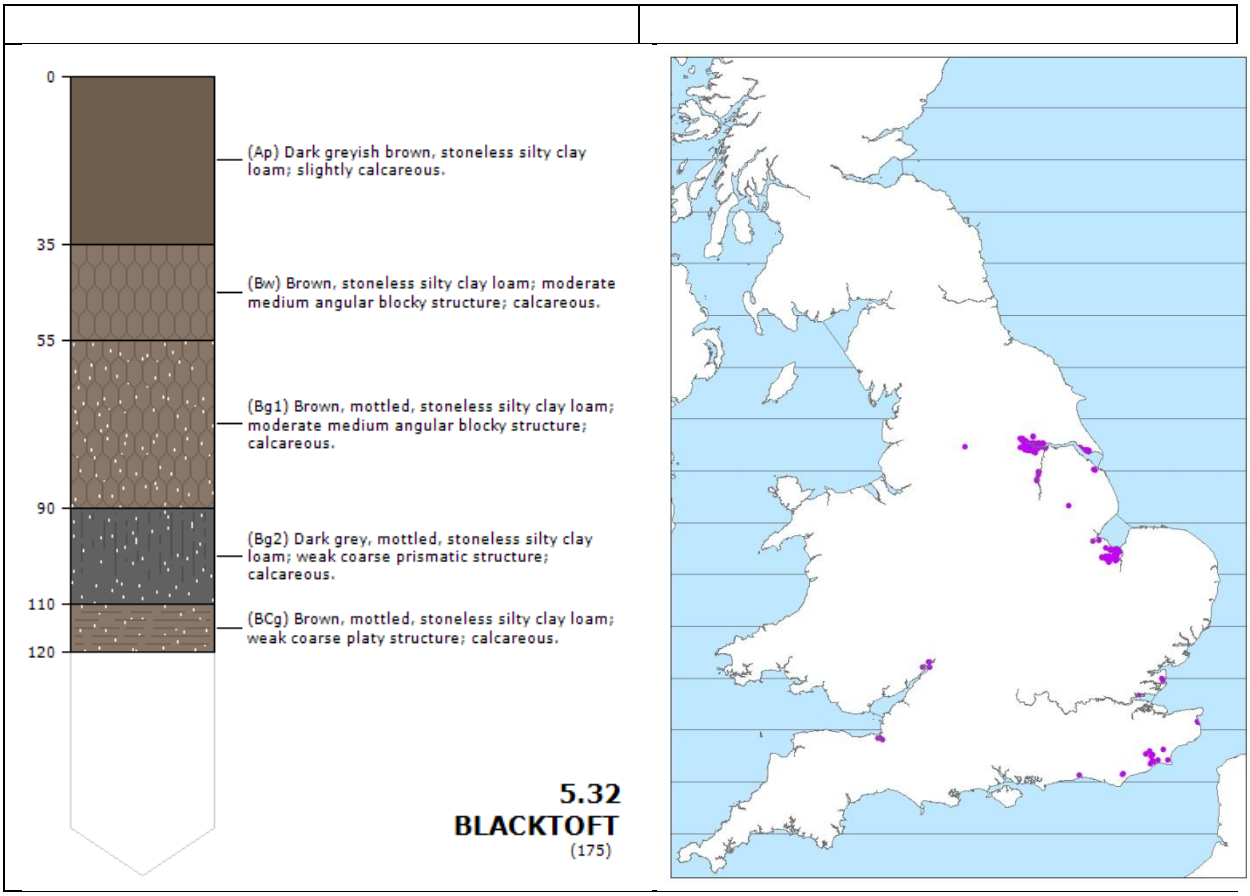
Cropping and Land Use

The Blacktoft association forms fertile land, most of it easy or moderately easy to work. More difficult clayey soils are restricted in extent, mainly on the lowest ground. Present cropping reflects the potential of the land which, although chiefly under cereals, grows potatoes, sugar beet and field vegetables. In most years there is ample opportunity for autumn tillage. Spring tillage is restricted in wet years on Newchurch and Wallasea soils. Cereals are best drilled in the autumn, leaving the suitable spring days free for sugar beet, potatoes and vegetables. Exposure is a limitation on the coast from sea winds sweeping across the treeless landscape. Weak topsoil structure is common because of the high silt and low organic matter contents, particularly in Romney soils where surface capping is likely after heavy rain if the seed bed is too fine. Subsurface compaction, causing surface wetness, is usual after sugar beet harvesting in wet conditions late in the year. This cannot be put right until the ground is fallow and dry enough for subsoiling, usually after harvest the next autumn. Direct drilling is not recommended because of the risk of compaction. The soils are well suited to large-scale vegetable growing, and there are vegetable processing plants nearby at King's Lynn. Drought is rarely a limitation and most crops except potatoes grow well without irrigation. Brussels sprouts and cabbage are grown, and need large applications of nitrogen fertilizer to yield well. Peas for freezing have increased in popularity in recent years. The soils are naturally

fertile and as most are calcareous, lime is rarely necessary except on Wallasea soils. Fertility is easily maintained. Manganese deficiency in sugar beet is possible where the pH is very high.

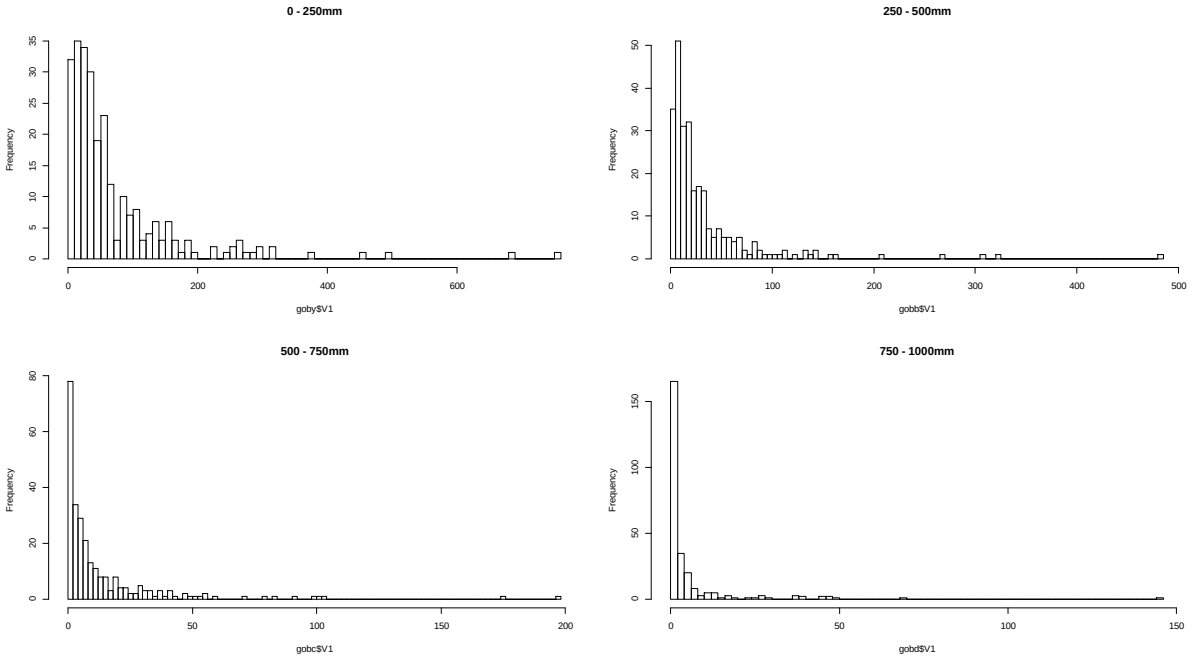
Definition

Major soil group:	05 brown soils	With dominantly brownish or reddish subsoils and no prominent mottling or greyish colours (gleying) above 40 cm depth. They are developed mainly on permeable materials at elevations below about 300 m.0.D. Most are in agricultural use.
Soil Group:	3 brown calcareous alluvial soils	In calcareous recent alluvium more than 30 cm thick.
Soil Subgroup:	2 gleyic brown calcareous alluvial soils	(faintly mottled with permeable subsoil)
Soil Series:		medium silty marine alluvium



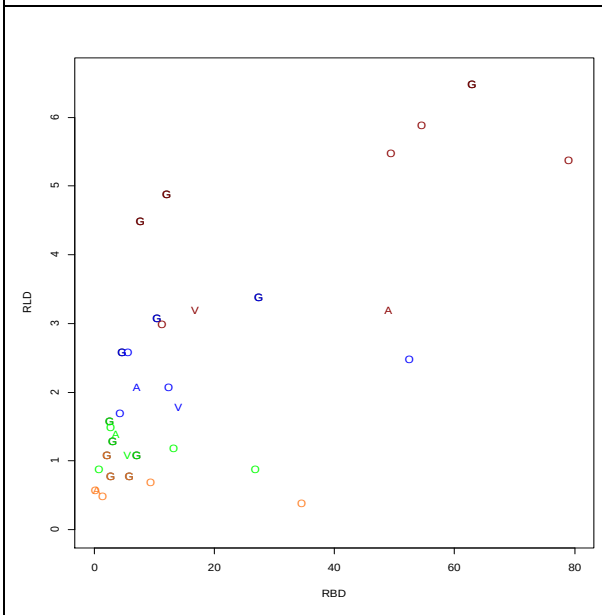
Supplementary Materials Part 4:

A: Distribution of RBD results at each of four depths

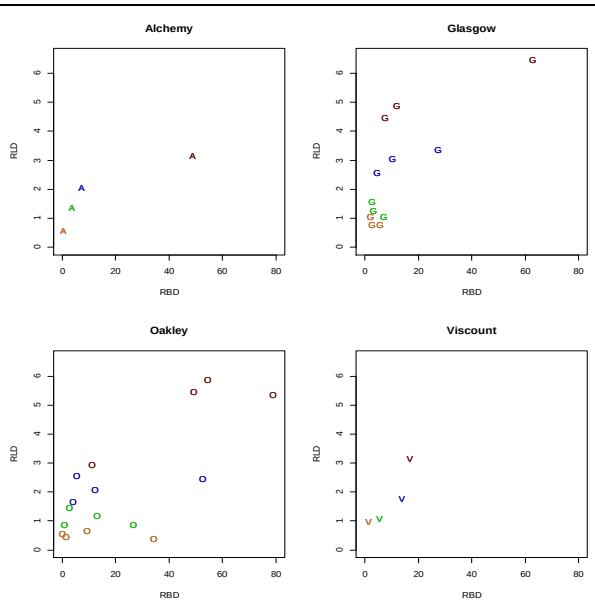


B: Distribution of RBD and RLD results for each wheat variety and depths

Correlations between root washing (RLD) and DNA based assay (RBD) showing varieties as letters and depths by colours. Depth represented in order dark red (0 – 250) > blue (250 – 500) > green (500 – 750) >orange (750 – 1000)



Varieties plotted together



Varieties plotted separately

The global correlation is	0.701, df = 34, p-value = <0.001
The Alchemy correlation is	0.892, df = 2, p-value = 0.108
The Glasgow correlation is	0.762, df =10, p-value = 0.004
The Oakley correlation is	0.746, df = 14, p-value = <0.001
The Viscount correlation is	0.900, df = 2, p-value = 0.110
The 2014 correlation is	0.674, df =22, p-value = <0.001
The 2012 correlation is	0.752, df =10, p-value = 0.004

Supplementary Materials Part 5: Processing time for a batch of samples is likely to be less than that required for soil washing assays. The time required for soil milling is approximately 20 minutes per plot (four depth horizons), for extractions of a batch of 12 plots (four depth horizons, extracted in duplicate) is approximately one day and for the DNA assay (qPCR set-up, running and data collation; four depth horizons, extracted in duplicate, PCR in triplicate) approximately half a day. Apart from a soil mill, the equipment needed is available in many research facilities.