Understanding the genetic components of deep root phenes, and developing a toolbox for breeders

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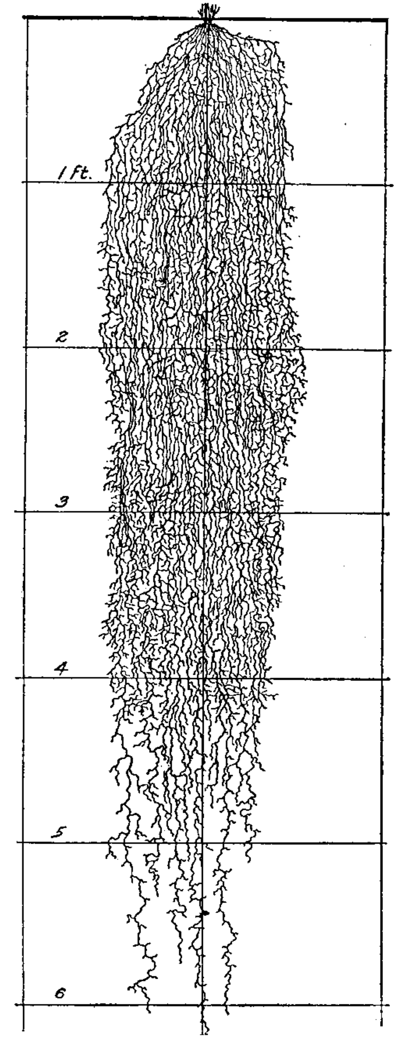

FIG. 73.—Mature root system of winter wheat.

--John E. Weaver (1926) *Root Development of Field Crops*,

IWYP122: Root^y: A root ideotype toolbox to support improved wheat yields

IWYP

International Wheat Yield Partnership

Research to Deliver Wheat for the Future

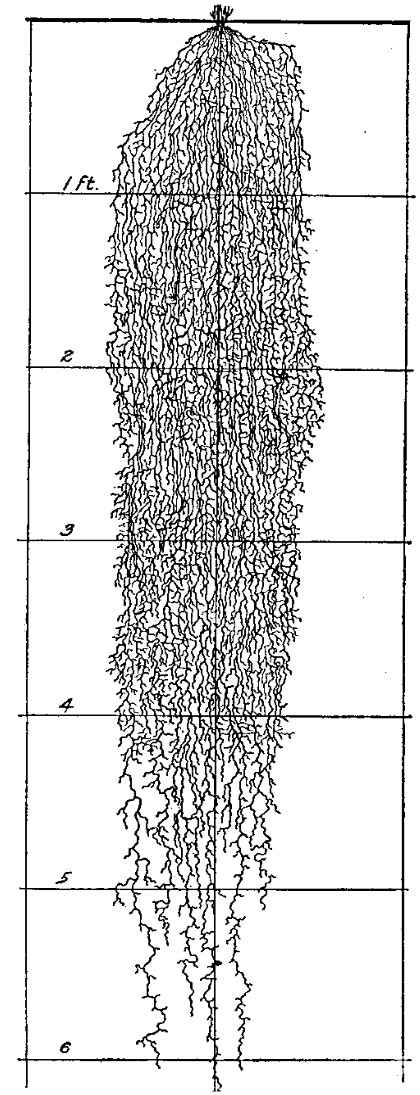

Fig. 73.—Mature root system of winter wheat.

Project Consortium

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   - Tanja Ehrlich, Onno Muller
7. CIMMYT, Texcoco, México
   - Matthew Reynolds, Francisco Pinto

Private Industry Partners

- KWS UK Ltd, UK
- Longreach Plant Breeders, Australia
- Limagrain UK Ltd, UK

Root^{y}: A root ideotype toolbox to support improved wheat yields

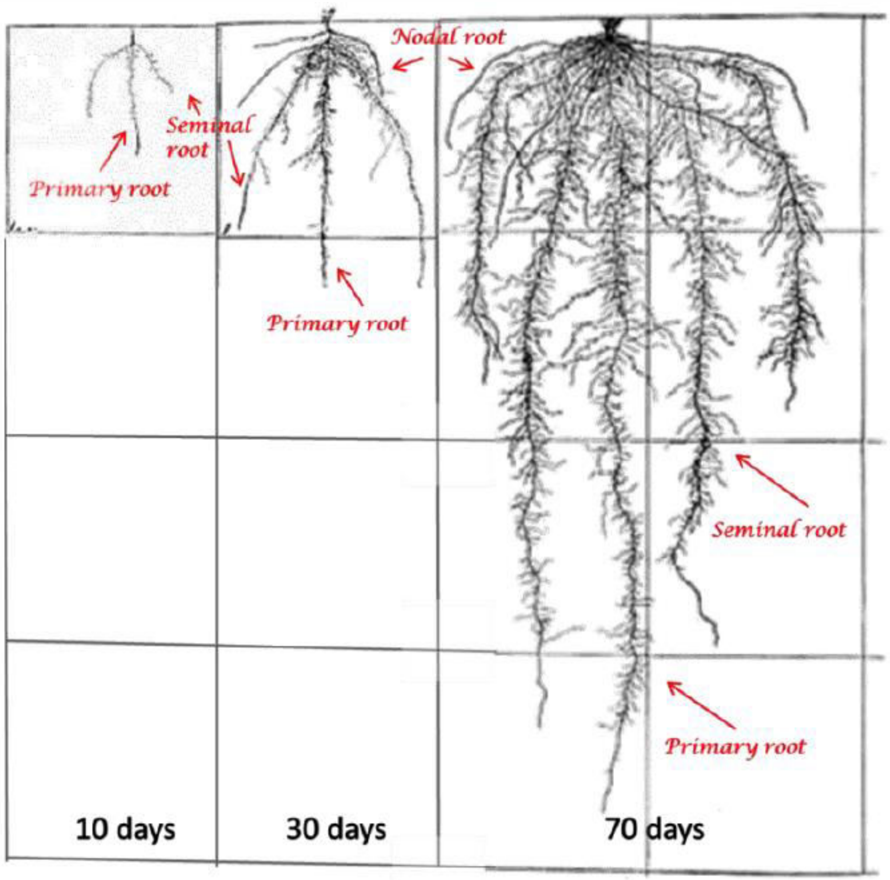
International Wheat Yield Partnership

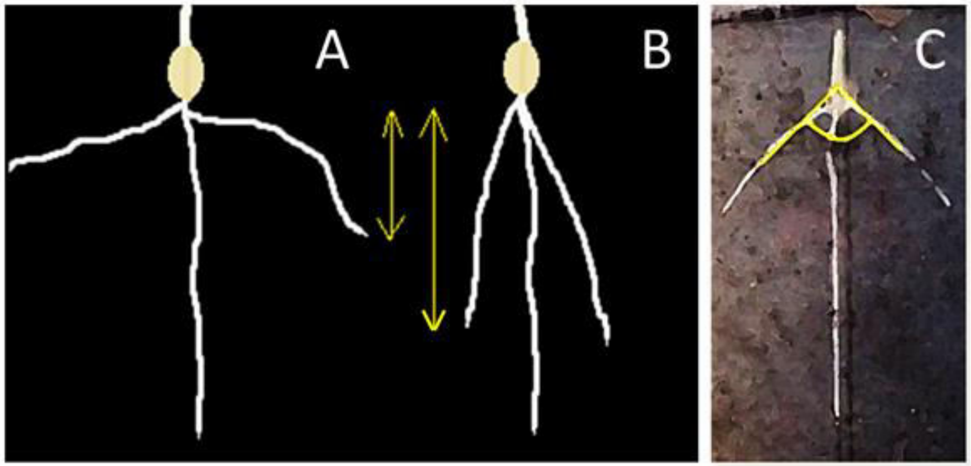
Research to Deliver Wheat for the Future

Aims of the project:

1. Provide characterised root alleles backcrossed into elite, high-yielding NW-European, Australian and CIMMYT lines
2. Provide a suite of genetic markers that can be used in various combinations to create an arsenal of root ideotypes to support high yields for a diversity of farmed environments
3. Test hypotheses on how different root phenotypes can contribute to yield potential
4. Provide know-how on advanced root phenotyping for controlled environments and field trials

Seedling root screening reveals genetic diversity for seminal root angle





- Use 202 lines of Avalon x Cadenza DH population
- Wide root angle (A) vs narrow root angle (B)
- Root angle is measured as the angle between the first pair of seminal roots (C).

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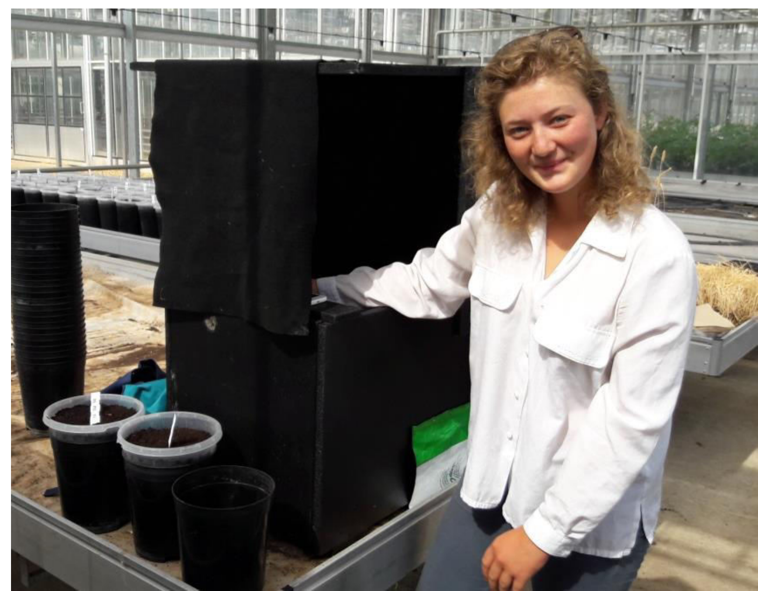
Emily Marr (NIAB/U. Cambridge

Methods: high throughput seedling root screening using the ‘clear pot’ method

Imaging box

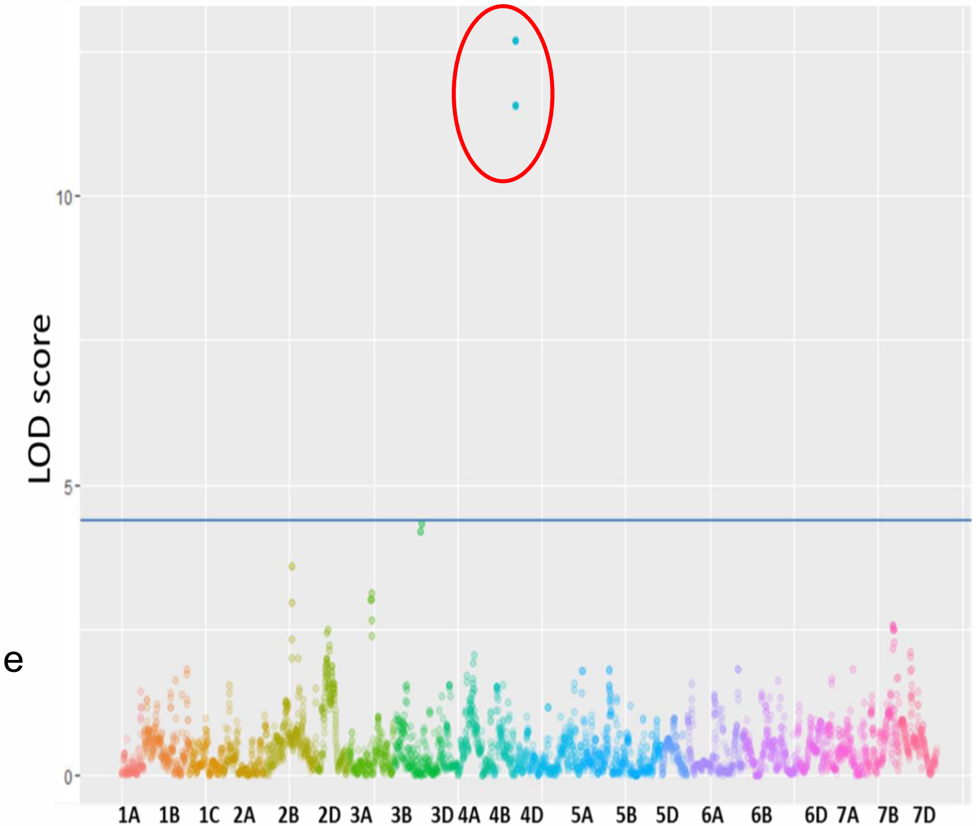


Richard et al. (2015) High-throughput phenotyping of seminal root traits in wheat. *Plant Methods* ***11, 13.***

Emily Marr (NIAB/U. Cambridge

A QTL on chromosome 4D is associated with root angle

- QTL identified by integrated composite interval mapping (ICIM)
- Only 4D QTL was consistent across 3 independent experiments
- D genome has a low marker density -> the QTL region is large.



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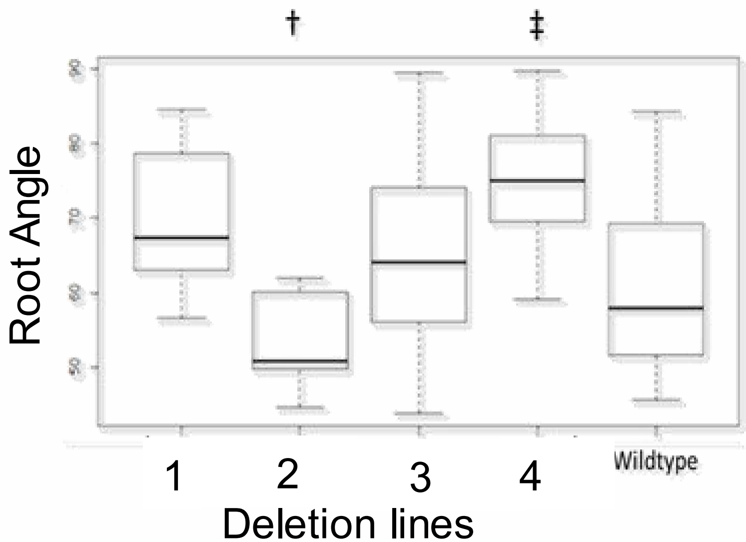
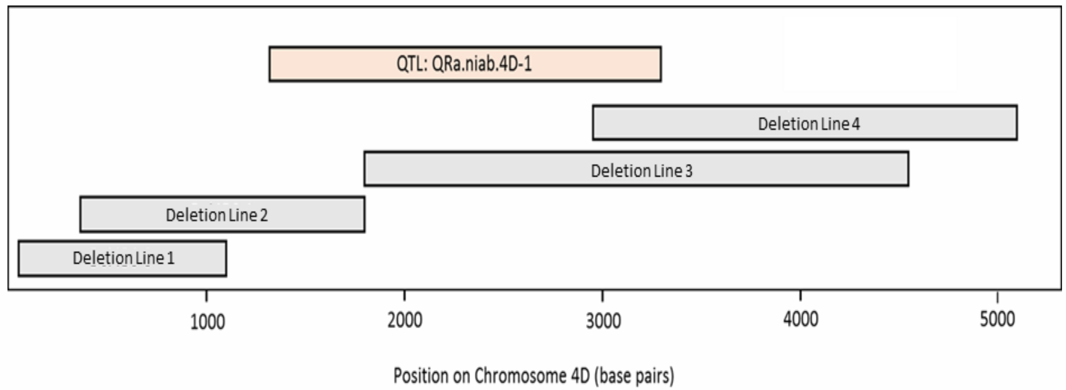
Deletion lines help to refine the QTL region



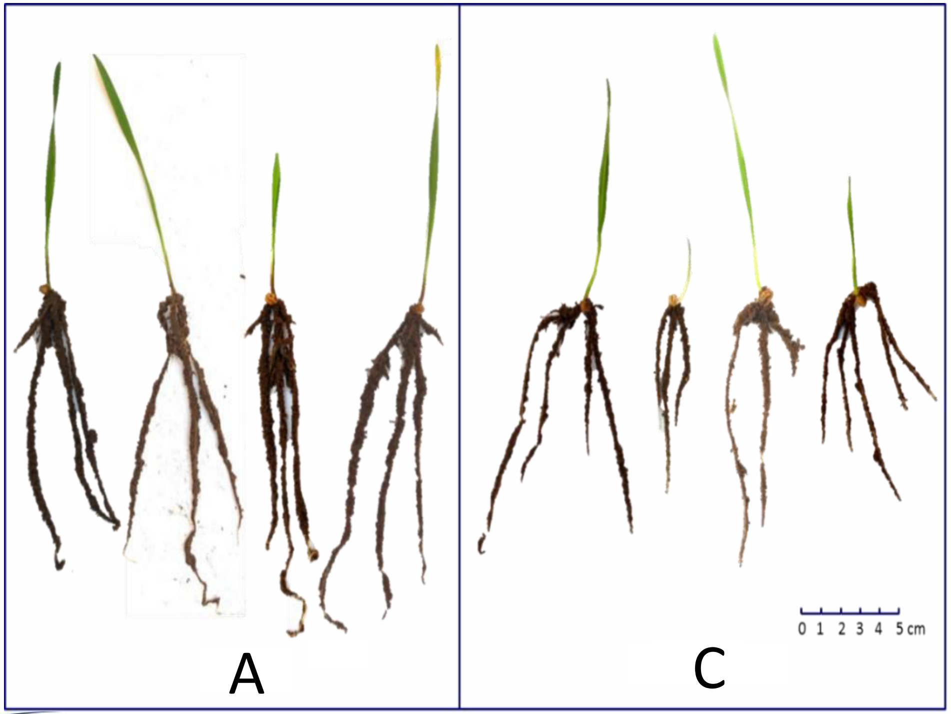


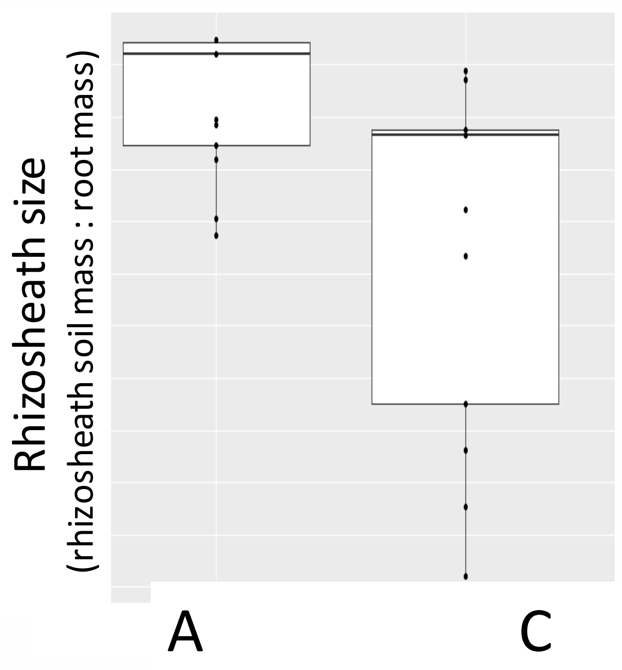
† significantly different from other deletion lines
‡ significantly different from wildtype

Chinese Spring lines with deletions overlapping with the QTL region were screened

Wheat varieties differ in rhizosheath size

- A has a larger rhizosheath than C relative to root weight.
- There is significant variation in polysaccharide release within the AxC DH mapping population





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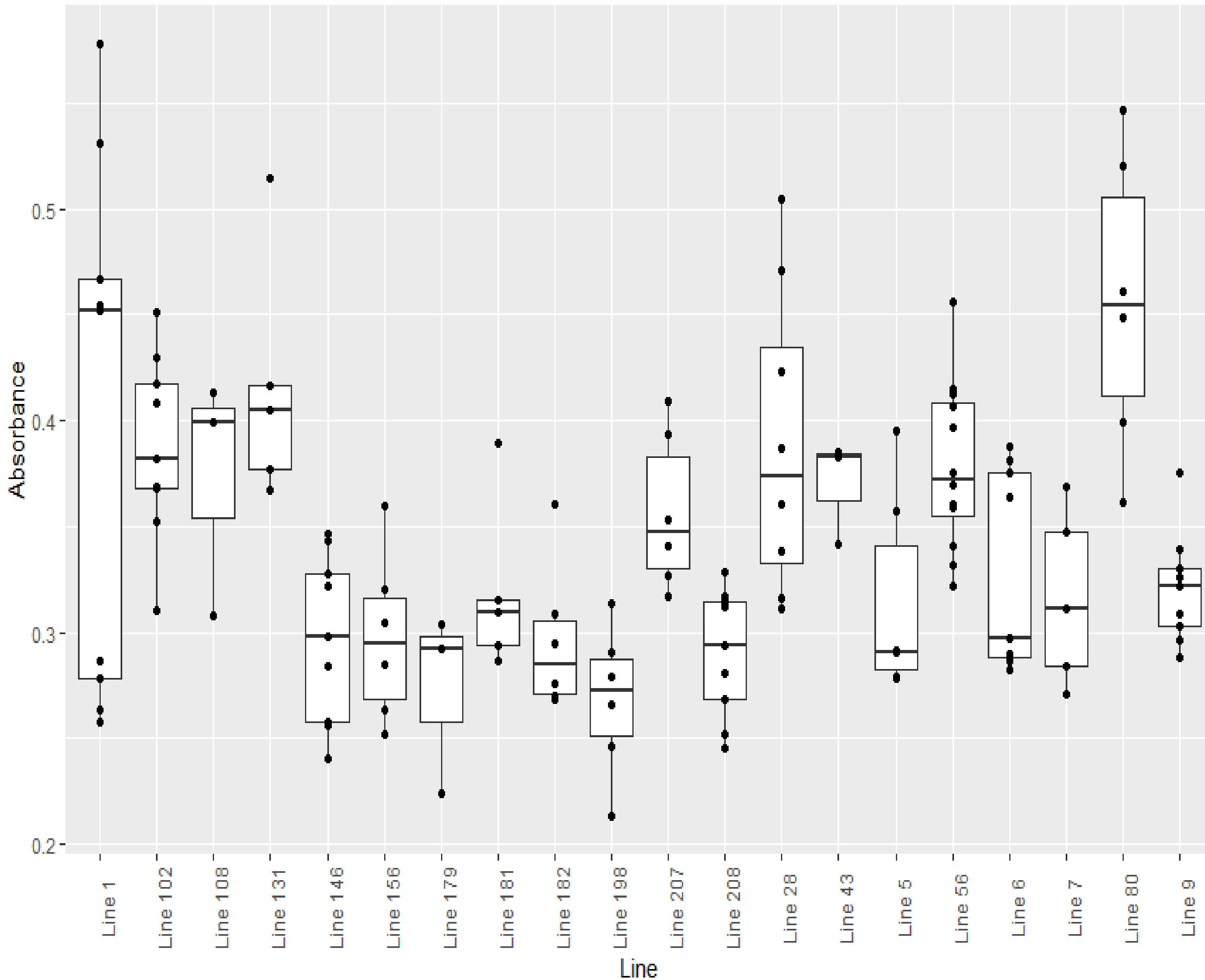
Data: Emily Marr, Univ. Cambridge/NIAB PhD student

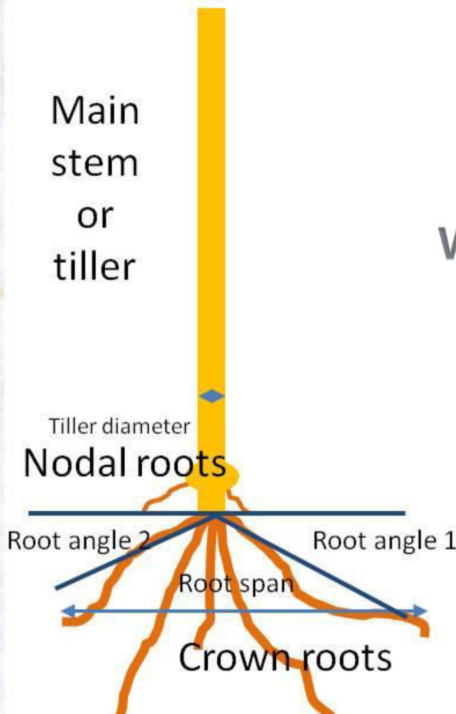
Polysaccharide secretion varies within the AxC doubled haploid wheat population



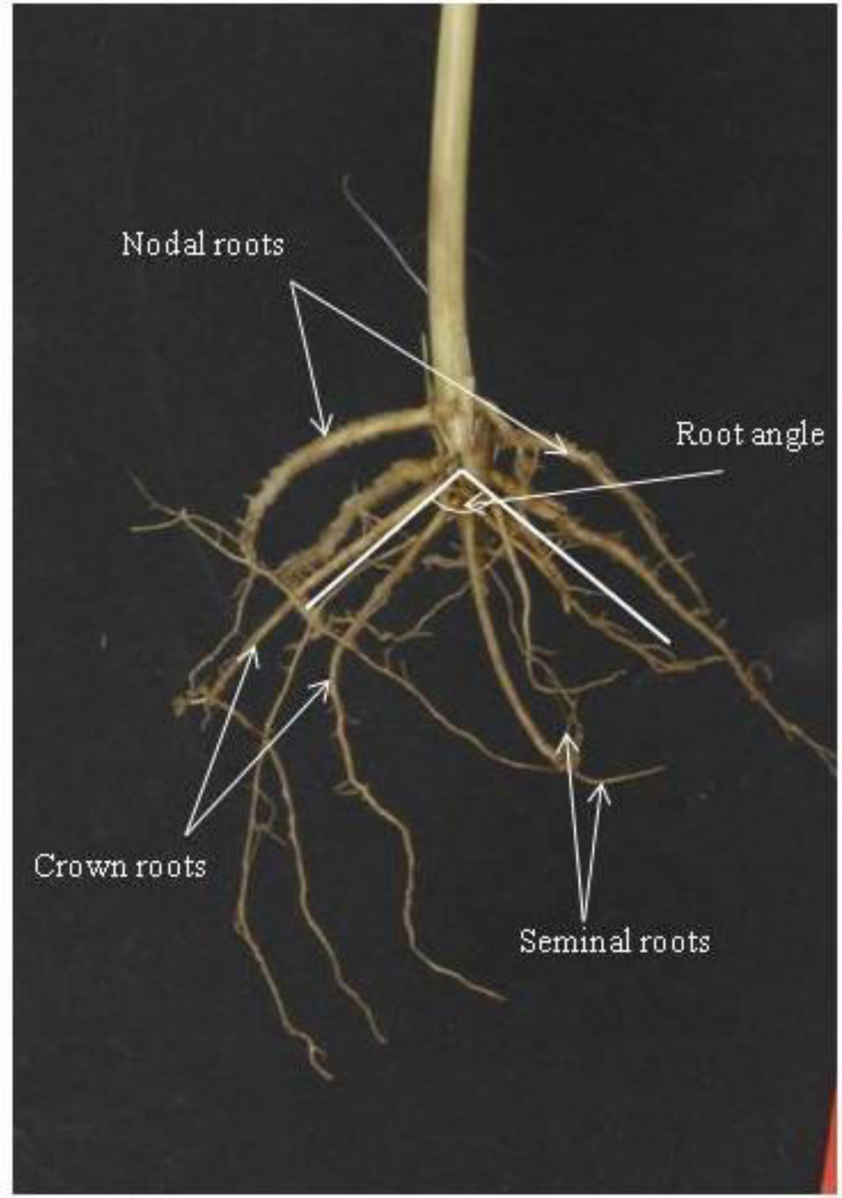
Data: Emily Marr,
Univ. Cambridge/
NIAB PhD student

Shovelomics of landrace and elite wheat lines under conventional and non-inversion tillage systems
NIAB and Organic Research Centre, 2016 & 2017

- Typical image of excavated, washed root system
- Different root classes visible
- Root angle can be measured



Whealbi



Examining roots *in situ* in the field…

Informative, but hard work and not exactly high throughput

Smith, C (2002) Root growth of sugar beet varieties in response to soil mechanical impedance and drought. MPhil, Aberdeen Univ.

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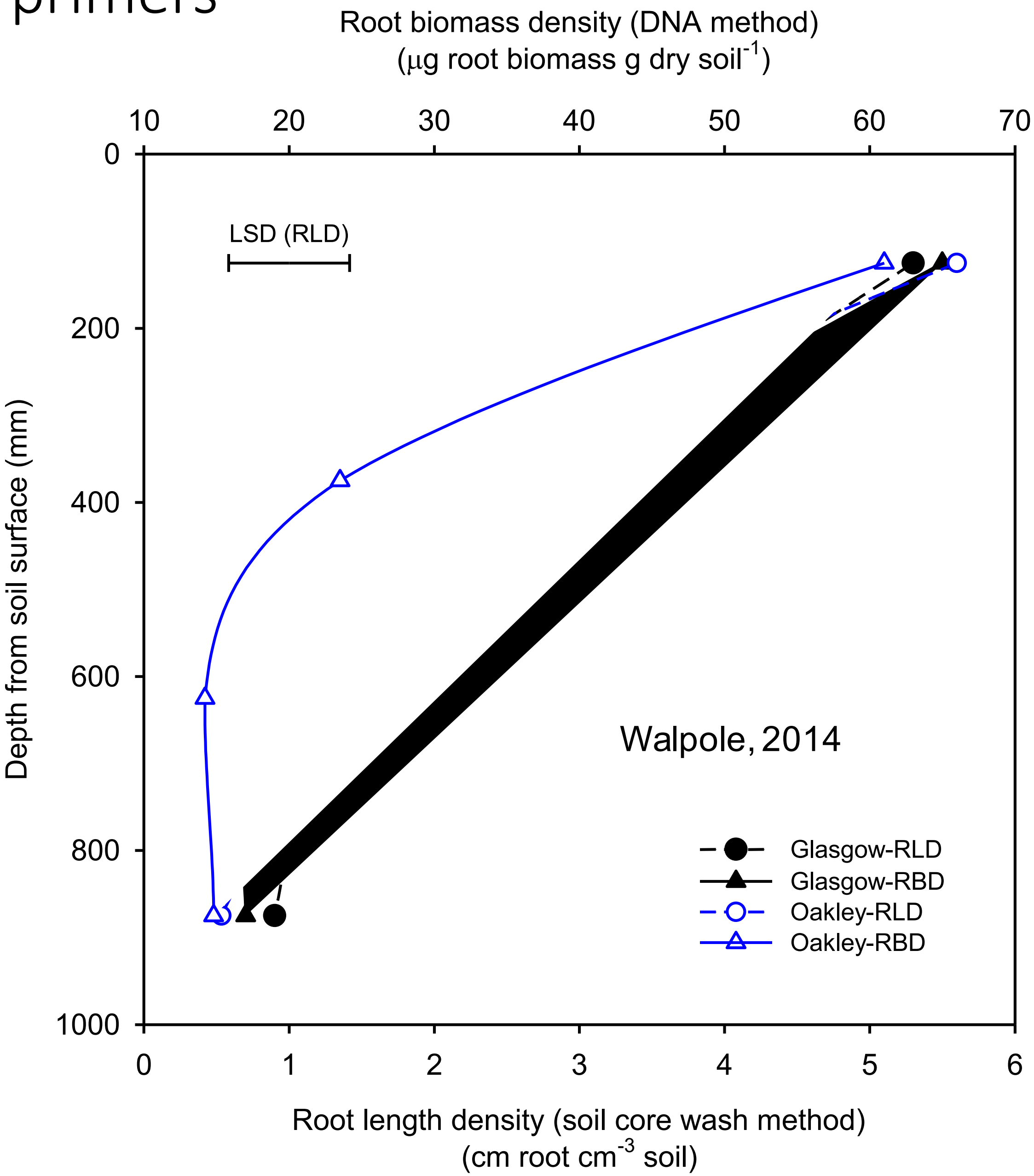
Midi-rhizotrons for root studies

Estimating root biomass via wheat root DNA primers



- Species-specific (can differentiate wheat from weed (blackgrass)
- Semi-quantitative
- Can detect spatial differences in root placement
- Soils must be dried and milled for homogeneous subsampling
- Labour and kit costs to consider

Credit: Huw Jones (NIAB)

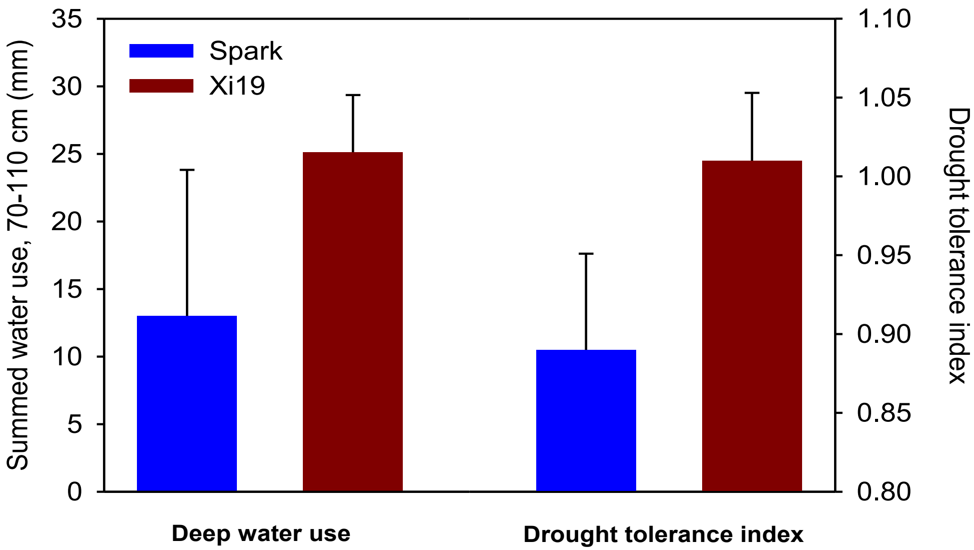
Inferring root activity by measuring patterns in soil water extraction using an FDR* capacitance-type soil moisture probe

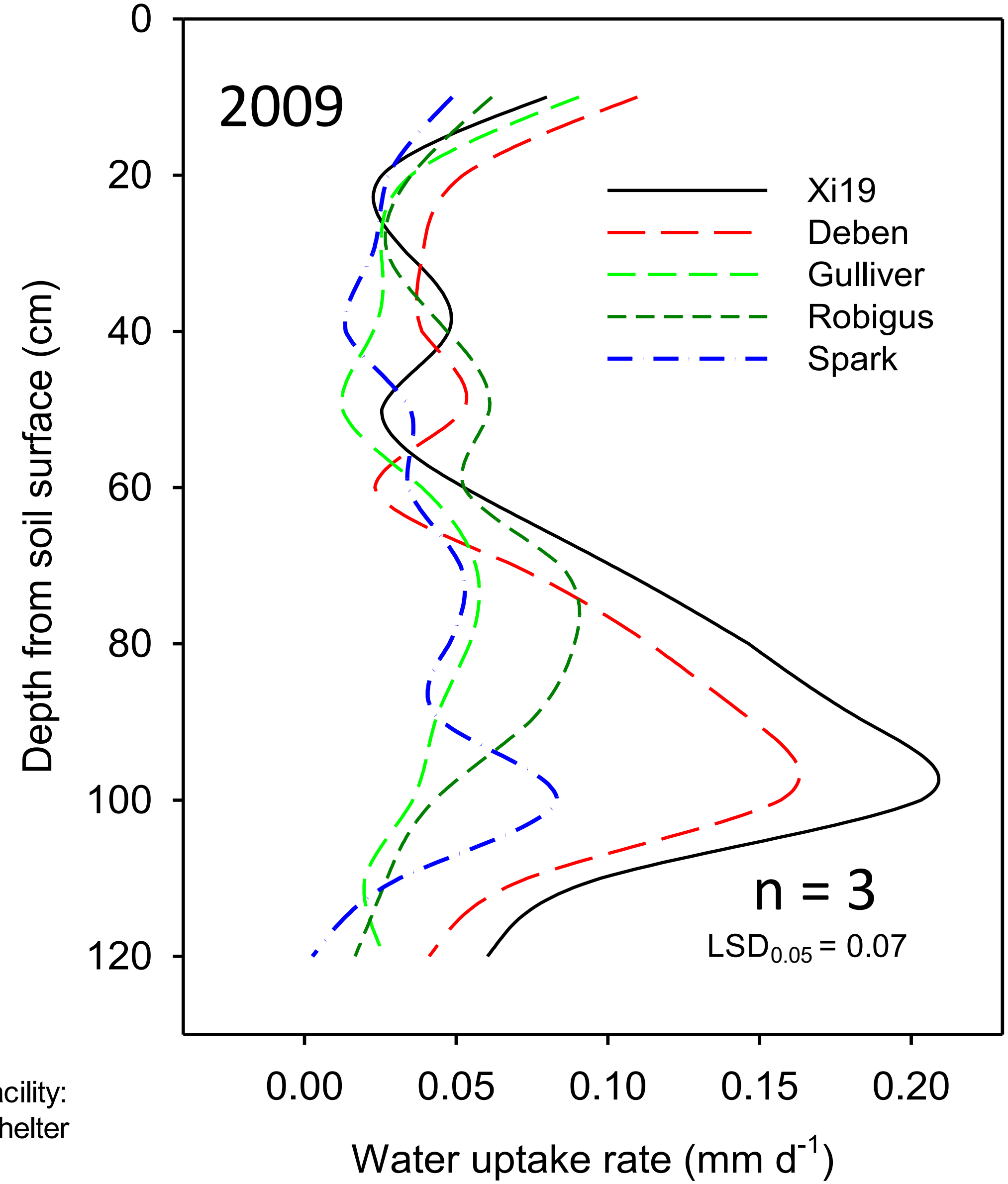
*Frequency domain reflectometry

Ober ES, Sharp RE (2013) Maintaining root growth in drying soil: a review of progress and gaps in understanding. In, Plant Roots: The Hidden Half, 4th Edition. A Eshel, T Beeckman, eds. CRC Press.

Wheat varieties differ in the ability to extract water from deep soil layers under droughted conditions

Measured every 10 cm over the period 2 weeks pre-anthesis to 2 weeks post-anthesis

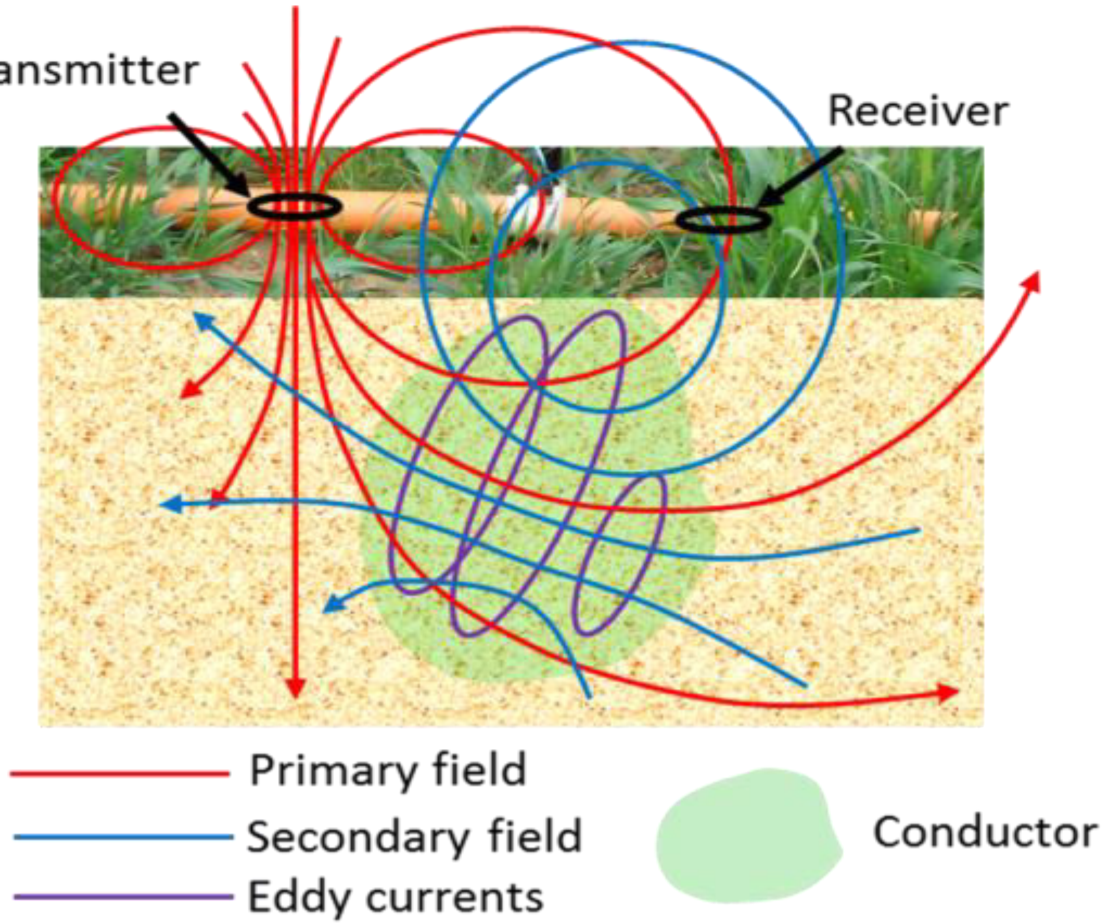




Managed drought facility: polytunnel rainout shelter

Ober et al. (2014) Genotypic differences in deep water extraction associated with drought tolerance in wheat. *Functional Plant Biology* ***41, 1078-1086.***

Using electromagnetic-induction (EMI) for rapid root phenotyping in the field: fast, non-invasive, computationally demanding



BBSRC bioscience for the future

Shanahan et al. (2015) The Use of Electromagnetic Induction to Monitor Changes in Soil Moisture Profiles beneath Different Wheat Genotypes. *Soil Science Society of America Journal* ***79, 459-466.***

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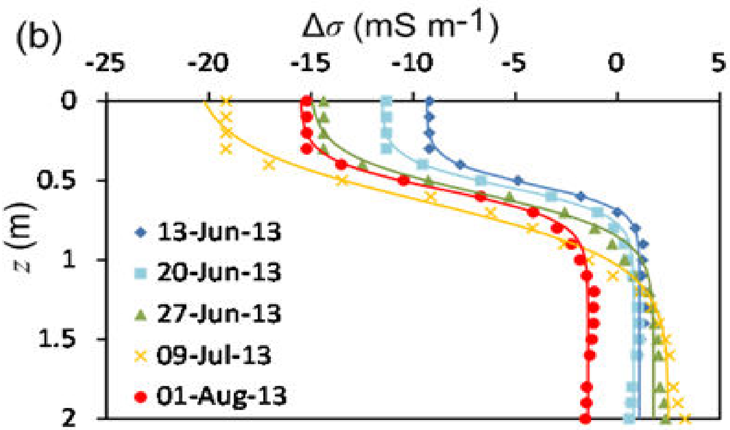
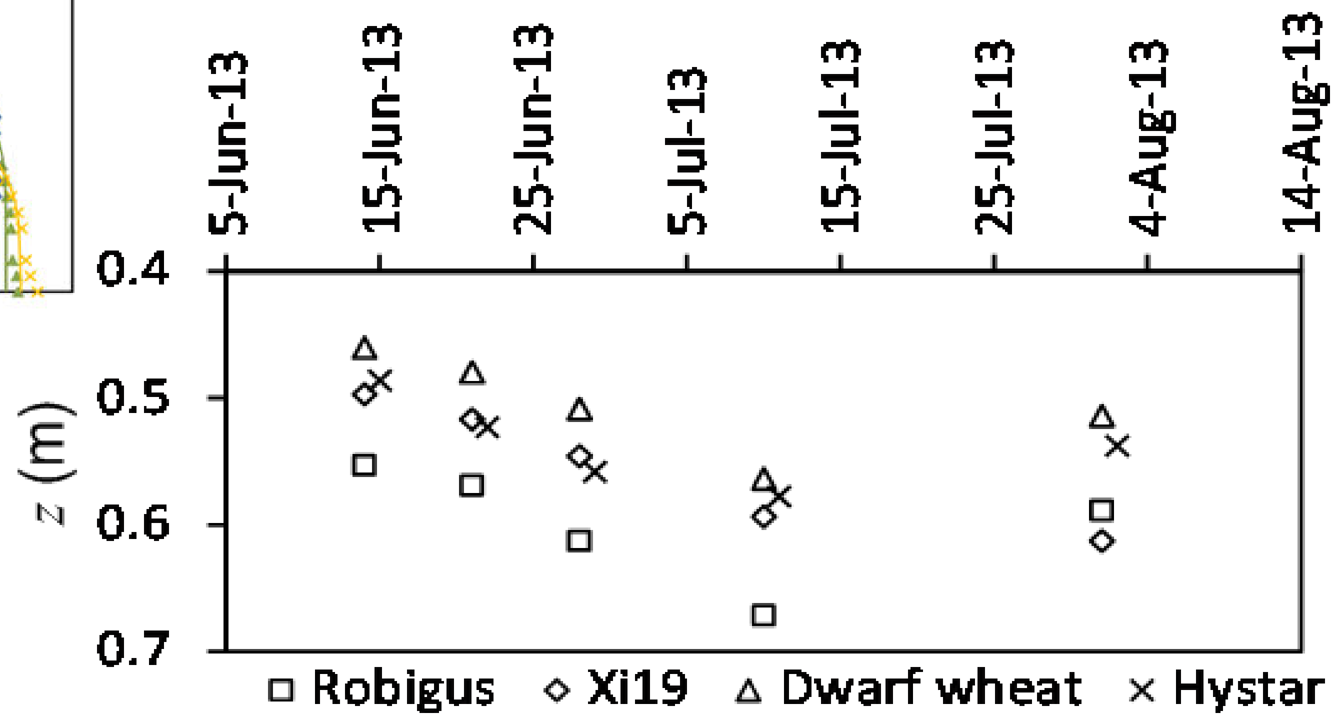
EMI soil moisture profiles derived from conductivity inversions

- Genotypic differences in soil water uptake are detected during a period of soil drying
- Not measuring roots directly, but inferring root activity





Movement of drying front during season

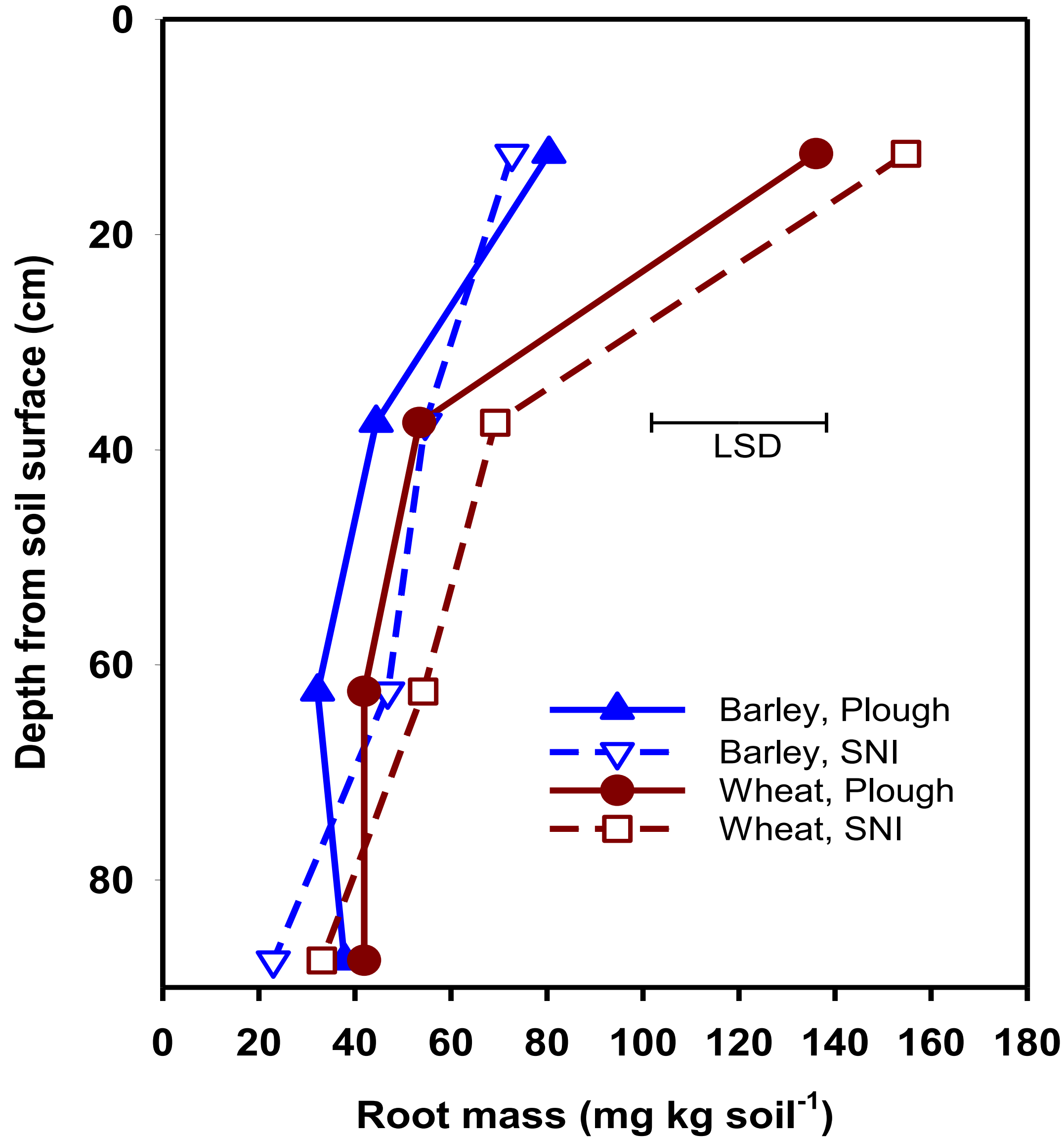
Shanahan et al. (2015)

Root mass distribution in the soil profile measured in soil cores at maturity.

Nathan Morris
David Clarke

Root mass distribution in the soil profile measured in soil cores at maturity in wheat and barley

Winter wheat showed significantly (P < 0.01) more root mass in upper soil layers than winter barley. There was more root mass under shallow non-inversion tillage, except in the deepest layers (P <0.05).



"There is no easy method of uncovering the root system, and unless one is willing to spend considerable time and energy, and exercise a great deal of patience, it is better not to begin. But once started, the work, although difficult, is very interesting and in fact even fascinating."

--John E. Weaver (1926) *Root Development of Field Crops*, p257.

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