Royal Botanic Gardens Kew

Kirkhouse Trust Meeting, Livingstone, Zambia
Monday 27th February 2023

Leveraging bean crop genetics and diversity for climate adaptation

Caspar Chater

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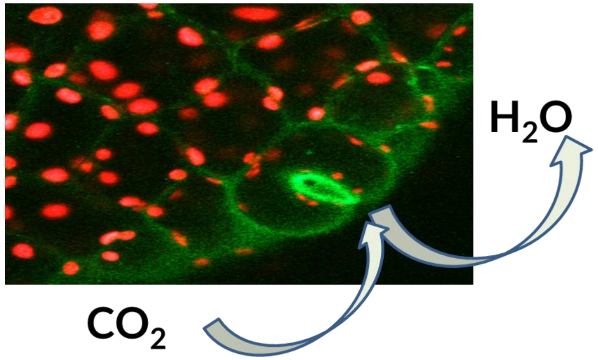
Stomata, gas exchange and plant water status

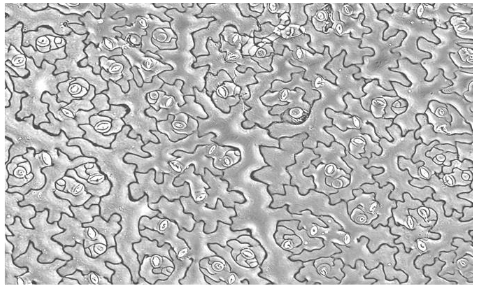
Stomata control water uptake and loss by transpiration.

Stomata control:

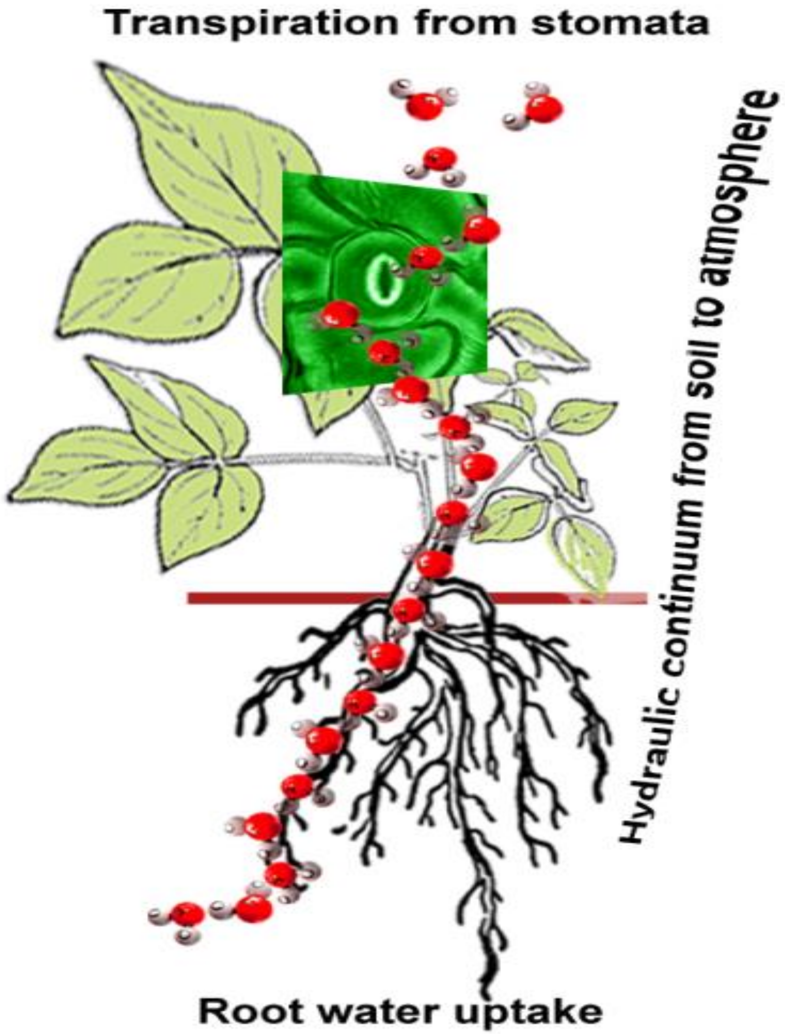
- **Water loss**
- **Nutrient accumulation**
- **CO_2 uptake**
- **Evaporative cooling**
- **Pathogen responses**



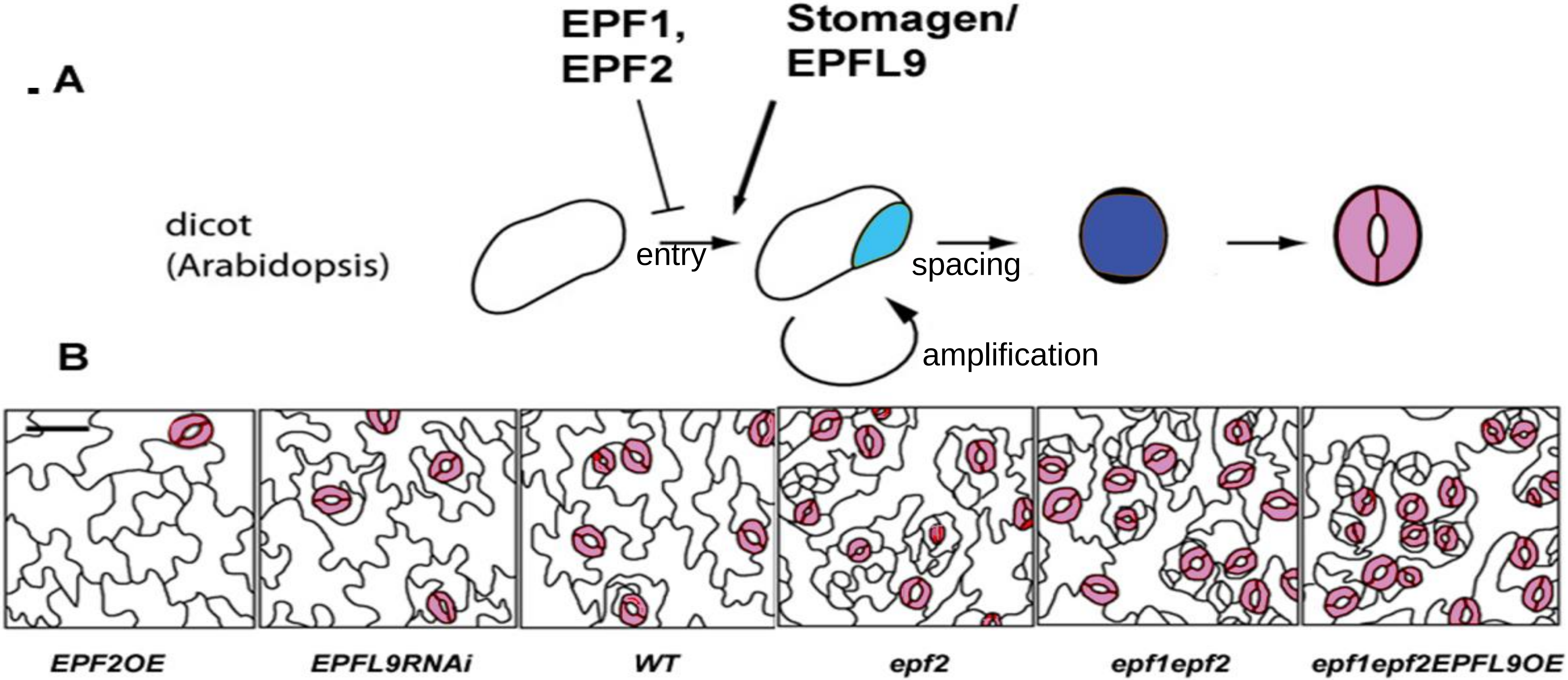
Short-term aperture adjustment



Long term developmental change



Stomatal development is tightly controlled



Suite of phenotypes permit direct physiological analyses

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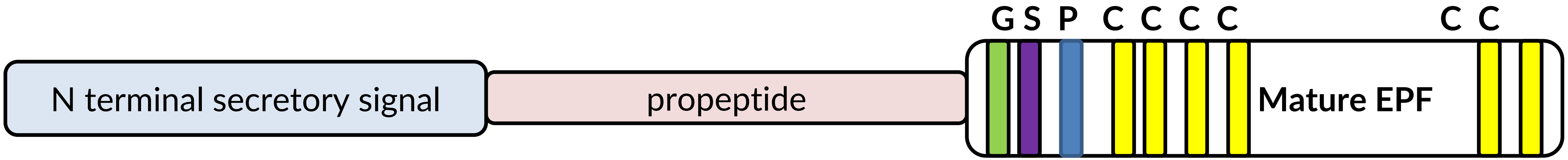
Epidermal Patterning Factors (EPFs)

- 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
doi:10.1093/jxb/erz248 Advance Access Publication 6 June 2019
This paper is available online free of all access charges (see https://academic.oup.com/jxb/pages/openaccess for further details)

RESEARCH PAPER

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

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

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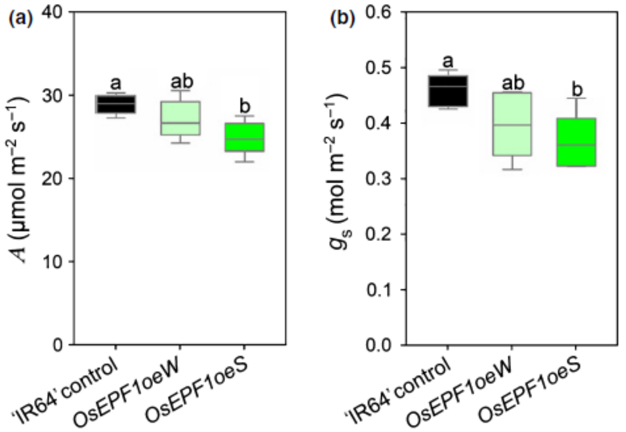
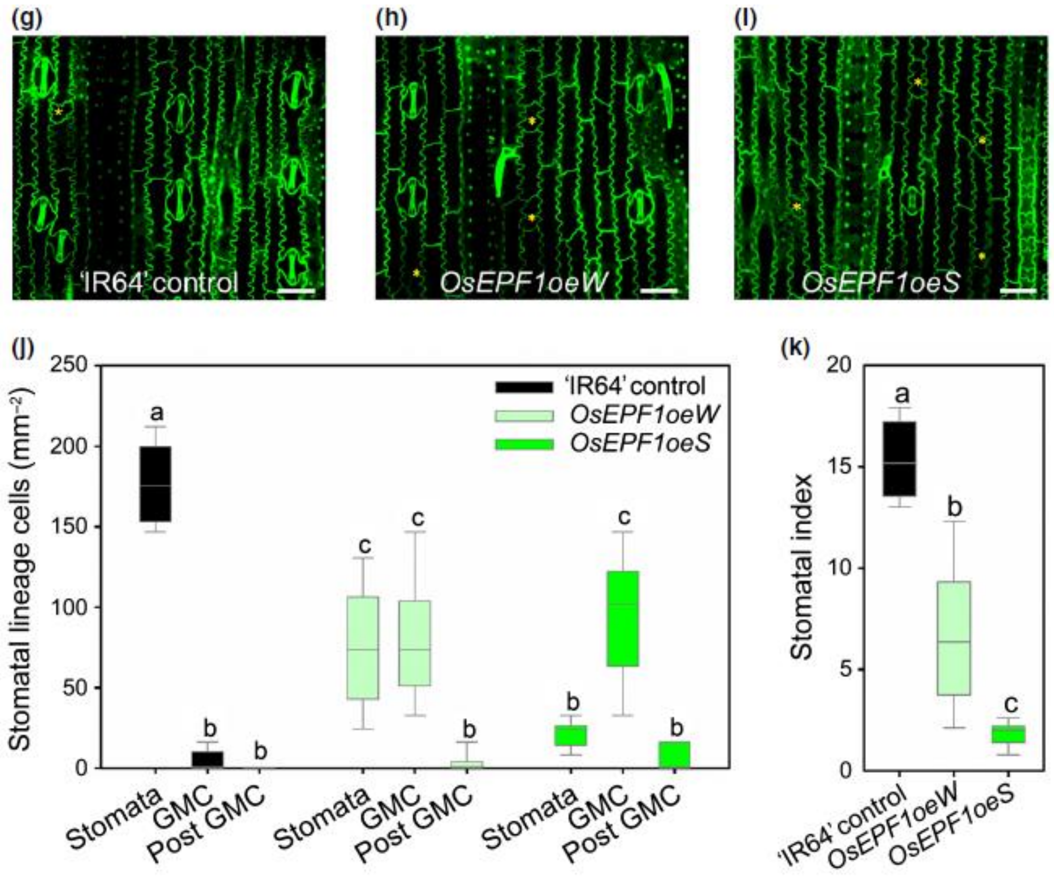
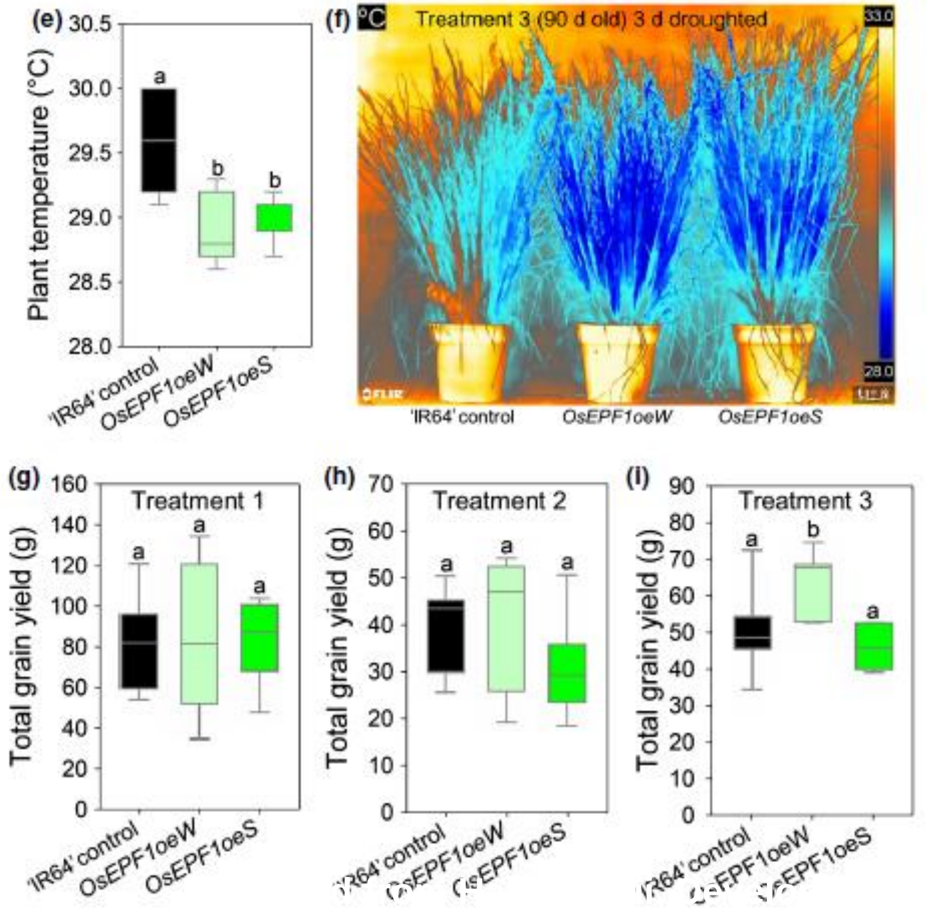
New Phytologist
Research

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

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







Reducing bean g_s could improve WUE without a C penalty

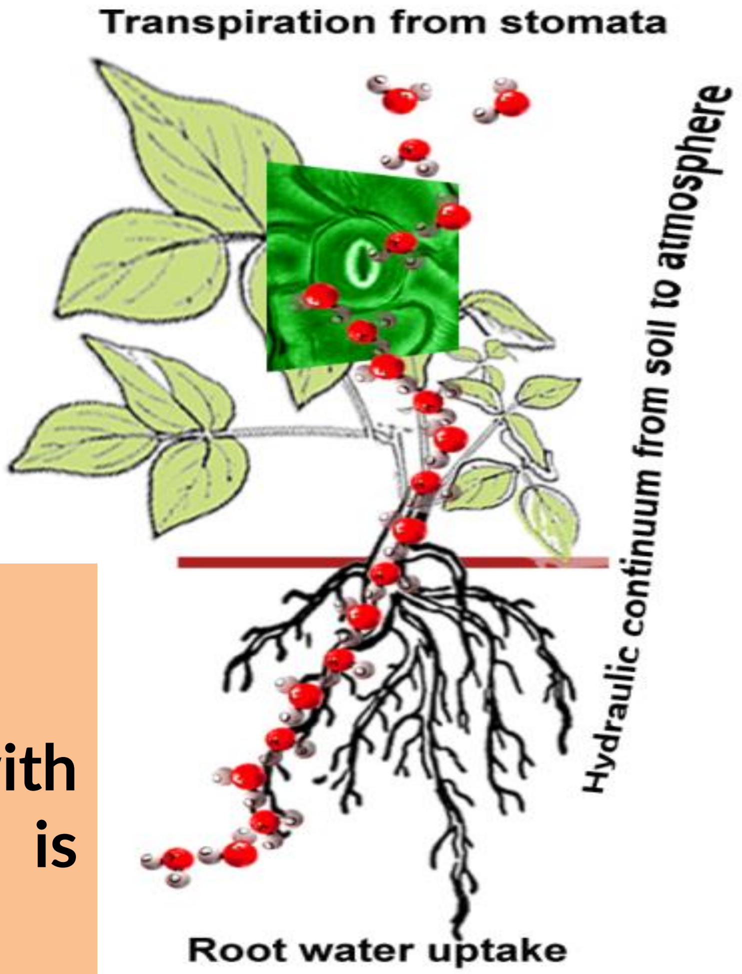
Legumes are special:

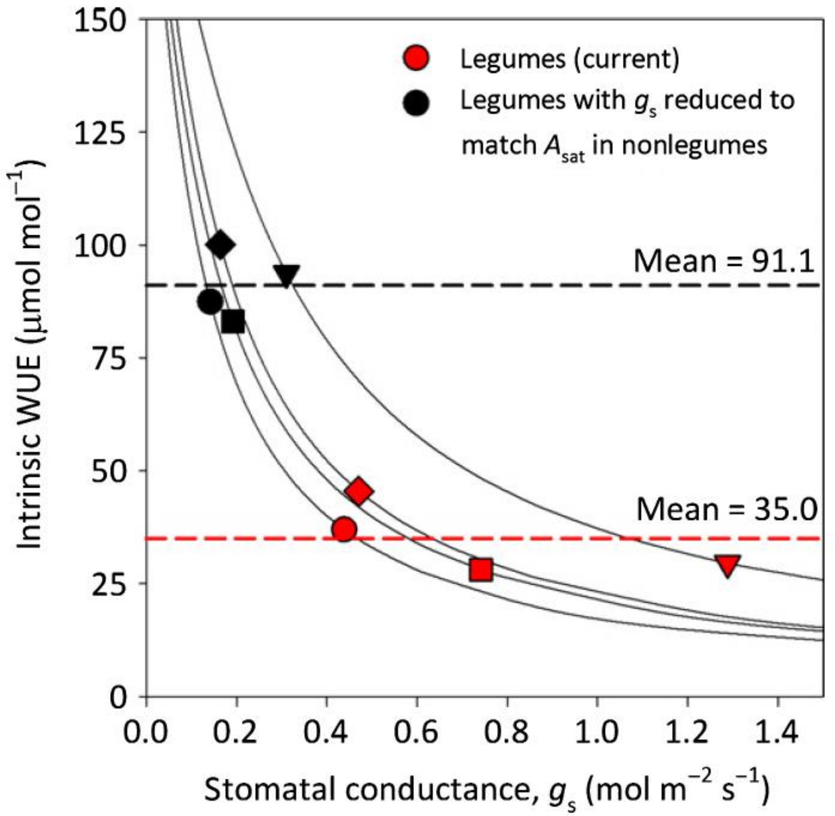
- leaf N non-limiting to photosynthesis (*A*).
- ∴ *A* not ∝ to leaf N.
- Reducing g_s could increase water use efficiency (WUE) 120–218% and maintain *A*.

How can we reduce g_s?

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

<u>But N fixation is Carbon hungry!</u>

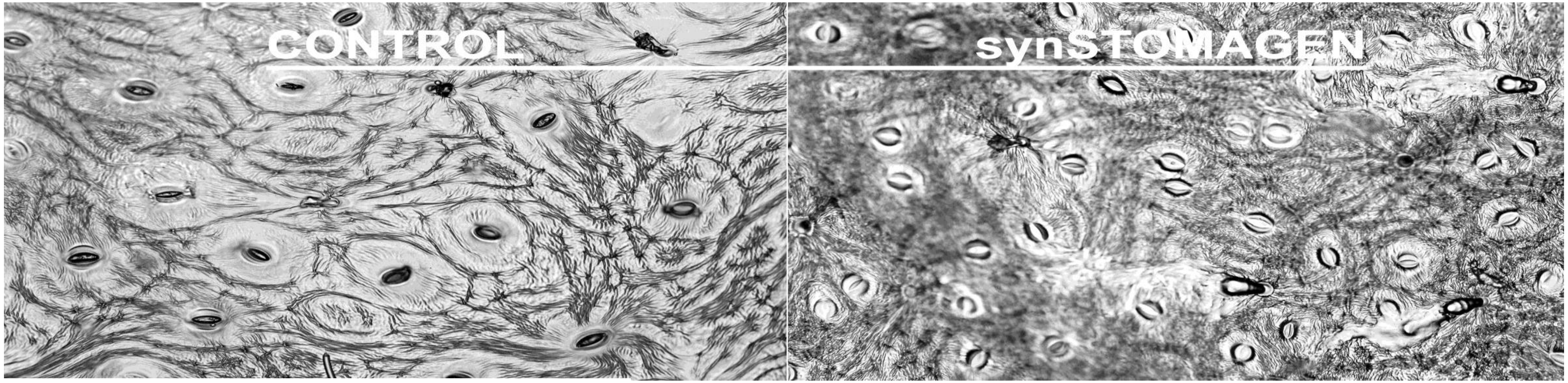


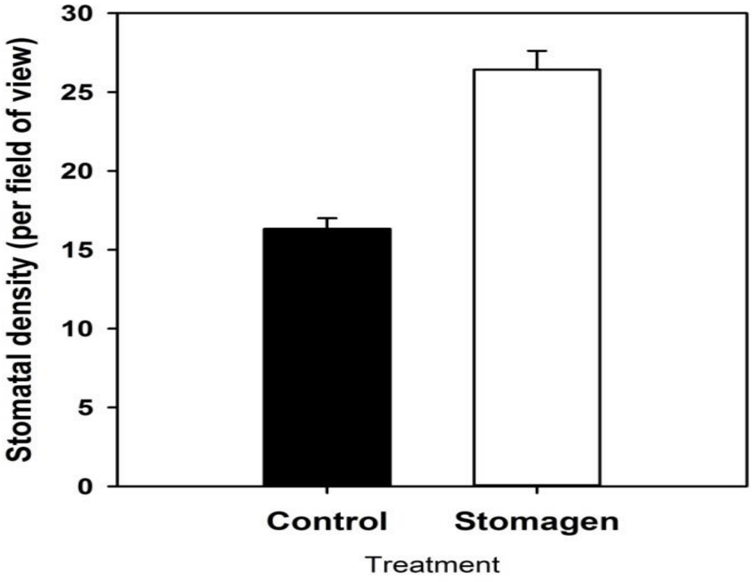


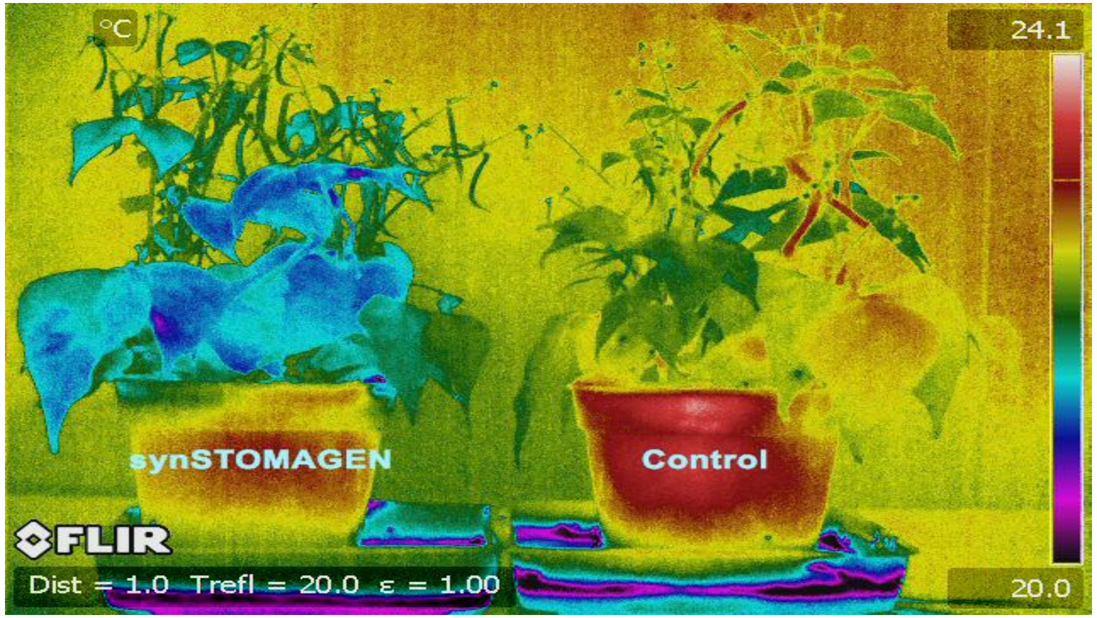
Simulated WUE gains from breeding legumes with reduced g_s. Lines: g_s vs WUEi relationships (circles, *Vicia faba*; diamonds, *Glycine max*; squares, *Lupinus alba*; triangles, *Cicer arietinum*).

Mark Adams *et al.* NewPhyt 2018.

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

CrossMark

RESEARCH ARTICLE

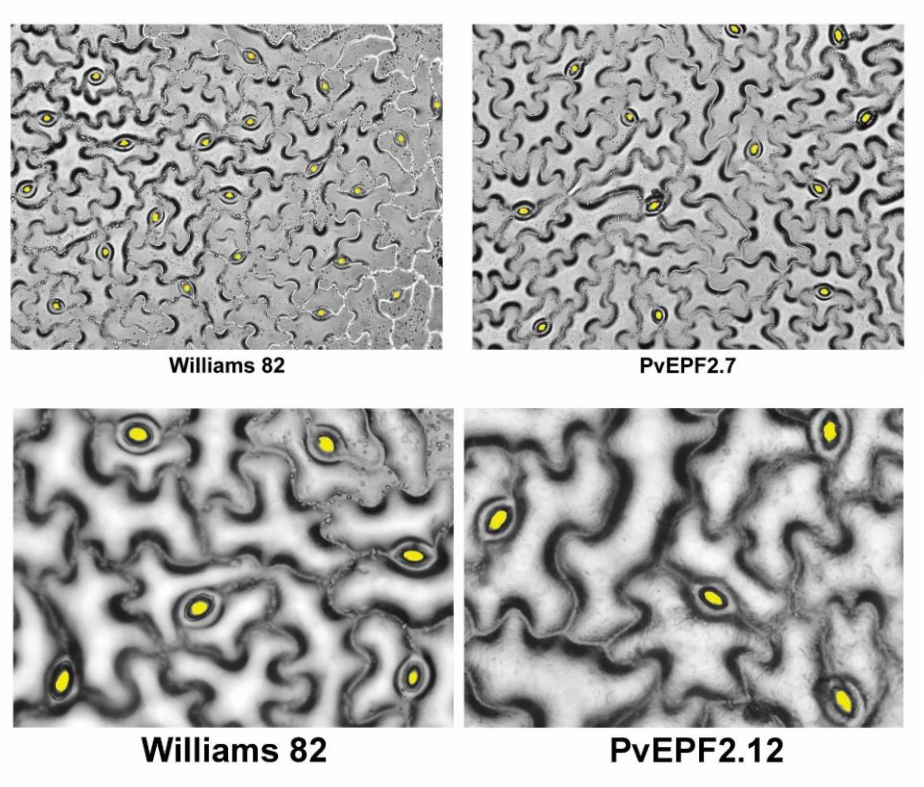
CRISPR-Cas9 and CRISPR-Cpf1 mediated targeting of a stomatal developmental gene *EPFL9* in rice

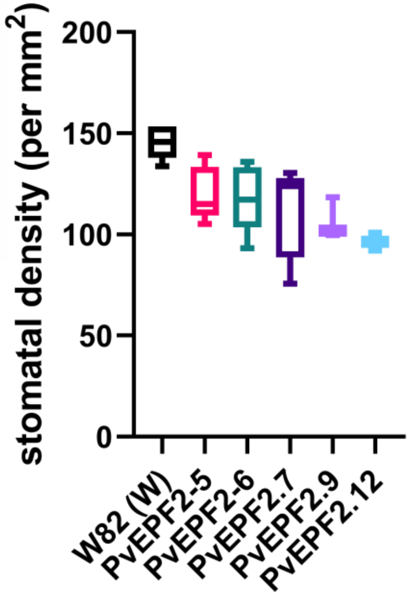
Xiaojia Yin[1] · Akshaya K. Biswal[1,3] · Jacqueline Dionora[1] · Kristel M. Perdigon[1] · Christian P. Balahadia[1] · Shamik Mazumdar[1] · Caspar Chater[2,4] · Hsiang-Chun Lin[1] · Robert A. Coe[1] · Tobias Kretzschmar[1] · Julie E. Gray[2] · Paul W. Quick[1,5] · Anindya Bandyopadhyay[1]

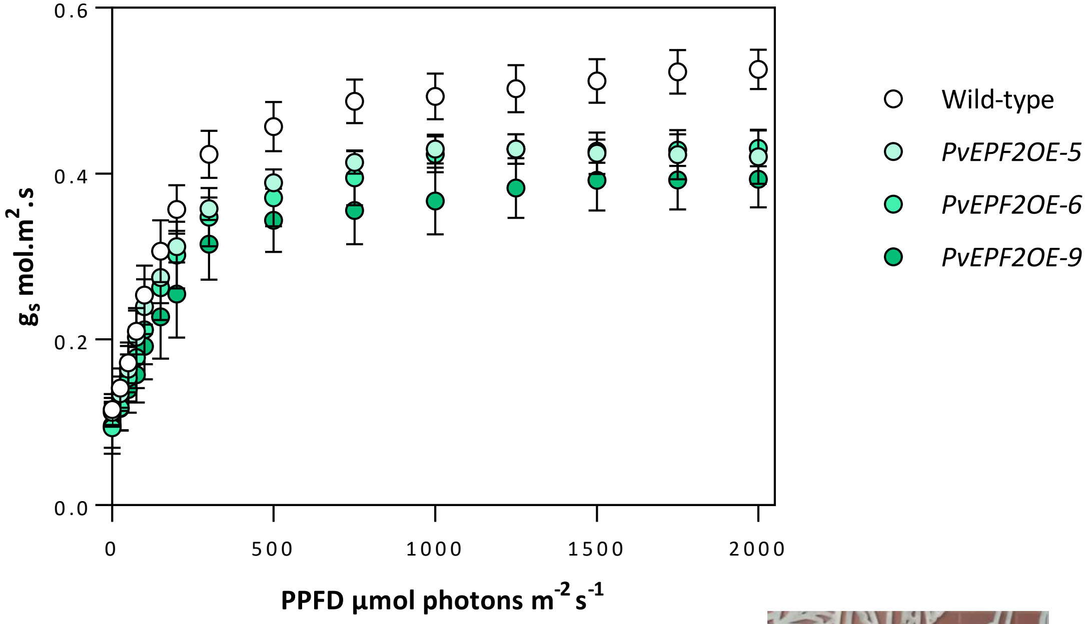
- *GmEPFL9* deletion could phenocopy *EPF2* overexpression:
- low SD and improved WUE.
- Collaborations with Tom Clemente (Nebraska), Andrew Leakey (Illinois), and Akshaya Biswal (CIMMYT).

GmEPFL9A gene structure and 1st intron Cas9 target site

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







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

Jess Dunn, Miles Bate-Weldon, Chater *et al*. unpublished.

Leveraging Peptides to Enhance legume N fixation for sustainable agriculture

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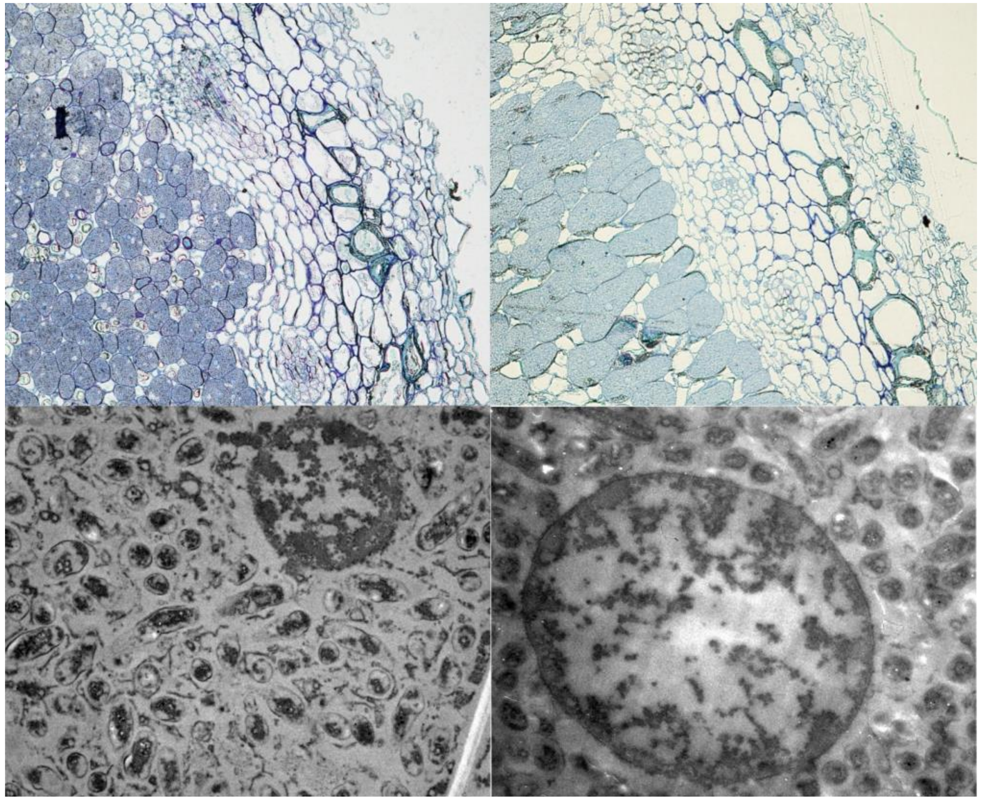
Dr. Carolina Isidra Arellano

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.

THE ROYAL SOCIETY

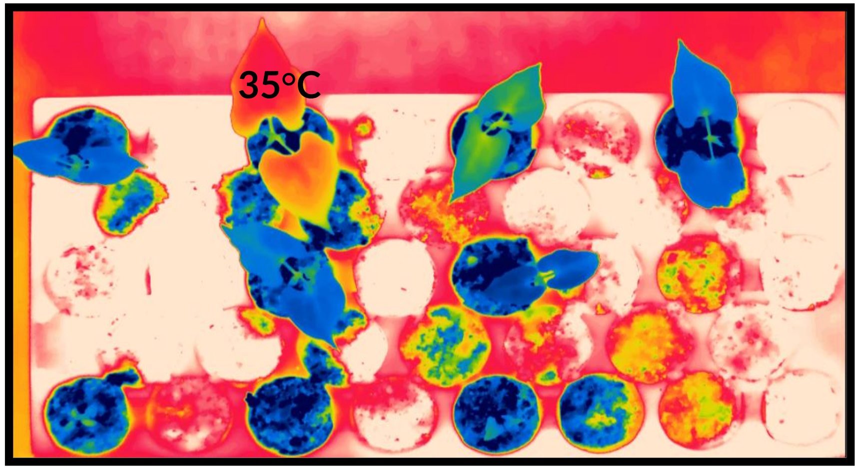
Newton Fund

IZTACALA

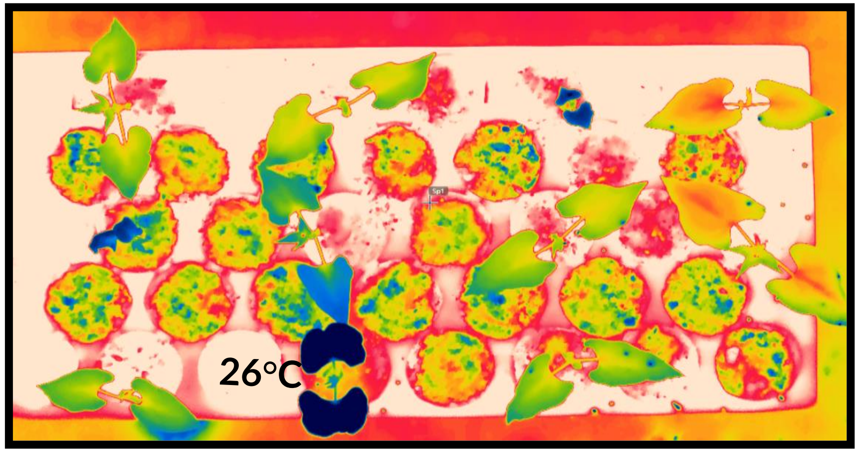
The University Of Sheffield.

GCRF Global Challenges Research Fund

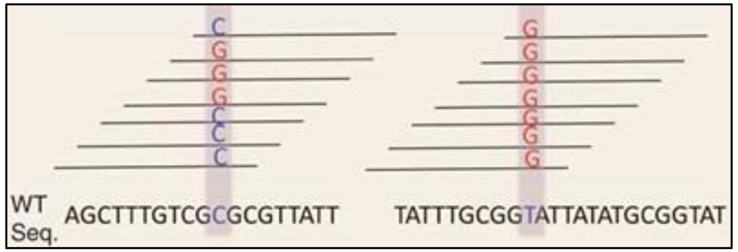
Common bean WUE and N fixation improvement



Identify ‘hot’ mutants



Identify ‘cool’ mutants



- 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

Royal Botanic Gardens Kew

Earlham Institute

Characterising Drought Tolerance in Colombian Common Beans

Kate Denning-James

Dr. Jose de Vega

- 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

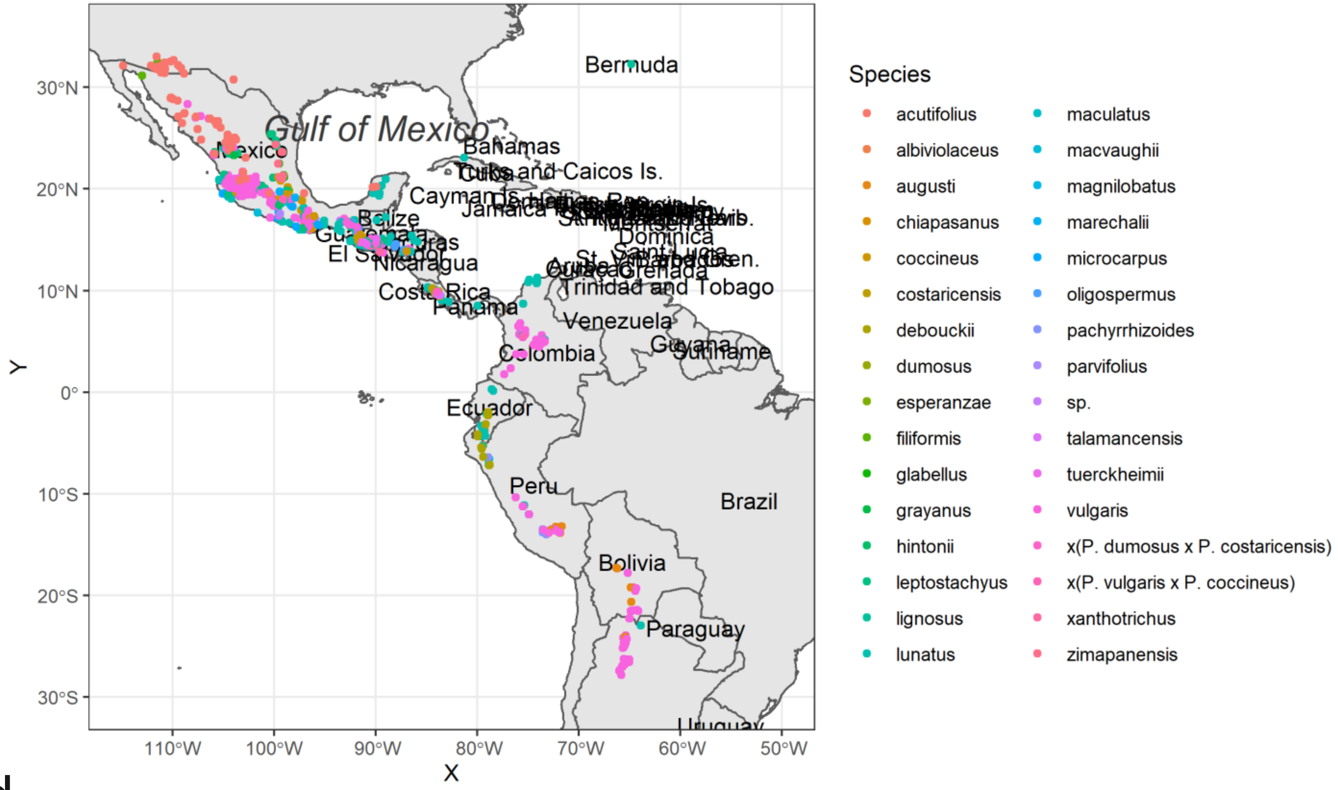
norwich research park
Doctoral Training Partnership

CIAT
International Center for Tropical Agriculture
Since 1967 *Science to cultivate change*

Phaseolus crop wild relatives with heat and drought stress tolerance traits

Dr. Claudia Lowe

- **FIGS: F**ocused **I**dentification of **G**ermplasm **S**trategy
- 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



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Milpa 2030: transdisciplinary approach

IPICYT
INSTITUTO POTOSINO DE INVESTIGACIÓN CIENTÍFICA Y TECNOLÓGICA, A.C.

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







BRITISH COUNCIL

Newton Fund

INSTITUTIONAL LINKS

SLP PROSPEREMOS JUNTOS
Gobierno del Estado 2015-2021

CONSEJO POTOSINO DE CIENCIA Y TECNOLOGÍA

Accelerated Diversification for Climate Resilient Agriculture


Available online at www.sciencedirect.com

ScienceDirect

Current Opinion in Plant Biology

Scaling up neodomestication for climate-ready crops

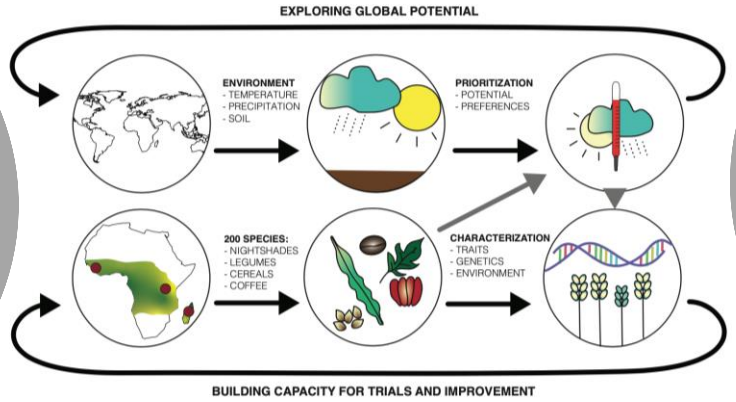
Rafal M. Gutaker[1], Caspar C. C. Chater[1], Jemima Brinton[1], Elena Castillo-Lorenzo[2], Elinor Breman[2] and Samuel Pironon[1]

Introduction

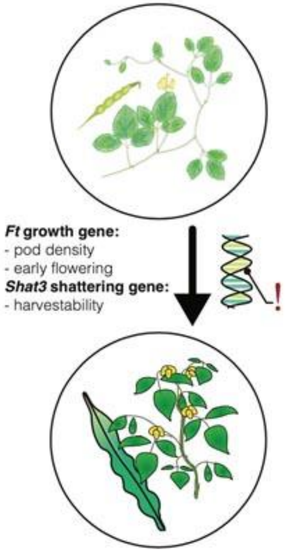
Domestication and neodomestication

Current Opinion in Plant Biology 2022, 66:102169

WS1.
Conserving and characterizing CWR



WS2.
Improving 3 indigenous species



- £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