Wheat Genetic Improvement Network

John Innes Centre

UK drought: why we need DT wheat!

WGIN Stakeholders Meeting

Clare Lister and Simon Griffiths

30/11/2017

Department for Environment Food & Rural Affairs

UK drought: why we need DT wheat!

WGIN Stakeholders Meeting

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Cathy Mumford and the Experimental Trials Team
Simon Orford, Rajani Awal, Axel Lucmort
Andrew Riche and RothRes Drone Team

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UK Drought Tolerance in Paragon x Garcia

- Drought Trial being repeated 2016-2017
- Location: Riverside Field, Church Farm, Bawburgh
- Field with lighter sandy soil and gentler slope

- **WHAT I NEED NOW IS A DROUGHT!**
- …… but maybe just over *my* field you're probably thinking!

LAST SLIDE IN 2016 STAKEHOLDERS MEETING PRESENTATION!

Be careful what you wish for…

(It's all about) Yield Stability…

WGIN phase 3

"Improving the resilience of the wheat crop through genetics and targeted traits analysis"

- Wheat growing conditions are subject to escalating climate volatility
- Acceptably high yield levels, with consistency between locations and years is an increasingly important target.
- It is easy to be stable and low!

- Is improved drought-tolerance one route to increased stability for UK wheat?

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… and why we need DT wheat

- Wheat is susceptible to drought at the start of stem extension (Stage 31) when grain number is being determined.
- In the last seven years drought in E. Anglia has occurred five times during April, which coincides with this vulnerable period.
- We have been looking for drought-tolerant (DT) characteristics in RILs generated from a cross between Paragon (UK spring wheat) and Garcia (bred for drought conditions in S. Europe).

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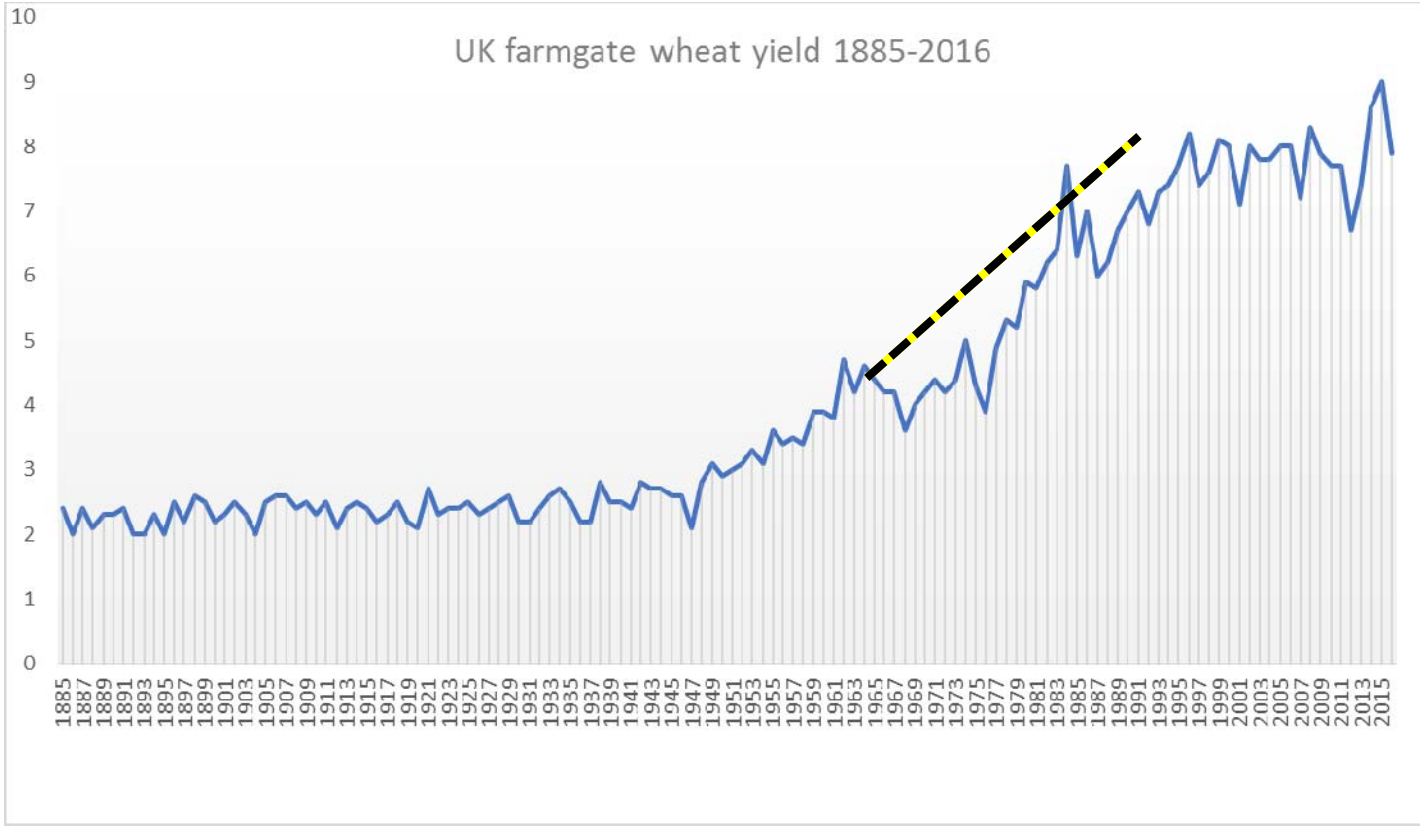
Grain Number



Increase in yield over this period not due to changes in grain size (= increased TGWT), but to changes in *grain number*.

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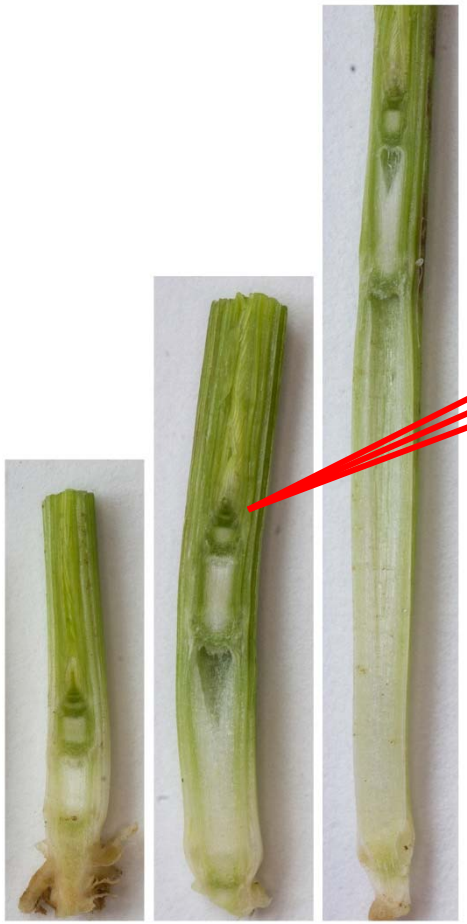
Grain Number

Staging of plants



30 **31** **32**

31

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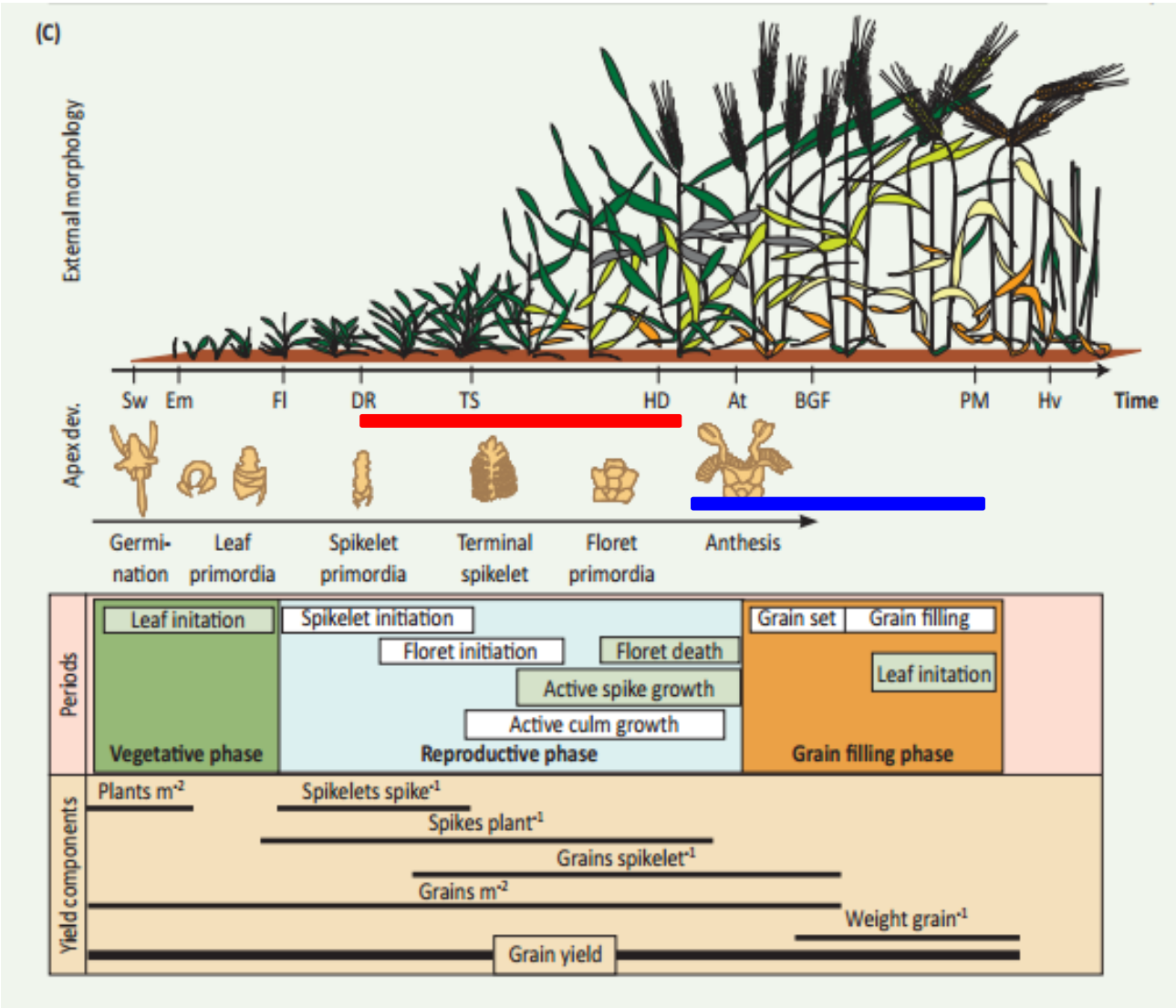
Grain number determined at the time of stem extension

Grain Number



Drought affects:
Grain number
up to anthesis
Grain size
post anthesis

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Gustavo Slafer

Grain Number

Eastern Daily Press

Dry spring and late frosts take their toll on East Anglia's farm crops

Chris Hill chris.hill@archant.co.uk @ChrisHill75

PUBLISHED: 18:23 28 April 2017 | **UPDATED:** 18:23 28 April 2017

Quote from **Andrew Francis**, Farm Manager at the Elveden Estate, near Thetford

"If a plant is under drought stress it knows it cannot support all these grains, so it will produce less [grains]. It is not massive but it could knock 5pc of the yield off and then if it cannot build a green canopy it cannot intercept enough light to fill the grains and the grains will come out small."

Grain Number

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April Drought

Eastern Daily Press

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PUBLISHED: 18:23 28 April 2017 | **UPDATED:** 18:23 28 April 2017

Quote from Phil Garnham, *Weatherquest*

"A lot of our customers have had crops failing because there is not been the persistence of rainfall that you would expect."

"After a dry winter we had a relatively wet January…

But in February we had half the average rainfall and in March it was 40pc. And in April, so far this month it has been 18mm of rain against an average of 44mm."

April Drought (and cold!)

theguardian

Farmers fear for their crops after the driest April on record

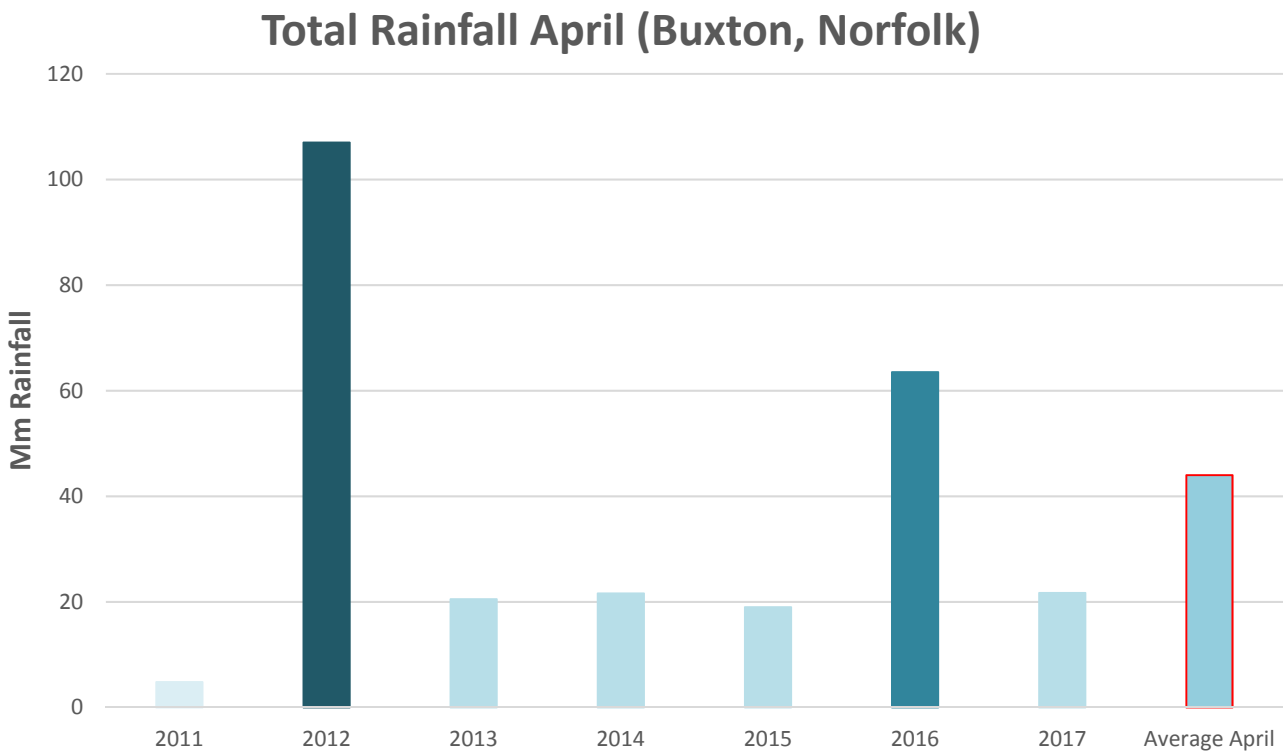
Helen Pidd North of England editor

Tuesday 9 May 2017 16.55 BST

"The other unusual thing about April was that the dry conditions were not accompanied by significant temperature increases, with the UK mean temperature just 0.6°C higher than average for the month."

Even more resilience required?

April Drought



Data courtesy of **http://www.buxton-weather.co.uk/weather.htm**

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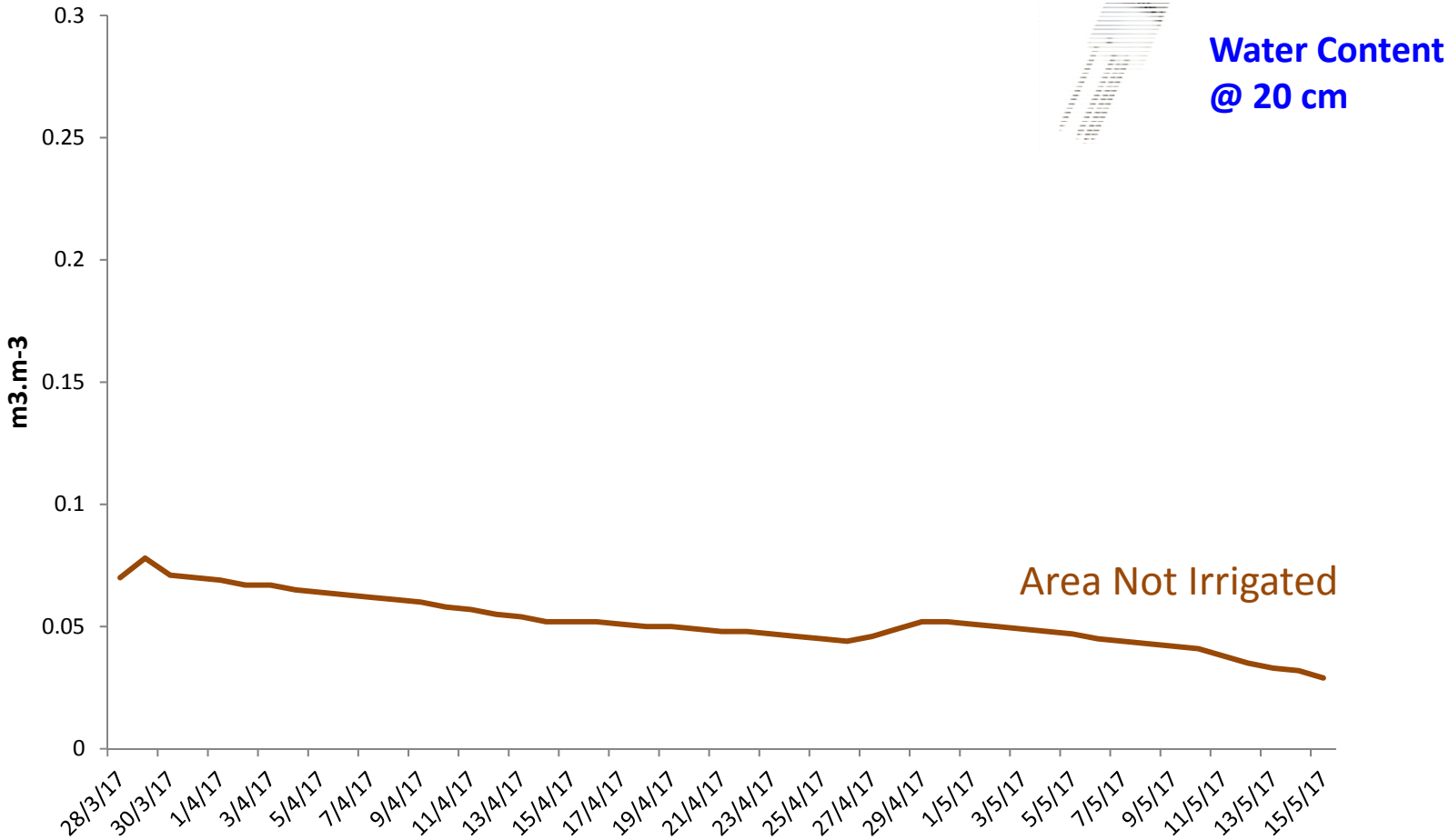
April Drought



Soil water data from the 2016-2017 PxG Drought Trial

In the 2015-2016 trial soil was waterlogged until early May!

Drought-tolerant characteristics

- Paragon x Garcia (PxG) RIL population produced within WGIN to specifically target UK drought
- Paragon is a UK spring wheat
- Garcia is grown in southern France and northern Spain, and therefore adapted to drought stress

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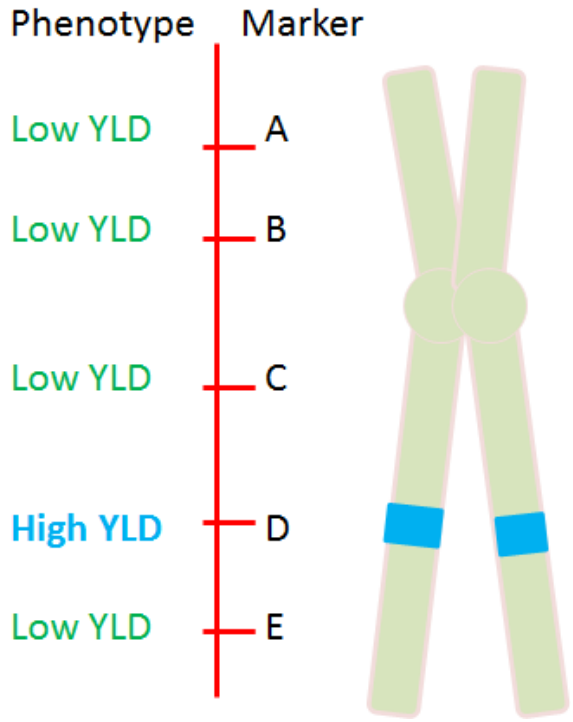
Drought-tolerant characteristics

- Potentially advantageous to look for DT characteristics in non-UK wheat varieties from hot dry areas, such as Garcia

- Phenotype data + marker data from this population should allow identification of specific chromosome regions from Garcia carrying DT genes (= *QTL mapping*)



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Drought-tolerant characteristics

- Precise genetic stocks (= NILs) can then be generated from lines carrying these regions and used to validate the phenotypic effect.

- If successful these chromosome regions could be introduced into breeding programmes to improve drought-tolerance and therefore resilience, in UK wheat

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Drought-tolerant characteristics

- 3 x Drought Trials with 177 PxG lines
- Church Farm, Bawburgh, Norfolk
  - 2015-2016 – no drought in April
  - 2016-2017 – April drought
  - 2017-2018 - ?

- 2 randomised reps each of Irrigated and Not Irrigated plots
- Multiple traits scored, measured or observations made

Date	Measured	Observations
Stage 31	Height	Awns
Booting	Yield	Ear Compactness
Ear Emergence	Specific Weight	Lodging
	TGWT	Tillering
		Waxiness
		Senescence

- QTL mapping carried out where sufficient data

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Drought-tolerant characteristics

Scored Date

- Stage 31 – only one rep scored (2017) to determine range (about three weeks)

- Booting and Ear Emergence

  2016: average similar in both NI and IR reps

  2017: average about 1 week earlier in NI reps

Drought-tolerant characteristics

Measured

- Height (HT)

  2016: average similar in both NI and IR reps

  2017: plants in NI plots significantly shorter

- Yield (YLD)
- Specific Weight (SW) and TGWT

  2016 values higher than 2017

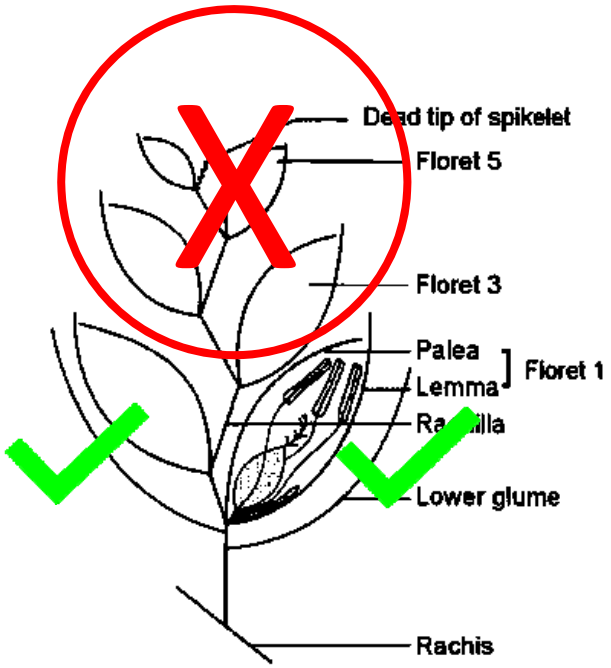
  NI values higher than IR – unexpected!

Drought-tolerant characteristics

- In NI plots drought causes some of the florets to abort -> lower grain number

- Remaining grain can compensate, becoming larger and heavier -> increasing TGWT?

- May be more uniform in size so better packing -> increased SW?



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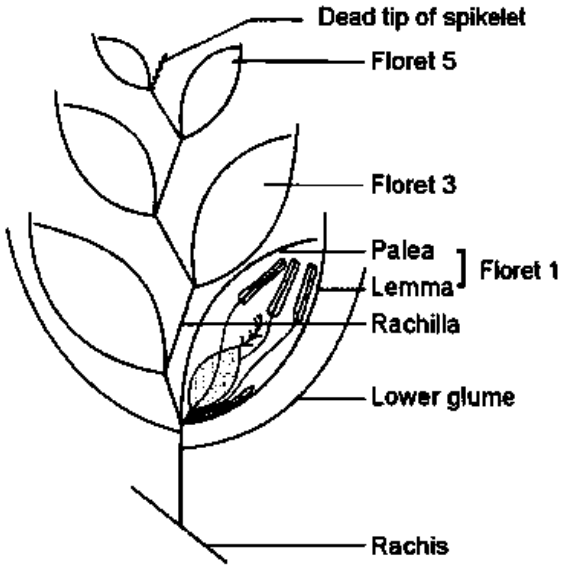
Drought-tolerant characteristics

- In IR plots more florets develop
  -> higher grain number



- Late drought reduces grain filling
  -> lower TGWT?

- The IR seed may be a mixture of sizes which do not pack well -> lower SW?

- But grain size and density not indication of quality!

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Drought-tolerant characteristics

Observations **made on whole or part of plots**

Contributing to drought tolerance or consequence of drought?

Phenotype	Observations
Awns	Increased awn length in NI plots
Ear Compactness	
Lodging	
Tillering	
Waxiness	
Senescence	

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Drought-tolerant characteristics

***Observations* made on whole or part of plots**

Contributing to drought tolerance or consequence of drought?

Phenotype	Observations
Awns	Increased awn length in NI plots
Ear Compactness	Increased ear compactness in NI plots
Lodging	More lodging in IR plots
Tillering	
Waxiness	
Senescence	

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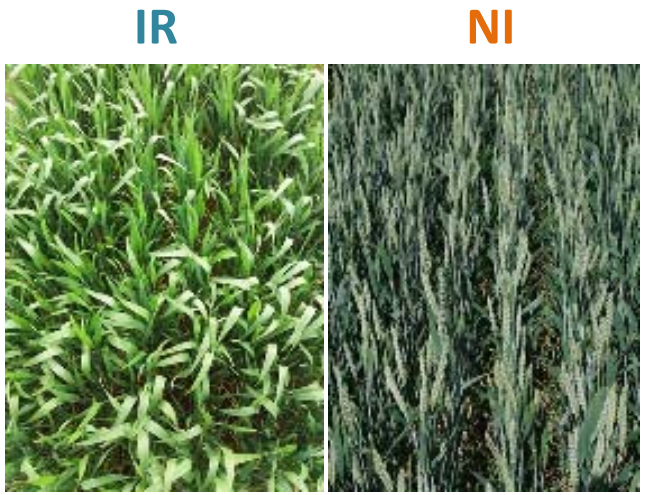
Drought-tolerant characteristics

Observations made on whole or part of plots

Contributing to drought tolerance or consequence of drought?

Phenotype	Observations
Awns	Increased awn length in NI plots
Ear Compactness	Increased ear compactness in NI plots
Lodging	More lodging in IR plots
Tillering	Decreased tillering in NI plots
Waxiness	Increased waxiness in NI plots
Senescence	Faster senescence in NI plots



Drought-tolerant characteristics

Regular UAV* imaging (S. Orford)

11/05/2017
Poor canopy in NI area

01/06/2017
More waxiness in NI area

30/06/2017
Earlier senescence in NI area

Harvested nearly two weeks earlier than 2016

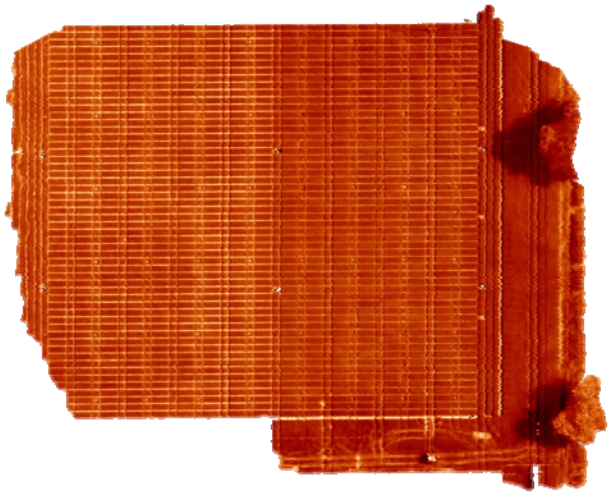
* Courtesy EI

Drought-tolerant characteristics

Rothamsted Research
Thermal imaging 25th May 2017

- Drought Trial ideal experiment to test and help develop their thermal imaging hardware and software

- Eight flights yielding thermal data



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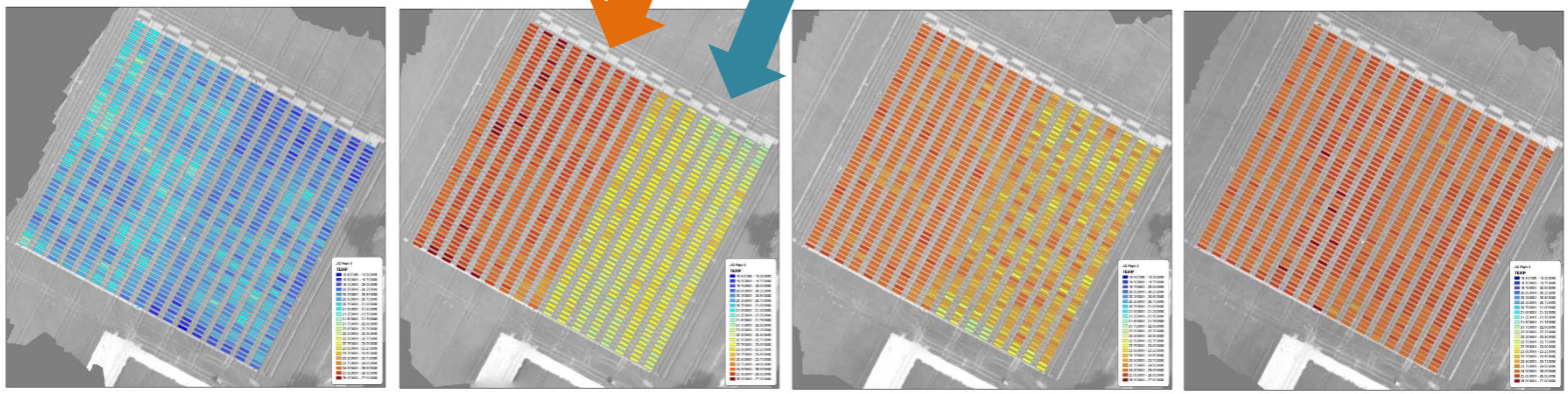
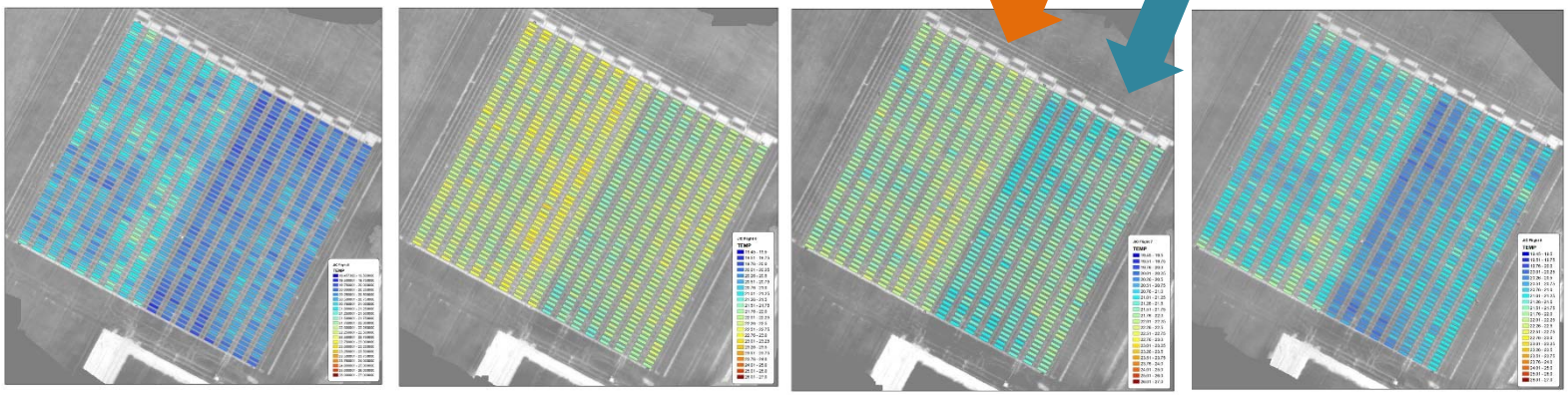
Results



8:47 9:38 10:40 11:14



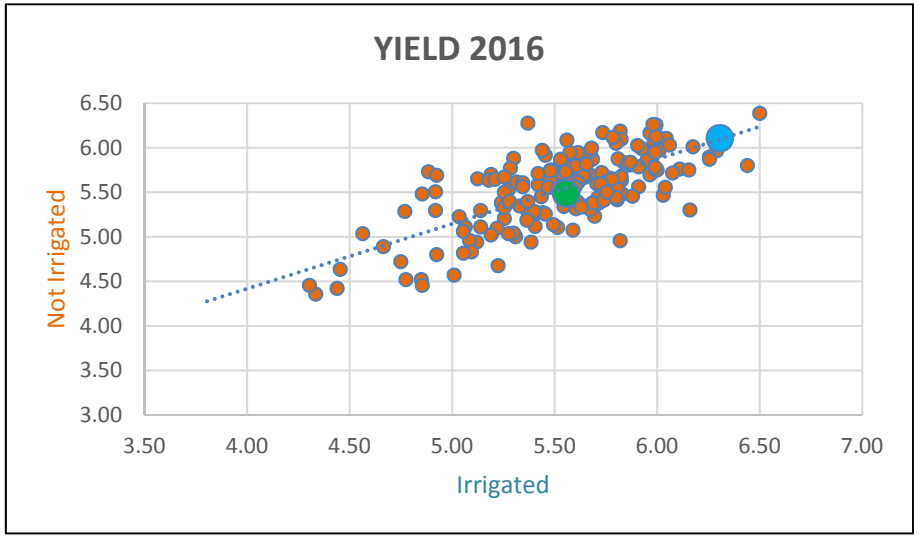
11:58 13:16 14:03 15:33

TEMP
- 19.45 - 19.5
- 19.51 - 19.75
- 19.76 - 20.0
- 20.01 - 20.25
- 20.26 - 20.5
- 20.51 - 20.75
- 20.76 - 21.0
- 21.01 - 21.25
- 21.26 - 21.5
- 21.51 - 21.75
- 21.76 - 22.0
- 22.01 - 22.25
- 22.26 - 22.5
- 22.51 - 22.75
- 22.76 - 23.0
- 23.01 - 23.25
- 23.26 - 23.5
- 23.51 - 23.75
- 23.76 - 24.0
- 24.01 - 25.0
- 25.01 - 26.0
- 26.01 - 27.0

Irrigated area heats up more slowly…
… then cools faster than the Not Irrigated area.

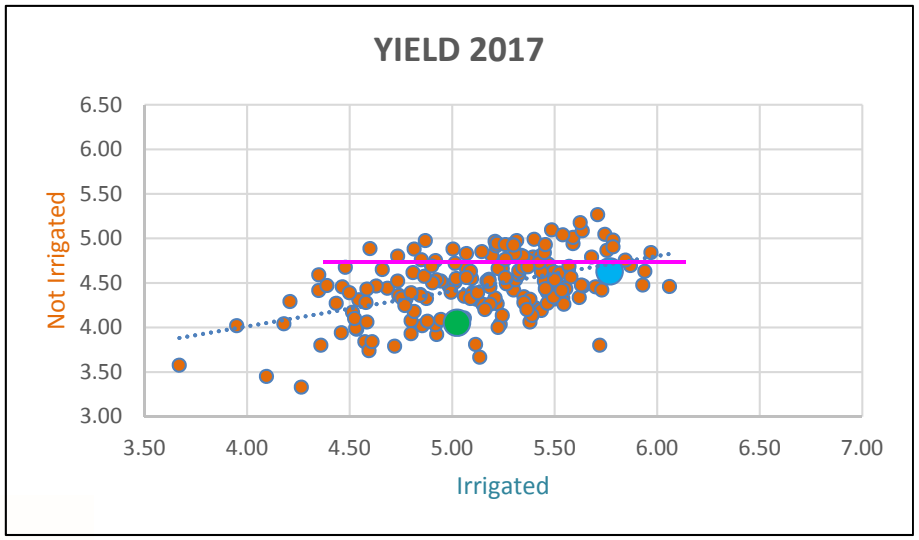
ROTHAMSTED RESEARCH

Drought-tolerant characteristics



Same yield for Paragon in NI and IR plots
Slightly higher yield for Garcia in IR plots

Garcia one of highest yielding lines

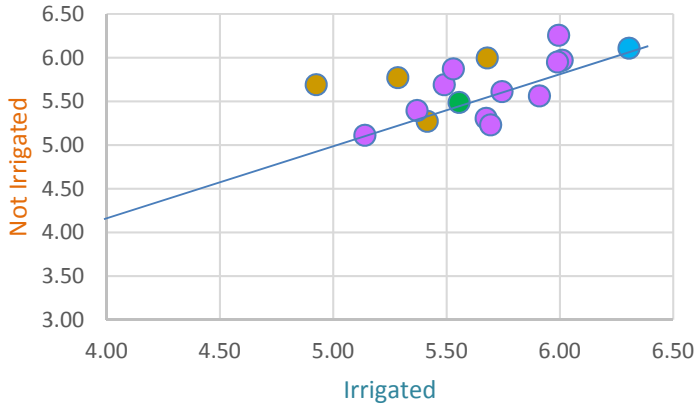


Yields at least 1.5 kg lower than 2016

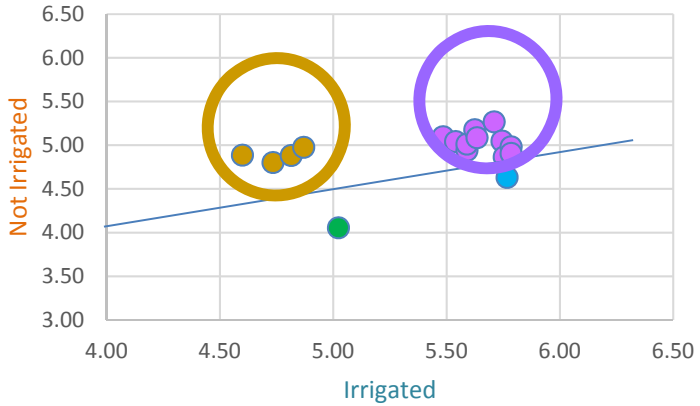
20% yield reduction for Paragon and Garcia between the IR and NI plots

Many lines performing better than Garcia in NI

Drought-tolerant characteristics



2016
No April drought



2017
April drought

Selected lines performing better than Garcia under drought conditions

Lines have highest yield in NI compared to IR

Lines have higher yield than Garcia in NI

Drought-tolerant characteristics

- Lines carry Garcia allele () for a TGWT QTL on 4D (=*Rht*)
- Has *smaller* grains but can produce *more grains* under drought conditions than other lines?

- Lines carry the Garcia allele () for a HT, YLD and SW QTL on 1A

- 14/15 lines carry the Garcia allele () for YLD QTL on 2B (not *Ppd*)
- Possible gene candidate for this QTL?

- 12/15 lines carry the Garcia allele () for SW QTL on 7D

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Future Work

- Third year of drought trial
- Use of “Rain-out” shelters
- Nominate Garcia alleles for inclusion in DFW Pre-breeding Toolkit
- Providing markers for selection of these alleles in breeding
- Selected PxG lines for Breeders to test
- Exploring drought-tolerance in other populations

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Summary

- There was significant drought in April 2017, during the start of stem extension
- Clear phenotypic differences were observed between lines grown in the IR and NI plots
- QTL mapping has identified chromosome regions from Garcia which may contribute to drought tolerance

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Resources and Technology

HAVE YOU HEARD ABOUT THE PARAGON LIBRARY?

WGIN has been part of an informal consortium developing NILs in the genetic background of the UK spring wheat Paragon. The collection, known as the Paragon Library, was developed at JIC and consists of around 350 lines.

The project involves crossing different combinations of genes, QTLs and mutations into the common background of Paragon and then studying the phenotypic effects. This uniform genetic background this will provide a unique insight into the potential value of these genetic effects for UK breeding and agriculture. Most of the effects were discovered in work funded by DEFRA, the BBSRC and AHDB and represent hundreds of person-years' of research.

Most of the Paragon Library has already been trialled in 1 m and 6 m plots for the duration of WGIN. Phenotypic data from these trials (phenotypes underlying grain yield and crop adaptation) should become available on the WGIN website from spring 2018.

The Paragon Library will be genotyped on the Axiom 35k Breeders' Array shortly and seed from the genotyped plants will be used to generate the resource for distribution.

NILs are available for multiple alleles of:
Rht-D1, Rht-B1, Rht8, Ppd-B1 Ppd-D1, Lr19, 1BL.1RS and *7B* (yield), 10 Heading Date QTL, *Vrn1, Vrn3*, grain size (5A, 7A), and selected WGIN mutants, such as EMS.

Clare Lister and Simon Griffiths

A REALLY USEFUL FIELD SCORING APP!

One of WGIN's remits is to explore and disseminate new technology. KDSmart is part of the "KDDart" platform from **DArT**. However the app can also be used in standalone mode for the collection of field data and is recommended by CIMMYT
http://www.cimmyt.org/

KDSmart can be downloaded **free** from Google Playstore onto an **Android** device. There are several demo trials to practice with (recommended!).

There is very detailed information available on how to use the app and they are responsive to feedback.
http://www.kddart.org/kdsmart.html
http://www.kddart.org/help/kdsmart/index.html

We used KDSmart for scoring the Paragon x Garcia Drought Trial at JIC this year and were very impressed with it's user-friendliness and performance.
We therefore feel confident in recommending it to farmers, breeders and researchers.
Give it a try, it's **free** after all!

Clare Lister and Simon Griffiths

*Disclaimer: **JIC** has no commercial arrangement with **Diversity Arrays Technology (DArT)**

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And finally… Publicity!

Eastern Daily Press

John Innes Centre trial aims to find wheat which can resist spring droughts

Chris Hill chris.hill@archant.co.uk @ChrisHill75

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