Impact of heat on wheat

Karine Chenu, Najeeb Ullah, Muhammed Yahya, Brian Collins, Troy Frederiks, Jack Christopher

QAAFI, The University of Queensland, Australia

Department of Agriculture and Fisheries, Australia

Increasing heat tolerance in wheat in Australia

1. Change in temperature across the Australian wheatbelt
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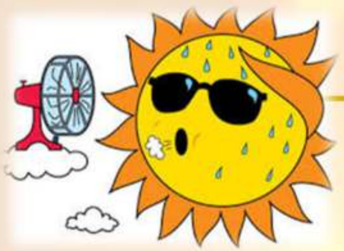
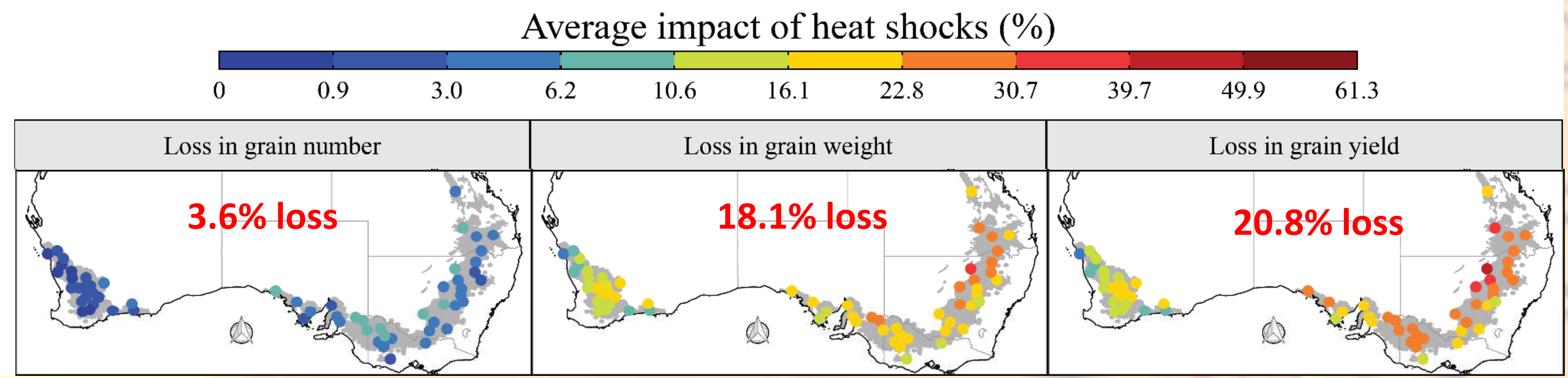


Australian wheat frequently experience heat stress

Behnam Ababaei



Mid-maturing cv Janz, sown on 15 May – Period: 1985-2017

Ababaei and Chenu. 2020. *Agricultural and Forest Meteorology.* 284:107889

Increase in temperature (since 1985)

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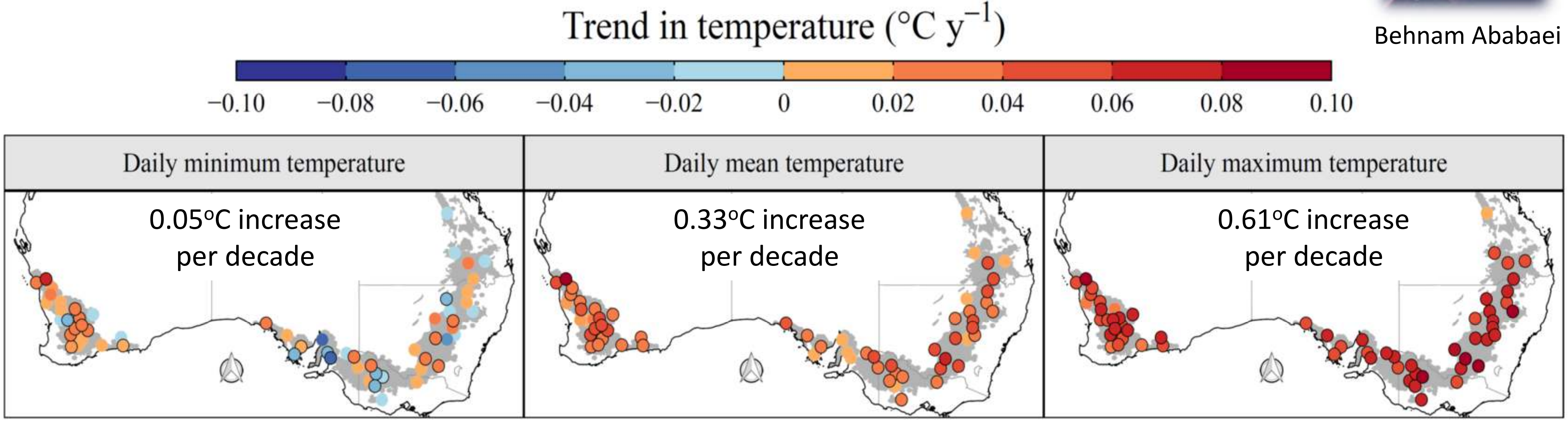
Chronic increase in temperature



Ababaei and Chenu. 2020. *Agricultural and Forest Meteorology.* 284:107889

Trend for Aug-Nov temperatures (1985-2017)

Increase in temperature (since 1985)

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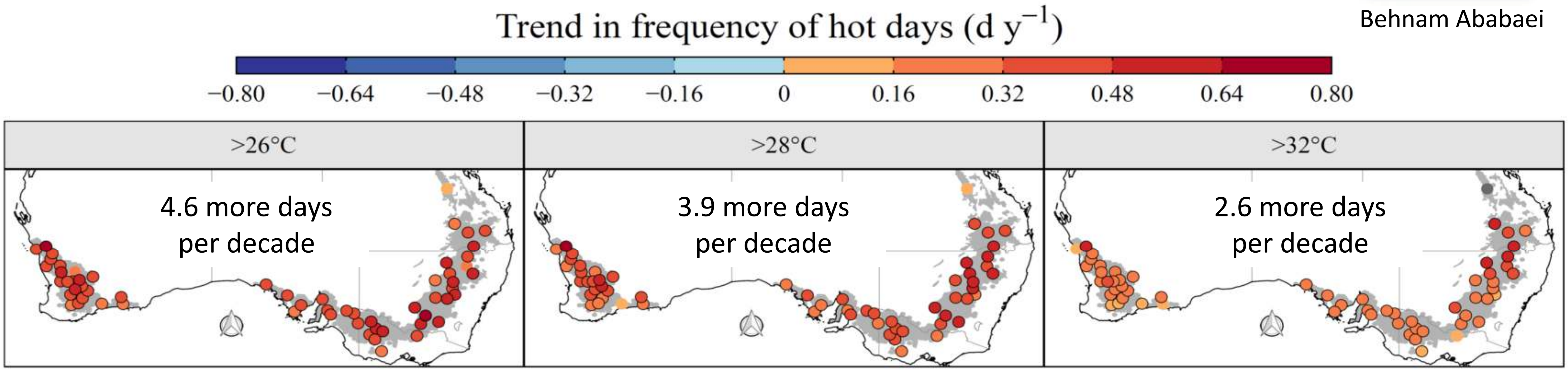
Daily variability - Increase in heatwaves



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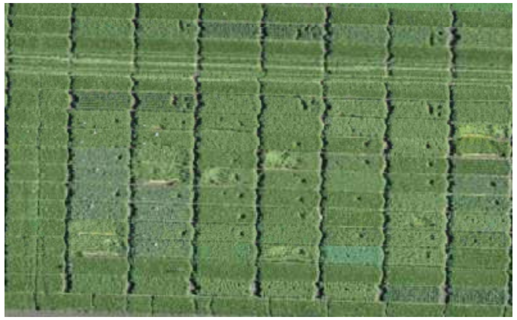
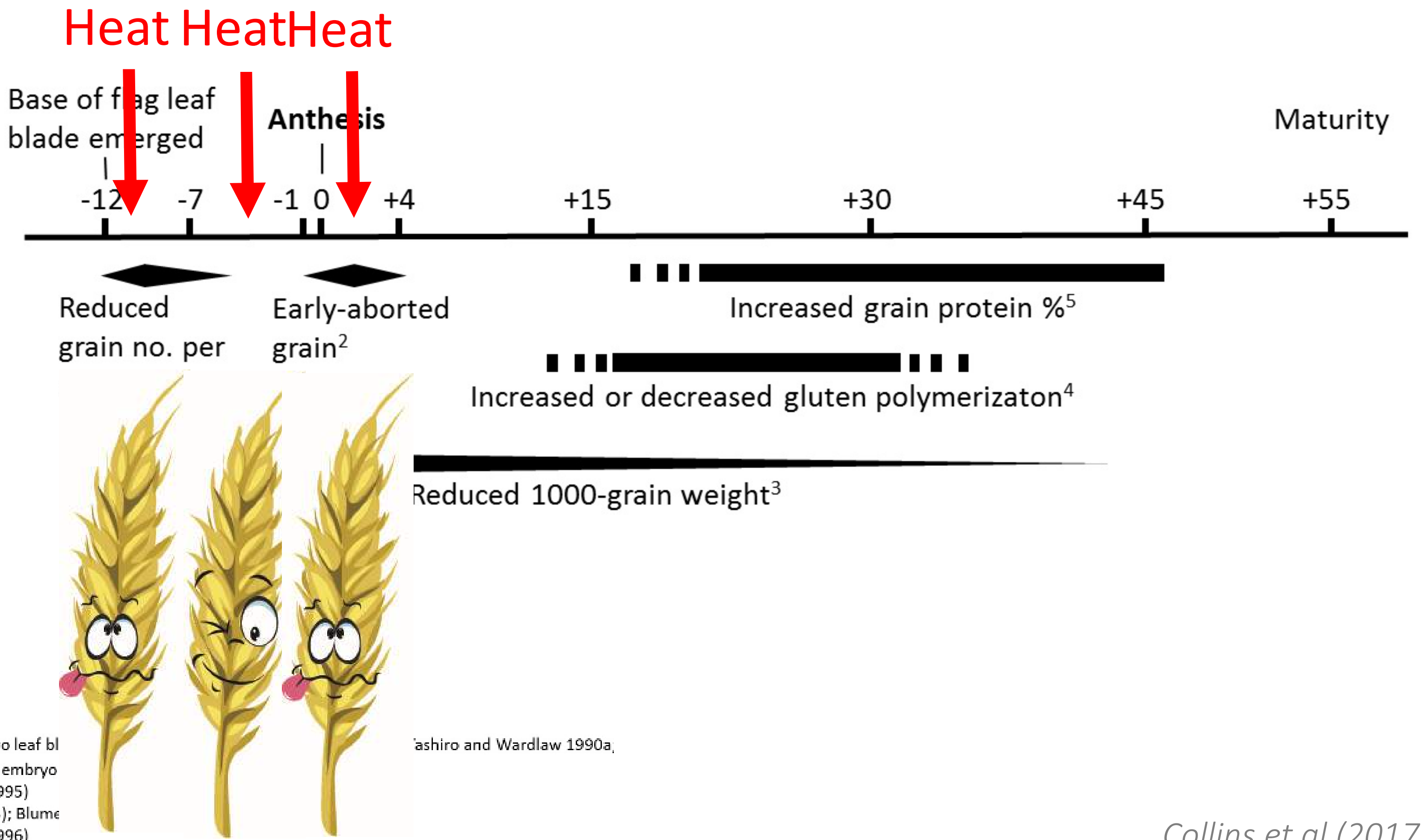


Importance of the timing and intensity of a stress



1. When base of last two leaf bl ... 'ashiro and Wardlaw 1990a,
2. Grains < 2.3 mm and embryo
3. Stone and Nicolas (1995)
4. Maphosa et al. (2014); Blume
5. Stone and Nicolas (1996)

Collins et al (2017) GRDC Update

Screening for heat tolerance

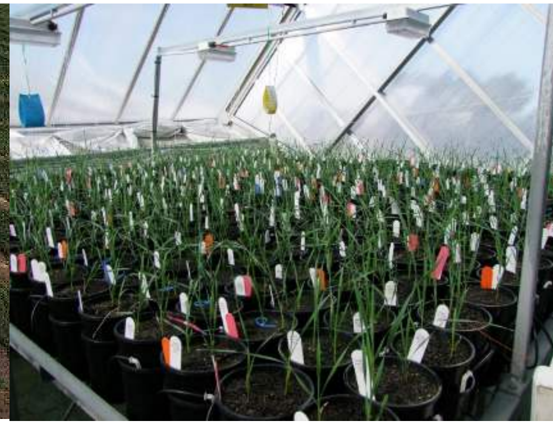
Existing methods to screen for heat tolerance:

- Different sowing dates (high number of lines, increased exposure to heat, but no control of heat stress)
- Heat tents – *passive heating* (installed at targeted stage, but different heat intensity if installed different days)
- Heat chambers – *active heating* (very accurate, low to medium number of lines, laborious and costly)
- Controlled environments (translation to the field?)

Late sowing (Photo: UQ)

Heat tent (U Leida)

Heat chambers at Narrabri PBI (Photo: K Shepherd)

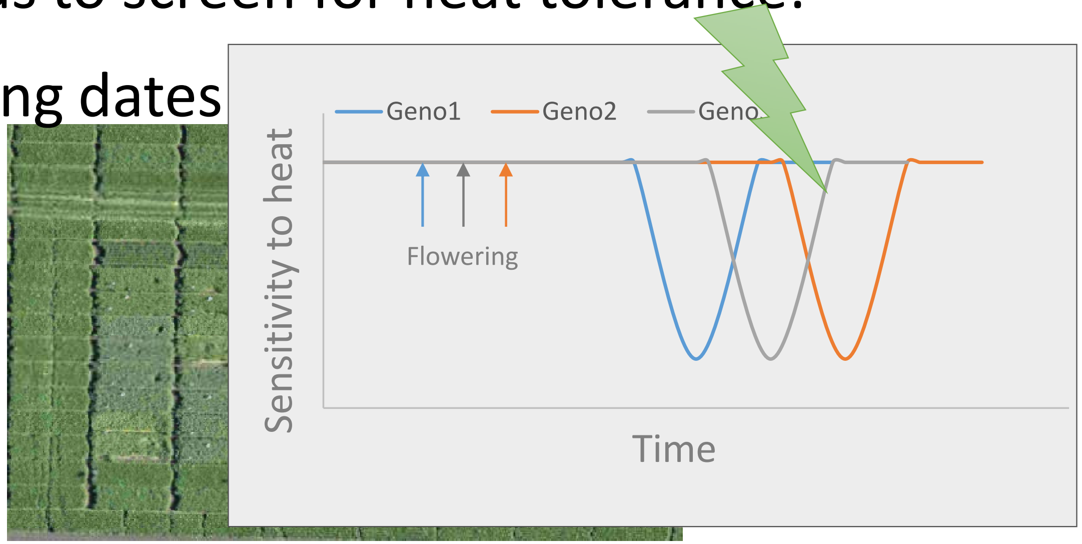


Controlled heat (UQ glasshouse)

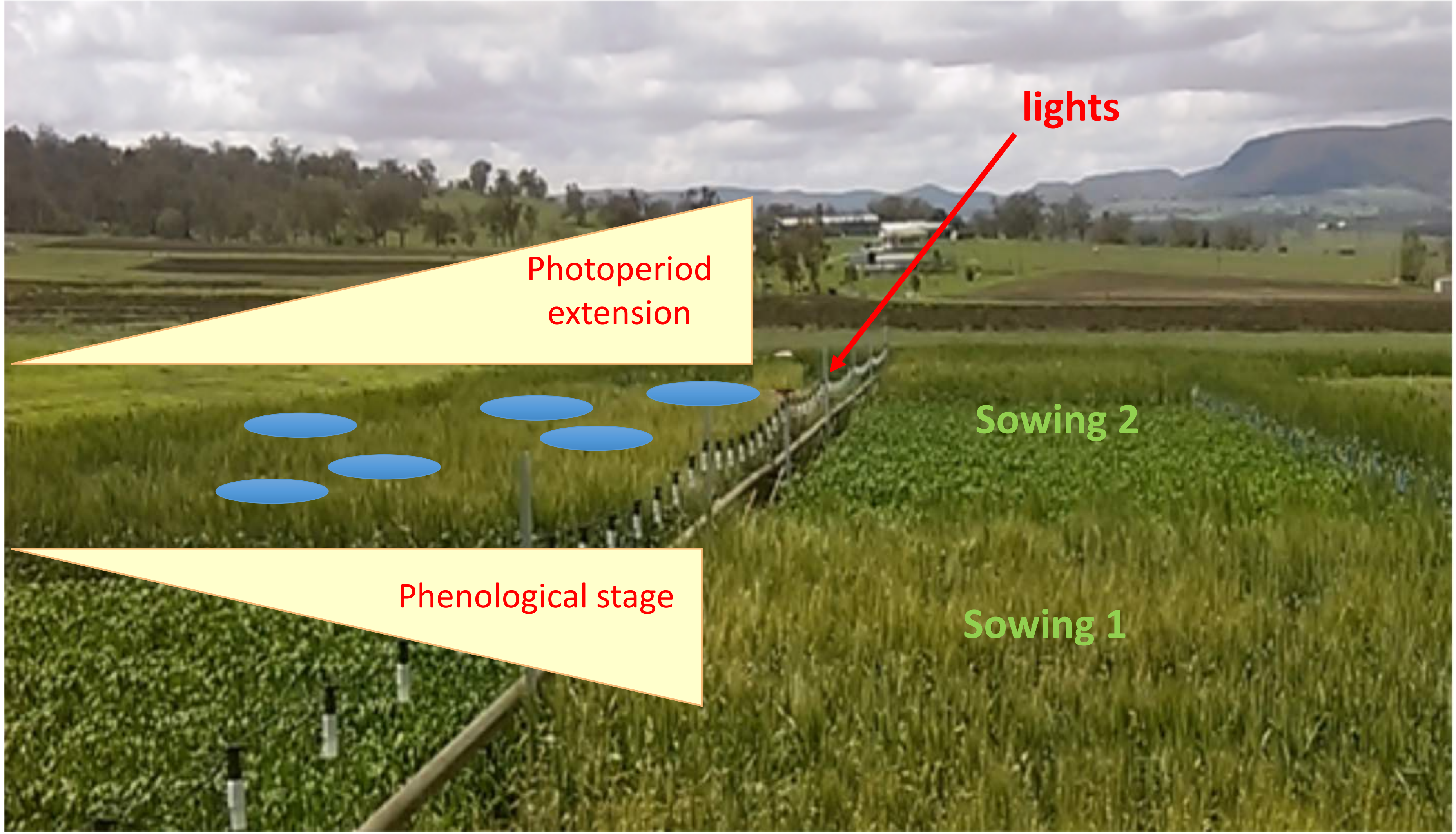
Screening for heat tolerance

Existing methods to screen for heat tolerance:

- Different sowing dates



New screening method for heat tolerance



Ullah et al. 2023. *European Journal of Agronomy*. 144: 126757.

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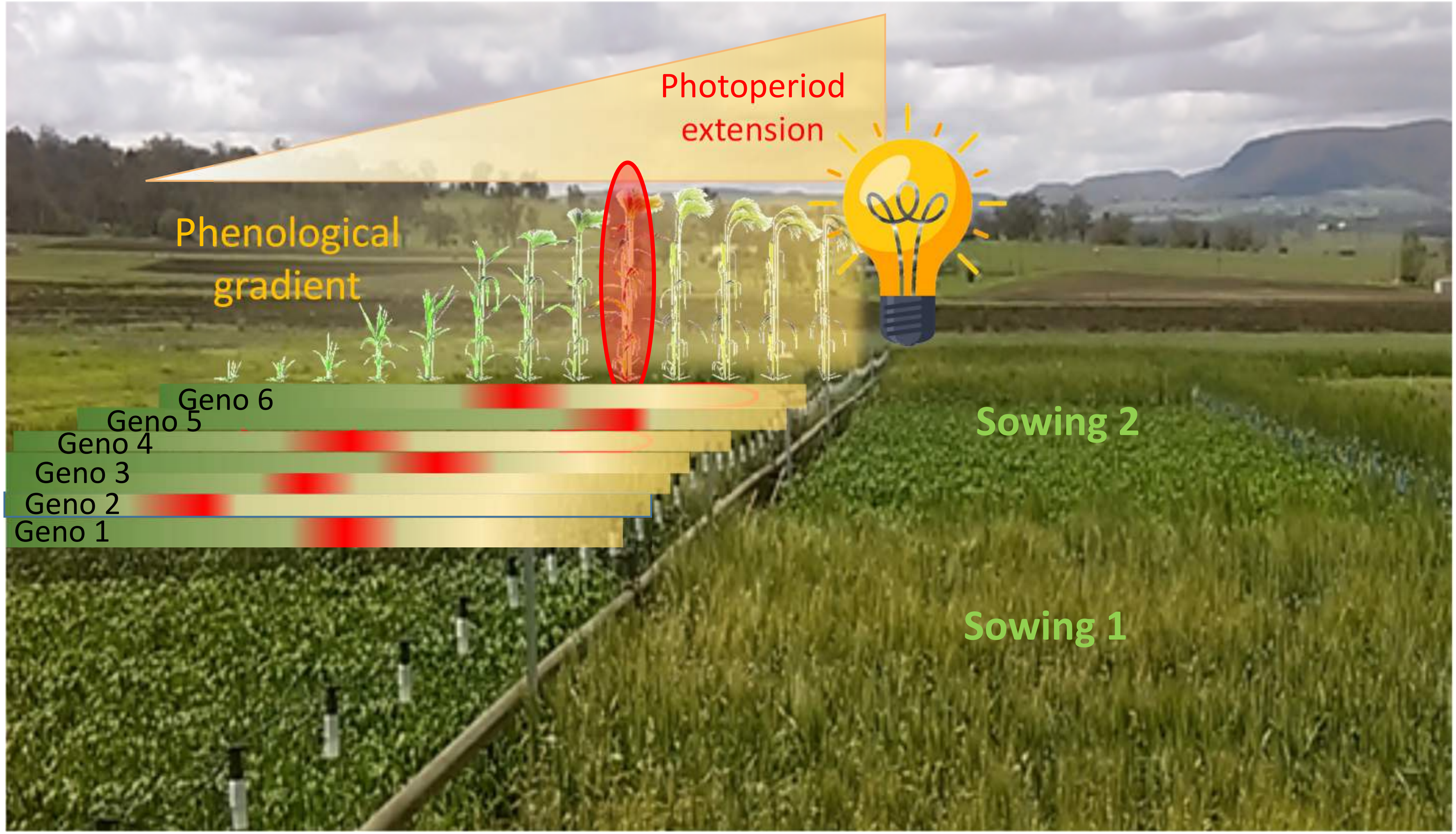

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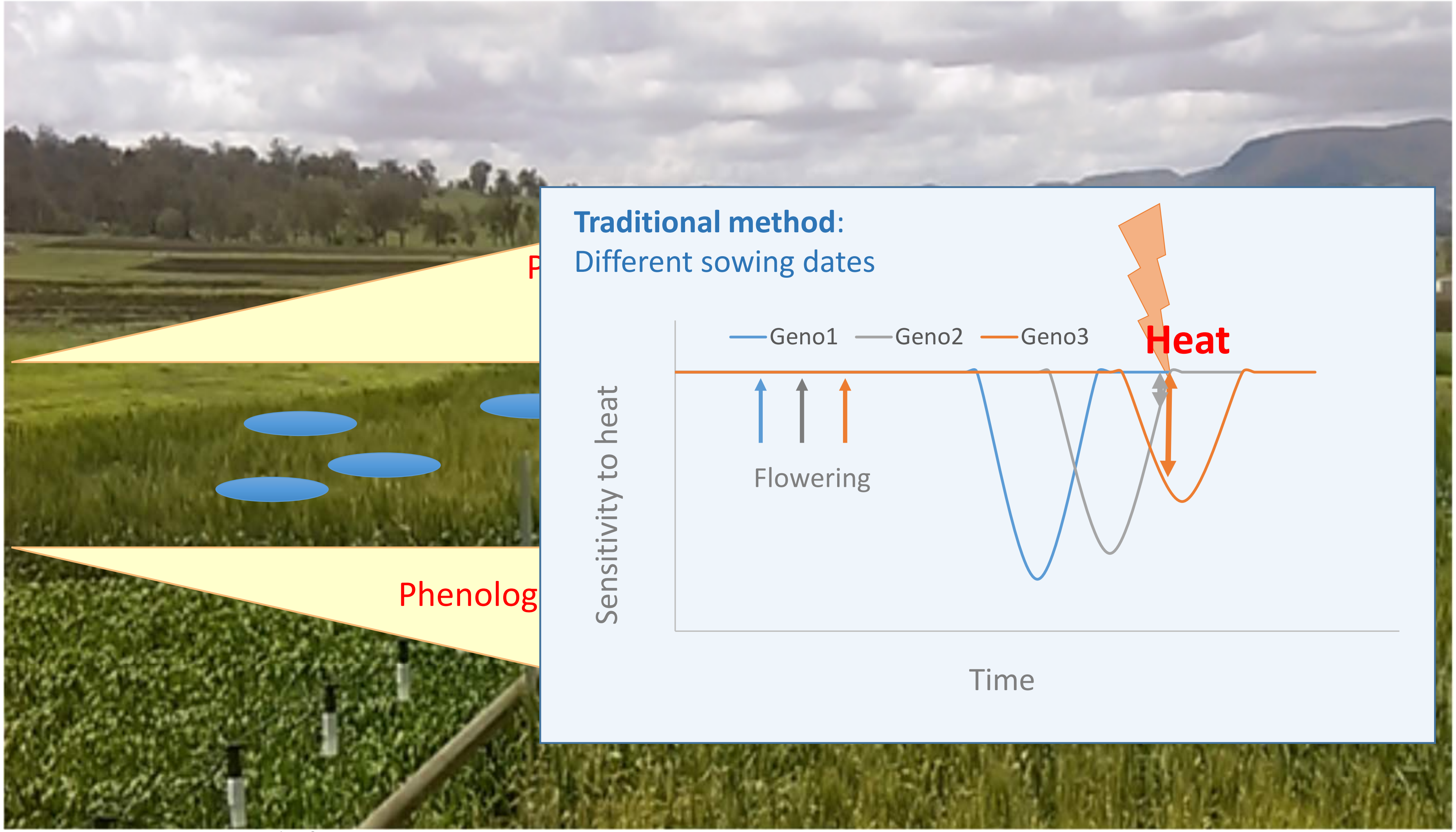

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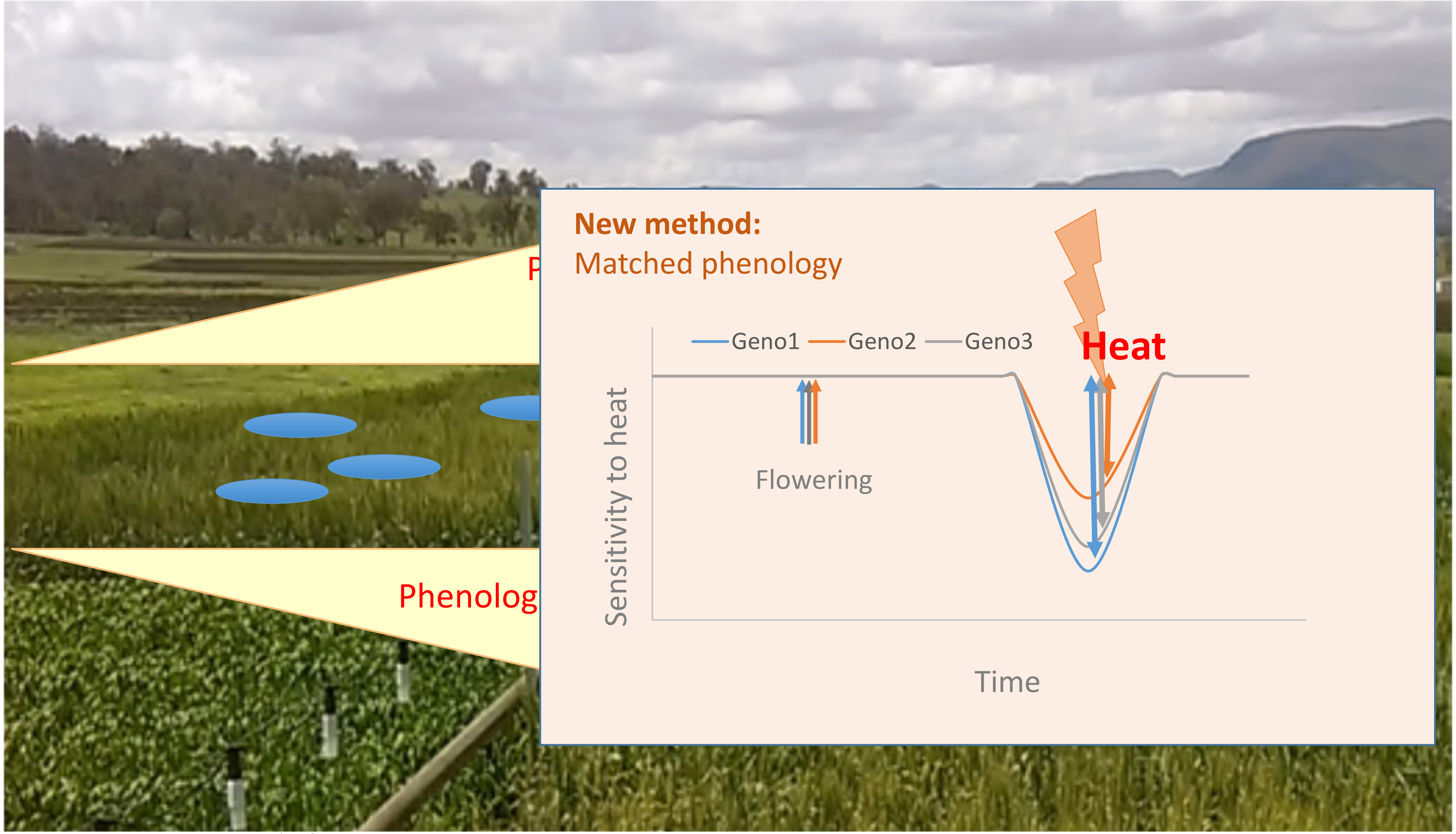

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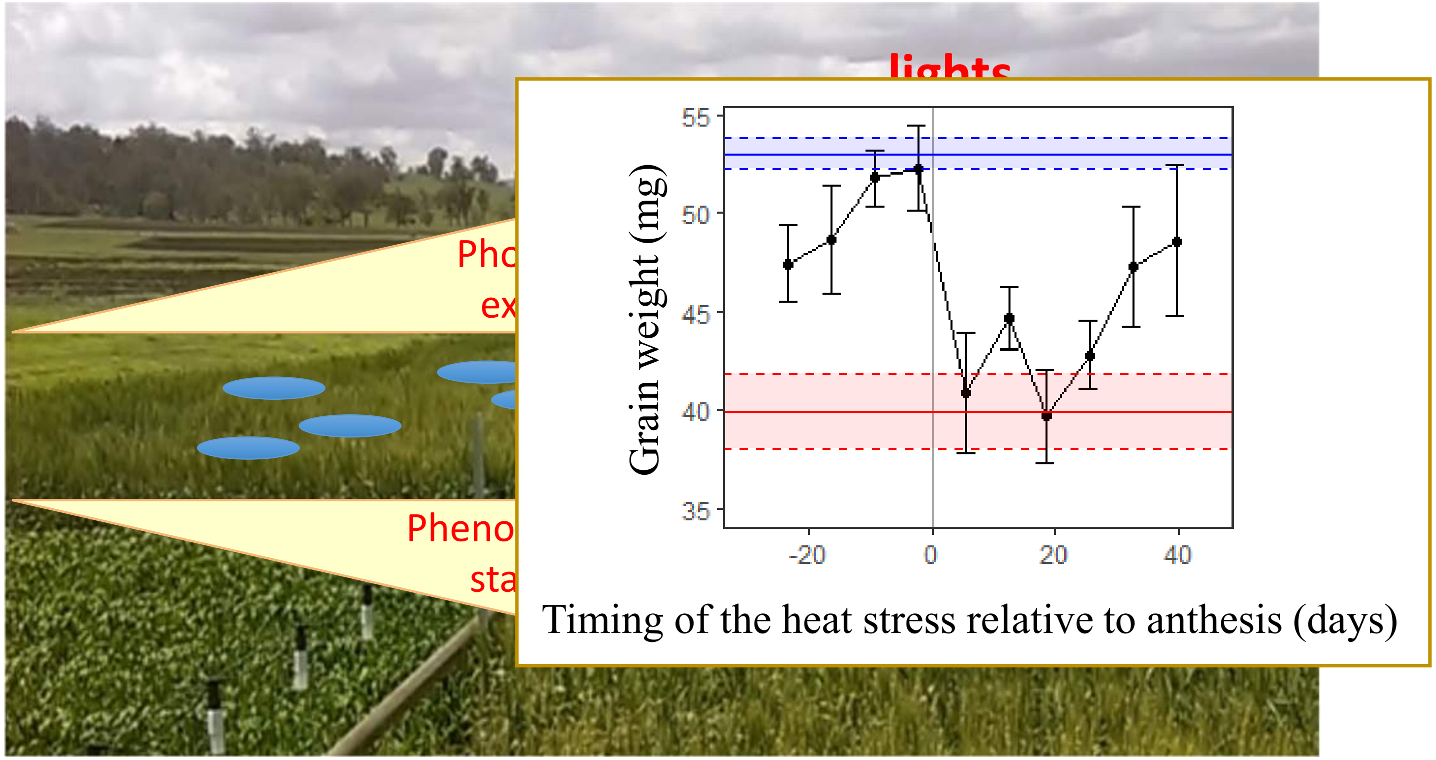

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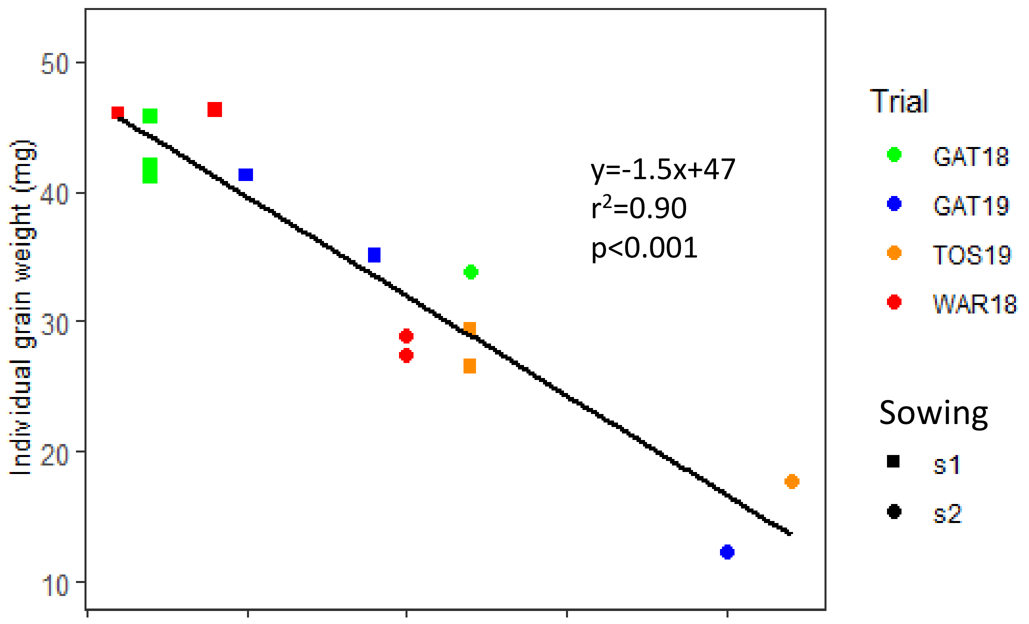


Najeeb Ullah

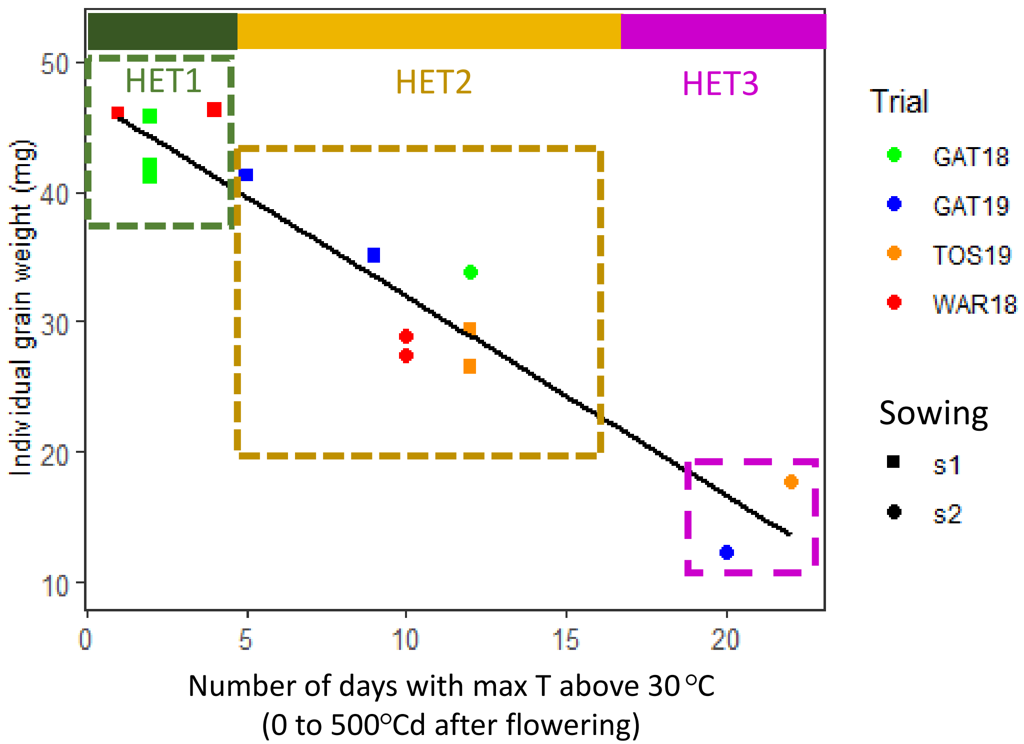
Multi-environment trials with different sowing dates (well irrigated)

⇒ Different levels of heat stress

Average results for 29-32 genotypes

Ullah et al. 2023. *European Journal of Agronomy*. 144: 126757..

New screening method for heat tolerance



Najeeb Ullah

Multi-environment trials with different sowing dates (well irrigated)

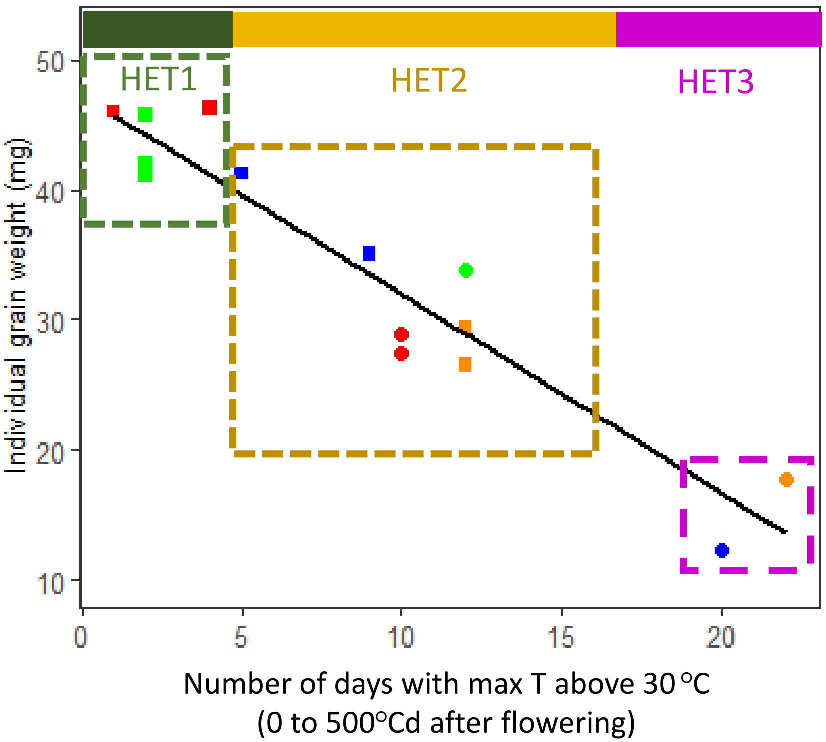
⇒ Different levels of heat stress

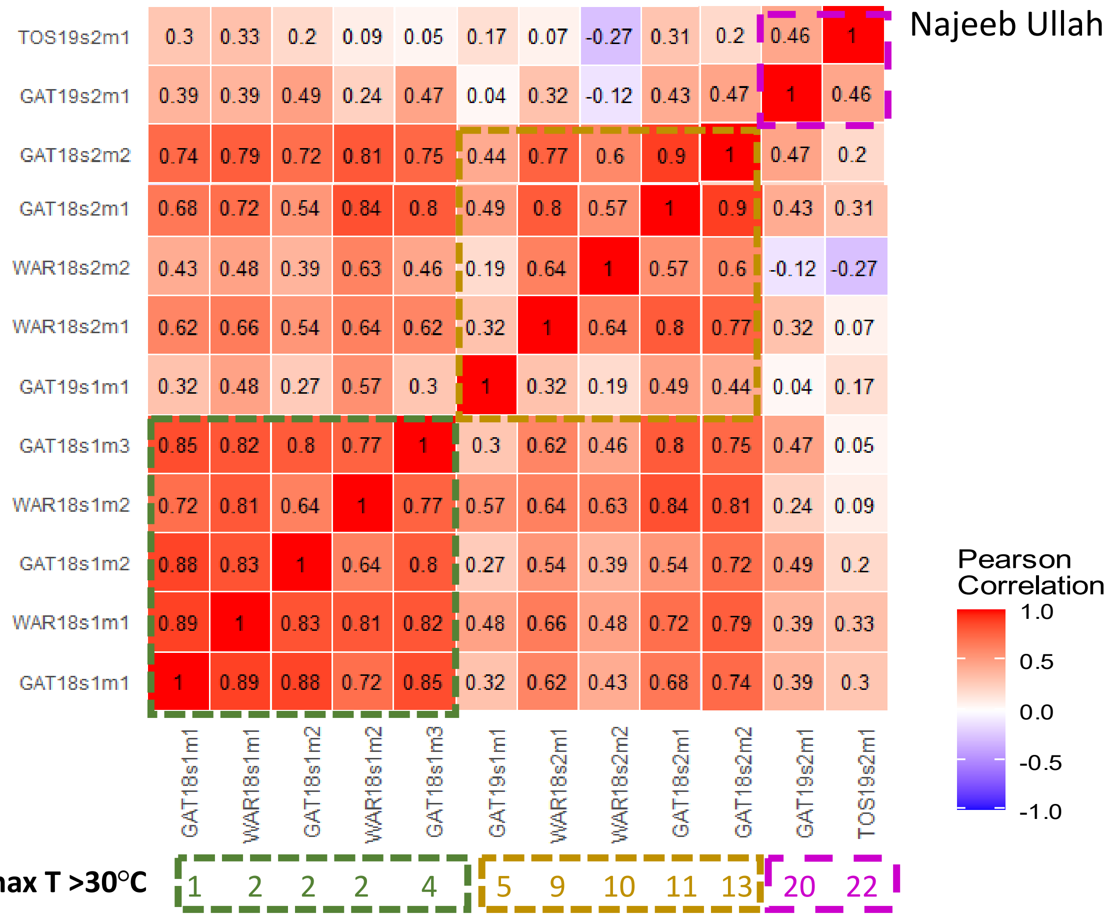
⇒ Moderate to high correlations (mostly >0.5) within Heat Environment Types for thousand grain weight (TGW)

⇒ Correlation much greater that what was found in conventional field plots (eg no correlation between trials within HET)

Ullah et al. 2023. *European Journal of Agronomy*. 144: 126757..

New screening method for heat tolerance





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New screening method for heat tolerance

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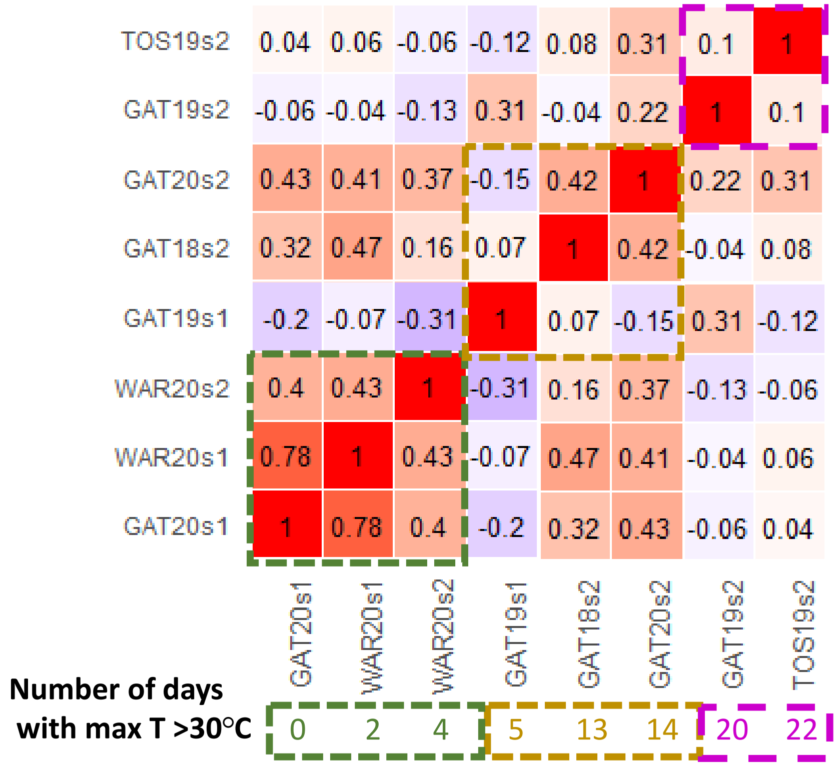
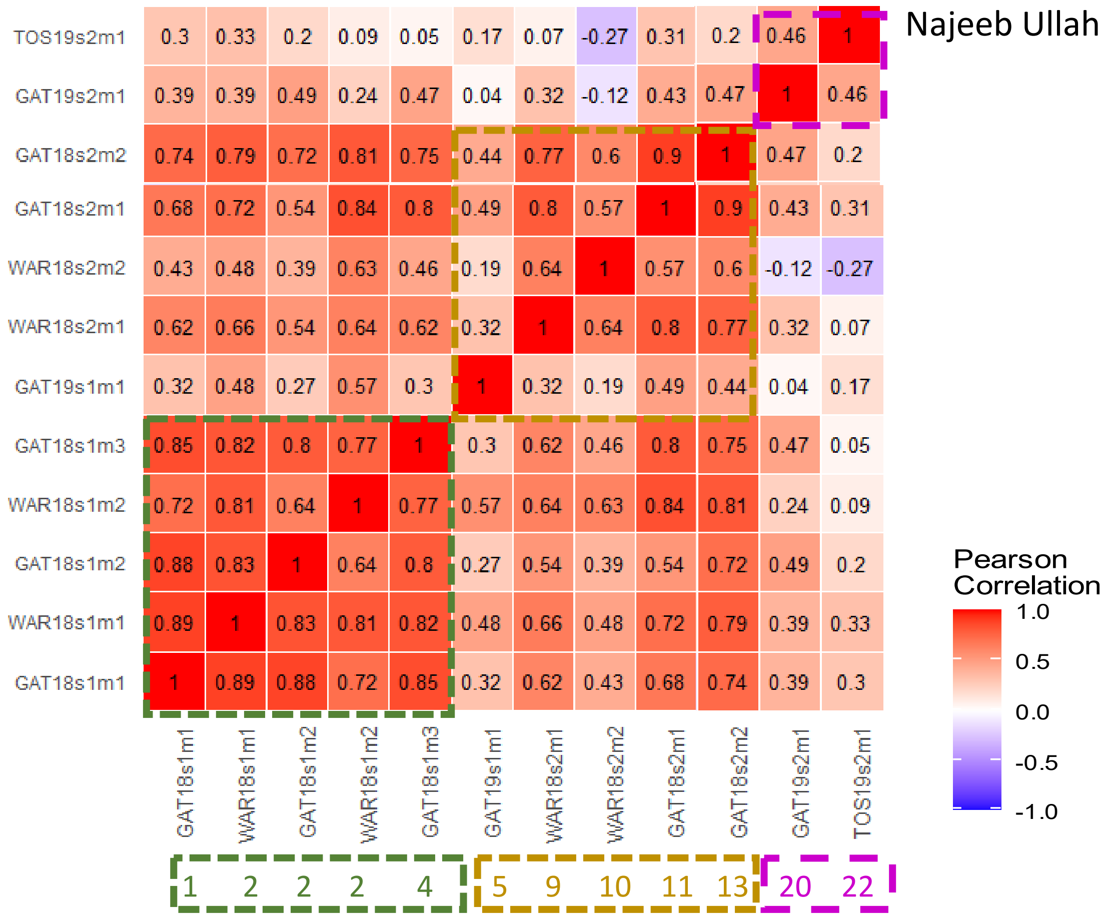
Traditional method:
Different sowing dates





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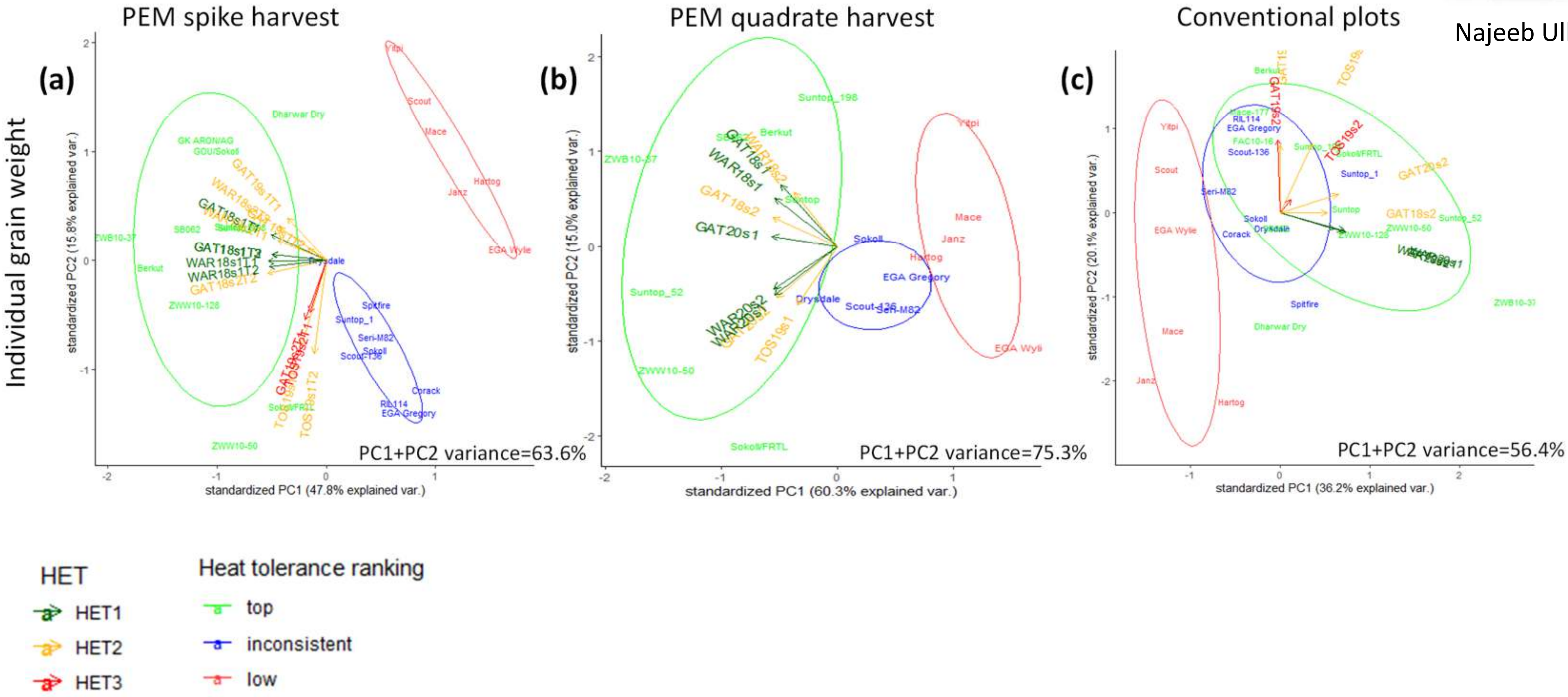

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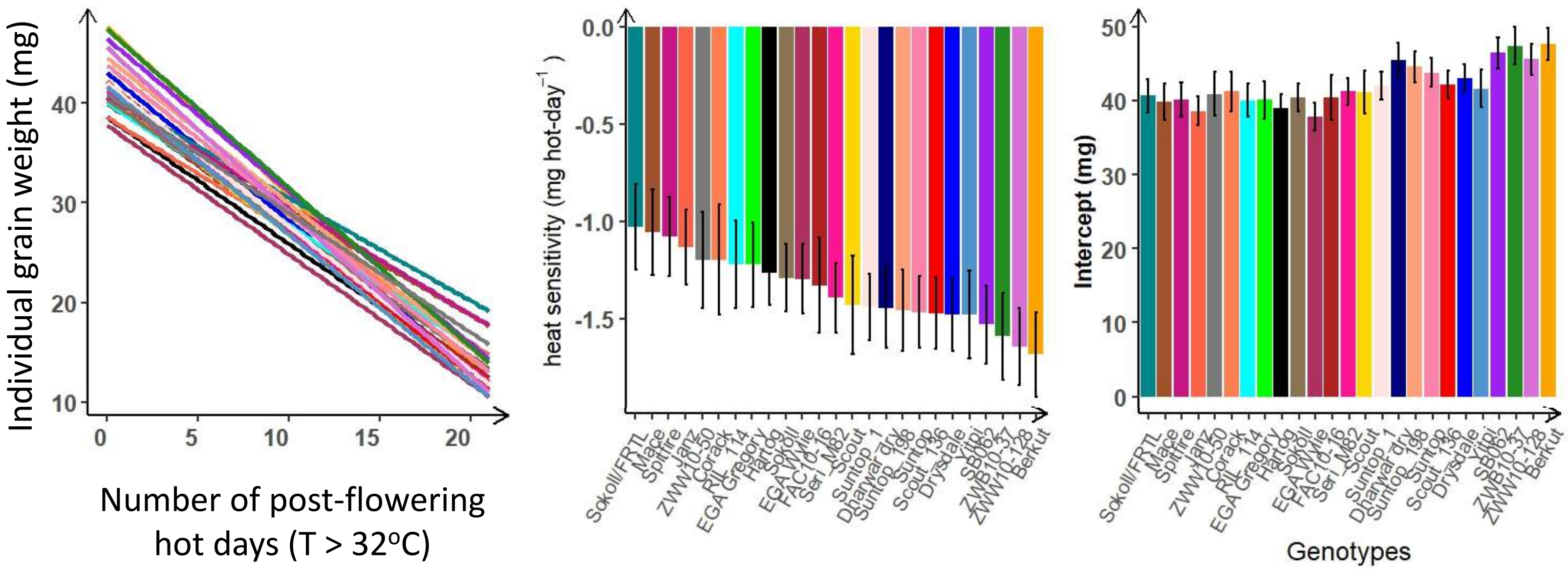
Genotypic variation in heat responses

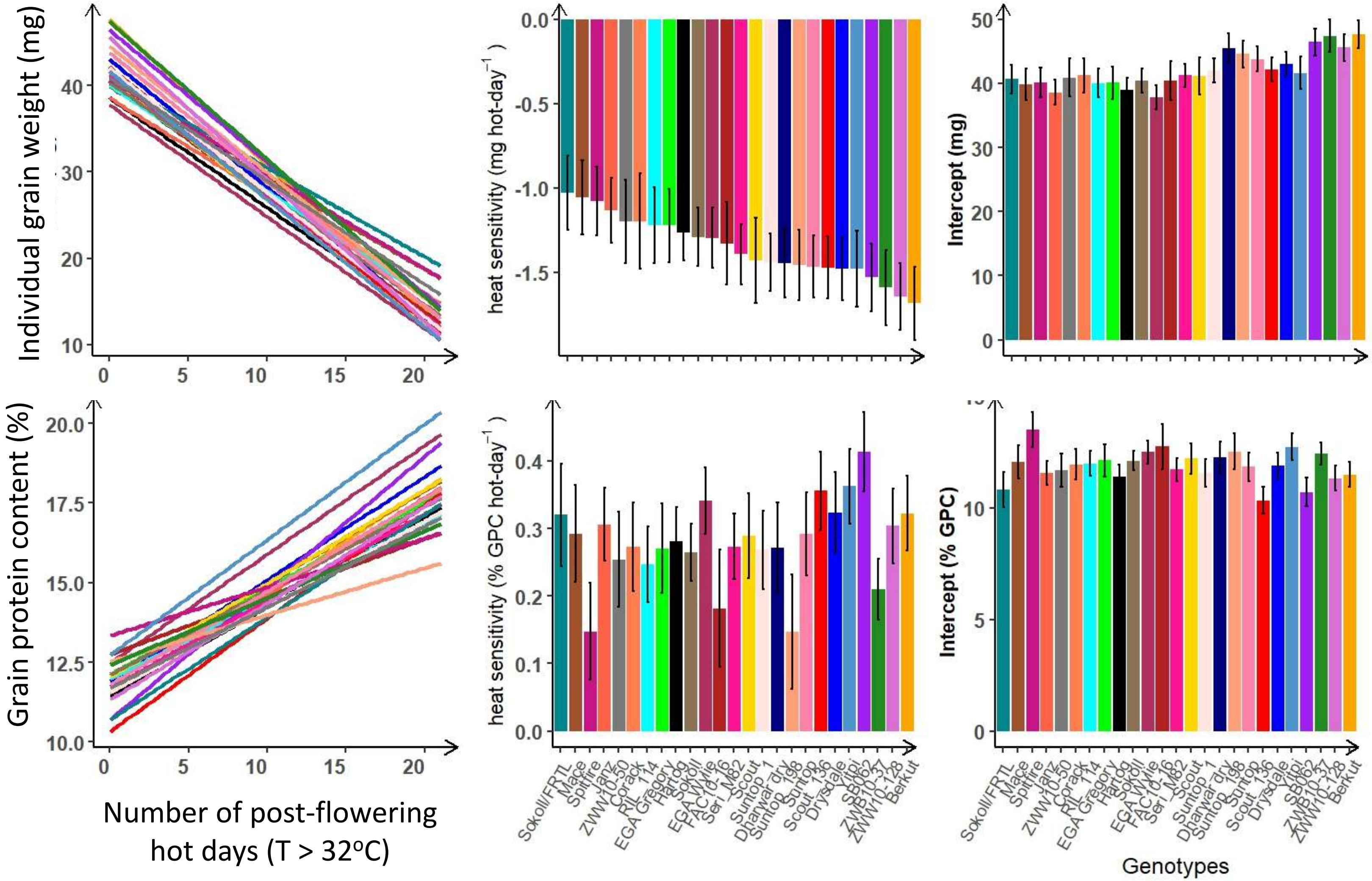


Muhammed Yahya

Yahya et al. 2024. *Australian Agronomy Conference*. 4pp.

22 wheat geno
in all trials

Genotypic variation in heat responses



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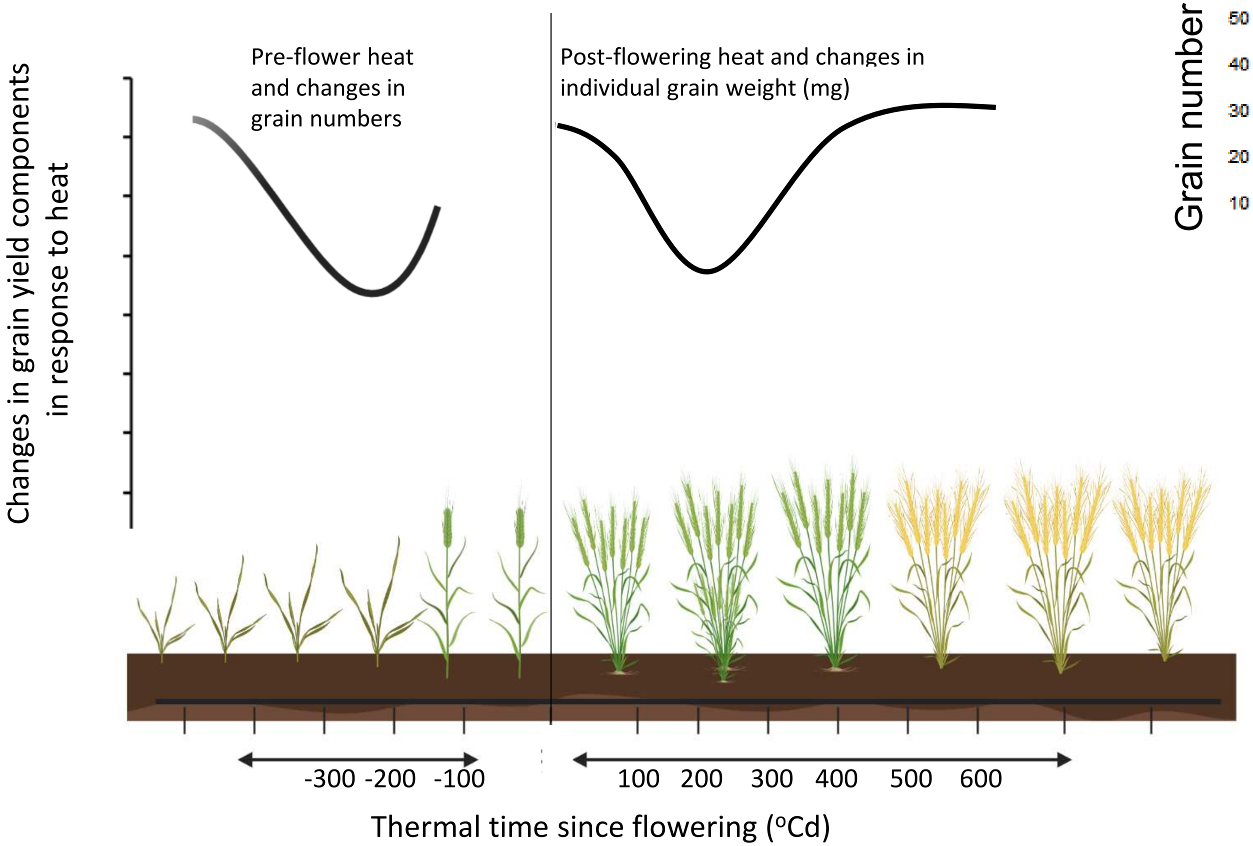
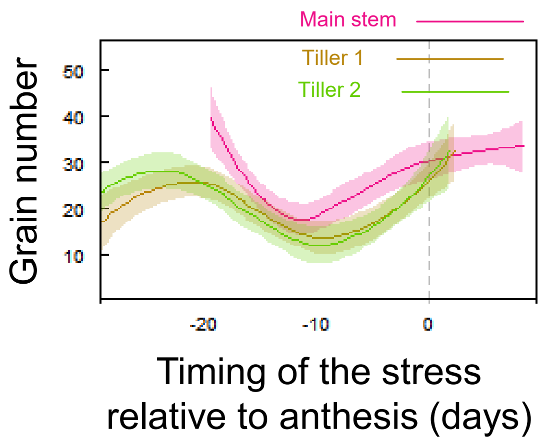
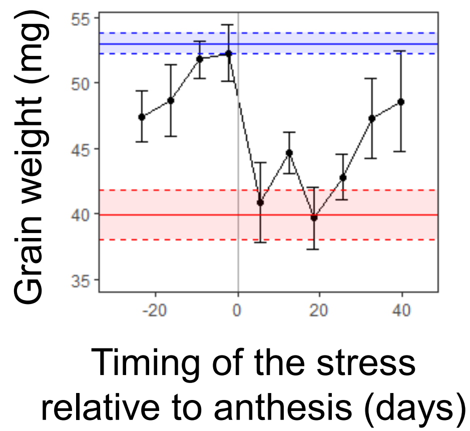
Heat impact on wheat

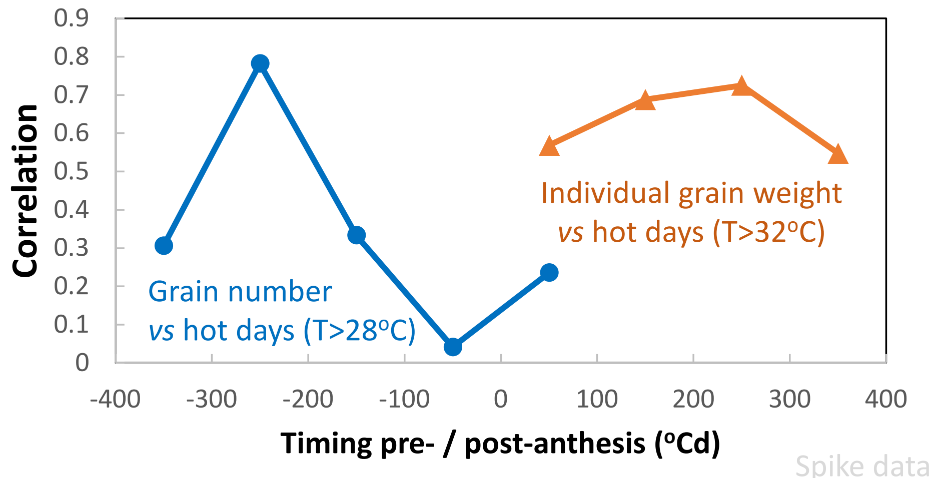


Glasshouse data



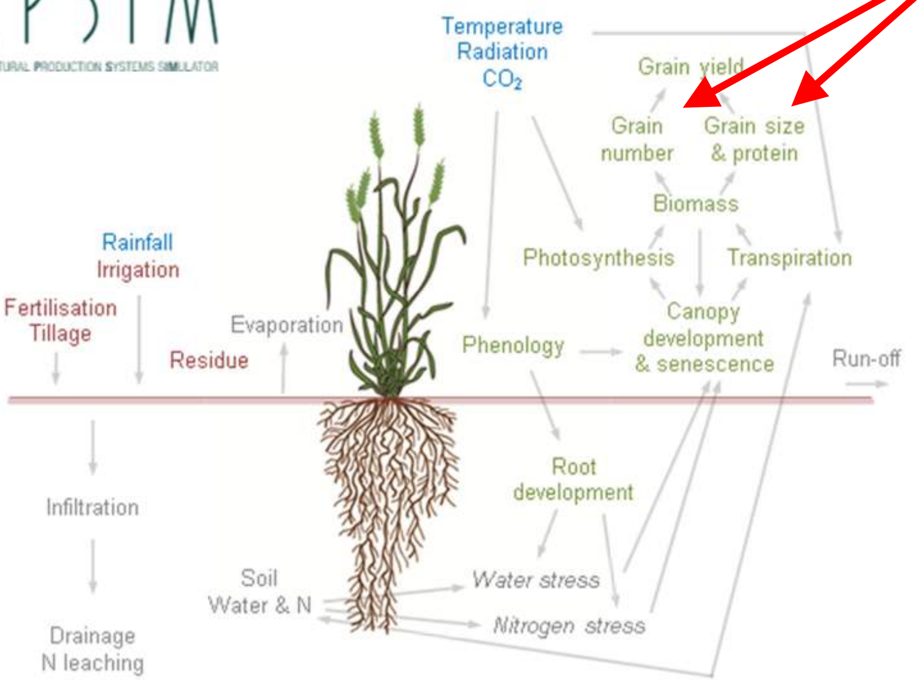


Field data

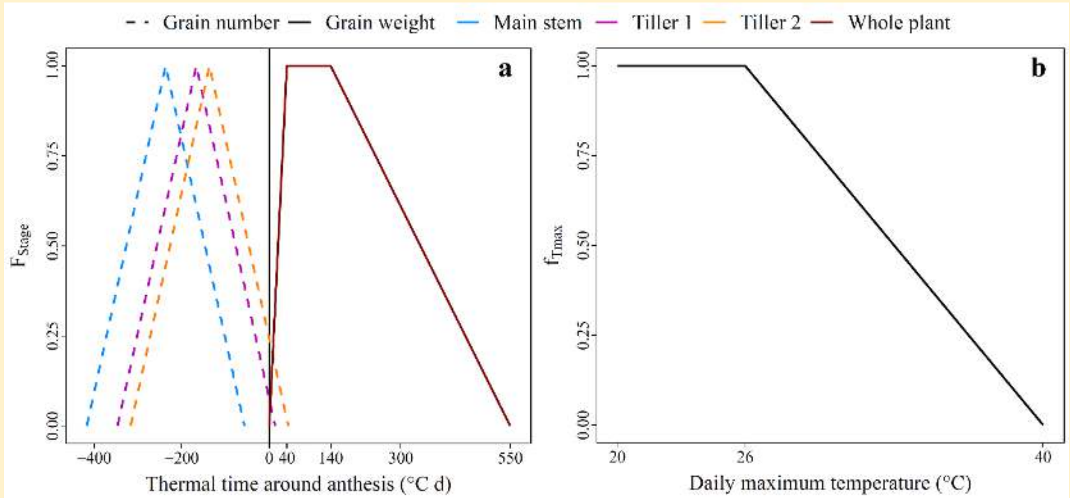


Chenu and Oudin. 2019. Agronomy conference. Wagga Wagga. 4pp.
Ullah et al. 2024. *Field Crops Research*. 316: 109489.

Impact of heat stress



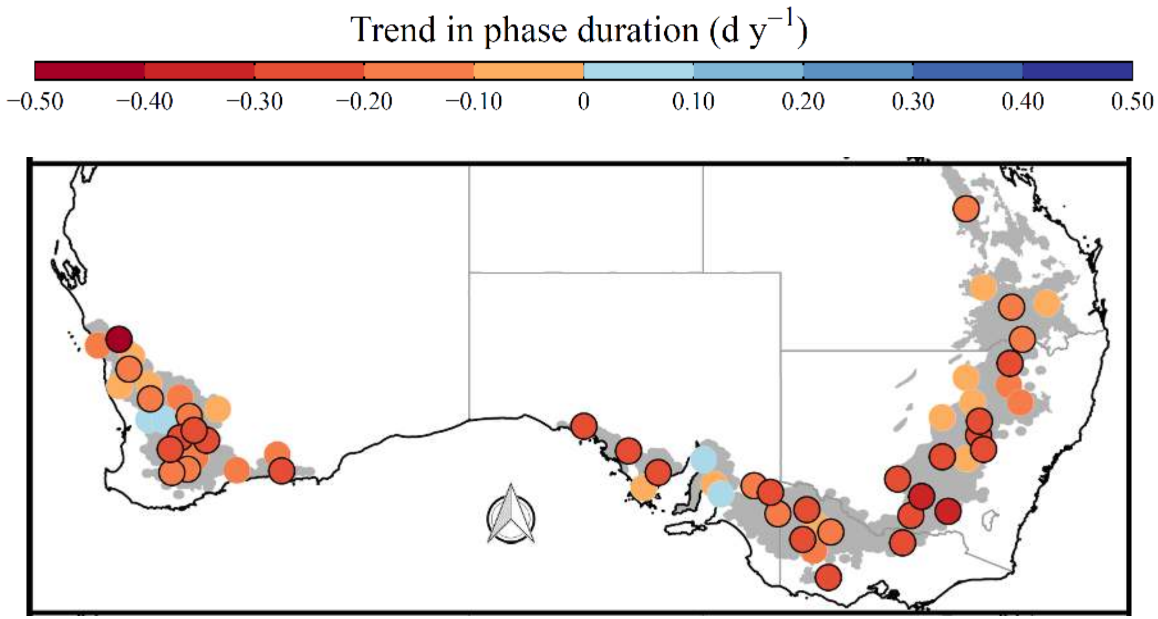
Heatwave impact functions



Ababaei and Chenu. 2020. *Agricultural and Forest Meteorology.* 284:107889

Reduction in the duration of the crop cycle

Behnam Ababaei



Wheat crop cycle shorten by 1.6 days per decade
=> Reduction in yield potential

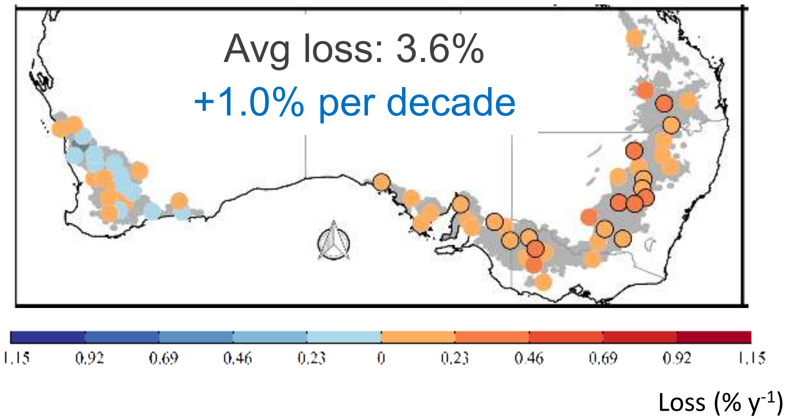
Mid-maturing cv Janz, sown on 15 May – Period: 1985-2017

Ababaei and Chenu. 2020. *Agricultural and Forest Meteorology.* 284:107889

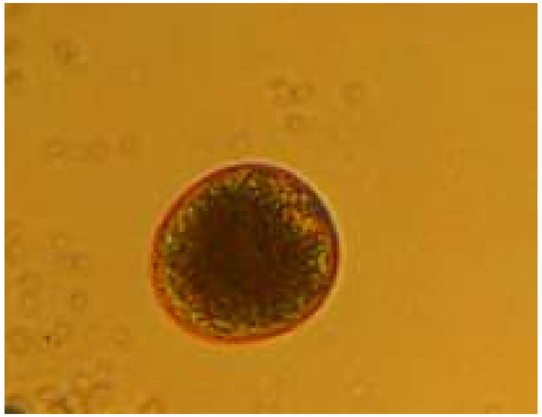
Heat shock impact on wheat

Behnam Ababaei

Grain number



Pre-flowering / meiosis heat



Non germinating pollen

Germinated pollen

Mid-maturing cv Janz, sown on 15 May – Period: 1985-2017

Ababaei and Chenu. 2020. *Agricultural and Forest Meteorology.* 284:107889

Heat shock impact on wheat

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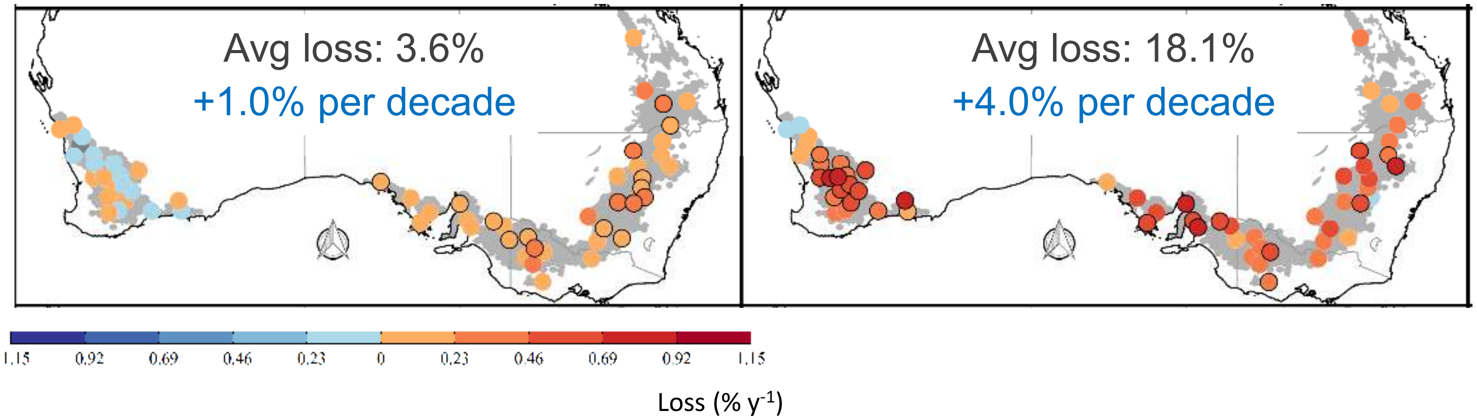
Grain number | **Thousand grain weight**



In Australian production environment, heat shocks impact more thousand grain weight than grain number
=> Importance to adapt wheat to post-flowering heat

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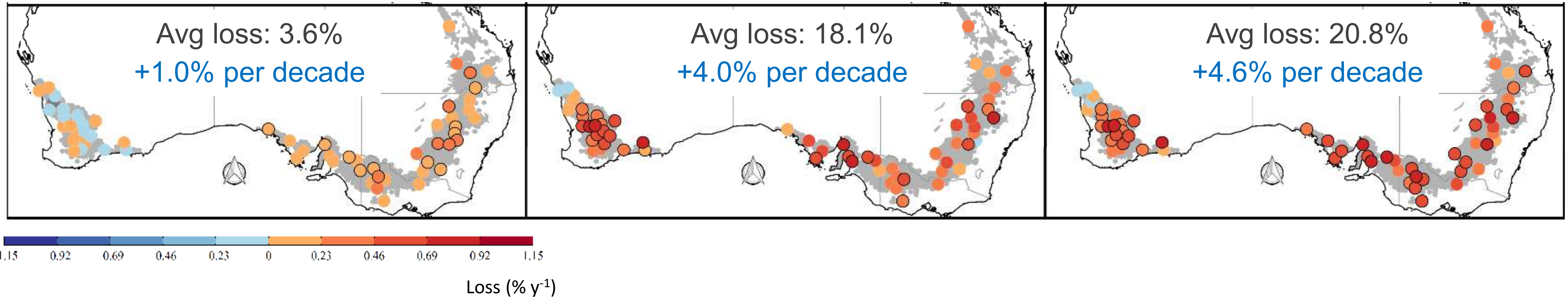
Heat shock impact on wheat

Behnam Ababaei

Grain number **Thousand grain weight** **Yield**



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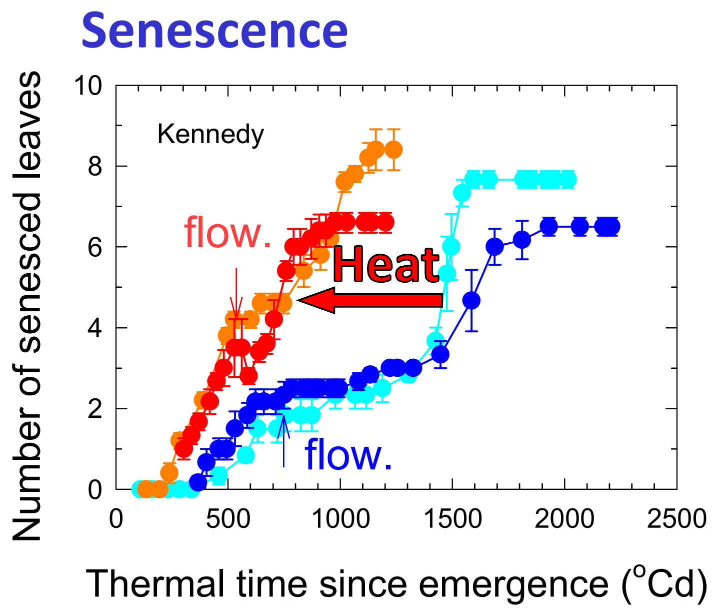
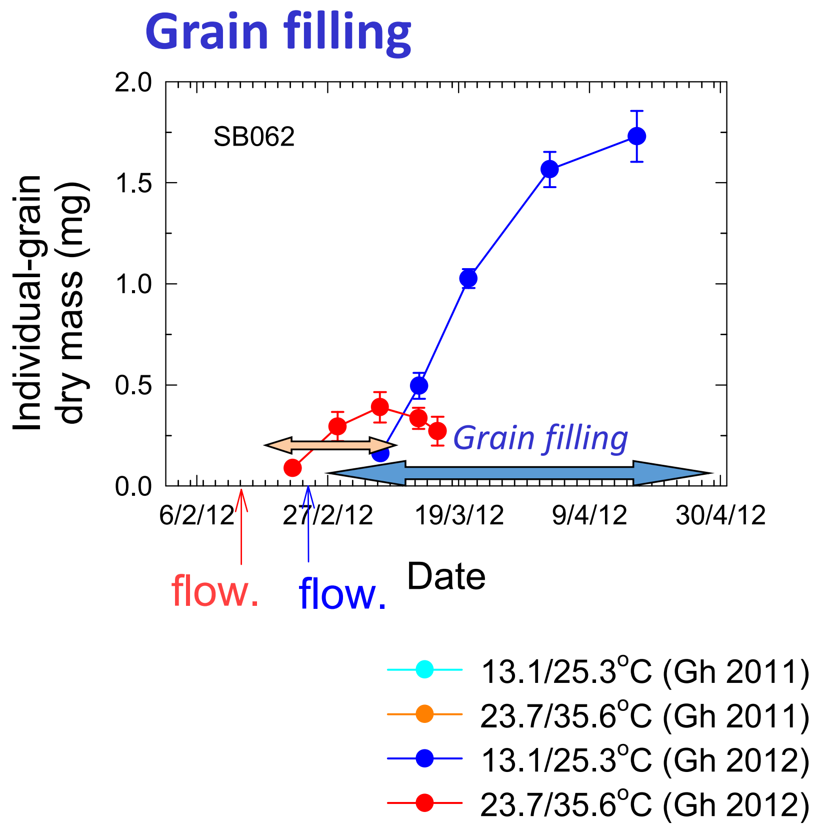
Post-flowering heat tolerance

Post-flowering impacts of heat





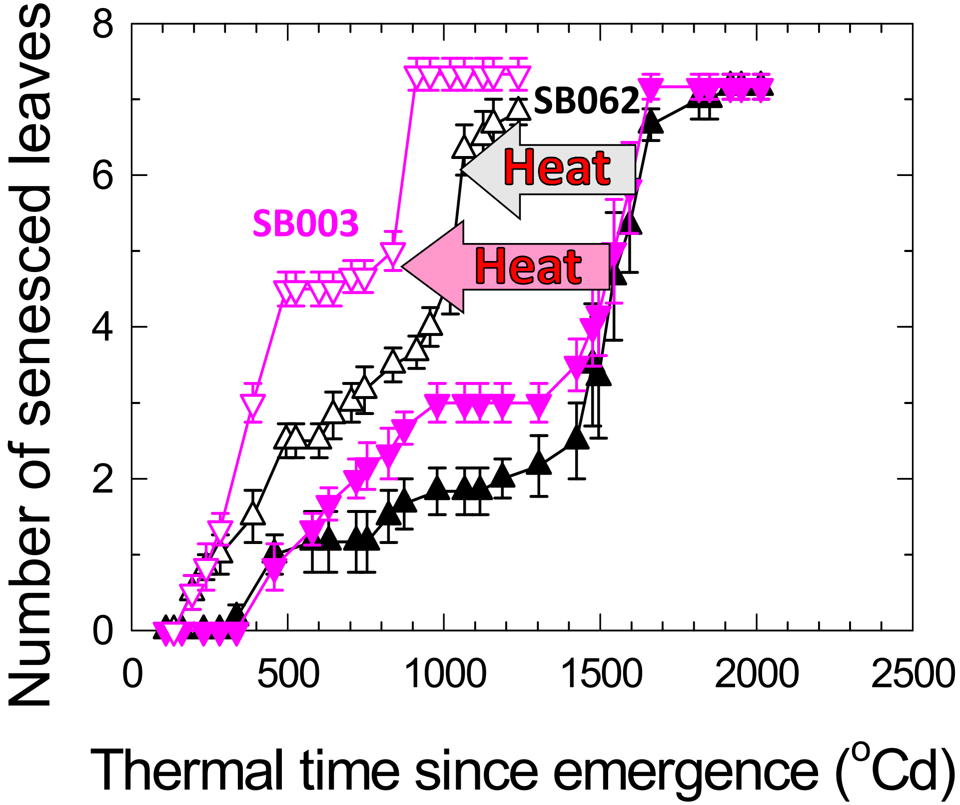
Florianne Oudin

Accelerated senescence – Reduced grain growth rate and duration – Reduced grain size

Genotypic variability in stay-green

Florianne Oudin

Senescence

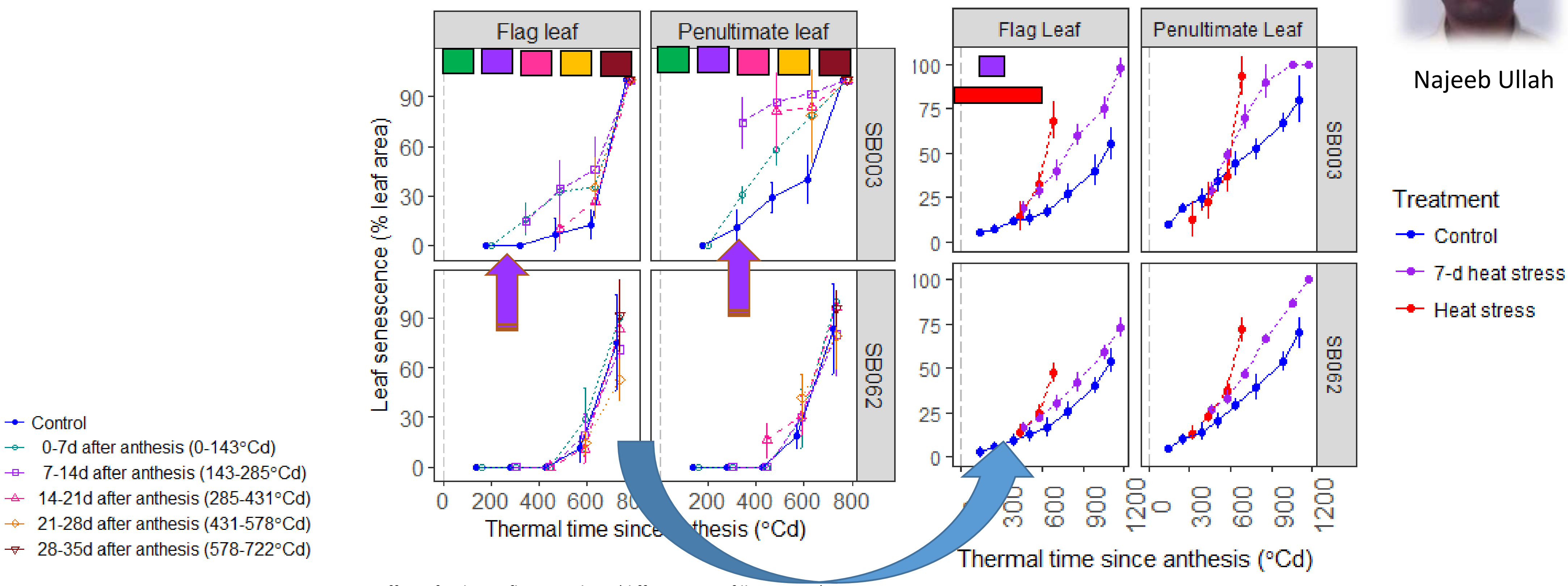


2 sister lines:

- very similar in controlled conditions
- Contrasted under post-flowering heat
  - . SB062 – stay-green
  - . SB003 – senescent
- Differences in grain size

Leaf senescence under short term (7d) heat stress

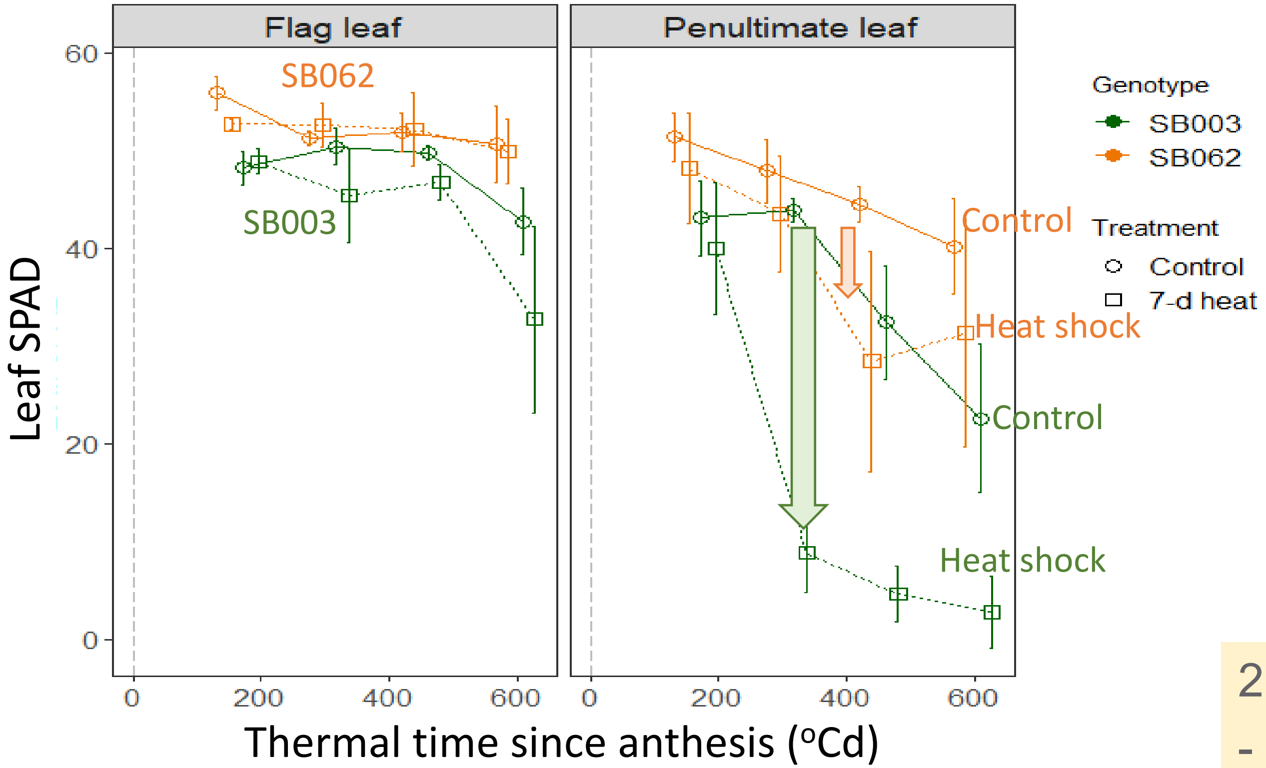
Najeeb Ullah



Effect of 7-d post-flowering heat (different grain filling stages) on senescence of top two leaves.

Effect of long-term and 7-d post-flowering heat (**7 days after anthesis**) on senescence of top two leaves.

Staygreen traits to improve heat tolerance



Najeeb Ullah

2 sister lines:

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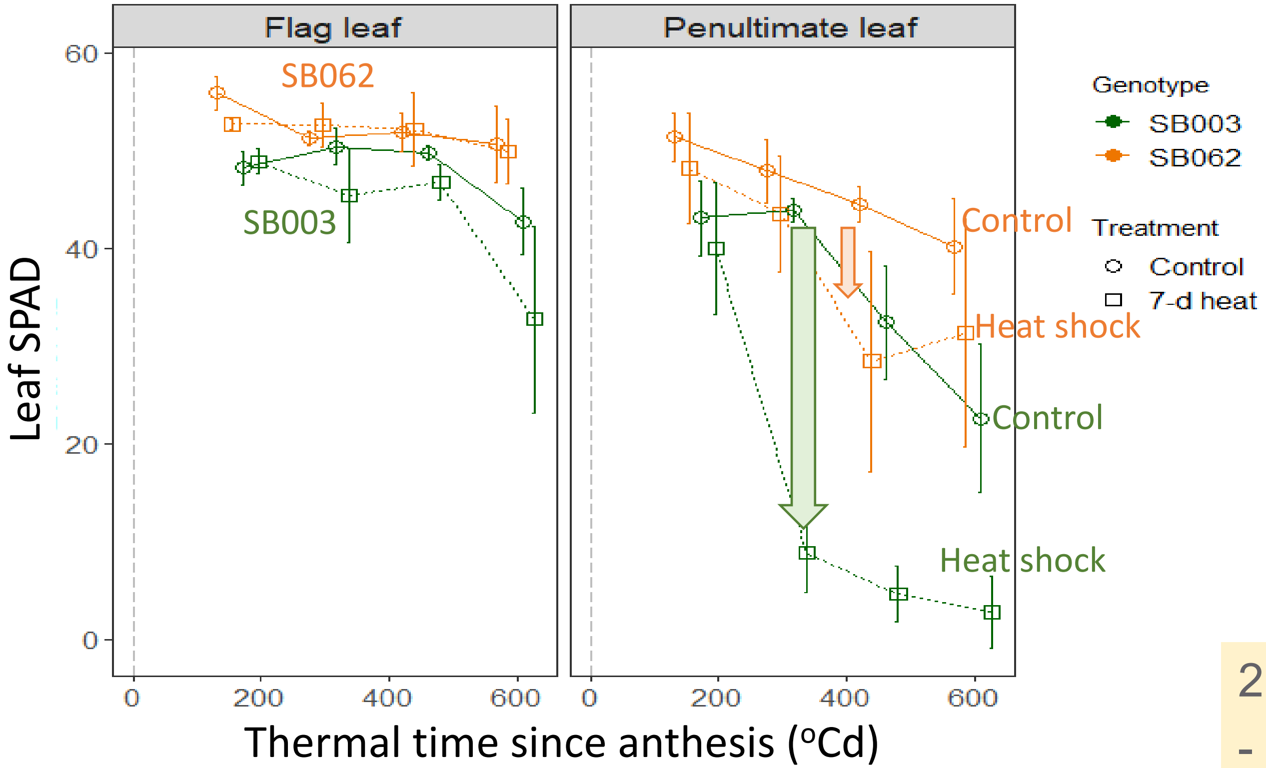
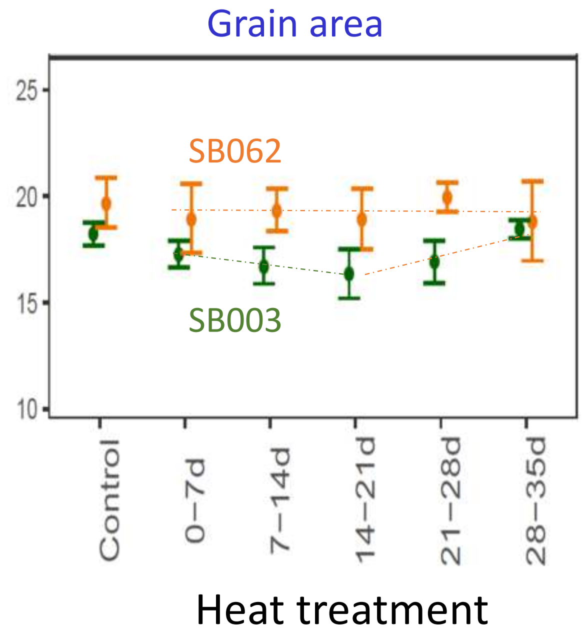
  . SB062 – stay-green
  . SB003 – senescent

Ullah and Chenu. 2019. Agronomy Australia Conference (25-29 August, Wagga Wagga, Australia). 4pp.

32.7/21.6°C day/night temp.

Staygreen traits to improve heat tolerance





Najeeb Ullah

2 sister lines:
- very similar in controlled conditions
- Contrasted under post-flowering heat
  . SB062 – stay-green – Big grains
  . SB003 – senescent – Small grains

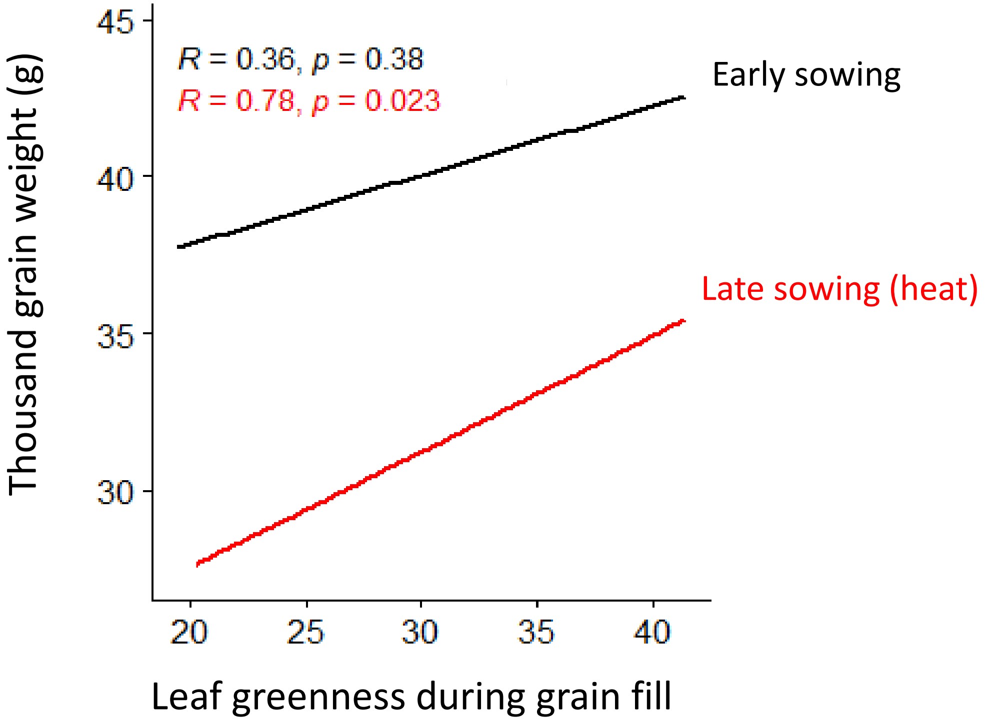
Ullah and Chenu. 2019. Agronomy Australia Conference (25-29 August, Wagga Wagga, Australia). 4pp.

32.7/21.6°C day/night temp.

Stay-green – Promising trait of adaptation

Najeeb Ullah

Senescence (Field trials)

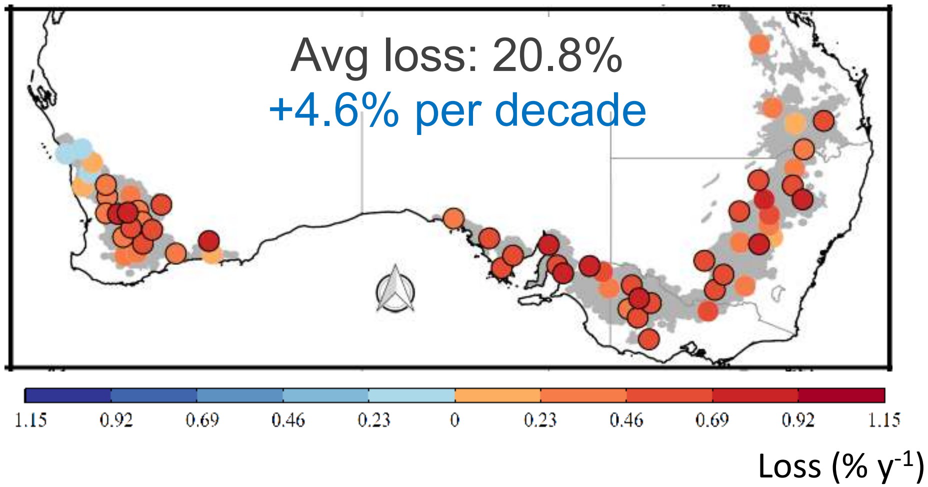


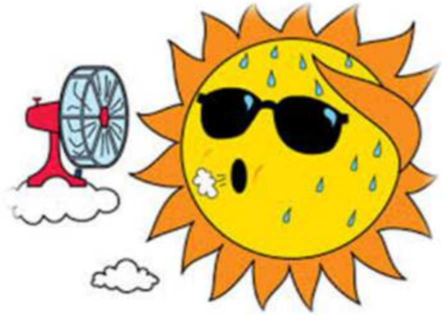
Genotypes with stay-green
are yielding more
in environments
with post-flowering heat stress

2nd marking of sowing 2 at Gatton (2018) - light trial

Need to improve heat tolerance

Heat-induced yield losses





Collins and Chenu. 2021. Climate Risk Management:100300.

Need to improve heat tolerance

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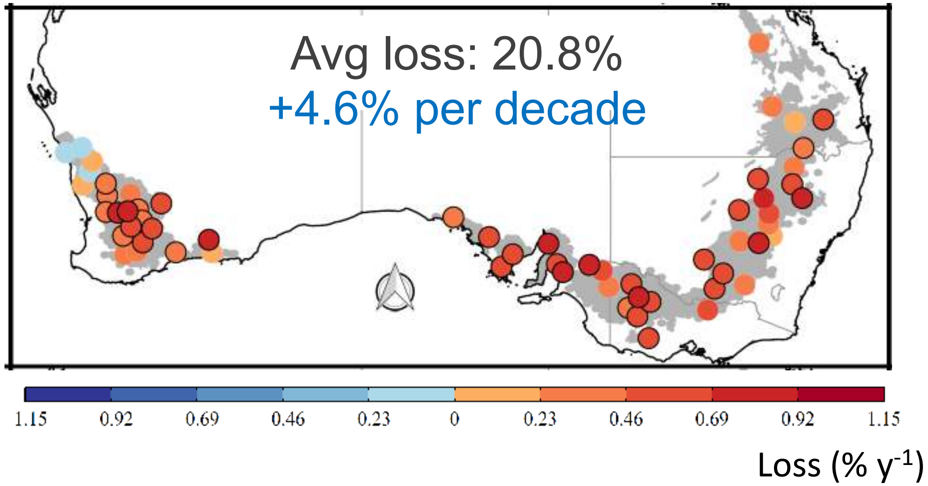
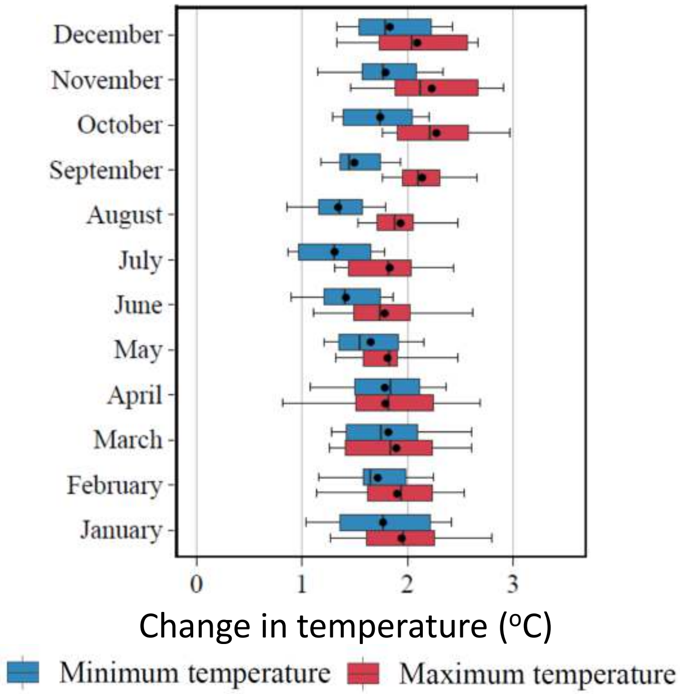
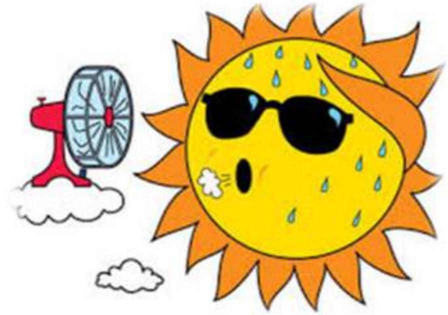


RCP 8.5

Projections for 2050





Urgent need for even better adapted cultivars

Collins and Chenu. 2021. Climate Risk Management:100300.

Key messages

1. Heat stress **already has a big impact** on wheat productivity in Australia, and has increasingly impacted wheat crops over the last decades
2. A **field-based phenotyping method** has been developed to reliably screen genotypes differing in flowering date
3. **Heat tolerant material** has been identified
4. Tolerance for **post-flowering** more than pre-flowering heat is required to improve wheat productivity in a warmer climate
5. **Stay-green** appears a promising trait to improve heat tolerance in Australian production environments
6. **Improving heat tolerance** of wheat varieties is needed to maintain/increase productivity in current and future climates (e.g. Collins and Chenu, 2021)

Acknowledgements

- Najeeb Ullah (UQ/QAAFI)
- Muhammed Yahya (UQ/QAAFI)
- Jack Christopher (UQ/QAAFI)
- Troy Frederiks (DAFF, Qld)
- Brian Collins (UQ/QAAFI)

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Department of Agriculture and Fisheries