

# Leveraging bean crop genetics and diversity for climate adaptation

Caspar Chater  
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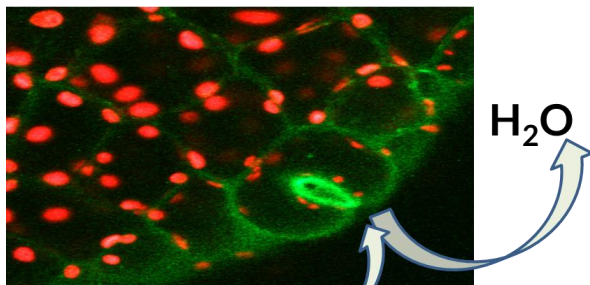


# Stomata, gas exchange and plant water status

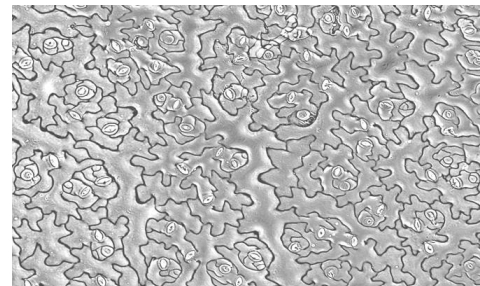
Stomata control water uptake and loss by transpiration.

Stomata control:

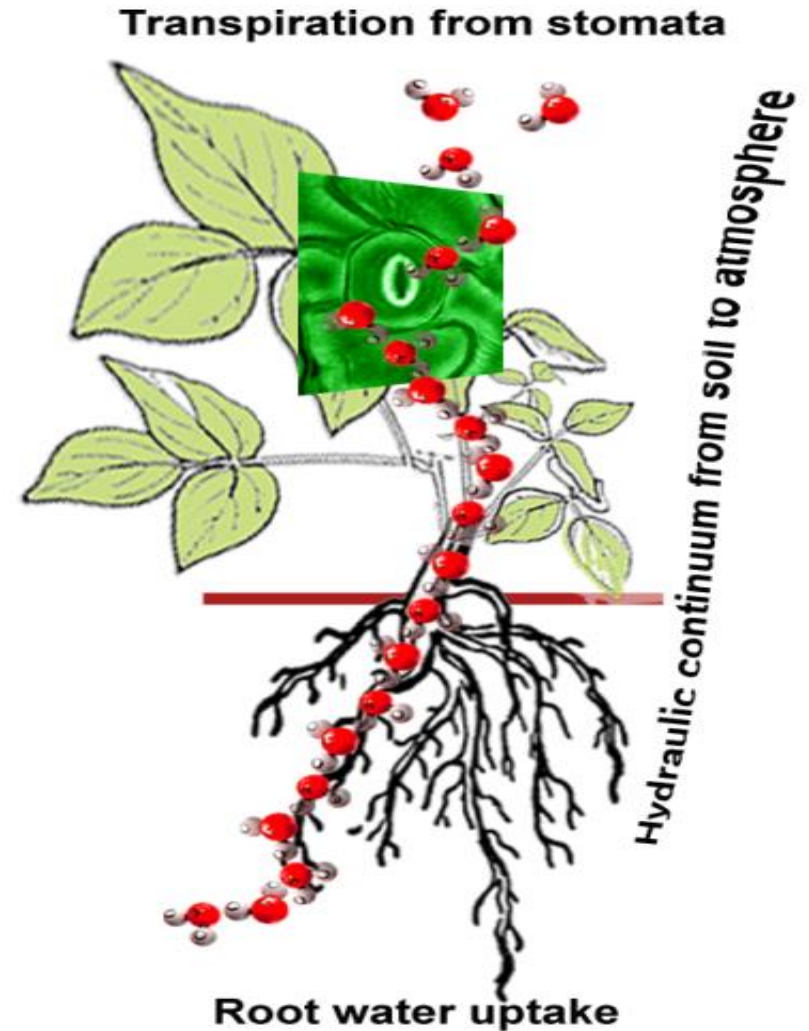
- Water loss
- Nutrient accumulation
- CO<sub>2</sub> uptake
- Evaporative cooling
- Pathogen responses



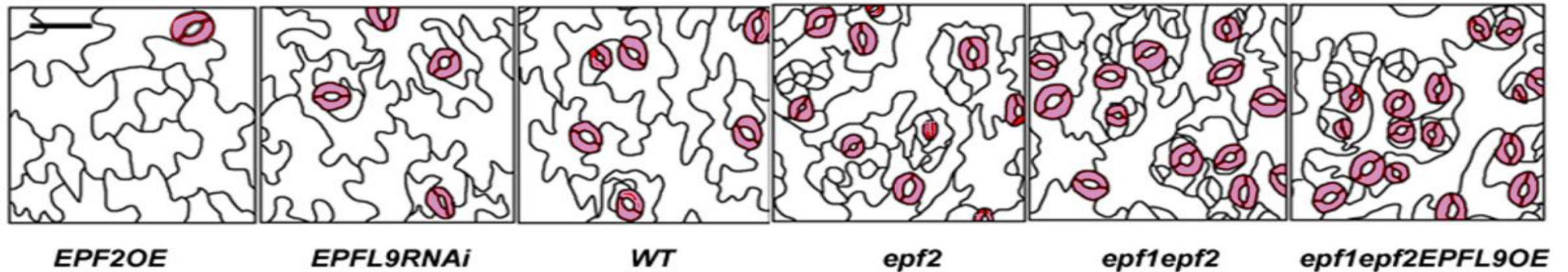
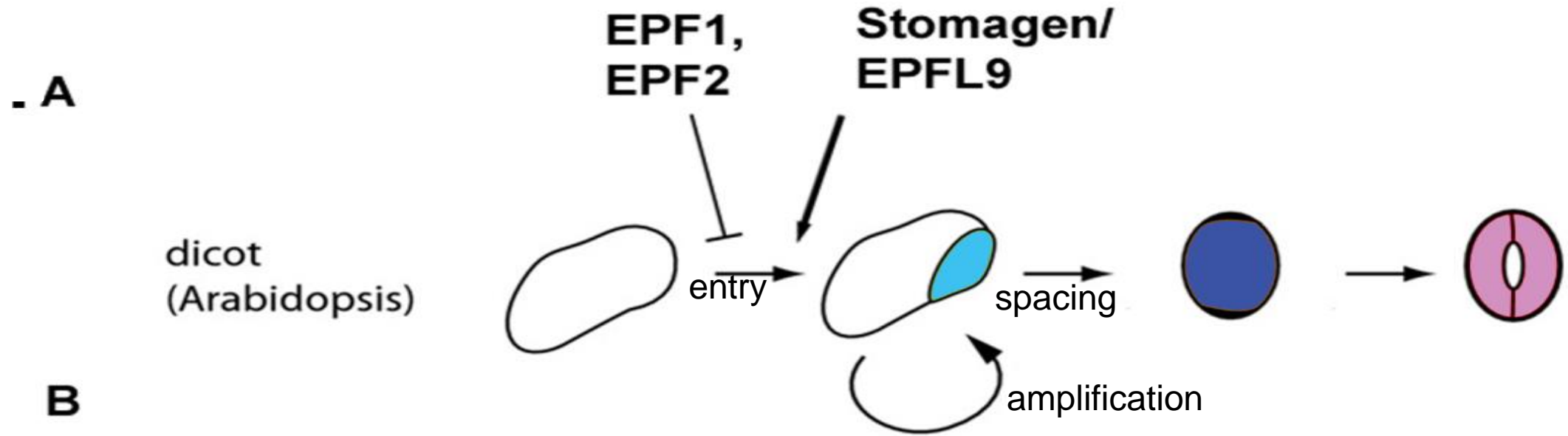
Short-term  
aperture  
adjustment



Long term  
developmental  
change



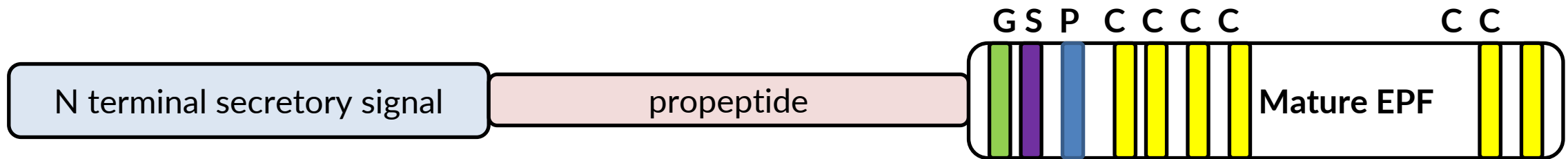
# Stomatal development is tightly controlled



Suite of phenotypes permit direct physiological analyses

# Epidermal Patterning Factors (EPFs)

- Cysteine-rich
- Cleaved and secreted peptides
- Fine-tune stomatal patterning processes
- Receptor agonists (EPF1/EPF2) inhibit stomata
- Receptor antagonist (EPFL9/Stomagen) induces stomata



# Improving drought tolerance by reducing stomatal densities

*Journal of Experimental Botany*

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RESEARCH PAPER

## Reduced stomatal density in bread wheat leads to increased water-use efficiency

Jessica Dunn<sup>1,\*</sup>, Lee Hunt<sup>1,\*</sup>, Mana Afsharinafar<sup>1</sup>, Moaed Al Meselmani<sup>1</sup>, Alice Mitchell<sup>1</sup>, Rhian Howells<sup>2</sup>, Emma Wallington<sup>2</sup>, Andrew J. Fleming<sup>3,†</sup> and Julie E. Gray<sup>1,†</sup>

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\* These authors contributed equally to this work.

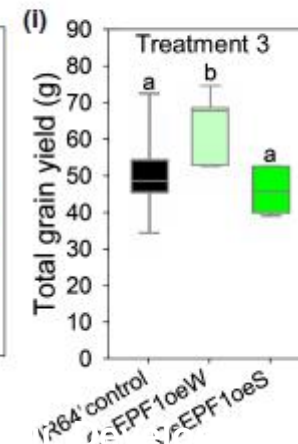
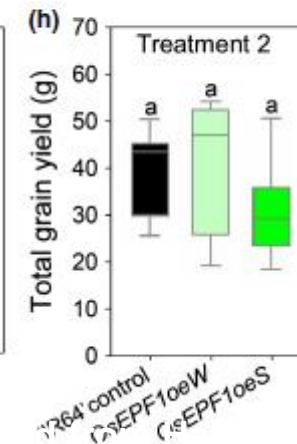
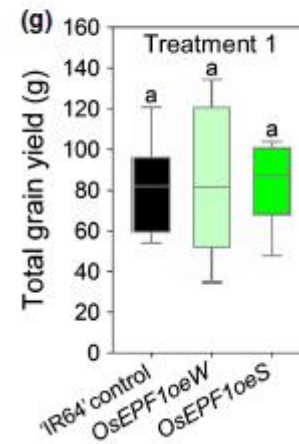
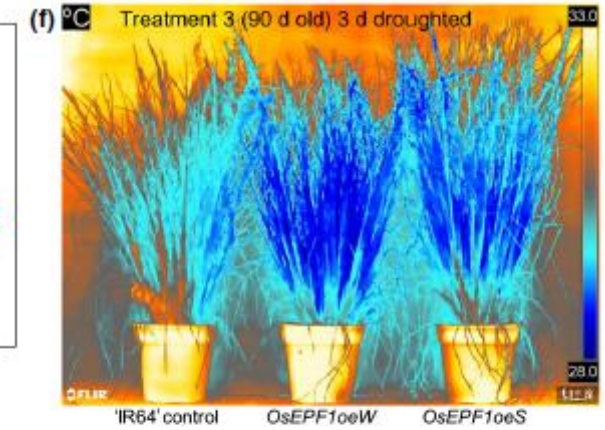
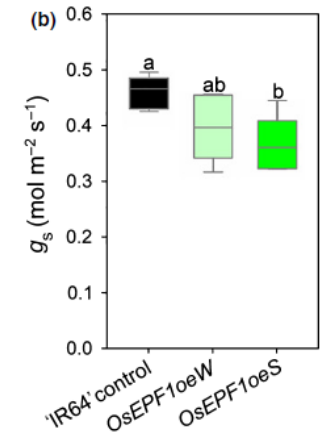
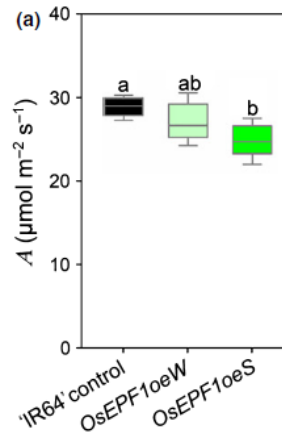
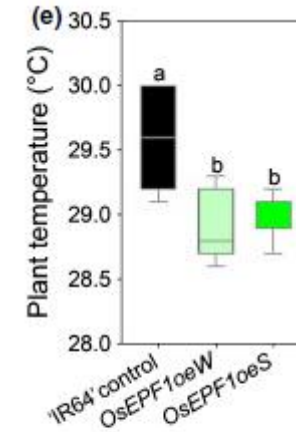
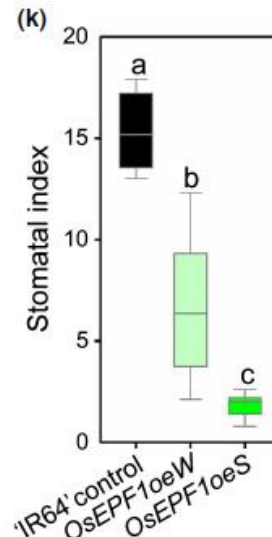
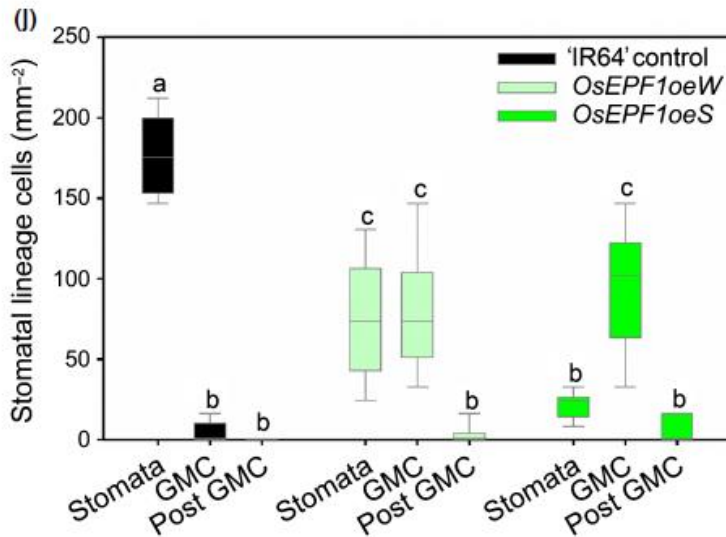
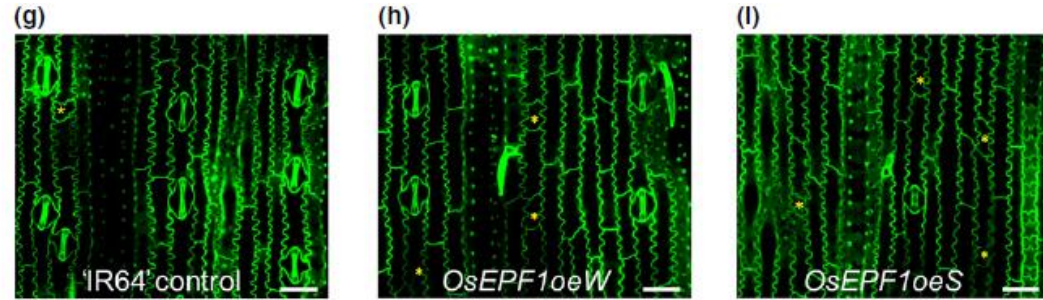
† Correspondence: [a.fleming@sheffield.ac.uk](mailto:a.fleming@sheffield.ac.uk) or [j.e.gray@sheffield.ac.uk](mailto:j.e.gray@sheffield.ac.uk)

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# Rice with reduced stomatal density conserves water and has improved drought tolerance under future climate conditions

Robert S. Caine<sup>1</sup> , Xiaojia Yin<sup>2</sup>, Jennifer Sloan<sup>1</sup> , Emily L. Harrison<sup>1</sup>, Umar Mohammed<sup>3</sup>, Timothy Fulton<sup>1,4</sup> , Akshaya K. Biswal<sup>2,5</sup> , Jacqueline Dionora<sup>2</sup>, Caspar C. Chater<sup>1,6</sup> , Robert A. Coe<sup>2,7</sup>, Anindya Bandyopadhyay<sup>2</sup>, Erik H. Murchie<sup>3</sup> , Ranjan Swarup<sup>3</sup> , W. Paul Quick<sup>2</sup> and Julie E. Gray<sup>1</sup> 



# Reducing bean $g_s$ could improve WUE without a C penalty

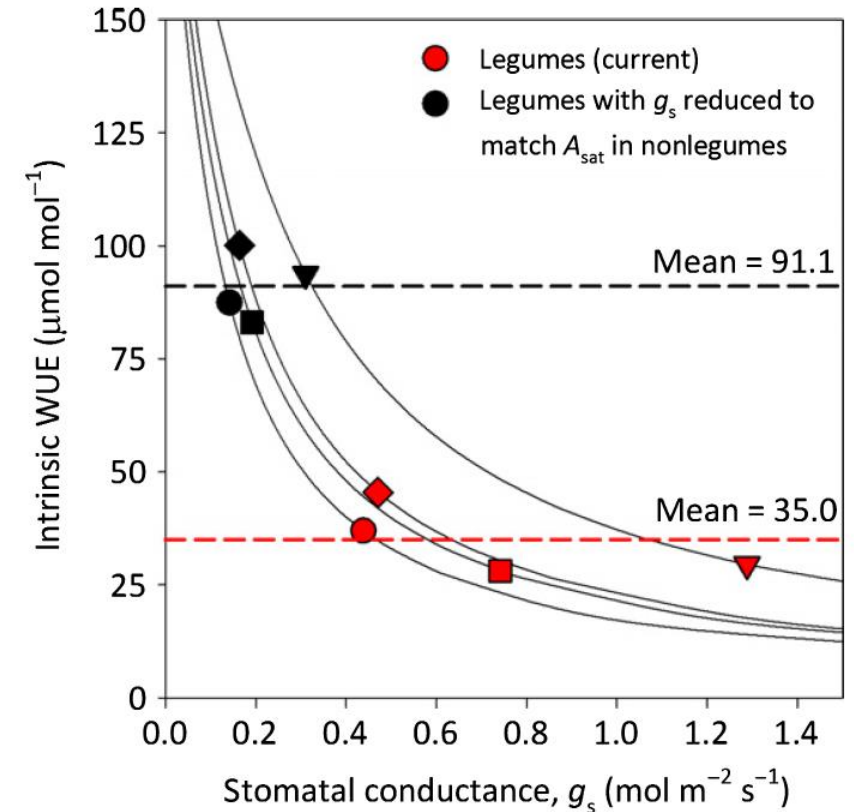
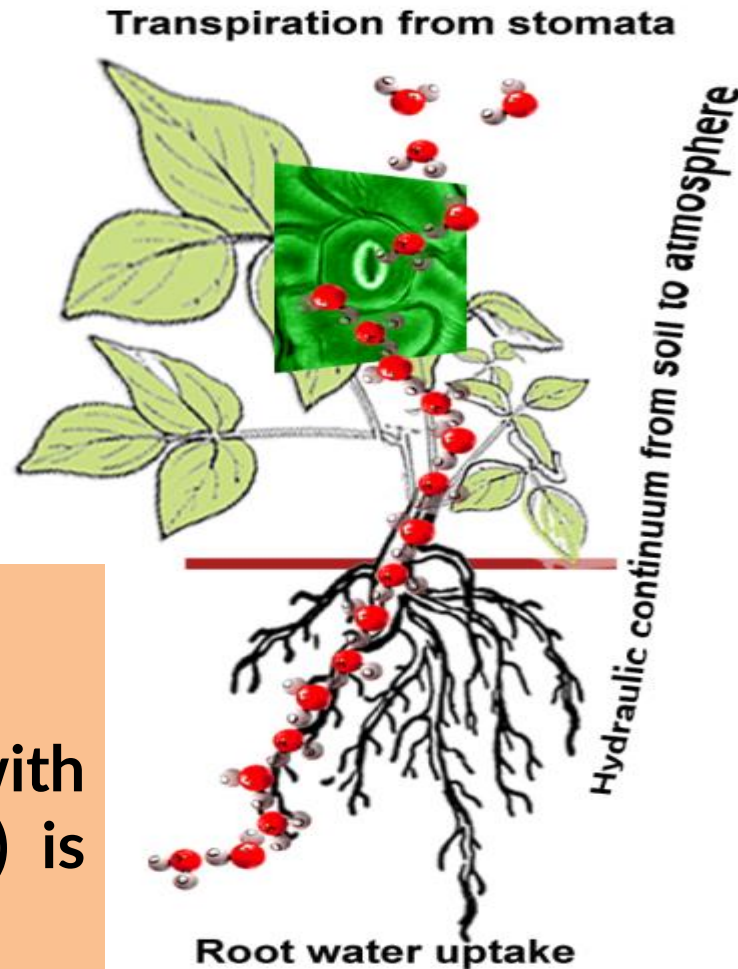
Legumes are special:

- leaf N non-limiting to photosynthesis (A).
- $\therefore A$  not  $\propto$  to leaf N.
- Reducing  $g_s$  could increase water use efficiency (WUE) 120–218% and maintain A.

How can we reduce  $g_s$ ?

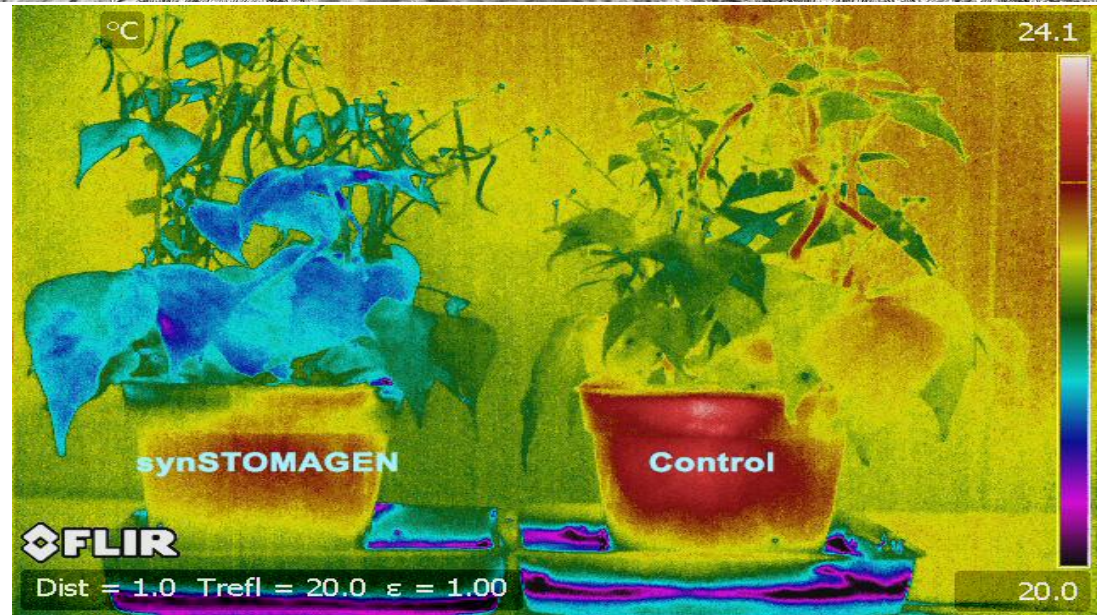
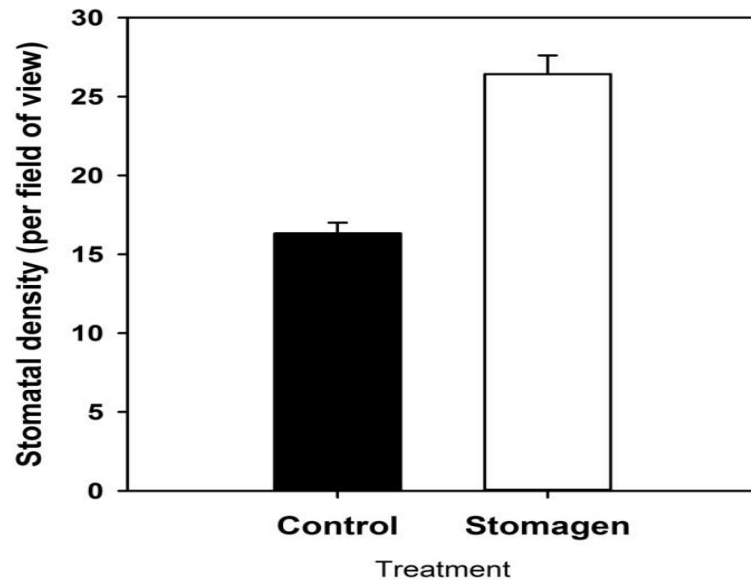
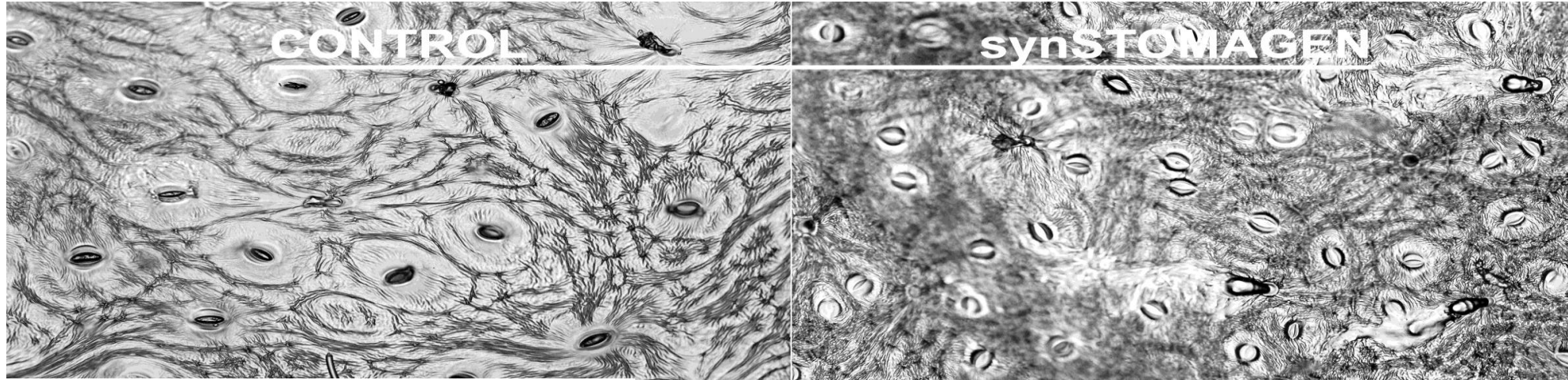
Breeding legume crops with low stomatal densities (SD) is one way.

**But N fixation is Carbon hungry!**



Simulated WUE gains from breeding legumes with reduced  $g_s$ . Lines:  $g_s$  vs WUEi relationships (circles, *Vicia faba*; diamonds, *Glycine max*; squares, *Lupinus alba*; triangles, *Cicer arietinum*).

# AtEPFL9 peptide promotes bean stomatal development





# Using the soybean model to test EPFs and low stomatal densities

Plant Cell Rep  
DOI 10.1007/s00299-017-2118-z

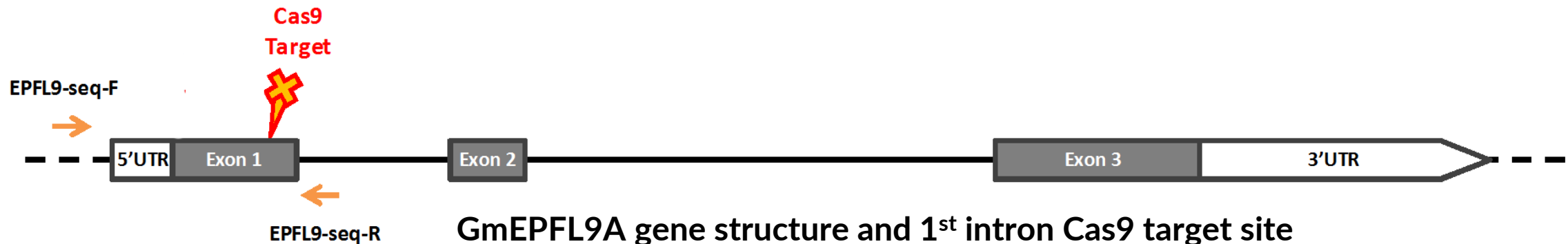


RESEARCH ARTICLE

## CRISPR-Cas9 and CRISPR-Cpf1 mediated targeting of a stomatal developmental gene *EPFL9* in rice

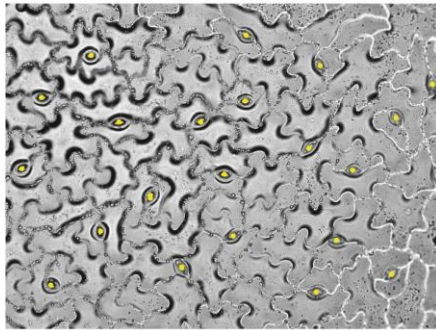
Xiaojia Yin<sup>1</sup> · Akshaya K. Biswal<sup>1,3</sup> · Jacqueline Dionora<sup>1</sup> · Kristel M. Perdigon<sup>1</sup> · Christian P. Balahadia<sup>1</sup> · Shamik Mazumdar<sup>1</sup> · Caspar Chater<sup>2,4</sup> · Hsiang-Chun Lin<sup>1</sup> · Robert A. Coe<sup>1</sup> · Tobias Kretzschmar<sup>1</sup> · Julie E. Gray<sup>2</sup> · Paul W. Quick<sup>1,5</sup> · Anindya Bandyopadhyay<sup>1</sup>

- *GmEPFL9* deletion could phenocopy *EPF2* overexpression:
- low SD and improved WUE.
- Collaborations with Tom Clemente (Nebraska), Andrew Leakey (Illinois), and Akshaya Biswal (CIMMYT).

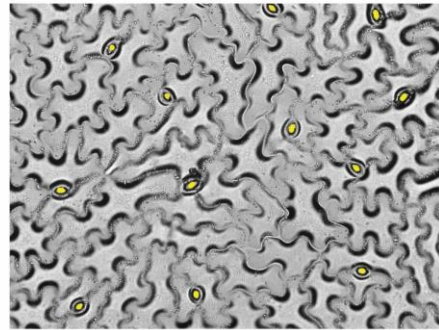




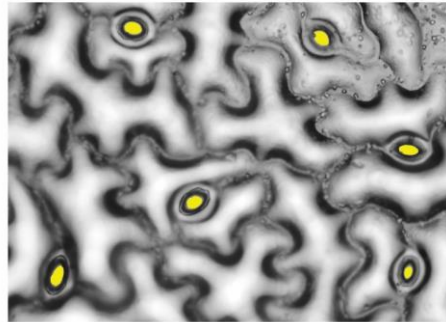
# Overexpression of Common bean *PvEPF2* reduces stomatal density in soybean



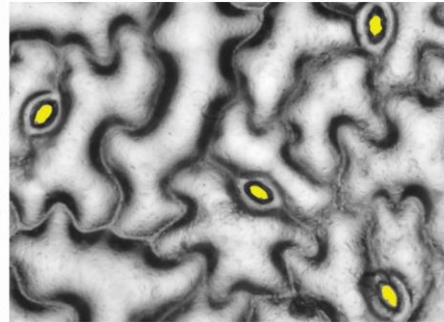
Williams 82



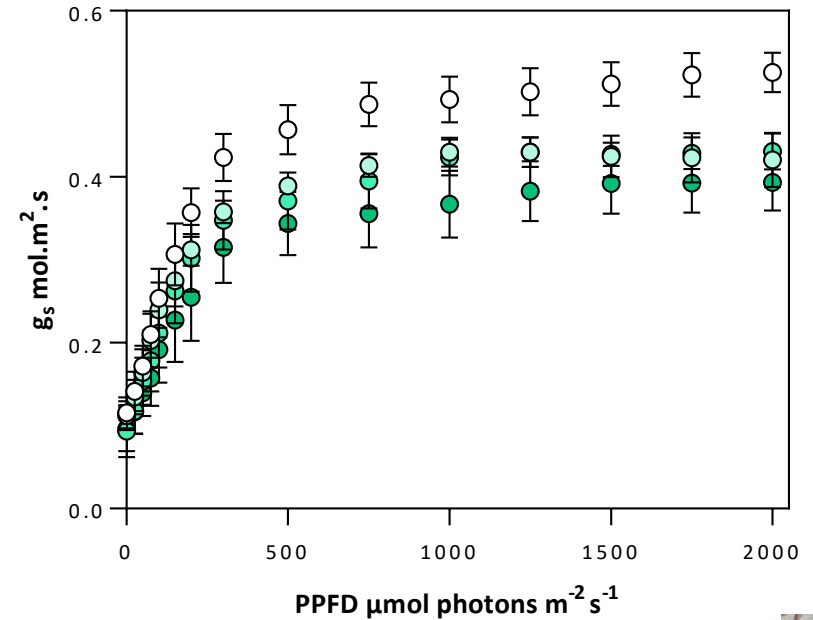
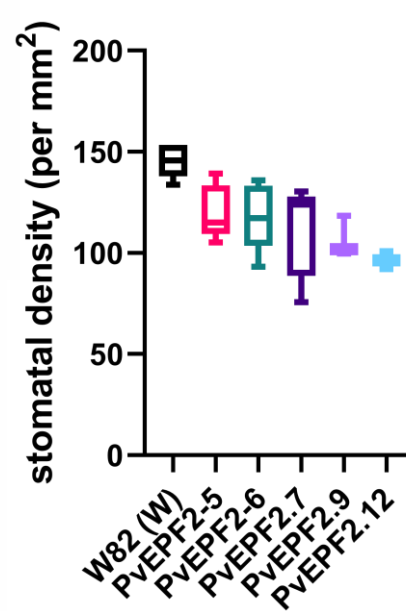
PvEPF2.7



Williams 82



PvEPF2.12



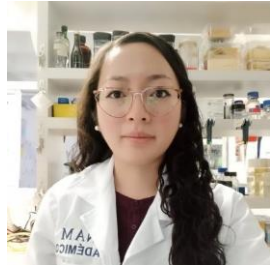
- Wild-type
- *PvEPF2OE-5*
- *PvEPF2OE-6*
- *PvEPF2OE-9*

Low-*SD* soybean have lower  $g_s$  and higher WUE





# Leveraging Peptides to Enhance legume N fixation for sustainable agriculture



Dr. Carolina Isidra Arellano



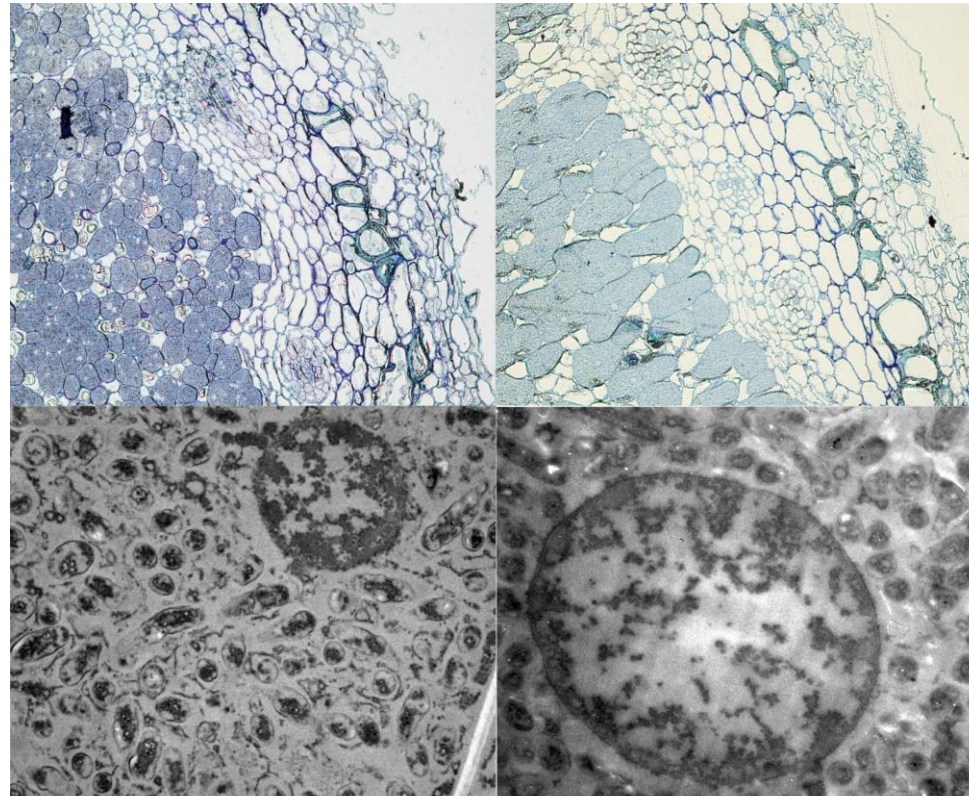
Dr. Litzy Ayra Pardo



Prof. Oswaldo Valdes-López



Prof. Julie Gray



- My stomatal EPF work has identified novel EPF signaling pathways in nodulation.
- By understanding bean N fixation we can improve crop yields and reduce negative environmental impacts.

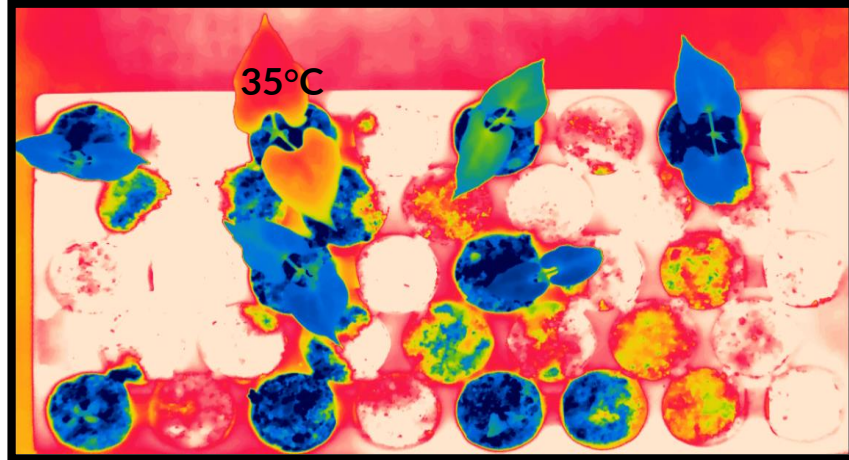


**Newton  
Fund**

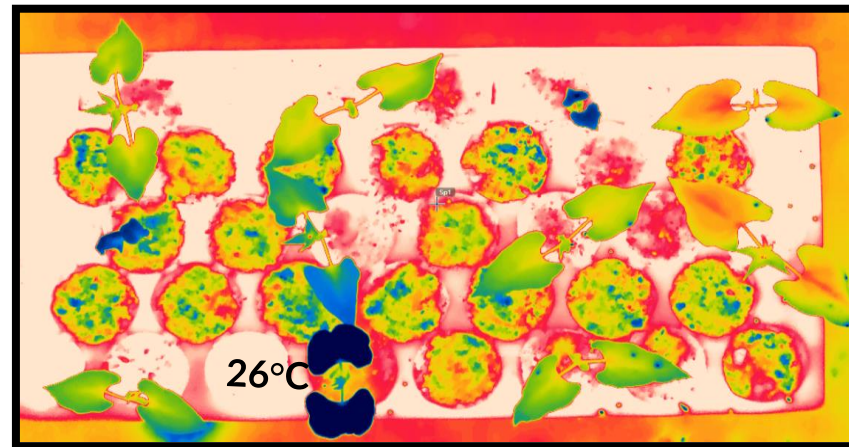


The  
University  
Of  
Sheffield.

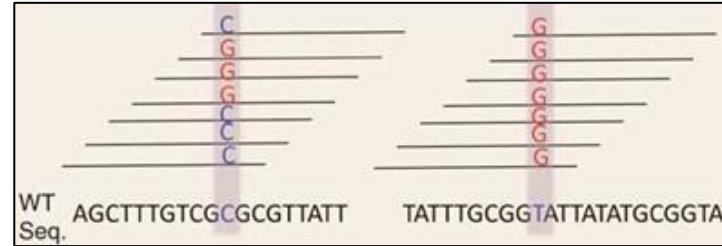




Identify 'hot' mutants



Identify 'cool' mutants



The University of Sheffield.

- WGS and transcriptomics to identify causative variation underlying phenotypes.
- Effects of and on WUE and N fixation.



Dr. Pablo Peláez



Dr. Delfeena Eapen



Dr. Alexis Acosta



Dr. Jose Polania



Prof. Alejandra Covarrubias



Prof. Gina Hernández



Centro de Ciencias Genómicas



Instituto de Biotecnología  
UNIVERSIDAD NACIONAL AUTÓNOMA DE MÉXICO



# *Characterising Drought Tolerance in Colombian Common Beans*



**Kate Denning-James**

- Diversity panel (Andean and Mesoamerican)
- Domesticated and wild
- Water deficit responses
- JIC Glasshouse vs CIAT field experiments.
- GWAS and transcriptomics
- To identify novel bean traits and diversity



**Dr. Jose de Vega**

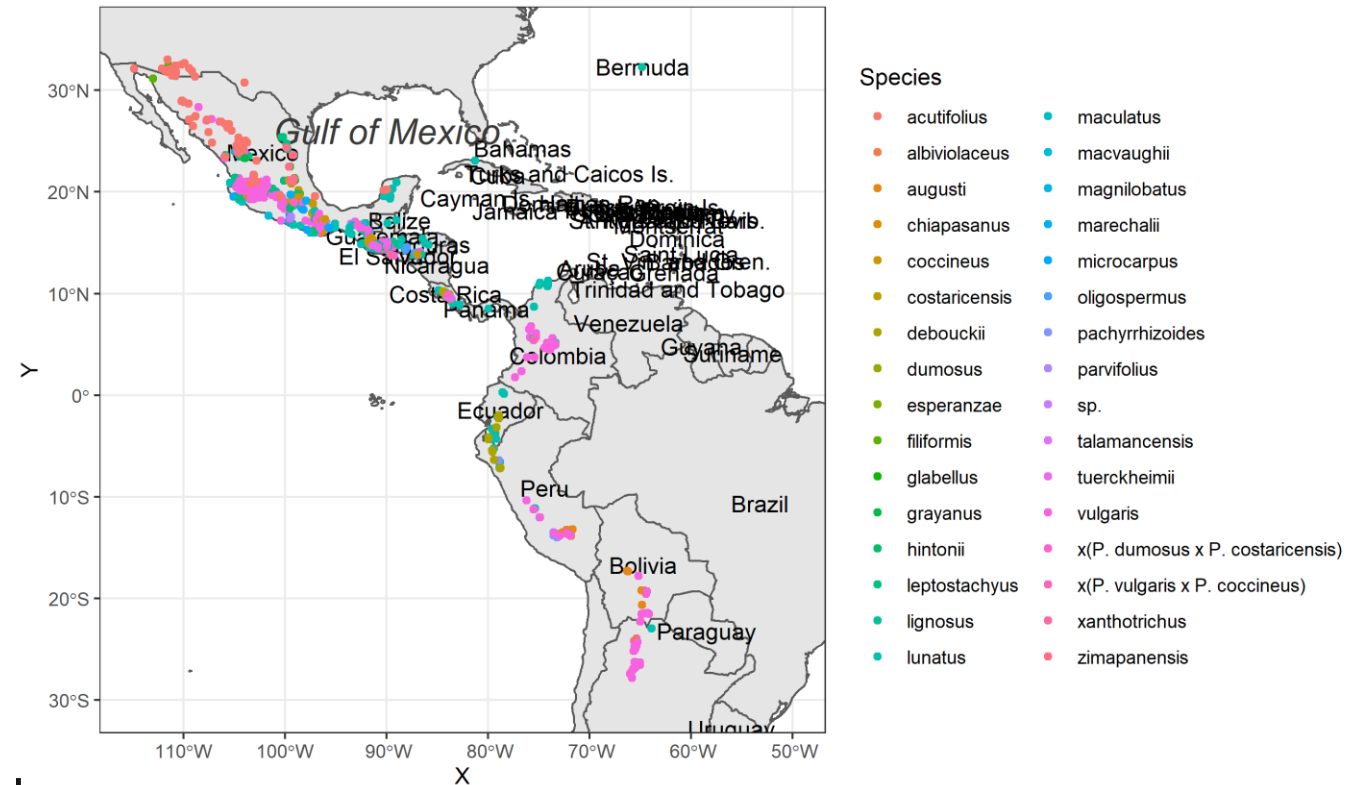


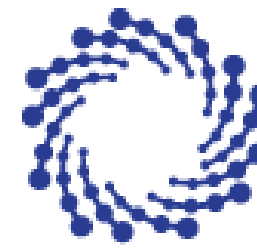
# Phaseolus crop wild relatives with heat and drought stress tolerance traits



Dr. Claudia Lowe

- **FIGS: Focused Identification of Germplasm Strategy**
- Ecogeographic variables in wild Phaseolus from hot / dry areas
- Faster than screening thousands of accessions in the glasshouse or field
- Test populations and identify traits





Dr. Justin Moat

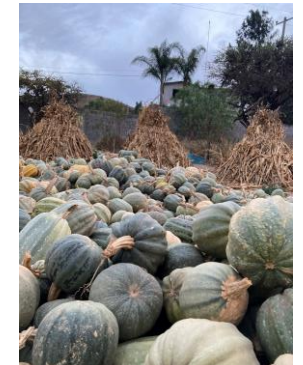
**Participatory Research:** Stakeholder interviews, workshops, and data collection

**Climate Niche Modelling:** Projections 10, 20, 30 years ahead.

**Experimental heat- and -drought resistant Altiplano milpa:** Comparing elite and landrace germplasm.



DRA. NATALIA MARTÍNEZ TAGÜEÑA  
IPICYT



# Accelerated Diversification for Climate Resilient Agriculture



Scaling up neodomestication for climate-ready crops  
Rafal M. Gutaker<sup>1</sup>, Caspar C. C. Chater<sup>1</sup>, Jemima Brinton<sup>1</sup>,  
Elena Castillo-Lorenzo<sup>2</sup>, Elinor Broman<sup>3</sup> and Samuel Pironon<sup>1</sup>

**Abstract**  
We can increase the stability of our food systems against environmental variability and climate change by following the footsteps of our ancestors and domesticating edible wild plants. Reinforced by recent advances in comparative genomics and gene editing technologies, neodomestication opens possibilities for a rapid generation of new crops. By steering the candidate selection pipeline with climatic parameters, we orient neodomestication efforts to increase food security against climate change. We highlight the role that the native species conservation and characterization will be key in this process. Utilization of genetic resources, entrusted to conservationists and researchers by local communities, has to be conducted with highest ethical standards and benefit-sharing in mind.

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**Current Opinion in Plant Biology** 2022, 66:102189

This review comes from a themed issue on **Genetics studies and molecular genetics**  
Edited by **Benjamin Chae** and **Daniel Kwanig**  
For a complete overview see the Issue and the Editorial  
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<https://doi.org/10.1016/j.copbi.2021.102189>  
1369-5269/22/\$ - See front matter © 2022 Elsevier Ltd. All rights reserved.

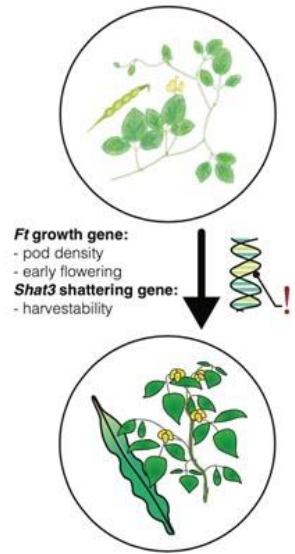
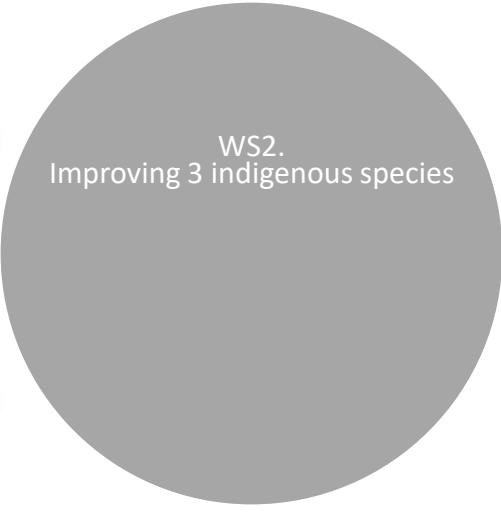
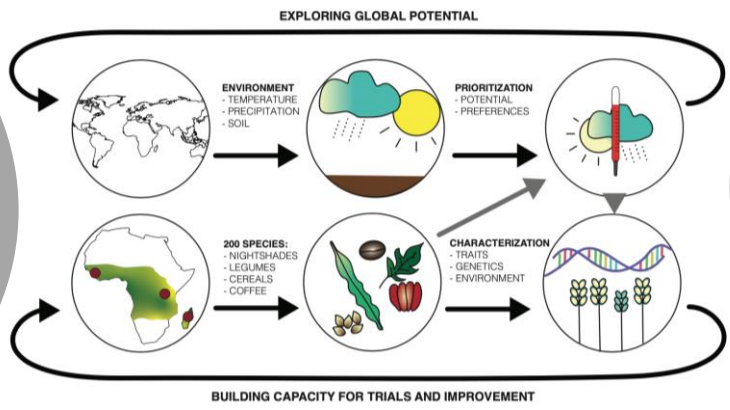
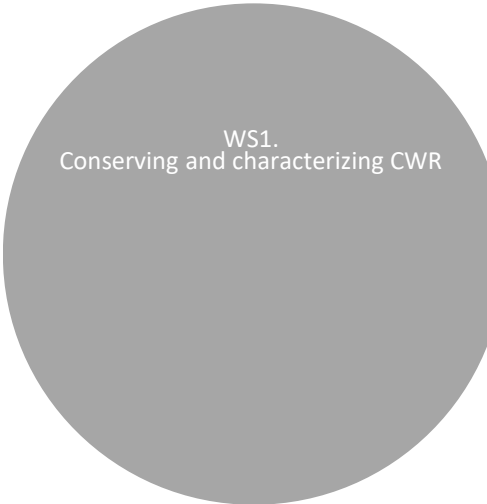
**Keywords**  
Neodomestication, Climate change, Food security, Agriculture, Adoption  
**Abbreviations**  
IPCC, Intergovernmental Panel on Climate Change; CGIAR, Consortium of International Agricultural Research Centers; MSBP, Mission Seed Bank Partnership; WFP, World Food Programme; DCI, Domestication Trait

**Introduction**  
Reports from the Intergovernmental Panel on Climate Change (IPCC) predict global mean temperatures to increase from pre-industrial levels by ~1–6 °C by the end of this century with potentially disastrous impacts on our

agricultural systems and food security [1]. Particularly dangerous to most crops is the forecasted increase in the frequency and severity of drought and heat events [2], but even climate variability and unpredictability themselves are detrimental to yields [3]. To protect food systems, researchers and breeders are incorporating environmental resilience traits from wild species into elite-level crops. Progress has been made with this approach, but it is very slow and difficult to implement due to highly complex genetic mechanisms underlying environmental resilience, often involving hundreds of genes, unexplained effects in new genetic contexts, and linkage with undesired traits [3]. The IPCC reports suggest that one of the main routes of adaptation to climate change is the utilization of agrobiodiversity, i.e., a wide variety of cultivated species, cultivated ecosystems, and agrarian practices [1]. Diverse edible plant species are adapted to a broad range of environments across the world, thus offering a solution to climate change threats [4]. However, undomesticated species have characteristics that impede their cultivation/ utilization as a large scale (e.g., spontaneous seed shedding before harvest). Domestication of climate-ready wild species might be an efficient strategy complementary to incorporating environmental resilience into existing crops. While domestication historically is a lengthy process, new gene editing tools hold promise for rapid change via a process called neodomestication.

In this article, we consider what is needed to scale up neodomestication as a familiar way to bolster our food security against climate change. First, we outline what domestication is, and the recent progress in rapid neodomestication efforts. Second, we review challenges for our agricultural systems that come with climate change. Finally, we address the neodomestication potential of wild plant species, pipeline for testing this potential, and capacity building while highlighting the ethical considerations and benefit-sharing responsibilities that come with neodomestication. We argue that the seed reserves and pipelines for the neodomestication process should be built as soon as possible as deploying neodomesticated crops into the field could face various challenges [7].

[www.sciencedirect.com](https://www.sciencedirect.com) **Current Opinion in Plant Biology** 2022, 66:102189



- £2.5 million project funded by Calleva.
- Focus on drought resilient crops for sub-Saharan Africa.
- Gene editing a *Vigna* crop for farmer and consumer acceptance.
- Target-species consultations with in-country partners and international experts



## Bean crops of the future:

- Stomata and nodules provide opportunities for crop improvement.
- Complex effects of above/below-ground legume signalling.
- Complex landscape of evolution, domestication, diversity, and culture.
- Fine-tune targets for more extreme climates.

**Improving our bean crops can strengthen food and water security under climate change**

