The delicate balancing act of climate control during flowering, pollination and seed development in sunflower

Nicky Creux

Carine Marshall, Uyabongeka Memela, Phrasia Mapfumo, Stacey Harmer

FABI

NATIONAL GRAIN RESEARCH PROGRAMME

INNOVATION AFRICA
UNIVERSITY OF PRETORIA

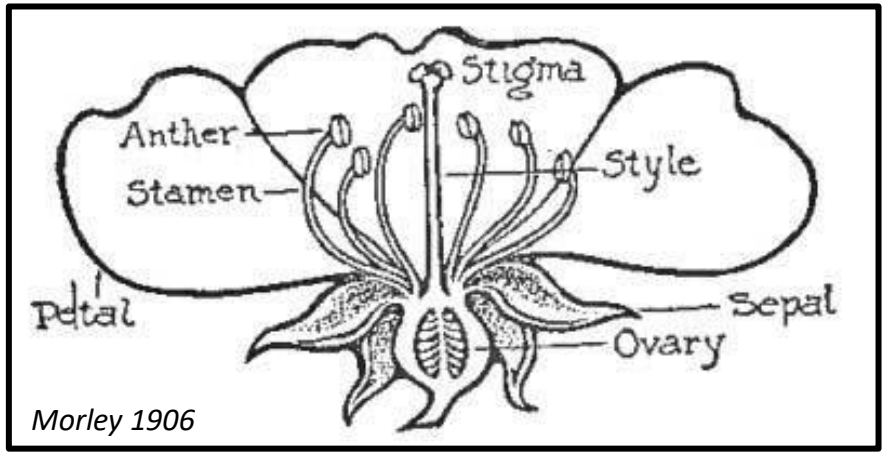
UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

@NickyCreux

Introduction

Cross pollination is all about timing and balance

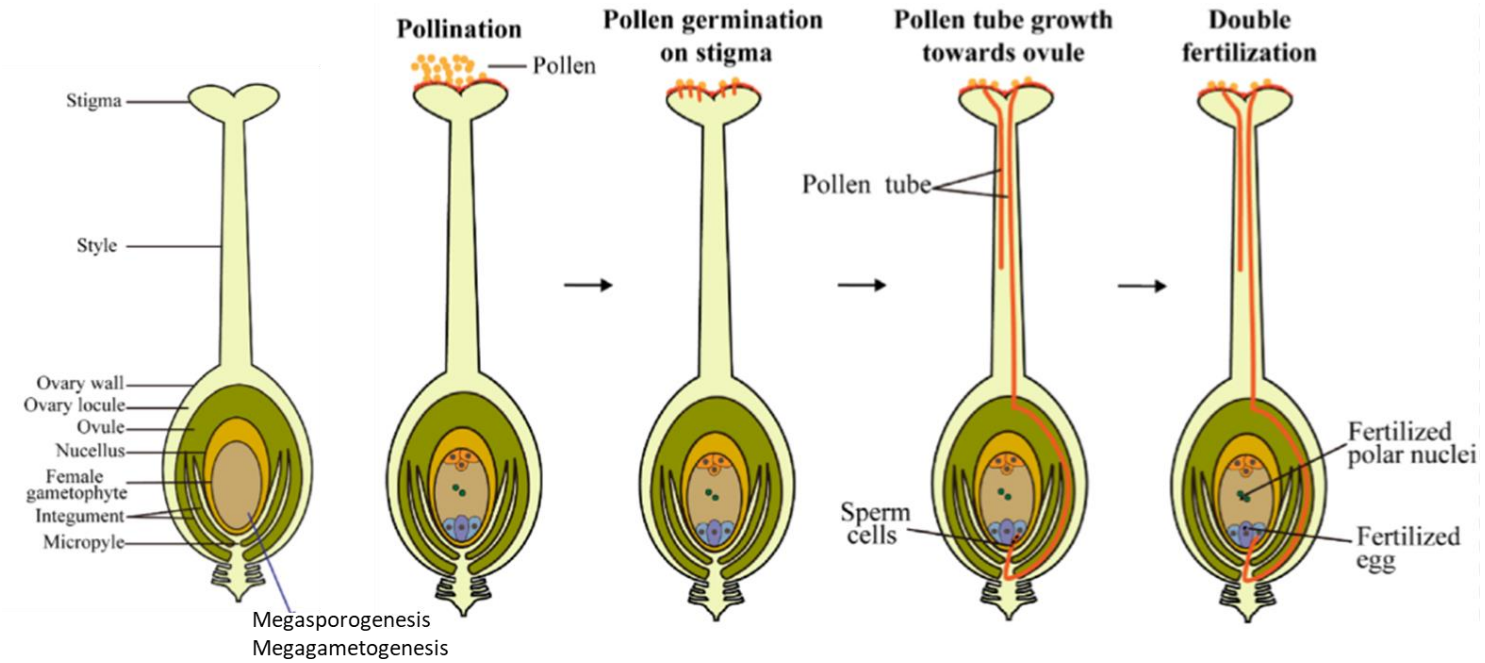
ENIVIRONMENTAL FACTORS
Wind
Humidity
Temperature
Light



Morley 1906

http://www.houstonzoo.org

Introduction



Too hot — **Too cold**

- Reduced pollen quality and quantity
- Poor pollen germination
- Failure of pollen-pistil interaction
- Pollen tube hyper growth
- Female gametophyte degeneration

- Reduced pollen quality and quantity
- Poor pollen germination
- Pollen tube growth rate reduced

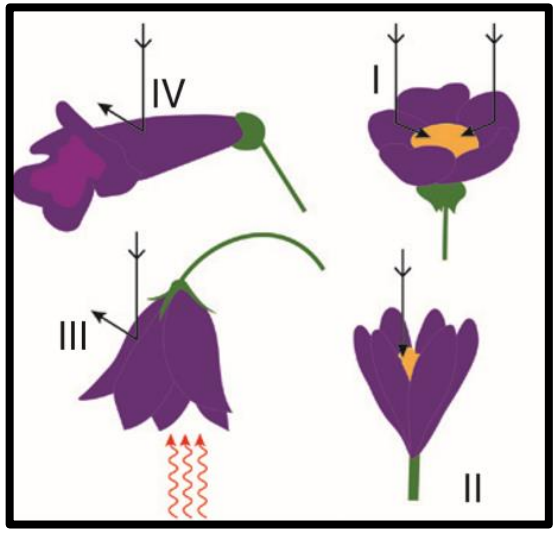
Hedhly. 2011 Environ and Experiment Bot. 74:9-16 *Rosbakh et al. 2018 Front Plant Sci. 9: 1036.* *Wang et al. 2021 Plant Cell Environ. 44:2200–2210*

Introduction

Plants modulate floral temperature via several different mechanisms

- Shape, position, color, orientation, opening

Flower shape and position



Flower orientation or reorientation

Flower opening and closure

van der Kooi et al. 2019 Annals of Botany 124: 343–353

Introduction

Circadian clock regulates diverse plant and animal processes

CIRCADIAN CLOCK

(Schleicher 1948; Lindauer Bilderbogen Series 1, No. 5)

(Cheng et al 2016; Plant Physiol Biochem)

(Barak et al 2000; Trends in Plant Sci)

Introduction

Juvenile sunflowers track the sun while at anthesis mature sunflower heads remain facing east

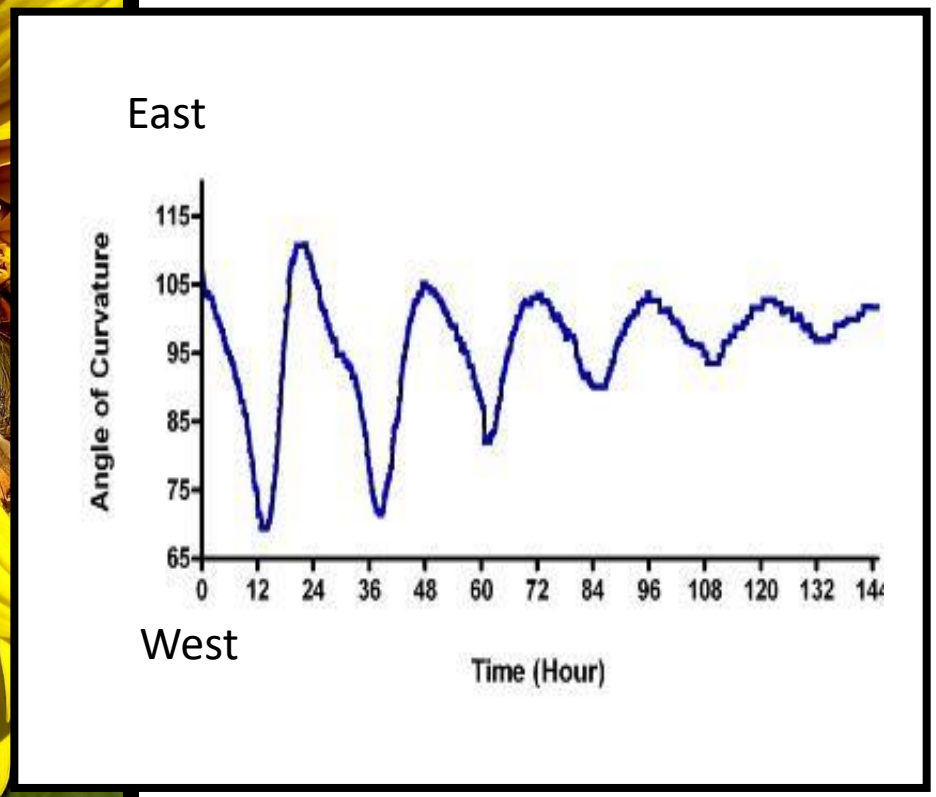
Atamian et al. 2016. Science. 353:587-590

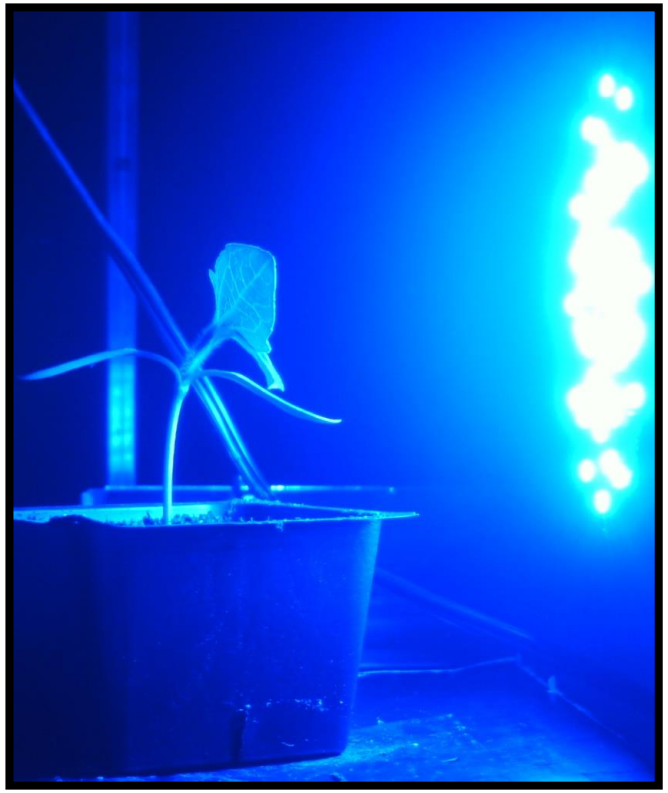
http://konijntje.deviantart.com

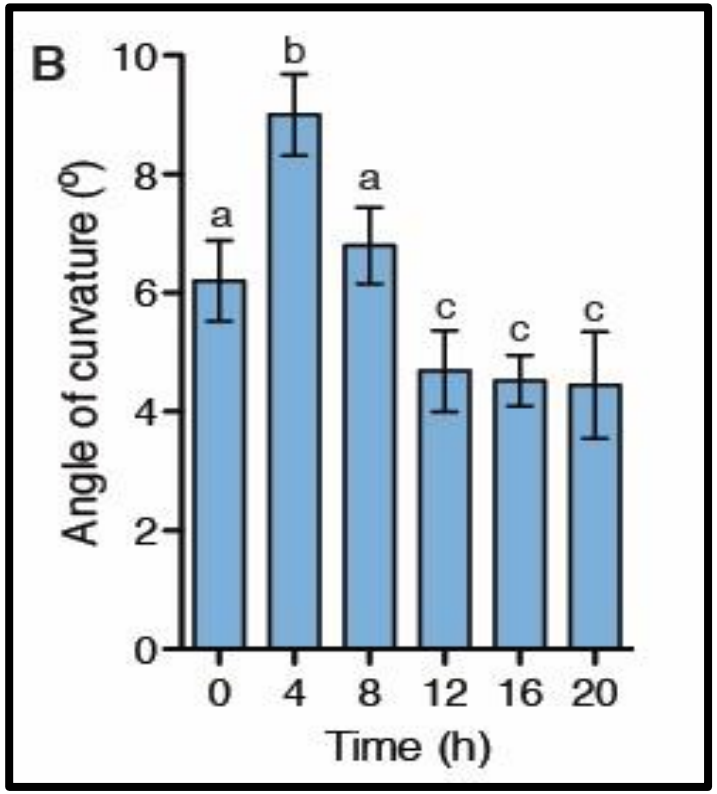
Question

- Do environmental cues and the circadian clock regulate sunflower head orientation?

Sunflower head orientation is regulated by the stems morning sensitivity to light





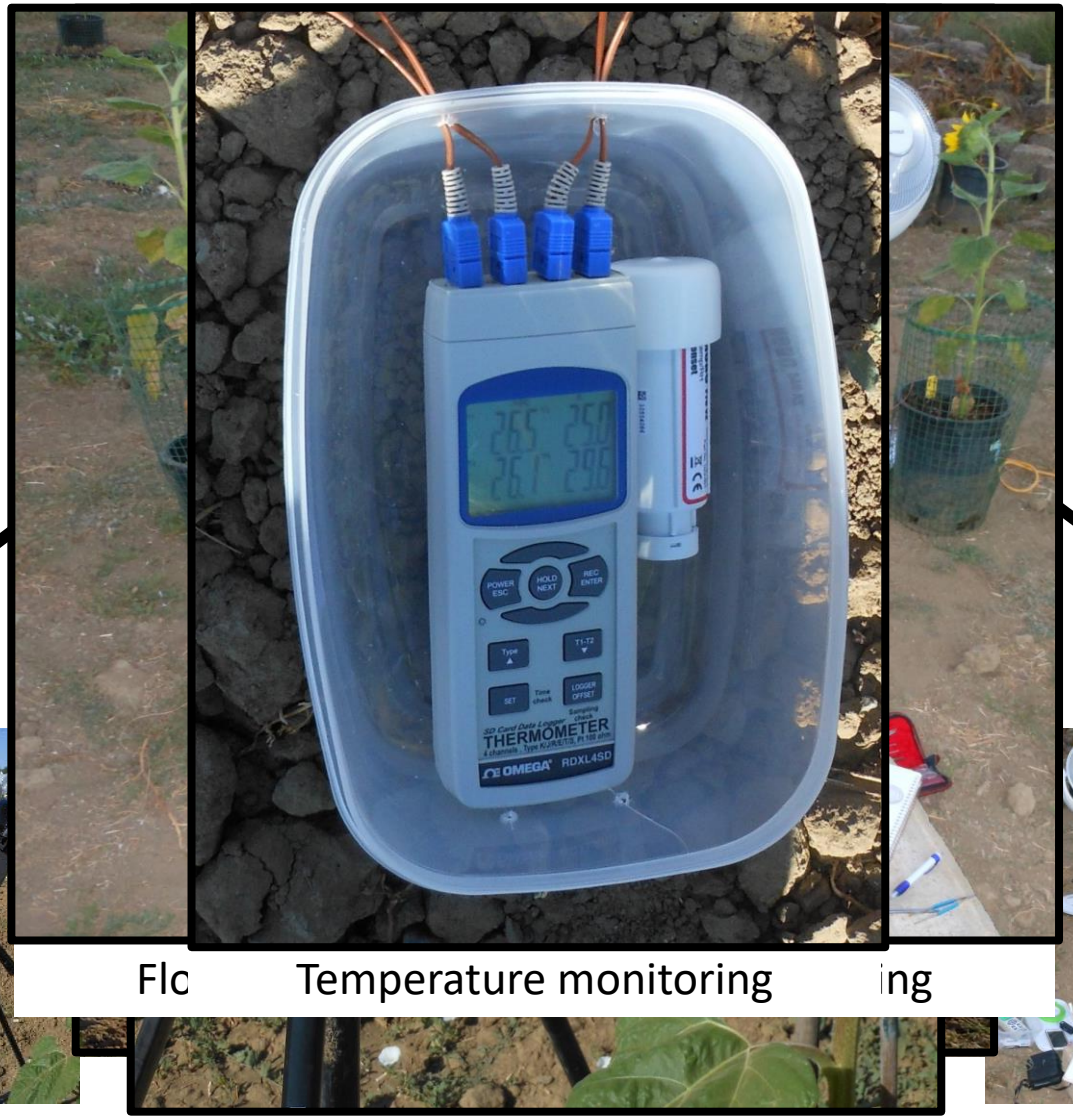


Atamian et al. 2016. Science. 353:587-590

Question

- Is there biological relevance to the orientation of a sunflower capitulum?

Field Methods



Flo Temperature monitoring ing

Pollinator video analysis

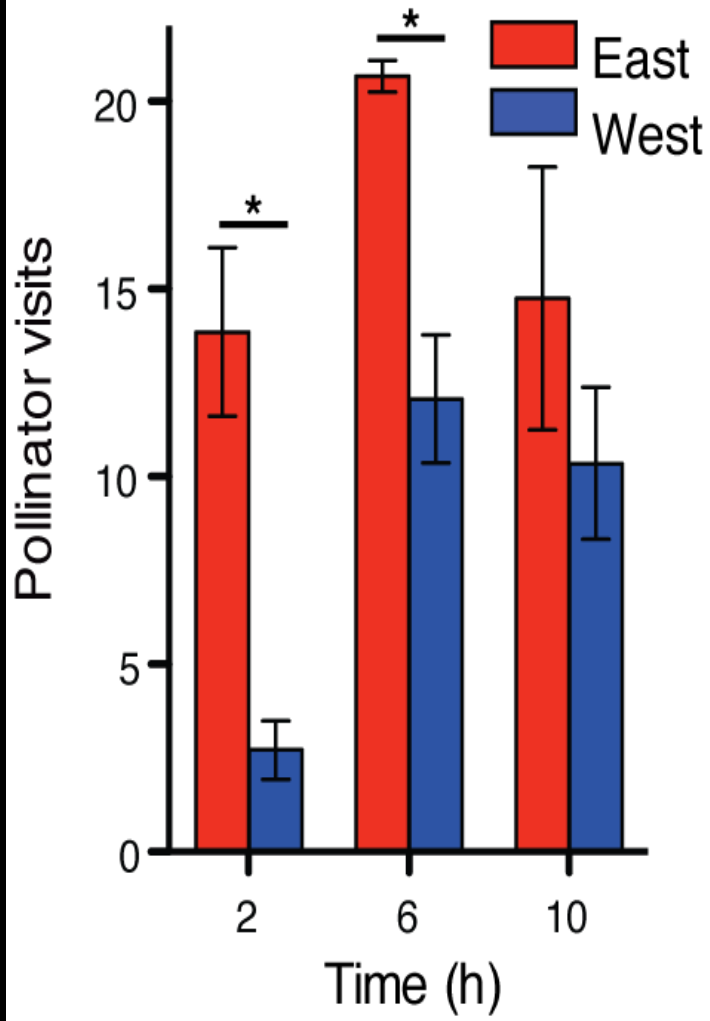
Time-lapse photog of floret maturat

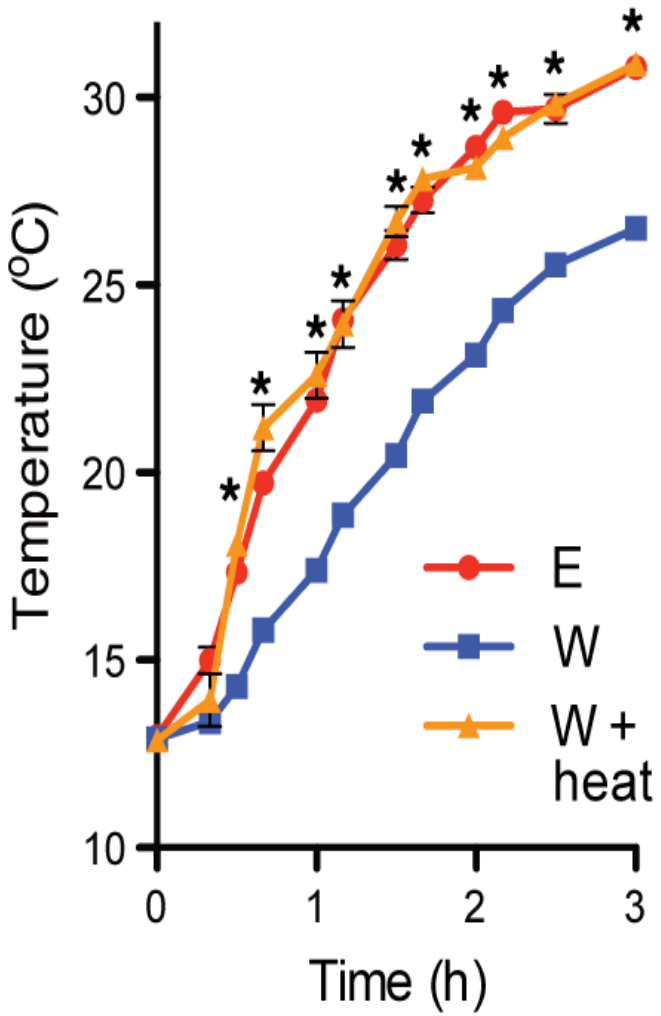
Time-lapse photography of floret maturation

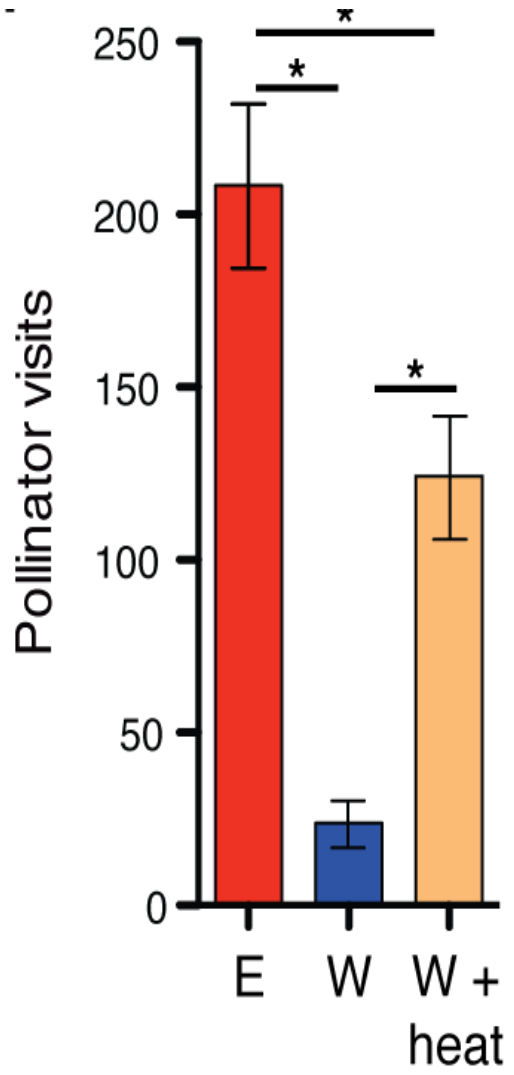
harvesting, and imaging

Temperature monitoring

Sunflower orientation affects temperature and pollinator visits







Atamian et al. 2016. Science. 353:587-590

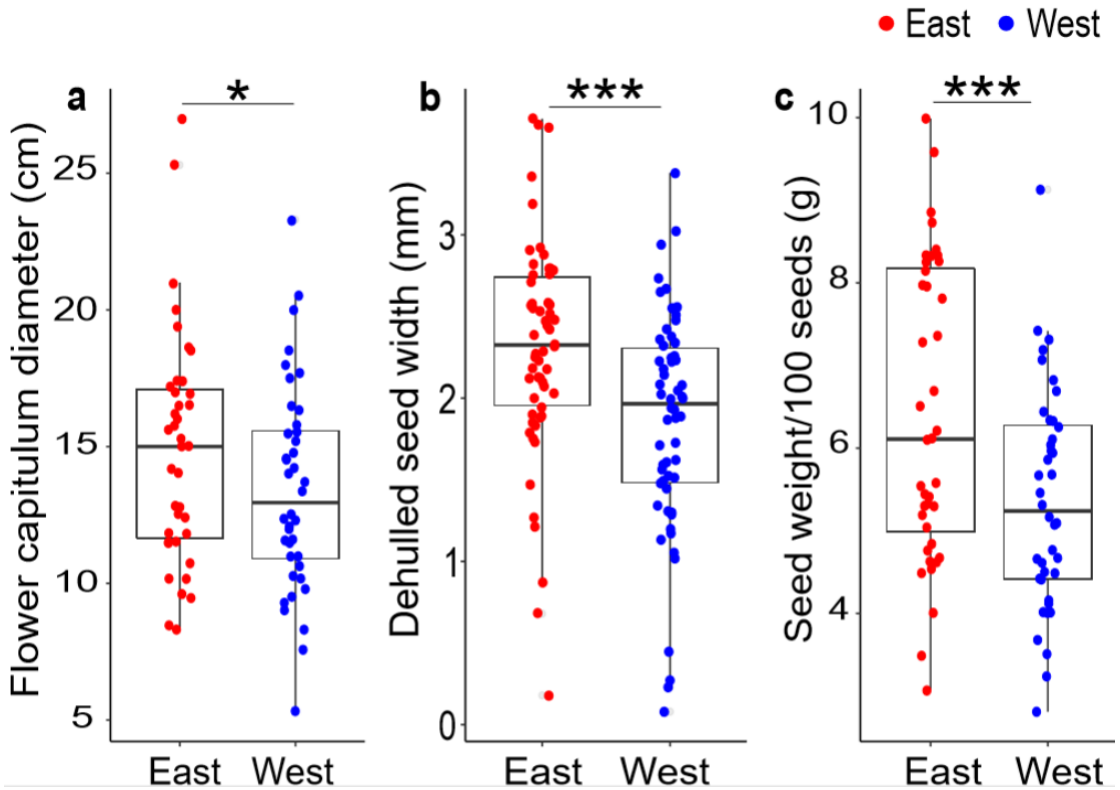
Question

- Do these higher early morning temperatures affect flower or seed physiology and pollination?

Sana Saeed

East-facing sunflowers show a male and female fitness advantage

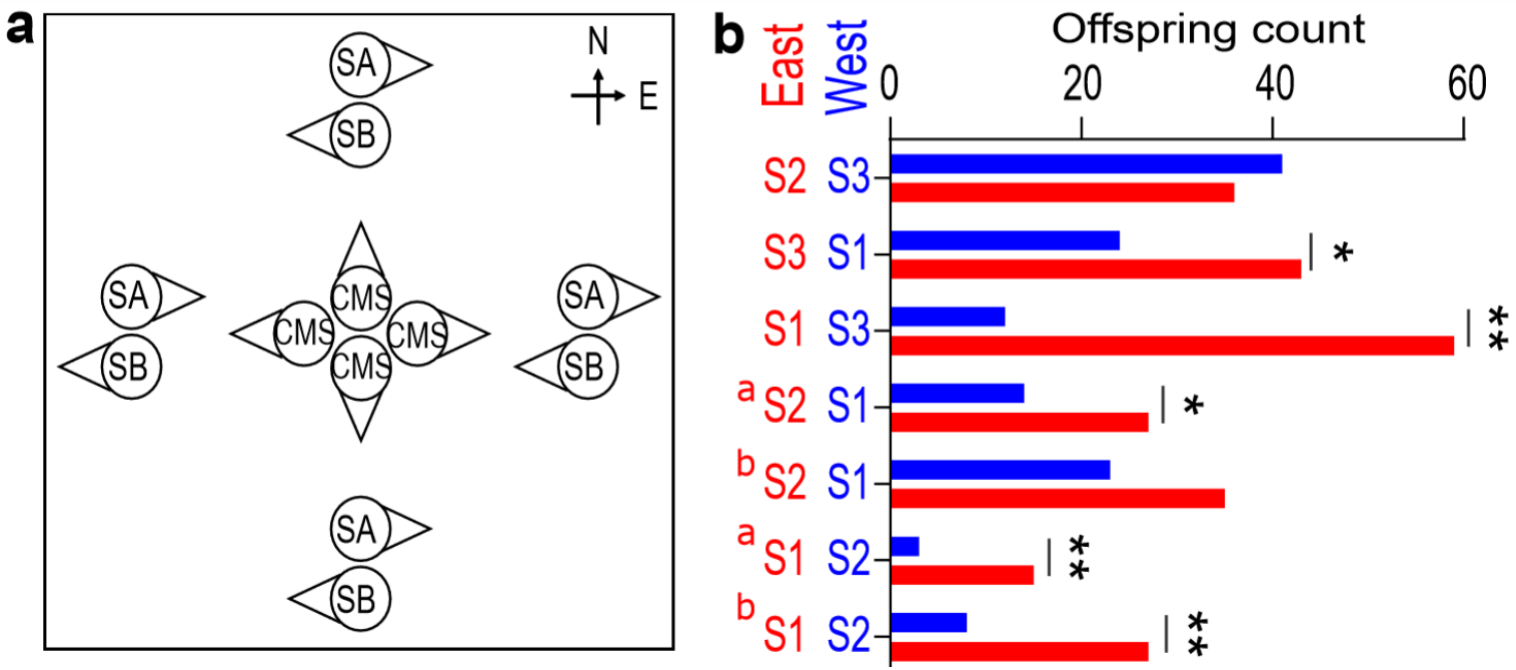
East-facing plants produce heavier better filled seed in a locality-specific manner



Creux et al. 2021. New Phytol, 232: 868-879

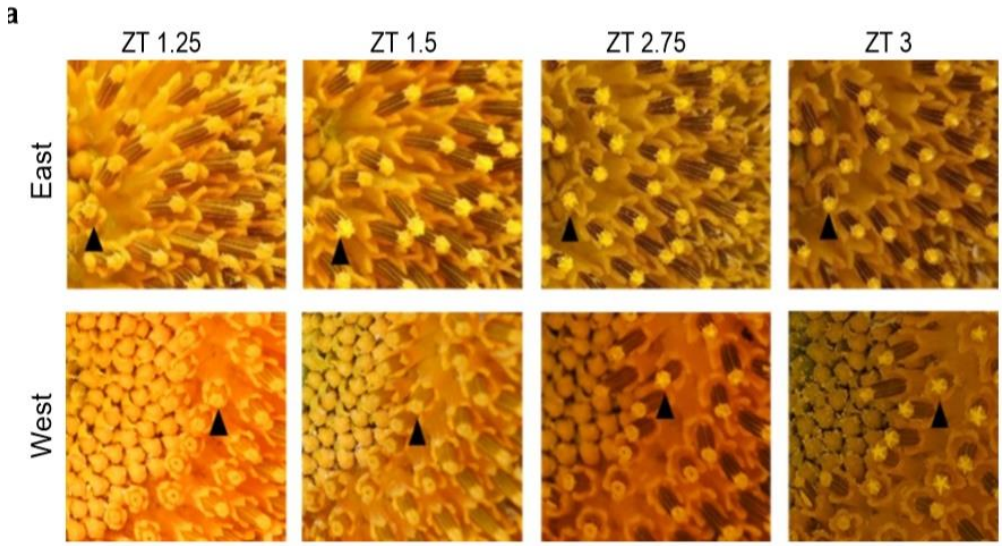
East-facing sunflowers show a male and female fitness advantage

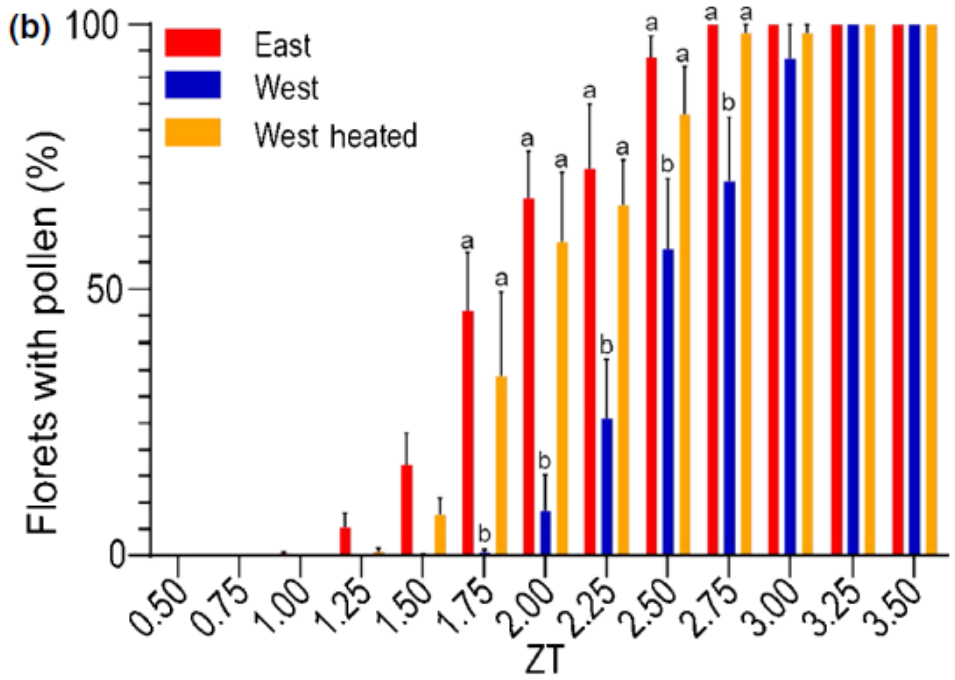
East-facing plants sire more off-spring



Creux et al. 2021. New Phytol, 232: 868-879

East-facing capitula presented pollen earlier due to temperature and partially overlaps with insect timing

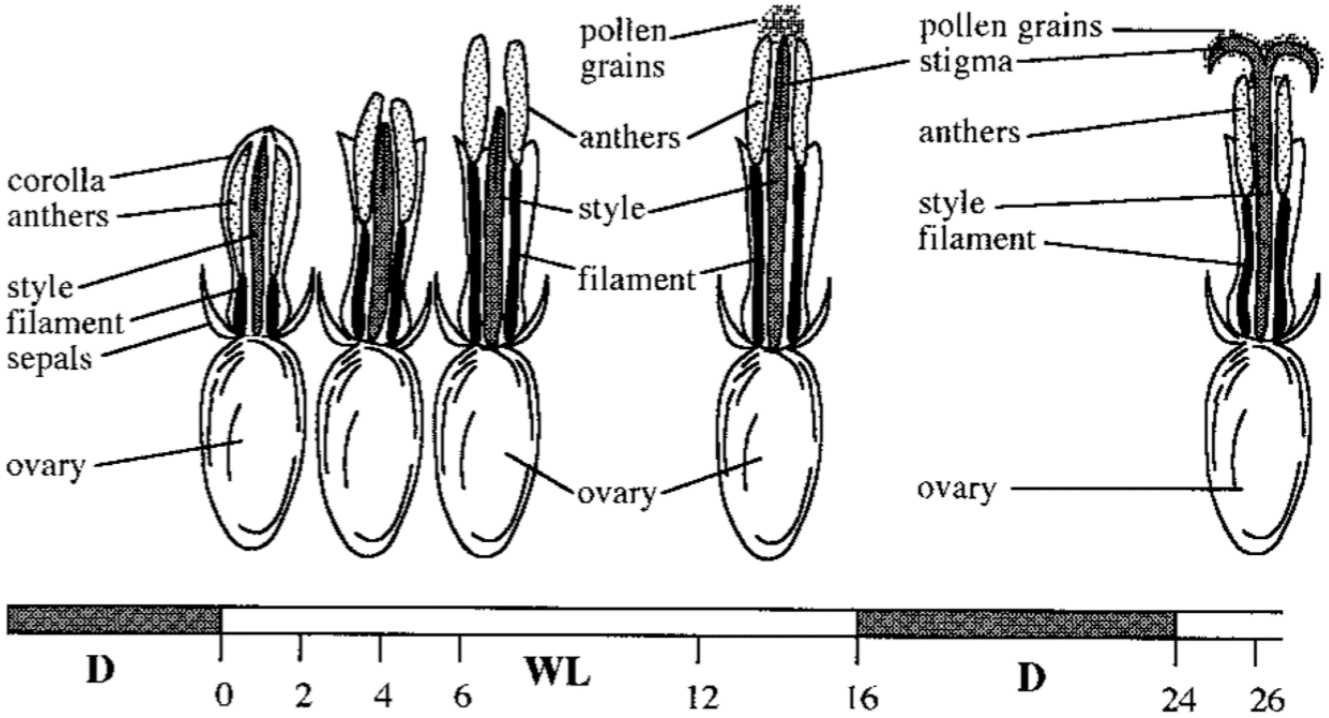




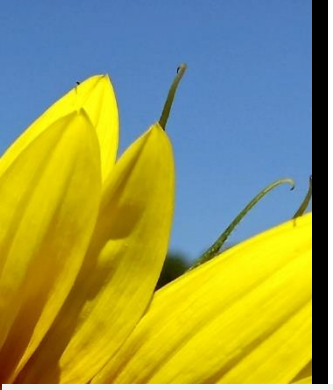
Creux et al. 2021. New Phytol, 232: 868-879

Question

How does temperature regulate the timing of pollen emergence?

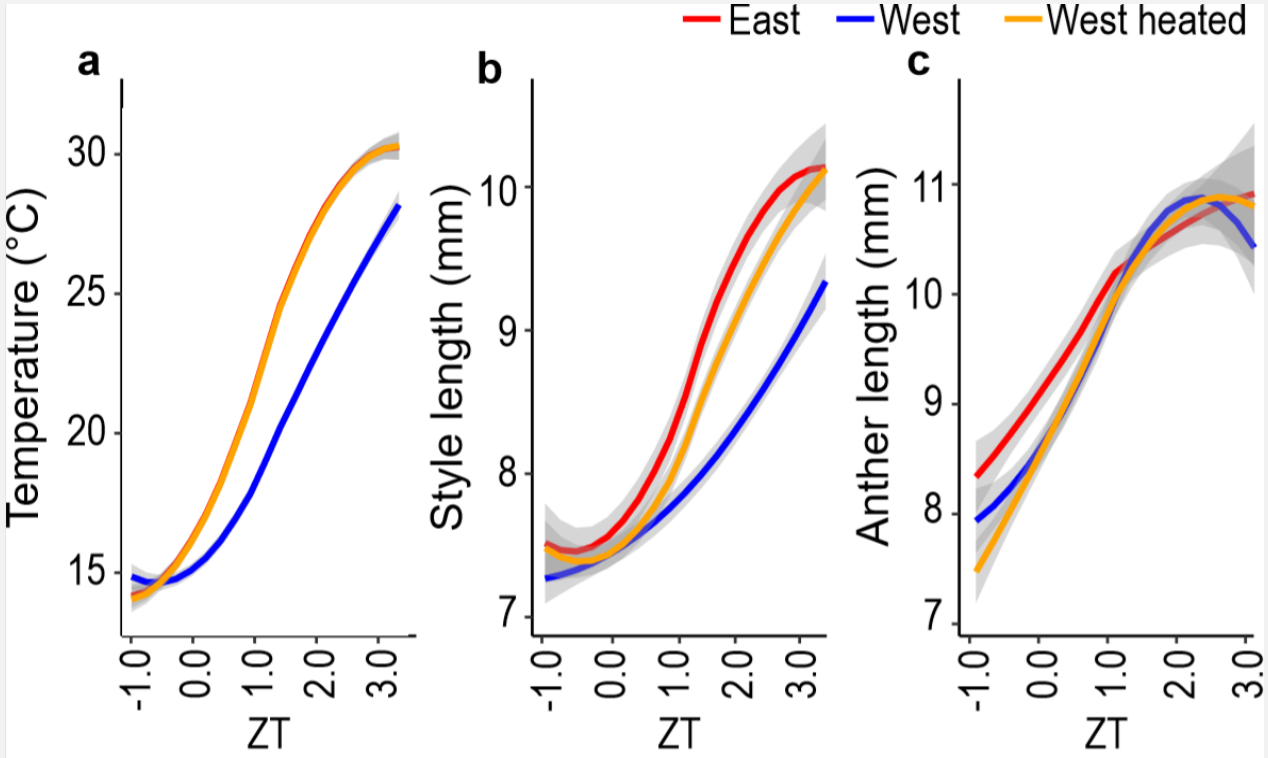


Lobello et al. 2000. JXB, 349: 1403 - 1412

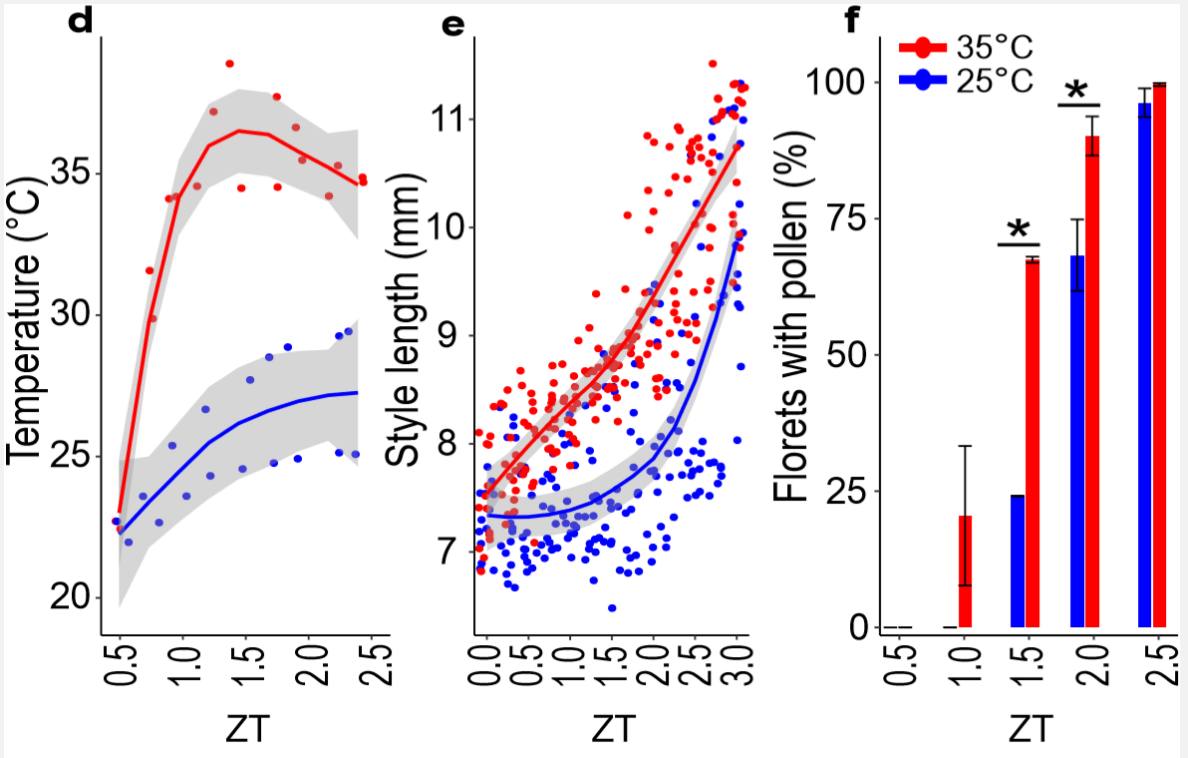


Temperature regulates rate of style elongation but not anther filament elongation.

Field measurements



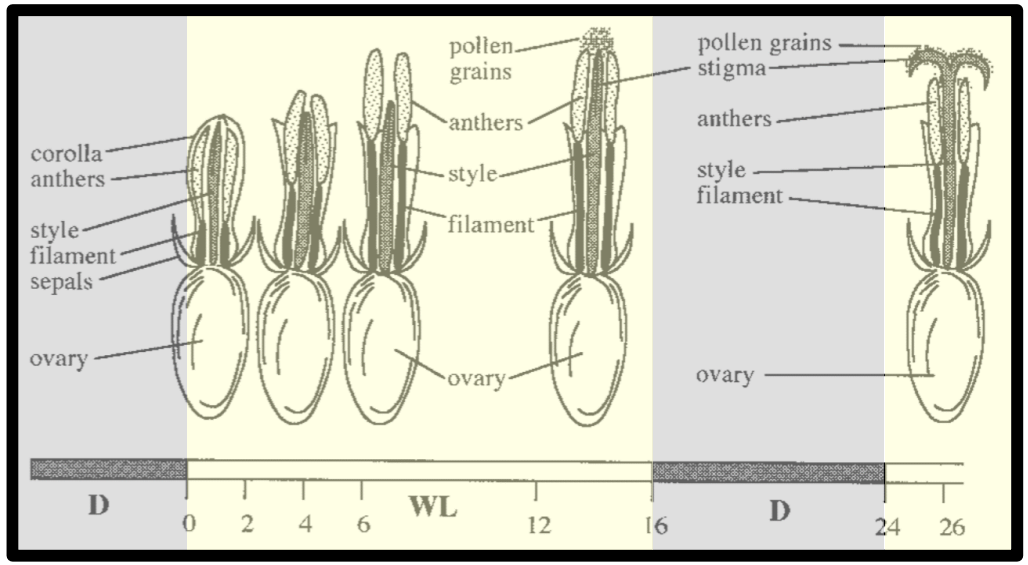
Chamber measurements

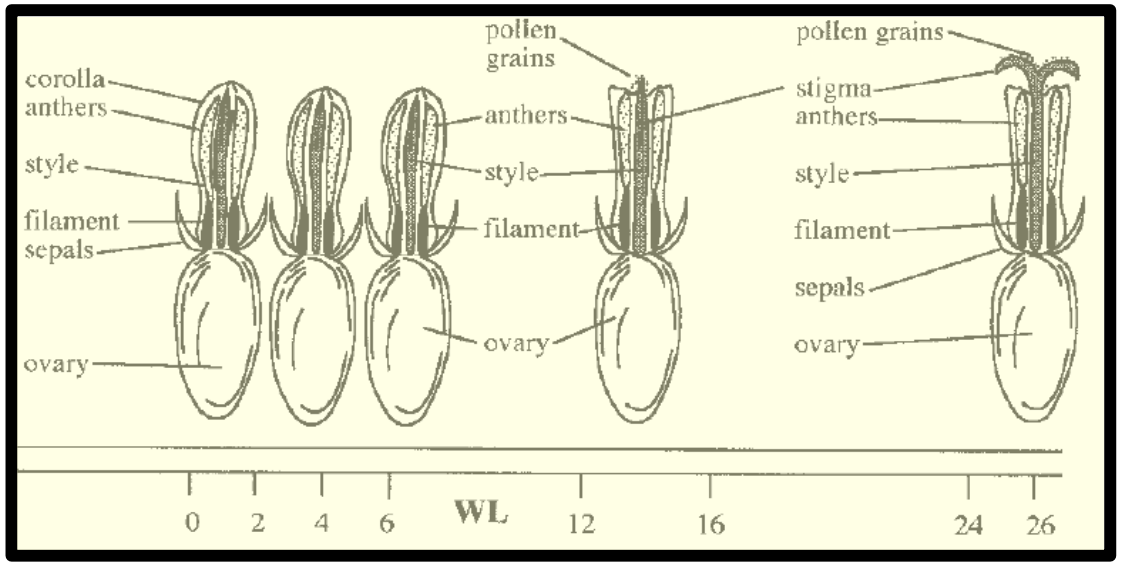


Creux et al. 2021. New Phytol, 232: 868-879

Question

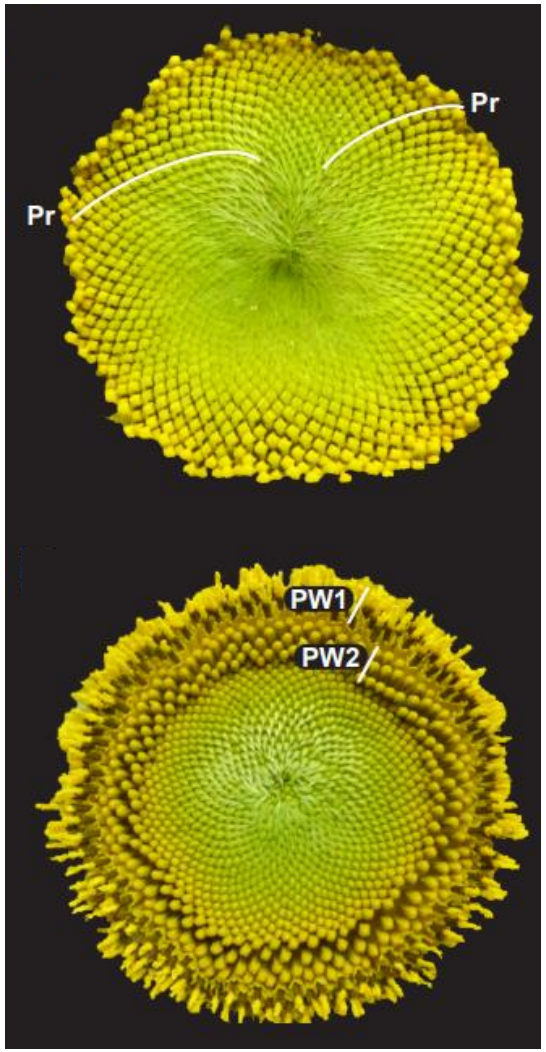
How do temperature, light and the circadian clock regulate floret opening?

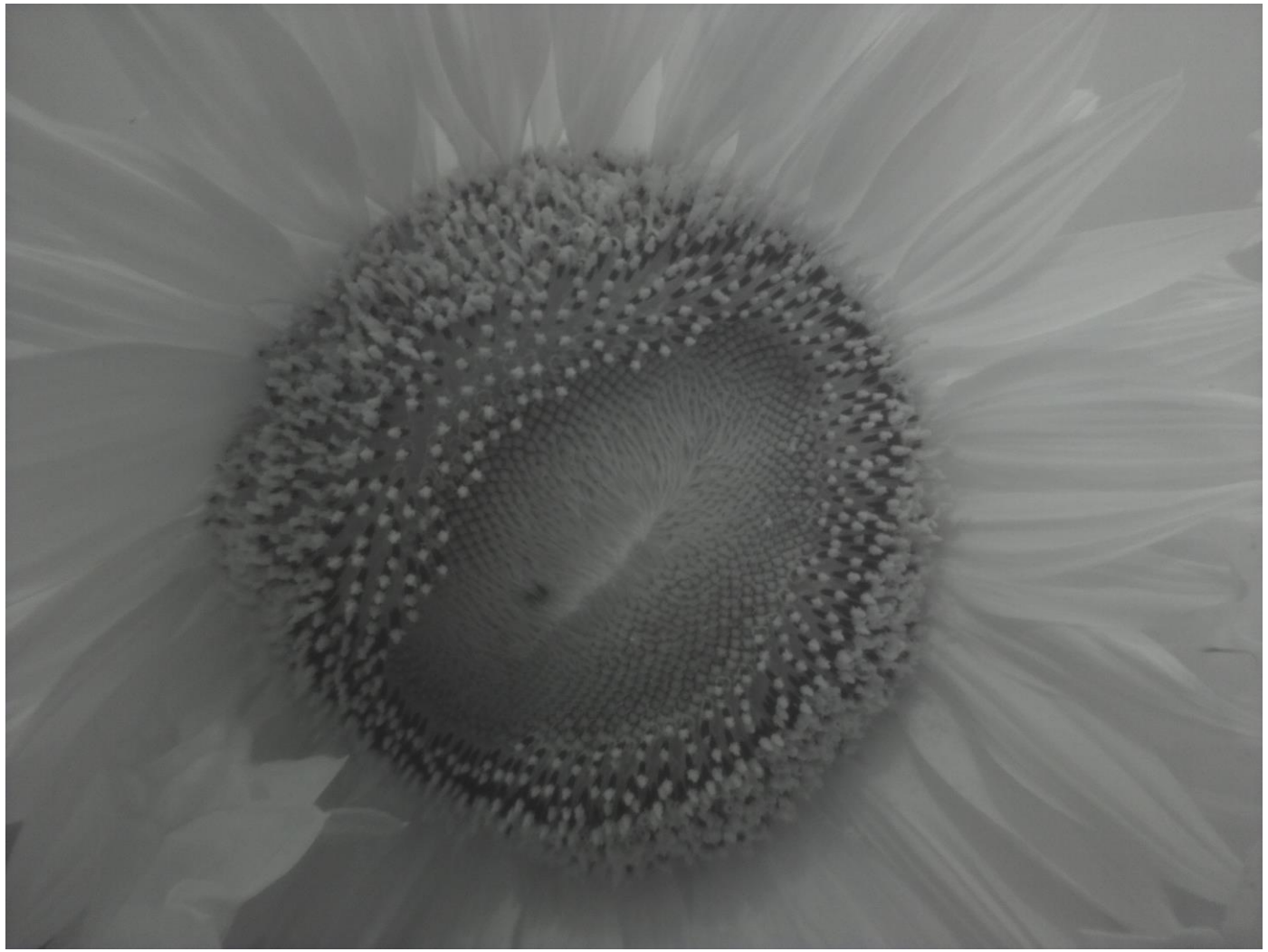




Lobello et al. 2000. JXB, 349: 1403 - 1412

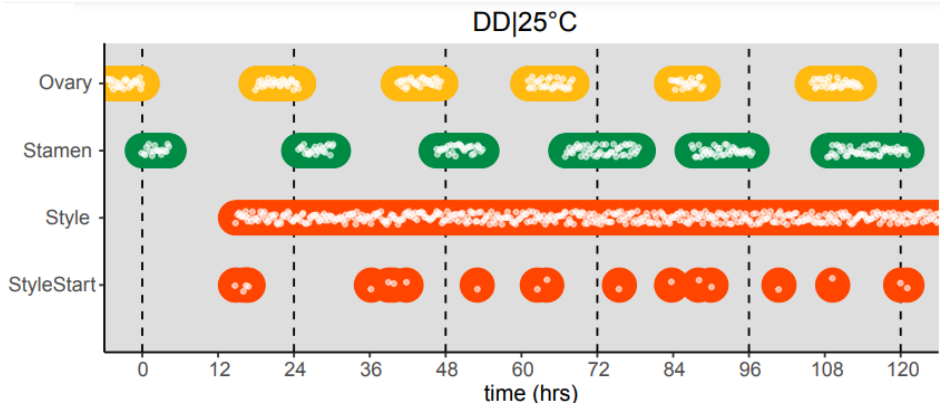
Florets arranged in a continuous developmental series spiraling from the center, but mature in grouped daily rings.

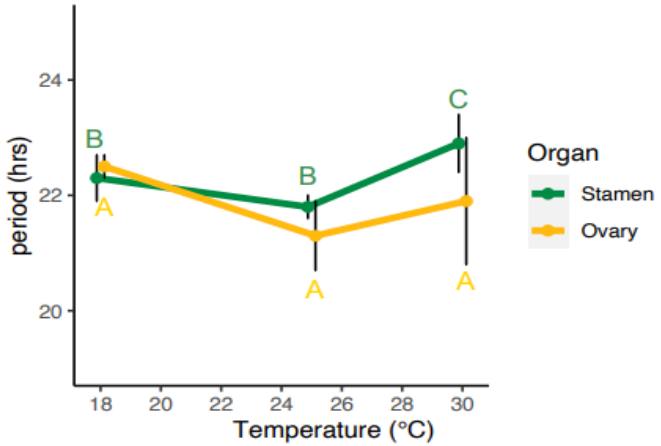


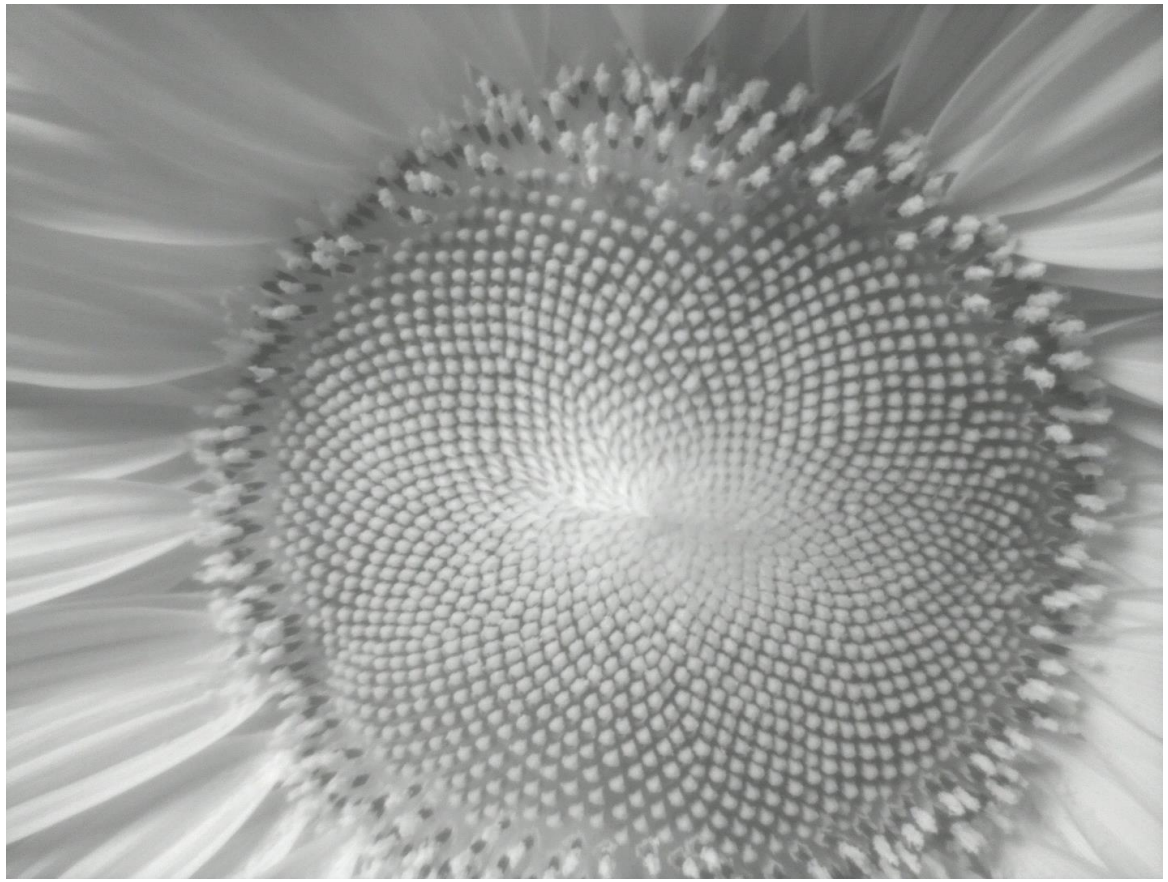


Marshall et al. submitted. eLife

The daily rhythms in floret development are regulated and gated by the circadian clock.







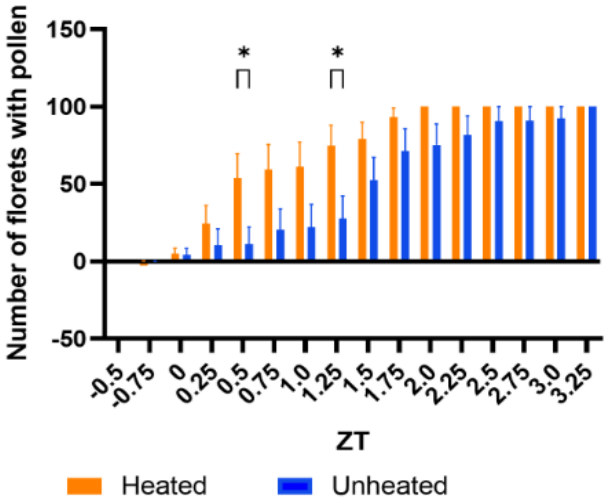
Marshall et al. submitted. eLife

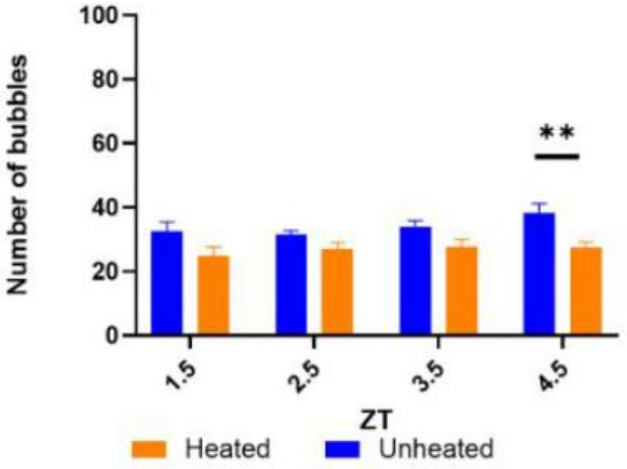
Question

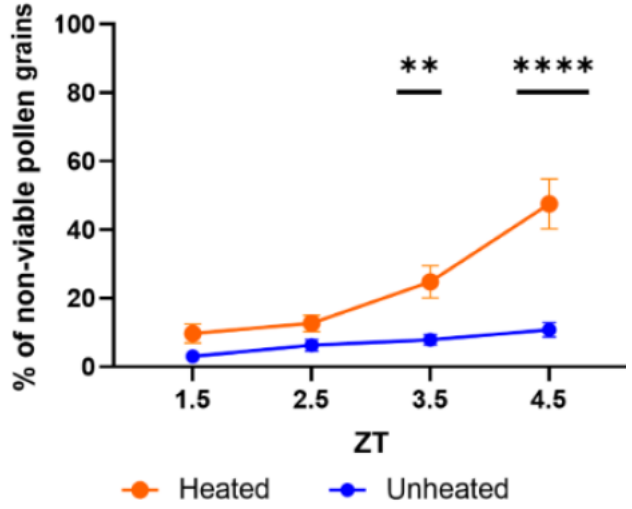
- If external cues such as light and temperature regulate floret maturation, what happens at elevated temperatures or under heat wave condition?

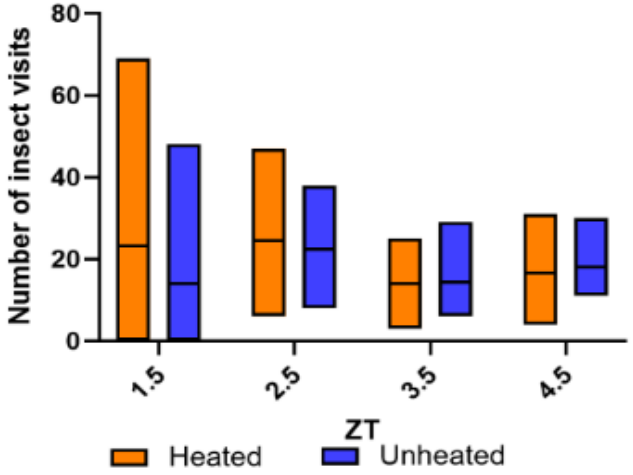
Uya Memela
MSc Student

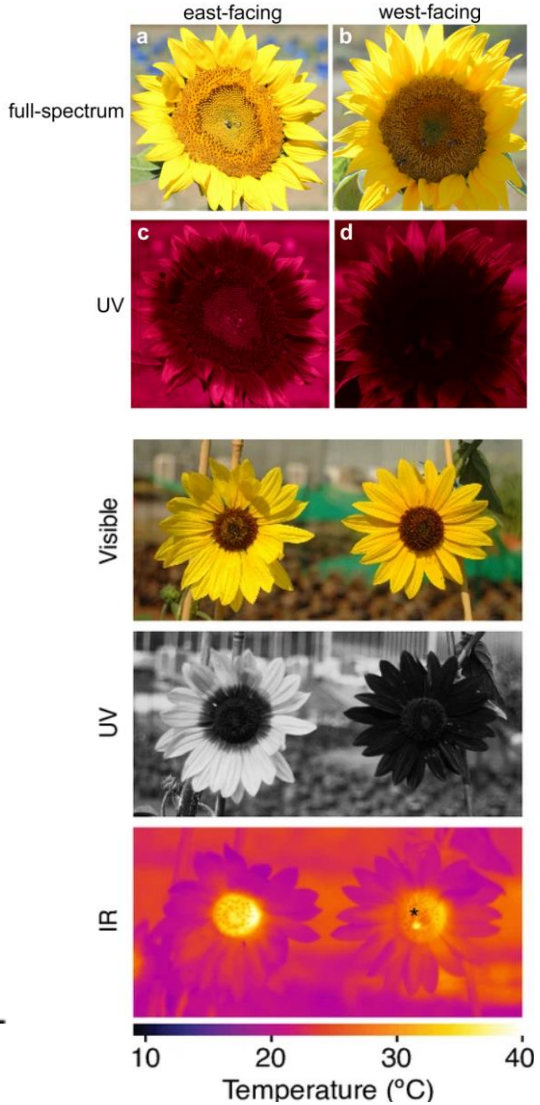
High temperatures change the timing of pollen emergence and limit pollination











Memela et al. in preparation

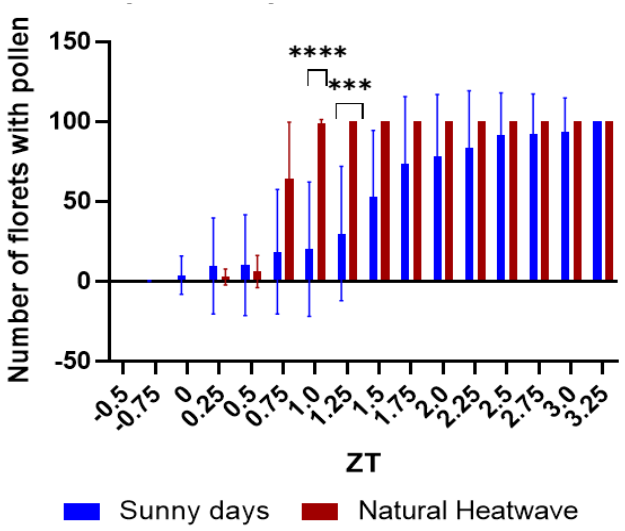
Todesco et al. 2022. eLife, 11:e72072

Creux et al. 2021. New Phytol, 232: 868-879

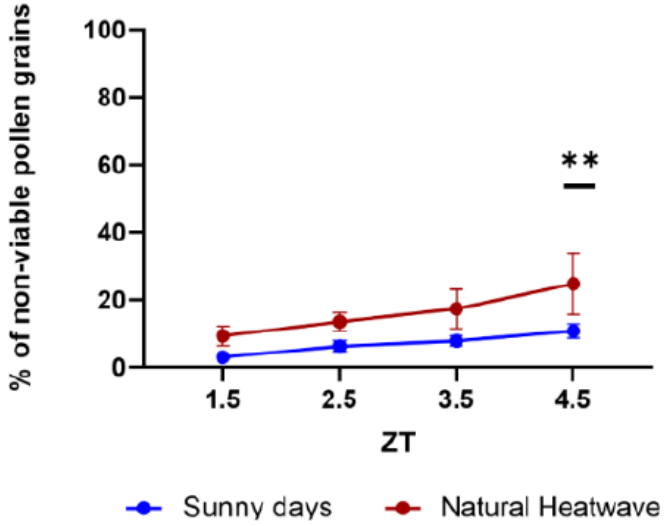
Uya Memela
MSc Student

Timing of pollination shifts earlier in a heat wave to maintain pollination at cooler temperatures.

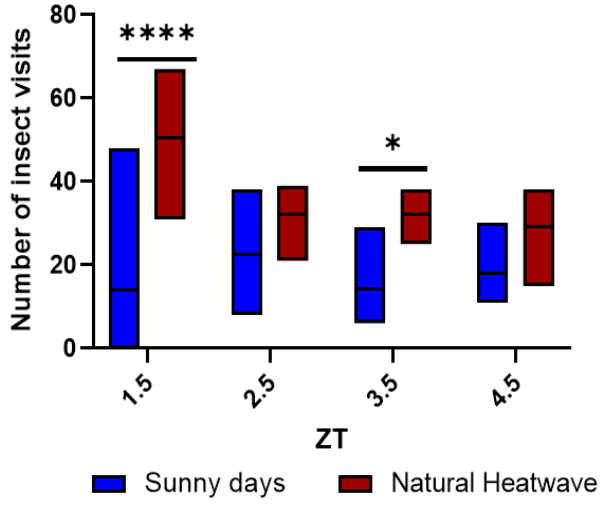
Timing of pollen presentation



Pollen viability



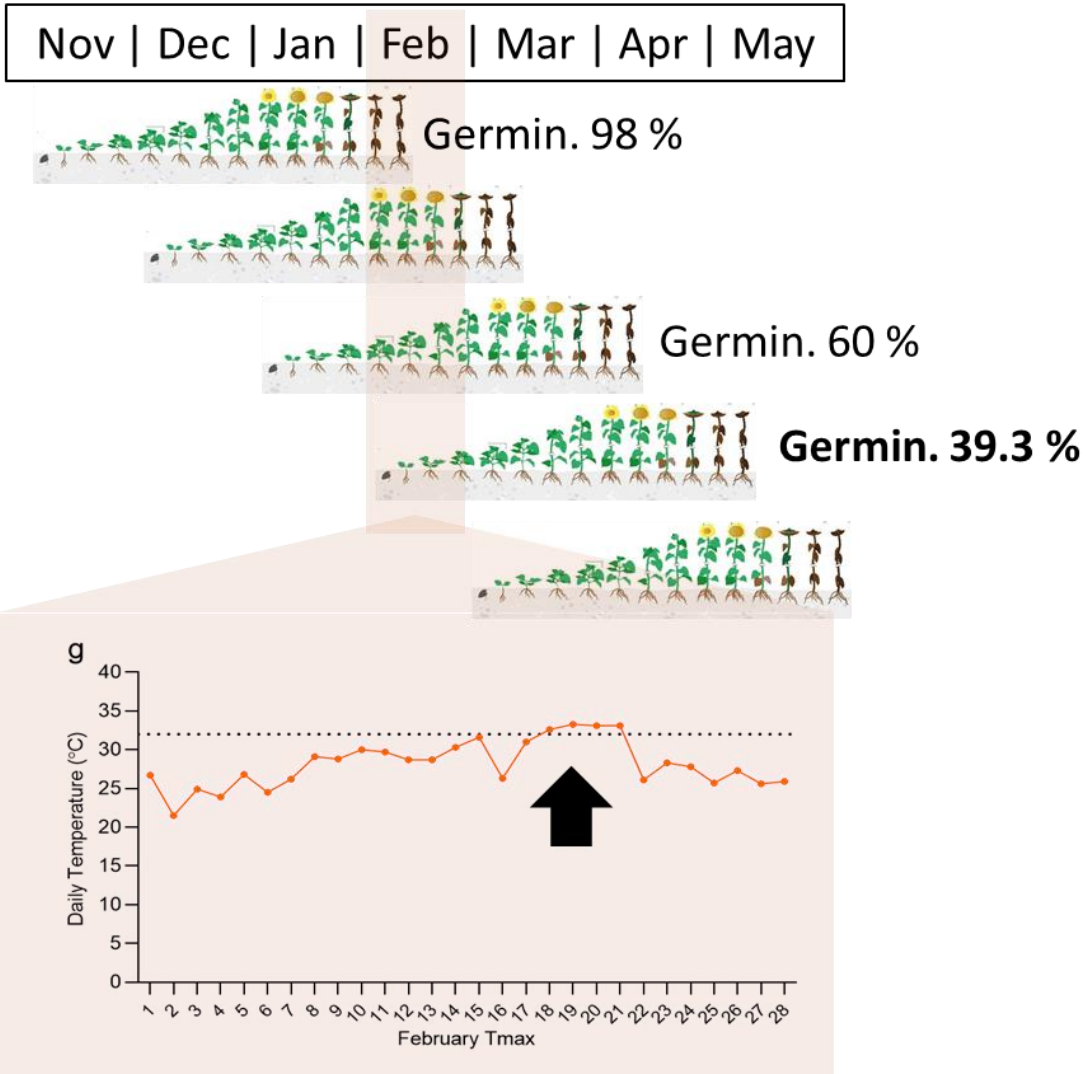
Timing of insect visits

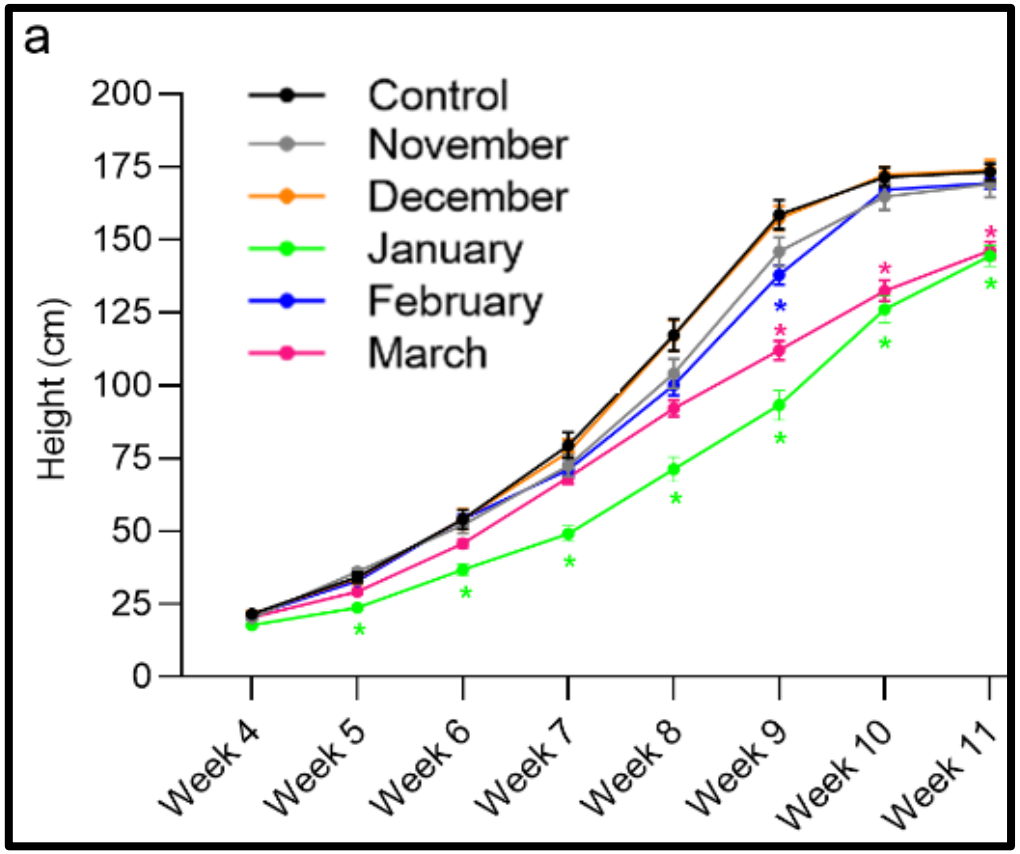


Memela et al. in preparation

Phrasia Mapfumo
(PhD student)

Heat stress at a juvenile stage may impact floral traits to maintain sunflower yield.



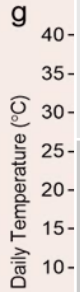


Phrasia Mapfumo
(PhD student)

Heat stress at a juvenile stage may impact floral traits to maintain sunflower yield.

Nov

Parameter	Jan 2021	Early planting	Very late planting
Average number of filled seeds	1352.93	1481.4	1013.13
Average number of unfilled seeds	53.67	140.73	239.47
Average total seeds	1466.27	1622.13	1252.6
Average 100 seed weight	5.33	7.8	3
Average seed diameter	3.58	3.74	3.0
Average grain filling %	92.56	91.44	80.26

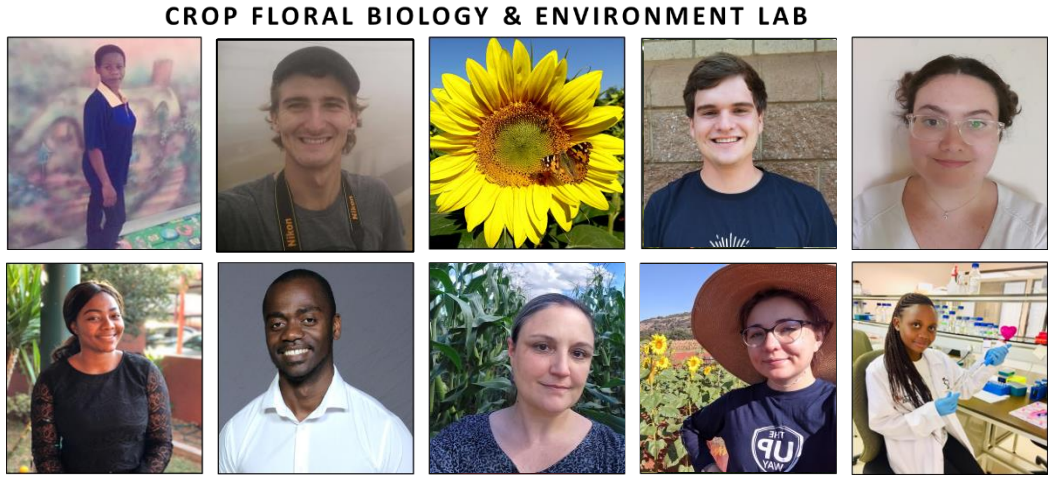


Conclusions

- Flower head orientation regulates microclimate to time pollen emergence and pollinator visits
- Temperature regulates style elongation to influence timing of pollen emergence
- Coincidence is required between the circadian clock, dark phase and developmental stage to regulate daily floret opening
- Sunflowers avoid heat stress by altering floral traits and timing of anthesis to maintain pollination.

Acknowledgements

- The Harmer Lab (UCDavis)
- The Blackman Lab (UCBerkeley)
- The UCDavis and University of Pretoria field management teams
- The Agricultural Research Council (ARC): Dr Swanevelder, Dr Maali
- Prof Emma Archer, Department of Geography, University of Pretoria
- The MPPI Lab (University of Pretoria)
- The Grain Research Programme (GRP)
- The Center of Excellence for Plant Health Biotechnology (CPHB)



Oil & Protein Seed Development Trust
& Oilseeds Advisory Comittee

Olie- & Protelensade Ontwikkelingstrust
& Oliesade Advieskomitee

ARC • LNR

NRF National Research Foundation

THE UNIVERSITY OF CALIFORNIA UCDAVIS DAVIS

NSF

@NickyCreux