Linking ambient temperature to crop growth and phenology on a cultivar specific basis

Lukas Kronenberg

21st annual WGIN stakeholder meeting

Norwich 2024-02-08

Temperature has a strong effect on plant phenology

Support the Guardian
Available for everyone, funded by readers
Subscribe Contribute
Search jobs Sign in
News Opinion Sport Culture Lifestyle More
UK World Climate crisis Newsletters Football Coronavirus Business Environment UK politics Education Society

Wild flowers

This article is more than 8 months old

Flowers arriving a month early in UK as climate heats up

Plants now bloom in mid-April on average, with scientists warning of mismatches with insects and birds

Damian Carrington
Environment editor
@dpcarrington
Wed 2 Feb 2022 06.00 GMT

BBC Sign in LIVE Home News Sport Weather iPlay
NEWS
Home | Israel-Gaza war | Cost of Living | War in Ukraine | Climate | UK | World | Business | Politics | Culture
Science & Environment

Climate change: UK plants now flowering a month earlier

2 February 2022 • Comments
Climate

Naturalists have been recording the appearance of spring blossom for centuries

By Helen Briggs
Environment correspondent

Privacy Policy | Feedback Follow 21.9M Tuesday, Oct 2
Mail Online Scie
Home | News | U.S. | Sport | TV&Showbiz | Australia | Femail | Health | Science | Money | T
Latest Headlines | Blue Origin | SpaceX | NASA | Apple | Google | Twitter

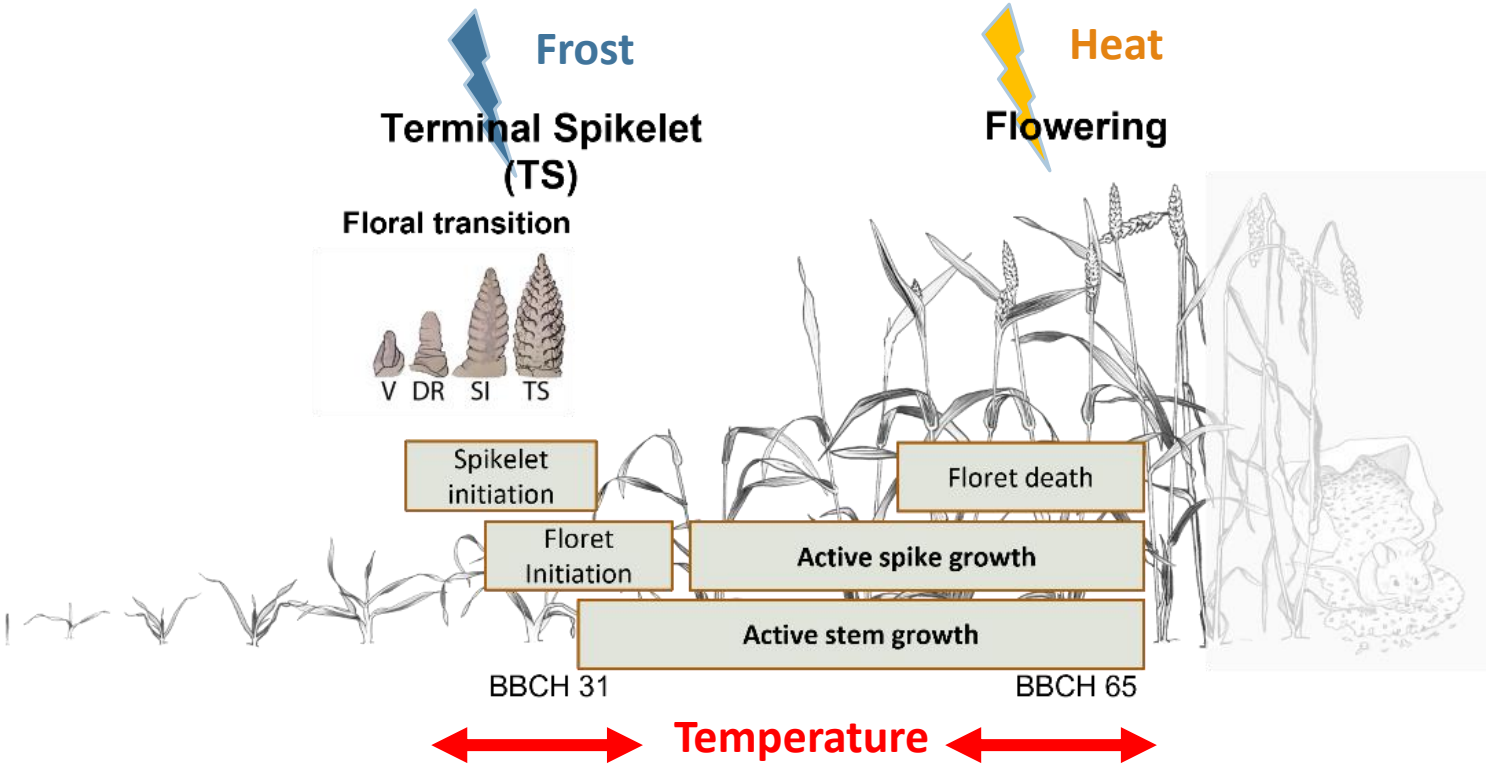
Spring could soon start in FEBRUARY: UK plants are flowering a month earlier due to climate change, study warns

- Climate change is causing plants in the UK to flower a month earlier on average
- That is the finding of a Cambridge University study analysing 406 plant species
- They looked at 400,000 observations from records dating back to 18th century
- Average first flowering date from 1987-2019 was a month earlier than 1753-1986

By SAM TONKIN FOR MAILONLINE
PUBLISHED: 01:42, 2 February 2022 | **UPDATED:** 13:34, 2 February 2022

Image source: University of Göttingen - E. Rezai - innovations-report.de

Critical phenological phases need to happen at the right time!



Example:

Wheat stem elongation phase

- critical for the formation of yield potential
- Longer duration → more grains per spike
- Frost around GS31 or heat around flowering reduce # grains and yield

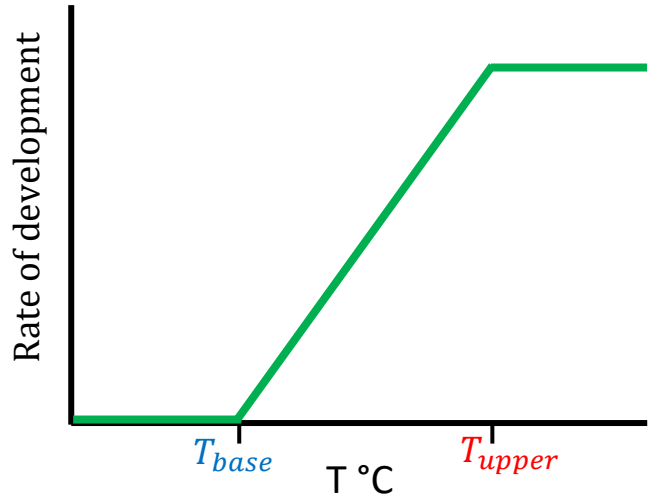
How do we quantify this?

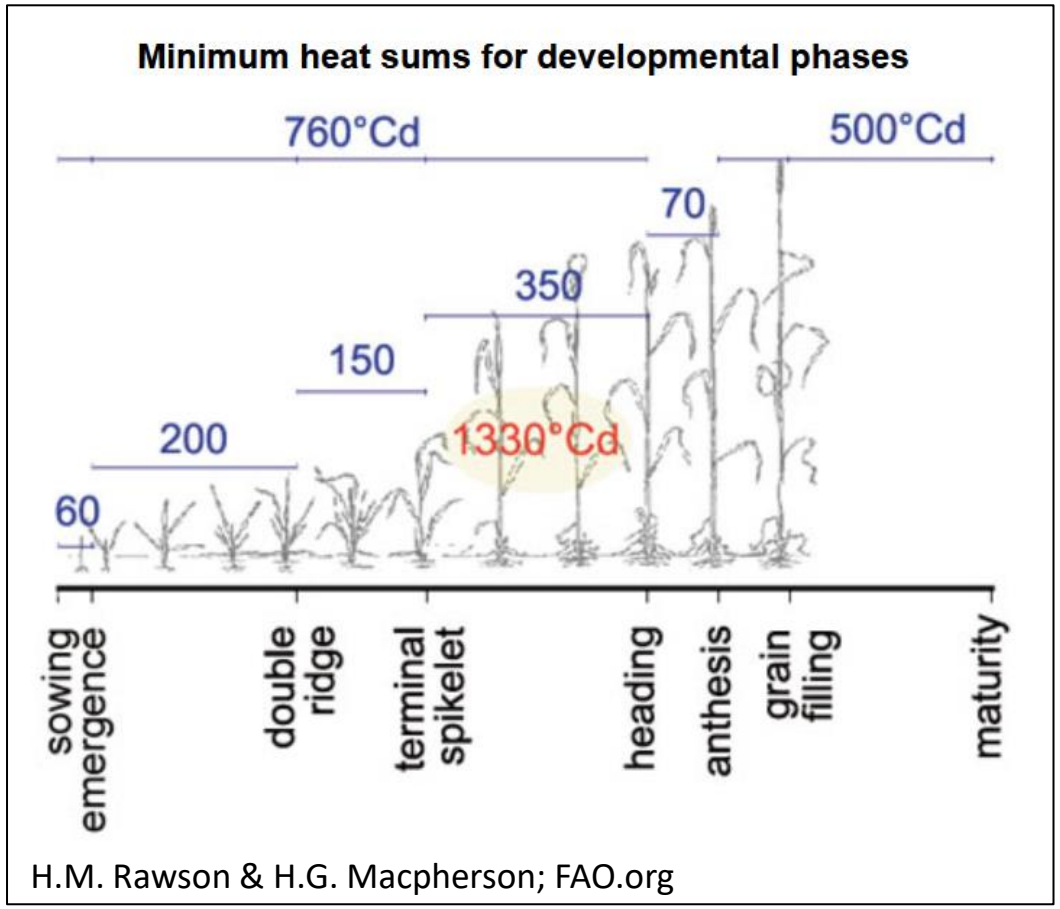
The concept of *G*rowing *D*egree *D*ays

a.k.a. ***thermal time*** *a.k.a.* ***heat sums***

$$\boldsymbol{GDD} = \sum_{d=1}^{n} \begin{cases} T_d\ mean\ -\ T_{base}, & T_{base} < T_d\ mean < T_{upper} \\ 0, & T_d\ mean < T_{base} \\ T_{upper}\ -\ T_{base}, & T_d\ mean > T_{upper} \end{cases}$$

$T_d\ mean$: daily mean temperature
T_{base} : ***species-specific*** base temperature
T_{upper} : ***species-specific*** upper temperature limit

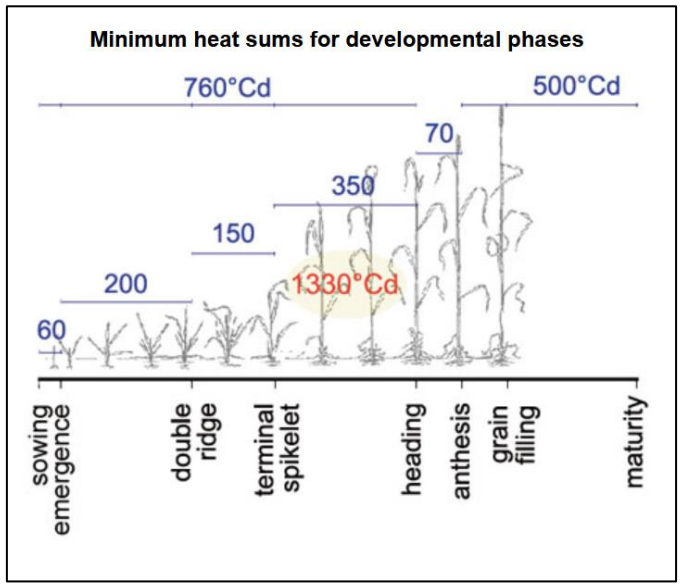


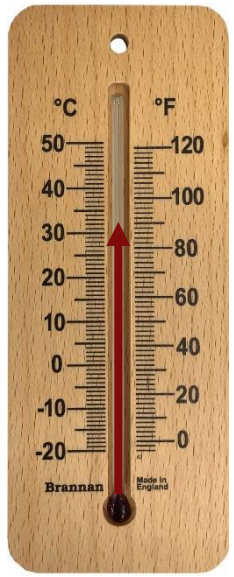


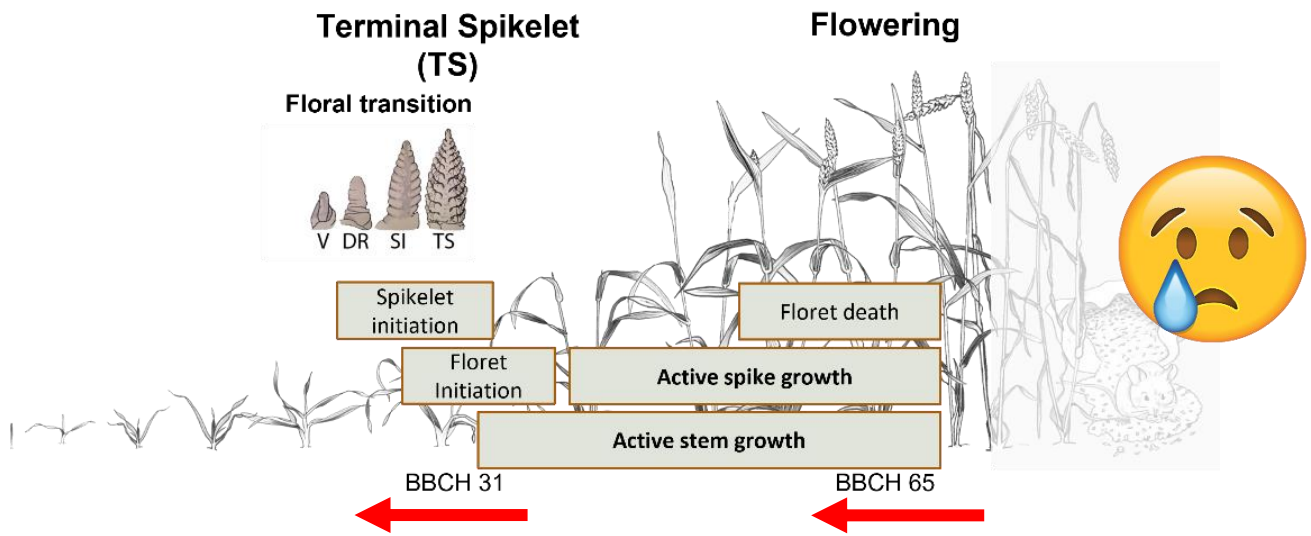
H.M. Rawson & H.G. Macpherson; FAO.org

→Crop modelling
→Agronomic crop management

Species specific temperature response…







Research

New Phytologist

Temperature responses of developmental processes have not been affected by breeding in different ecological areas for 17 crop species

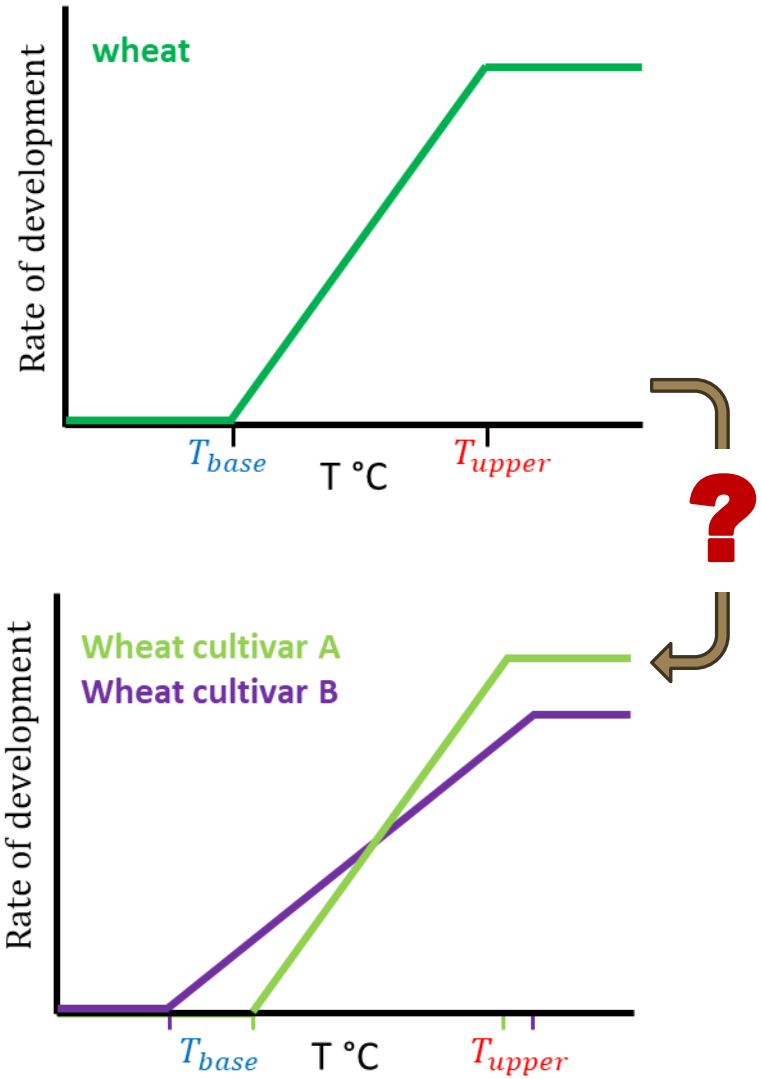
Boris Parent[1] and François Tardieu[2]

[1]Australian Centre for Plant Functional Genomics, PMB1, Glen Osmond, SA 5064, Australia; [2]INRA, UMR759 Laboratoire d'Ecophysiologie des Plantes sous Stress Environnementaux. Place Viala, F-34060 Montpellier, France

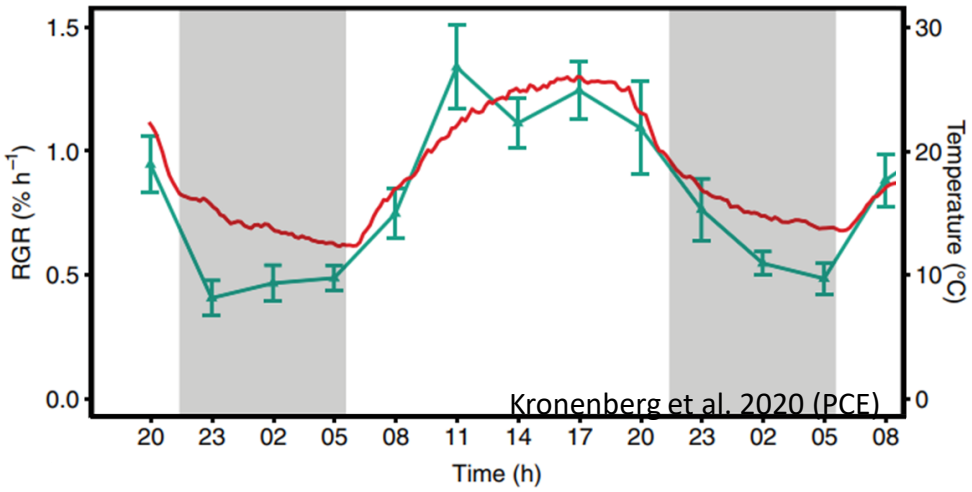
… Or rather cultivar specific temperature response ?

Feldversuch mit Winterweizen: Gegenüberstellung der Sorte „Tommi" aus dem Jahr 2002 und der Sorte „Heines VII" aus dem Jahr 1950 in der Phase zwischen Beginn des Ährenschiebens und Beginn der Blüte. Universität Göttingen

image source: University of göttingen
- E. Rezai - innovations-report.de



Growth is very sensitive to temperature!



Kronenberg et al. 2020 (PCE)

→ **use growth as temperature response indicator**

→ Measure canopy height increase in the field, on a plot-level basis

→ Using drones

SCIENTIFIC REPORTS

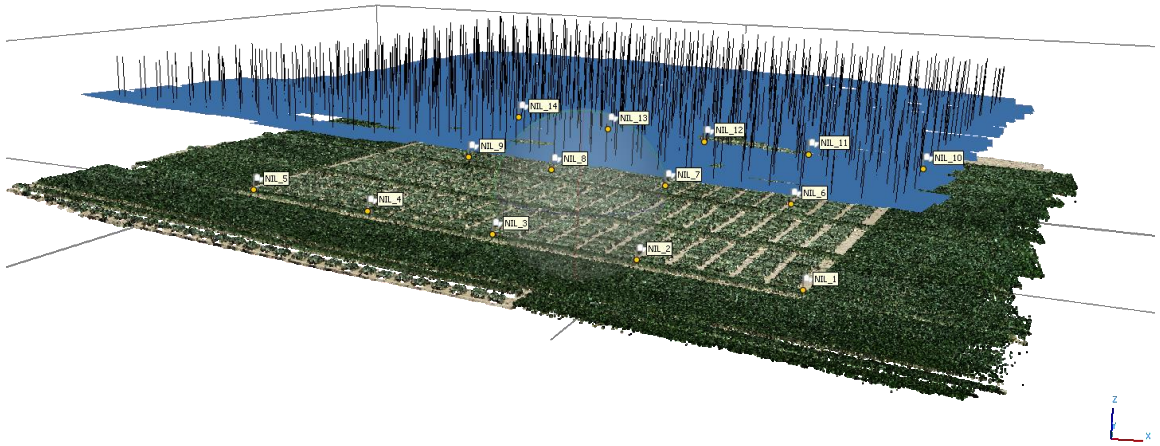
OPEN

Climate change effect on wheat phenology depends on cultivar change

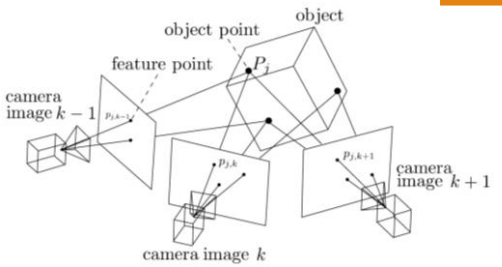
15 June 2017
6 March 2018

Ehsan Eyshi Rezaei[1,2,4], Stefan Siebert[1,4], Hubert Hüging[3] & Frank Ewert[1,3]

How to measure canopy height with a drone?



Structure from motion

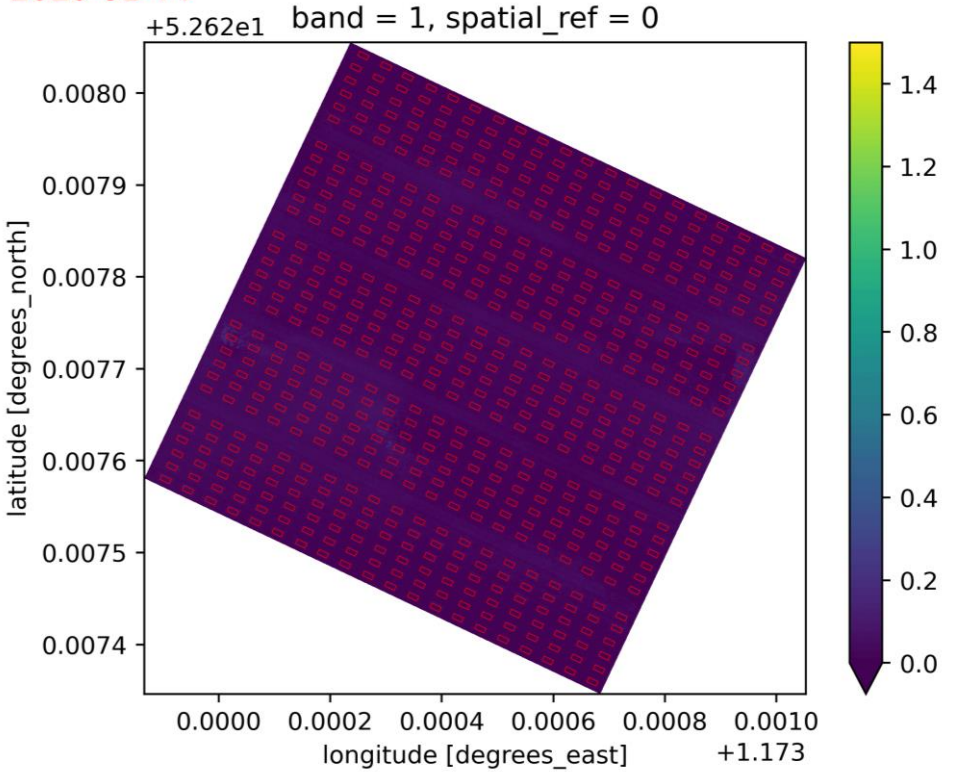


Moulon et al., 2013;
DOI: 10.1007/978-3-642-37447-0_20

3D point cloud / digital elevation model

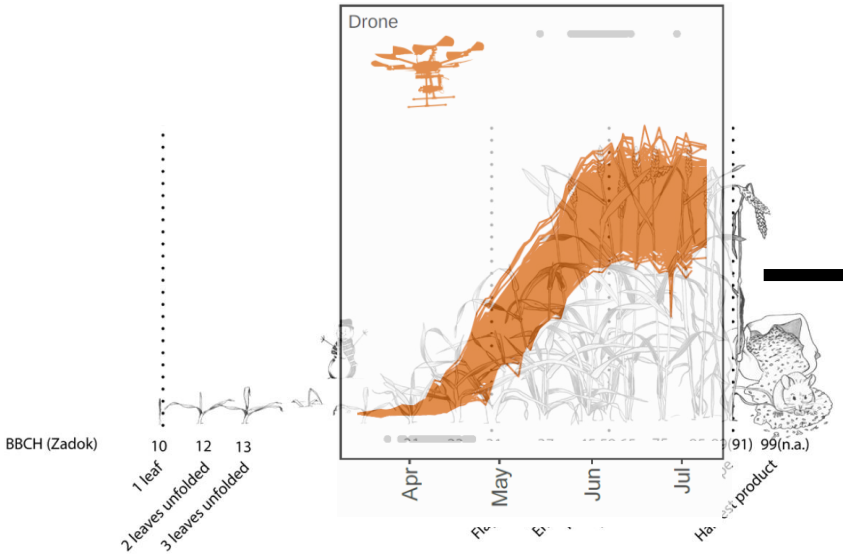
Plot canopy height extraction
[zonal statistics]

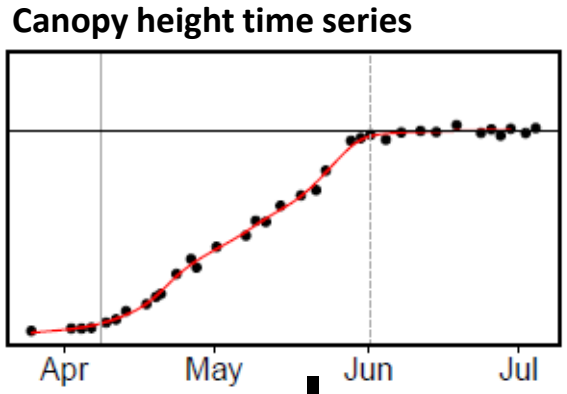
Canopy height time series

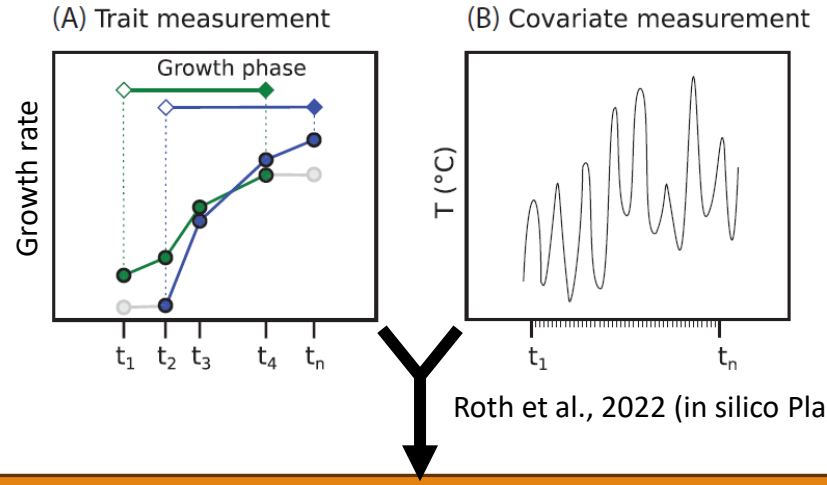


https://shiny.usys.ethz.ch/PhenoFlyPlanningTool/
Roth et al., 2018; Plt.Methods

Canopy height time series allow to model cultivar-specific timing of stem elongation and its temperature response





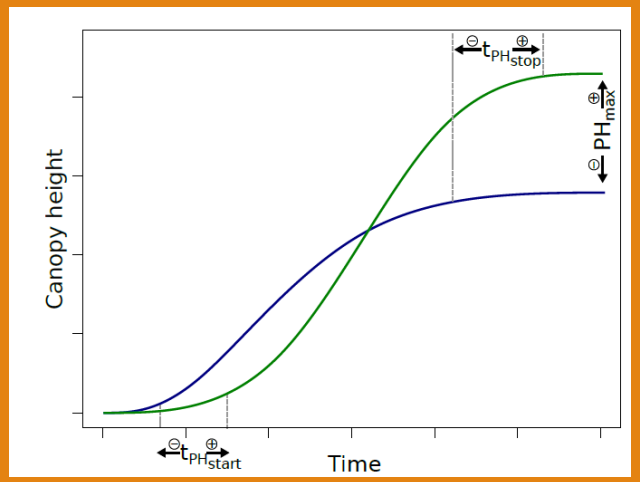


Roth et al., 2022 (in silico Plants)

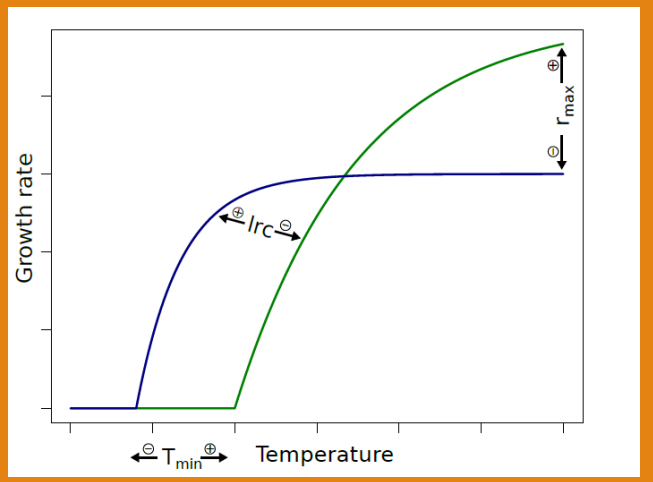
Using canopy height measurements, we can obtain plot (-> cultivar) specific

- **Temperature response** parameters
  - T_{min} base temperature
  - *Lrc* *per se* response
  - r_{max} «intrinsic» growth at optimum T
- Timing of stem elongation

Timing of stem elongation



Temperature response

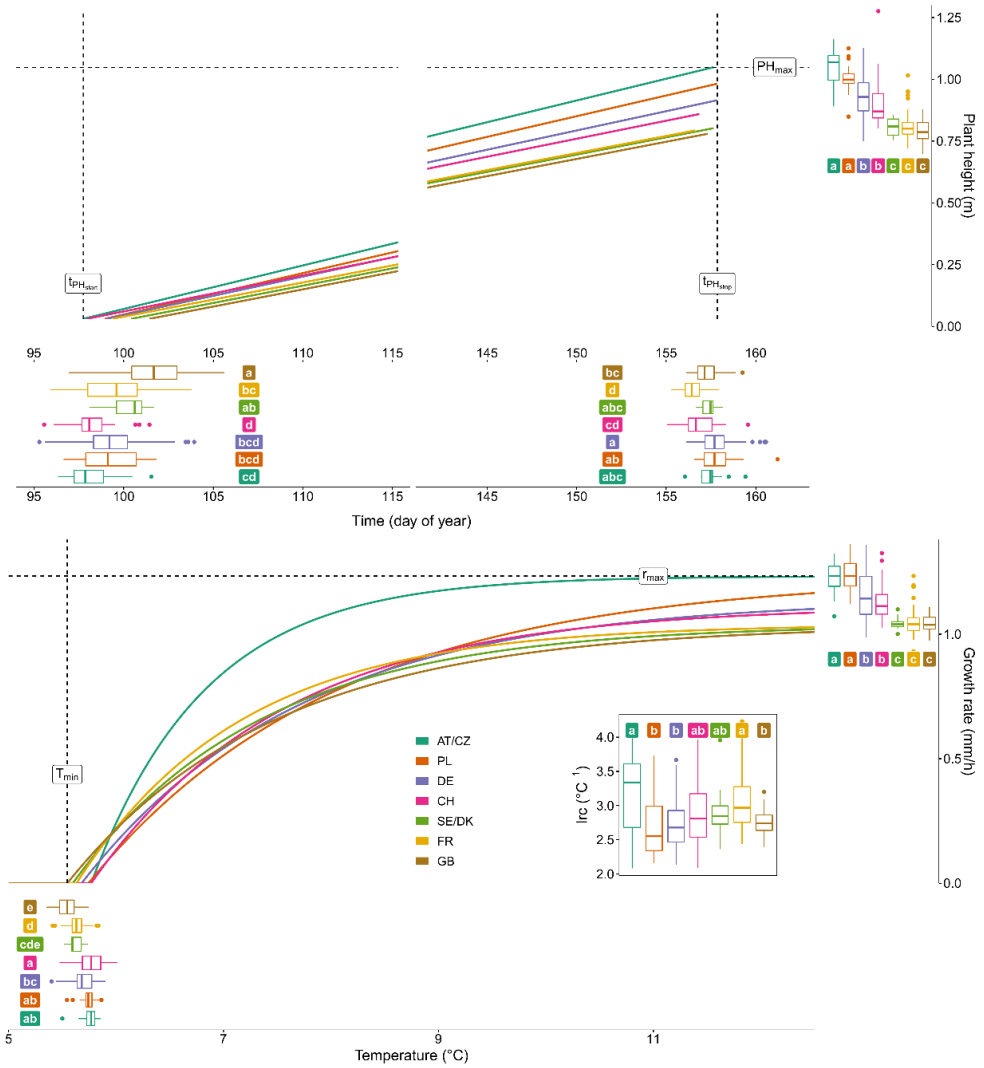


Kronenberg et al 2017 (Euphytica)
Kronenberg et al. 2020 (JXB)
Roth & Kronenberg et al. 2023 (JXB)

Temperature response and phenology in European elite germplasm

- GABI wheat; 330 varieties
- Grown 2015-2018

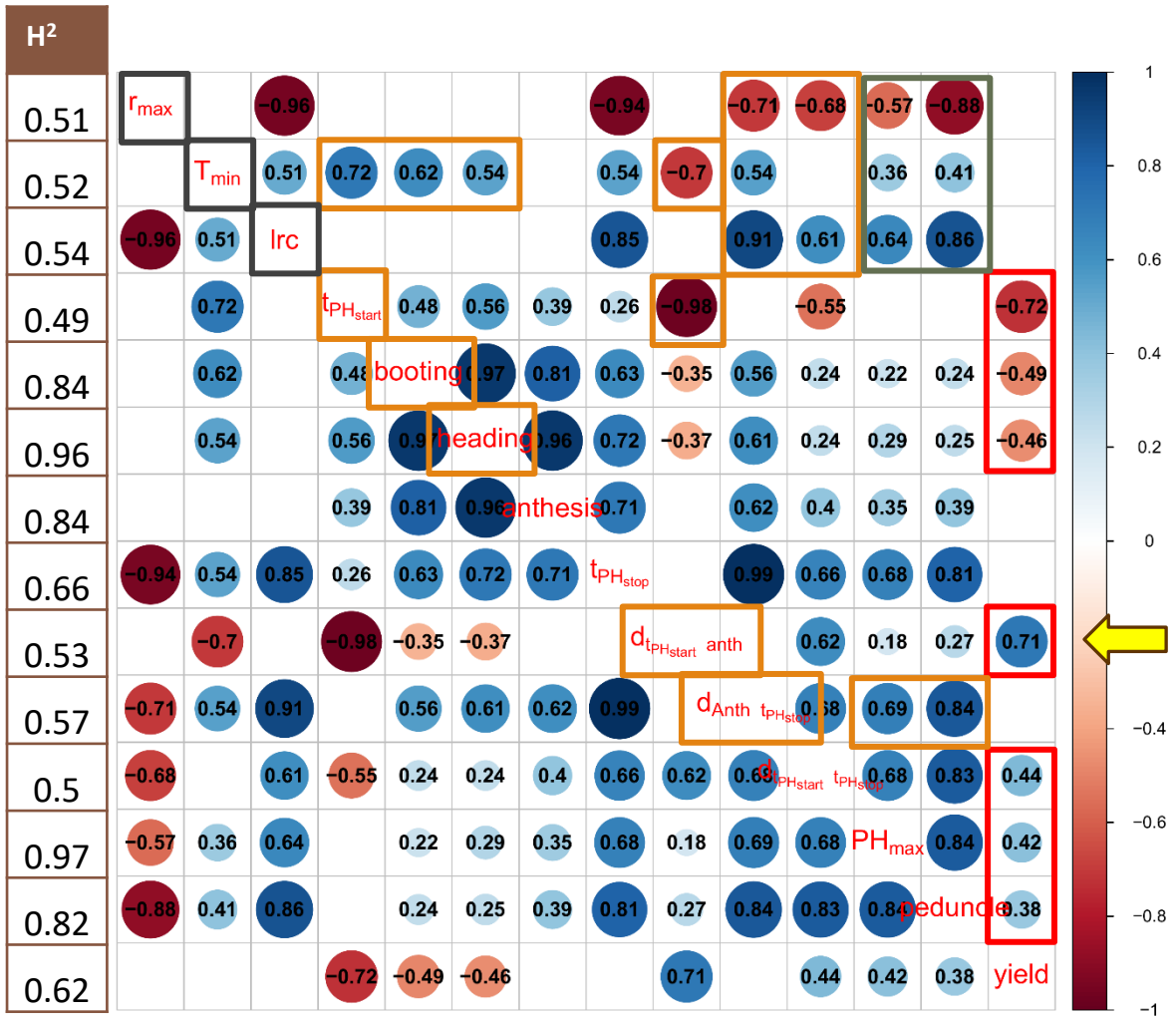
Trait	Heritability
r_{max}	0.89
lrc	0.29
T_{min}	0.63
PHmax	0.98
tPHstart	0.77
tPHstop	0.87

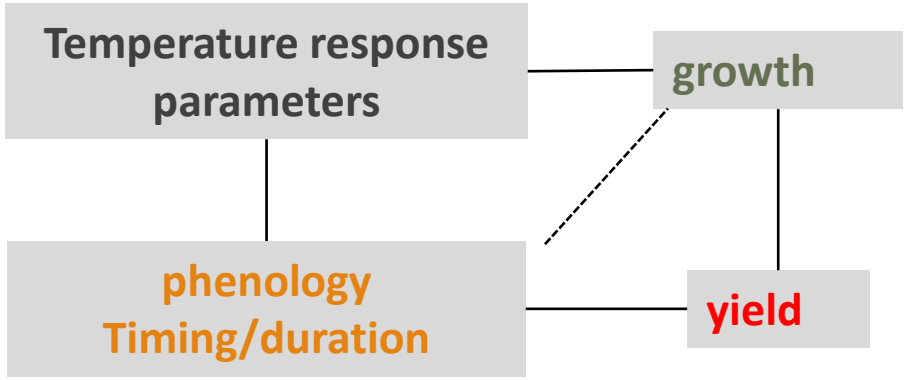


- High heritabilities
  → *We can select for these traits*
- Significant differences among varieties regarding country of registration
  → *Breeding can affect temperature response*
- East > West gradient for height and r_{max}
- West > East gradient for start, Tmin and lrc (to some extent)

Kronenberg et al., 2021; JXB
Roth & Kronenberg et al., 2023; JXB

Temperature response, phenology & yield in the DFW toolkit NILs





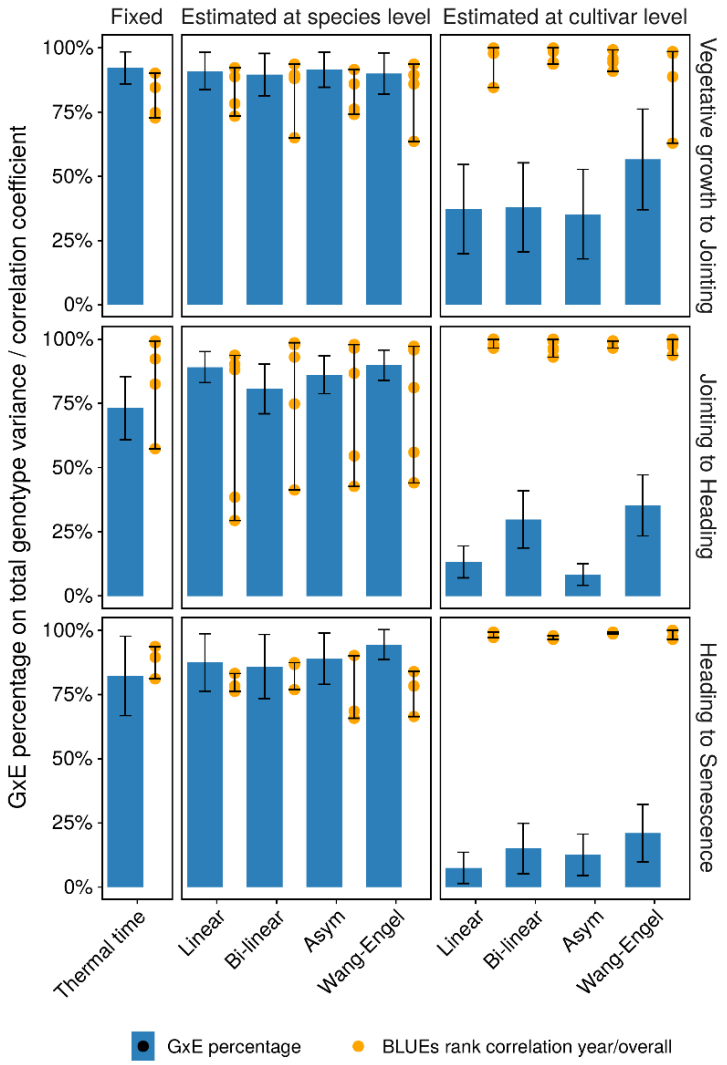
Temperature response affects growth and phenology

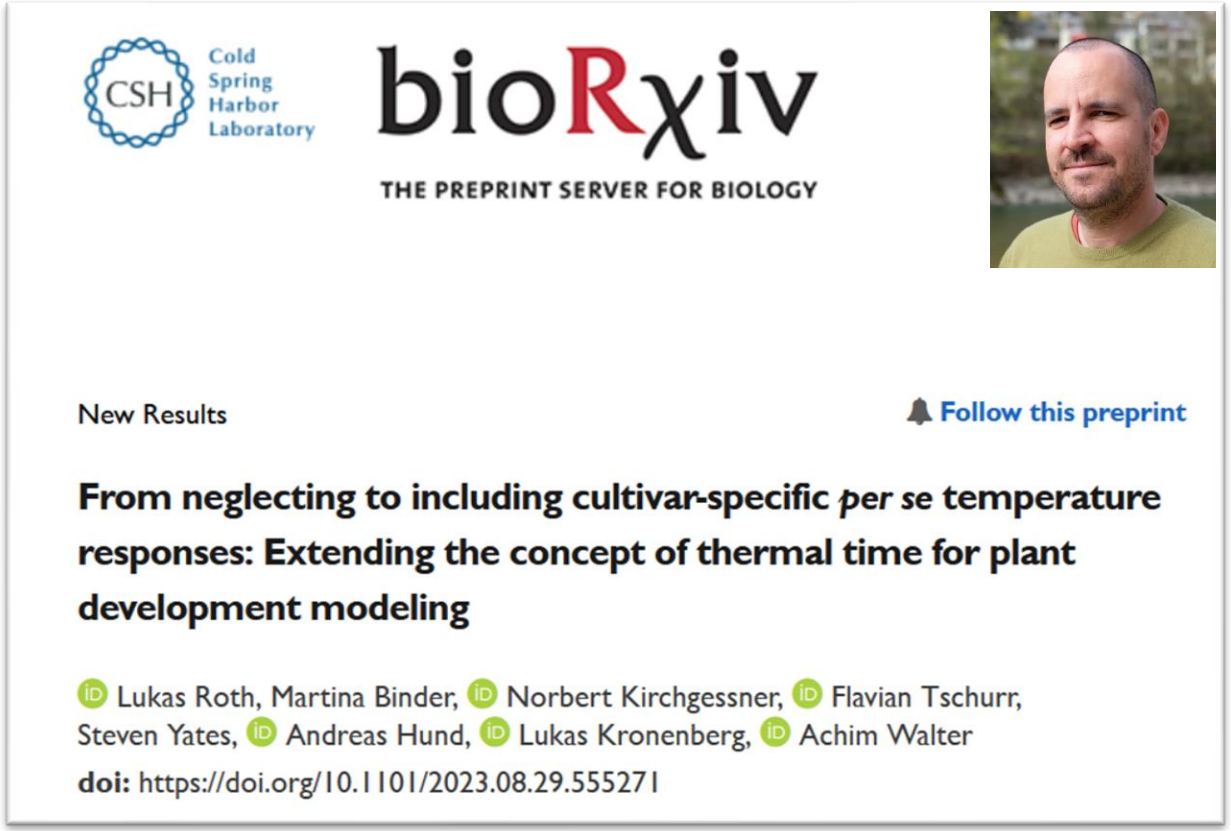
- **Which affect yield**
- r_g (SE duration, yield) = **0.71**

High throughput phenotyping allows investigating dynamic traits!

- Under field conditions
- In large population
- Resolvable on a genotypic level

Cultivar-specific temperature response greatly improves phenology prediction!





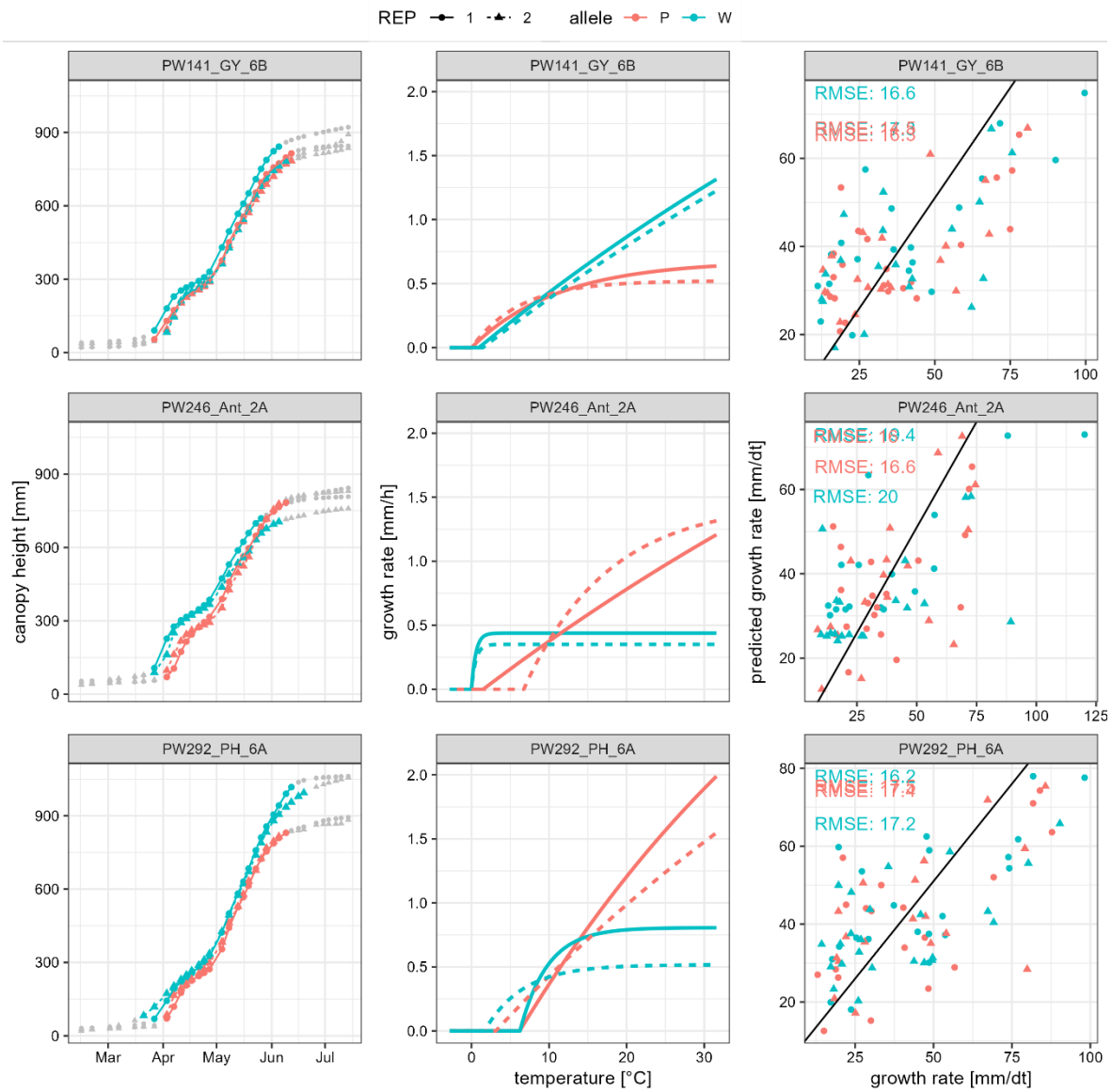
Conclusions

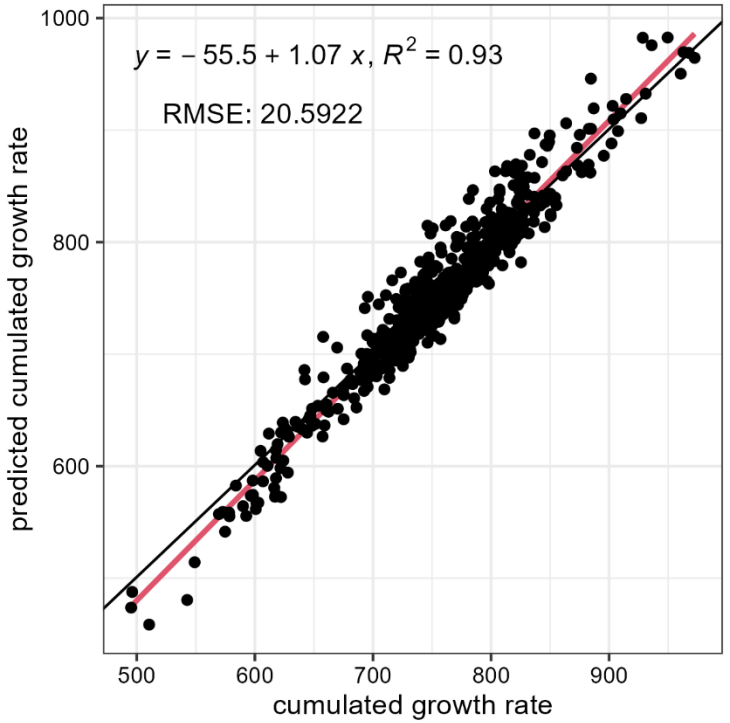
- **High throughput field phenotyping** allows to characterize wheat **temperature response** on a **cultivar-specific** level
- Origin **specific temperature response pattern** indicate their relevance **for local adaptation**
- Using **cultivar-specific** temperature response parameters may **improve crop models**
- **High heritability** indicates suitability for direct **phenotypic** selection or applications in **genomic-** or **marker assisted selection**
  - Improving local adaptation
  - Fine-tuning phenology

Special thanks to:

Funding
Swiss National Science Foundation (SNF)
BBSRC Designing Sustainable Wheat (DSW)

Model fits DFW academic toolkit 2023

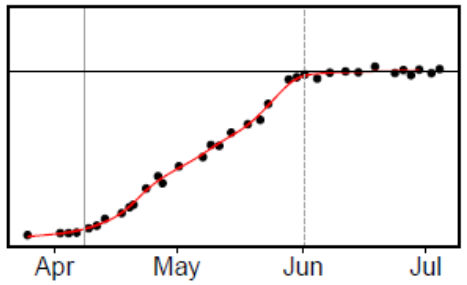


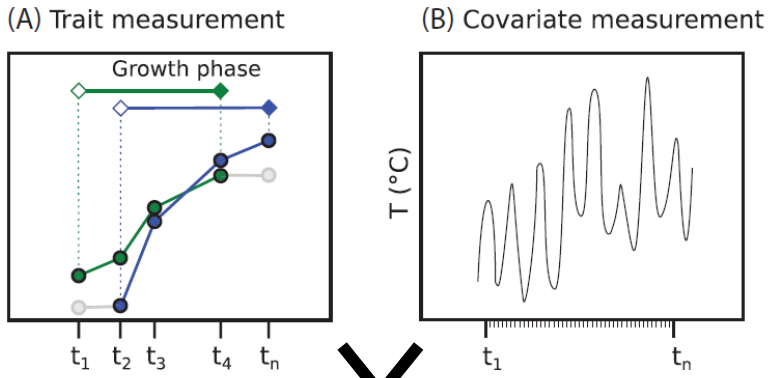


Trait	Heritability
r_{max}	0.51
lrc	0.54
T_{min}	0.52
PHmax	0.97
tPHstart	0.49
tPHstop	0.66

Canopy height time series allow to model genotype-specific timing of stem elongation and its temperature response

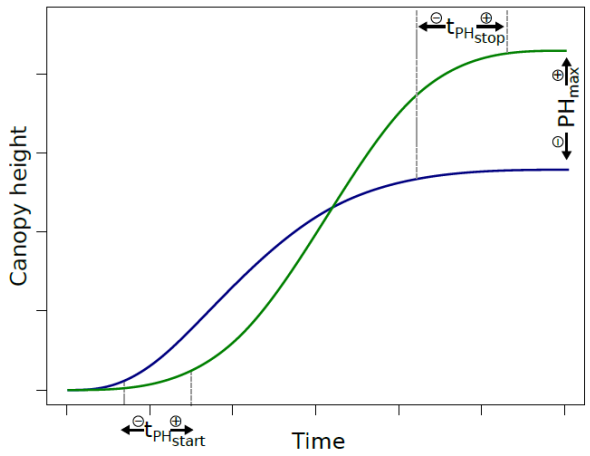
Canopy height time series



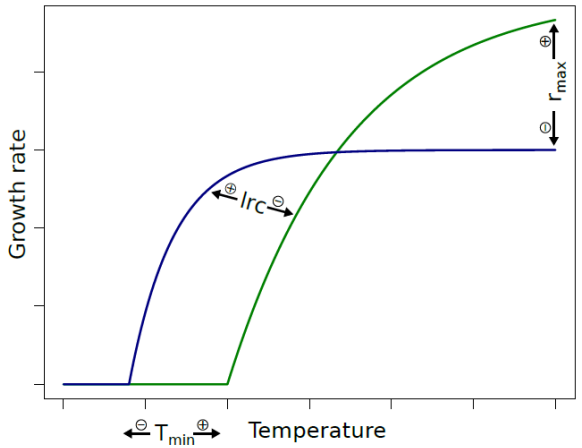


QMER
Roth et al. 2021; Field Crops Research

Timing of stem elongation



Temperature response



Roth et al., 2022; in silico Plants

$$y_t = \sum_{d=t_0}^{t} \left(\sum_{h=1}^{n_d} r(T_{dh}, \theta) \cdot \Delta m_h \right)$$

$$r = r_{\max} \cdot (1 - \exp(-\exp(s) \cdot (T - T_{\min})))$$

$$r_{\text{asym}}(T) = \begin{cases} r, & r > 0 \\ 0, & \text{otherwise} \end{cases},$$

Kronenberg et al. 2017; Euphytica
Kronenberg et al., 2021; JXB
Roth & Kronenberg et al. 2023; JXB