47th New Phytologist Symposium:

Extreme Heat: extending the thermal limits of life

2–5 June 2026 | Cordoba, Spain

https://www.newphytologist.org/events/47-nps

Organising Committee

Owen Atkin, Australian National University, Australia (Chair)
Cristina C. Bastias, University of Córdoba, Spain
Andrew Feldman, NASA / University of Maryland, USA
Kevin Hultine, Phoenix Desert Botanical Garden, USA
Belinda Medlyn, Western Sydney University, Australia
Adrienne Nicotra, Australian National University, Australia
Rafael Villar, University of Córdoba, Spain

Table of Contents

Programme

Pre-event: Monday 1 June	
19:00–21:00	Informal gathering at the Mercado Victoria (https://www.mercadovictoria.com/), we have reserved an area. Drinks and food will be available to purchase.
Day 1	**Tuesday 2 June**
Approx. 8:30am	Free visit to the Mosque of Cordoba, a World Heritage Site Details confirmed directly with those that signed up.
From 11am	**Registration - please collect your name badge and lunch tickets** Poster presenters should put up their posters during this time.
From 12 noon	Lunch – Rectory café (please provide waiting staff with your lunch ticket)
13:00–13:30	**Welcome from the University of Cordoba** Vice-Rector for Sustainable Campus, Amanda Penélope García Marín **Welcome from the organising committee** Owen Atkin and Rafael Villar
Session 1: Heatwaves and plant life – when and where Chair – Owen Atkin, Australian National University, Australia Co-Chair - Alice Gauthey, University of Birmingham, United Kingdom	
13:30	**1.1 Extreme heat across the soil, plant, animal, atmosphere continuum** Michael R. Kearney, University of Melbourne, Australia
14:00	**1.2 The heat is on: plant and soil relationships with temperature in Earth's hottest terrestrial landscapes** Sasha Reed, US Geological Survey, USA
14:30	**1.3 Panel discussion** Owen Atkin (Facilitator): • Mike Kearney: microclimate and surface-temperature modelling perspective. • Sasha Reed: empirical insights from the hottest terrestrial environments. • Adrienne Nicotra: connect variability in heat exposure to biological consequences. • Rocio Hernandez-Clemente: place-based perspective on recurrent extreme heat.
15:15–15:50	Refreshment break – Rectory café
Session 2: Eco-evolutionary responses to extreme heat Chair – Cristina C Bastias, University of Cordoba, Spain Co-Chair – Renee Prokopavicius, Western Sydney University, Australia	
16:00	**2.1 Constrained thermal tolerance and the future of ecosystem services** Joanne Bennett, Charles Sturt University, Australia
16:30	**2.2 The upper thermal limit of photosynthetic function in 26 *Eucalyptus* and *Corymbia* species depends more on leaf size than climate-of-origin** Kristine Crous, Western Sydney University, Australia
16:40	**2.3 Extending the thermal limits of life: thermal tolerance and life history of grasses from extremely hot geothermal areas** Aelys Humphreys, Stockholm University, Sweden
16:50	**2.4 Rethinking thermal vulnerability: from population trade-offs to community context** Cleber Chaves, State University of Campinas, Brazil
17:00	**2.5 Coping with extreme heat: drivers of variation in plant physiological tolerance** Andy Leigh, University of Technology, Sydney, Australia
17:30–18:15	**2.6 Flash talks** See the full list in the abstract book
18:15–19:30	Poster session – odd numbered posters
19:30–20:15	Drinks reception – in the courtyard (weather permitting)

Day 2	Wednesday 3 June
08:55	Morning announcements
Session 3: Adapting plant metabolism to heatwaves Chair – Carl Ng, University College Dublin, Ireland Co-Chair – Surbhi Mali, CSIR-Institute of Himalayan Bioresource Technology (IHBT), India	
09:00	**3.1 Priming for heat stress resilience: decoding underlying signalling mechanisms** Annapurna Allu, IISER Tirupati, India
09:30	**3.2 When heat breaks photosynthesis: enzymes, diffusion, and the hidden bottleneck** Demi Sargent, Hawkesbury Institute for the Environment, Western Sydney University, Australia
09:40	**3.3 Defining the limits and trade-offs of plant photosynthetic heat tolerance under extreme heat** Bradley Posch, Desert Botanical Garden, USA
09:50	**3.4 Exposure time, not temperature alone, determines the thermal limits of leaf respiration under heat stress across thermally contrasting biomes** Daniel Cowan-Turner, Australian National University, Australia
10:00	**3.5 Why and how? Quantitative determination of plant programmed cell death induced by extreme heat** Joanna Kacprzyk, University College Dublin, Ireland
10:30	Refreshment break - in the courtyard (weather permitting)
11:00–12:30	**3.6 Discussion session – data and collaboration** Chaired by Pieter Arnold, Australian National University, Nicole Bison, The University of British Columbia, Dan Noble, Australian National University, & Brad Posch, Desert Botanical Garden
12:30–13:30	Lunch – Rectory café (please provide waiting staff with your lunch ticket)
Session 4: Water to mitigate heat stress Chair – Charlotte Grossiord, EPFL & WSL, Switzerland Co-Char - Yan Moraes, University of Cambridge, United Kingdom	
13:45	**4.1 Heat stress or high VPD? Towards disentangling thermal effects and atmospheric drought effects on vegetation** Dani Way, Australian National University, Australia
14:15	**4.2 An interaction of stomatal signal transduction pathways confers heat-stress-induced stomatal opening** Nattiwong Pankasem, University of California San Diego, USA
14:25	**4.3 Hydraulic stress limits thermal acclimation in trees under chronic drought** Alyssa Kullberg, École polytechnique fédérale de Lausanne (EPFL), Switzerland
14:35	**4.4 Flower bud cooling: sepal specific enhancement of transpiration protects pollen development and improves fertility during heatwaves** Martijn Jansen, Radboud University, the Netherlands
14:45	**4.5 How did the plants learn to buffer hotter and drier conditions?** Celia Rodriguez-Domiguez, CSIC - IRNAS Seville, Spain
15:15	Refreshment break – Rectory café

Session 5: Modelling impacts of heatwaves Chair – Rich Norby, University of Tennessee, USA Co-Chair –Camille Sicangco, Hawkesbury Institute for the Environment, Western Sydney University, Australia	
15:45	**5.1 The kinetic basis of photosynthetic heat tolerance** Sean Michaletz, The University of British Columbia, Canada
16:15	**5.2 Dry air, hotter land: how vegetation responses amplify future warming** Julia Green, University of Arizona, USA
16:25	**5.3 Plant vulnerability to heat and drought stress in the hottest places on Earth: evidence from *Vachellia erioloba* in the Kalahari** Kerry-Anne Grey, University of Oxford, United Kingdom
16:35	**5.4 Paleo-ecosystem simulations of deep time heating episodes are a tool for studying trait-environment influences on plant survival and biogeography in a heating Earth** William Matthaeus, Trinity College Dublin, Ireland
16:45	**5.5 A stocktake: how well can we predict effects of extreme heat on plant photosynthesis, water use and growth?** Belinda Medlyn, Western Sydney University, Australia
17:15–18:15	**5.6 Breakout sessions** Smaller groups will meet to further address data and collaboration Feedback to be shared in the final session Chaired by Pieter Arnold, Australian National University, Nicole Bison, The University of British Columbia, Dan Noble, Australian National University, & Brad Posch, Desert Botanical Garden
18:15–19:30	Poster session – even numbered posters
19:30–20:15	Drinks reception – courtyard (weather permitting)

Day 3	Thursday 4 June
08:55	Morning announcements
Session 6: Plant-biotic interactions during heatwaves Chair – Mike Kearney, University of Melbourne, Australia Co-Chair – Inmaculada Criado-Navarro, Instituto de Agricultura Sostenible (IAS-CSIC), Spain	
09:00	**6.1 Thermal limits of plant reproduction: when pollen sets the boundary of life** Sergey Rosbakh, Leibniz University Hannover, Germany
09:30	**6.2 Soil microbial diversity decline amplifies heat stress impacts on plant metabolism and productivity** Uttam Kumar, Ben-Gurion University of the Negev, Israel
09:40	**6.3 Exploring and mitigating the effects of extreme heat on blueberry pollination and pollinators** Rufus Isaacs, Michigan State University, USA
09:50	**6.4 The effect of heat shock on arbuscular mycorrhizal fungus growth and nutrient transport** Victoria Terry, Vrije Universiteit Amsterdam, Netherlands
10:00	**6.5 Root-microbial decoupling under climate extremes** Madhav Thakur, University of Bern, Switzerland
10:30	Refreshment break – in the courtyard (weather permitting)

Session 7: Ecosystem responses to a future, hotter world Chair – Adrienne Nicotra, Australian National University, Australia Co-Chair – Milagros Rodriguez-Caton, IANIGLA-CONICET, Argentina	
11:00	**7.1 Temperature-driven changes to forest functioning** Adriane Esquivel-Muelbert, University of Cambridge, United Kingdom
11:30	**7.2 Water availability modulates the thermal sensitivity of tree growth responses to climate variability in the Amazon** Kathelyn Paredes Villanueva, Universidad Autónoma Gabriel René Moreno, Bolivia
11:40	**7.3 Atmospheric heat stress outweighs rainfall in regulating herbaceous biomass production in a Mediterranean shrubland** Marcelo Sternberg, Tel Aviv University, Israel
11:50	**7.4 Tropical forests are facing increasing risks of exposure to critical temperature thresholds** Mukund Rao, Lamont-Doherty Earth Observatory, Columbia University, USA
12:00	**7.5 Effects of extreme high temperature on carbon exchange in three typical ecosystems** Hua Lin, Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, China
12:30–12:40	**Group Photo – on the steps at the main entrance to the Rectory**
12:40–13:45	Lunch – Rectory café (please provide waiting staff with your lunch ticket)
Session 8: Designing food systems and landscapes for a hotter world Chair – Tracy Lawson, University of Illinois Urbana-Champaign, USA Co-Chair – John Mackenzie, Australian National University, Australia	
14:00	**8.1 Achieving sustainable crop productivity in a hotter world** Elizabete Carmo-Silva, Lancaster University, United Kingdom
14:30	**8.2 Evidence for adaptation to heat stress in cropping systems** Aidan Farrell, The University of the West Indies- St. Augustine Campus, Trinidad and Tobago
14:40	**8.3 Genome-wide association analyses show distinct genetic architecture for photosynthetic heat tolerance in wheat and barley** Hanna Amoanimaa-Dede, University of New England, Australia
14:50	**8.4 Extreme cooling enables extreme heat survival in plants** Joanna Feehan, Michigan State University, USA
15:00	**8.5 Designing urban landscapes to cope with a hotter world** Kevin Hultine, Desert Botanical Gardens, Phoenix, USA
15:30	Refreshment break – Rectory café
16:00 – 17:00	**8.6 Breakout sessions – Discussing solutions to the challenges of extreme heat** • Natural and urban ecosystems – Chaired by Adrienne Nicotra and Kevin Hultine • Agricultural systems – Chaired by Owen Atkin, Elizabete Carmo-Silva, Tracy Lawson and Dani Way
17:00	Close of sessions for Thursday
19:15 – 22:30	Symposium dinner Bodegas Campos (Calle Lineros 32. 14002 Córdoba) Arrive 19:15 for a drinks reception and appetisers followed by a three-course dinner and a Flamenco show.

Day 4	Friday 5 June
08:55	Morning announcements
Session 9: Remote sensing of heatwaves Chair – Belinda Medlyn, Western Sydney University, Australia Co-Chair – Antonio J. Pérez-Luque, Institute of Forest Sciences (ICIFOR) INIA-CSIC, Spain	
09:00	**9.1 Impacts of heat on plants as seen from space** Andrew Feldman, NASA / University of Maryland, USA
09:30	**9.2 Resilience and recovery from an extreme heatwave: impacts of the June 2021 heat dome on trees and forests of the US Pacific Northwest** Christopher Still, Oregon State University, USA
09:40	**9.3 Canopy temperature drivers across ecosystems and remote sensing measurement challenges** Jen Diehl, NASA Goddard Space Flight Center, USA
09:50	**9.4 Unravelling drivers of heat and drought stress across genotypes and seasons using optical-thermal-spectral and fluorescence indicators in sorghum** Spoorthi Nagaraju, The University of Queensland, Australia
10:00	**9.5 Remote sensing of stress impacts on plant metabolism** Rocio Hernandez Clemente, University of Córdoba, Spain
10:30	Refreshment break – in the courtyard (weather permitting) **All poster votes to be submitted by at the end of the break**
Session 10: Closing Plenary Chair – Sasha Reed, US Geological Survey, USA Co-Chair - Kali Middleby, French National Institute for Research and Development, France	
11:00	**10.1 Plant life in a hotter planet: can they manage alone?** Fernando Valladares, CSIC, Madrid
11:30	**10.2 Closing panel discussion** This closing panel discussion will integrate insights from across the symposium to reflect on what extreme heat means for the future of plant life Sasha Reed (Facilitator): • Fernando Valladares • Elizabete Carmo Silva • Sergey Rosbakh • Belinda Medlyn
12:30	Closing and prizes **The Organising Committee and Maarja Öpik, *New Phytologist* Editor-in-Chief**
12:45 – 14:00	Lunch – Rectory café (please provide waiting staff with your lunch ticket)
Approx. 15:00	Visit to the Mosque of Cordoba, a World Heritage Site Limited to delegates who have signed up. Details sent to those who signed up.

Publishing your work with the New Phytologist Foundation

If you have questions about publishing your work in the New Phytologist Foundation journals *New Phytologist* and *Plants, People, Planet*, we encourage you to take the opportunity at the symposium to talk to the Managing Editor of *New Phytologist*, Helen Pinfield-Wells, and journal Editors in attendance (Owen Atkin, Charlotte Grossiord, Tracy Lawson, Belinda Medlyn, Carl Ng, Richard Norby, Maarja Öpik, Sasha Reed and Nathalie Verbruggen). We have put together **a showcase of recently published *New Phytologist* and *Plants, People, Planet* papers on the theme of extreme heat** that will be of interest to delegates.

Speaker Abstracts

1.1

Extreme heat across the soil, plant, animal, atmosphere continuum
Michael Kearney
University of Melbourne, Australia

The biotic impact of a heatwave is highly contextual; it depends on the magnitude and duration of the event, the exposure and sensitivity of the organisms of interest, and the biophysical state of the landscape. Vegetation has a strong and complex influence on all these contextual factors, with feedbacks mediated by transpiration and leaf temperature. Our ability to predict heatwave impacts on any particular organism therefore hinges on our general understanding of plant environmental responses. In this talk I will give an overview of modelling approaches my group has been developing to capture these interactions across the soil, plant, animal, atmosphere continuum, including the development of a biophysical modelling ecosystem in the Julia programming environment. I will include empirical examples drawing from heat waves in southern Australia, including the recent January 2026 event.

1.2
The heat is on: plant and soil relationships with temperature in Earth's hottest terrestrial landscapes
Sasha Reed ORCID iD
U.S. Geological Survey, USA

Temperature represents a fundamental control over organismal physiology, community composition, evolution, and ecosystem function for terrestrial systems worldwide. The role of temperature in hot environments, such as those often found in deserts, and in consistently warm environments, such as tropical rain forests, lends unique insight into the thermal limits of life. The hottest terrestrial environments provide a natural laboratory for identifying mechanisms that determine the bounds of organismal performance and ecosystem function under extreme heat, and inform forecasts of how ecosystems will respond to increasingly hot temperatures. In addition to the multifaceted (and spectacular) adaptations of biota experiencing extreme heat, organisms and ecosystems in hot environments often show strong, threshold-type responses to seemingly modest further warming. There are also critical interactions between high temperatures and resources such as water and nutrients, which help determine the likelihood and consequences of temperature-induced ecosystem state change. Understanding how vegetation and soils respond to, and, in turn, regulate temperature at Earth's surface is essential for anticipating and managing terrestrial ecosystems into the future. This talk will synthesize observational, experimental, and modeling data to explore how plant and soil thermal limits in hot environments regulate terrestrial function and create feedbacks that influence our planet's climate.

1.3 **Opening panel discussion**

This panel discussion will establish the conceptual foundation for the New Phytologist Symposium Extreme Heat: extending the thermal limits of life by exploring how extreme heat is understood in plant science. It will integrate perspectives from microclimate modelling, empirical observations from extremely hot environments, organismal responses to spatial variability in heat exposure, and long term, place-based experience of extreme heat. The goal will be to provide a framework for later sessions that examine physiological tolerance, acclimation, adaptation, and ecosystem responses.
The discussion will also explicitly link the science to the location of the meeting, recognising Córdoba and Mediterranean systems as contemporary examples of landscapes already living with recurrent extreme heat.

Panellists:
Owen Atkin (Facilitator): linking discussion to the broader narrative of the symposium.

- **Mike Kearney**: microclimate and surface temperature modelling perspective.
- **Sasha Reed**: empirical insights from the hottest terrestrial environments.
- **Adrienne Nicotra**: connect variability in heat exposure to biological consequences.
- **Rocio Hernandez-Clemente**: place-based perspective on recurrent extreme heat.

The audience are encouraged to join in the discussion on Slido

2.1
Constrained thermal tolerance and the future of ecosystem services
Joanne Bennett ORCID iD
Gulbali Institute, Charles Sturt University, Australia

Understanding how plants and ectothermic organisms tolerate extreme heat is central to predicting climate-change impacts on ecosystems. Biological responses are shaped not only by rising mean temperatures but also by increasingly intense heatwaves, which together impose acute and cumulative thermal stress. In this talk, I synthesise evidence from comparative physiology, evolutionary analyses, and long-term ecological data to show that strong evolutionary constraints on upper thermal tolerance limit adaptive responses to extreme heat, with cascading consequences for ecosystem functioning.
Global syntheses of thermal traits across plants and ectotherms demonstrate that upper thermal limits are bounded by strong evolutionary constraints and evolve far more slowly than lower limits. This limited evolutionary flexibility under rapid warming is particularly concerning during heatwaves. Historical collections and resampling studies reveal declines in cold-adapted ectotherms, accompanied by shifts in plant–pollinator interactions and reductions in pollination services. These patterns emerge in landscapes largely free from land-use change, highlighting climate warming as a primary driver of ecological reorganisation.
Together, these findings indicate that constrained heat tolerance in plants and ectotherms is already reshaping species interactions and ecosystem function. As climate extremes intensify, progress in conservation and management will depend on embedding ecologically meaningful thermal limits and spatial thermal heterogeneity across landscapes into predictive frameworks.

2.2

The upper thermal limit of photosynthetic function in *26 Eucalyptus* and *Corymbia* species depends more on leaf size than climate-of-origin

Kristine Crous ORCID iD[1], Josef Garen ORCID iD[1], Pieter Arnold ORCID iD[2], Danzey Lisa ORCID iD[3], Camille Sicangco[1], Catherine Pottinger ORCID iD[3], Erin Rogers[1], Adrienne Nicotra ORCID iD[2], Andrea Leight ORCID iD[3]

[1]Western Sydney University, Australia. [2]Australian National University, Australia. [3]University of Technology Sydney, Australia

Heatwaves have become more intense and widespread across the globe with many locations now hitting 50°C. Such close-to-lethal temperatures are a growing risk to forest health, resulting in increased tree mortality, but the upper thermal tolerance limits of many trees are currently unknown. Both temperature intensity and exposure duration contribute to a given "heat dose" resulting in heat damage accumulation at which point photosynthesis stops functioning. Here we investigated photosystem impairment in 22 *Eucalyptus* and *Corymbia* species from different climates across Australia. Using 30 duration-temperature combinations, heat stress responses were measured using chlorophyll fluorescence (F_V/F_M), which declines as heat stress accumulates. None of the leaves remained functional beyond 5 minutes at 56°C, indicating a clear upper thermal limit for the *Eucalyptus* and *Corymbia* species. About half of the species coped with 30 minutes at 44°C. There was a clear relationship between heat tolerance and leaf size, but not with leaf thickness, whereas heat dose relationships did not differ with climate-of-origin. Understanding heat dose thresholds is key for predicting the likelihood of plant mortality due to increasing heat stress in a future hotter world.

2.3

Extending the thermal limits of life: thermal tolerance and life history of grasses from extremely hot geothermal areas

Aelys Humphreys ORCID iD, Johan Ehrlén, Jan-Niklas Nuppenau

Stockholm University, Sweden

Geothermal areas are formed where Earth's inner heat is transported to the surface, resulting in peculiar formations including fumaroles, geysers and hot streams and soils. These places are high stress, low diversity environments, with the main factor limiting the presence of most life there being heat. In addition, most geothermal areas are found at high elevations or latitudes, meaning that the surrounding non-thermal areas can get bitterly cold, and creating sharp thermal gradients from scorching to freezing over short geographic distances. Thus, geothermal areas constitute natural laboratories for studying adaptation to thermal extremes. Here, we present grasses (Poaceae) occurring at extremely hot (<70˚C) sites across several geothermal areas. Specifically, we present ongoing research on life history shifts in response to geothermal heat and the consequence of adapting to extreme heat on performance under cooler conditions. Preliminary results point to different adaptive strategies for different species in different geothermal areas, suggesting that there are multiple routes to extending the thermal limits of life, even among closely related species. Our research also challenges the idea of shared upper thermal limits across the eukaryote Tree of Life.

2.4

Rethinking thermal vulnerability: from population trade-offs to community context

Cleber Chaves ORCID iD[1], Kenneth Feeley ORCID iD[2], Clarisse Palma-Silva ORCID iD[1]
[1]State University of Campinas, Brazil. [2]University of Miami, USA

Why do some plant populations thrive under heat while others collapse, even under similar climates? And why do some communities show large differences in thermal strategies among co-occurring species?
In this talk, I synthesize insights from recent works across tropical montane systems to argue that thermal vulnerability is not simply a function of exposure to temperature, but an emergent property shaped by evolutionary history, dispersal constraints, and the biotic environment in which populations and species are embedded. At the population level, coordinated trait syndromes reveal consistent trade-offs between tolerance and avoidance. Yet when scaling up to whole communities, elevation alone fails to explain patterns of divergence. Instead, community diversity and phylogenetic structure appear to play a central role in determining where and how thermal strategies diversify.
This perspective challenges the common assumption that climate is the dominant axis structuring thermal niches, and suggests that predictions of climate sensitivity may be incomplete if they ignore who co-occurs with whom, and under which evolutionary constraints. By bridging physiology, evolution, and community ecology, this talk proposes a broader framework for understanding how tropical plant assemblages may respond to increasing thermal extremes.

2.5

Coping with extreme heat: drivers of variation in plant physiological tolerance

Andy Leigh ORCID iD
University of Technology Sydney, Australia

Understanding the vulnerability of plant species and communities to heat extremes is an urgent priority for plant ecologists and land managers alike. Key morphological plant traits associated with thermal protection vary across environments, often underpinned by phylogeny. We therefore might expect that physiological traits, such as critical temperatures for photosynthetic function, would likewise vary across contrasting biomes and/or taxonomic groups. A global focus on plant thermal tolerance research over recent years suggests that the story is more complex. While biome of origin can explain a certain amount of variation in physiological heat tolerance, more often such patterns are weak or absent, especially under common garden settings. Likewise, higher level phylogeny – genus, family – rarely strengthens predictive models, whereas species routinely explains a major proportion of variation in heat tolerance. Adding to these challenges is the wide variation in response within species. For example, timing of measurement can be a strong influence, both at micro (time of day, pre/post treatment) and macro (date, season) scales, generally associated with environmental acclimation. To fill key knowledge gaps, research efforts must focus on the cost of acclimation, how this changes with increased temperatures, how such costs in turn affect recovery and ultimately, reproductive fitness.

2.6 Flash talks

The following poster presenters will give a 3 minute flash talk, See their full abstracts in the poster section

2-Pieter Arnold: Resilience and sensitivity of photosynthetic tissue to increasing heat load

4-Nicole Bison: Protein stability-function tradeoffs predict shape of thermal performance curves

10-Martina Chacón: Beyond thermal and hydric limits: xylem formation during prolonged stem shrinkage in a South American dryland tree

14-Virginia Crisafull: Microclimatic refugia: canopy plants as thermal buffers

15-Margaux Didion-Gency: Keeping it cool: how leaf morphology modulates thermal safety

16-Mateus Fabbris: Estimating V_{cmax} temperature dependence: a novel approach

22-Brandon Hastings: Honami dynamics and crop photosynthesis in a warming, turbulent atmosphere

25-Akhil Javad: Ineffective transpirational cooling threatens dry tropical forest leaves

30-Pia Labenski: Predicting forest responses to compound heat-drought extremes using a process-based modelling framework

35-Qiannan Leng: Contrasting heat tolerance strategies and productivity of evergreen and deciduous angiosperm forests

40-Na Luo: Understanding leaf thermal tolerance from a carbon allocation perspective

44-María Isabel Márquez-Pérez: Resilience of woody fungal pathogens under water stress and ecophysiological responses of olive trees

48-Joy Ojo: Leaf hyperspectral reflectance predicts grain yield in heat-tolerant wheat

53-Hegarty Philip: Heat-driven evaporative demand intensifies transpiration sensitivity to soil drying in European beech

70-Eduardo Zelada: Evaluating UV-B seed priming effects on vegetative tomato heat tolerance

3.1
Priming for heat stress resilience: decoding underlying signalling mechanisms
Annapurna Allu
IISER Tirupati, India

Climate change is intensifying at an unprecedented pace, subjecting plants to increasingly frequent and intense episodes of heat stress. This poses a significant threat to global agriculture and food security. Acquired thermotolerance, where prior exposure to a non-lethal heat stress (priming) enhances plant survival during subsequent severe stress, offers a promising adaptive strategy. Recent research has revealed that acquired thermotolerance is orchestrated by a multilayered regulatory network encompassing transcriptional, epigenetic, post-transcriptional, and metabolic pathways. Yet, the processes by which priming signals are perceived, processed, and integrated into these networks remain largely unresolved. In our study, we explore how priming cues reshape transcriptional regulatory networks, enabling plants to reprogram gene expression and mount an effective stress response. Uncovering these regulatory mechanisms is key to both advancing fundamental plant biology and enabling the development of climate-resilient crops for sustainable agriculture.

3.2
When heat breaks photosynthesis: enzymes, diffusion, and the hidden bottleneck
Demi Sargent ORCID iD[1,2], Warren Conaty ORCID iD[2], Robert Sharwood ORCID iD[1]
[1]Hawkesbury Institute for the Environment, Western Sydney University, Australia. [2]CSIRO, Australia

Extreme heat is a major constraint on plant carbon assimilation, yet the processes that ultimately define the upper limits of photosynthesis remain incompletely resolved. Using the exceptional evolutionary diversity of the *Gossypium* genus, I investigate how photosynthetic performance is maintained under high temperature and compound heat and drought stress.
Across multiple comparative experiments, including controlled temperature responses and simulated heatwave events (42°C for five days), substantial interspecific variation exists in the ability to sustain CO_2 assimilation under extreme heat. While species from hotter climates often possess Rubisco with superior high-temperature kinetics and more thermotolerant Rubisco activase, these biochemical advantages alone do not fully explain whole-leaf photosynthetic performance. Instead, recent evidence from temperature and drought experiments reveal that mesophyll conductance (g_m) becomes a critical, temperature-sensitive bottleneck, constraining CO_2 delivery to Rubisco under extreme conditions.
By integrating gas-exchange physiology, enzyme kinetics, and emerging insights into internal CO_2 diffusion, this work demonstrates that extending the thermal limits of photosynthesis requires coordinated optimisation of both biochemical capacity and CO_2 supply. These findings reposition mesophyll conductance as a key, yet underappreciated determinant of photosynthetic resilience to extreme heat, with implications for predicting plant responses to climate extremes and identifying new targets for crop improvement.

3.3
Defining the limits and trade-offs of plant photosynthetic heat tolerance under extreme heat

Bradley Posch ORCID iD[1,2], Madeline Moran ORCID iD[1], Dan Koepke[1], Alexandra Schuessler[1], Luiza Aparecido ORCID iD[3], Benjamin Blonder ORCID iD[2], Kevin Hultine ORCID iD[1]
[1]Desert Botanical Garden, USA. [2]University of California, Berkeley, USA. [3]Unversity of Utah, USA

Rising atmospheric temperatures are triggering heatwaves at higher frequencies, duration and intensity across the globe, However, our understanding of 'how hot is too hot?' for plant function and survival remains limited, largely because of the difficulty of gathering *in situ* empirical data at temperatures that represent the heatwaves of the near future. Located in Phoenix, USA, the Desert Botanical Garden offers a unique opportunity to investigate plant responses to extreme heat by leveraging summer maximum air temperatures that regularly exceed 45°C. Here, I will present an overview of ongoing research examining plant photosynthetic heat tolerance, highlighting new insights into the physiological dynamics of plant responses under extreme heat. These include the species-specific capacity to employ evaporative cooling to maintain leaf temperatures below the damage thresholds of Photosystem II despite an increased risk of hydraulic failure, as well as evidence of trade-offs between the heat mitigation strategies of transpirational leaf cooling versus Photosystem II heat acclimation that emerge when plants are exposed to air temperatures exceeding 50°C. These results demonstrate the critical need for continued experimental work conducted at air temperatures that reflect the likely maximum summer temperatures of coming decades.

3.4
Exposure time, not temperature alone, determines the thermal limits of leaf respiration under heat stress across thermally contrasting biomes

Daniel Cowan-Turner ORCID iD[1], Xuan Hu[1], Peter B Reich[2], Mark Stitt[3], Kevin L Griffin[4], Matthew H Turnbull[5], Mirindi E Dusenge[1], Danielle A Way[1], Andrew P Scafaro[1], Owen K Atkin[1]
[1]Australian National University, Australia. [2]University of Minnesota, USA. [3]Max-Planck-Institut für Molekulare Pflanzenphysiologie, Germany. [4]Columbia University, USA. [5]University of Canterbury, New Zealand

Respiration is a fundamental process that constrains the thermal limits of plant life. Short-term measurements show leaf dark respiration (R) increases near-exponentially with temperature (T) until reaching extreme heat, often >50°C. However, short-term R–T curves do not capture responses over ecologically relevant timescales. Here, we quantified respiratory response to temperature (19-45°C) over one to 11 hours in 50 tree and shrub species growing in thermally contrasting biomes in Australia and USA including: hot-arid desert, tropical rainforest, temperate woodland, temperate wet-forest, boreal forest, arctic. Respiration remained stable at 19 and 25˚C over the measurement period but generally declined at 35˚C and especially 45˚C which are below lethal thresholds inferred from shorter-term R-T curves. With increasing exposure to 45˚C, R progressively fell below values predicted by standard temperature-response models. The magnitude of this decline was generally larger for species from cooler biomes than warmer regions. Heat sensitivity through time also differed among plant functional types and species with differing leaf mass-leaf area ratios. These results demonstrate that exposure time plays an important role in determining the thermal limits of leaf respiration and reveal inherent species differences in how long respiratory metabolism can be maintained over durations.

3.5

Why and how? Quantitative determination of plant programmed cell death induced by extreme heat.

Joanna Kacprzyk ORCID iD, Paul F. McCabe ORCID iD, Carl Ng ORCID iD
University College Dublin, Ireland

As global temperatures surge beyond historical norms, plants increasingly face episodes exceeding 45°C, conditions that can trigger catastrophic cellular damage, tissue death, and ecosystem collapse. While research has defined the thermal limits of many plant species, the molecular and cellular determinants of survival versus death under extreme heat are not fully understood. Using tractable model systems, such as root hair assays and cell suspension cultures, we can quantify programmed cell death (PCD) in individual cells with high precision and dissect the transition from protective acclimation response to irreversible damage. These methods, informed by realistic heat application regimes and combined stress experiments, can open the door to integrative studies linking molecular signalling with whole-plant thermotolerance. In addition, we put forward the idea of adapting the concept of thermal performance curves to cellular systems as a novel, quantitative route to better connect cell-level stress physiology with organismal and ecological outcomes. Understanding how plant cells regulate their survival under extreme heat will not only inform strategies for enhancing crop resilience but also contribute to broader discussions on biological boundaries to life in a warming world.

3.6

Data & Collaboration discussion session

Chaired by Pieter Arnold, Australian National University, Nicole Bison, The University of British Columbia, Dan Noble, Australian National University, & Brad Posch, Desert Botanical Garden

We aim to take advantage of the collection of heat-related global expertise at the symposium to:

- Identify opportunities to synthesise existing datasets
- Explore coordinated approaches to data collection, including distributed experiments
- Develop new collaborative initiatives and outputs

Ultimately, we aim to initiate a coordinated, global effort to quantify plant responses to extreme heat. By equipping a global collaborative network with reproducible and affordable methods we would create that capacity to capture the impacts of extreme heat on plants around the world.

To ensure the session is as productive as possible, we are asking participants to complete a short survey in advance: https://lancasteruni.eu.qualtrics.com/jfe/form/SV_578jpFgLjEwO3J4

The survey focuses on:

- The systems and traits you work on
- Data you currently collect or hold
- Key scientific questions you think the community should address
- Gaps in current datasets
- Your interest in contributing to collaborative efforts

The results will be summarised at the start of the session and used to shape the discussion. Our aim is that the session leads to concrete outcomes, which may include potential synthesis papers, community resource articles, shared datasets, and coordinated experimental approaches.

4.1

Heat stress or high VPD? Towards disentangling thermal effects and atmospheric drought effects on vegetation

Danielle Way
Australian National University, Australia

While we often attribute plant responses to heat events and warming to temperature stress, these thermal stresses usually coincide with periods of high vapour pressure deficit (VPD). The co-occurrence of these two stresses makes it difficult to ascertain the relative roles of temperature and high VPD on vegetation, which could lead to misinterpretation of what is driving negative responses of vegetation to heat. Here, I will draw on results from meta-analyses of warming studies and of elevated VPD experiments, as well as ecosystem responses to climate, to discuss the need to account for VPD effects when considering how high temperatures affect plants and ecosystems.

4.2

An interaction of stomatal signal transduction pathways confers heat-stress-induced stomatal opening

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High temperatures affect stomatal opening and plant water-use efficiency. Our recent study proposed two distinct mechanisms, depending on heat stress levels: stomatal opening in response to warming is mediated by elevated CO_2 assimilation and low leaf internal CO_2 sensing via the HT1-MPK4/12 CO_2 sensor module. Another mechanism at higher temperatures causes plants to lose water without photosynthetic gain, potentially promoting evaporative cooling. We further genetically dissected these heat-induced photosynthesis-uncoupled mechanisms and found that heat-stress-induced stomatal opening is disrupted in mutant alleles that impair a guard cell-expressed transmembrane receptor-like kinase, which functions in ion channel regulation. Stomatal heat responses in *nced3/nced5* double-mutant leaves, which disrupt rate-limiting ABA biosynthetic genes, are unaffected. Interestingly, the *ht1* mutant alleles, which lack the major CO_2-sensing component and have been shown to disrupt the stomatal warming response, show no strong stomatal heat-stress phenotype. Furthermore, heat-induced stomatal opening is disrupted in leaves of new high-order guard cell sensor mutants. The presented research will show that a combination of guard cell receptors contributes to heat-stress-induced stomatal opening. These findings open a new understanding of the molecular mechanisms underlying heat-stress-induced stomatal opening.

4.3

Hydraulic stress limits thermal acclimation in trees under chronic drought

Alyssa Kullberg ORCID iD[1,2], Arianna Milano[1,2], Yike Ma[1], Patrick Favre[1,2], Kate Johnson[3], Jin Wu[4,5], Zhengfei Guo[4], Jonas Gisler[2], Marcus Schaub[2], Charlotte Grossiord[1,2]
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The capacity of trees to withstand intensifying hot-drought events depends on coordination between hydraulic safety and leaf thermoregulation, yet the limits of this coordination under chronic stress remain poorly understood. Here, we show that five years of chronic soil moisture limitation fundamentally constrains leaf thermoregulation. We studied two temperate tree species with contrasting water-use strategies, European beech (*Fagus sylvatica*) and downy oak (*Quercus pubescens*), subjected to a five-year manipulation of soil moisture and air temperature. We quantified acclimation responses in leaf temperature regulation, hydraulic safety margins (HSMs), thermal safety margins (TSMs), and leaf scorching. Under sustained warming with ample soil water, both species acclimated to maintain stable leaf temperatures and positive TSMs, indicating that thermal acclimation is possible without hydraulic stress. In contrast, chronic drought narrowed HSMs and weakened evaporative cooling, reducing thermoregulation capacity. When heat and drought co-occurred, stomatal closure triggered a hydraulic–thermal feedback, leading to loss of cooling, exceedance of thermal thresholds, PSII failure, and leaf scorching in drought-vulnerable beech. These results show that trees can acclimate to warming alone, but not to combined heat and drought, which drive cascading failures that limit forest resilience to future hot-droughts.

4.4

Flower bud cooling: sepal specific enhancement of transpiration protects pollen development and improves fertility during heatwaves

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Early pollen development is a bottleneck for plant fertility in heatwave conditions and has been shown to be sensitive to the microclimate surrounding the inflorescence. Mechanisms that protect this process and explain variation in tolerance levels between genotypes are poorly understood.
Here, we use direct measurement and manipulation of the flower bud core temperature, transpiration and pollen viability to describe flower bud cooling, a novel mechanism for heat adaptation. Sepal transpiration in young, still closed, flower buds reduces the temperature inside the flower bud and thereby the impact of heat on developing tomato pollen. This process depends on heat-induced opening of sepal stomata.
The major pollen thermotolerance QTL, qPV11, is shown to specifically enhance sepal transpiration, as opposed to leaf transpiration, and thereby protect pollen development. Manipulation of stomatal regulation in near-isogenic lines for qPV11 shows that the effect of qPV11 depends on functional stomatal regulation. Large-scale evaluation in both a production field and greenhouse showed that qPV11 improves pollen viability and fruit set in heatwave-affected complex cultivation environments.
These findings highlight enhanced flower bud cooling as a naturally evolved adaptation against heatwaves and qPV11 as genetic component in the differential regulation of transpiration between reproductive and vegetative tissues.

4.5

How did the plants learn to buffer hotter and drier conditions?

Celia M. Rodriguez-Dominguez ORCID iD
Instituto de Recursos Naturales y Agrobiologia de Sevilla (IRNAS-CSIC), Spain

As plants first colonized terrestrial environments, they faced hotter and drier conditions in the absence of the aquatic buffering medium, requiring profound adjustments both above- and belowground. Because heat and dryness are increasingly co-occurring, disentangling their impacts on plant performance is urgent but challenging. Yet immobile plants have evolved refined signalling networks to integrate multiple stresses. By considering their combined effects, we can outline the strategies that have enabled plants—and especially angiosperms—to cope with increasing atmospheric demand and declining water availability.
In temperate environments—where species lack morphological adaptations to extreme heat and aridity—rising temperatures and reduced water availability impose growing constraints. On acclimation timescales, plants deploy physiological and biochemical responses that vary with stress intensity and duration. Under well-watered conditions, high temperatures elevate vapour pressure deficit, enhancing transpiration-driven leaf cooling as long as hydraulic supply matches demand. Once this balance fails, angiosperms rely on precise signalling pathways, including ABA-mediated stomatal closure and derived stimulation of root growth. Under drought conditions, increased soil–root resistance limits transpiration, forcing plants to depend on internal water stores (hydraulic capacitance) that may enhance the ability to buffer the combined effects of heat and drought stress-induced injuries. Understanding these mechanisms is essential as warming and drying trends reshape temperate vegetation and future landscapes.

5.1

The kinetic basis of photosynthetic heat tolerance

Sean Michaletz ORCID iD, Nicole Bison ORCID iD
The University of British Columbia, Canada

Photosynthesis fuels the biosphere and is a key regulator of Earth's climate. As Earth warms, heat stress threatens to irreversibly impair the molecular machinery of photosynthesis, potentially pushing ecosystem productivity and carbon sequestration beyond a tipping point. Current approaches to quantifying photosynthetic heat tolerance often focus solely on temperature, overlooking exposure time, or rely on temperature-time correlations that do not identify causal mechanisms, limiting inference and prediction. Here we develop a mechanistic theory for heat inactivation of photosynthesis based on principles of chemical kinetics, and test it using data for photosystem II (PSII), the first step in the photosynthetic apparatus. Our framework links the effects of both temperature and exposure time, and enables direct tests of competing hypotheses for how heat impairs photosynthesis. Data from diverse plant species suggest that protein (not lipid membrane) denaturation is the primary mechanism of heat-induced inactivation of PSII. The theory also predicts a general upper temperature limit of 55-60°C for acclimation of photosynthetic heat tolerance, a prediction supported by global PSII data. This quantitative, mechanistic framework can be incorporated into global change models to improve forecasts of how vegetation and the biosphere will respond to future climate change.

5.2

Dry air, hotter land: how vegetation responses amplify future warming

Julia Green[1], Trevor Keenan[2], Philippe Ciais[3], Xu Lian[4], David Moore[1]
[1]*University of Arizona, USA.* [2]*University of California, Berkeley, USA.* [3]*LSCE, France.* [4]*Peking University, China*

Temperature regulates vegetation dynamics through both thermal and hydrologic pathways. While climate change driven warming is typically assessed using air temperature (Tair), vegetation directly experiences land surface temperature (LST), which remains comparatively understudied. Key gaps persist in understanding how LST is changing and whether vegetation responses to LST amplify future warming.
Here, we integrate model simulations and observations using a dual emergent constraint to quantify projected differences between LST and Tair (ΔT) by 2100. We show that LST increases are expected to outpace Tair across most global regions, implying more extreme thermal stress on vegetation than previously recognized. The largest projected increases in ΔT occur where increasing atmospheric dryness increasingly constrains vegetation function. This suggests that future warming will impose stronger limitations on plant function than currently estimated, while reduced transpiration is likely to further elevate LST. Consequently, reliance on Tair alone leads to systematic underestimation of temperature impacts on vegetation dynamics and the land carbon sink. Accurate representation of LST in Earth system models is therefore essential for improving projections of ecosystem responses and climate feedbacks.

5.3

Plant vulnerability to heat and drought stress in the hottest places on Earth: evidence from *Vachellia erioloba* in the Kalahari

Kerry-Anne Grey ORCID iD[1], Carla Staver[2], Yadvinder Malhi[1], Nicola Stevens[1], Shannon Conradie[3]
[1]*University of Oxford, United Kingdom.* [2]*Princeton University, USA.* [3]*University of the Witwatersrand, South Africa*

Drylands are under increasing pressure globally from climate change, yet the impact of climate extremes on trees in these regions remains poorly understood. This study uses fully field-based experiments, diurnal gas-exchange observations and heat exposure modelling to quantify how extreme heat and water stress affect the dominant tree of the Kalahari, *Vachellia erioloba*. Drought reduced the survival of seedlings, although growth was unaffected. Heat stress had no effect on seedling survival or growth, but it strongly altered leaf physiology, suppressing photosynthesis and enhancing respiration, decreasing overall carbon gain. *Vachellia erioloba* is predicted by our model to maintain positive net photosynthesis even up to 50°C and during a naturally occurring heat anomaly adult trees still maintained low levels of photosynthetic activity but avoided gas exchange during the hot hours of the day. Range-wide exposure modelling indicated that since the start of the century exposure to heat inducing a 50% reduction in net CO_2 assimilation has doubled in parts of its range and may triple in areas by mid-century. Together, increased drought-induce seedling mortality, reduced carbon uptake and increased exposure to significant heat stress suggests that *V. erioloba* is vulnerable to acute heat and drought stress events, despite being adapted to hot, arid environments.

5.4

Paleo-ecosystem simulations of deep time heating episodes are a tool for studying trait-environment influences on plant survival and biogeography in a heating Earth

William Matthaeus ORCID iD[1], Dan Lunt[2], Joseph White[3], Daniel Peppe[3], Jonathan Wilson[4], Jennifer McElwain[1]
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The Triassic-Jurassic (T-J) boundary saw global ecological upheaval driven by volcanism, with extremely elevated atmospheric CO_2 (>2000 ppm) and temperatures (GMST >24°C), including extensive turnover in dominant plant taxa and biogeographic limitations. Mechanistic models (i.e., *paleo*-BGC) parameterized using paleo-traits (functional traits measured in fossils) can be used to test the impact of traits on ecosystem processes, including plant survival. We present a sensitivity analysis on paleo-traits relevant to plant water use, measured from two T-J dominants: maximum stomatal conductance (gmax) and xylem vulnerability to cavitation-induced embolism (ΨC). Using Paleo-BGC, traits are tested in the climate space of the T-J, distilled from global climate model simulations (HadCM-3B). We test whether water-use trait coordination (1) limits forest cover and (2) results in the same pattern of community turnover observed at two well-studied T-J sites. We compare the maximum temperatures of T-J forest climate spaces at several CO_2 levels with the thermal tolerance of forest trees from neo-botany and calculate leaf temperatures implied by *Paleo*-BGC. Process-based simulations parameterized show where, how, and why plants survived or went extinct during deep-time heating episodes, and allow hypothesis testing against the fossil record—enabling better vegetation projections under different anthropogenic CO_2 emissions scenarios.

5.5

A stocktake: how well can we predict effects of extreme heat on plant photosynthesis, water use and growth?

Belinda Medlyn
Western Sydney University, Australia

This talk will review the current state-of-the-art in modelling effects of extreme heat on plant performance. I will first review our increasing understanding of the short-term effects of high temperatures on plant photosynthesis, stomatal behaviour and leaf damage, and how these effects are being incorporated into models of leaf physiology. I will then examine the implications of these short-term responses for plant growth over the longer term, using the dynamic vegetation model LPJ-GUESS to illustrate the sensitivities of plant growth. The talk will finish with a research agenda to improve model capacity to predict the effects of future extreme heatwaves.

5.6

Breakout groups from the Data & Collaboration discussion session

Chaired by Pieter Arnold, Australian National University, Nicole Bison, The University of British Columbia, Dan Noble, Australian National University, & Brad Posch, Desert Botanical Garden

Locations of discussion breakouts will be confirmed at the end of session 5.5, and shared on the WhatsApp group.

6.1

Thermal limits of plant reproduction: when pollen sets the boundary of life

Sergey Rosbakh
Leibnitz University Hannover, Germany

Climate warming is pushing biological systems towards their thermal limits, yet most assessments of plant heat tolerance focus on vegetative tissues. Reproduction, particularly the male gametophyte, may represent a more vulnerable and ultimately limiting stage. Here, I synthesise comparative and experimental evidence demonstrating that pollen thermal sensitivity constrains plant performance across ecological and evolutionary scales.

First, a global synthesis across 191 species shows that pollen temperature limits (Tmin, Topt, Tmax) vary widely but are consistently lower than those of vegetative tissues. Pollen heat tolerance is only weakly associated with leaf tolerance and exhibits phylogenetic conservatism and climatic structuring, indicating evolutionary constraint. Second, experimental chronic heat stress in wild species reveals strong reductions in male gametophyte performance and seed production, even when seed mass and germination capacity are largely maintained. Third, a newly compiled database covering 274 species highlights large interspecific variation in pollen longevity, suggesting that functional lifespan further narrows the effective fertilisation window under hot and desiccating conditions.

Together, these findings indicate that species persistence under extreme heat may be constrained less by vegetative survival than by the thermal vulnerability and temporal limitation of pollen function. Incorporating reproductive thermal limits is therefore essential for predicting plant responses to climate change.

6.2

Soil microbial diversity decline amplifies heat stress impacts on plant metabolism and productivity

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Soil microbial biodiversity is crucial for ecosystem stability, functionality, and sustainable food production. However, the combined effects of heatwaves and microbial diversity loss on plant productivity remain poorly understood. Since plant seeds harbour distinct endophytes that contribute to plant development and stress tolerance, we hypothesized that declining soil microbial diversity would reduce plant productivity and intensify heat-stress responses, while the functional composition of seed endophytes would remain relatively stable. We established a soil microbial diversity gradient by mixing agricultural and gamma-irradiated soils, and grew *Setaria viridis* through a full life cycle. Plant physiological and stress-related traits, together with rhizosphere microbial community structure and functional responses, were assessed under combined microbial diversity loss and heatwave stresses. A decline in soil microbial diversity was associated with significant reductions in plant height, biomass, root growth, and yield. Physiological stress indicators, such as malondialdehyde, proline, and anthocyanins, increased markedly, indicating that reduced soil microbial diversity acts as an environmental stressor. Heatwave exposure further changed leaf metabolomic and proteomic composition, including a strong upregulation of small heat shock proteins. Despite these changes, functional composition of seed endophytes remained similar to parental seeds, suggesting an inherent buffering capacity that may support reproductive success under environmental perturbations.

6.3

Exploring and mitigating the effects of extreme heat on blueberry pollination and pollinators

Rufus Isaacs ORCID iD[1], Jenna Walters ORCID iD[2], James Santiago ORCID iD[3], Thomas D Sharkey ORCID iD[1]
[1]*Michigan State University, USA.* [2]*University of Maine, USA.* [3]*University of Illinois, USA*

Spring weather in the Great Lakes region of the United States has included short periods of very high temperatures in recent years. Some of these extreme heat events occurred during flowering of blueberry (*Vaccinium corymbosum*), followed by poor yields in the regions' blueberry farms. We investigated the response of blueberry flowers to field-relevant periods of high heat, and the subsequent effects on blue orchard bees (*Osmia lignaria*) provided pollen from heat stressed plants. Blueberry pollen germination and tube growth were inhibited by conditions exceeding 32ºC, and a brief exposure of 4 hours caused irreversible damage to the pollen. Varying the timing of heat stress relative to flower development revealed that bud swell was a particularly sensitive period of development. A no-choice cage study showed that mason bees (*Osmia lignaria*) foraging on plants previously exposed to brief extreme heat had lower fecundity, disrupted development, and lower survival to adulthood when larvae consumed pollen from these plants compared to those without extreme heat exposure. The implications of these results for managing crops through extreme heat conditions will be discussed, along with our current research to develop mitigation strategies to protect crop yields through increasingly variable weather conditions.

6.4

The effect of heat shock on arbuscular mycorrhizal fungus growth and nutrient transport

Victoria Terry ORCID iD[1], Max Kerr Winter[2], Jeroen Scheepers[1], Vasilis Kokkoris[1], Toby Kiers[1], Tom Shimizu[2]
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Arbuscular mycorrhizal fungi (AMF) are soil fungi that form symbioses with ~70% of plants, creating extensive underground, unseptated networks, gathering nutrients from the soil and transporting them to plant partners in exchange for carbon. These networks impact soil nutrient cycling, carbon sequestration, soil aggregation, and other ecosystem processes.

AMF are often studied in the context of plant stress mitigation and can ameliorate the effects of heat stress on plants. However, far less is known about responses in the fungi, especially on the level of cellular function and network dynamics.

To investigate heat stress on AMF, we monitored hyphal network growth *in vitro* in symbiotic cultures of *Rhizophagus irregularis*. We imaged networks every two hours before and for 15 days after a 24-hour heat shock at 25°C, 30°C, 35°C, or 40°C using a high-resolution imaging robot. Additionally, we imaged cytoplasmic and lipid transport using fluorescent lipid staining and remote-controlled optical positioning systems.

We found that both network growth and cytoplasmic and lipid flow speed decline significantly following short-term exposure to 40˚C. These results demonstrate that extreme heat can directly impair AMF network function, suggesting that increasing frequency and severity of heat events may compromise not only fungal performance, but the ecological and symbiotic benefits AMF provide.

6.5

Root-microbial decoupling under climate extremes

Madhav P. Thakur[1], Gerard Martínez-De León[1], Hang Zhao[1], Huiying Liu[2], Hao Wang[3]
[1]University of Bern, Switzerland. [2]Lanzhou University, China. [3]East China Normal University, China

As climate extremes intensify, thermal and hydrological stressors are restructuring biotic interactions in ways that challenge established ecological frameworks. Recent research has shown that root-microbial relationships can decouple under warming, yet we lack mechanistic understanding of how the combined effects of heat and drought alter these relationships — interactions that are fundamental to ecosystem stability and functioning. In this talk, I will first present evidence of warming-induced decoupling between root and microbial respiration phenology. I will then show that root traits are stronger predictors of microbial respiration phenology than root respiration phenology under warming. Finally, I will demonstrate how interactive heat and drought extremes alter connectance between root traits and soil microbial communities. I will close by arguing that root-microbial decoupling represents a coherent and predictable response to climate extremes — and that root traits offer a tractable entry point for forecasting it.

7.1

Temperature-driven changes to forest functioning

Adriane Esquivel Muelbert
University of Cambridge, United Kingdom

Tree mortality rates have increased in many forests, raising concerns about the future these systems, their biodiversity, and their climate mitigation capacity. Temperature is expected to contribute to increases in tree mortality and forest functioning by increasing water stress, affecting photosynthesis, and favouring pathogens. In this talk, I assess the evidence for the effects of temperature on changes in tree mortality. I focus on tropical systems assessing whether and where these systems could be reaching their physiological threshold. In Amazonia, forests in drier and warmer regions that have been exposed to the highest rates of temperature change are also the ones experiencing the greatest increases in tree mortality. Yet, our understanding on the impacts of different climatic drivers on forests, including temperature, is limited by our capacity to connect tree ecophysiology and demography, particularly in diverse tropical systems.

7.2

Water availability modulates the thermal sensitivity of tree growth responses to climate variability in the Amazon

Kathelyn Paredes Villanueva ORCID iD[1], Iokanam Pereira[1], Alacimar Guedes[1], Amanda Damasceno[1], Carla Farias[1], Maria Juliana Monte[1], Juliane G. Menezes[1], Jessica de Araújo Campos[2], Pamella Leite[1], Jefferson Moraes[1], Florian Hofhansl[3], Richard J. Norby[4,5], Laynara F. Lugli[1], Juliana Schietti[1], David M. Lapola[6], Carlos A. Nobre Quesada[1]
[1] National Institute for Amazonian Research, Brazil, [2]Federal University of the Jequitinhonha and Mucuri Valleys, Brazil, [3] International Institute for Applied Systems Analysis, Austria, [4]University of Birmingham, UK, [5]Oak Ridge National Laboratory, USA, [6] State University of Campinas, Brazil

The Amazon rainforest is a key component of the carbon cycle. Its carbon sink is weakening as tree mortality offsets growth. Although rising CO_2 can enhance photosynthesis, uncertainty in biomass gains is partly due to hydraulic and carbon allocation constraints. As baseline for the AmazonFACE CO_2 enrichment experiment, we analyzed climate-driven growth from >1,400 trees across six plots (2016-2025). Mixed-effects models showed that temperature effects on relative growth (size-standardized diameter growth) were weak alone but depended strongly on precipitation (Tmax: $\beta = -0.00018$, $t = -0.12$; Tmin: $\beta = 0.0105$, $t = 8.79$). Precipitation amplified thermal sensitivity differently for daytime and nighttime temperatures, with warmer nights enhancing growth and warmer days reducing it (precip×Tmax: $\beta = -0.0335$, $t = -12.55$; precip×Tmin: $\beta = 0.0236$, $t = 12.85$). The El Niño–Southern Oscillation (ENSO) enhanced growth, particularly during El Niño ($\beta = 0.0243$, $t = 23.10$). Absolute growth (diameter increment, cm yr^{-1}) showed stronger interactions (precip×Tmax: $\beta = -1.30$, $t = -9.30$; precip×Tmin: $\beta = 0.98$, $t = 10.24$), and stem productivity was structured by taxonomic identity (Genus variance = 0.295). Thus, Amazon forest growth may emerge from hydro-thermal interactions and diel temperature asymmetry, explaining heterogeneous forest responses to global change.

7.3

Atmospheric heat stress outweighs rainfall in regulating herbaceous biomass production in a Mediterranean shrubland

Marcelo Sternberg ORCID iD[1], Shay Adar[1], Darya Perry[1], Jaime Kigel[2]
[1]Tel Aviv University, Israel. [2]The Hebrew University of Jerusalem, Israel

Extreme heat and the associated rise in atmospheric water demand are emerging as dominant regulators of plant functioning, yet long-term experimental evidence from natural drylands remains limited. Using a unique 23-year rainfall-manipulation experiment in a Mediterranean shrubland, combined with high-resolution meteorological data and interpretable machine-learning models, we show that atmospheric heat stress—quantified by vapour pressure deficit (VPD) and diurnal temperature range (DTR)—outweighs rainfall in controlling herbaceous biomass production. Biomass declined sharply under high VPD and large DTR even when seasonal precipitation was average, indicating a shift from hydrological drought limitation toward heat-driven “atmospheric drought.”

These ecosystem-scale responses mirror physiological mechanisms documented at leaf and canopy levels: stomatal closure under elevated VPD, reduced night-time recovery under large DTR, and intensified soil–atmosphere coupling. Although wet-year legacies moderately buffered drought impacts, they failed to offset productivity losses under extreme heat conditions.

Our results reveal that Mediterranean herbaceous communities, traditionally viewed as rainfall-limited, are increasingly governed by atmospheric heat stress. This transition has major implications for forecasting ecosystem responses in climate-change hotspots: rising VPD, heatwaves and thermal extremes will likely shorten growing seasons, suppress biomass even in wet years, and challenge precipitation-based predictions of dryland productivity.

7.4

Tropical forests are facing increasing risks of exposure to critical temperature thresholds

Mukund Rao[1], Nina van Tiel[2], Gaston Lenczner[2], Charlotte Grossiord[2], Devis Tuia[2]
[1]Lamont-Doherty Earth Observatory of Columbia University, USA. [2]Ecole Polytechnique Federale de Lausanne (EPFL), Switzerland

Understanding how close tropical forests are to critical temperature thresholds that might impede photosynthetic activity is vital in a world where heat waves have become more severe and frequent. Using remotely-sensed surface temperature and species distribution maps, we studied the spatiotemporal variation in the thermal safety margins (TSM, difference between Tcrit, the critical photosynthetic temperature, and maximum canopy temperature) of 219 tropical tree species in South America, Southeast Asia, and Central Africa between 2001 − 2020. Despite overall high-temperature tolerance with an average Tcrit of 45.9˚C, we observed a consistent decline in the TSM of global tropical forests. The average pantropical TSM decline was 0.4˚C/decade, with the strongest decline in South America (0.5˚C/decade). Over the 20-year period, areas experiencing canopy temperatures surpassing the average Tcrit across reported species increased from 45 to 59 Mha in the tropics (4.2% of study area). This increases to 10.9% for areas where temperatures have surpassed the Tcrit of the most vulnerable reported species. When considering Earth System Models predicted trends under medium-to-high emission scenarios, average Tcrit may be exceeded in an area of 86 Mha by 2050 and 164 Mha by 2100 (over 10% of the study area), suggesting major feedbacks to the global carbon cycle and biodiversity.

7.5

Effects of extreme high temperature on carbon exchange in three typical ecosystems

Hua Lin, Qinghai Song, Nawatbhrist Kitudom
Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, China

With global change, heatwave events occur frequently, which alters ecosystem carbon exchange. Using in-situ flux data of tropical rainforest (TRF), Savanna shrub-grassland (SAV) and subtropical evergreen broad-leaved forest (STF), we analysed their temperature sensitivity and physiological response thresholds. The optimal photosynthetic temperatures (T_opt) of the three ecosystems were 29.9℃ (SAV), 25.5℃ (TRF), and 17.4℃ (STF), respectively, which were 2.7–3.5℃ higher than the mode of local air temperature. TRF had the highest GPP and the widest temperature range maintaining 50% GPP (WD_T50: 7.32℃), SAV had the lowest GPP with a WD_T50 of 6.58℃, and STF had the narrowest WD_T50 (4.34℃). T50 causing a 50% decrease in GPP were occasional events during normal years, whereas VPD_50 was a chronic stress in SAV, indicating that the low productivity of SAV was caused by persistent drought stress. The extreme dry-hot event in Yunnan Province in 2019, the most severe since 1961, severely damaged SAV's GPP because the leaf temperature of some plants exceeded their thermal safety margins, while TRF and STF were barely affected. In conclusion, although vegetation in dry-hot regions has certain adaptability to dry-hot environments, their carbon sink capacity is most vulnerable to extreme dry-hot events.

8.1
Achieving sustainable crop productivity in a hotter world
Elizabete Carmo-Silva ORCID iD, Armida Gjindali, Rebecca E. Biney, Haixia Yu, Ingrid Robertson, Rhiannon Page, Dawn Worrall, Zuzanna Kaminska, Clayton Dilks, Douglas J Orr
Lancaster University, United Kingdom

Agricultural crops increasingly experience unpredictable weather extremes during their growth cycle that threaten their productivity, including increased intensity, duration, and frequency of heatwaves. Rubisco catalyses the first step in the conversion of carbon from CO_2 into plant biomass: the carboxylation of ribulose-1,5-bisphosphate (RuBP). The enzyme is characterized by several inefficiencies and crop plants can allocate more than 50% of their leaf protein content to Rubisco to maintain adequate photosynthetic capacity to support plant growth and development. Despite this high abundance, Rubisco activity frequently limits carbon assimilation at the top of crop canopies. Under heat stress, plants produce greater amounts of Rubisco inhibitors and Rubisco activase—the catalytic chaperone that removes those inhibitors from Rubisco catalytic sites—becomes impaired and unable to maintain Rubisco in its active form. This talk will discuss diversity in Rubisco activase within and across species and approaches to make the catalytic chaperone more thermotolerant to maintain crop productivity in increasingly hot environments.

8.2
Evidence for adaptation to heat stress in cropping systems
Aidan Farrell ORCID iD
The University of the West Indies - St. Augustine Campus, Trinidad and Tobago

In 2022 a team of authors from the Intergovernmental Panel on Climate Change (IPCC) published a review of currently implemented climate adaptation options for agriculture. In preparation for the next IPCC assessment a sub-team are currently completing an updated review. This research draws on the data from both assessments and seeks to synthesize the evidence for effective adaptation to heat stress in cropping systems globally. Scoping reviews were performed by systematically categorizing adaptation options that have been implemented on farm and tested in published literature. The results, from >300 studies, were compiled within an annotated database. Adaptation options that related to heat stress in crops were selected from within the database and the effectiveness of each option evaluated. The results reveal widespread use of agronomic options such as water management and agroforestry, but there is less evidence for progress through alteration of physiological mechanisms (e.g. *via* plant breeding and biotechnology). The potential of each adaptation option across different cropping systems and agroecological zones will be discussed, alongside future prospects for the integration of physiological traits for heat avoidance and heat tolerance.

8.3

Genome-wide association analyses show distinct genetic architecture for photosynthetic heat tolerance in wheat and barley

Hanna Amoanimaa-Dede ORCID iD[1], Beata Sznajder[2], Joy Ojo[1], Andrew F Bowerman[3], Julian Taylor[2], Dini Ganesalingam[4], Richard M Trethowan[5], Owen K Atkin[3], Onoriode Coast[1]
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Photosystem II (PSII) heat tolerance enhances crop adaptation to heat stress. Studying cereal crop responses to high temperatures during the heat-sensitive flowering stage can enable the identification of the underlying genetic basis of photosynthetic heat tolerance and lead to improved selection of resilient varieties. We generated data on photosynthetic heat tolerance (i.e. T_{crit}) from a total of four distinct thermal environments to investigate the differences in the genetic architecture of wheat (n = 175 genotypes) and barley (n = 205 genotypes) T_{crit}. Although the heritability of T_{crit} was generally low (in wheat, h^2 ranging between 0.138 and 0.244; in barley, h^2 = 0.29), we identified one genomic locus for T_{crit} in wheat (2B) and four loci for T_{crit} in barley (5H, 6H, and two on 7H). Genetic correlations (r_g) of wheat T_{crit} (n = 191 genotypes) with other heat tolerance traits – respiratory oxygen consumption in the dark (R_{dark}) and PSII oxygen evolution (PSII O_2) – varied across the environments and traits, with the highest r_g being with R_{dark} and PSII O_2 measured at 35 °C (r_g = -0.90 and 0.57, respectively). These findings suggest that T_{crit} has partially distinct genetic signatures in wheat and barley. Our findings can inform breeding for heat-tolerant cereals.

8.4

Extreme cooling enables extreme heat survival in plants

Joanna Feehan
Michigan State University, USA. Carnegie Science, USA

The livelihoods of an estimated ~1.2 billion people are at risk from extreme heat impacts on agrifood systems, highlighting the need for science-based approaches to improve resilience and sustainability. We are investigating mechanisms of extreme heat adaptation in *Tidestromia oblongifolia*, a desert plant that thrives in Death Valley where air temperatures can reach 55°C. Using natural populations, we identified individuals that survive repeated daily exposure to 60 °C air temperatures for 6–8 hours over at least 20 days. High-throughput infrared thermal imaging data indicates that extreme heat adaptation is enabled through extreme physiological cooling, as individuals who survive our heat regimen record significantly lower leaf temperatures than those that do not survive. Energy-budget modelling indicates that this extreme cooling phenotype is primarily mediated by stomatal conductance. Using whole-genome sequencing of survivors and nonsurvivors, we aim to map extreme-heat adaptation loci in *T. oblongifolia*. Our studies provide insights into mechanisms of extreme heat adaptation in complex organisms that could be leveraged to engineer heat-resilient crops.

8.5
Designing urban landscapes to cope with a hotter world
Kevin Hultine
Desert Botanical Garden, USA

Urban heat islands often reach temperatures that are 8 – 10°C above surrounding rural locations due to heat absorbing infrastructure that can achieve surface temperatures of over 80°C. Intensifying heatwaves coupled with urban heat islands is among the most profound climate-caused human health threats around the globe, causing hundreds of thousands of deaths per year world-wide. As a consequence. mitigating the effects of urban heat islands is now recognized as one of societies grand challenges for improving human health and enterprise. Using the city of Phoenix as a case study, this presentation highlights the challenges and opportunities for expanding urban greenspace, and reducing urban heat islands in one of the hottest major cities on the planet. Similar to many urban landscapes, Phoenix is located in a region where water demand dramatically outpaces local water reserves, thus, requiring water conservation strategies that potentially reduces opportunities for green infrastructure planning, implementation and maintenance. This presentation introduces novel technologies and opportunities using next-generation sensor arrays, phenotyping and remote monitoring to establish the smartest and most effective green infrastructure possible to mitigate urban heat islands given limited water resources.

8.6

Breakout sessions – Discussing solutions to the challenges of extreme heat

- Natural and urban ecosystems – Chaired by Adrienne Nicotra and Kevin Hultine
- Agricultural systems – Chaired by Owen Atkin, Elizabete Carmo-Silva, Tracy Lawson and Dani Way

Further details to be confirmed

Locations of the breakout rooms will be shared at the end of session 8.5, and on the WhatsApp Group

9.1
Impacts of heat on plants as seen from space
Andrew Feldman
NASA GSFC, USA. University of Maryland, USA

Satellites are measuring Earth’s terrestrial biosphere at increasingly finer spatial and temporal resolutions, and across electromagnetic spectra, providing extensive opportunities for evaluating plant responses to heat. Here, I highlight several use cases to understand regional plant response to heat:
(i) Land surface temperature can be sampled at 5km and 15-minute scales by geostationary satellites, useful for evaluating the degree to which vegetation in hot, dry ecosystems is transpiring and cooling the surrounding environment.
(ii) Commonly used satellites (i.e., MODIS, SMAP) can track differing photosynthetic and internal water content responses to extreme heat versus extreme dry events in the western U.S. in 2020-2021.
(iii) Newer, higher spatial resolution satellites (<100m) can evaluate rapid responses of different plant functional types to extremes. Specifically, I demonstrate that ECOSTRESS captures reduced evaporation during hot-dry spell events across the U.S., where vast spatial variability of responses is shown with locally differing sensitivity for grass and tree species.
(iv) Finally, high resolution imagery during heatwave onset will be presented showing hotter leaf temperatures for some vegetation types than others.
These insights demonstrate that satellite observations enable a scaled-up understanding of plant responses to extreme heat, especially when connected to ground measurements.

9.2

Resilience and recovery from an extreme heatwave: impacts of the June 2021 heat dome on trees and forests of the US Pacific Northwest

Christopher Still ORCID iD[1], Linnia Hawkins[2], Bharat Rastogi[3], Jen Diehl[4], Paola Arroyo-Vargas[5], Chris Daly[1], Cole Doolitte[6], Rich Fiorella[7], William Hammond[8], Chad Hanson[1]
[1]Oregon State University, USA. [2]Columbia University, USA. [3]University of Colorado, USA. [4]Northern Arizona University, USA. [5]Portand State University, USA. [6]Marquette University, USA. [7]Los Alamos National Laboratory, USA. [8]University of Florida, USA

Understanding drivers, consequences, and mechanisms underlying forest heat damage is essential. During a record-shattering heatwave ("Heat Dome") in late June 2021, many areas of the US Pacific Northwest experienced multiple days of extremely high air temperatures. Sunlit leaf temperatures exceeded known damage thresholds (>45ºC) for multiple hours during the heatwave. I will present a multi-scale analysis of how this heatwave affected trees and forests of this region. Tree-level responses included canopy bud damage and sharp reductions in growth in 2021 following stem dehydration; growth impacts extended into subsequent growing seasons, suggesting continued impacts that exceed those observed following an earlier severe drought. A post-heatwave spike in seedling mortality was observed across multiple elevations, which could affect future species composition. Ecosystem-scale responses included a pronounced increase in evapotranspiration and sharp drop in photosynthesis during the heatwave, and these fluxes were affected for multiple weeks afterward. Canopy greenness was reduced along with increased leaf mortality and litterfall. Satellite observations and modelling show the extreme heat led to widespread foliar mortality on ~300,000 ha of forests. Together, these cross-scale impacts highlight which tree species, forest types and ages, and landscape positions are likely to be resilient or susceptible to heat extremes.

9.3

Canopy temperature drivers across ecosystems and remote sensing measurement challenges

Jen Diehl ORCID iD[1,2], Andrew Feldman[1,2]
[1]NASA Goddard Space Flight Center, Biospheric Sciences Laboratory, USA. [2]University of Maryland, Earth System Science Interdisciplinary Center, USA

Extreme heat is reshaping ecosystem function, with canopy temperatures often exceeding surrounding air temperatures and approaching physiological limits. First, I investigate whether canopy temperature exceeds air temperature across ecosystems. My recent work demonstrates that canopy temperature consistently exceeds or closely tracks air temperature, using long-term near-surface thermal infrared remote sensing observations across the National Ecological Observatory Network in the United States. However, the magnitude of canopy-air temperature differences varies significantly among vegetation types (e.g., grasses are hotter than deciduous forests). Vegetation types also differ in their sensitivities to the environmental drivers shaping these gradients, indicating that vegetation type provides a first-order understanding of how ecosystems experience and respond to heat extremes.

These ecological insights rely on accurate canopy temperature observations across ecosystems. However, remotely sensed thermal measurements are influenced by many confounding factors, which can introduce biases. Second, I will briefly discuss remote sensing measurements uncertainties under high temperatures and strategies to improve these measurements. This includes findings from a Thermal Bakeoff workshop in Arizona that I led, which reveals that commonly used thermal cameras underestimate temperature at high temperatures. Such principles are critical for measuring extreme heat across ecosystems, whether in the field, with aircraft, or with satellites.

9.4

Unravelling drivers of heat and drought stress across genotypes and seasons using optical-thermal-spectral and fluorescence indicators in sorghum

Spoorthi Nagaraju ORCID iD, Cheng Qian, Dongxue Zhao, Andries Potgieter
Centre for Crop Science, Queensland Alliance for Agriculture and Food Innovation, The University of Queensland, Australia

Increasing global temperature constrains crop productivity by disrupting plant water relations and photosynthetic function well before visible symptoms appear. Developing early, scalable indicators of such stress responses remain a major challenge for crop improvement under climate change. Here, we investigated whether integrated thermal and hyper-spectral metrics can detect heat-drought stress signals in sorghum and explain downstream impacts on root function and yield. Multi-genotype field experiments were conducted across two growing seasons at the Hermitage Research Station, Australia. Canopy hyperspectral imagery, and proximal physiological measurements using Li-600 were collected across key developmental stages. Preliminary results in first season exemplified the ability of the Temperature-Vegetation Dryness Index (TVDI), derived from NDVI-canopy temperature space, consistently separated genotypes with contrasting water-stress responses by mid-season. Early-stage optical indices, OSAVI and canopy temperature depression, were strong predictors of root water extraction depth and efficiency. Proximal measurements confirmed the physiological basis of these patterns: canopy temperature was negatively correlated with stomatal conductance, while maximum chlorophyll fluorescence were positively associated with grain yield. Ongoing work extends this framework by extracting solar-induced chlorophyll fluorescence (SIF) to evaluate its potential as an early, non-destructive indicator of stress sensitivity and yield formation. Overall, our results highlight the value of combining spectral and fluorescence indicators for phenotyping climate-resilient sorghum.

9.5

Remote sensing of stress impacts on plant metabolism

Rocio Hernandez-Clemente ORCID iD
University of Córdoba, Spain.

Remote sensing is transforming the way we monitor the physiological impacts of environmental stress on vegetation. Under rising temperatures, recurrent droughts and more frequent heatwaves, hyperspectral and thermal imaging provide complementary information on plant metabolism, including pigment regulation, water status, stomatal control, photosynthetic functioning and canopy energy balance. These approaches are particularly valuable for detecting stress before visual symptoms become evident, supporting a shift from retrospective forest assessment towards early warning.

This talk will provide an overview of how hyperspectral-thermal remote sensing can be used to assess physiological alterations caused by water and heat stress in declining forests. The talk will discuss the potential of UAV/drone, airborne and satellite platforms, highlighting their complementary roles across spatial scales: from individual-tree assessment using very high-resolution data to regional monitoring and long-term satellite time series.

To translate spectral and thermal signals into quantitative information on physiological variables, however, physically based radiative transfer models are needed. These models provide the link between sensor observations and plant function by simulating how leaf and canopy traits control reflected, emitted and fluoresced radiation. Their inversion enables the retrieval of key functional traits, such as pigment pools, leaf water and dry matter content, LAI and photosynthetic capacity, while thermal indicators provide insight into stomatal regulation and evaporative cooling.

As an applied example, the talk will present recent work in Mediterranean oak forests of the southwest Iberian Peninsula, where hyperspectral and thermal imagery, radiative transfer modelling and thermal time series were used to detect early water-stress signals linked to oak decline.

10.1
Plant life in a hotter planet: can they manage alone?
Fernando Valladares
CSIC Spain, Spain

Plants detect heat through subtle changes in the fluidity of their cell membranes, which activate calcium ion channels, triggering a heat shock response within a matter of minutes. In a desperate race against time, the plant synthesizes protective proteins and metabolites such as proline to safeguard its molecular structures before extreme heat degrades its enzymes and halts photosynthesis. Physically, plants attempt to cool themselves by growing smaller, thinner leaves that dissipate heat more effectively or by sacrificing their water reserves to cool their surface through evaporation—a strategy that becomes suicidal when heat combines with drought. The impact of warming extends invisibly but lethally to pollinators, as heat waves degrade the nutritional quality of pollen and drastically reduce the nectar reward. This sort of heat-induced “junk food” triggers a collapse in the food web, where bee larvae consuming heat-stressed pollen suffer massive mortality and surviving adults see their lifespans drastically shortened. Global warming disrupts the delicate balance of the soil microbiome that interacts with plants, sometimes turning former bacterial allies into opportunists or facilitating the invasion of pathogens that take advantage of the plant’s suppressed immune system under extreme conditions. In response to this crisis, some plants have evolved a chemical distress signal mechanism through their roots to recruit specific soil microbes that can provide immediate resistance against heat stress. These biological interactions act as a determining factor that can either mitigate or amplify the impacts of climate change: while a diverse plant community can mitigate extreme heat by creating cooler, more humid microclimates, the loss of key symbionts or the emergence of new diseases can exacerbate the vulnerability of entire ecosystems. The survival of ecosystems and crops depends not only on the resilience of an isolated species, but on the integrity of a network of biological interactions that is now faltering under unprecedented warming.

10.2 Closing panel discussion

This closing Panel discussion will integrate insights from across the symposium to reflect on what extreme heat means for the future of plant life, from natural ecosystems to managed systems and the biotic interactions that sustain them. The discussion will focus on broader lessons that have emerged repeatedly across sessions, spanning ecosystem vulnerability, food systems, plant–water relations, and plant–microbial interactions.

The conversation will consider where limits to resilience are becoming apparent, how interacting stresses such as heat, water limitation, and biological interactions shape outcomes. Emphasis will be placed on the consequences of repeated and cumulative heat events, whether current understanding is sufficient to anticipate long term impacts on biodiversity, productivity, and ecosystem services, and what solutions are available to help address the challenges posed by extreme heat.

This session will also include time for feedback from the breakout discussion sessions from earlier in the symposium on Data and collaboration (Wednesday), and Solutions to challenges of extreme heat (Thursday)

Panellists

Sasha Reed (Facilitator):

- Fernando Valladares
- Elizabete Carmo Silva
- Sergey Rosbakh
- Belinda Medlyn

List of Posters

* denotes they are giving a flash talk

1.	Luiza Maria Aparecido	Physiological sensitivity of hybrid oaks to environmental stressors	University of Utah	USA
2.	Pieter Arnold *	Resilience and sensitivity of photosynthetic tissue to increasing heat load	Australian National University	Australia
3.	Maxwell Bergström	Scorched, not senescent: when hot droughts burn leaves instead of aging them	EPFL	Switzerland
4.	Nicole Bison *	Protein stability-function tradeoffs predict shape of thermal performance curves	The University of British Columbia	Canada
5.	Marion Boisseaux	Who wins and who loses under warming? Functional traits and distinctiveness shape demographic responses in mountain plant communities across the Northern Hemisphere.	CNRS	France
6.	Eva Anna Burgunder	Future climate conditions shift fungal communities and increase severity of soilborne diseases in table beets	University of Basel	Switzerland
7.	Erick Calderon-Morales	It is all about VPD: disentangling the effects of temperature and VPD over residual conductance	Hawkesbury Institute for the Environment, Western Sydney University	Australia
8.	Francisco Javier Cano	Leaf width drives intraspecific differences in sorghum thermotolerance during extreme heat waves	Instituto de Ciencias Forestales (ICIFOR-INIA), CSIC	Spain
	Francesc Castanyer-Mallol	Novel infrared-based device for simulating plant heatwaves under open-field conditions *This will be an exhibit in the lobby	Agro-Environmental and Water Economics Research Institute (INAGEA)	Spain
9.	Lohengrin Cavieres	Elevational variation in high-temperature tolerance of native and exotic plant species in the Andes of central Chile	Universidad de Concepcion	Chile
10.	Martina Chacón *	Beyond thermal and hydric limits: xylem formation during prolonged stem shrinkage in a South American dryland tree	Instituto Argentino de Nivología, Glaciología y Ciencias Ambientales (IANIGLA-CONICET),	Argentina
11.	Han Chen	Asymmetric constraints of leaf thermal tolerance on geographic patterns of evergreen and deciduous plants	South China Botanical Garden, Chinese Academy of Sciences	China
12.	Tino Colombi	Go big or go many? Physiological controls of carbon retention in roots under warming	University of Nottingham	United Kingdom
13.	Inmaculada Criado-Navarro	Linking soil metabolomics with biotic components to understand functional adaptation in biological soil crusts	Instituto de Agricultura Sostenible (IAS-CSIC)	Spain
14.	Virginia Crisafulli *	Microclimatic refugia: canopy plants as thermal buffers	Centro de Investigaciones Sobre Desertificación (CIDE, CSIC-UV-GV)	Spain
15.	Margaux Didion-Gency *	Keeping it cool: How leaf morphology modulates thermal safety	Ecological and Forestry Applications Research Center (CREAF)	Spain
16.	Mateus Fabbris *	Estimating V_{cmax} temperature dependence: a novel approach	University of São Paulo (USP)	Brazil
17.	Hafiz Umar Farooq *	Seed yield under field heat stress is associated with seed number and harvest index rather than seed size in interspecific quinoa populations	King Abdullah University of Science and Technology	Saudi Arabia

18.	Sophie Fauset	How do mature penduculate oak (*Quercus robur*) tree canopies respond to heat waves and elevated CO_2? A study on canopy temperature and leaf heat tolerance.	University of Plymouth	United Kingdom
19.	Alice Gauthey	Contrasting effects of elevated CO_2 on oak seedling photosynthesis during single and consecutive heatwave events	University of Birmingham	United Kingdom
20.	Oula Ghannoum	Thermal and heat-shock responses of photosynthesis in Sorghum with contrasting leaf width	Western Sydney University	Australia
21.	Anna Haigh	Hotter than hot: using passive heating in a Douglas-fir canopy to assess the effect of extreme heat on photosynthesis.	Oregon State University	USA
22.	Brandon Hastings*	Honami dynamics and crop photosynthesis in a warming, turbulent atmosphere	University of Nottingham	United Kingdom
23.	Cross Heintzelman	Balancing heat and drought tolerance: evidence for physiological trade-offs in *Quercus ilex*	École polytechnique fédérale de Lausanne	Switzerland
24.	Hampus Holmberg	Native tree species shows divergent strategies in leaf and branch level water economy but no acclimation along an elevational gradient in Rwanda	University of Gothenburg	Sweden
25.	Akhil Javad*	Ineffective transpirational cooling threatens dry tropical forest leaves	University of Leeds	United Kingdom
26.	Kiyosada Kawai	Leaf heat tolerance predicts photosynthetic and survival responses to experimental heat extremes in 18 dipterocarp species in Peninsular Malaysia	Japan International Research Center for Agricultural Sciences	Japan
27.	Tanaka Kenzo	Temperature dependence of leaf gas exchange and growth traits in tropical montane forest trees in Peninsular Malaysia	Japan International Research Center for Agricultural Sciences	Japan
28.	Leonidas Kougiteas	Exploring patterns of molecular alteration in oilseed rape under recurring heat events	UNICAEN, INRAE, UMR 950 EVA	France
29.	Andrew Kowalski	Physical mechanisms of stomatal gas exchanges at very high temperatures	University of Granada	Spain
30.	Pia Labenski*	Predicting forest responses to compound heat-drought extremes using a process-based modelling framework	Karlsruhe Institute of Technology	Germany
31.	Lucrezia Laccetti	The genomic basis of germination sensitivity to thermal extremes across the geographical range of the cliff species *Brassica incana*	University of Naples Federico II	Italy
32.	Xuelei Lai	A temperature-dependent protein phase transition underlies bidirectional cold and heat stress tolerance in rice	National Key Laboratory of Crop Genetic Improvement	China
33.	Aneesh Lale	Rice root system architecture shows adaptive responses to high temperature stress	University of Nottingham	United Kingdom
34.	Fernando Alfredo Lattanzi	Summer survival of temperate forage grasses in subtropical climates: the roles of thermal and water stress.	INIA	Uruguay
35.	Qiannan Leng*	Contrasting heat tolerance strategies and productivity of evergreen and deciduous angiosperm forests	South China Botanical Garden, Chinese Academy of Sciences	China
36.	Igor Lima	The thermal cost of fast living: acquisitive strategies trade heat tolerance for rapid growth in tropical trees	University of São Paulo	Brazil
37.	Hui Liu	Leaf habit-based thermal tolerance of woody species: from ecophysiology to biogeography	South China Botanical Garden, Chinese Academy of Sciences	China

38.	Yao Liu	Irrigation strategy to enhance seedling resilience to compound heat-drought events in tree nurseries	Northumbria University	United Kingdom
39.	Rosana López	Warming constrains phenotypic plasticity and alters drought–shade trade-offs in European beech seedlings	Universidad Politécnica de Madrid	Spain
40.	Na Luo*	Understanding leaf thermal tolerance from a carbon allocation perspective	South China Botanical Garden, Chinese Academy of Sciences	China
41.	John Mackenzie	Maintaining rubisco concentration linked to better photosynthetic performance in wheat following a simulated heatwave	Australian National University	Australia
42.	Surbhi Mali	Source-derived signals determine sink productivity under heat stress in potato (*Solanum tuberosum* L.)	CSIR-Institute of Himalayan Bioresource Technology (IHBT)	India
43.	María José Marcos Palacios	Photosynthetic traits: early warning indicators of oak decline due to water stress in the Iberian Peninsula	University of Córdoba,	Spain
44.	María Isabel Márquez-Pérez*	Resilience of woody fungal pathogens under water stress and ecophysiological responses of olive trees	University of Cordoba	Spain
45.	Kali Middleby	In situ evidence for a critical temperature threshold driving stomatal re-opening and widespread photosynthesis-conductance decoupling in tropical trees	French National Institute for Research and Development	France
46.	Yan Moraes	Revealing the thermal limits of gas exchange in giant tropical trees	University of Cambridge	United Kingdom
47.	Bryn Morgan	Co-regulation of water use and canopy temperature in desert trees	Massachusetts Institute of Technology	USA
48.	Joy Ojo*	Leaf hyperspectral reflectance predicts grain yield in heat-tolerant wheat	University of New England	Australia
49.	Enrique Ostria	Integrated physiological, metabolic, and transcriptomic analysis reveals divergent heat stress responses in Chenopodium quinoa and *Amaranthus cruentus*.	Universidad de Concepción	Chile
50.	Sona Pandey	Heat stress responses in heat-tolerant c4 crops: insights from *Setaria* and Sorghum	Donald Danforth Plant Science Center	USA
51.	Elisa Pellegrino (presenting on Wednesday)	Arbuscular mycorrhizal fungi buffer crop performance under thermal extremes: a global meta-analysis	Scuola Superiore Sant'Anna	Italy
52.	Antonio J. Pérez-Luque	Optimal partitioning drives carbon allocation responses to climate in Mediterranean pine reforestations	Institute of Forest Sciences (ICIFOR) INIA-CSIC	Spain
53.	Hegarty Philip*	Heat-driven evaporative demand intensifies transpiration sensitivity to soil drying in European beech	Technical University of Munich (TUM)	Germany
54.	Pravarthika Prakash	Investigating the interplay between auxin and pH in fine-tuning root growth responses to heat stress	University of Nottingham	United Kingdom
55.	Renee Prokopavicius	Predicting cumulative heat damage of Eucalyptus species under experimental heat plus drought stress	Western Sydney University	Australia
56.	Marjaana Rantala	Prolonged daily heat exposure impairs photosynthetic electron transport in *Arabidopsis thaliana*	University of Turku	Finland
57.	Iida-Maria Rantanen	Impact of long-term heat stress on photosystem II repair dynamics in *Arabidopsis thaliana*	University of Turku	Finland
58.	William Reinar	Mutation load and adaptation under chronic heat in *Arabidopsis thaliana*	University of Oslo	Norway

59.	Sami Rifai	Evaluating the consistency of diurnal trends of vapour pressure deficit across terrestrial ecoregions	Adelaide University	Australia
60.	Ginés Rodríguez-Castilla	Forest multifunctionality declines along temperature and aridity gradients in Mediterranean regions	University of Córdoba	Spain
61.	Milagros Rodriguez-Caton	Thermal thresholds for carbon assimilation decline in the wet tropical forest of Costa Rica	IANIGLA-CONICET	Argentina
62.	Nadine Ruehr	From heat stress to recovery: water availability determines tree resilience to extreme temperatures	Karlsruhe Institute of Technology	Germany
63.	Robert Sharwood	Increasing heat resilience of photosynthetic carbon assimilation to improve crop productivity	Hawkesbury Institute for the Environment, Western Sydney University	Australia
64.	Camille Sicangco	Weighing the options: a test of alternative stomatal optimisation models at high temperatures	Hawkesbury Institute for the Environment, Western Sydney University	Australia
65.	Ilaine Silveira Matos	Heat impacts on leaf-level tolerance to drought	Adelaide University	Australia
66.	Matthias Stegner	Heat-dose tolerance in tropical plants	University of Innsbruck	Austria
67.	Harihar Jaishree Subrahmaniam	Beyond lethal thresholds: dynamic heat-stress traits reveal adaptive genetic variation in wild *Arabidopsis thaliana*	University of Hamburg	Germany
68.	Sonia Vega-Rosete	Climate-origin distance and functional traits predict heat tolerance of urban trees under climate warming	University of Córdoba	Spain
69.	Yang-Si-Ding Wang	Efficiency-safety tradeoffs in leaf carbon, hydraulic and thermal traits: economics and safety as hubs	South China Botanical Garden, Chinese Academy of Sciences	China
70.	Eduardo Zelada*	Evaluating UV-B seed priming effects on vegetative tomato heat tolerance	Lancaster University	United Kingdom
71.	Jana Zeppan	Rethinking thermal tolerance: Seasonal dynamics and exposure duration shape leaf thermal safety margins in temperate trees	Karlsruhe Institute of Technology	Germany
72.	Francisco Tomás Riera	Thermal signals of drought stress: predicting forest decline under extreme heat conditions	University of Córdoba	Spain

Poster abstracts

Poster 1
Physiological sensitivity of hybrid oaks to environmental stressors

Luiza Maria Aparecido ORCID iD[1], Rafael Freitas[1], Sarah Hinners[2]
[1]University of Utah, USA. [2]Red Butte Garden and Arboretum, USA

As climate change intensifies heat and drought events, hybridization is often proposed as a mechanism for species range expansion and adaptation. However, the ecophysiological advantages of hybridization in high-elevation ecosystems remain under-researched. We evaluated ecophysiological differences between seven oak species—two xeric non-hybrids (*Quercus gambelii*, *Q. turbinella*) and five hybrids (xeric x xeric; xeric x mesic)—at the University of Utah's Cottam's Oak Grove. Midday gas exchange, leaf water potentials, specific leaf area (SLA) and thermal traits (Tleaf, Tcrit, TSM) were measured across a seasonal gradient from June to September 2025. Non-hybrids exhibited significantly different, often higher, gas exchange rates compared to hybrids. While all species demonstrated thermo-acclimation by increasing Tcrit following a heatwave, hybrids generally showed greater sensitivity to vapor pressure deficit (VPD) and temperature stressors than non-hybrids. Lower SLA in xeric species correlated with improved thermoregulation and cooler leaves. Our findings partially support significant trait differences (H1) but fail to support the hypothesis that hybrids adapt more effectively than non-hybrids (H2). Hybridization may only serve as a viable ecological strategy when parent species possess similar physiological responses to environmental extremes.

Poster 2

Resilience and sensitivity of photosynthetic tissue to increasing heat load

Pieter Arnold ORCID iD[1], Rosalie Harris[1,2], Sabrina De Zen[1], Andy Leigh[3], Lydia Guja[4], Adrienne Nicotra[1]
[1]Australian National University, Australia. [2]Scripps Institution of Oceanography, USA. [3]University of Technology Sydney, Australia. [4]Umwelt Ecology, Australia

It is well established that plants can survive and be resilient to living in hot and dry conditions. Yet – now and in the future – extreme climatic events exacerbated by background warming will push even the toughest plants closer to their physiological limits. We have developed and applied new approaches to assess the tolerance of photosystems to evaluate the sensitivity of plants to increasing thermal load – the explicit combination of temperature intensity and exposure duration. Using a botanical garden survey, we explored how thermal load sensitivity of photosynthetic tissue differed among 80 phylogenetically and morphologically diverse species. We found that leaves with higher water content and higher mass per area generally were more sensitive to heat load, which we hypothesise is related to thermoregulatory strategy. However, that left considerable variation in sensitivity that was unrelated to leaf traits. Using our recently established Thermal Load Sensitivity framework that integrates heat intensity with exposure duration, we find evidence for phylogenetic signal that have not been previously apparent from static heat tolerance measures. Our current research is both building theoretical models to explore heat load impacts, and empirical investigations of the capacity for plant tissues to repair damage and restore function following heat doses.

Poster 3

Scorched, not senescent: when hot droughts burn leaves instead of aging them

Maxwell Bergström ORCID iD[1,2], Arianna Milano ORCID iD[1,2], Alyssa Kullberg ORCID iD[1,2], Thibaut Juillard ORCID iD[1,2], Kate Johnson ORCID iD[3], Philipp Schuler ORCID iD[4,2], Yann Vitasse ORCID iD[2], Charlotte Grossiord ORCID iD[1,2]

[1]EPFL, Switzerland. [2]WSL, Switzerland. [3]CREAF, Spain. [4]University of Berkley, USA

Hot droughts are becoming increasingly frequent worldwide, causing widespread and abrupt leaf discolouration in temperate forests. Because changes in leaf colour are commonly associated with autumnal senescence, such discolouration is often interpreted as premature or stress-induced senescence. Nonetheless, under hot droughts, excessive heating and/or hydraulic failure may cause leaf tissue damage, leading to *leaf scorching*. Although visually similar to senescence, leaf scorching arises from fundamentally different physiological processes and remains poorly studied.

Using climate chambers, we exposed three species (*Fagus sylvatica*, *Quercus pubescens*, and *Prunus mahaleb*) to four temperature treatments (25°C, 35°C, 40°C, and 45°C) under severe water limitation. Through physiological (predawn and midday water potential, chlorophyll content, stomatal conductance, maximum potential quantum efficiency of Photosystem II, leaf embolism) and leaf colour measurements, we aimed to identify physiological tipping points of leaf scorching and to provide a clearer distinction between the leaf discolouration processes.

Leaf scorching occurred only under the two highest temperature treatments, with its extent varying among species according to their thermotolerance. Notably, in *Fagus sylvatica*, leaf tissue damage appears to develop prior to leaf embolism, indicating that temperature excess rather than hydraulic dysfunction was the primary trigger of scorching under extreme heat.

Poster 4

Protein stability-function tradeoffs predict shape of thermal performance curves

Nicole Bison ORCID iD[1], Pieter A. Arnold[2], Andy Leigh[3], Adrienne Nicotra[2], Sean Michaletz[1]

[1]The University of British Columbia, Canada. [2]Australian National University, Australia. [3]University of Technology Sydney, Australia

The temperature dependence of photosynthesis is central to predicting plant responses to climate warming, yet it remains unclear how constraints at the level of proteins and enzymatic processes scale up into co-variation and trade-offs among the thermal traits used to compare thermal responses across individuals, taxa, and environments, including maximum photosynthesis rate (A_{max}), optimal temperature (T_{opt}), and thermal breadth ($T_{breadth}$). The '*Jack-of-all-Temperatures-is-a-Master-of-None'* (JoaT) hypothesis predicts a trade-off between A_{max} and $T_{breadth}$, based on biophysical constraints arising from enzyme stability-function trade-offs. However, empirical support in plants has been mixed. Here, we revisit this hypothesis using plant thermal performance (assimilation–temperature (A-T) curves) and thermal tolerance (fluorescence-based (F-T) curves describing heat damage to photosystem II, PSII). Contrary to the JoaT hypothesis, A_{max} did not trade off against $T_{breadth}$ and instead was positively associated with it. However, our results strongly support the core mechanistic premise underpinning JoaT when thermal stability is quantified using alternative metrics to $T_{breadth}$. A_{max} declined with multiple independent measures of thermal stability, including T_{opt}, the deactivation energy above T_{opt} ($E_{d,A}$), and fluorescence-derived thresholds of PSII damage (e.g. T_{50}). Our results reconcile decades of mixed evidence for the JoaT hypothesis and reveal a clear stability–function trade-off for photosynthesis.

Poster 5

Who wins and who loses under warming? Functional traits and distinctiveness shape demographic responses in mountain plant communities across the Northern Hemisphere

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Extreme warming is increasingly exposing plant communities to thermal conditions well beyond their historical range, yet predicting which species will persist or disappear remains a major challenge. Mountain ecosystems, shaped by long-term cool climates and high biodiversity, are particularly vulnerable to rising temperatures. Warming may profoundly reshuffle which phenotypes are favoured, potentially promoting functionally extreme species, those with traits values far from other species in the community, *i.e.* functional distinctiveness. This study investigates how functional traits and distinctiveness shape species' responses to warming using a unique large-scale dataset from whole-community transplant experiments conducted across multiple mountain regions in the Northern Hemisphere. Our results show that warming favors competitive rather than colonizing strategies, typically associated with rapid establishment in new habitats. Moreover, the effect of functional distinctiveness seems context-dependent: species that went extinct were more functionally distinct, suggesting higher vulnerability. Conversely, persistent species benefit from their distinctiveness, exhibiting higher final abundance compared to others. We suggest that functional distinctiveness amplifies species' sensitivity to thermal stress, by either promoting their persistence or their predisposition to extinction. Incorporating functional originality thus improves predictions of climate change impacts on biodiversity, as it enhances our understanding of the processes structuring plant communities.

Poster 6

Future climate conditions shift fungal communities and increase severity of soilborne diseases in table beets

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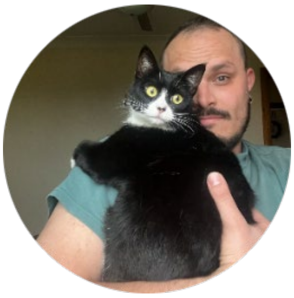
With climate change, the intensity of crop diseases is likely to change. In Switzerland, wetter springs and hotter and drier summers are suspected to have increased the incidence of soilborne diseases in table beets (Beta vulgaris). However, the impact of climate change on soilborne pathogens remains unclear. To investigate climatic effects on fungal community dynamics and plant health, beets were grown in six naturally disease-infested agricultural soils. The beets were grown in phytotrons under climate projections for Switzerland under different representative concentration pathways (RCP 4.5 and 8.5) by the end of the century, compared to a past control climate. Beet disease development was assessed over an entire growing season and six months during storage. Climate effects on disease outcome were especially severe in the early growth phase, represented by increased seedling damping-off in the majority of soils under future climatic conditions. Initial soil re-inoculation experiments and fungal community profiling of the roots of beet seedlings indicate that specific fungal taxa, such as Fusarium, are likely responsible for the increase in disease on table beets under warmer conditions. At harvest, we observed yield reduction of 25-60% under future climate conditions, likely caused by pathogens and abiotic stress such as drought.



Poster 7

It is all about VPD: disentangling the effects of temperature and VPD over residual conductance

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Tree die-off events associated with extreme heat have increased worldwide. These events are unpredictable and catastrophic, killing millions of trees in short timescales and causing substantial changes in ecosystem processes. During these extreme conditions, trees respond by closing their stomata to minimize water conductance, yet residual water loss (g_{res}) continues through leaky stomata, cuticle, and bark and it has been hypothesized to be key determinant of tree mortality. However, determining the consequences of rising temperatures for tree mortality has been challenging due to the confounding influence of VPD when temperature rises. To quantify the effects of temperature and VPD on water loss we measured g_{res} temperature response curves ranging from 25°C to 55°C under two VPD conditions; maintaining VPD below 2kPa across temperatures and letting VPD co-vary with temperature increments on branches of *Eucalyptus* species with contrasting drought tolerances to address the following question: What is the net effect of VPD and temperature over g_{res}? Whereas our temperature treatment had a minor effect over g_{res}, the combination of temperature and VPD increased g_{res} exponentially across all species. Our results might challenge the idea that stomatal conductance is used to avoid heat stress during heatwaves and underscore the importance of accounting for VPD in assessing tree responses to extreme heat events.

Poster 8

Leaf width drives intraspecific differences in sorghum thermotolerance during extreme heat waves

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Sorghum is globally recognized for its resilience to arid climates due to its C4 pathway, yet increasing extreme heat events threaten its stability. This study evaluated 13 sorghum genotypes, using maize as a control, under three temperature regimes (daily means: 22, 28, and 35°C). At 44 days post-germination, a simulated heatwave was imposed, reaching a 45°C daily mean for 6 hours over three consecutive days. Results revealed significant intraspecific variability governed by leaf architecture and gas exchange. While all genotypes increased stomatal conductance (gs) under heat, narrow-leafed genotypes exhibited superior thermotolerance compared to wide-leafed counterparts and the maize control particularly those grown at lower temperature. Narrow leaves reduce boundary layer resistance, facilitating efficient convective cooling and preventing reach critical temperatures. Molecular analysis of two extreme genotypes showed that the tolerant line enhanced membrane stability and upregulated heat shock proteins (HSPs), antioxidants, and osmoprotectants. This confirms that a narrow-leaf morphotype is a critical mechanism for maintaining physiological integrity during extreme events. Our findings suggest that selecting for narrow-leaf traits and thermotolerance is a viable breeding strategy to improve sorghum productivity in warming environments, leveraging natural genetic variation to ensure yield stability under climate change.

Exhibition – in Lobby

Novel infrared-based device for simulating plant heatwaves under open-field conditions

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Understanding how plants tolerate extreme heat is essential for anticipating ecosystem resilience under accelerated climate change. However, realistic simulation of heatwaves under field conditions has been limited by the low thermal precision of passive methods and by the cost or limited portability of active systems. In this study, we present and validate an affordable, modular device that reproduces realistic thermal increments through control of leaf temperature using a non-transpiring artificial leaf. This approach overcomes a key limitation of infrared heaters — their weak influence on air temperature — by directly targeting leaf thermal load, the biologically relevant variable that governs plant responses to heat stress.
By enabling precise leaf-level thermal control with minimal disturbance to surrounding environmental conditions, the instrument provides experimental realism previously inaccessible in open-field settings. The setup was applied under field conditions to generate combined heatwave and drought scenarios in three crop species and one endemic species from Mallorca, demonstrating robustness and versatility across contrasting physiological contexts. Our results confirm this tool offers an effective approach for studying plant thermal limits under realistic field conditions.
During the symposium, the device will be available for viewing and operational demonstration, allowing attendees to examine its experimental potential.

Poster 9

Elevational variation in high-temperature tolerance of native and exotic plant species in the Andes of central Chile

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Understanding plant tolerance to high temperatures is critical for predicting vegetation responses to climate warming, particularly in mountain ecosystems where the exposure to high temperatures varies with elevation. We assessed the tolerance to high temperatures of photosystem II (TCH) in 213 plant species (165 natives and 48 exotics) along a wide elevational gradient (1200–3600 m a.s.l.) in the Andes of central Chile where treeline is at 2200 m a.s.l. We evaluated the roles of elevation, plant origin, growth form, and plant height on the heat tolerance. TCH varied significantly with elevation, displaying a non-linear pattern with maximum values at mid elevations (~2500 m a.s.l.). Native species exhibited, on average, slightly higher TCH than exotics, although this difference was not consistent across elevations. No significant interactions were detected between elevation and species origin or growth form, and plant height explained only a small fraction of the variation in TCH. These results indicate that elevational environmental filtering is the dominant driver of PSII heat tolerance, overriding effects of plant stature, growth form, or biogeographic origin. Our findings suggest that thermal tolerance in mountain species reflects adaptation to local thermal regimes rather than simple structural or taxonomic differences, with important implications for predicting plant vulnerability to increasing heat extremes under climate change.

Poster 10

Beyond thermal and hydric limits: xylem formation during prolonged stem shrinkage in a South American dryland tree

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Heat waves and associated heat stress are intensifying across South America, threatening dry forests. Arid-adapted trees are central to sustaining wood productivity under rising temperatures. We studied growth responses of *Neltuma flexuosa*—the dominant tree in Argentina's Monte dry forest—by combining high-resolution dendrometer records with histological analyses of xylem formation over July 2021 to March 2024. Daily stem-radius cycles revealed strong correlations between Maximum Daily Shrinkage and ERA5 air temperature (Spearman $\rho \approx 0.81$), underscoring the tight coupling between thermal stress and stem water dynamics. Despite prolonged shrinkage during extreme heat events, trees maintained cambial activity and formed narrow xylem rings. Seasonal analysis showed that 2022–2023 was the warmest on average, with 25 days above 30 °C concentrated between November and February. During this extreme drought, xylogenesis phases were advanced and shortened, completing vessel maturation by late November. In contrast, 2023–2024 recorded lower mean temperatures but exhibited the longest heat wave, lasting 10 consecutive days above 30 °C (January 23–February 1, 2024), with extended xylogenesis phases and growth rings maturing by early March. By linking local growth responses to globally intensifying heatwave dynamics, our results contribute to understanding how climate extremes threaten ecosystem productivity and resilience worldwide.

Poster 11

Asymmetric constraints of leaf thermal tolerance on geographic patterns of evergreen and deciduous plants

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The niche breadth–range size hypothesis proposes that widespread species possess broader physiological tolerances; however, this paradigm may obscure the true adaptive strategies of plants with different leaf habits. By integrating measurements of leaf photosynthetic heat and cold tolerances with climatic variables and global occurrence records across 237 plant species (116 evergreen, 121 deciduous from 20 sites across China), we systematically quantified the coupling relationships among thermal tolerance breadth, climatic niches, and geographic boundaries. We found contrasting patterns between the two types: (1) Physiologic-geographic paradox: despite occupying wider latitudinal spans, deciduous plants exhibit significantly narrower thermal tolerance ranges than evergreens; (2) Asymmetric constraints: the southern distribution boundaries of deciduous species are strictly constrained by heat tolerance, whereas the northern distribution boundaries of evergreens are limited by cold tolerance; and (3) Divergent climatic drivers: heat and cold tolerances of evergreens are driven by the maximum and minimum temperatures of the growing season (T_{gs_max} and T_{gs_min}), respectively, whereas phenological avoidance decouples cold tolerance from T_{gs_min}. Overall, our findings challenge the niche breadth–range size hypothesis, demonstrating asymmetric constraints on the geographic patterns of evergreen and deciduous plants. Consequently, cold-avoiding deciduous species may be more vulnerable under a warming climate, placing individuals near their southern boundaries at severe risk of range contraction.

Poster 12

Go big or go many? Physiological controls of carbon retention in roots under warming

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Despite the pivotal role of plant roots in the terrestrial carbon cycle, the physiological mechanisms regulating soil carbon inputs through roots remain poorly understood. Experiments with rice (*Oryza sativa*) revealed non-linear temperature responses in carbon partitioning between carbon retention in newly formed root biomass and carbon losses through respiration, with maximum carbon retention reached at 28 °C. Three-dimensional quantification of root anatomy using high-resolution X-ray Computed Tomography (1.8 µm) provided evidence that these partitioning patterns were driven by growth processes at the cellular level. With increasing cortical cell size, indicating greater contribution of cell expansion over cell division to root growth, more carbon was retained in root biomass and less was lost through root respiration. Performing experiments with rice wild type and an ABA biosynthesis mutant (*Osaba2-1*) demonstrated that the genotypic ability to maintain cell expansion upon warming increased carbon retention in root biomass. Integrating our experimental findings with literature data covering various land use types further highlighted the pivotal importance of fundamental root physiological processes in estimating soil carbon inputs. We therefore advocate explicitly including root physiology and its genetic and environmental underpinnings in the assessment of global warming impacts on soil carbon dynamics and related ecosystem functions.

Poster 13

Linking soil metabolomics with biotic components to understand functional adaptation in biological soil crusts

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Biocrusts occur globally in ecosystems with sparse vegetation, especially in natural drylands. Important ecosystem services have been attributed to them. Soil metabolomics is an emerging and powerful approach that integrates soil chemistry, biology, and ecology. In this study, a total of 28 plots, 20 m x 20 m in size, were surveyed in an arid natural area located in Almeria. For each plot, biocrusts and bulk soils (1-10 cm depth) were studied through untargeted metabolomic (LC−QTOF), nematode diversity, metabarcoding, and physicochemical and biological properties. Data analysis revealed both functional adaptation and spatial heterogeneity linked to biocrust development. Biocrusts concentrated a suite of metabolites associated with intense biological activity, nutrient cycling, and stress tolerance. Meanwhile, bulk soils act as a reservoir for more persistent organic compounds and benefit from the outcomes released by the biocrust. We also found functional pathways suggesting adaptation in stress-related metabolism, such as phenylalanine, tyrosine, betaine, and inositol metabolism. Furthermore, metabolomic fingerprints were strongly interconnected with other soil properties and biotic components, such as nematodes, bacteria, and fungi. In conclusion, integrating soil metabolomics with other soil analyses has proven to be a powerful approach for uncovering biotic and abiotic interactions and has enhanced our understanding of the biocrust.

Poster 14

Microclimatic refugia: canopy plants as thermal buffers

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In an era of increasing extreme climatic events, understanding how ecosystems mitigate heat at the scale of living organisms is critical. We investigated the thermal buffering capacity of the most abundant canopy species at Doñana National Park (Southern Spain), a Mediterranean biodiversity hotspot highly vulnerable to climate change. Here, the microhabitats provided by canopies offer a vital defense for plant recruitment. Utilizing a high-resolution network of 216 microclimatic sensors, we quantified the thermal buffering of nine dominant canopy species (*Cistus calycinus, C. libanotis, Cytisus grandiflorus, Erica scoparia, Halimium halimifolium, Juniperus turbinata, Salvia rosmarinus, Stauracanthus genistoides*, and *Ulex australis)* against their immediate open-ground counterparts.

Our results demonstrate that these species act as "thermal buffers". Specifically, this buffering capacity is significantly accentuated during extreme heat events: while open soil temperatures reached 50°C, we recorded reductions of up to 20°C under the canopy. Species like *Juniperus turbinata* showed the highest efficiency, drastically reducing maximum heat exposure. Maintaining canopy structural diversity is thus a fundamental strategy to extend the thermal limits of life and safeguard biodiversity in increasingly hostile Mediterranean environments.

Poster 15

Keeping it cool: How leaf morphology modulates thermal safety

Margaux Didion-Gency ORCID iD[1], Jordi Martinez-Vilalta ORCID iD[1,2], Eva Castells ORCID iD[1,2], Kate Johnson ORCID iD[1], Gerard Sapés ORCID iD[1]
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More frequent and increasingly hot droughts are pushing plants closer to their thermal limits worldwide, altering carbon uptake, growth, and survival. Plants can adjust their thermal tolerance either physiologically through higher cell thermal limits or morphologically through greater heat dissipation surfaces. However, the relative importance of physiological and morphological adjustments remains poorly understood.
This project investigated the influence of leaf morphology on leaf thermal tolerance, particularly though evaporative cooling, under both well-watered and drought conditions. Young potted shrubs of *S. pterophorus* were subjected to a range of non-lethal to lethal temperatures, and morphological and physiological leaf traits were measured, including thermal limits, photosynthetic efficiency, leaf temperature, stomatal conductance, transpiration, specific leaf area, leaf perimeter, leaf angle, and curling.
By linking leaf form and function under heat and water stress, this research provide novel fundamental insights on how plants adjust to heat and drought and help determine their resilience to future climate.

Poster 16

Estimating V_{cmax} temperature dependence: a novel approach

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Understanding the thermal response of photosynthesis is essential for predicting how vegetation responds to global warming. Across biomes, plants exhibit consistent shifts in the optimum temperature (T_{optV}) of Rubisco's maximum carboxylation rate (V_{cmax}). However, intraspecific variability in this functional trait is often overlooked as data collection based on full A-Ci curves is difficult, potentially limiting our ability to assess species' adaptive capacity. Using a portable gas exchange system (LI-6800), we generated high-density response curves (~15 points) of net assimilation rate under ambient CO_2 and saturating light (A_{sat}) across a range of leaf temperatures. We then applied a newly developed method to estimate T_{optV} by converting A_{sat} to V_{cmax} and fitting a peaked Arrhenius function, allowing the precise derivation of activation and deactivation energies as well as the entropy term for individual leaves. This approach enables more extensive measurements and provides a more accurate characterization of V_{cmax} temperature dependence. We applied this approach to investigate variations in T_{optV} among 10 tree species (five individuals per species), with similar age and growth conditions, in a semi-deciduous tropical restored forest. Our results revealed substantial intraspecific variation in T_{optV}, exceeding interspecific variability, suggesting strong resilience within this plant community to ongoing global warming.

Poster 17
Seed yield under field heat stress is associated with seed number and harvest index rather than seed size in interspecific quinoa populations

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Quinoa (*Chenopodium quinoa* Willd.) is a highly nutritious, gluten-free crop valued for its high protein and iron contents, but its cultivation in hot environments is limited by reproductive heat stress (HS) that reduces pollen viability, seed set, and yield. To assess genetic variation under HS, we evaluated broad-sense heritability and trait associations for yield-related traits in two interspecific populations using F3:4 families grown under field HS in summer 2025. The populations were derived from crosses between heat-sensitive Andean parents CQ8 or CQ9 and a common heat-tolerant wild *Chenopodium berlandieri* parent (CB3). Both populations experienced vegetative and reproductive HS (35–40°C), but CQ8 × CB3 encountered more severe reproductive stress because flowering and seed filling coincided with temperatures exceeding 40°C. Depending on survival, one to four plants per family were harvested and evaluated for dry weight, seed weight, 10-seed weight, harvest index, and estimated seed number. Family-mean broad-sense heritability for seed number and harvest index was higher in CQ8 × CB3 than in CQ9 × CB3, whereas 10-seed weight remained highly heritable in both crosses. However, its weak negative correlation with family-mean seed weight indicated that reproductive performance under HS depended more on seed number and biomass partitioning than on seed size.

Poster 18
How do mature penduculate oak (*Quercus robur*) tree canopies respond to heat waves and elevated CO_2? A study on canopy temperature and leaf heat tolerance

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The response of plants to changing environmental conditions is of global importance due to their role in provision of ecosystem services. Plant growth under elevated carbon dioxide (eCO_2) is known to induce physiological changes in trees. Such changes may alter leaf energy balance, potentially reducing cooling and increasing canopy temperatures, with implications for future plant functioning. However, evidence from natural forest ecosystems on how eCO_2 affects canopy thermal regimes remains limited. This research aimed to i) quantify the impact of eCO_2 on canopy temperatures, ii) determine the upper limits of leaf heat tolerance and its acclimation to a natural heatwave, and iii) consider the combined impact of eCO_2 and the heatwave on the thermal safety margin (maximum canopy temperature - leaf heat tolerance) of mature *Quercus robur* at the Birmingham Institute of Forest Research Free-Air CO_2 Enrichment (BIFoR-FACE) facility. Canopies in eCO_2 were approximately 1 °C warmer than those in ambient CO_2, with the largest differences occurring during high-temperature periods. Leaf heat tolerance (based on chlorophyll fluorescence) was high and increased with heatwave exposure, however thermal safety margins reduced both with high temperatures and eCO_2. These findings indicate that eCO_2 may increase vulnerability to warming in mature temperate forest canopies.

Poster 19

Contrasting effects of elevated CO_2 on oak seedling photosynthesis during single and consecutive heatwave events

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Climate change is expected to increase both atmospheric CO_2 concentrations and the frequency of extreme heat events, yet their combined effects on tree physiology remain unclear. In a glasshouse, we investigated the interactive effects of ambient and elevated CO_2 on photosynthesis (A_{net}) and stomatal conductance in oak seedlings exposed to no heatwave, a single heatwave, or two consecutive heatwaves.
Elevated CO_2 did not enhance photosynthetic rates under control conditions. However, during the first heatwave event, seedlings grown under elevated CO_2 maintained higher A_{net} compared to those grown under ambient CO_2, indicating a short-term mitigation of heat stress. In contrast, during the second heatwave, seedlings previously exposed to an initial heatwave showed increased photosynthesis relative to plants experiencing heat stress for the first time. This acclimation effect was particularly evident under ambient CO_2. These findings suggest that elevated CO_2 may confer temporary resilience to acute heat stress but does not necessarily enhance tolerance to recurrent heat events. Conversely, seedlings grown under ambient CO_2 exhibited stronger acclimatory responses to repeated heatwaves, potentially indicating greater physiological plasticity under fluctuating thermal stress. Our results highlight the importance of considering heatwave recurrence when predicting forest responses to future climate scenarios.

Poster 20

Thermal and heat-shock responses of photosynthesis in *Sorghum* with contrasting leaf width

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Understanding how *Sorghum bicolor* varieties maintain photosynthesis under rising temperatures is critical for developing heat-resilient crops. We examined physiological, metabolic, and biochemical responses to heat stress in a narrow-leaf and broad-leaf sorghum genotype. Plants were subjected to controlled heat treatments, including a six-day heat shock, and assessed using metabolomics, transcriptomics, gas-exchange temperature responses, and in vitro activities of key C4 enzymes (PEPC, Rubisco, NADP-ME) from 20 to 45°C.
The heat-tolerant narrow-leaf genotype consistently sustained higher photosynthetic rates at elevated temperatures and improved performance during heat shock. This resilience was supported by both constitutive and inducible accumulation of heat-shock proteins, osmoprotectants, raffinose-family oligosaccharides, and glutamate-related amino acids. Enhanced ROS-scavenging capacity and suppressed SnRK1 signalling likely reduced oxidative damage. In contrast, the heat-sensitive broad-leaf genotype showed reduced photosynthesis and distinct acclimation pathways.
Across genotypes, photosynthetic optima peaked at 30–35°C, with declines at higher temperatures driven mainly by biochemical limitations. Although enzyme activities increased with temperature, the broad-leaf genotype exhibited early PEPC and Rubisco deactivation and low NADP-ME stability at 45°C. Superior enzyme stability and metabolic homeostasis underpinned the narrow-leaf genotype's thermal resilience, highlighting key traits for breeding climate-resilient C4 cereals.

Poster 21

Hotter than hot: using passive heating in a Douglas-fir canopy to assess the effect of extreme heat on photosynthesis

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Extreme hot temperatures can lead to reductions in gross primary productivity, alterations to metabolic processes, and increased mortality risk. Heat exposure in plants depends on leaf energy balance and species' thermotolerance. Soil water availability can impact transpiration-driven cooling, yet little is known on how it could affect leaf thermotolerance. Understanding how environmental conditions mediate the upper limits of leaf thermotolerance therefore is critical to predicting forest carbon uptake patterns under heat and drought. In this study, in situ passive heaters were employed to increase branch temperatures in the upper canopy of second-growth Douglas-fir trees in the HJ Andrews Experimental Forest in western Oregon, U.S.A.. Study trees were subject to irrigation treatments in which half of the sampled trees received 5mm of water depth equivalent each day throughout the growing season. Using dark-adapted fluorescence, gas exchange, and non-structural carbohydrates as proxies for photosynthesis and metabolism, we found a negative relationship between heat intensity and carbon fixation, particularly in developing foliage. Further, we found faster recovery following heat events in the late-season compared to early-season. These findings highlight the importance of understanding how heat wave timing impacts leaf development and seasonal phenology.

Poster 22

Honami dynamics and crop photosynthesis in a warming, turbulent atmosphere

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Increasing extreme heat events intensify the environmental variability experienced by crops, including wind-driven movements that generate rapid light fluctuations influencing photosynthesis. Understanding how crops function under these combined heat stress and dynamic light scenarios may offer new opportunities to enhance yield. Yet current photosynthetic models do not account for wind-induced motion, largely because these complex movements are difficult to quantify. Honami—wave-like motion propagating across crop canopies—is a common response to turbulent airflow and can now be detected and measured using modern computer vision approaches. Recent work from our group shows that canopy waves actively modulate the light environment through biomechanical traits, influencing the photosynthetic performance of crops experiencing Honami. Building on this, we aim to identify the physical properties of canopy waves and incorporate them into photosynthetic models that explicitly include wind effects. As global warming continues to shift optimal wheat-growing regions and increase atmospheric turbulence, understanding how canopy biomechanics interact with dynamic light is critical for predicting yield and selecting cultivars suited for future climates. We are currently analyzing aerial drone video of wheat fields using multiscale differential dynamic microscopy to characterize canopy wave dynamics under a range of environmental conditions, including those intensified by extreme heat.

Poster 23

Balancing heat and drought tolerance: evidence for physiological trade-offs in *Quercus ilex*

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Hot droughts pose a growing threat to forest ecosystems, yet the physiological mechanisms underlying tree acclimation remain poorly understood. Trade-offs between drought tolerance and thermotolerance, and the influence of canopy microclimate, are rarely addressed. We studied long-term precipitation exclusion (over 20 years) in mature *Quercus ilex* trees to assess drought and heat tolerance. During summer 2025, physiological responses were measured in control and droughted trees, comparing sun-exposed and shaded leaves. Key metrics included thermal tolerance of photosynthesis and cell integrity (T_{EL}), gas exchange, and plant water status.
Thermal tolerance varied with site, treatment, and canopy position. Control trees generally had higher T_{EL} than droughted trees, though patterns differed between sites. Plant water potential showed limited treatment effects, suggesting hydraulic acclimation. Canopy position strongly influenced thermotolerance. In droughted trees, sun-exposed leaves had higher T_{EL} than shaded leaves in Spain, but in France, shaded leaves had higher T_{EL} than sun-exposed leaves. Under control conditions, shaded leaves consistently showed higher T_{EL}. Long-term drought acclimation modifies heat responses in a canopy-position-dependent manner. Canopy microclimate also plays a critical role in shaping thermotolerance, emphasizing its importance for predicting forest resilience under climate change.

Poster 24

Native tree species shows divergent strategies in leaf and branch level water economy but no acclimation along an elevational gradient in Rwanda

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Warmer and drier conditions are challenging the water economy of trees in a changing climate. Minimizing water losses of leaves and bark during drought as well as taking up water when these surfaces are wet are strategies to cope with this. We studied the effects of temperature on leaf and branch level water economics in a transplant experiment along a natural elevational gradient in Rwanda (Rwandatree.com). Minimum leaf and bark conductance (gmin and *g*bark; at both 25°C and 45°C) as well as foliar and bark water uptake (FWU and BWU) were measured in a broad range of native tree species.
There were large species differences for all traits. Some species show a conservative strategy with both low loss and uptake of water, while others show the opposite. In some species, however, water loss and uptake are decoupled, indicating different pathways for these fluxes. This may be caused by higher concentrations of trichomes facilitating water uptake but not necessarily increasing water loss. Acclimation was weak or absent for all traits. Water losses were much higher at 45°C compared to 25°C, highlighting the strong effect of extreme heat on plant water conservation.

Poster 25

Ineffective transpirational cooling threatens dry tropical forest leaves

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The essential roles that tropical forests including dry forests play in global carbon, water and nutrient cycles are threatened by predicted extreme temperatures in future climates. Our understanding of leaf thermoregulation suggests that leaves may avoid overheating of leaves via transpirational cooling reducing chances of physical damage to the leaves. However, observed leaf temperatures from tropical forests are regularly substantially higher than air during the warm dry summers. To understand the reason, we analysed long-term, high-frequency leaf temperature records, together with leaf trait and microclimate data from an Indian tropical forest where leaves reach very high temperatures. We show that steady-state leaf energy balance model accurately predicts the observed leaf temperatures. We then show that the simulated stomatal conductance is substantially low that it prevents effective cooling via transpiration, and this resulted from vapor pressure deficit driven stomatal closure. We further analyse the climate space to tentatively extend our results to other regions of the dry tropics, and we suggest that these forests may also not be able to cool their leaves effectively. This may add to concerns of the adverse effects of rising temperatures on the function and health of these forests.

Poster 26

Leaf heat tolerance predicts photosynthetic and survival responses to experimental heat extremes in 18 dipterocarp species in Peninsular Malaysia

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Tropical forests in Southeast Asia store large biomass and support high timber productivity, yet climate change-induced heat extremes may threaten future wood production. Therefore, understanding and predicting heat tolerance are essential for achieving climate change adaptation in forestry. However, studies on heat tolerance remain limited for tropical timber species. Here, we investigated interspecific variation in leaf heat tolerance in relation to photosynthetic and survival responses to experimental heat extremes in saplings of 18 dipterocarp species, a major timber group in Southeast Asia. Leaf heat tolerance was evaluated using T_{50}, the temperature causing a 50% reduction in initial maximum quantum efficiency (F_v/F_m). Species occurring in seasonally dry climates exhibited higher T_{50}, higher post-heat F_v/F_m, and greater survival than species restricted to ever-wet climates. T_{50} was positively associated with post-heat F_v/F_m and survival across species. These findings suggest that species adapted to seasonally dry climates possess greater resilience to heat extremes, and that T_{50} provides a practical and effective index of heat tolerance for tropical timber species.

Poster 27

Temperature dependence of leaf gas exchange and growth traits in tropical montane forest trees in Peninsular Malaysia

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Tropical montane forests occur in central Peninsular Malaysia and play key roles in soil conservation and biodiversity. Although global warming is expected to affect tree regeneration, the physiological and growth responses of montane tree seedlings to elevated temperatures remain poorly understood. Seedlings of four canopy tree species (*Agathis borneensis*, *Shorea platyclados*, *Exbucklandia populnea*, *Quercus oidocarpa*) were raised at a higher elevation (1,400 m) and transplanted to two hotter lowland sites at 150 m and 40 m. Three, six, and twelve months after transplantation, maximum photosynthetic rates and dark respiration rates were measured across a temperature range of 15–40°C. The maximum quantum yield of photosystem II (Fv/Fm), growth and leaf traits were also recorded. Seedling growth was lower at the lowland sites than at the montane site, whereas Fv/Fm showed little variation among sites. Photosynthesis exhibited a unimodal response to temperature, with an optimum below 25°C at the higher elevation site and 25–30°C at the lower elevation sites, whereas respiration rates increased exponentially with temperature. Increased respiratory carbon loss under hotter conditions likely contributed to the reduced growth of transplanted seedlings at the two lower elevation sites.

Poster 28

Exploring patterns of molecular alteration in oilseed rape under recurring heat events

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Rising global temperatures are prompting more studies on their impacts on seed quality and on the stress-induced molecular regulations in crop species. Exposure to stress can modify plant response to future events through gene expression changes, the “stress memory” allows modifications to be maintained between events (Type I memory genes) or triggers heightened expression after a subsequent stress (Type II memory genes). These memory effects eventually lead to either the mitigation or amplification of the stress effect. We studied the transcriptome of *Brassica napus* (cv. Aviso) seeds from plants exposed to three different recurring heat stress sequences that varied in the recovery phase duration, aiming at (i) exploring the gene expression modifications under recurring or single heat events and (ii) identifying type I and type II 'memory genes' that modulate plant's responses to recurring heat stresses. Preliminary results indicate that elevated temperatures modulate biological processes related to morphogenesis and circadian rhythms. Both single and recurring heat events significantly alter responses to ROS, oxygen levels, and protein regulation. Clustering analyses identified clusters of ‘memory genes’ reflecting memory effects and associated with abiotic stress responses, metabolic homeostasis, transcriptional regulation, and anaerobic respiration. These insights open avenues for the breeding of climate smart crops under fluctuating heat conditions.

Poster 29

Physical mechanisms of stomatal gas exchanges at very high temperatures

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Extreme heat fundamentally alters the physics of leaf gas exchange, yet most physiological frameworks assume diffusion through dry air governs the movement of oxygen (O_2), carbon dioxide (CO_2), and water vapour. Recent work challenges this assumption by demonstrating that during transpiration water vapour dynamics fundamentally restructure the gaseous environment within leaves, most significantly at very high temperatures. As leaf temperature rises, increased vapour pressure in substomatal cavities dilutes O_2 and CO_2 partial pressures via Dalton's law, rendering these cavities strongly O_2-depleted relative to ambient air. Under such conditions, classical diffusion theory cannot explain the outward flux of photosynthetically produced O_2, as diffusive gradients favour inward movement. A physically consistent explanation arises when vapour-induced pressure gradients are considered. Even small pressure differences can drive non-diffusive mass flow through stomata, enabling O_2 export and biasing transport of all gases outward. This physical mechanism intensifies with temperature, shifting leaf gas exchange away from purely diffusive control and reducing water-use efficiency during heat stress.

Poster 30

Predicting forest responses to compound heat-drought extremes using a process-based modelling framework

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Extreme heat and drought increasingly threaten forest ecosystems. While the impacts of drought are increasingly represented in ecosystem models, mechanistic representation of heat stress remains rare, limiting our ability to predict the consequences of future extremes on forest functioning.

We present a conceptual framework to integrate heat stress into process-based ecosystem models, capturing both direct and indirect effects of high temperatures. Thermal, hydraulic, and carbon dynamics are coupled by linking heat and hydraulic stress, while accounting for long-term feedbacks from different carbon allocation strategies. A key advancement is the incorporation of cumulative heat-dose functions that impair photosynthesis and tissue integrity based on realistic canopy temperature gradients. Associated repair mechanisms and temperature-dependent residual leaf conductance are explicitly represented.

These processes will be implemented in the LandscapeDNDC ecosystem model, parameterized using experimental measurements of species-specific heat tolerance, and evaluated with stand-level data on canopy temperatures, fluxes, and photosynthetic activity. Simulations across heat-drought scenarios will then allow quantifying species-specific responses and critical thresholds.

This framework translates state-of-the-art mechanistic knowledge of heat and coupled heat-drought stress into process-based models, providing a novel tool to identify conditions under which forests may approach functional limits under ongoing climate change.

Poster 31

The genomic basis of germination sensitivity to thermal extremes across the geographical range of the cliff species *Brassica incana*

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Extreme heat events are increasingly exposing plant populations beyond their historical thermal limits, yet it remains unclear whether tolerance to such novel extremes arises only after exposure or can emerge as a by-product of adaptation to local environments. In particular, the genomic basis of plant adaptation to extreme heat during early life stages remains poorly understood. Here, we tested whether local climatic conditions shape population variation in germination sensitivity to extreme temperatures and identified the genetic variants underlying tolerance to heat beyond the currently experienced range. Using the cliff species *Brassica incana*, we quantified germination responses of 14 wild populations to local temperatures and unprecedented thermal extremes. We then combined whole-genome sequencing with genome-wide association analyses, genome-environment associations and scans of spatial genomic differentiation to detect signatures of selection linked to thermal sensitivity. Populations from warmer environments showed higher germination performance under extreme conditions, indicating that local adaptation can confer tolerance to novel environments. Genomic regions associated with germination response to hot extremes displayed signatures of selection and were enriched for genes involved in heat and drought tolerance. Overall, our results suggest that local adaptation can extend the upper thermal limits of germination, enhancing population resilience under increasing extreme heat.

Poster 32

A temperature-dependent protein phase transition underlies bidirectional cold and heat stress tolerance in rice

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Extreme temperature events driven by global climate change pose a major threat to rice productivity, yet the molecular mechanisms by which rice plants perceive and integrate cold and heat stress remain largely unresolved. Using forward genetic approaches, we identify OsSRO1c as a dual temperature-stress regulator that undergoes reversible, temperature-dependent phase transitions. Under cold stress, OsSRO1c forms liquid-like condensates and co-condenses with the transcription factor DREB2b, enhancing its transcriptional activity and activating cold-responsive genes, thereby promoting cold tolerance. In contrast, under heat stress, OsSRO1c transitions into a dispersed soluble state and interacts with the transcription factor OsNAP, leading to the induction of heat shock proteins and enhanced heat tolerance. These findings uncover a previously unrecognized mechanism by which a single protein senses and responds to bidirectional temperature stress through distinct phase states. Importantly, haplotype analysis identifies a naturally occurring elite OsSRO1c allele that is simultaneously associated with enhanced cold and heat tolerance, underscoring its strong potential for climate-resilient rice breeding. This dual functionality enables the coordinated improvement of tolerance to opposing temperature extremes through harnessing natural variation at a single genetic locus. Collectively, our work reveals a novel protein phase transition-dependent mechanism for temperature stress perception in rice and provides a promising genetic target for developing climate-smart rice varieties.

Poster 33
Rice root system architecture shows adaptive responses to high temperature stress
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There is a growing interest in cultivating rice in non-paddy irrigated systems to reduce its carbon footprint. The downside of this cultivation strategy is that the root system would be exposed to significantly higher temperatures without the temperature buffering effect of submergence. Our research aims to understand the changes in rice root system architecture and anatomy under elevated temperatures. Our findings indicate that an increase in temperature, leads to several architectural and anatomical changes the most interesting of which is the change in mass partitioning into crown roots from the primary root and shoot. Fluorescence imaging of phloem transport shows that though phloem unloading is severely reduced in the primary root, a lesser reduction is observed in the crown roots, hinting that there may be a metabolic preference which makes crown roots more resilient. Phytohormones, like ABA and auxin, could play a crucial role in the observed phenotypic changes, as the *aba2-1* and *aux1-3* show contrasting changes in overall biomass partitioning compared to wild type. We are currently exploring the molecular mechanisms governing these responses using transcriptomics and we hope these insights have the potential to facilitate the development of temperature-tolerant rice varieties better suited for upland cultivation methods.

Poster 34
Summer survival of temperate forage grasses in subtropical climates: the roles of thermal and water stress
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Summer survival of temperate forage grasses is the primary bottleneck for pasture persistence in subtropical South America, increasing costs and reducing resilience of pastoral animal production. The disappearance of mild summers over the last 20 years exacerbates this problem. Previously, we found that deficient nitrogen nutrition and the presence of flowering tillers markedly depress vegetative tiller survival, but root system size plays a minor role. Here we report how defoliation management interacts with summer conditions to regulate tiller fate under field conditions. Using controlled defoliation regimes imposed before and during summer, combined with contrasting water availability and shading treatments, we found that tiller survival exhibited a strong defoliation × summer environment interaction. Intense defoliation events substantially increased the risk of vegetative tiller death, particularly under water deficit and in tillers with reduced carbohydrate reserves. The response was associated with and impaired capacity to withstand high midday and early-afternoon irradiation. Tall fescue (*Loilum arundinaceum*) and orchardgrass (*Dactylis glomerata*) showed higher tolerance than perennial ryegrass (*Lolium perenne*). In undefoliated plants, mortality was not linked to short-lived thermal extremes, but to the cumulative seasonal load of high irradiation as summer progressed. These results identify residual leaf area and carbohydrate reserves as key management targets to buffer stress and improve persistence.

Poster 35
Contrasting heat tolerance strategies and productivity of evergreen and deciduous angiosperm forests

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The increasing frequency and intensity of extreme heat and drought events have emerged as a major constraint on terrestrial ecosystem productivity and stability. In this study, we combine plant heat and drought tolerance traits from sites worldwide, extract climatic variable and satellite-derived gross primary productivity (GPP) of each site, and then compare their differences and relationships between evergreen and deciduous angiosperm forests. We focus on how productivity and its stability respond to high-temperature and/or limited water conditions, and how these responses are coordinated with plant heat and drought tolerance. We found that evergreen species generally maintain higher and more stable productivity under environmental stress, indicating a greater capacity to buffer extreme conditions. In contrast, deciduous species often achieve higher instantaneous productivity under favorable environments, but their productivity declines more sharply during extreme events, likely due to their more vulnerable thermal and hydraulic strategies. This study provides physiological mechanistic insights into contrasting productivity responses between evergreen and deciduous forests, and helps to predict dynamics of forest carbon sequestration under future climate change scenarios.

Poster 36

The thermal cost of fast living: acquisitive strategies trade heat tolerance for rapid growth in tropical trees

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Extreme heat threatens tropical forest carbon uptake by pushing photosynthesis beyond thermal optima. While transpirational cooling can mitigate heat stress, this strategy depends on hydraulic function and may trade-off with safety. We tested whether photosynthetic thermal optimum (T_{opt}) aligns with leaf economics and hydraulic strategies in eight tropical tree species. We measured T_{opt} of the maximum rate of RuBP carboxylation (T_{OptV}), hydraulic vulnerability (P_{50}), wood density (WD), leaf mass to area ratio (LMA), and maximum stomatal conductance (g_{smax}), and we assessed trait coordination using multivariate analyses. As a result, despite T_{optV} showed no significant relationship with P_{50} (p=0.395), T_{optV} was strong coordination with other traits, increasing with WD (r=0.70) and decreased with g_{smax} (r=-0.68). Principal Component Analysis explained 82% of functional variation in two axes, showing that species cluster along a conservative-acquisitive spectrum. Conservative species (high WD, low g_{smax}) exhibited higher T_{optV} (up to 40.6°C), while acquisitive species (low WD, high g_{smax}) showed lower $T_{opt\ V}$ (down to 37.8°C). These findings challenge the simple T_{optV}-P_{50} hypothesis and suggest whole-plant functional syndromes, specially WD and stomatal regulation, better predict plant thermo tolerance. This suggests that conservative species may be more resilient to warming, with implications for tropical forest responses to climate change.

Poster 37

Leaf habit-based thermal tolerance of woody species: from ecophysiology to biogeography

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The increasing temperature fluctuations and drought events are posing a growing threat to plants. However, how plants tolerate multiple stresses and form their distributions remain poorly understood. For ecophysiology, we measured leaf heat tolerance (LHT) of 36 urban species during the record-breaking 2022 heat waves, and of 58 species from hot-dry and warm-wet habitats to explore their structural basis and coordination with drought tolerance. For biogeography, we measured LHT and cold tolerance of over 200 species from forests across China and calculated their distribution boundaries. We found that: (1) evergreen species suffered less leaf damage during the heat waves and exhibited higher LHT than deciduous species. LHT was significantly correlated with leaf mass per area (LMA), leaf thickness and thickness of spongy tissue. (2) Leaf heat and drought tolerance were weakly associated, while leaf economics linked closely with heat and drought tolerance through photosynthetic rate and LMA, respectively, with LHT primarily influenced by leaf habit. (3) The south boundary of deciduous species was limited by their LHT, whereas the north boundary of evergreen species was limited by their cold tolerance. Overall, LHT is linked with drought tolerance through carbon economics, and constrains species distribution boundaries, both influenced by leaf habit.

Poster 38

Irrigation strategy to enhance seedling resilience to compound heat-drought events in tree nurseries

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Compound heat-drought events are increasing in frequency and severity under climate change, threatening nursery seedling production and UK's woodland creation efforts. Advances in mid-range weather forecasting now enable prediction of these events 5-15 days ahead, creating a unique opportunity to develop targeted irrigation protocols that can optimise seedling physiology during an event and promote rapid recovery after. Our project combines ecophysiology and modelling approaches and focuses on field-grown seedlings of four native woodland species (*Quercus robur*, *Betula pendula*, *Alnus glutinosa*, and *Pinus sylvestris*). With controlled growth-chamber experiments, we are characterising seedling physiological responses to simulated heat-drought events, and assessing how 1) irrigation regimes immediately before the event and 2) prior exposure to drought-rewatering cycles modify these responses by inducing physiological 'memory'. These findings will inform field experiments in summer 2026 and be co-developed into practical decision-support tools with nursery stakeholders.

Poster 39

Warming constrains phenotypic plasticity and alters drought–shade trade-offs in European beech seedlings

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Phenotypic plasticity enables trees to cope with heterogeneous environments, yet its sensitivity to warming remains poorly understood. We investigated how elevated growth temperature alters plastic responses of *Fagus sylvatica* to drought and shade using a factorial experiment manipulating temperature, soil water availability, and light intensity under constant vapor pressure deficit. We quantified growth, biomass allocation, gas exchange, leaf water relations, hydraulic traits, and stem anatomy.

Warming reduced total biomass, leaf area, and carbon balance, while increasing transpiration and residual water loss. Crucially, elevated temperature constrained phenotypic plasticity, particularly for traits related to hydraulics, leaf water relations, and growth, thereby limiting the ability of seedlings to adjust to drought. Under water stress, warming impaired osmotic adjustment, reduced leaf safety margins, and disrupted trait coordination, indicating a narrowing of the functional response space. In contrast, under shaded and well-watered conditions, warming enhanced plasticity in leaf production and gas exchange, promoting a more acquisitive strategy based on low-cost leaves, albeit at the expense of hydraulic safety.

These results show that warming not only shifts trait means but also reshapes the magnitude and direction of plastic responses to co-occurring stressors. Temperature-induced reductions in plasticity may therefore critically constrain beech regeneration under future climates characterized by hotter, drier, and light-limited understory conditions.

Poster 40
Understanding leaf thermal tolerance from a carbon allocation perspective
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Leaf thermal tolerance is a key indicator of plant capacity to withstand both heatwaves and cold spells under climate change. However, the physiological mechanisms mediating variance in leaf thermal tolerance remain poorly understood. Carbon allocation provides a promising framework for understanding such variance in leaf thermal tolerance. Here, we investigated leaf thermal tolerance and carbon allocation metrics across 95 species sampled from six forests in China. Our results reveal that leaf cellulose concentration is positively associated with heat tolerance and starch concentration is negatively linked to cold tolerance, a pattern primarily driven by deciduous species. Meanwhile, starch indirectly enhances leaf heat tolerance through its positive association with cellulose. These findings indicate that both structural carbohydrates (SCs, e.g., cellulose) and non-structural carbohydrates (NSCs, e.g., starch) play distinct roles in shaping leaf heat and cold tolerance. This study demonstrates how carbon allocation regulates leaf thermal tolerance and provides a potential pathway for improving trait-based predictions of forest resilience under ongoing climate change.

Poster 41
Maintaining rubisco concentration linked to better photosynthetic performance in wheat following a simulated heatwave
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Heatwaves are becoming more frequent and intense and increasingly limit wheat productivity by constraining photosynthesis. However, variation in the physiological response of wheat to acute heat stress is not well characterised. In this study, we investigated the relationship between leaf Rubisco concentration and photosynthetic performance in wheat exposed to simulated heatwave conditions. A set of high-performance wheat genotypes was grown under controlled environments and subjected to short-term high-temperature episodes designed to mimic field-relevant heatwaves. Gas exchange measurements were combined with biochemical quantification of Rubisco to assess photosynthetic responses before and after heat stress. All genotypes responded by downregulating Rubisco concentration, but the amount of downregulation was variable, and genotypes that maintained higher Rubisco concentration were consistently associated with greater net CO_2 assimilation rates under heatwave conditions, driven primarily by improved carboxylation capacity. These findings indicate that maintaining Rubisco abundance may contribute to superior photosynthetic resilience during transient heat events and highlight Rubisco concentration as a potential physiological trait for improving wheat heat tolerance.

Poster 42

Source-derived signals determine sink productivity under heat stress in potato (*Solanum tuberosum* L.)

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Photosynthesis underpins plant productivity, yet rising global temperatures disrupt carbon assimilation and allocation, leading to severe yield penalties in temperate crops. Potato, globally important staple, is heat sensitive, as elevated temperatures impair photosynthesis, disturb source-sink coordination, and suppress tuberization. While effects of heat on sink are well documented, mechanistic role of source fitness in shaping sink productivity remains unexplored. To dissect source-sink dynamics under heat, we employed heat-sensitive (HS), heat-tolerant (HT) genotypes in self- (HS/HS, HT/HT) and reciprocal grafts (HS/HT, HT/HS). Plants were grown under control conditions (22/18°C) until tuber initiation and then exposed to heat stress (32/28°C). Heat reduced tuber yield, with tuberization inhibited in HS/HT grafts, whereas HT/HS plants successfully tuberize. Gas exchange analyses revealed HS scions showed compensatory increase in photosynthetic rate under heat, whereas HT maintained stable photosynthetic performance. Transcriptome profiling of leaves and stolons identified carbon metabolism and transport as central regulators, supported by metabolite analyses of soluble sugars and starch. HS/HT showed sharp decline in stolon starch, critical for tuber bulking. Genetic validation using *SP6AOE* and *SWEET11OE* lines further demonstrated source-derived signals determine sink strength and are disrupted under heat. Collectively, our findings establish source fitness as key determinant of tuber productivity under elevated heat.

Poster 43

Photosynthetic traits: early warning indicators of oak decline due to water stress in the Iberian Peninsula

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Oak forests, which are of great ecological and economic value in the Iberian Peninsula, have experienced rapid decline in recent decades. Photosynthetic traits, such as *Vcmax*, are fundamental to understanding the physiological alterations of trees affected by water stress, as they provide information on plant health and their responses to pathogens and adverse environmental conditions. Therefore, they can serve as an early warning indicator of forest decline. Multiple studies have confirmed their reliability in crops, but not in tree species such as *Quercus ilex*.
In this research, with the help of remote sensing, we delve into the role of photosynthetic traits as critical early warning indicators for the early detection of pre-decline symptoms in *Quercus ilex* during periods of maximum stress. Using field observations, such as canopy damage assessment and hyperspectral images obtained in the study area, we identify and empirically examine photosynthesis along with other vegetation parameters and indices.
This analysis allowed us to effectively distinguish asymptomatic trees from symptomatic ones. In addition, we performed temporal simulations using the *SCOPE* radiative transfer model to parameterise photosynthesis. This approach allowed us to quantify key functional traits of plants, such as *Vcmax*, which differed significantly between asymptomatic and symptomatic trees.

Poster 44

Resilience of woody fungal pathogens under water stress and ecophysiological responses of olive trees

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Olive branch dieback is a re-emerging disease in rainfed olive orchards in Spain, mainly caused by *Neofusicoccum* species (Botryosphaeriaceae), and associated with crop intensification, restrictions on pruning-residue burning, and increasing drought. Lepra disease, caused by *Phlyctema vagabunda*, has also been linked to shoot dieback. This study evaluated the behavior of *Neofusicoccum mediterraneum*, *N. parvum*, and *P. vagabunda* under laboratory, field, and controlled stress conditions. Mycelial growth across temperature and water potential gradients showed that *Neofusicoccum* species tolerated high temperatures (30 °C) and low water potentials (-15 MPa), whereas *P. vagabunda* was sensitive to heat and water stress. Pathogenicity was evaluated in a 13-year-old orchard using ten major Spanish olive cultivars, revealing cultivar-dependent responses: ‘Gordal Sevillana’ exhibited the greatest necrosis length and branch mortality, whereas ‘Picudo’ was the most resistant. Previous field observations have linked higher susceptibility to Botryosphaeriaceae species in woody crops to underwater-stress conditions. A pot experiment using ‘Gordal Sevillana’ showed that water stress did not modify pathogen behavior, as water-stressed plants and non-stressed plants were equally susceptible to *N. mediterraneum*. Overall, *Neofusicoccum* species maintained pathogenicity under warm conditions and limited water availability, highlighting the interaction between woody pathogens and abiotic stress in perennial crops.

Poster 45

In situ evidence for a critical temperature threshold driving stomatal re-opening and widespread photosynthesis-conductance decoupling in tropical trees

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Extreme heat is intensifying across the tropics, yet we lack in-situ data on how approaching critical temperatures affects the physiology of mature forest canopies. A possible response that challenges major climate-vegetation model assumptions is the decoupling of photosynthesis and stomatal conductance (g_s), where g_s stays high while photosynthesis declines.
We aimed to quantify how widespread photosynthesis-gs decoupling is across tropical tree species from contrasting climates and test whether it trades off with sensitivity to heat, drought, or vapour pressure deficit (VPD). We measured in-situ temperature responses (22-48°C, VPD=2.5kPa) of photosynthesis, g_s, and g_1 in 80 mature individuals encompassing 16 species along an elevation gradient in Panama, as well as leaf-level turgor loss point and VPD sensitivity.
All species showed an exponential rise in g_1 with temperature, indicating widespread decoupling. Although both photosynthesis and g_s declined above their thermal optima, stomatal re-opening at extreme temperatures (~45°C) occurred in 55% of curves. Notably, the temperature at which g_s increased again was higher in lowland than upland individuals, indicating greater heat tolerance in trees from hotter environments. We found no evidence of coordination between heat, drought, and VPD sensitivity.
These results provide rare field-based evidence that tropical trees exhibit diverse temperature-dependent stomatal strategies that may shape forest resilience under future heatwaves.

Poster 46

Revealing the thermal limits of gas exchange in giant tropical trees

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Tropical forests absorb ca. 25% of anthropogenetic carbon emission. Within these systems, the largest 1% of trees (giant trees) contribute to around 50% of tropical carbon sink. These giants, exposed above the canopy, are expected to be more vulnerable to extreme heat, but we have limited information about their heat physiology. During a hot-dry season, we assessed diurnal leaf thermoregulation and gas exchange patterns of 11 giant Amazonian trees (50–175cm DBH) from different species – including for the largest Amazonian tree species.
The species varied largely in their maximum leaf temperature (T_{leaf}; 30.6–42.3 °C) and leaf-to-air temperature differences (ΔT; -2.3–9.0 °C). However, their stomatal thermal sensitivity (T_{gs-50}; leaf temperature at which stomata conductance decreased by 50%) varied only by 3°C (30.1–33.2 °C). Larger trees exhibited lower T_{leaf}, ΔT and T_{gs-50}, indicating that smaller giants are more heat-tolerant (higher T_{gs-50}) whereas larger giants are more heat-avoidant (lower T_{leaf}).
Our results reveal alternative strategies among giant tropical tree species to cope with thermal stress, which are strongly modulated by tree size. Understanding gas exchange variation and responses to heat amongst giant tropical trees can help us predict the thermal limits of the tropical forests carbon sink.

Poster 47

Co-regulation of water use and canopy temperature in desert trees

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Plants employ a range of water-use strategies to withstand limitations in water supply and increases in atmospheric demand. At the same time, water-use strategies alter canopy energy balance, leading to changes in canopy temperature that can impact photosynthesis, creating distinct tradeoffs between water and temperature regulation. However, the extent of these tradeoffs is a key uncertainty in understanding plant responses to hydroclimatic stress. Here, we use a unique dataset of near-surface remotely sensed retrievals of canopy conductance, transpiration, and temperature to assess how desert trees co-regulate their water status and temperature. We leverage a moisture gradient and seasonality in temperature to evaluate species-specific plant responses to both isolated (cool, dry and hot, wet) and combined (hot, dry) water and temperature stress and compare them to reference (cool, wet) conditions. We find that species exhibit different water-use strategies in response to supply- and demand-driven water stress, but exhibit similar responses to thermal stress. Under most conditions, plants face tradeoffs between hydraulic function and avoiding thermal stress. However, when both supply and demand are high, water and canopy temperature regulation can become decoupled. Altogether, our findings reveal two unexpected plant behaviors that may be particularly vulnerable to climate change.

Poster 48

Leaf hyperspectral reflectance predicts grain yield in heat-tolerant wheat

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Scaling up estimates of grain yield is critical for developing high-yielding, heat-tolerant wheat varieties. However, conventional yield assessment under heat stress remains constrained by time-consuming and costly multi-environment field trials. Leaf hyperspectral reflectance provides an integrated measure of key physiological processes such as photosynthesis and dark respiration efficiency, and nutrient composition that are directly linked to grain yield. Here, we leveraged this mechanistic relationship to develop a non-invasive, high-throughput phenotyping tool for predicting wheat yield. We used 1,396 paired whole-plot yield and leaf hyperspectral reflectance data from 203 wheat genotypes grown under varying temperature conditions and compared four modelling approaches: partial least squares regression (PLSR), random forest, support vector regression, and extreme gradient boosting. PLSR applied to the full light spectrum (400–2500 nm) achieved the highest prediction accuracy (R^2 = 0.80; root mean square error (RMSE) = 0.77). This performance suggests that spectral signatures capture the net effect of heat stress on critical physiological determinants of yield. Our results show, for the first time, that predictive models leveraging leaf spectral traits can deliver rapid and accurate yield estimates. This approach enables crop improvement programs to make more robust selections, for heat-tolerant wheat.

Poster 49

Integrated physiological, metabolic, and transcriptomic analysis reveals divergent heat stress responses in *Chenopodium quinoa* and *Amaranthus cruentus*

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Heatwaves are increasing in frequency and intensity, threatening crop productivity and resilience. Understanding the mechanistic basis of crop heat stress responses is therefore critical. We studied physiological, metabolic, and transcriptomic responses of quinoa (*Chenopodium quinoa*, C_3) and amaranth (*Amaranthus cruentus*, C_4) to a simulated heatwave, with emphasis on post-stress performance. Heat exposure reduced net CO_2 assimilation, stomatal conductance, electron transport rate, and midday leaf water potential in *A. cruentus*, while intrinsic water-use efficiency remained unchanged. In contrast, *C. quinoa* maintained stable photosynthetic performance and leaf water status. Antioxidant responses differed between species, with higher SOD and CAT activities in *C. quinoa* and increased APX activity in *A. cruentus*, indicating distinct antioxidant strategies. Metabolomic analyses revealed divergent metabolic adjustments: *A. cruentus* accumulated amino acids, soluble carbohydrates, and showed enrichment of pathways related to carbon metabolism, redox balance, and osmoprotection, whereas *C. quinoa* preferentially enriched amino acid catabolism, organic acid metabolism, and the tricarboxylic acid cycle. Transcriptomic analyses indicated upregulation of genes related to heat shock protection, proteolysis, antioxidant defense, and transport in *A. cruentus*, while *C. quinoa* predominantly regulated ABA signaling, ubiquitination, and antioxidant-related transcripts. These results highlight contrasting yet effective strategies enabling both species to cope with extreme heat events.

Poster 50

Heat stress responses in heat-tolerant C4 crops: Insights from *Setaria* and Sorghum

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Heat stress is a major environmental constraint that severely limits crop productivity worldwide. Even modest increases in the mean global temperature (1–2 °C) are projected to cause substantial yield losses (3–7%) in major food crops. Global average temperatures have already risen by more than 1 °C over the past century and are expected to continue to increase due to ongoing climate change. C4 plants, including the model grass *Setaria viridis* and the crop species sorghum (*Sorghum bicolor*), are generally considered thermotolerant and are predicted to outperform C3 plants at elevated temperatures. However, our recent findings indicate that brief episodes of high-temperature stress during critical developmental stages can have profound long-term consequences. Although plants exposed to transient heat stress often exhibit normal growth and no visible stress symptoms for several weeks following treatment, significant reductions in seed yield and quality are observed at later developmental stages. Furthermore, we have identified specific components of the heterotrimeric G-protein complex as key regulators of thermotolerance in *Setaria* and sorghum. Overexpression of these proteins leads to rapid activation of heat stress responsive transcription factor networks and sustained photosynthetic activity, thereby mitigating the detrimental effects of heat stress.

Poster 51

Arbuscular mycorrhizal fungi buffer crop performance under thermal extremes: a global meta-analysis

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Extreme heatwaves are intensifying globally, threatening crop productivity and agroecosystem stability. Arbuscular mycorrhizal fungi (AMF) can enhance plant stress tolerance, but their effectiveness under thermal extremes remains unclear. We conducted a global meta-analysis to quantify AMF effects on plant performance under high temperature (HT), low temperature (LT), and optimal temperature (OT). The dataset included studies using single AMF strains, multi-species consortia, and AMF combined with plant growth–promoting bacteria. AMF inoculation significantly improved plant morphological, physiological, and biochemical traits under HT compared with non-inoculated controls, although effect sizes were generally smaller than under OT. Root colonization was largely maintained at HT, indicating functional persistence of the symbiosis. Responses under LT were more variable but remained positive overall. Multi-species AMF consortia and AMF–bacteria combinations showed greater resilience across temperature extremes than single isolates. Heat stress was also associated with shifts in plant gene expression linked to stress responses and symbiotic functioning. Overall, AMF mitigate, but do not fully offset, the negative effects of thermal stress. Our findings highlight the potential of optimized microbial consortia to enhance crop resilience under increasingly frequent temperature extremes.
(this poster will be presented on Wednesday 3rd June)

Poster 52

Optimal partitioning drives carbon allocation responses to climate in Mediterranean pine reforestations

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Reforestation is increasingly proposed as a nature-based solution to mitigate climate change, although its capacity to enhance the terrestrial carbon sink remains uncertain under warmer and drier conditions. Here we analyse carbon dynamics in Mediterranean pine reforestation across a wide ecological gradient including elevational variation and four native pine species with contrasting drought tolerance (*Pinus halepensis, P. pinaster, P. nigra* and *P. sylvestris*). Combining remote sensing information and dendrochronological plots, we estimated proxies of forest productivity and growth (EVI, NPP and aboveground biomass increment, ABI) and evaluated long-term carbon allocation patterns using the ABI:NPP ratio. Carbon uptake and allocation were strongly controlled by climate, increasing with water availability but decreasing with higher temperatures. Across species and environments, patterns were consistent with optimal partitioning theory, showing that drought-tolerant species allocate proportionally less carbon aboveground, while warmer and drier conditions promote greater belowground investment. Relationships were non-linear, with saturation of productivity and aboveground allocation above 750 mm precipitation and under temperatures below 12°C. Pines showed a remarkable acclimation capacity to climatic stress through a plastic carbon allocation ratio. These results provide a framework for species selection and improve assessment of the potential and limitations of reforestation as a climate mitigation strategy.

Poster 53

Heat-driven evaporative demand intensifies transpiration sensitivity to soil drying in European beech

Hegarty Philip[1], Yanqiao Li[1], Dikshya Maharjan[1], Gerhard Schmied[1], Jana Zeppan[2], Nadine Ruehr[2], Bálint Jákli[1], Richard Peters[1], Tina Koehler[1], Mutez Ahmed[1]

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Vapour pressure deficit (VPD) is a key indicator of atmospheric dryness. Similar VPD values can result from low humidity or high temperature. In the latter, plants may experience both atmospheric drought and heat stress, requiring contrasting mechanisms: stomatal opening to promote transpiration and cooling, or closure to conserve water and protect hydraulics. How plants resolve this trade-off remains unclear. Using European beech in controlled environments, we disentangled the effects of heat- and humidity-driven VPD increases on plant water regulation under different soil water availability. We combined continuous measurements of transpiration and leaf water status with assessments of hydraulics and leaf and root morphology. Morphological traits and hydraulic conductance were unaffected by the VPD driver. However, when high VPD was driven by temperature, transpiration, and leaf water potential declined in wetter soil, revealing amplified sensitivity to drying. Heat-driven VPD also increased thermal tolerance thresholds. These findings indicate that critical atmospheric limits on transpiration are emergent, dynamic properties of plant–atmosphere interactions rather than static physiological limits. Understanding these dynamics is vital for predicting plant water use and survival in a warming world with more frequent, intense heatwaves.

Poster 54

Investigating the interplay between auxin and pH in fine-tuning root growth responses to heat stress

Pravarthika Prakash ORCID iD, Aneesh Lale, Rahul Bhosale

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Plant roots are essential for water and nutrient uptake, making their architecture and growth critical determinants of crop productivity. Rising soil temperatures driven by climate change pose a significant threat to root function and plant yield. However, the mechanisms underlying root responses to heat stress remain poorly understood. Our previous work indicates that external pH plays an important role in regulating plasma membrane (PM)-ATPases during root heat stress responses. In parallel, auxin differentially regulates PM-ATPase activity, and heat stress modulates auxin levels and signaling in plant roots. Nevertheless, the molecular mechanisms coordinating pH and auxin signaling under heat stress remain unclear. Here, we investigate the interplay between auxin and pH in regulating PM ATPase activity and root growth during heat stress. We show that high temperature inhibits root growth and reduces auxin levels and signaling output. Disruption of the auxin pathway, either pharmacologically using auxinole or through knockout mutants, similarly impairs root growth under heat stress. Moreover, post-stress recovery is compromised under more acidic conditions (pH 4.8) and when PM ATPase activity is inhibited. Together, our findings suggest that auxin signaling and pH-dependent regulation of PM ATPases are critical for root thermoresponse and represent targets for improving crop resilience.

Poster 55

Predicting cumulative heat damage of *Eucalyptus* species under experimental heat plus drought stress

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Climate warming is increasing the frequency of extreme heat but predicting tree species vulnerability remains difficult. To address this, we exposed ten *Eucalyptus* species from arid to humid habitats (mean annual precipitation= 340-1240 mm) to moderate drought stress followed by a five-day heatwave (maximum T_{air}= 45 °C) in a controlled experiment. Half the species were impacted with >20% crown dieback. Crown dieback and topkill among species were correlated with the leaf water potential at turgor loss point (π_{tlp}; R^2=0.70) and peak leaf temperature (T_{leaf_max}; R^2=0.53), respectively. Functional traits were better correlated to observed differences in maximum quantum yield of PSII (F_v/F_m) among plants under drought stress alone, including xylem pressure inducing 50% loss of hydraulic conductivity due to embolism, leaf size, and leaf mass per area (R^2=0.13-0.26). Fewer traits were correlated to the F_v/F_m of heat- and drought-stressed plants (R^2=0.11-0.17). These results highlight that (1) key plant functional traits associated with drought-induced tree dieback often fail to capture responses to heat plus drought stress, but (2) traits such as π_{tlp} and T_{leaf_max} were critical predictors of dieback among species. These findings reveal trait limitations under compound stress and identify key predictors for prioritising climate resilience of *Eucalyptus* forests.

Poster 56

Prolonged daily heat exposure impairs photosynthetic electron transport in *Arabidopsis thaliana*

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The rapidly warming climate is driving increasingly frequent and intense heat waves worldwide, posing major challenges to plant metabolism, growth, and survival. Despite the central role of photosynthesis in plant productivity, the effects of prolonged heat stress on the primary reactions of photosynthesis remain poorly understood. Here, we studied how long-term heat exposure affects growth and photosynthetic performance in the model plant *Arabidopsis thaliana*. Plants were exposed daily to high temperature (38.5 °C) for 4h throughout the growth period. Prolonged heat stress reduced plant biomass by ~60% and photosynthetic pigment content by about 30%. In contrast, the abundance of the main pigment–protein complexes that drive the photosynthetic electron transport chain, namely photosystem II (PSII) and photosystem I (PSI), remained comparable to control plants. However, the performance of both photosystems was significantly impaired, indicating functional limitations. Strikingly, the Cytochrome b_6f complex, which mediates electron transfer between photosystems, was reduced by 30–40%. We propose that downregulation of the cytochrome b_6f complex restricts electron delivery to PSI, thereby limiting photosynthetic performance. This response likely represents an adaptive mechanism that prevents PSI over-reduction and photodamage, protecting the integrity of the photosynthetic machinery at the cost of reduced photosynthetic efficiency and growth.

Poster 57
Impact of long-term heat stress on photosystem II repair dynamics in *Arabidopsis thaliana*
Iida-Maria Rantanen, Laura Laihonen, Tutta Tomberg, Linda Vuorijoki, Paula Mulo, Marjaana Rantala
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Photosynthesis is the key determinant of plant growth and thus sustains all life on Earth. Global warming and increasingly frequent heat waves impair photosynthesis, posing a major threat to crop production. Photosynthetic electron transfer chain is catalyzed by pigment-protein complexes, Photosystems (PS)I and PSII, which are interconnected via Cytochrome b_6f complex. Both photosystems are surrounded by external light harvesting complex (LHC) antennas. PSII-LHCII complex is particularly sensitive to damage caused by accumulation of reactive oxygen species (ROS) under abiotic stress conditions. To counteract this, plants have evolved PSII-repair mechanism in which damaged PSII complexes are replaced with newly synthesized functional units. During PSII repair cycle PSII-LHCII disassembles, reaction center protein D1 is degraded and replaced by newly synthetized copy, which is then integrated into the reassembled PSII-LHCII complex. Here, we show that long-term heat stress in *Arabidopsis thaliana* leads to increased ROS formation and in accumulation of non-functional PSII-LHCII complexes. To assess PSII damage, we inhibited *de novo* synthesis of the D1 protein using lincomycin and examined the effects of high-temperature stress on PSII function. Our results demonstrate that PSII activity declines dramatically in heat-stressed samples compared to control plants, suggesting impairment of the PSII repair cycle.

Poster 58
Mutation load and adaptation under chronic heat in *Arabidopsis thaliana*
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Recent studies show that heat stress substantially increases the mutation rate in *Arabidopsis thaliana.* An elevated mutation rate could facilitate adaptation but also impose a mutational load that reduces plant performance.

To investigate how heat-induced mutations align with plant performance, we conducted a mutation accumulation experiment in *Arabidopsis thaliana* under chronic heat stress and under control conditions. We tracked *de* novo mutations occurring in *Arabidopsis thaliana* genomes exposed to chronic heat stress over nine generations using whole-genome sequencing. Subsequently, we quantified germination timing and growth in offspring of the ancestral plant and for selected lines at generation one, five, and nine in a common garden experiment.

Heat-treated lines showed reduced plant performance in early generations, consistent with an initial fitness cost. By generation nine, however, these lines displayed phenotypic recovery, despite having accumulated a substantial amount of *de novo* mutations.

These results indicate that heritable, adaptive responses to sustained heat can emerge within nine generations in *Arabidopsis thaliana*, even under a markedly elevated mutation rate. Elevated mutational input under heat stress does not necessarily constrain adaptation and may instead coincide with an evolutionary response to stressful heat.

Poster 59

Evaluating the consistency of diurnal trends of vapour pressure deficit across terrestrial ecoregions

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Increasing air temperatures cause a co-occurring increase in Vapour Pressure Deficit (VPD). The negative impacts of increasing VPD on plant growth are well documented, but importantly - increasing daytime VPD reduces plant water-use-efficiency, whereas night time increases may accelerate whole-plant water losses owing to residual conductance across leaves and stems.

Here we use the ERA5 climate reanalysis (1950-2025) to ask if long-term changes in nighttime VPD are proportional to daytime changes. Next, ERA5 has higher uncertainty in less instrumented tropical regions, so we attempt to corroborate VPD trends with land skin temperature (LST) retrievals derived from the MODIS satellite remote sensing record (2002-2025).

We find increases in VPD are widespread and particularly prominent across Africa, the Middle East, the southern Amazon, the Gran Chaco, and the western United States. Daytime trends are 40-50% higher than nighttime trends, and these diurnal discrepancies are largest across Amazonia and the Congo basin. This diurnal difference is also greatest in hotter seasons. Uncertainty remains because while daytime VPD trends are correlated with satellite-derived LST trends, the nighttime LST and VPD trends are not well correlated. Although less severe than daytime VPD increases, nighttime VPD increases will exacerbate plant water stress across most of the planet.

Poster 60

Forest multifunctionality declines along temperature and aridity gradients in Mediterranean regions

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In Mediterranean ecosystems, the months with the highest temperatures coincide with the lowest precipitation, exposing forests to high levels of environmental stress and compromising multiple ecosystem functions. We assessed the effects of high temperatures and aridity on ecosystem multifunctionality across four forest types dominated by *Pinus halepensis*, *P. pinaster*, *Quercus faginea*, and *Q. ilex*. We selected 67 forest plots along a gradient of temperature and aridity across the Iberian Peninsula. Multifunctionality was quantified from ten ecosystem functions encompassing over- and under-story biomass and productivity, forest regeneration, detrital stocks, plant and fauna diversity, and soil carbon storage. When considering all forest types together, forest multifunctionality declined with increasing temperature of the driest month (DMT). However, when analysed separately by forest type, multifunctionality decreased significantly with DMT only in the two pine-dominated forests. Individual ecosystem functions exhibited contrasting responses to temperature and aridity, indicating function-specific sensitivities to climatic stress. Additionally, we found a significant role of edaphic conditions (N and P) in modulating climate-function relationships. Overall, our study reveals the effect of high temperatures and aridity on a multidimensional assessment of forest functioning, providing new insights into which Mediterranean forest types may be most vulnerable to ongoing warming and increasing aridification.

Poster 61

Thermal thresholds for carbon assimilation decline in the wet tropical forest of Costa Rica

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Climate change is threatening the capacity of tropical forests to remain a carbon sink. Warming temperatures, high vapor pressure deficit (VPD), and excess light can reduce CO_2 photosynthetic uptake. However, disentangling the role of these frequently correlated factors remains a challenge. Here, we use quantum efficiency of photosystem-II in the light (ϕPSII) as an indicator of photosynthetic efficiency. We study top-of-canopy leaves for six common tree species at an eddy covariance tower at La Selva Biological Station, Costa Rica. We find that declines in ϕPSII are most strongly triggered by plant temperature exceeding air temperature (Tair), while light and VPD are less prominent drivers. Leaf and canopy temperatures follow Tair until a threshold of around 29°C and 27°C Tair, respectively, after which plant temperature exceeds Tair. We show that these thresholds are more frequently exceeded around or just after noon, and result in decreased carbon assimilation at both leaf and canopy scales. The lower canopy-scale thermal threshold could be explained by a combination of mixed shading in the larger field of view compared with leaf measurements. This study helps to better understand carbon uptake response to increasing heat across scales and calls for caution when using midday satellite remote-sensing retrievals.

Poster 62

From heat stress to recovery: water availability determines tree resilience to extreme temperatures

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Extreme heatwaves are increasing in frequency and intensity, often coinciding with high vapour pressure deficit and soil water limitation. While immediate impacts of heat stress on plant metabolism are increasingly recognised, less is known about how trees recover from heat stress and how water availability influences the transition from reversible stress responses to lasting functional impairment.
Here, we synthesize experimental findings across temperate tree species to examine how water availability modulates heat responses and recovery from the leaf to the whole-tree scale. Leaf-level measurements across broadleaf species show that sufficient water supply enables evaporative cooling, limiting leaf overheating and promoting rapid recovery following heat stress, whereas mild drought elevates leaf temperatures and delays recovery. Results from a combined heat and drought experiment in a conifer species further demonstrate that drought amplifies heat impacts by constraining transpiration and inducing metabolic and hydraulic impairment. Although assimilation and whole-tree carbon balance recovered rapidly, reductions in leaf and stem hydraulic conductance persisted, coinciding with altered post-stress carbon allocation, increased carbohydrate storage, and delayed belowground translocation.
Together, these findings indicate that compound heat-drought events result in excessive canopy heating and hydraulic impairment, which limit recovery success and promote stress legacies.

Poster 63

Increasing heat resilience of photosynthetic carbon assimilation to improve crop productivity

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Building climate resilience in Australia's grain crop production is crucial to the future supply of nutritious food within water limited environments. Extreme climate events and variable rainfall are threatening crop yield and quality necessitating new solutions to ensure optimal water use within future cropping systems. We have sought to identify new biochemical solutions within C_3 and C_4 plants that confer improved responses to carbon assimilation and water-use-efficiency (WUE). We have identified the main biochemical targets which include the CO_2 fixing enzyme of the Calvin cycle ribulose-1,5-bisphosphate carboxylase / oxygenase (Rubisco) and its catalytic regulatory protein Rubisco activase (RCA). Our modelling suggests that increasing the activity of Rubisco and the thermotolerance of RCA under elevated temperatures will provide increases to carbon assimilation under both well-watered and water deficit conditions. We have discovered Rubisco's from C_3 and C_4 plants that have superior thermal responses to CO_2 fixation and would offer improved assimilation under future simulated climates. In addition, we have discovered RCA isoforms that have improved activity under elevated temperatures and are resilient to misfolding at elevated temperatures. The next step is to transplant these isoforms into key crops and test for improved performance under elevated temperature and water deficit conditions. An update of our research will be presented.

Poster 64

Weighing the options: a test of alternative stomatal optimisation models at high temperatures

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Stomatal optimisation models centre upon a fundamental tradeoff for plants: opening stomata promotes carbon uptake, but closing stomata prevents water loss. However, stomatal opening can occur at high temperatures, causing evaporative cooling which limits thermal damage to leaves. Under hot, dry conditions stomatal behaviour is therefore subject to another tradeoff: conservation of water versus the need to cool leaves below critical thermal thresholds.

Here, we present a series of stomatal optimality models and test how different strategies weighing carbon gain against hydraulic, respiratory, and/or thermal costs influence predicted stomatal behaviour. We test these strategies against data from a whole tree chamber experiment in which *Eucalyptus parramattensis* trees were subject to a heatwave.

Under heatwave conditions, models with a hydraulic cost predict decoupling between photosynthesis and transpiration better than a conventional model. Incorporation of thermal and respiratory costs does not reduce the discrepancy between observations and models, suggesting that plants do not optimise their stomatal behaviour to avoid thermal damage.

Our results indicate that instantaneous optimisation models have limited capacity to capture leaf gas exchange at high temperatures. Given the increasing occurrence of heatwaves globally, it is important to account for extreme temperatures in predictive stomatal models.

Poster 65

Heat impacts on leaf-level tolerance to drought

Ilaine Silveira Matos ORCID iD, Namalu Abeysundara, Janithya Dishani Kodituwakku Dharmawardhane, William Wighton
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Hotter droughts are intensifying globally and causing major plant die-offs, yet how heat affects drought-tolerance at leaf level remains elusive. While it is well known that elevated temperature strongly and non-linearly increases leaf water loss, it is unclear how this impacts drought tolerance, typically measured as P50 or P88 (water potentials causing 50% or 88% loss of hydraulic conductivity from embolisms), since these traits are rarely measured at elevated temperatures. Hotter conditions may cause leaves to embolize faster and/or at less negative water potentials due to reductions in water viscosity and changes in water-xylem interactions. We tested this in leaves of five Eucalyptus species with contrasting drought tolerances. Preliminary results show that heated leaves (temperature ~45°C, vapour pressure deficit 6.7 kPa) embolize up to 3x faster than controls (25°C, 1.9 kPa) and had, on average, slightly less negative P50 (heat/control =-4.7/5.3 MPa) and P88 values (heat/control =-5.3/-6.4 MPa). This means that heated leaves can lose water transport capacity sooner than previously expected. This heat effect is not yet represented in hydraulic model frameworks but might be important to better predict plant mortality risk in a hotter and drier world.
change.

Poster 66

Heat-dose tolerance in tropical plants

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Increasing global temperatures and heat waves pose a major threat to plant survival, yet biome-specific limits of heat tolerance remain poorly understood. While tropical air temperature trends are well documented, measurements of leaf temperature - the driver of heat stress - are scarce, and the role of heat exposure duration in shaping foliar heat tolerance remains unknown. At La Gamba Tropical Station, Costa Rica, we investigated leaf-air temperature relationships and heat-dose effects on leaf heat tolerance in five tropical species. We hypothesized that (i) leaf temperatures are similar to air temperature due to transpirational cooling, and (ii) tropical species exhibit reduced heat-dose sensitivity compared with temperate species, reflecting adaptation to prolonged heat exposure. Leaf temperature measurements revealed that leaves exceeded air temperature by up to 18°C, reaching daily maxima of almost 50°C, even in the rainy season. Controlled heat treatments (38-64°C, 1-512 min) showed that slopes, representing the rate of decline of heat tolerance with exposure duration, and intercepts, reflecting baseline LT_{50} at short exposures, largely overlapped with temperate species. These findings suggest conserved heat-dose response mechanisms across biomes and highlight the need to assess whether heat acclimation potential in tropical plants can mitigate increasing heat stress under climate change.

Poster 67

Beyond lethal thresholds: dynamic heat-stress traits reveal adaptive genetic variation in wild *Arabidopsis thaliana*

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Heat extremes constrain plant performance, yet how genetic and ecological variation shape heat-stress responses remains unresolved. We quantified thermotolerance in *Arabidopsis* accessions from the Iberian–Moroccan collection, including five geographically structured genetic clusters (two relicts and three non-relicts; 12 accessions per cluster), to disentangle physiological responses and ecological drivers of variation. Accessions were exposed to heat stress (46, 48, and 50°C), and time-resolved chlorophyll fluorescence (Fv/Fm) was measured as an indicator of photosystem II efficiency. We derived curve-based thermotolerance traits to capture temporal cumulative performance (five times between 30 min and 4 hr), maximum physiological damage, and early stress sensitivity, as highly tolerant accessions did not reach a 50% lethal threshold.

Thermotolerance traits varied among genetic clusters and relict lineages showed the strongest differentiation. Moroccan relicts maintained high photosynthetic performance with minimal early decline, whereas Iberian relicts exhibited a rapid loss of photosynthetic efficiency. Genome-wide SNPs associated with thermotolerance exhibited elevated allele-frequency divergence and high genetic differentiation. Environmentally, thermotolerance was subordinated to the geographic and environmental variation within each genetic cluster’s range. Our results demonstrate that curve-based metrics capture hidden natural variation in thermotolerance, outperform classical estimates, and link dynamic physiological responses to geo-ecological gradients and adaptive genetic divergence.

Poster 68

Climate-origin distance and functional traits predict heat tolerance of urban trees under climate warming

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Urbanization together with climate warming pose important threats to the survival and functioning of urban vegetation, particularly ornamental species that may fail to acclimate to new climates. We analyzed the thermal tolerance limits of 17 urban trees in Córdoba (Spain), differing in origin (native vs. exotic), leaf habit (evergreen vs. deciduous), and biogeographic region (Mediterranean, Temperate or Sub-tropical). At species level, we measured photosynthetic fluorescence at nine thermal intervals (25º- 60ºC) to obtain the thermal damage thresholds of PhotoSystem II (T_{crit}, T_{50}, and T_{90}) and linked it to climate-origin distance and leaf and wood traits. Native Mediterranean and temperate exotics showed the highest thermotolerance. In contrast, subtropical exotics were the most heat-sensitive, particularly those with greater climate-origin distances, which showed earlier PSII damage (low T_{crit}) and a steeper decline in PSII performance with increasing temperature. T_{crit} and T_{50}, positively associated with conservative traits, mainly wood density and leaf mass per area. These findings highlight careful species selection for urban planning, as tropical species used as ornamental may perform poorly in drier climates.

Poster 69

Efficiency-safety tradeoffs in leaf carbon, hydraulic and thermal traits: economics and safety as hubs

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South China Botanical Garden, Chinese Academy of Sciences, China. University of Chinese Academy of Sciences, China

The increasing severity of global warming and drought has caused significant disruption to leaf carbon gain, highlighting the urgent need to understand how plants balance contrasting demands between resource acquisition efficiency and safety under stress. However, it remains poorly understood how plants modulate this conflict across carbon, hydraulic and thermal adaptation strategies.
Here we measured six leaf traits that represent the efficiency and safety of carbon, hydraulic, and thermal regulation across 102 species from five forests ranging from low to high precipitation and temperature.
We found a general efficiency-safety trade-off within economic, hydraulic, and thermal traits, respectively, mainly affected by the opposing effects of climate and leaf habit on efficiency and safety traits. Furthermore, safety traits are closely coordinated in the same direction whereas directions of associations between efficiency traits are varying, indicating leaf functions are potentially unified by a safety spectrum. Specifically, carbon traits dominate in both trait network and structural equation model, and leaf habit influence all traits, suggesting that leaf economics are key to integrate different leaf functions.
Our findings highlight the central hub roles of economics and safety in leaves across diverse hydrothermal environments, which will enhance our understanding of how plants coordinate different functions and provide new insights to trait-based models for predicting future vegetation.

Poster 70

Evaluating UV-B seed priming effects on vegetative tomato heat tolerance

Eduardo Zelada ORCID iD[1], Christoph Geilfus[2], Axel Mithöfer[3], Wagdy Sobeih[4], Mike Roberts ORCID iD[1], Ian Dodd ORCID iD[1]
[1]Lancaster University, United Kingdom. [2]Hochschule Geisenheim University, Germany. [3]Max-Planck-Institut fur chemische Okologie, Germany. [4]Lightworks Poly, United Kingdom

Rising temperatures are increasingly threatening tomato (*Solanum lycopersicum*) production worldwide. Whether seed priming treatments mitigate detrimental effects of long term heat stress on tomato is not clear. We developed an ultraviolet-B (UV-B) seed priming treatment to evaluate physiological responses of primed and non-primed well irrigated plants (cv. Alisa Craig) under control (26/20°C) and heat stress (40/32°C) for 7 days. Although heat stress similarly impacted photosynthesis, biomass and stomatal anatomy parameters in both treatments, primed plants had occasionally lower stomatal conductance and elevated leaf temperatures, with a significant relationship between these traits ($R^2 = 0.36$, $p = 0.015$). Isotope discrimination analysis also showed that primed plants had an altered carbon and nitrogen coupling metabolism, suggesting a distinct water conservation strategy. Heat stress significantly increased ABA concentration irrespective of priming but suppressed JA biosynthesis overall. Primed plants maintained more stable JA levels under heat stress, suggesting jasmonate involvement in heat stress response. Under polytunnel conditions (48/24°C), a comparable physiological response was observed in primed plants using an F1 tomato hybrid. Since UV-B seed priming affected tomato physiological responses, we aim to elucidate priming-induced genetic and hormonal mechanisms upon prolonged heat stress.

Poster 71

Rethinking thermal tolerance: seasonal dynamics and exposure duration shape leaf thermal safety margins in temperate trees

Jana Zeppan, Clara Arnold, Anna Sontheim, Pia Labenski, Nadine Ruehr
Karlsruhe Institute of Technology, Germany

Leaf thermal tolerance (e.g. Tcrit and T50) and thermal safety margins (Leaf temperature – T50) are widely used to assess plant heat resistance. While these thresholds are often assumed to be static, they may vary seasonally and are strongly dependent on the measurement methods, such as the heat exposure duration. Here, we investigate how seasonality and heat exposure duration influence thermal tolerance and thermal safety margins in a pot experiment with seven temperate tree species.
We found Tcrit and T50 to vary markedly across the season, with seasonal shifts exceeding interspecific differences. Moreover, increasing exposure duration from 15 to 240 min reduced estimates of T50 and Tcrit by up to 5°C, indicating that commonly used short-duration assays strongly overestimate thermal tolerance. We propose deriving dynamic thermal safety margins by applying a heat-dose framework that integrates temperature and exposure duration to better capture cumulative heat stress under natural conditions. Together, our results demonstrate that accounting for the dynamic nature of thermal tolerance is essential for ecologically meaningful assessments of plant vulnerability to heat stress.

Poster 72

Thermal signals of drought stress: predicting forest decline under extreme heat conditions

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University of Cordoba, Spain

Abstract text
Extreme heat events associated with climate change are increasing in frequency and intensity, exacerbating water stress and contributing to forest decline in Mediterranean oak ecosystems. This study evaluates the potential of thermal remote sensing–derived metrics to predict forest decline severity and incidence in the southeastern Iberian Peninsula (Co rdoba, Spain), a region highly exposed to recurrent heat extremes.

We combined field-based visual assessments of tree health (severity and incidence levels) with a comprehensive set of thermal and spectral variables derived from airborne data acquired on the same dates. These variables include annual NDVI and EVI, canopy temperature metrics (mean, maximum, minimum, and standard deviation), air temperature, relative humidity, temperature–air temperature differentials (Tc–Ta), Crop Water Stress Index (CWSI), temperature covariance, and flight-based temperature variability metrics (range, relative range, and variance), as well as multi-year aggregated variables. A temporal framework incorporating lagged variables from previous years was used to assess their predictive capacity.

Random Forest models were implemented to identify the most relevant predictors and evaluate model performance across different classification schemes. Results indicate that canopy temperature–based indices, particularly those integrated into water stress indices such as CWSI, are the most influential predictors of current forest health status. Additionally, maximum canopy temperature and CWSI consistently emerged as key variables for predicting temporal changes in forest condition.

Overall, our findings demonstrate that thermal remote sensing metrics, especially when aggregated into physiologically meaningful indices, provide valuable insights

into forest decline dynamics and have significant potential for early detection and monitoring of drought-induced stress.

List of participants

Role	First name	Last name	Affiliation*	Country
Selected speaker	Spoorthi	Aladahalli Nagaraju	The University of Queensland	Australia
Invited speaker	Annapurna	Allu	IISER Tirupati	India
Selected speaker	Hanna	Amoanimaa-Dede	University of New England	Australia
Poster presenter	Luiza Maria	Aparecido	University of Utah	United States
Poster presenter	Pieter	Arnold	Australian National University	Australia
Organising committee & *New Phytologist* Editor	Owen	Atkin	Australian National University	Australia
Organising committee	Cristina C.	Bastias	University of Cordoba	Spain
Delegate	Frederik	Baumgarten	University of Basel	Switzerland
Invited speaker	Joanne	Bennett	Gulbali Institute, Charles Sturt University	Australia
Poster presenter	Maxwell	Bergström	EPFL & WSL	Switzerland
Poster presenter	Nicole	Bison	The University of British Columbia	Canada
Poster presenter	Marion	Boisseaux	CNRS CEFE	France
Delegate	Giovanni	Bortolami	EPFL	Switzerland
Poster presenter	Eva	Burgunder	University of Basel	Switzerland
Poster presenter	Erick	Calderon Morales	Hawkesbury Institute for the Environment	Costa Rica
Poster presenter	Francisco Javier	Cano	ICIFOR-INIA, CSIC	Spain
Invited speaker	Elizabete	Carmo-Silva	Lancaster University	United Kingdom
Poster presenter	Francesc	Castanyer	INAGEA, Agro-Environmental and Water Economics Institute	España
Poster presenter	Lohen	Cavieres	Universidad de Concepción	Chile
Poster presenter	Martina	Chacón	IANIGLA-CONICET	Argentina
Delegate	Alex	Cheesman	James Cook University	Australia
Poster presenter	Han	Chen	South China Botanical Garden, Chinese Academy of Sciences	China
Poster presenter	Tino	Colombi	University of Nottingham	United Kingdom
Selected speaker	Daniel	Cowan-Turner	Australian National University	Australia
Poster presenter	Inmaculada	Criado-Navarro	Instituto de Agricultura Sostenible (IAS-CSIC)	España

Role	First name	Last name	Affiliation*	Country
Poster presenter	Virginia	Crisafulli	Centro de Investigaciones sobre Desertificación	España
Selected speaker	Kristine	Crous	Western Sydney University	Australia
Poster presenter	Margaux	Didion-Gency	Ecological and Forestry Applications Research Center (CREAF)	Spain
Selected speaker	Jen	Diehl	NASA Goddard Space Flight Center & University of Maryland	United States
Delegate	Emma	Docherty	University of Leeds	United Kingdom
Invited speaker	Adriane	Esquivel Muelbert	University of Cambridge	United Kingdom
Poster presenter	Mateus	Fabbris	University of São Paulo (USP)	Brazil
Poster presenter	Hafiz Umar	Farooq	King Abdullah University of Science and Technology	Saudi Arabia
Selected speaker	Aidan	Farrell	The University of the West Indies	Trinidad and Tobago
Poster presenter	Sophie	Fauset	University of Plymouth	United Kingdom
Selected speaker	Joanna	Feehan	Michigan State University & Carnegie Science	United States
Invited speaker & Organising Committee	Andrew	Feldman	NASA GSFC/University of Maryland	United States
Delegate	Joerg	Fettke	University of Potsdam	Germany
Delegate	Jaume	Flexas	Universitat de les Illes Balears	España
Poster presenter	Alice	Gauthey	University of Birmingham	United Kingdom
Poster presenter	Oula	Ghannoum	Western Sydney University	Australia
Selected speaker	Julia	Green	University of Arizona	United States
Selected speaker	Kerry-Anne	Grey	University of Oxford	South Africa
Session Chair & *New Phytologist* Editor	Charlotte	Grossiord	EPFL & WSL	Switzerland
Poster presenter	Anna	Haigh	Oregon State University	United States
Poster presenter	Brandon	Hastings	University of Nottingham	United Kingdon
Poster presenter	Cross	Heintzelman	EPFL	Switzerland
Invited speaker	Rocio	Hernandez-Clemente	University of Córdoba	Spain
Delegate	Tanja	Hofmann	University of Illinois	United States
Poster presenter	Hampus	Holmberg	University of Gothenburg	Sweden
Delegate	Elena	Hoyle	University of Nottingham	United Kingdom
Invited speaker & Organising Committee	Kevin	Hultine	Desert Botanical Garden	United States

Role	First name	Last name	Affiliation*	Country
Selected speaker	Aelys	Humphreys	Stockholm University	Sweden
Selected speaker	Rufus	Isaacs	Michigan State University	United States
Selected speaker	Martijn	Jansen	Radboud University - Wageningen University	the Netherlands
Poster presenter	Akhil	Javad	University of Leeds	United Kingdom
Invited speaker	Joanna	Kacprzyk	University College Dublin	Ireland
Delegate	Ashwini	Kalyan	University of Nottingham	United Kingdom
Delegate	Steve	Kannenberg	West Virginia University	Unites States
Poster presenter	Kiyosada	Kawai	JIRCAS	Japan
Invited speaker	Michael	Kearney	The University of Melbourne	Australia
Poster presenter	Tanaka	Kenzo	JIRCAS	Japan
Delegate	Tina	Koehler	Technical University of Munich (TUM)	Germany
Poster presenter	Leonidas	Kougiteas	Normandie Université	France
Poster presenter	Andrew	Kowalski	University of Granada	España
Selected speaker	Alyssa	Kullberg	EPFL	Switzerland
Selected speaker	Uttam	Kumar	Ben-Gurion University of the Negev	Israel
Poster presenter	Pia	Labenski	Karlsruhe Institute of Technology (KIT)	Germany
Poster presenter	Lucrezia	Laccetti	University of Naples Federico II	Italy
Poster presenter	Xuelei	Lai	National Key Laboratory of Crop Genetic Improvement	China
Poster presenter	Aneesh	Lale	University of Nottingham	United Kingdom
Poster presenter	Fernando	Lattanzi	INIA Uruguay	Uruguay
Session Chair & *New Phytologist* Editor	Tracy	Lawson	University of Illinois / University of Essex	United States
Invited speaker	Andy	Leigh	University of Technology Sydney	Australia
Poster presenter	Qiannan	Leng	South China Botanical Garden, Chinese Academy of Sciences	China
Delegate	Yanqiao	Li	Technical University of Munich	Germany
Poster presenter	Igor	Lima	University of Campinas	Brazil
Invited speaker	Hua	Lin	Xishuangbanna Tropical Botanical Garden, CAS	China
Delegate	Roman Mathias	Link	TUD Dresden Technical University	Germany
Poster presenter	Yao	Liu	Northumbria University	United Kingdom

Role	First name	Last name	Affiliation*	Country
Poster presenter	Hui	Liu	South China Botanical Garden, Chinese Academy of Sciences	China
Poster presenter	Rosana	López Rodríguez	Universidad Politécnica de Madrid	Spain
Poster presenter	Na	Luo	South China Botanical Garden, Chinese Academy of Sciences	China
Poster presenter	John	Mackenzie	Australian National University	Australia
Poster presenter	Surbhi	Mali	CSIR - Institute of Himalayan Bioresource Technology	India
Delegate	Maren	Mansika	University of Oslo	Norway
Poster presenter	Renee	Marchin Prokopavicius	Western Sydney University	Australia
Poster presenter	María tomas	Marcos Palacios	University of Córdoba	Spain
Poster presenter	María Isabel	Márquez-Pérez	University of Córdoba	Spain
Delegate	Andrea	Martín Díaz	Estación Biológica de Doñana (EBD-CSIC)	Spain
Selected speaker	William	Matthaeus	Trinity College Dublin	Ireland
Invited speaker, Organising Committee & *New Phytologist* Editor	Belinda	Medlyn	Western Sydney University	Australia
Invited speaker	Sean	Michaletz	The University of British Columbia	Canada
Poster presenter	Kali	Middleby	French National Institute for Research and Development	France
Poster presenter	Yan	Moraes	University of Cambridge	United Kingdom
Poster presenter	Bryn	Morgan	Massachusetts Institute of Technology	United States
Selected speaker	Cleber Juliano	Neves Chaves	Universidade Estadual de Campinas (UNICAMP)	Brasil
Session Chair & *New Phytologist* Editor	Carl	Ng	University College Dublin	Ireland
Delegate	Bach	Nghiem	University of Nottingham	United Kingdom
Organising committee	Adrienne	Nicotra	Australian National University	Australia
Delegate	Daniel	Noble	Australian National University	Australia
Session Chair	Richard	Norby	University of Tennessee	United States
Poster presenter	Joy	Ojo	University of New England	Australia
New Phytologist Editor-in-Chief	Maarja	Öpik	University of Tartu New Phytologist	Estonia
Poster presenter	Enrique	Ostria-Gallardo	Universidad de Concepción	Chile
Poster presenter	Sona	Pandey	Donald Danforth Plant Science Center	United States

Role	First name	Last name	Affiliation*	Country
Selected speaker	Nattiwong	Pankasem	University of California San Diego	United States
Selected speaker	Kathelyn	Paredes Villanueva	Instituto Nacional de Pesquisas da Amazônia (INPA), Brasil	Bolivia
Poster presenter	Elisa	Pellegrino	Scuola Superiore Sant'Anna	Italy
Poster presenter	Antonio J.	Pérez-Luque	Institute of Forest Sciences (ICIFOR) INIA-CSIC	Spain
Poster presenter	Hegarty	Philip	Technical University of Munich (TUM)	Germany
Staff – Events & Promotion Manager	Christine	Phillips	The New Phytologist Foundation	United Kingdom
Delegate	Xavier	Picó	Estación Biológica de Doñana (EBD-CSIC)	Spain
Staff – Managing Editor, *New Phytologist*	Helen	Pinfield-Wells	The New Phytologist Foundation	United Kingdom
Selected speaker	Brad	Posch	Desert Botanical Garden	United States
Poster presenter	Pravarthika	Prakash	University of Nottingham	United Kingdom
Poster presenter	Marjaana	Rantala	University of Turku	Finland
Poster presenter	Iida-Maria	Rantanen	University of Turku	Finland
Selected speaker	Mukund	Rao	Lamont-Doherty Earth Observatory	United States
Invited speaker	Sasha	Reed	U.S. Geological Survey	Unites States
Poster presenter	William	Reinar	University of Oslo	Norway
Delegate	Miquel	Ribas-Carbo	Universitat Illes Balears	Catalunya
Poster presenter	Sami	Rifai	Adelaide University	Australia
Poster presenter	Ginés	Rodríguez-Castilla	University of Cordoba	Spain
Poster presenter	Mili	Rodriguez-Caton	IANIGLA- CONICET	Argentina
Invited speaker	Celia M.	Rodriguez-Dominguez	IRNAS-CSIC	Spain
Invited speaker	Sergey	Rosbakh	Leibnitz University Hannover	Germany
Poster presenter	Nadine	Ruehr	Karlsruhe Institute of Technology	Germany
Poster presenter	Ilaine	S Matos	Adelaide University	Australia
Delegate	Gerard	Sapes	CREAF Campus UAB	Spain
Selected speaker	Demi	Sargent	Western Sydney University	Australia
Poster presenter	Robert	Sharwood	Western Sydney University	Australia
Poster presenter	Camille	Sicangco	Hawkesbury Institute for the Environment	Australia
Delegate	Dhanush S	Srikanthan	University of Potsdam, Golm-Potsdam	Germany

Role	First name	Last name	Affiliation*	Country
Poster presenter	Matthias	Stegner	University of Innsbruck	Österreich
Selected speaker	Marcelo	Sternberg	Tel Aviv University	Israel
Selected speaker	Christopher	Still	Oregon State University	United States
Poster presenter	Harihar Jaishree	Subrahmaniam	University of Hamburg	Germany
Selected speaker	Victoria	Terry	Vrije Universiteit Amsterdam	the Netherlands
Invited speaker	Madhav P.	Thakur	University of Bern	Switzerland
Volunteer	Francisco	Tomás-Riera	University of Córdoba	Spain
Invited speaker	Fernando	Valladares	CSIC Spain	España
Poster presenter	Sonia	Vega	Universidad de Córdoba	España
New Phytologist Editor	Nathalie	Verbruggen	Université libre de Bruxelles	Belgium
Organising committee	Rafael	Villar	University of Cordoba	Spain
Poster presenter	Yang-Si-Ding	Wang	South China Botanical Garden, Chinese Academy of Sciences	China
Invited speaker	Dani	Way	Australian National University	Australia
Delegate	Albert	Wissing	PlantDitech - Evivia Business Consultancy	Germany
Poster presenter	Eduardo	Zelada	Lancaster University	United Kingdom
Poster presenter	Jana	Zeppan	Karlsruhe Institute of Technology	Germany