Biodiversity for mountain resilience: seeds in the landscape

Hugh W. Pritchard
Royal Botanic Gardens Kew, Wakehurst Place
h.pritchard@kew.org

1. Introduction to Kew Science
2. Persistence and use of seeds in the landscape
3. **Alpine and mountain seed germination**

7 July 2019

Royal Botanic Gardens Kew

Seed germination of alpine and mountain species

Hugh W. Pritchard
h.pritchard@kew.org

defra
Department for Environment Food and Rural Affairs

EcoSeed
Seed performance in a changing climate

The University of Warwick

Outline

1. Thermal control of germination (traits) – connecting micro- with macro-scale modelling

2. Alpine and mountain species seed germination

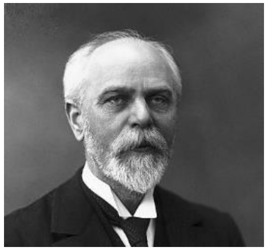
Charlotte Seal

Eduardo Fernandez-Pascual

Rosangela Picciau

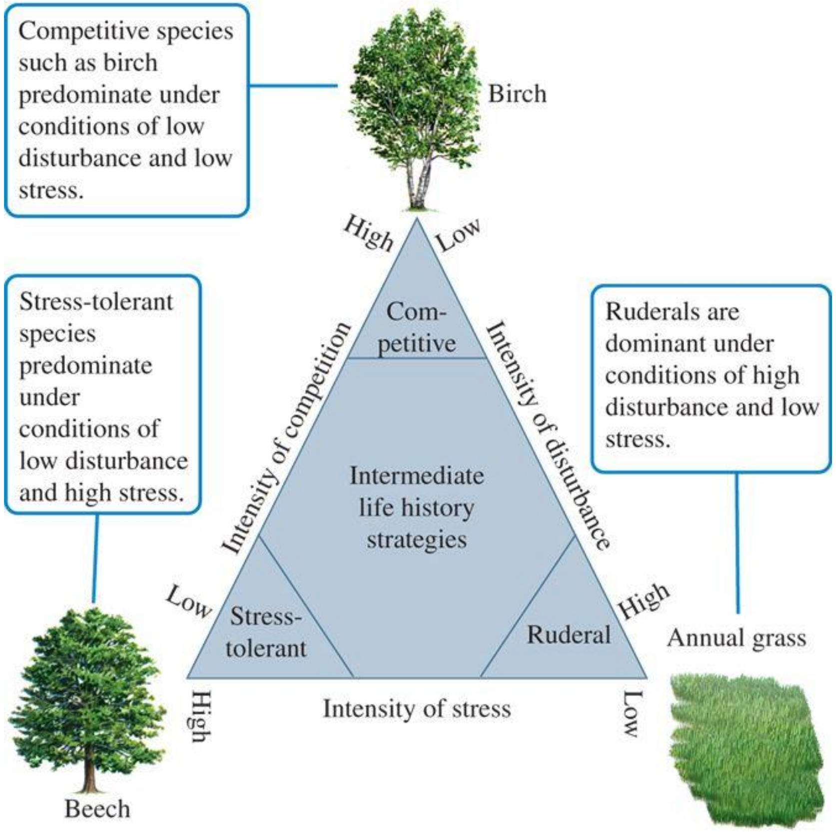
Elena Castillo-Lorenzo

The origins of trait-based ecology



Raunkiaer 1934
(Life forms)

Grime 1977
(Plant strategies)



Acknowledgement:
Borja Jimenez-Alfaro

The global spectrum of traits

Adult plant height (m)

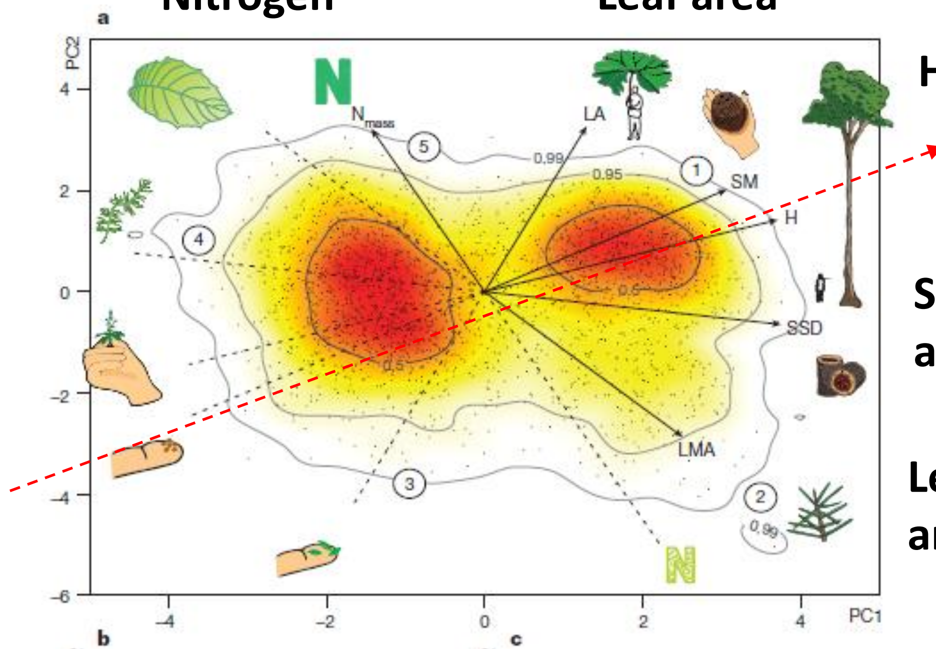
Stem specific density (mg mm^{-3})

Leaf area (mm^2)

Leaf mass per area (g m^{-2})

N content per unit leaf mass (mg g^{-1})

Diaspore mass (mg)



Diaz et al (2016) The global spectrum of plant form and function. *Nature* 536

Acknowledgement:
Borja Jimenez-Alfaro

How do seed traits matter?

frontiers in Plant Science

(2014)

Seed germination strategies: an evolutionary trajectory independent of vegetative functional traits

*Gemma L. Hoyle[1], Kathryn J. Steadman[2], Roger B. Good[3,4], Emma J. McIntosh[1], Lucy M. E. Galea[1] and Adrienne B. Nicotra[1]**

IAVS

Journal of Vegetation Science **27** (2016) 637–645

FORUM

Seed germination traits can contribute better to plant community ecology

Borja Jiménez-Alfaro, Fernando A.O. Silveira, Alessandra Fidelis, Peter Poschlod & Lucy E. Commander

Journal of Ecology

British Ecological Society

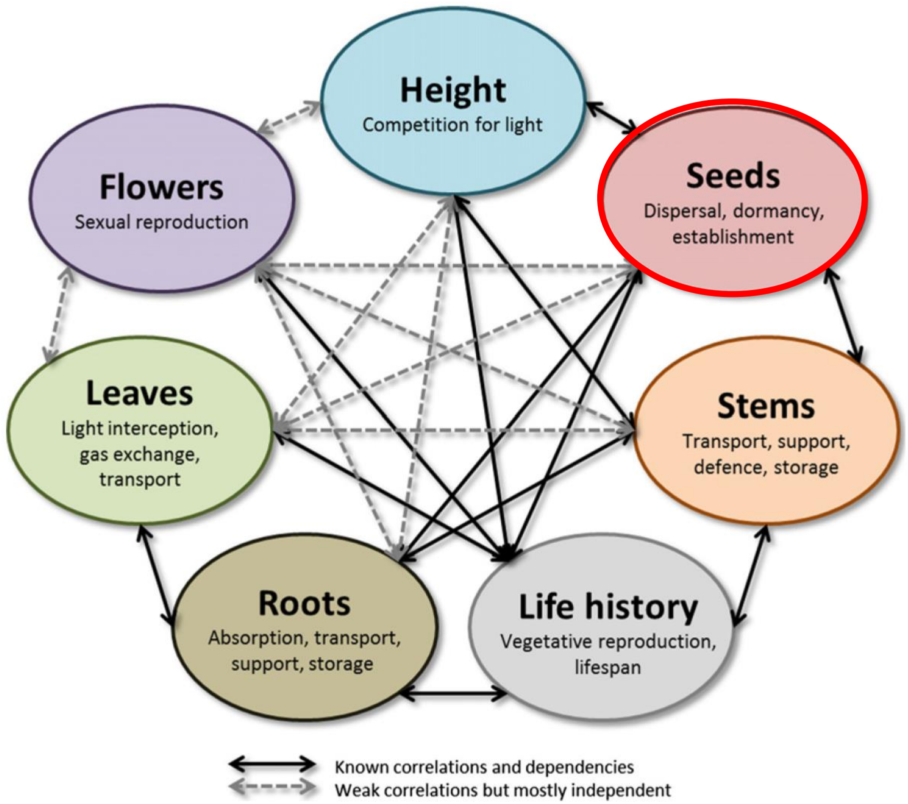
Journal of Ecology 2016, **104**, 1284–1298 doi: 10.1111/1365-2745.12613

Regeneration: an overlooked aspect of trait-based plant community assembly models

Julie E. Larson* and Jennifer L. Funk

Acknowledgement:
Borja Jimenez-Alfaro

How do seed traits matter?



What traits?

Laughlin (2014) The intrinsic dimensionality of plant traits and its relevance to community assembly. *Journal of Ecology* 102

Acknowledgement:
Borja Jimenez-Alfaro

What seed traits?

Seed mass
Dispersal syndrome
Dispersal distance
Coat thickness
Desiccation tolerance
Oil content
Water content
Longevity in soil
Dormancy
Temp. for germination
Response to light
Response to smoke
Etc.

Resource allocation (size)

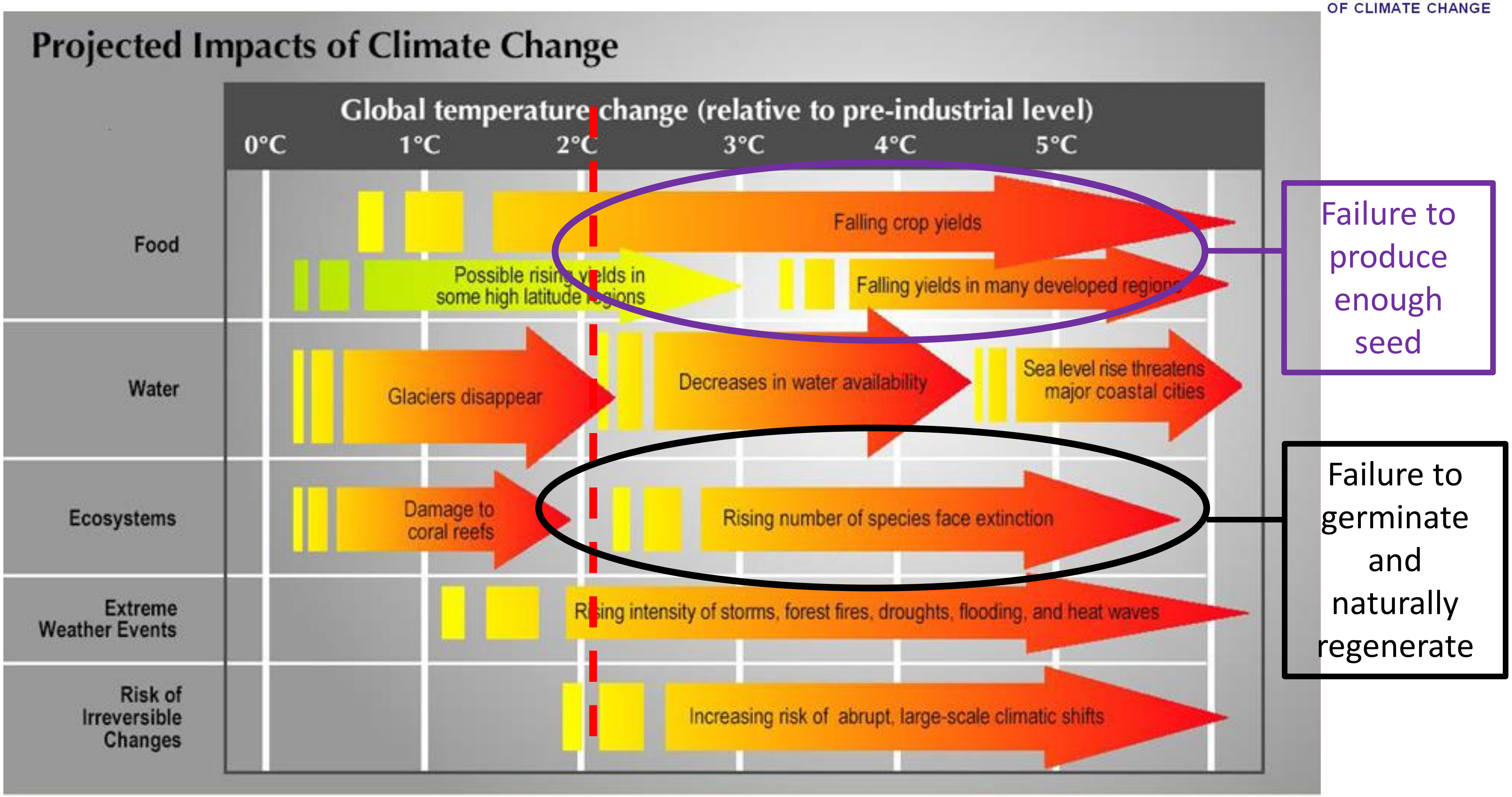
Different ecological functions (and physiological responses)

Acknowledgement:
Borja Jimenez-Alfaro

1. Thermal control of germination – connecting micro- with macro-scale modelling

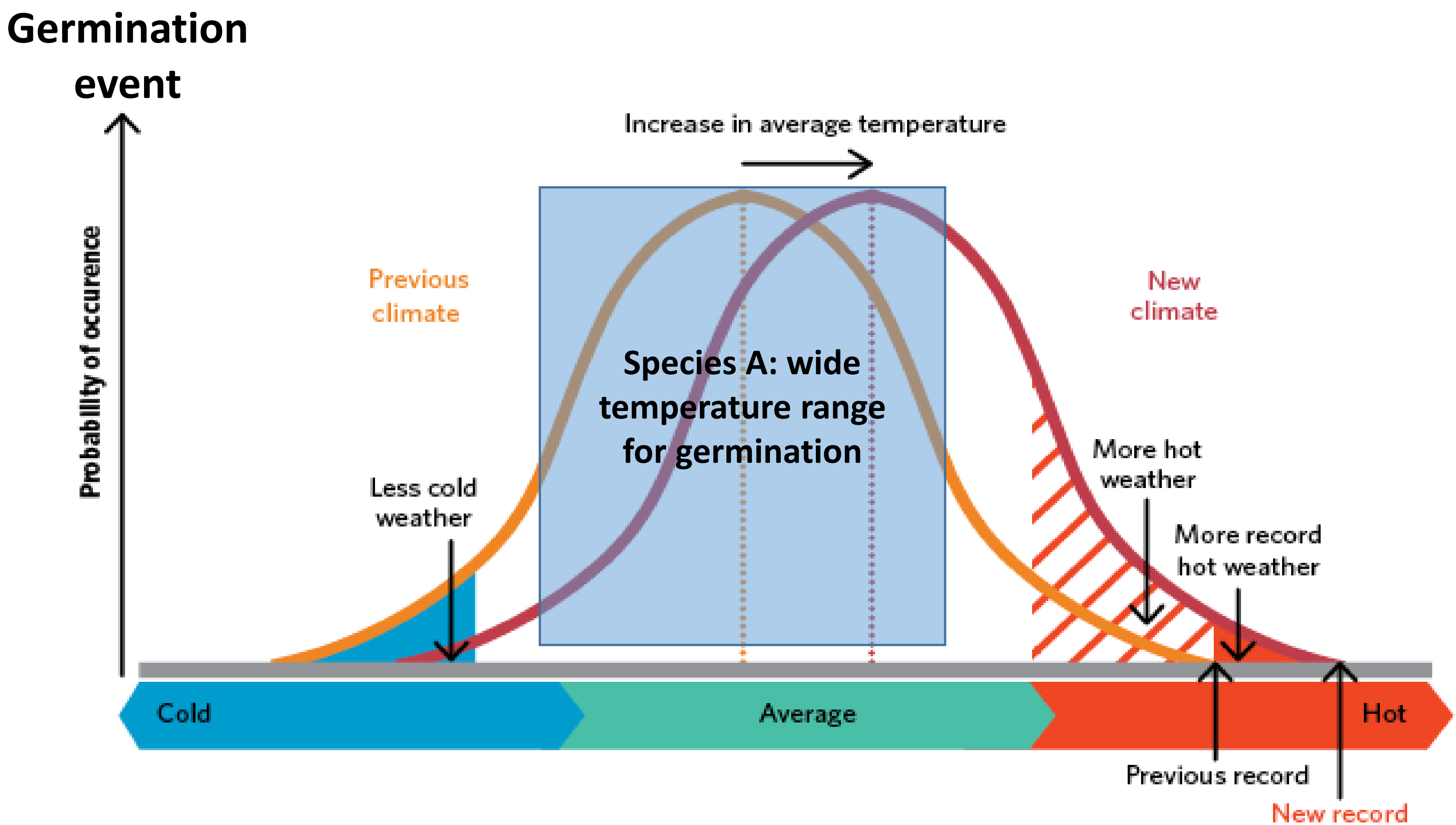
- Characterising physiological function
- Thresholds for germination
- Rates of germination.

Global change



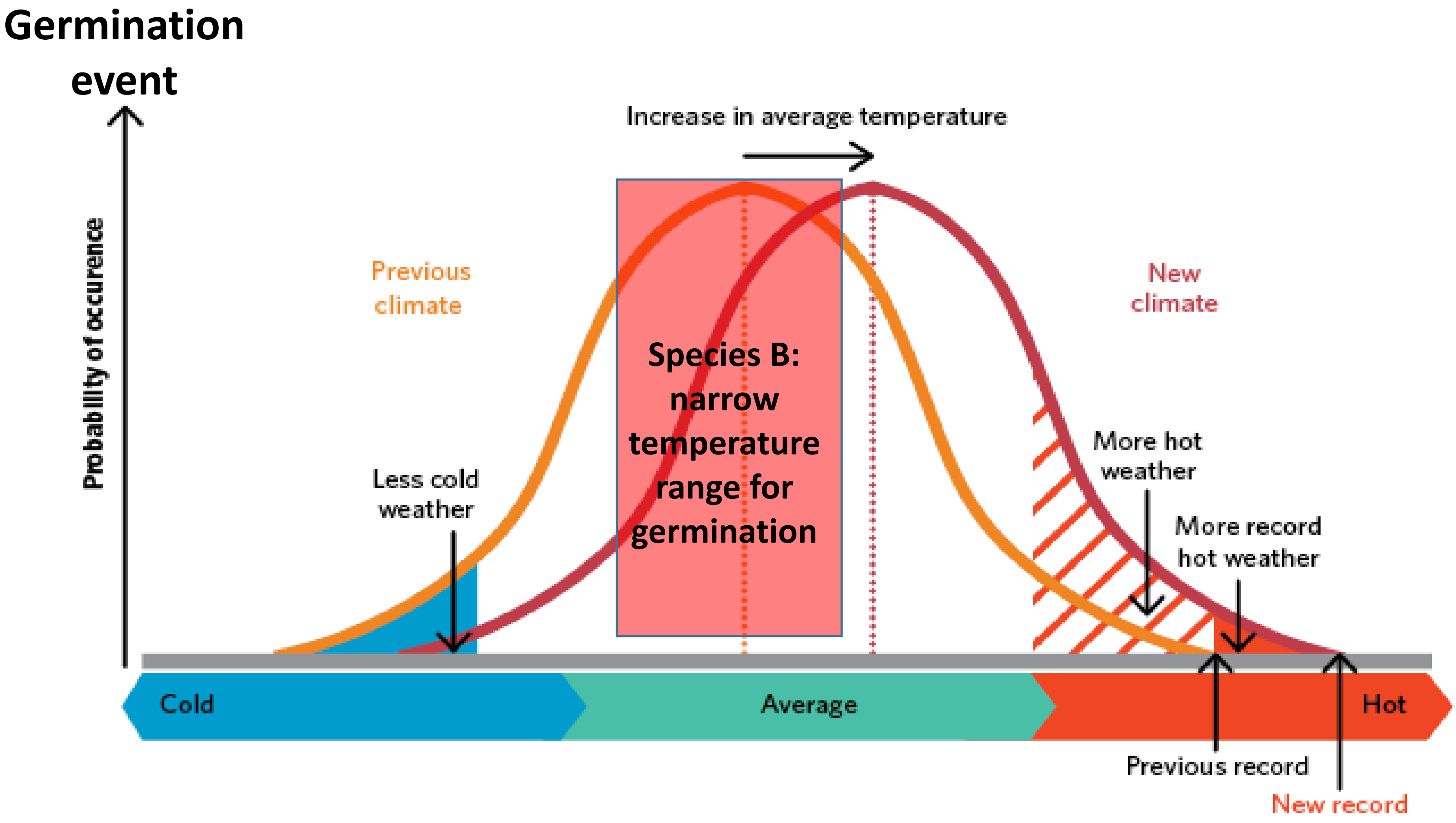
C = Celsius; CO_2 = Carbon Dioxide
Source: Adapted from the *Stern Review on the Economics of Climate Change*.

Temperature distribution: previous and new



Climate Commission (Australia) 2013: http://climatechangeauthority.gov.au/reviews/targets-and-progress-review/part/chapter-2-science-and-impacts-climate-change

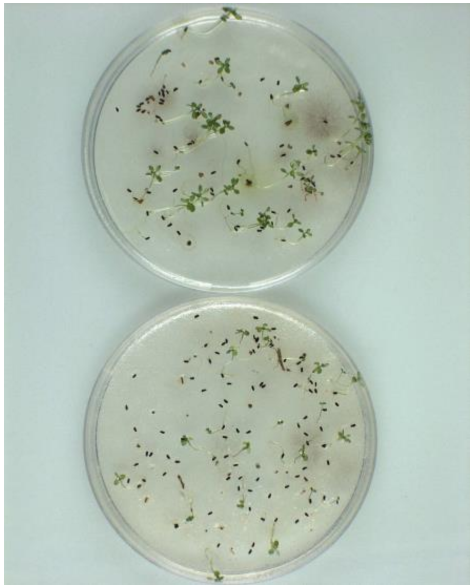
Temperature distribution: previous and new



Climate Commission (Australia) 2013: http://climatechangeauthority.gov.au/reviews/targets-and-progress-review/part/chapter-2-science-and-impacts-climate-change

Seed physiology and ecology

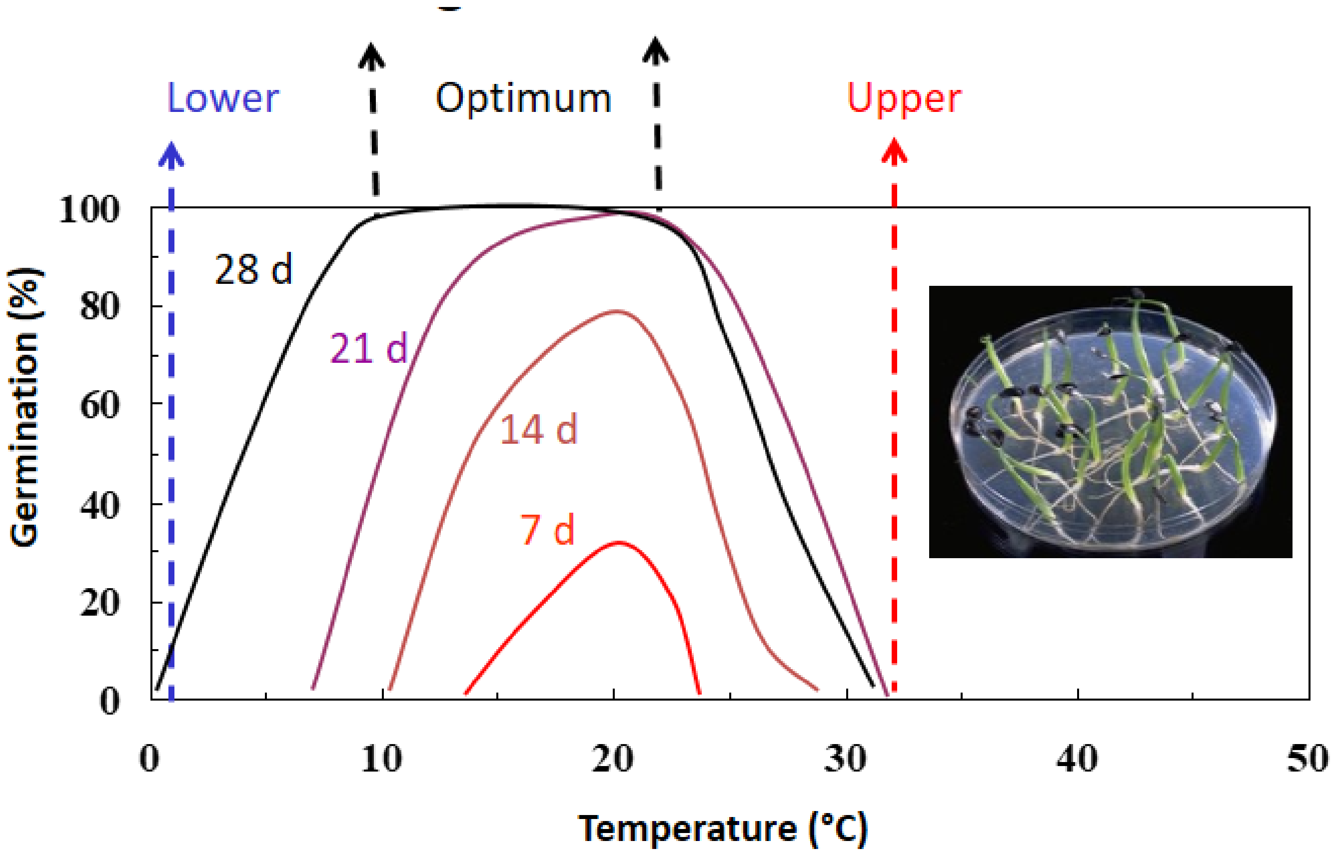




> 30 environmental chambers AND two thermal-gradient plates (64 temperature-light combinations)

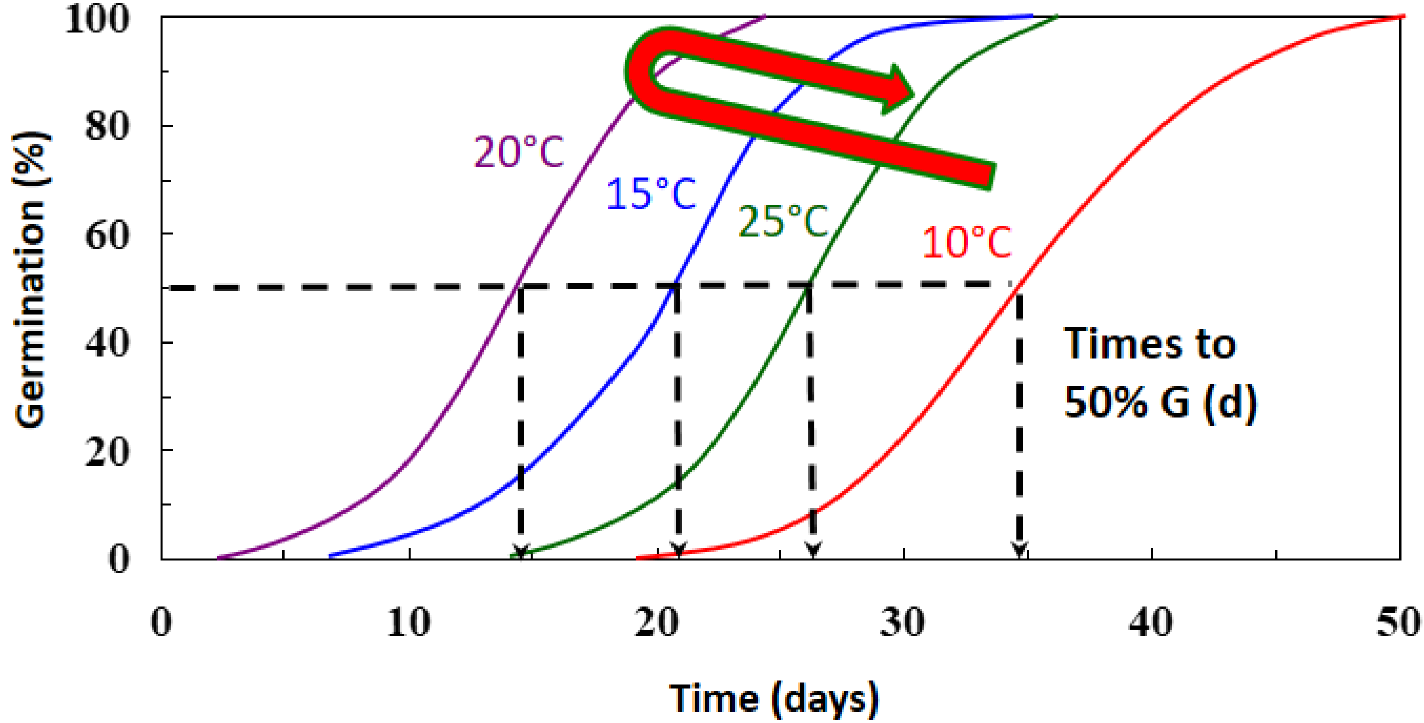
Comparative Seed Biology

Germination: total



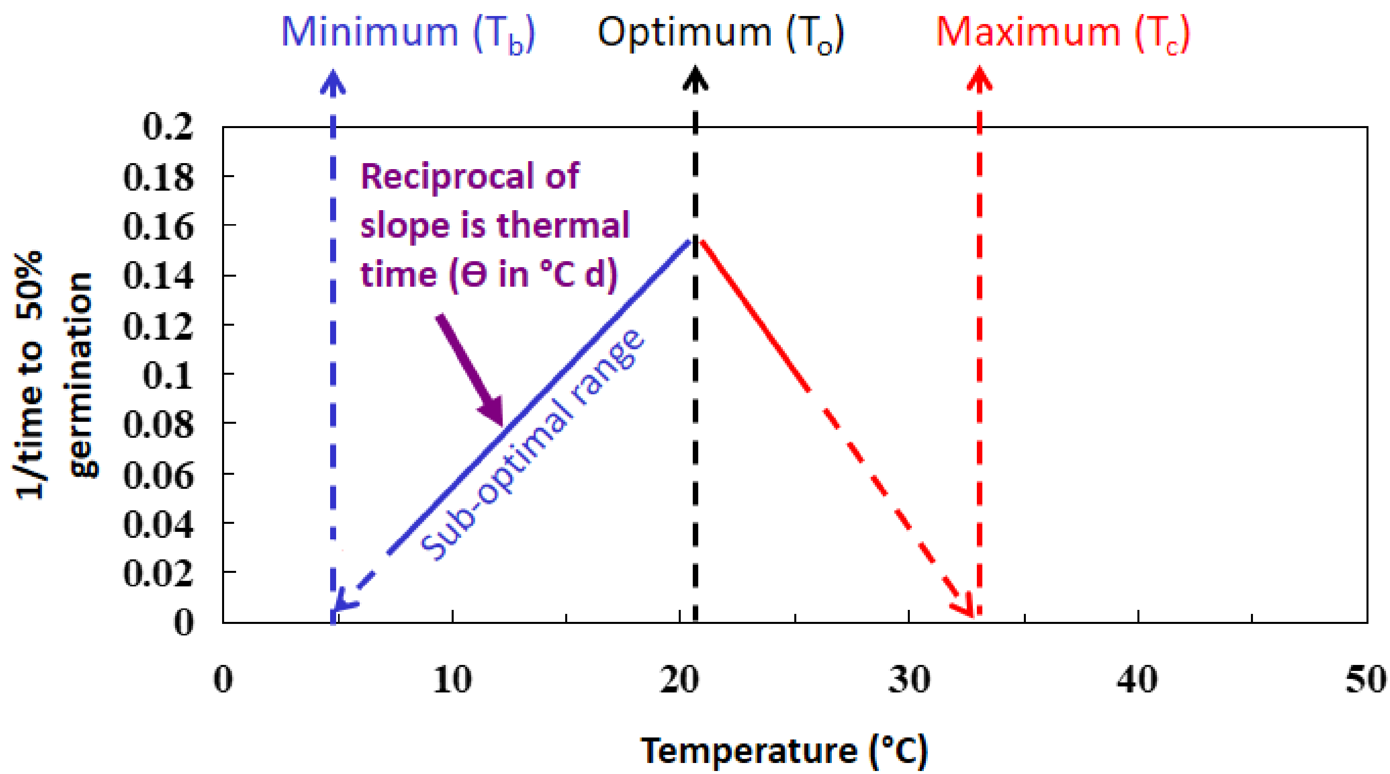
Climate Commission (Australia) 2013: http://climatechangeauthority.gov.au/reviews/targets-and-progress-review/part/chapter-2-science-and-impacts-climate-change

Germination: progress



Climate Commission (Australia) 2013: http://climatechangeauthority.gov.au/reviews/targets-and-progress-review/part/chapter-2-science-and-impacts-climate-change

Germination: rate



Climate Commission (Australia) 2013: http://climatechangeauthority.gov.au/reviews/targets-and-progress-review/part/chapter-2-science-and-impacts-climate-change

Thermal time (50% G) model

(Garcia-Huidobro et al., 1982)

$$1/t_g(\mathrm{d}^{-1}) = (T - T_b)/\theta_g$$

Germination rate

Germination temperature

Base temperature for germination

Thermal time (°C d)

Agricultural and Forest Meteorology 200 (2015) 222–232

Contents lists available at ScienceDirect

Agricultural and Forest Meteorology

journal homepage: www.elsevier.com/locate/agrformet

ELSEVIER

Review

Ranges of critical temperature and water potential values for the germination of species worldwide: Contribution to a seed trait database

C. Dürr[a,*], J.B. Dickie[b], X.-Y. Yang[c], H.W. Pritchard[b]

> 240 species

In situ germination

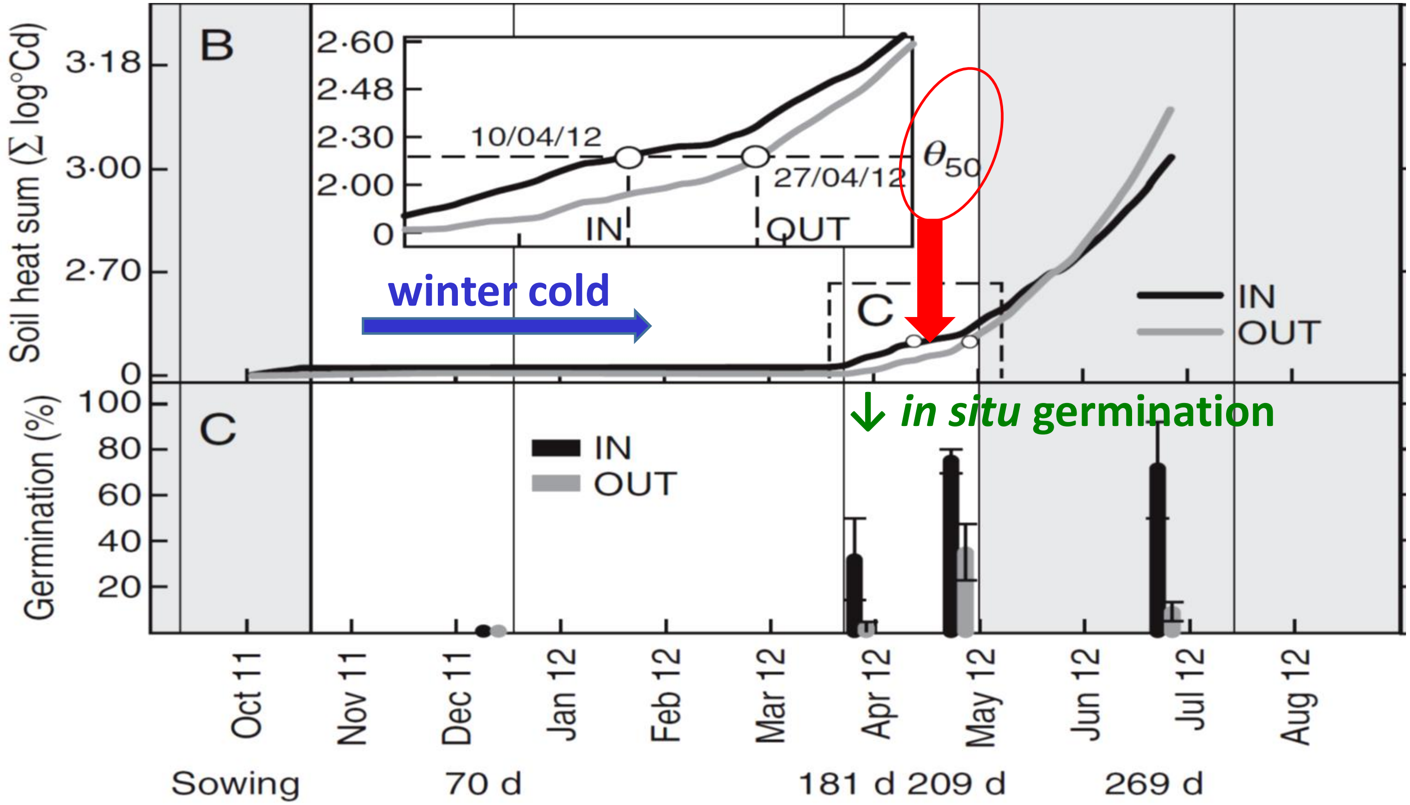
Mediterranean mountain regions of Sardinia (up to 1300 m a.s.l.)

Acknowledgement:
Efisio Mattana

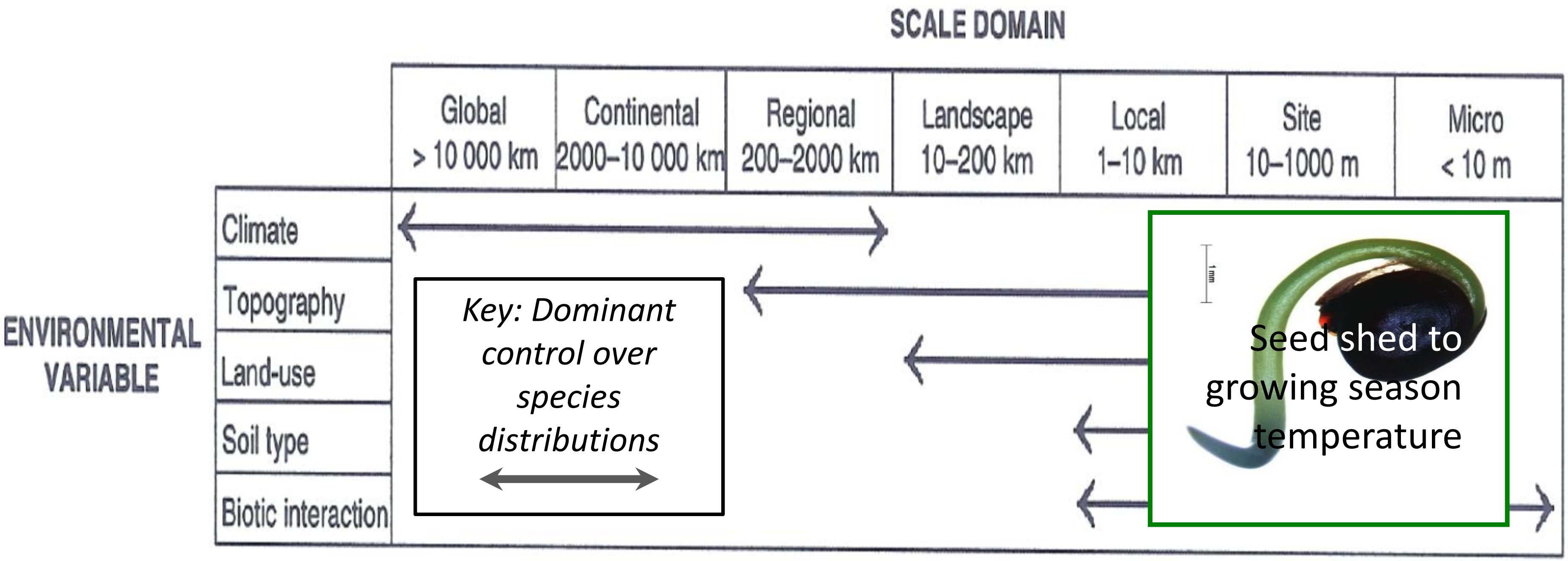
Thermal time and global change

Rhamnus persicifolia (1000 – 1300 m a.s.l.)

Porceddu et al. (2013) Ann. Bot.



Implications: species distribution models



Moving beyond simple habitat models based on bioclimatic envelopes to regeneration niche.

Thermal time models for seeds – what we know

$$1/t_g(\mathrm{d}^{-1}) = (T - T_b)/\theta_g$$

Germination rate

Germination temperature

Base temperature for germination

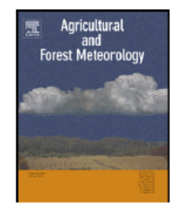
Thermal time (°C d)

Agricultural and Forest Meteorology 200 (2015) 222–232

Contents lists available at ScienceDirect

Agricultural and Forest Meteorology

journal homepage: www.elsevier.com/locate/agrformet



ELSEVIER

Review

Ranges of critical temperature and water potential values for the germination of species worldwide: Contribution to a seed trait database

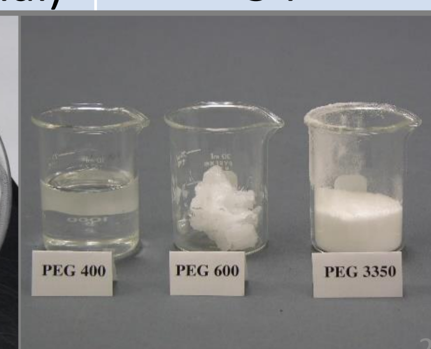
CrossMark

C. Dürr[a,*], J.B. Dickie[b], X.-Y. Yang[c], H.W. Pritchard[b]

Biodiversity: analysis of 243 species

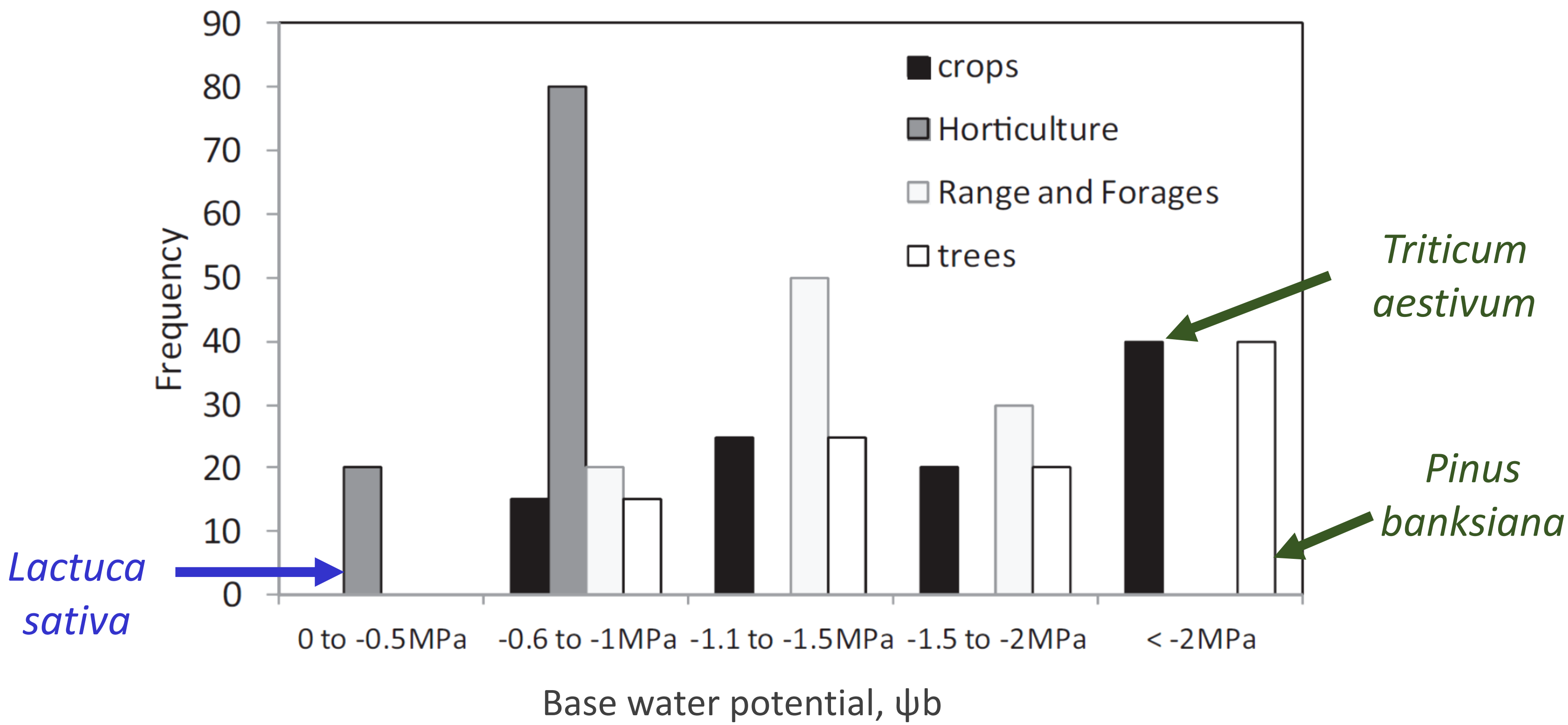
Type of species	% of dataset
Tree, bush, shrub	40
Forage, grass	32
Crop	12
Vegetable, ornamental, fruit	7
Others (wild, medicinal, etc)	5
Cacti	4

Germination trait	Number of species
T_b (base)	223
T_o (optimum)	110
(sub-opt) Thermal time (ϴ, °C d)	
T_c (ceiling, max)	72
Ψ_b (base water potential)	54



http://doi.pangaea.de/10.1594/PANGAEA.829536

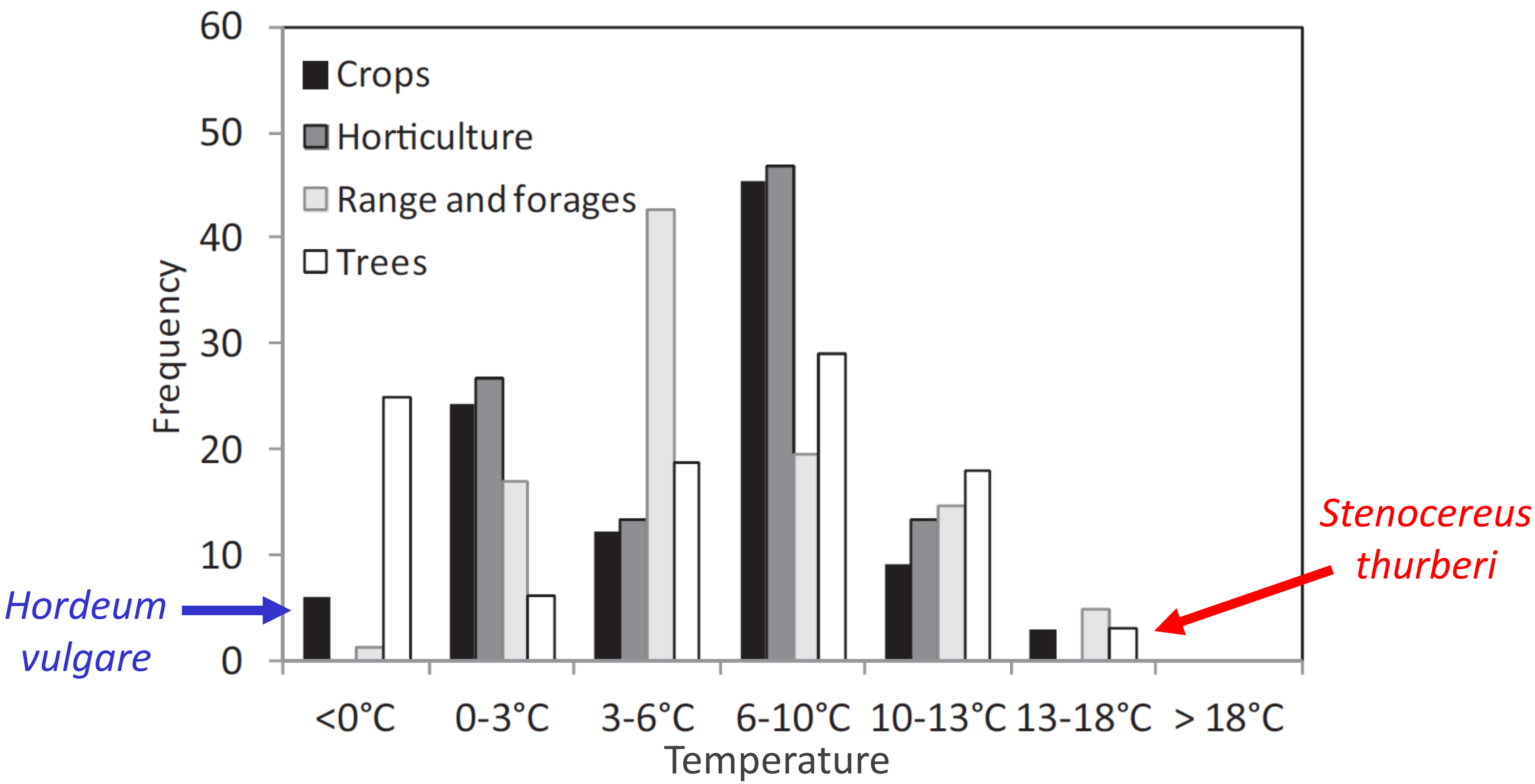
Drought germination (ψ_b) down to -2.9 MPa



Horticultural sp. tend to prefer higher water potentials

Durr et al. (2015; Agri & Forest Met.)

T_b varies from -1.7 to 18°C



All groups have species with high and low T_b

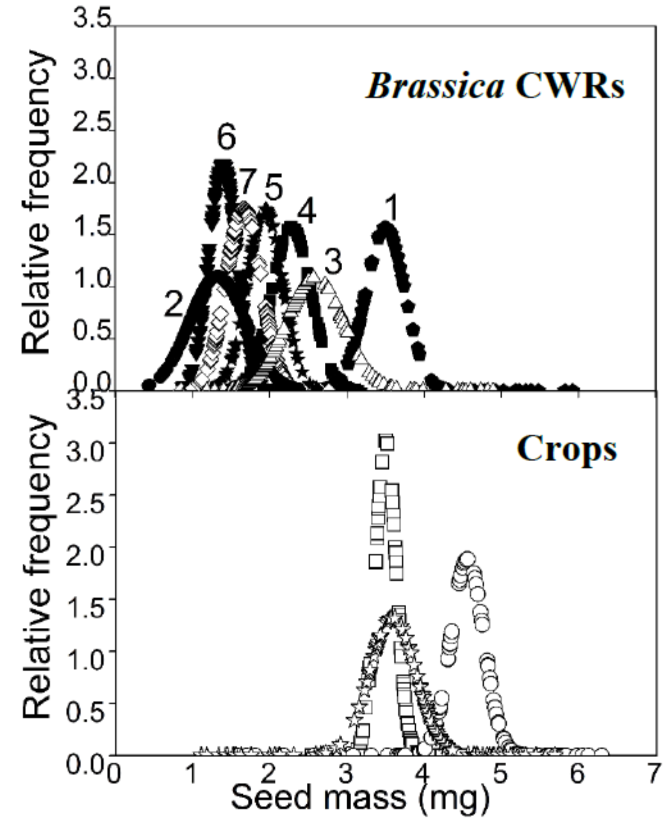
Durr et al. (2015; Agri & Forest Met.)

Germination phenotype in wild Brassicas

Species / line	Site	Monthly mm / °C
B. rapa	Switzerland	94 / 9
B. nigra	England	69 / 10
B. rapa	France	64 / 11
B. rapa subsp. *campestris*	Turkey	41 / 5
B. rapa subsp. *sylvestris*	Morocco	27 / 12
B. tournefortii	Egypt	5 / 21
B. rapa subsp. *sylvestris*	Algeria	1 / 26
B. oleracea	France	? / ?
B. oleracea HV line	Warwick, England	Con + Dr / 20
B. oleracea LV line	Warwick, England	Con + Dr / 20

Drier

Castillo-Lorenzo et al. (2019)

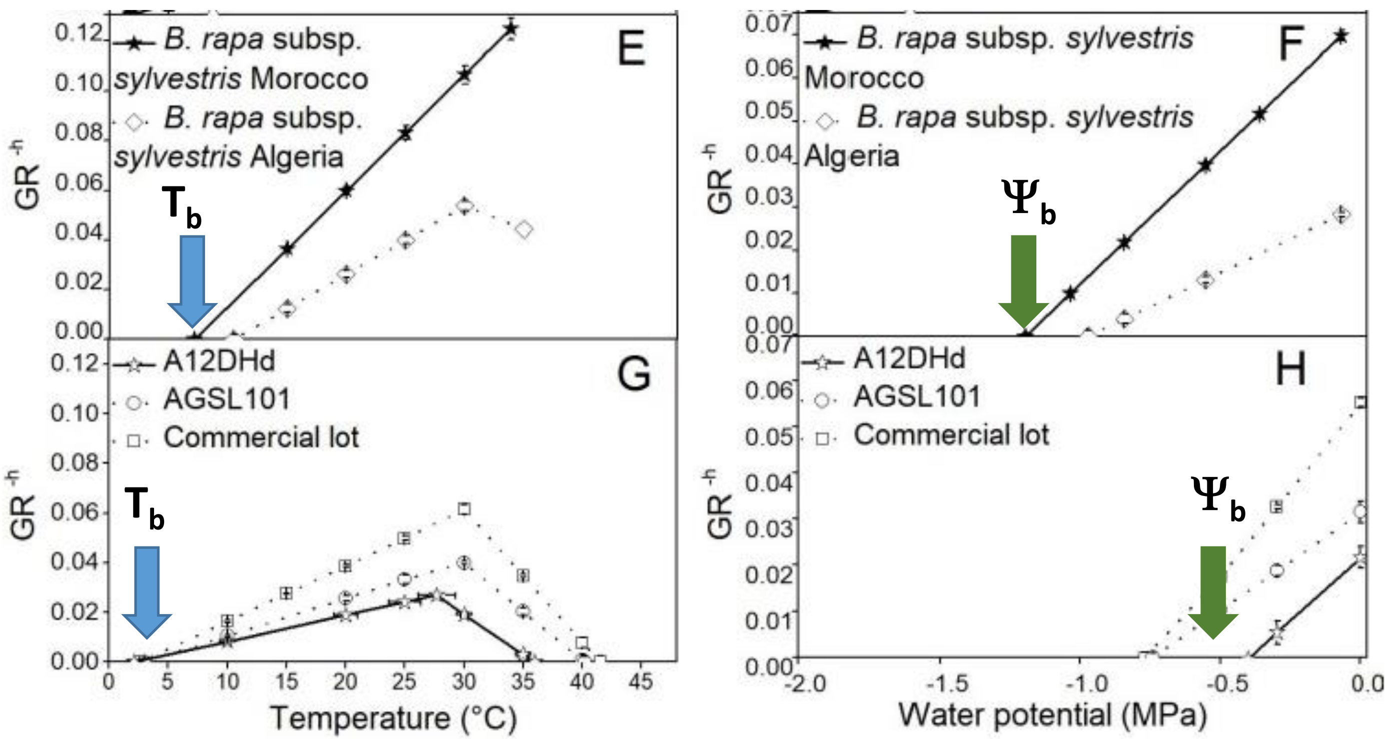


10 seed lots of crop, (inbred) research lines (low and high vigour) and CWR (N Africa to England)

Brassica seed lots: germination traits

CWR

Crop and inbred lines



- Variation in $T_{b,}$, thermal time, Ψ_b and hydrotime; continuum of responses;
- Crops have higher Ψ_b but not shorter thermal time than CWR.

Castillo-Lorenzo et al. (under review)

Thermal memory

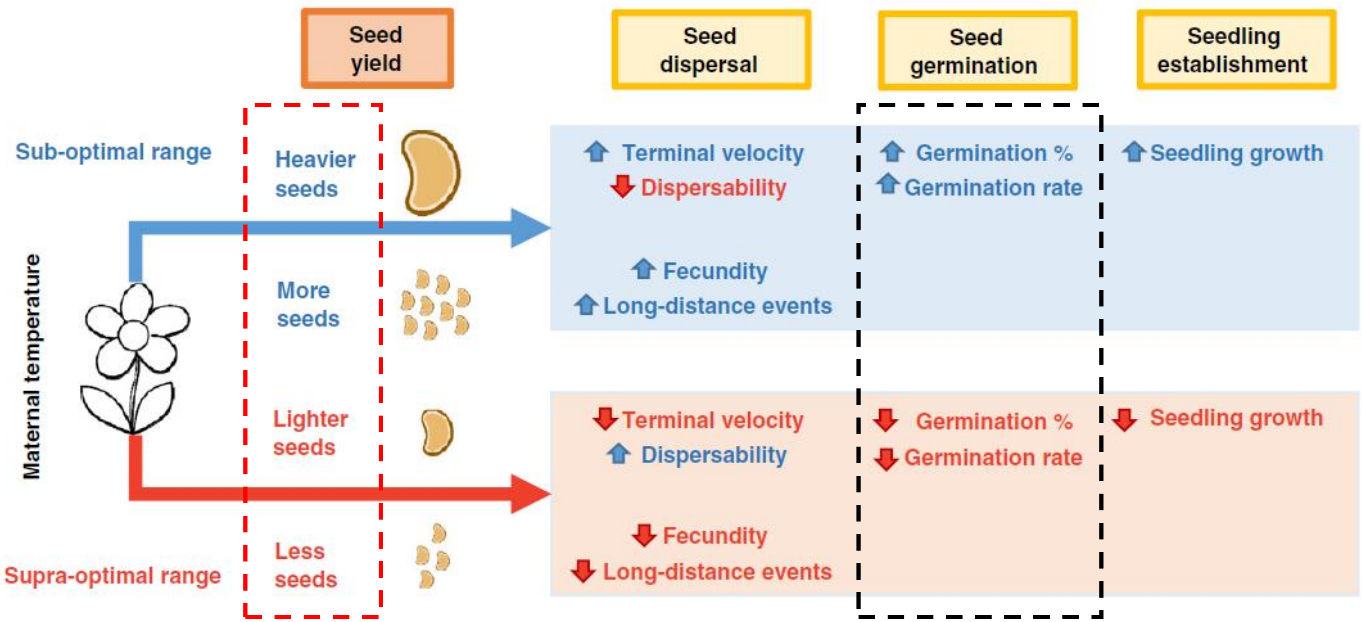
Meta-analysis reveals two regulatory hubs influencing seed thermal memory

BIOLOGICAL REVIEWS
Cambridge Philosophical Society

Original Article

Seeds of future past: climate change and the thermal memory of plant reproductive traits

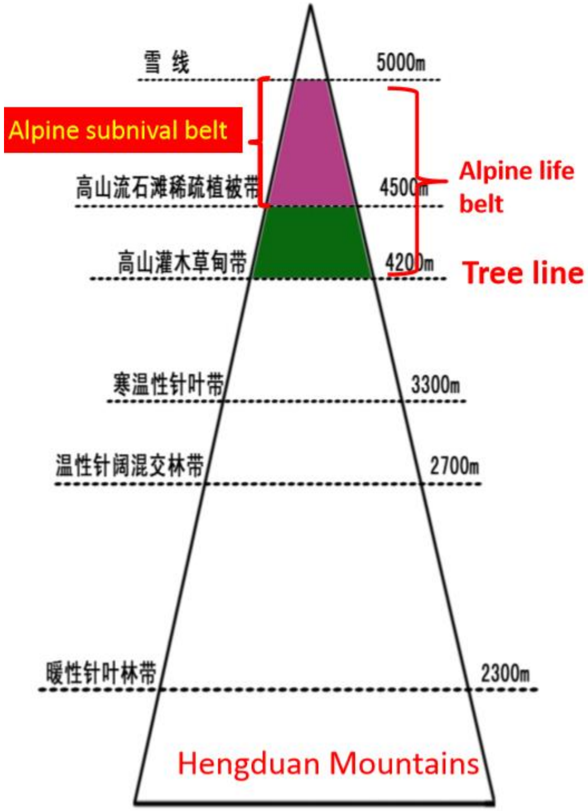
Eduardo Fernández-Pascual, Efisio Mattana, Hugh W. Pritchard

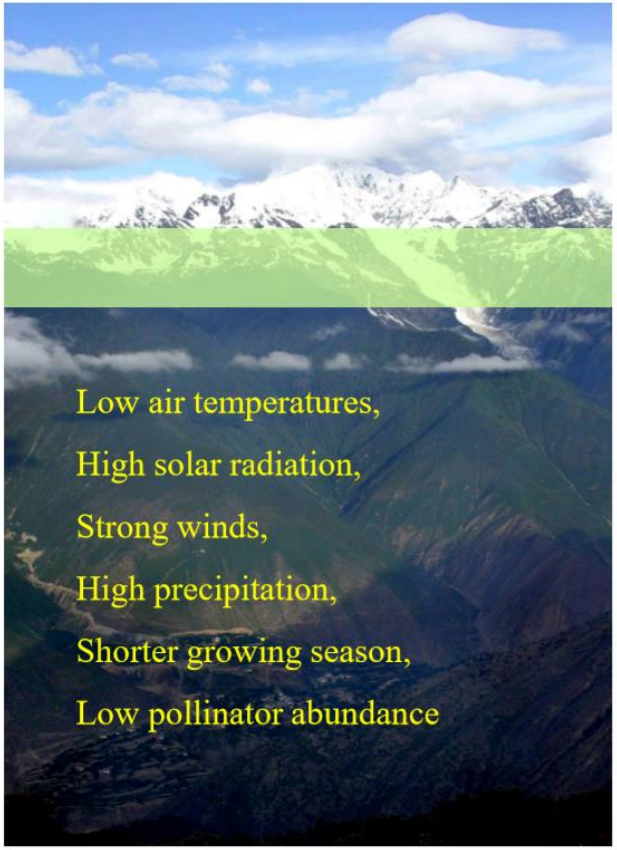


(1) Seed size

(2) Seed germination physiology

2. Alpine and mountain species germination





Hostile work environment: cold, low oxygen, strong UVB, wind, rainfall

Case study: Sardinia
Effects of altitude on germination

Thermal thresholds for seed germination in Mediterranean species are higher in mountain compared with lowland areas

Rosangela Picciau[1,2], Hugh W. Pritchard[3], Efisio Mattana[1,3] and Gianluigi Bacchetta[1,2]

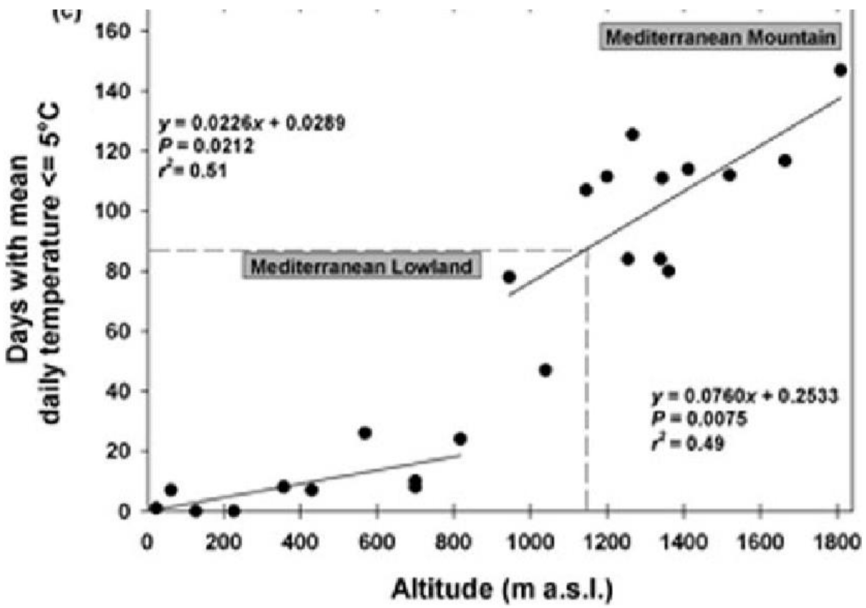
Seed Science Research

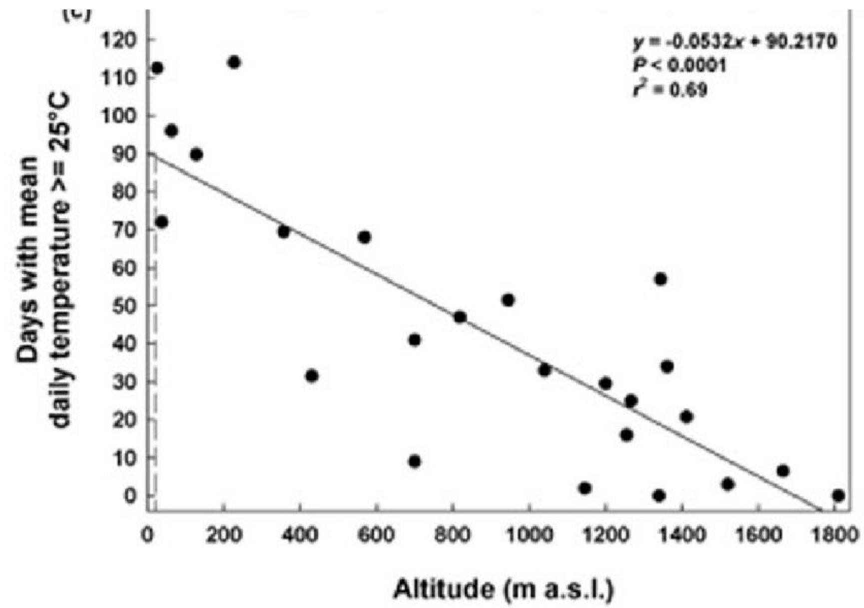
26 species

Families: Brassicaceae, Ranunculaceae, Caryophyllaceae, Scrophulariaceae, Cistaceae, Asteraceae, Fabaceae, Lamiaceae, Rhamnaceae, Rutaceae,

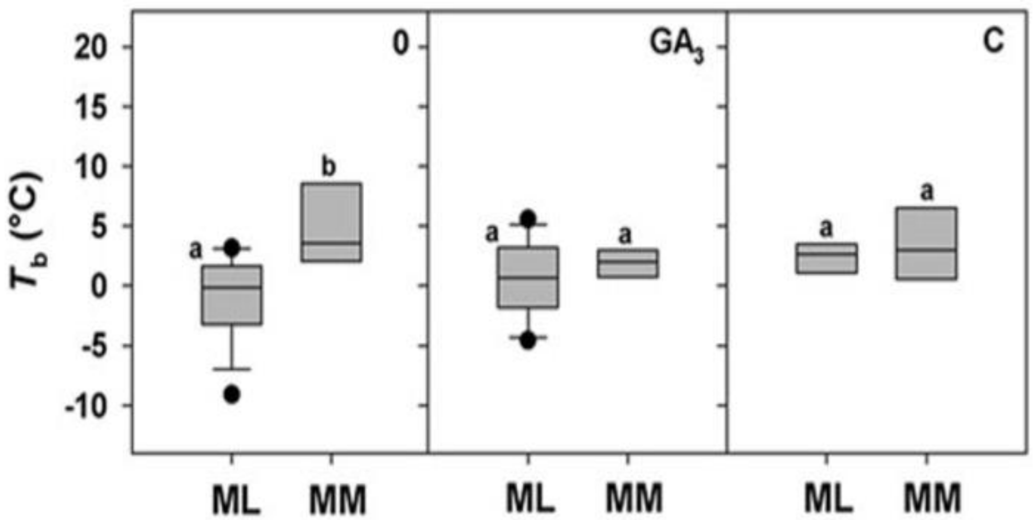
25 – 1810 m a.s.l.

Case study Sardinia:
Cold and hot days





Case study Sardina:
Germination at chilling temperature



Control

Gibberellic acid

3 month, cold

Case study Italian Alps

Calcareous versus siliceous grassland

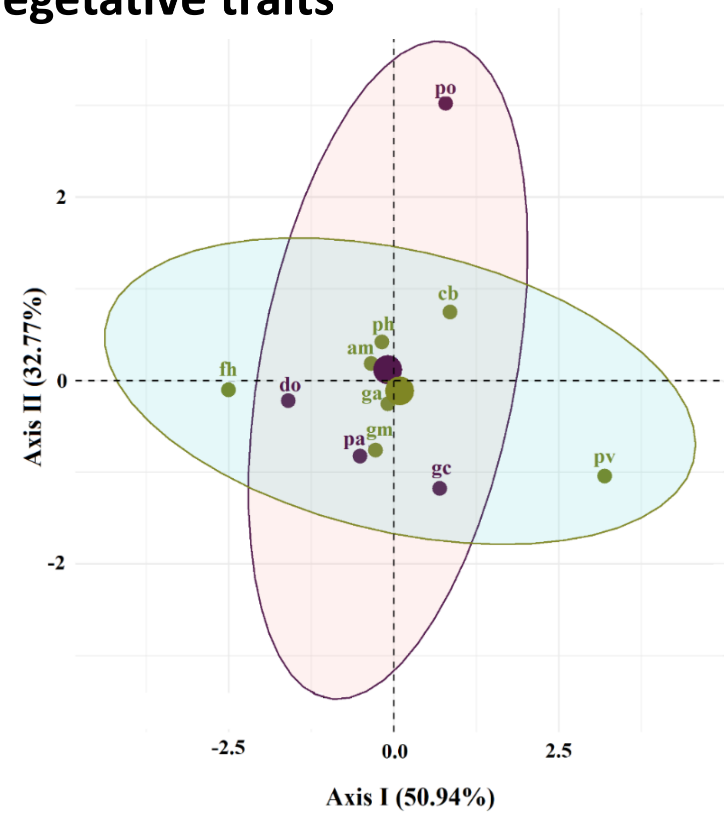
- Similar climate (i.e. MAT, time of snowcover)
- Different local environment (i.e. soil properties)

Images: Maria Tudela Isanta and Andrea Mondoni

6 pairs of con-generic species;
1 pair of co-family species

Case study Italy:
Seed germination traits

Vegetative traits



Calcareous Siliceous

TRY-database:

- Specific leaf area (SLA, mm^2mg^{-1})
- Leaf area (LA, mm^2)
- Leaf dry matter content (LDMC, $mg\ g^{-1}$)

Tudela Isanta et al. (2018)
Alpine Botany

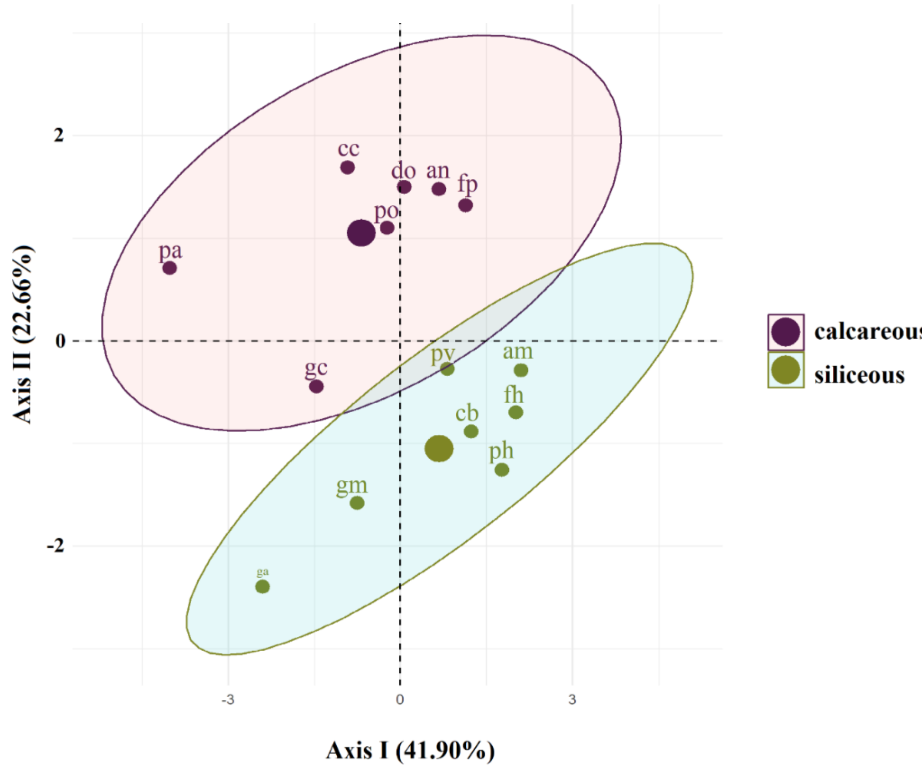
Case study Italy Alps:
Seed germination traits

Experimentally determined:

- Cardinal temperatures (T_b, T_o, T_c)
- Base water potential (Ψ_b)
- Range of pH germination

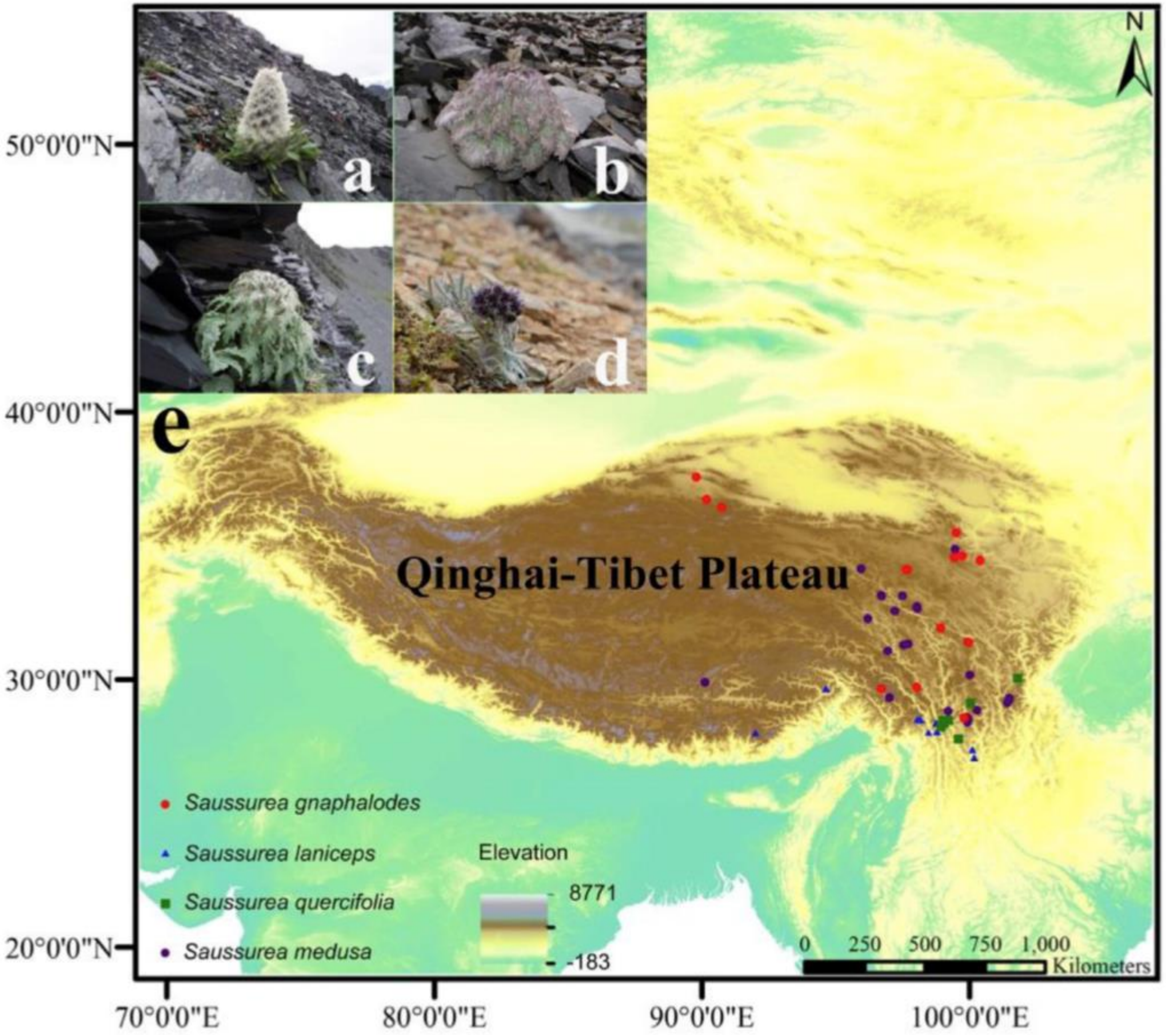
Tudela Isanta et al. (2018) Alpine Botany

Germination traits



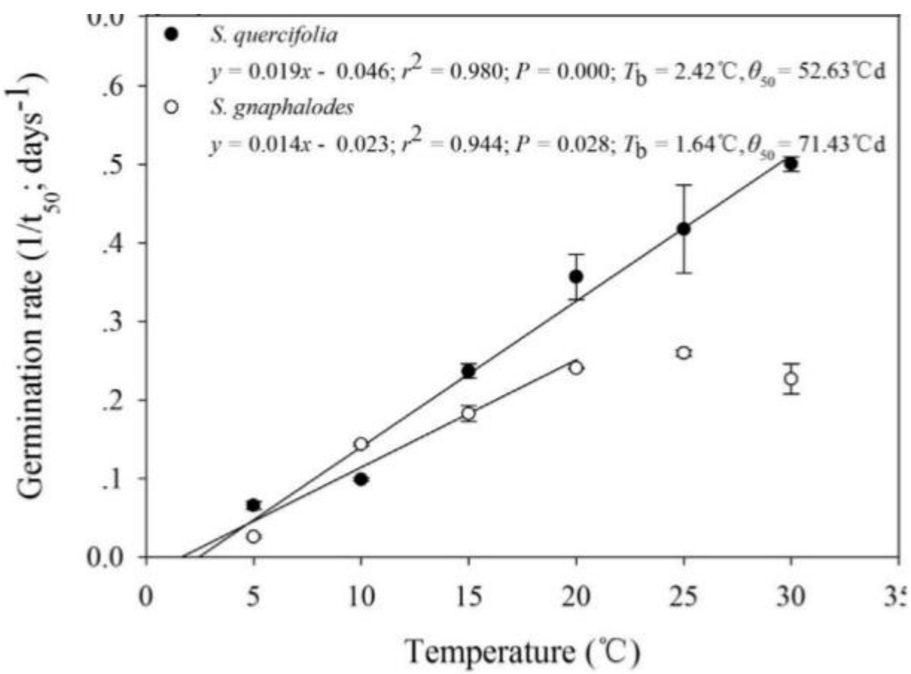
Calcareous species have high base temperature (T_b) and lower base water potential (Ψ_b)

Case study China: *Saussurea*



- Medicinal species threatened with overharvesting.
- 4500 m a.s.l.

Case study China:
Saussurea



Contents lists available at ScienceDirect

Global Ecology and Conservation

journal homepage: http://www.elsevier.com/locate/gecco

ELSEVIER

Original Research Article

Species distribution modelling and seed germination of four threatened snow lotus (*Saussurea*), and their implication for conservation

Deli Peng [a], Lu Sun [b], Hugh W. Pritchard [c], Juan Yang [d], Hang Sun [b], Zhimin Li [a,*]

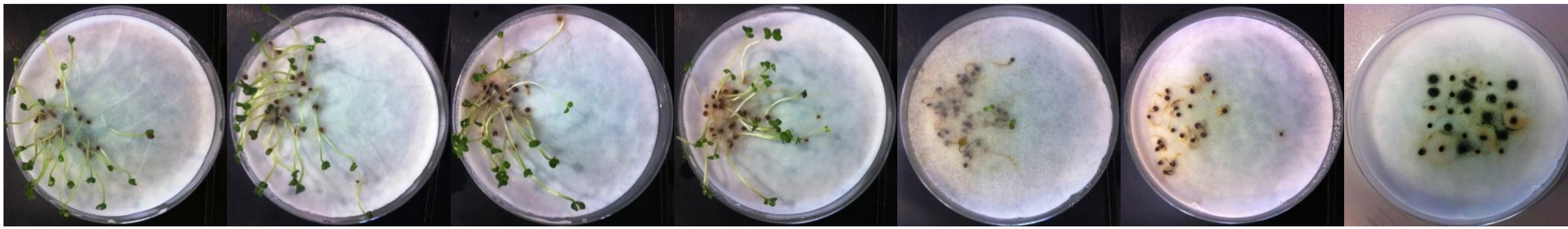
Matters to resolve:

1. When is warm, too-warm?

2. What to measure.

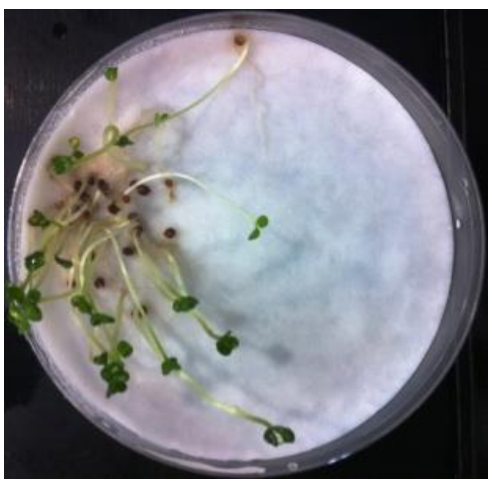
When is warm, too-warm?

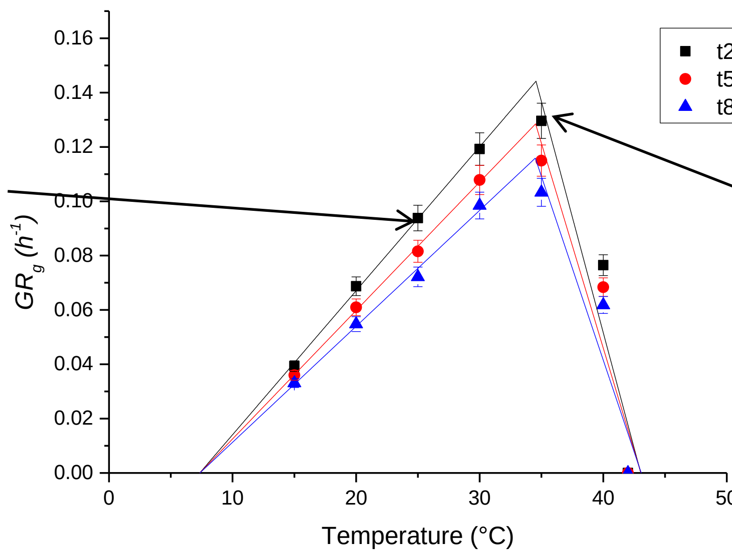
Brassica rapa. subspecies *sylvestris*

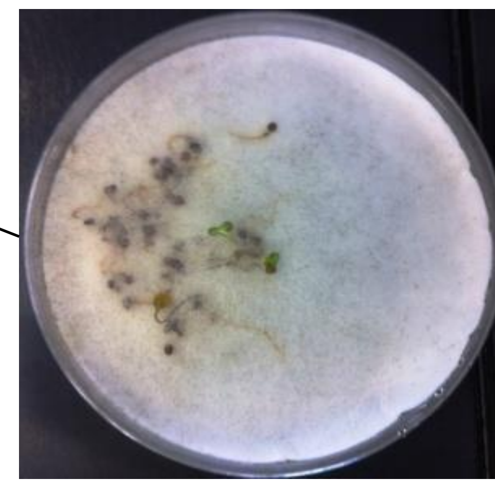


15°C 20°C 25°C 30°C 35°C 40°C 42°C

Optimum temperature for germination rate produces unhealthy seedlings.



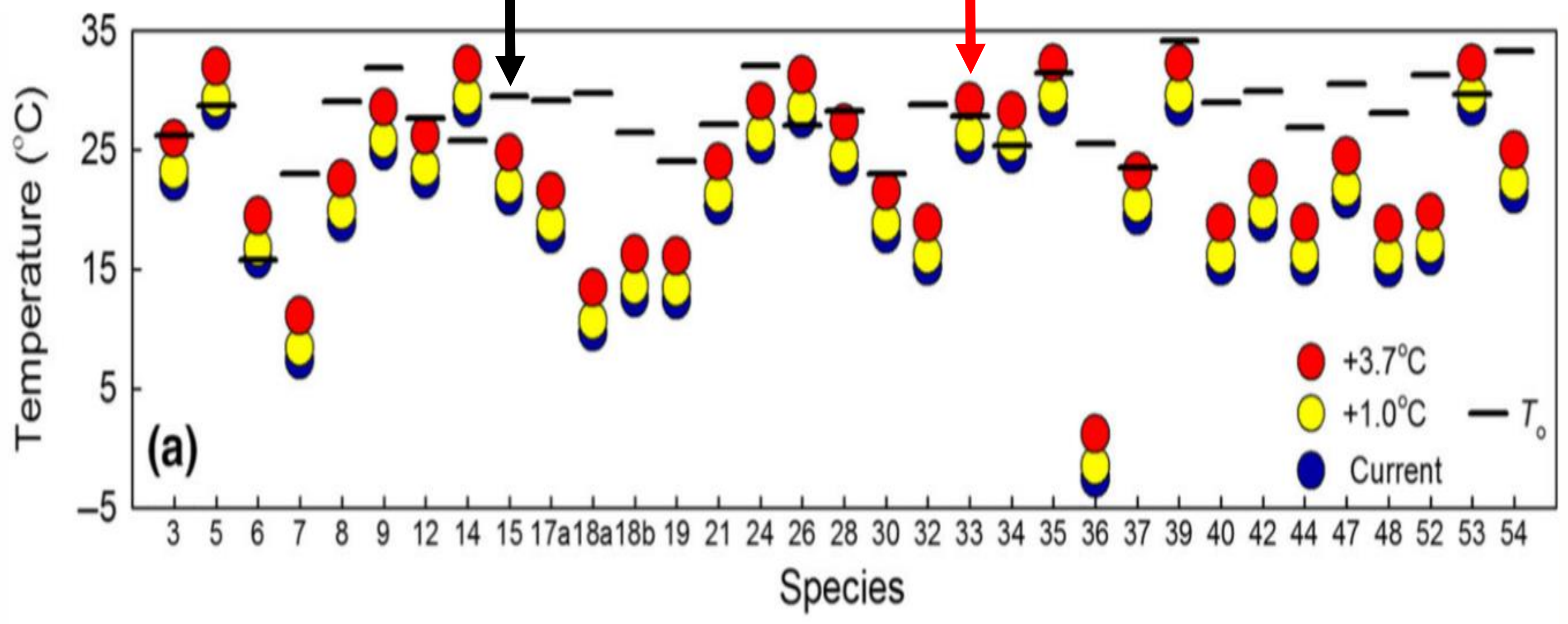




When it is too warm for cacti

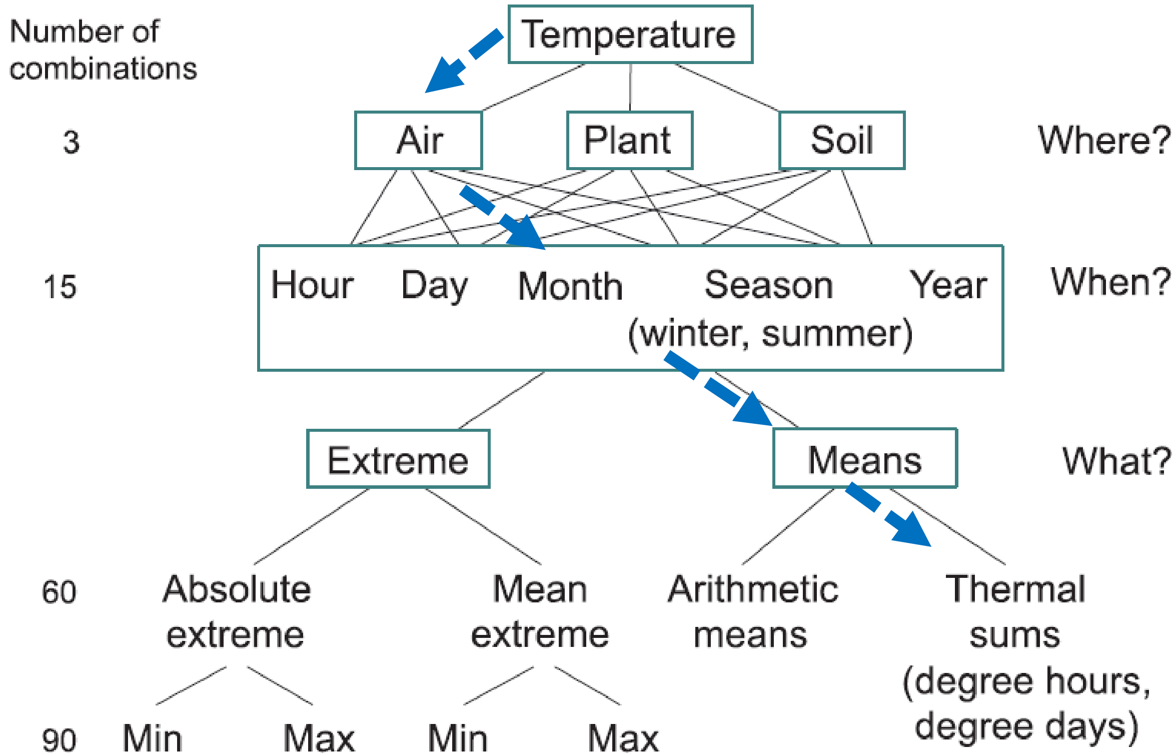
Current optimum temperature for germination

Temperature now exceeds optimum for germination



Seal et al (2017) Global Change Biology

What to measure



Contents lists available at ScienceDirect

Perspectives in Plant Ecology, Evolution and Systematics

journal homepage: www.elsevier.com/locate/ppees

Review

The 90 ways to describe plant temperature☆

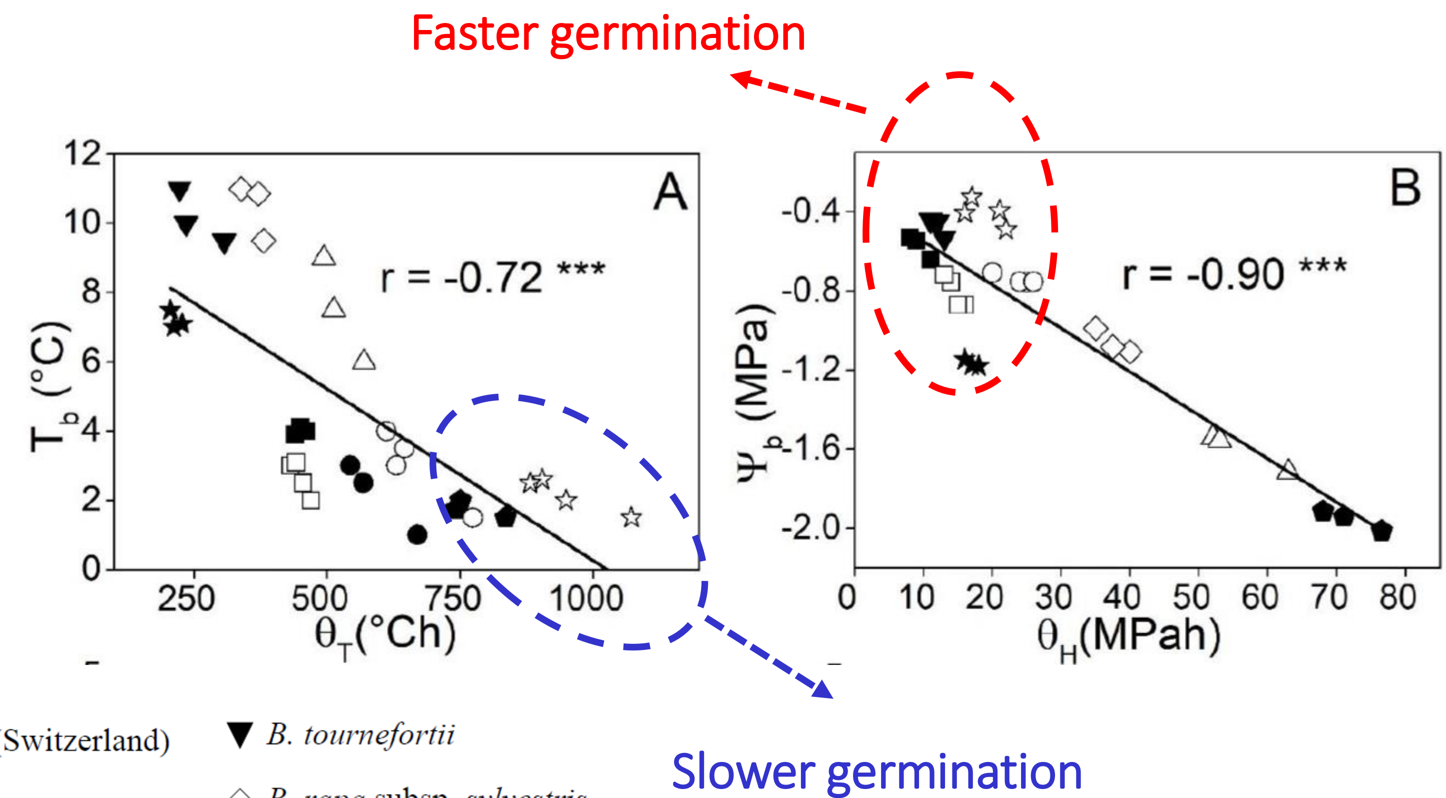
Christian Körner*, Erika Hiltbrunner

Royal Botanic Gardens Kew

Summary

1. Seed germination can be described by thermal- and hydro-thermal models;
2. Parameters of the model explain niche preferences;
3. Parameters varying with environmental temperature and reflect maternal thermal memory;
4. Parameters help understand risk to natural seed germination in relation to climate change models;
5. Need wider range of species to be characterised from diverse floras, leading to development of a global model.

All *Brassica* seed lots: co-correlants



⬟ *B. rapa* (Switzerland)

● *B. nigra*

△ *B. rapa* (France)

■ *B. rapa* subsp. *campestris*

★ *B. rapa* subsp. *sylvestris* (Morocco)

▼ *B. tournefortii*

◇ *B. rapa* subsp. *sylvestris* (Algeria)

☆ A12DHd

○ AGSL101

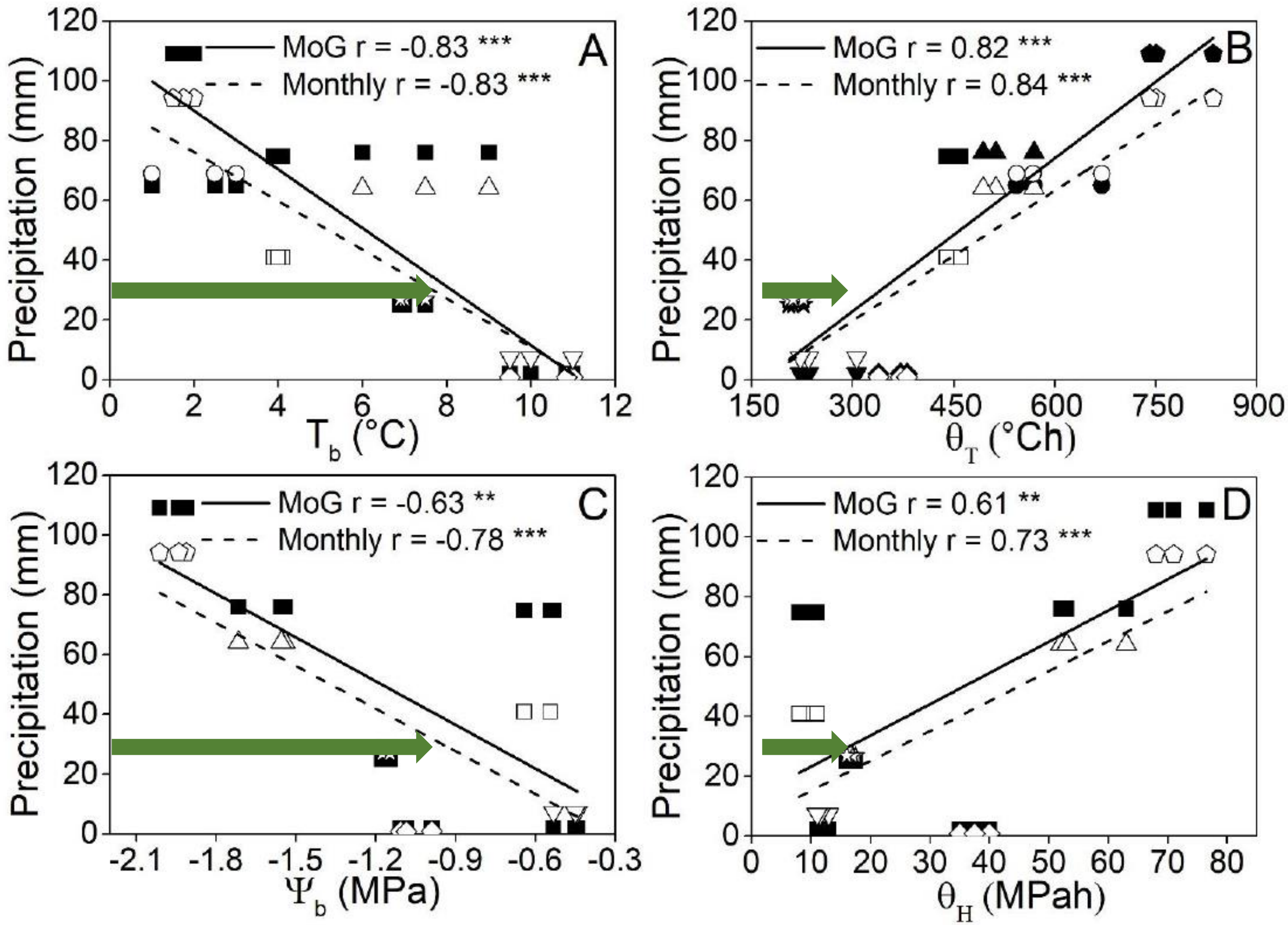
□ Commercial seed lot

Castillo-Lorenzo et al. (under review)

Associations between thresholds and rates (thermal- or hydro-time)

CWR seed lots and environment

Thresholds



Rates

CWR drier environments yield seeds with higher T_b, higher Ψ_b and faster germination

Castillo-Lorenzo et al. (under review)