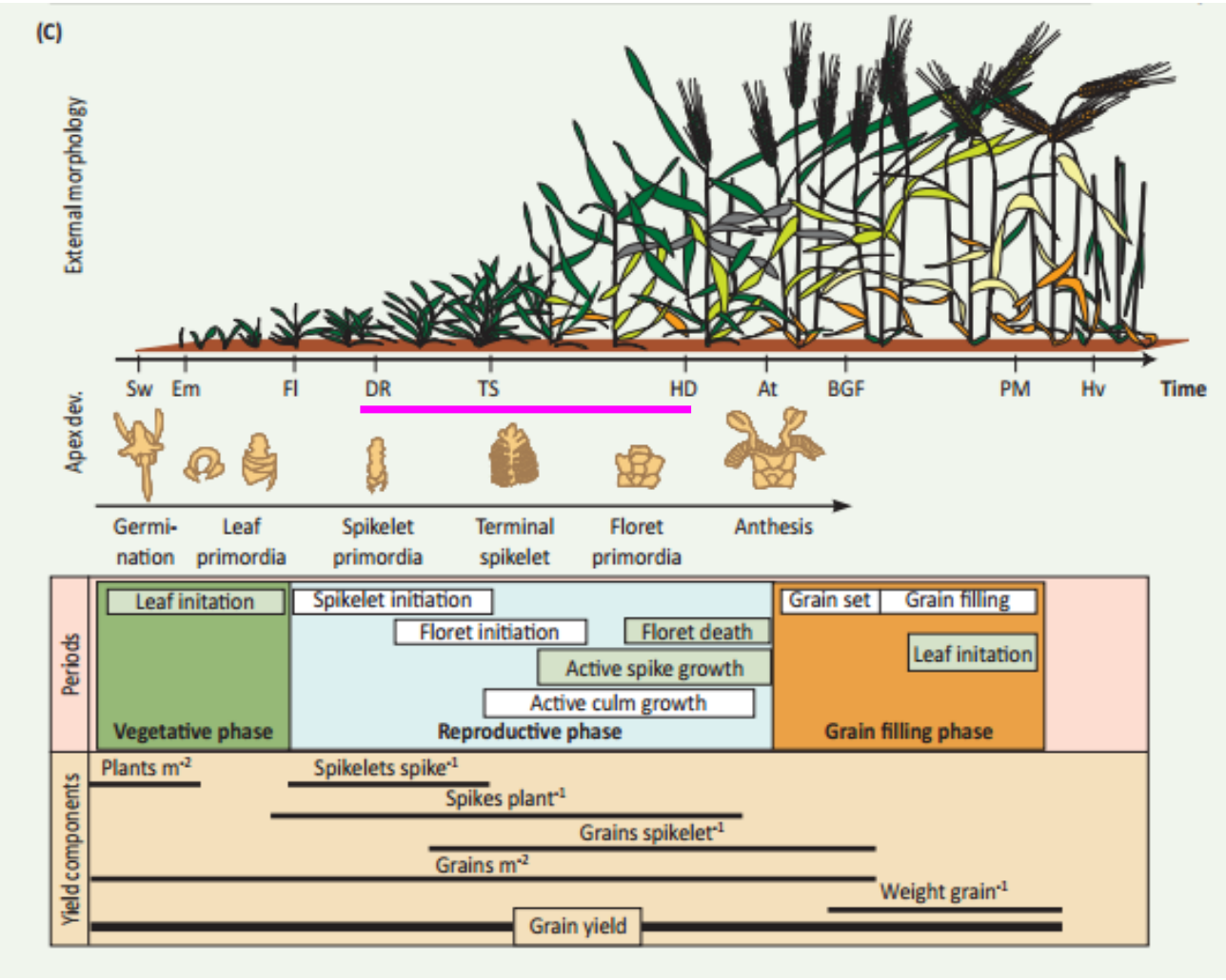
# Breeding wheat for a hotter climate

Simon Griffiths

John Innes Centre

8th February 2024

# When does heat and drought stress matter?




- Most sensitive stage for:
  - **grain number** is the two week interval before anthesis
  - **grain size**, the grain filling period
  - Grain number is most plastic and therefore most sensitive
  - So, in UK May is a key month

- But we lack accuracy both in terms of cardinal temperatures for the crop AND predicted climate…..

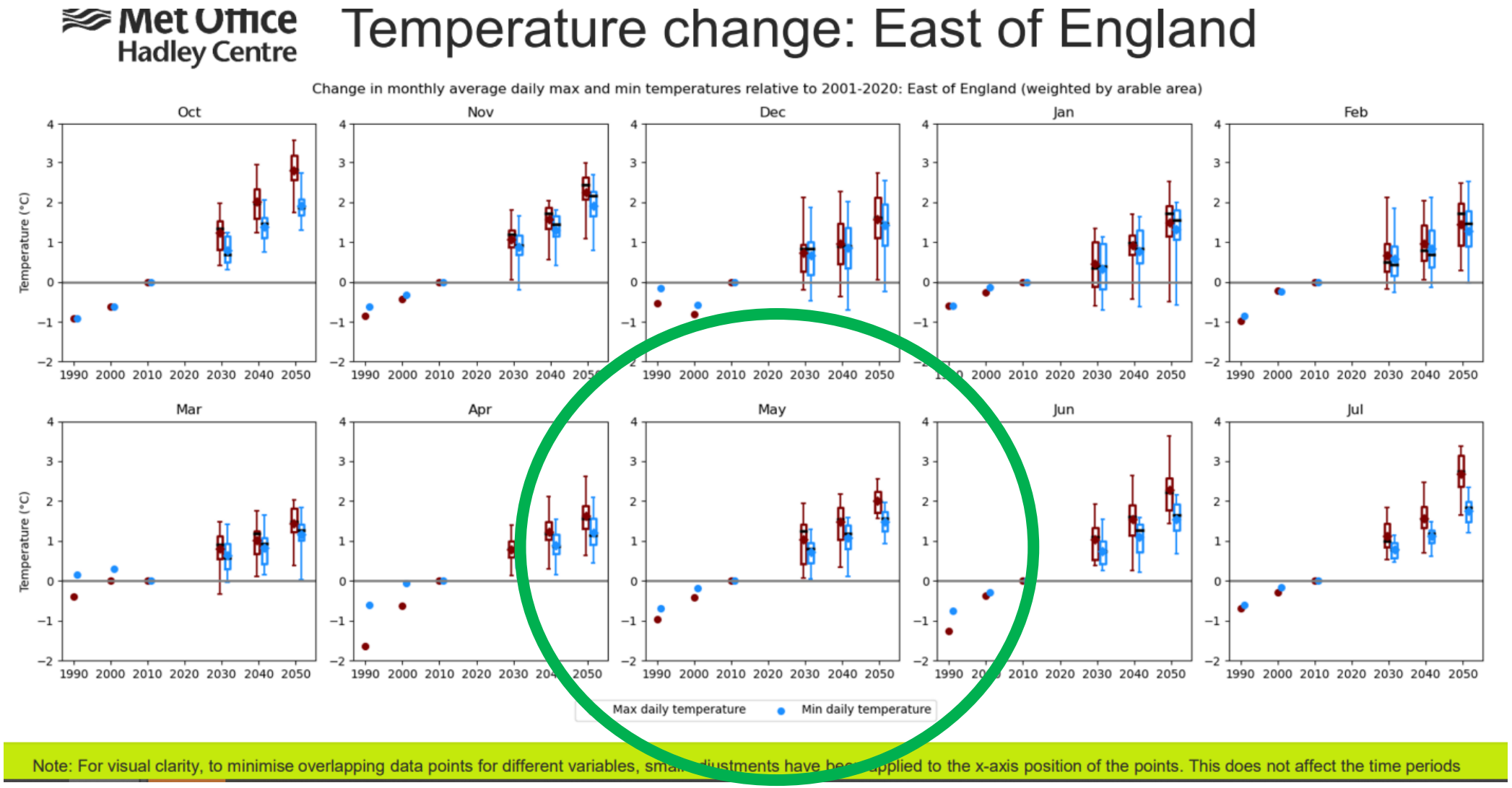
# WGIN collaboration with Met Office

Andrew Cottrell

Thomas Crocker

Met Office
Hadley Centre

# Met office can produce increasingly detailed climate projections

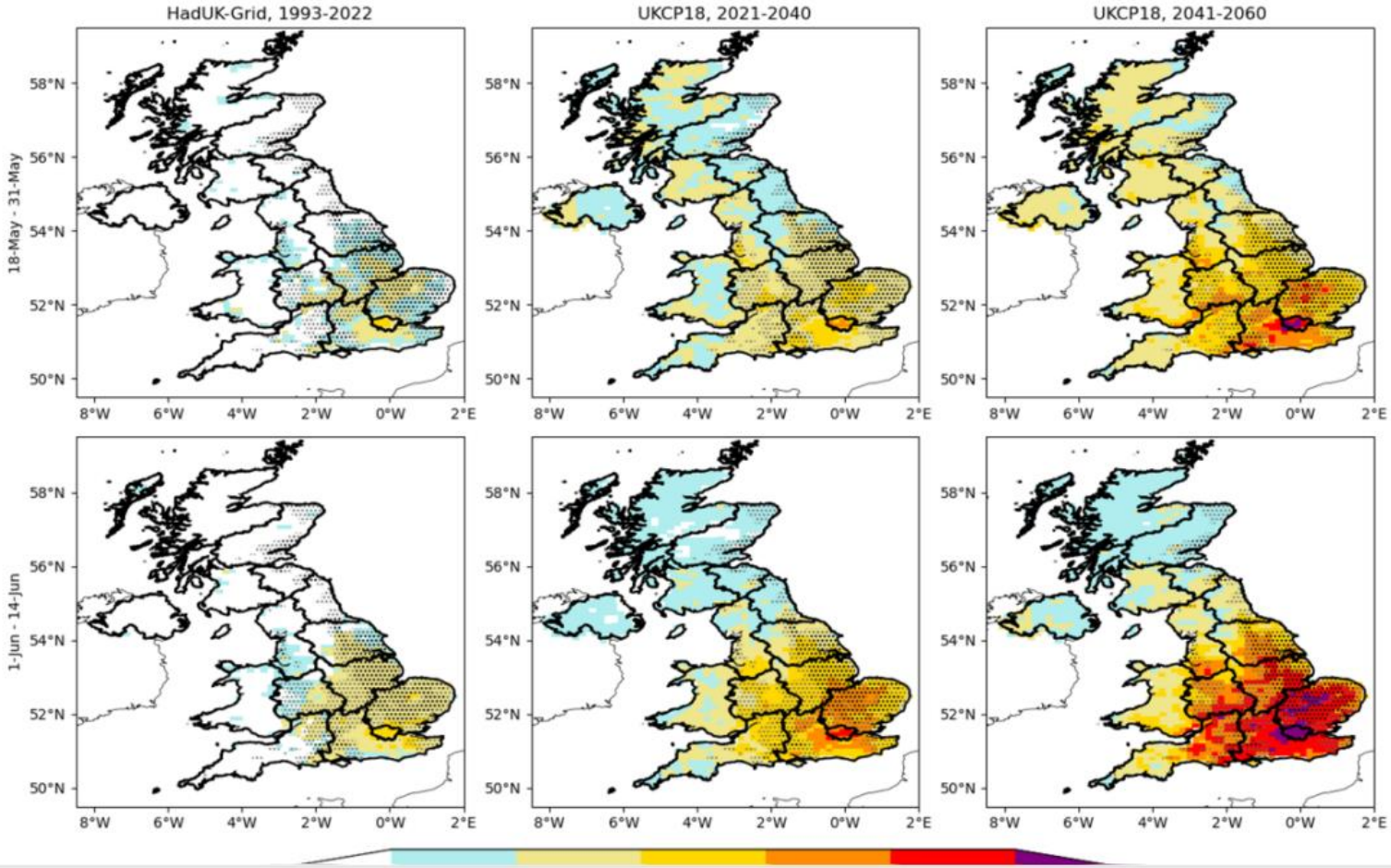


# When (if ever) will late May temperatures impact wheat yield?

Met Office Hadley Centre

## Maximum daily temperature

Proportion of years with threshold exceedances: 1-day Max daily temperature above 27°C
Stippling indicates main arable areas




Late May

Early June

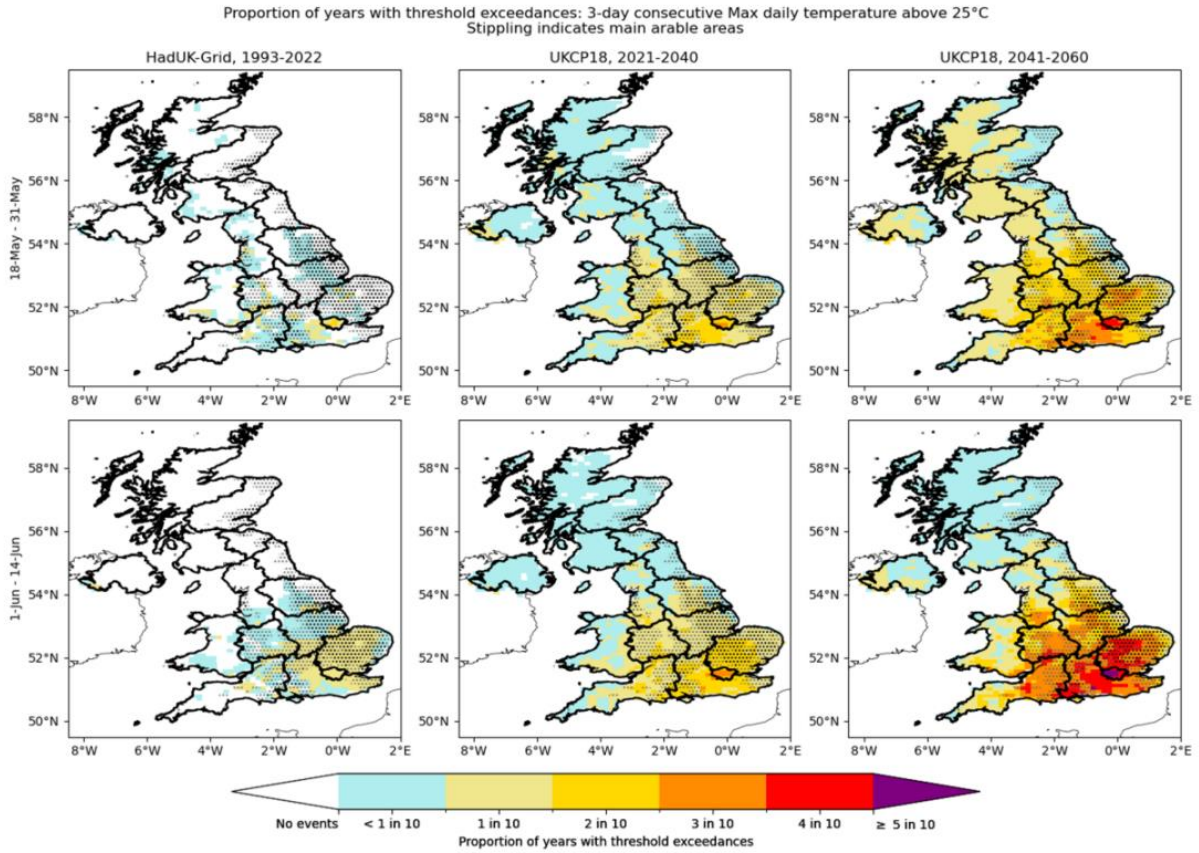
Days of $27^0$C

Wheat Genetic Improvement Network

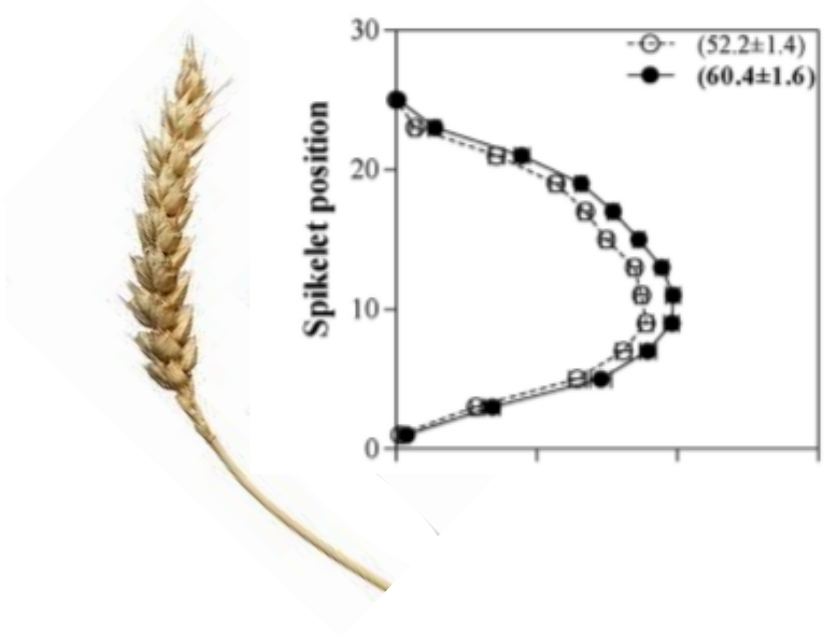
# Mini heat waves

Met Office Hadley Centre

## Consecutive 3-day max daily temperature



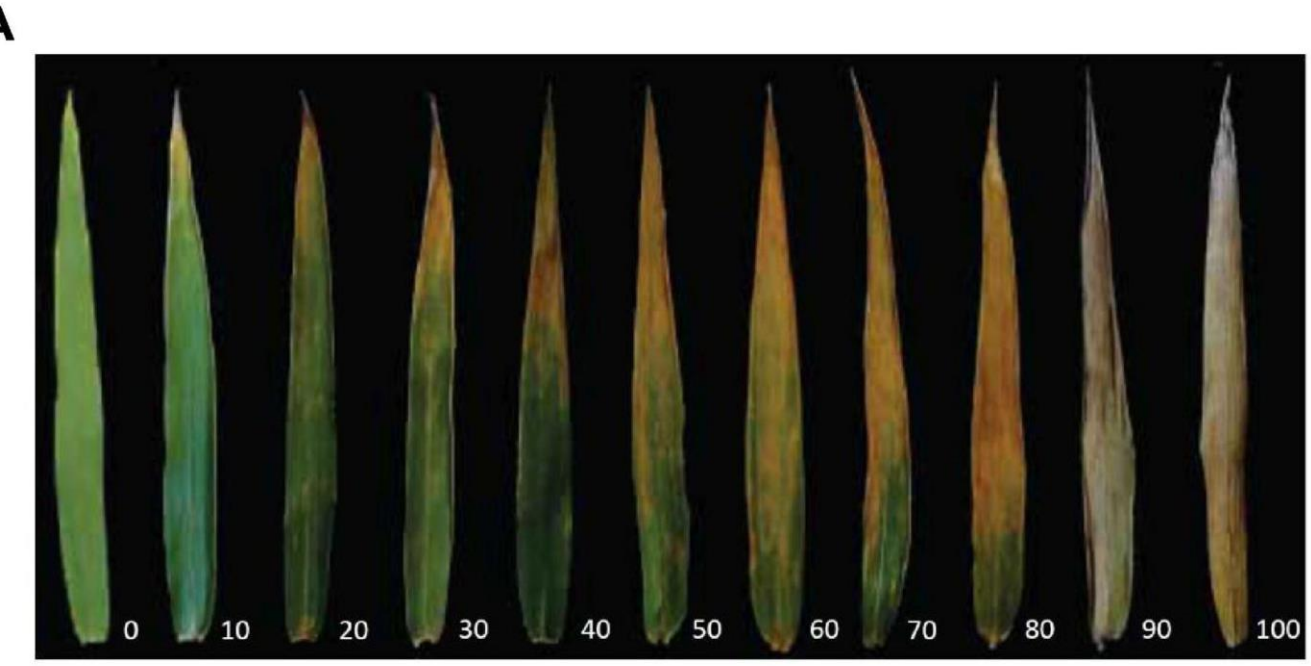
# Possible effects-June

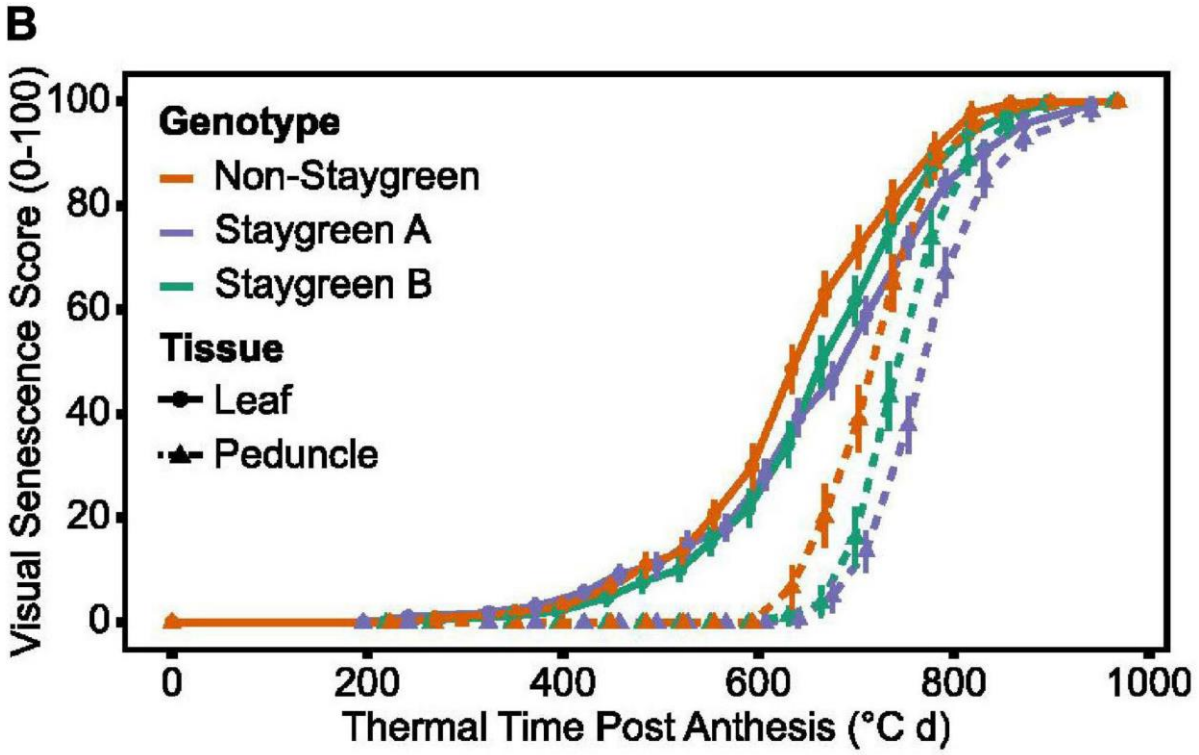



Reduced survival of
distal florets

**Prieto et al** "Physiological determinants of fertile floret survival in wheat as affected by earliness per se genes under field conditions" European Journal of Agronomy 99 (2018) 206–213

# Possible effects-July



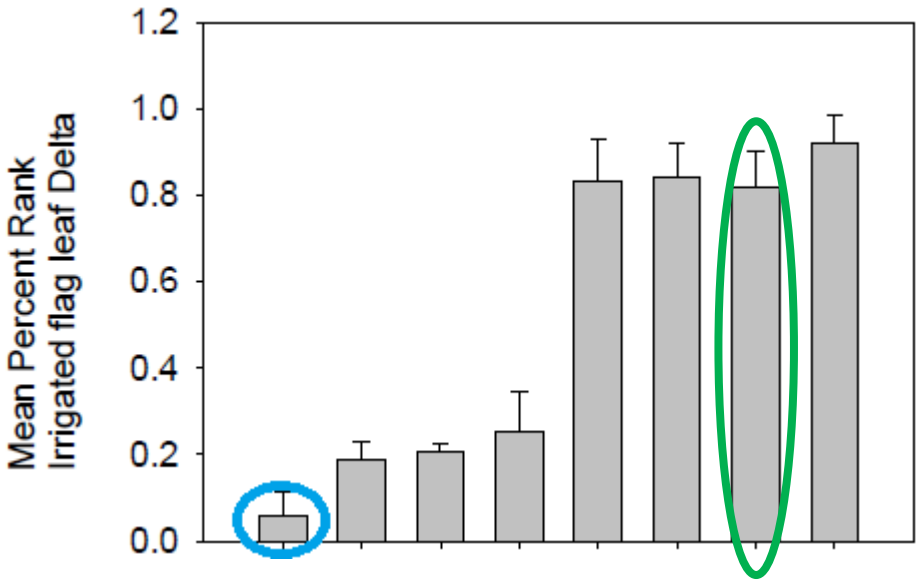




Accelerated senescence- less time for grain filling

# UK drought tolerance

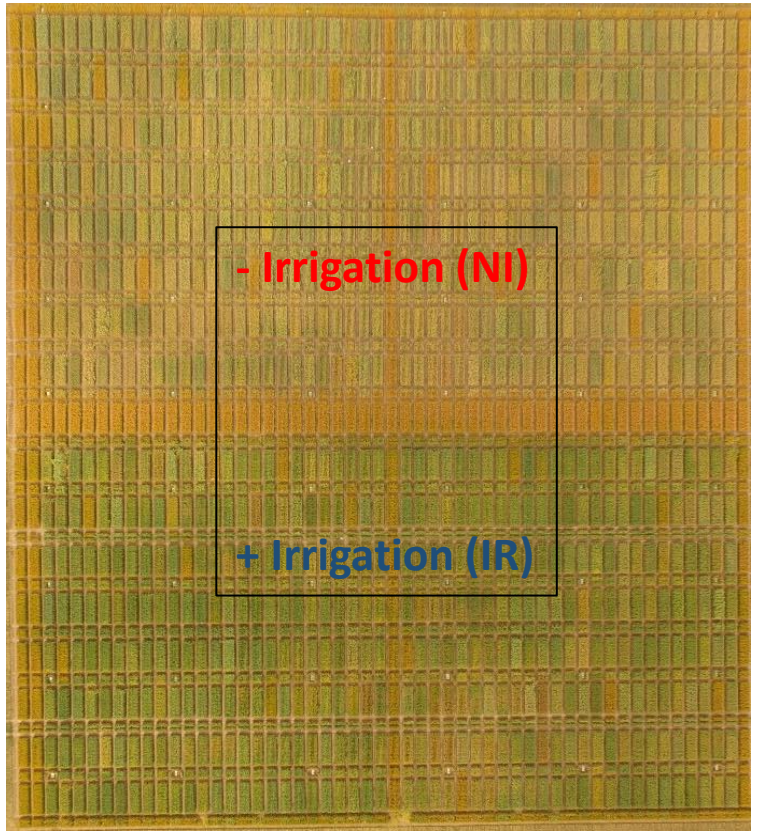
- LINK project indicated that the carbon isotope discrimination ratio (Delta) has a negative correlation with Drought Tolerance
- Four varieties showed consistently low values for carbon isotope discrimination ratio, which included **Garcia**. **Paragon** had a consistently high ratio
- The **Paragon** **x** **Garcia** population was originally generated to map this QTL

Eric Ober- NIAB

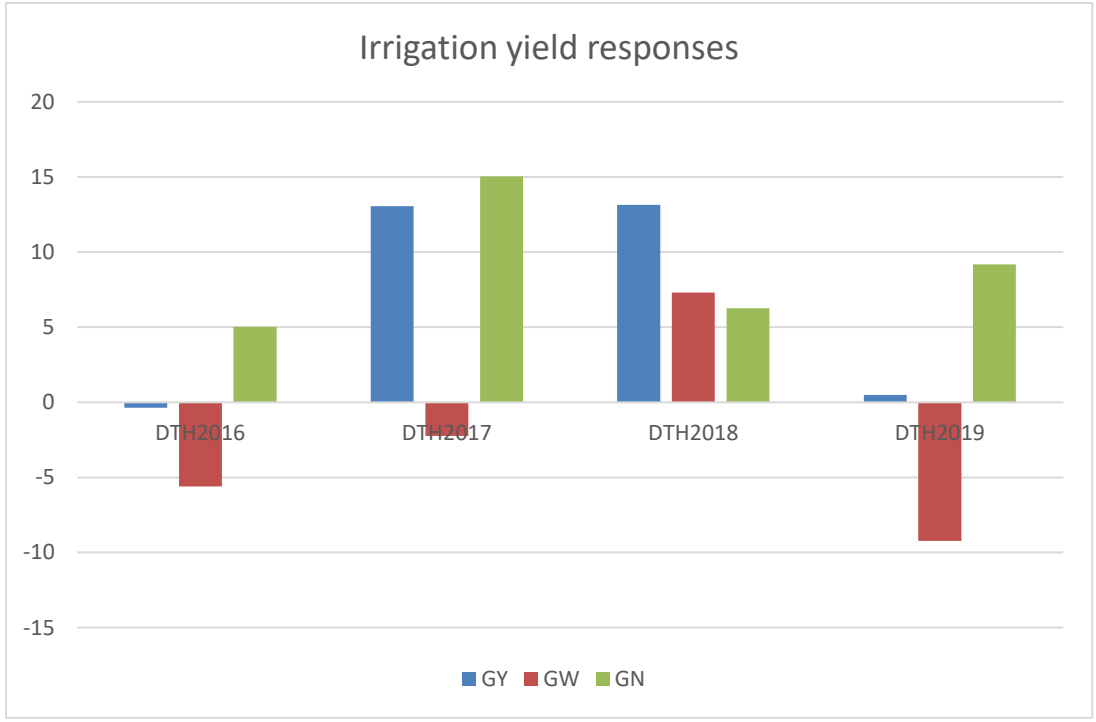


# Look for useful genes in drought-adapted wheat

- For example southern Europe for which variety Garcia was developed.
- The Paragon x Garcia RIL population was generated within WGIN to study drought tolerance (DT)
- 177 RILs used in 4 years of trials (2016-2019)
- Phenotype and yield data analysed
- Comparison of IR and NI plots

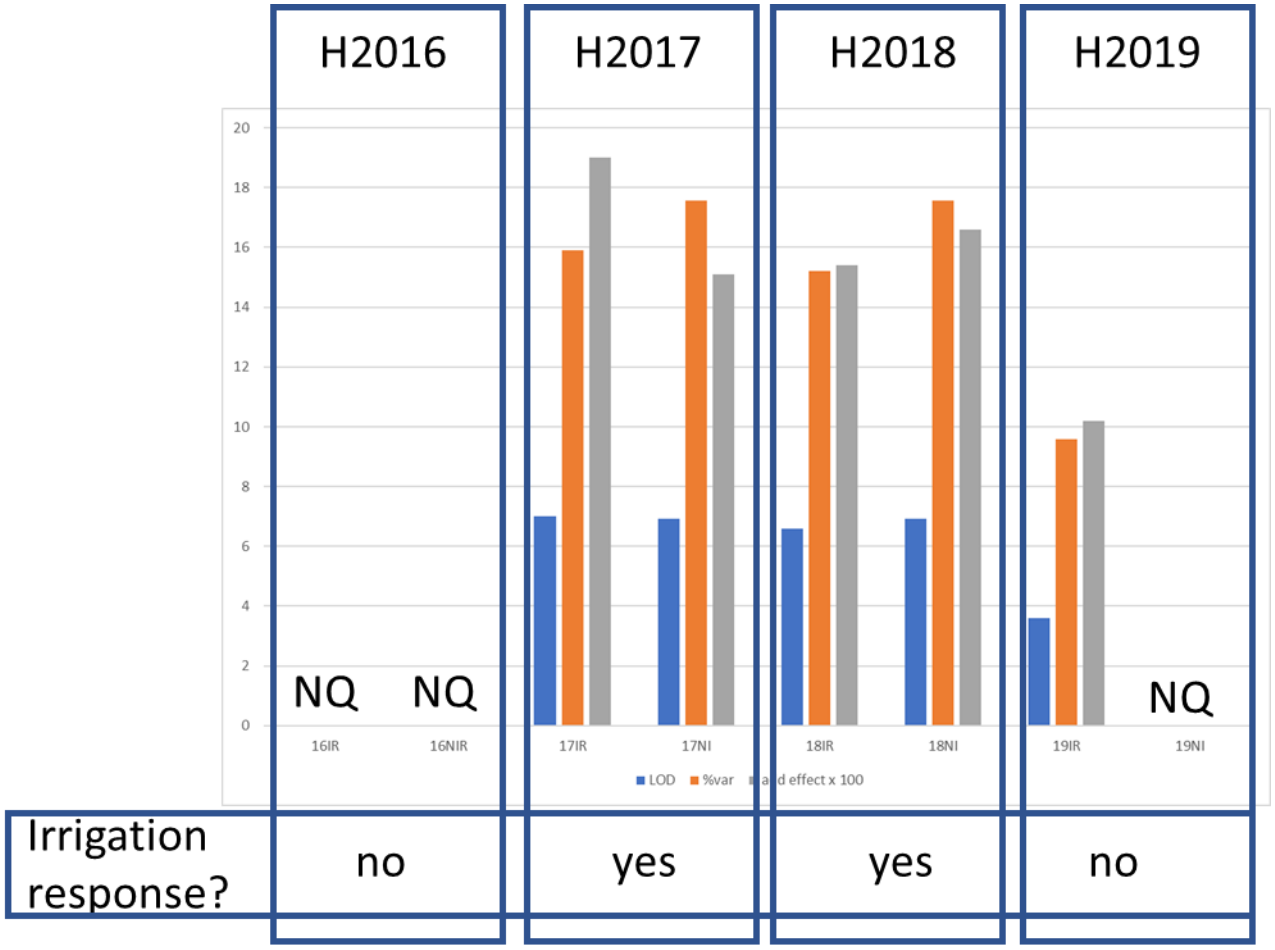


# Agricultural drought definition



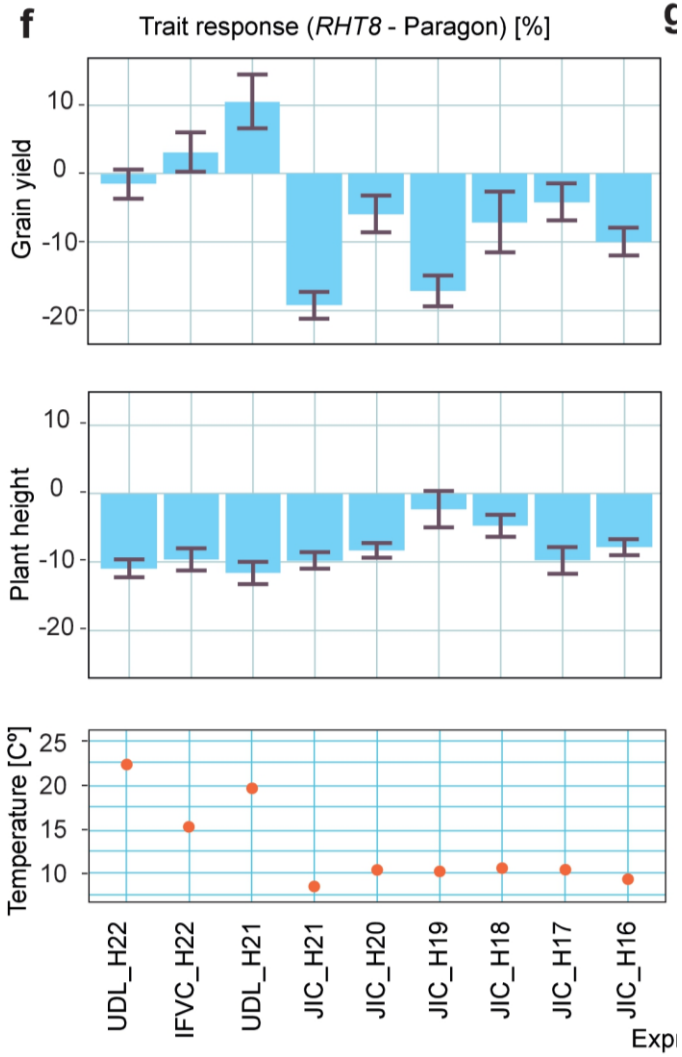

- Irrigation resulted in a yield increase in two of the four seasons= harvest 2017 and 2018

# Garcia carries confers a yield increase in drought years



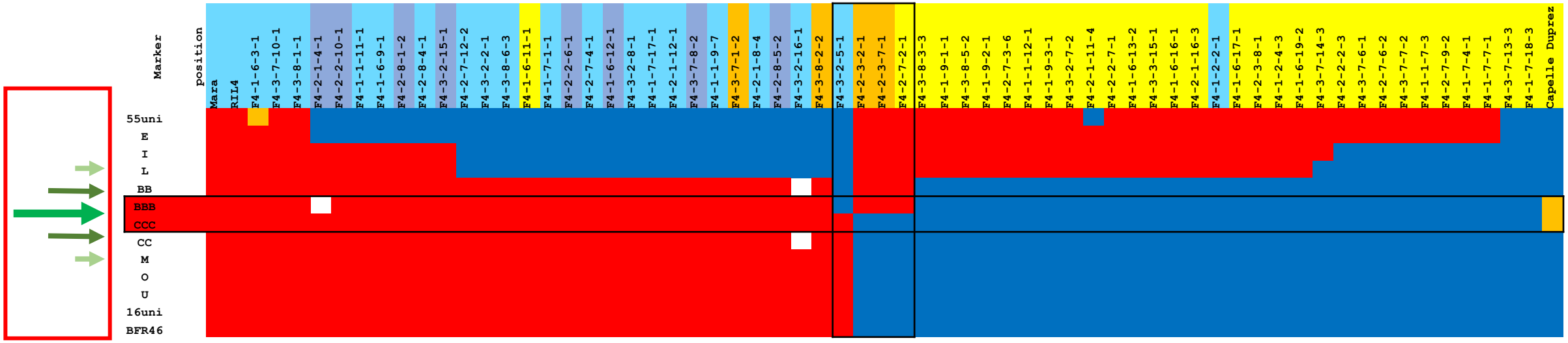

- Genetic effects identified using Quantitative Trait Locus (QTL) analysis
- QTL any detected when irrigation gave a yield benefit
- QTL “validated” using Near Isogenic Lines in the DSW Breeders Toolkit

# *Rht8* confers an adaptive advantage in Mediterranean environments, useful in the UK?




- *Rht8* is reduces plant height and is considered an "alternative" semi dwarfing gene
- Long term anecdote that Rht8 was especially effective in Med, but many confounding factors
- Paragon library of NILs includes *Rht8*
- Grown in UK, Spain, and Serbia
- Height reduction is consistent
- Yield enhancement specific to Med

# *Rht8* mapped to between markers *BBB* and *CCC* in RIL4 x Cappelle Desprez population




3 rounds of markers
to map location of *Rht8*

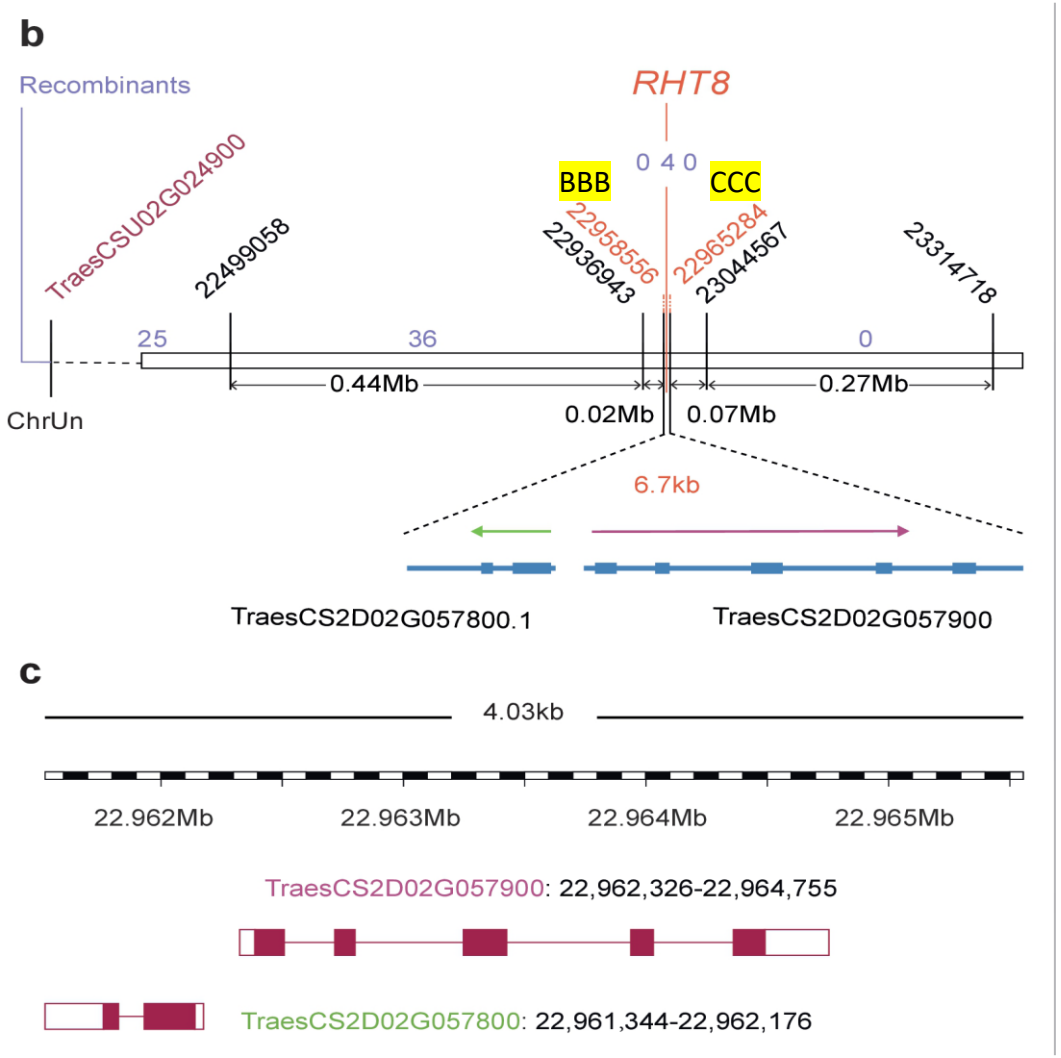
PHENOTYPE

Short / Short (consensus score)

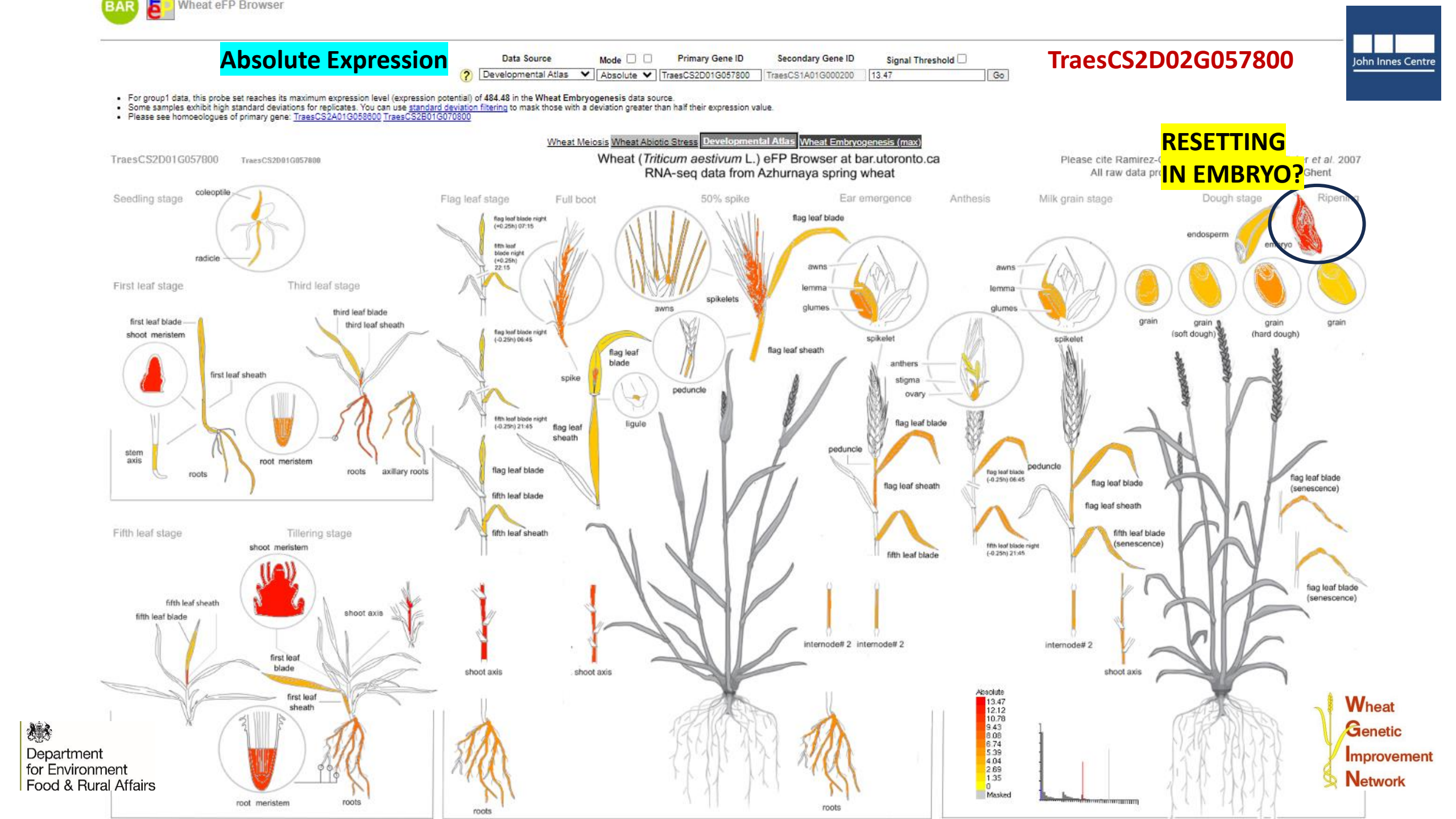
Tall / Tall (consensus score)

**Obviously these markers are available to anyone who wants them!**

# Two genes in *Rht8* genetic interval




**TraesCS2D02G057800 TraesCS2D02G057900**


BAR
Wheat eFP Browser
Absolute Expression
Data Source
Mode
Primary Gene ID
Secondary Gene ID
Signal Threshold
Developmental Atlas
Absolute
TraesCS2D01G057800
TraesCS1A01G000200
13.47
Go
TraesCS2D02G057800
John Innes Centre
For group1 data, this probe set reaches its maximum expression level (expression potential) of 484.48 in the Wheat Embryogenesis data source.
Some samples exhibit high standard deviations for replicates. You can use standard deviation filtering to mask those with a deviation greater than half their expression value.
Please see homoeologues of primary gene: TraesCS2A01G058600 TraesCS2B01G070800
Wheat Meiosis
Wheat Abiotic Stress
Developmental Atlas
Wheat Embryogenesis (max)
TraesCS2D01G057800
Wheat (Triticum aestivum L.) eFP Browser at bar.utoronto.ca
RNA-seq data from Azhurnaya spring wheat
RESETTING IN EMBRYO?
Seedling stage
coleoptile
radicle
First leaf stage
Third leaf stage
first leaf blade
shoot meristem
first leaf sheath
third leaf blade
third leaf sheath
stem axis
roots
root meristem
roots
axillary roots
Fifth leaf stage
Tillering stage
shoot meristem
fifth leaf sheath
fifth leaf blade
shoot axis
first leaf blade
first leaf sheath
root meristem
roots
Flag leaf stage
Full boot
50% spike
Ear emergence
Anthesis
Milk grain stage
Dough stage
Ripening
flag leaf blade night (+0.25h) 07:15
fifth leaf blade night (+0.25h) 22:15
flag leaf blade night (-0.25h) 06:45
fifth leaf blade night (-0.25h) 21:45
flag leaf blade
fifth leaf blade
fifth leaf sheath
spike
flag leaf sheath
ligule
awns
spikelets
peduncle
flag leaf blade
awns
lemma
glumes
spikelet
flag leaf sheath
anthers
stigma
ovary
flag leaf blade
peduncle
flag leaf sheath
fifth leaf blade
awns
lemma
glumes
spikelet
endosperm
embryo
grain
grain (soft dough)
grain (hard dough)
grain
peduncle
flag leaf blade
flag leaf sheath
fifth leaf blade (senescence)
flag leaf blade (senescence)
flag leaf blade (senescence)
shoot axis
shoot axis
internode# 2
internode# 2
internode# 2
shoot axis
roots
roots
Absolute
13.47
12.12
10.78
9.43
8.08
6.74
5.39
4.04
2.69
1.35
0
Masked
Please cite Ramirez-
et al. 2007
All raw data pr
Ghent
Department for Environment Food & Rural Affairs
Wheat Genetic Improvement Network

# Absolute Expression

Data Source: Developmental Atlas | Mode: Absolute | Primary Gene ID: TraesCS2D01G057900 | Secondary Gene ID: TraesCS1A01G000200 | Signal Threshold: 88.74 | Go

## TraesCS2D02G057900

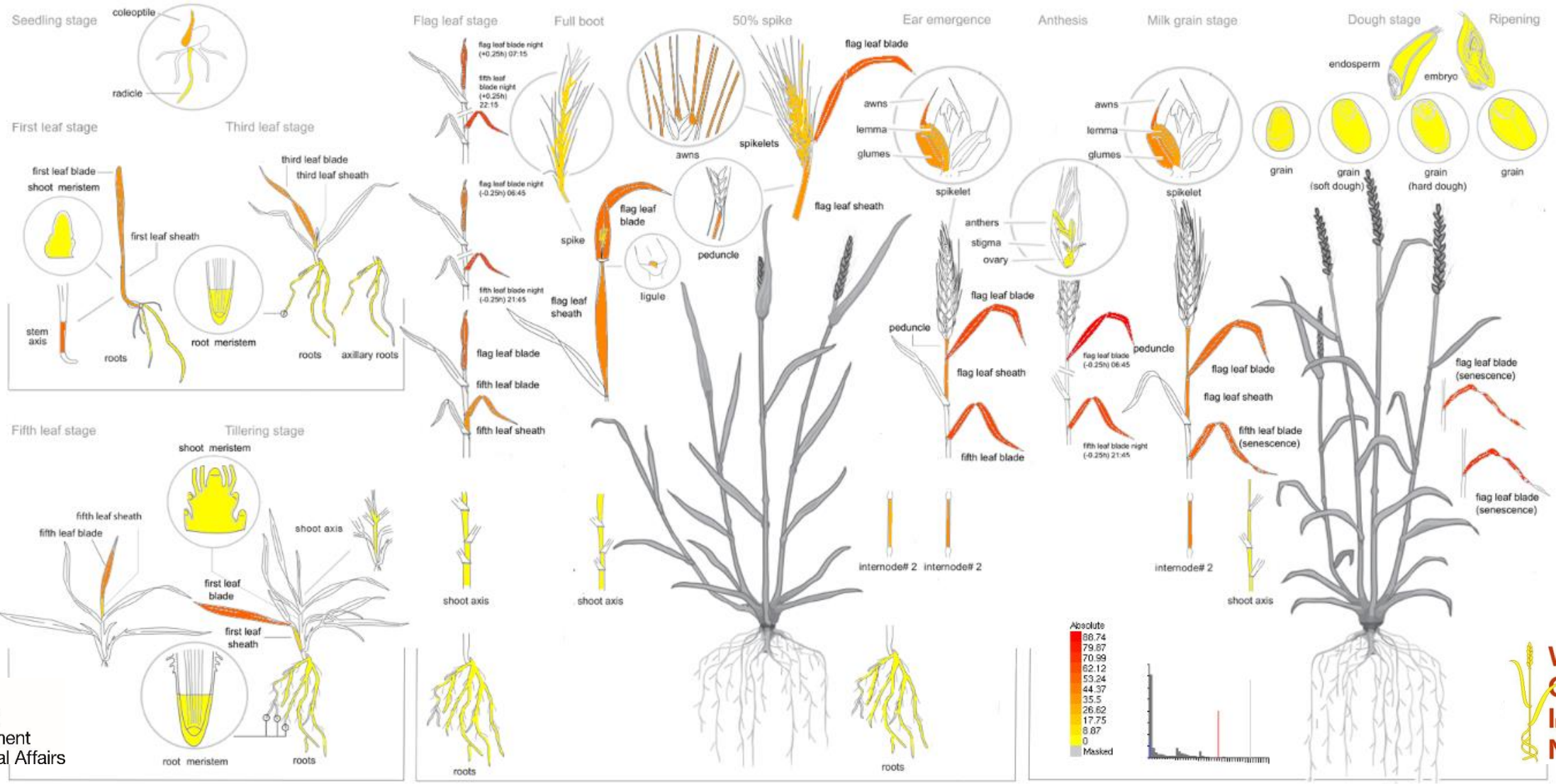
- For group1 data, this probe set reaches its maximum expression level (expression potential) of **2545.2** in the **Wheat Embryogenesis** data source.
- For group1 data, note the maximum signal value has increased to 88.74 from 13.47. Use the Signal Threshold option to keep it constant at 13.47, or enter a value in the Signal Threshold box, such as 2545.2. The same color scheme will then be applied across all views.
- Some samples exhibit high standard deviations for replicates. You can use standard deviation filtering to mask those with a deviation greater than half their expression value.
- Please see homoeologues of primary gene: TraesCS2A01G058700 TraesCS2B01G070700

Wheat Meiosis | Wheat Abiotic Stress | Developmental Atlas | Wheat Embryogenesis (max)

TraesCS2D01G057900 TraesCS2D01G057900

Wheat (*Triticum aestivum* L.) eFP Browser at bar.utoronto.ca
RNA-seq data from Azhurnaya spring wheat

Please cite Ramirez-Gonzalez *et al.* 2018 and Winter *et al.* 2007
All raw data provided by Bayer CropScience, Ghent

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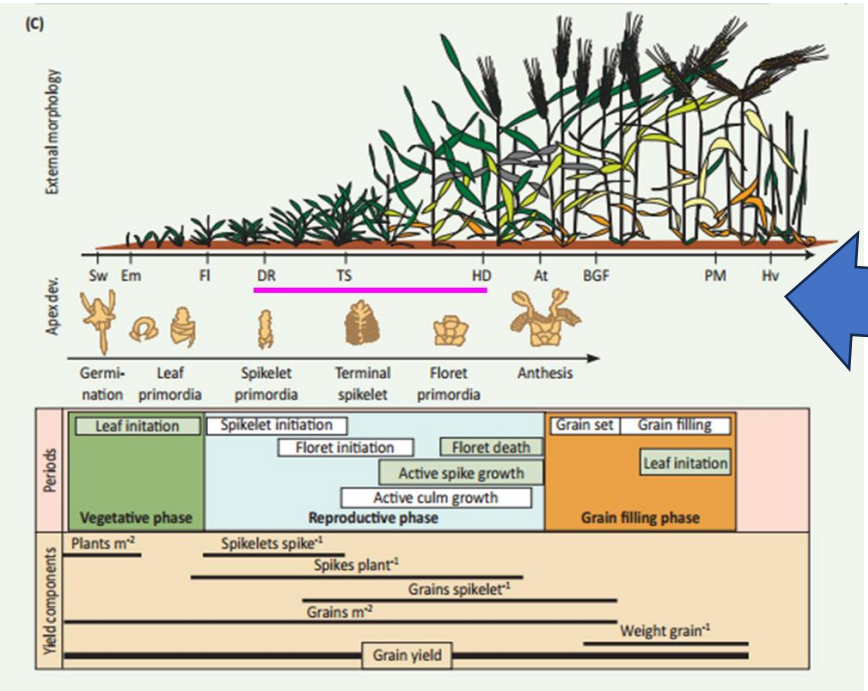
# What about roots? The hidden half!




?

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# Starke has a strong root system





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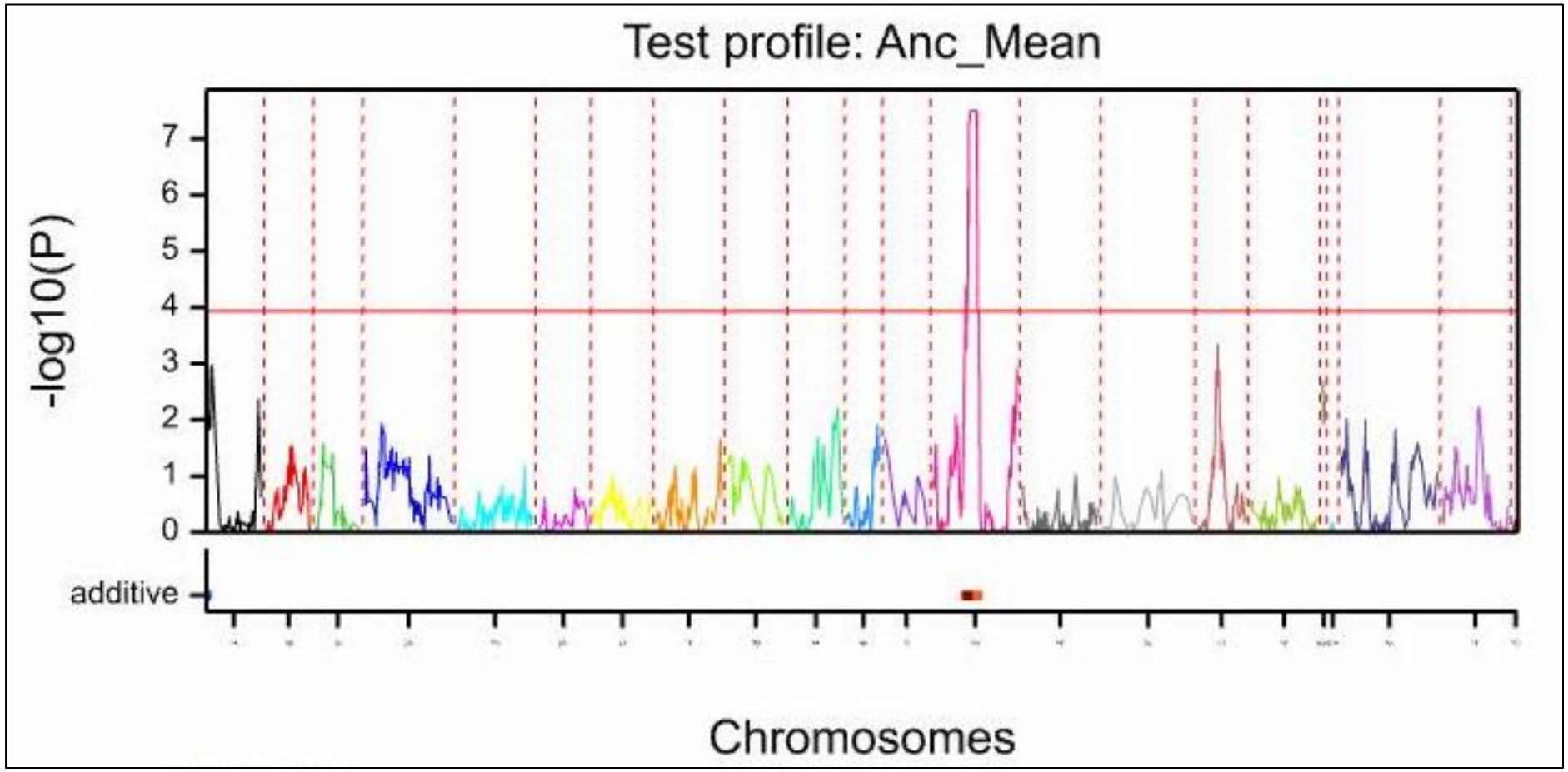
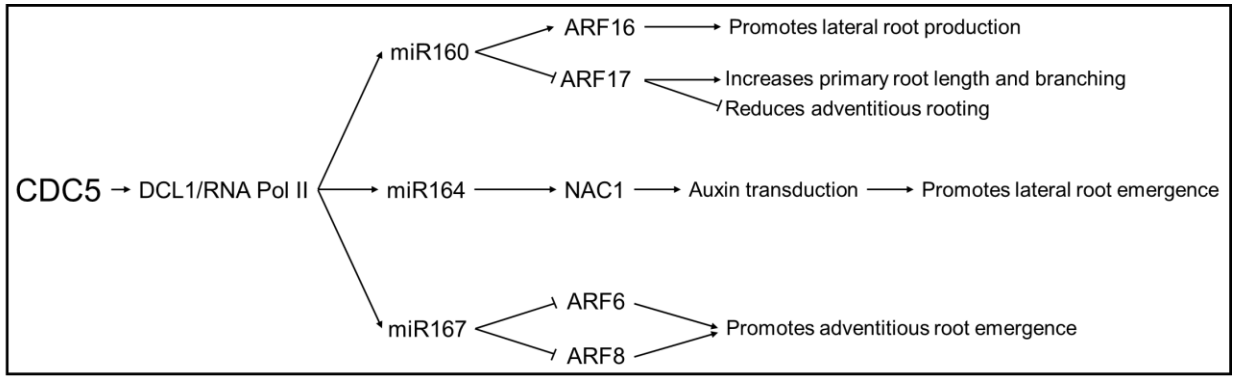
# A major QTL for increased anchorage strength

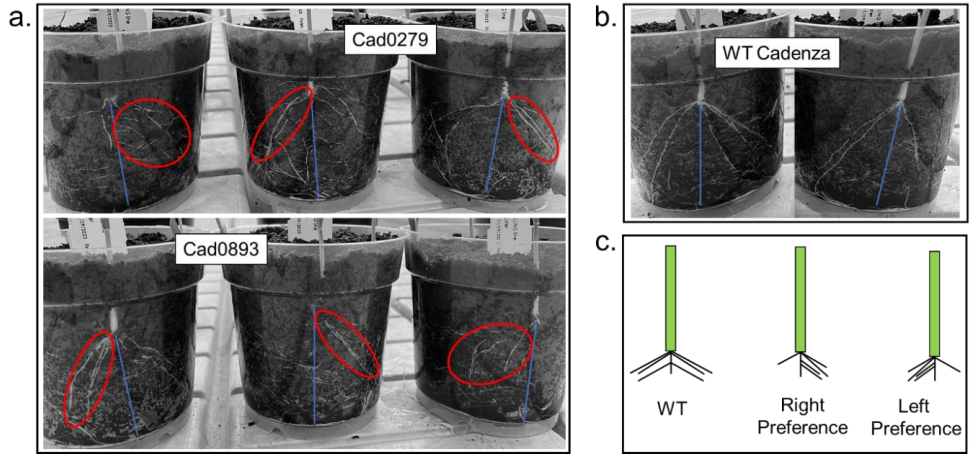


# CDC5 is an interesting candidate gene for this QTL




Known role of CDC5 in root hormone signalling

Lucy Blagden (UEA MSc student)




TILLING mutants of CDC5 show root phenotypes

# Future genetics for climate change questions

- With very good projections for future climate- How would the current RL perform under those conditions?
- Do breeders have the genetic variation they need?
- How will the UK wheat growing landscape change?
- WGIN has identified 3 QTL that might confer advantage under drought- what are the mechanisms?  How can they be deployed in breeding?
- Recent genomics work in the Watkins Collection shows how much diversity is absent in modern wheat. How can we access this variation for climate adaptation?

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# THANKS!

Clare Lister

Working above and beyond for the John Innes Centre since 1989!