Two fully-funded PhD projects for UK nationals available – starting January 2025

Two projects unified by the use of an under-utilized (orphan) crop that uses the efficient C₄ pathway are available with Professors Johannes Kromdijk and Julian Hibberd at the Department of Plant Sciences, University of Cambridge. You will join a team in our laboratories working in this area.

**Background:** One of the grand societal challenges for the coming decades is to provide sufficient food, both in calories and nutritious quality for a growing human population. While the Green Revolution delivered astonishing increases in crop production, its success has been coincident with the deployment of fewer crops to produce our food (Khoury et al. 2014). This reduction in the diversity of crop species decreases resilience of food systems and threatens food security. A second consequence of the Green Revolution was that the main components driving yield were optimized, with a key exception being the process of photosynthesis. These projects are designed to address both these consequences of the Green Revolution and in so doing contribute knowledge to allow a more productive and sustainable agriculture for the future.

Outside of the handful of commodity crops that supply the bulk of plant calories and protein globally, there is a vast range of non-commodity edible species. Often referred to as orphan crops, these species often exist in an underdeveloped state, reflecting limited investment to improve their agricultural value. These species hold untapped potential to enhance nutritional food security (Sogbohossou et al. 2018). Both of the PhD projects below will use *Gynandropsis gynandra*, an orphan leafy vegetable crop native to large parts of Africa and Asia. *G. gynandra* is an important source of nutrients such as vitamins minerals, and is an important dietary component to reduce malnutrition. The two projects below are embedded in a grant-funded project to develop new genomic resources and mapping populations to facilitate pre-breeding research, in collaboration with National Institute for Agricultural Botany and University of Abomey-Calavi (Benin).

**Project 1:** Desirable traits in *G. gynandra* are leafiness, nutritional quality associated with high levels of vitamins, minerals, protein content and a range of secondary metabolites with associated medicinal properties as well as high photosynthetic capacity and yield. *G. gynandra* is both self-pollinated and out-crossing. While the former is the current prevailing way of seed propagation, the latter potentially provides opportunities for generation of more productive hybrid cultivars. From previous work we also know that there is strong variation in photosynthetic capacity between different accessions (Reeves et al 2018). To design the most effective breeding strategies, it is important to know the genetic determinants and how different traits depend on each other. For example, the nutritious quality of leaves is in part determined by photosynthetic and photoprotective pigments. In addition, leafiness may have a strong impact on the concentration of photosynthetic proteins across plant leaf area. And finally, heterosis strongly impacts biomass production, but its impact on nutritional quality and photosynthetic capacity is unclear. To address these questions, the project will be able to draw on unique and recently developed existing mapping panels (a diversity collection and MAGIC RILs) with matching genotypic marker data, as well as several linked biparental populations being developed to form a bespoke NAM population. All three populations contain strong genetic variation in agronomic and photosynthetic traits which will be leveraged to find genetic determinants of phenotypic variation. The expected outcomes are an increased understanding of the impacts of heterosis, defined QTL for leafiness, nutritional quality and photosynthetic capacity, and understanding of the extent to which these traits are linked.
Project 2: *G. gynandra* uses the efficient C₄ pathway and is closely related to the C₃ model *Arabidopsis thaliana* (Brown *et al.* 2005). C₄ photosynthesis allows increased nitrogen and water use efficiencies, but also productivity gains of up to 50%. We have an incomplete understanding of the genetic basis underpinning C₄ photosynthesis and so it is not currently possible to predictively engineer or improve the pathway. In almost all C₄ species gene expression is showing altered patterns between tissues such that photosynthesis is compartmented between cells such as the mesophyll and bundle sheath (Hibberd and Covshoff, 2010). This project will build on recent advances we have made in understanding how genes important for the C₄ pathway are regulated in both the C₃ and C₄ state (Dickinson *et al.* 2020; Dickinson *et al.* 2023; Singh *et al.* 2023; Borba *et al.* 2024), and in single cell sequencing technologies that have provided unparalleled insight into regulatory networks upstream of C₄ photosynthesis genes (Swift *et al.* 2023). We have also observed substantial diversity in the photosynthetic properties of *G. gynandra* accessions (Reeves *et al.* 2018) and for this reason generated mapping panels with matching genotypic marker data, as well as several linked biparental populations to form a bespoke NAM population. Using these diversity panels combined with our standard approaches to dissect gene regulation, we now wish to identify genes that control the compartmentation of photosynthesis between cell-types in *G. gynandra* to allow these processes to be engineered in the future.

References:

Khoury *et al.* (2014) PNAS 111: 4001-4006  
Dickinson *et al.* (2020) Nature Plants 6, 1468-1479  
Dickinson *et al.* (2023) bioRxiv 2023.09. 05.556297  
Singh *et al.* (2023) Science Advances 9, eade9756  
Borba *et al.* (2024) Plant Physiology 193, 2306-2320  

How to apply:

Email your cv and a cover letter explaining your interest in the project(s) to Johannes Kromdijk (jk417@cam.ac.uk) and Julian Hibberd (jmh65@cam.ac.uk) before 15 July 2024, please mention AKAYA PhD in the email subject. Project start date will be Lent 2025 (Jan 5, 2025).