The *Gossypium* genus – an untapped pool of novel photosynthetic traits for cotton?

Demi Sargent[1,2], Warren Conaty[2] and Robert Sharwood[1]

ALTHOUGH developmentally regulated by temperature and radiation, cotton yield and productivity can be hampered by high temperature in the form of rising average temperatures and extreme heat events such as heatwaves. In Australia in particular, heatwaves regularly co-occur with drought, exacerbating the effects of heat stress as the ability of the plant to regulate its temperature through evapotranspiration of water vapour is diminished. So developing climate-adapted cotton cultivars is a key step towards 'future-proofing' the Australian cotton industry to withstand increasingly challenging future climates.

As photosynthesis is a critical process that underpins yield, improving the resilience, performance and efficiency of photosynthesis is a potential target to improve crop yields under challenging climatic conditions. Screening for and exploiting the natural diversity of photosynthesis in cotton varieties and wild relatives is a promising approach. Cotton (*Gossypium hirsutum*) is a suitable candidate for such an approach because the *Gossypium* genus of which this species belongs is large and diverse, comprised of over 50 species.

These species are categorised into eight diploid* genomes (A, B, C, D, E, F, G and K) and one tetraploid genome (AD) to which cultivated cotton (*G. hirsutum* and *G. barbadense*) belong. These different genomes, and even the species within each genome, vary enormously in their evolutionary origin and therefore the climates to which they've evolved.

These climates range from tropical monsoon to arid desert climates. Consequently, these species have developed a remarkable array of morphological characteristics, ranging from trees to prostrate creepers. These evolutionary differences spotlighted these species as potential sources of novel traits for resistance against abiotic stresses such as heat and drought.

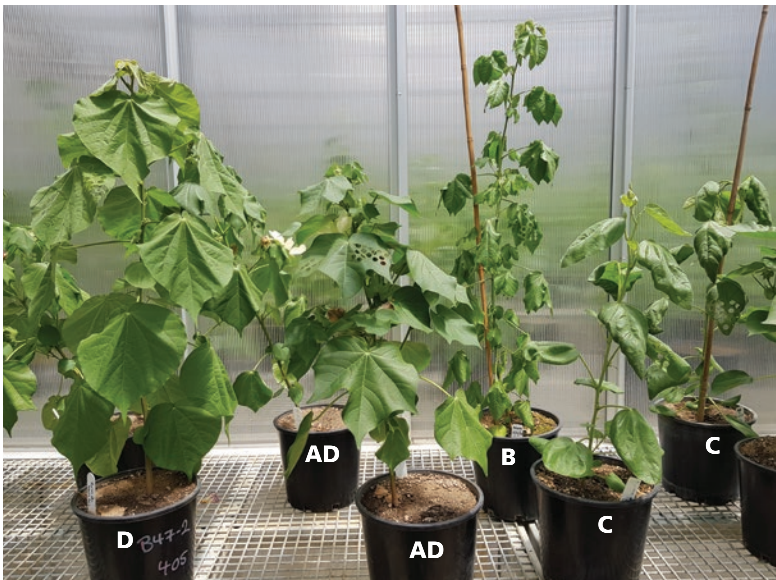
Our research at the Hawkesbury Institute for the Environment and CSIRO Narrabri, supported by the Cotton Research and Development Corporation (CRDC) will investigate the potential to utilise photosynthetic traits from within the *Gossypium* genus in the development of climate-adapted cotton cultivars.

Through screening the responses of diverse species to a range of heat and drought stress conditions, we have started identifying wild *Gossypium* species from which novel resilience traits could be sourced. With further investigation, we aim to identify a range of physiological, biochemical and molecular mechanisms linked to heat and drought tolerance.

We have used the Diurnal Canopy Photosynthesis and Stomatal Conductance (DCaPST) simulation platform to test the effect of exploiting various photosynthetic traits of diverse *Gossypium* species on cotton radiation use efficiency (RUE) and therefore biomass accumulation. Through these simulations, we have demonstrated that several photosynthetic enhancements could improve cotton's biomass accumulation by around five per cent under high temperature stress.

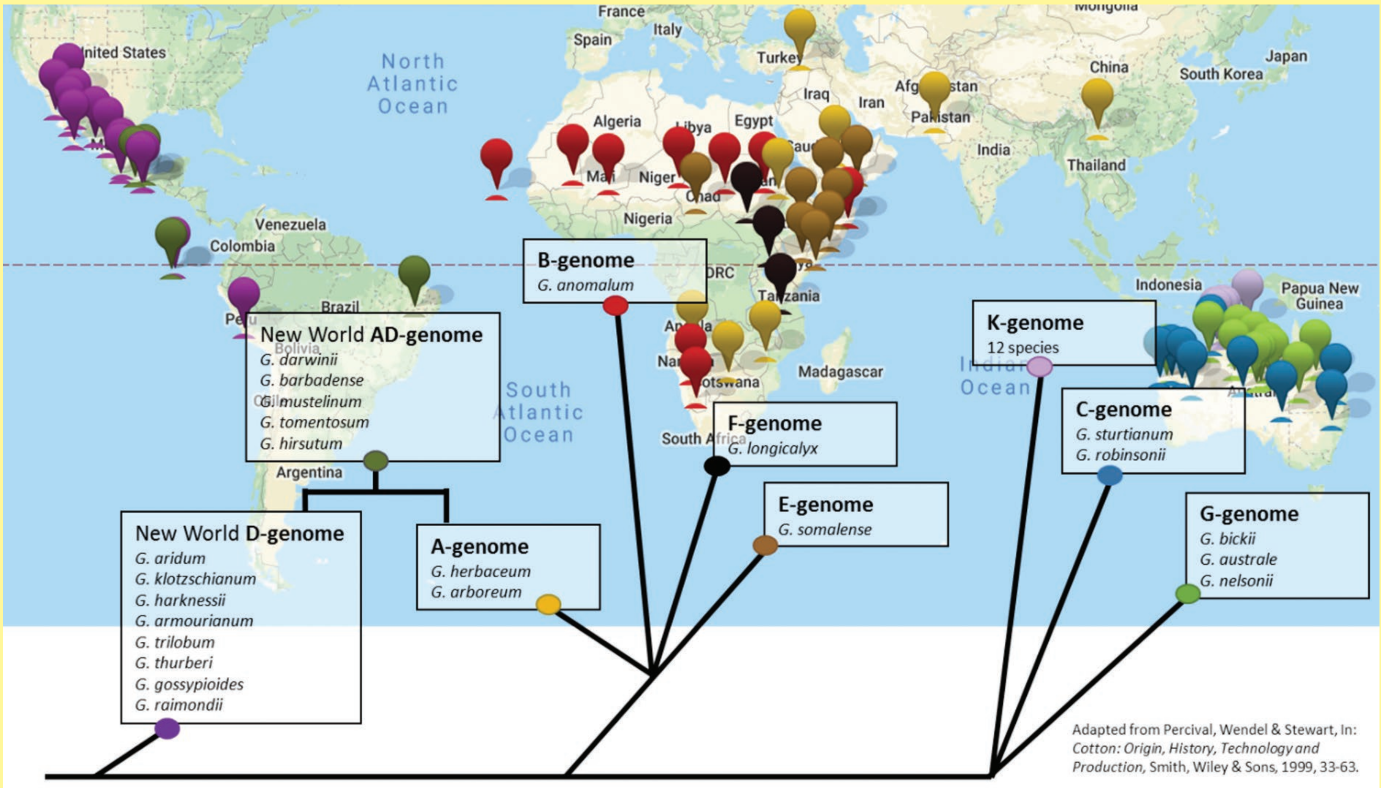
Due to the inability of many of these species to hybridise with the tetraploid *G. hirsutum*, the transfer of these

The research involves exploring the photosynthetic traits of wild cotton relatives.



A variety of diverse Gossypium species (genomes indicated on pots) in a heatwave experiment: G. hirsutum (back left and front middle), African B genome species (back middle), Australian C genome species (back right and front right), Peruvian D genome species (front left).

FIGURE 1: Phylogenetic tree of the Gossypium species, categorised into their respective genomes, overlaying the geographical distribution of each species



mechanisms are likely to require gene technology approaches such as synthetic biology tools to achieve the most effective and efficient trait transfer.

Synthetic biology encompasses many genetic manipulation and regulation approaches such as Golden Gate cloning (gene assembly) and CRISPR-Cas9 gene editing. Synthetic biology is a promising pathway for applying this novel research as it enables the introduction of multiple genes in a single transgenic event, bypassing incompatibility challenges posed by breeding with wild species.

It can also enable the assembly of specifically designed genomes from the ground up from a set of standardised genetic parts, which can then be transferred into the target cell or organism. Fundamental research such as this study on photosynthesis are the first step towards realising this potential improvement in cotton resilience to abiotic stresses.

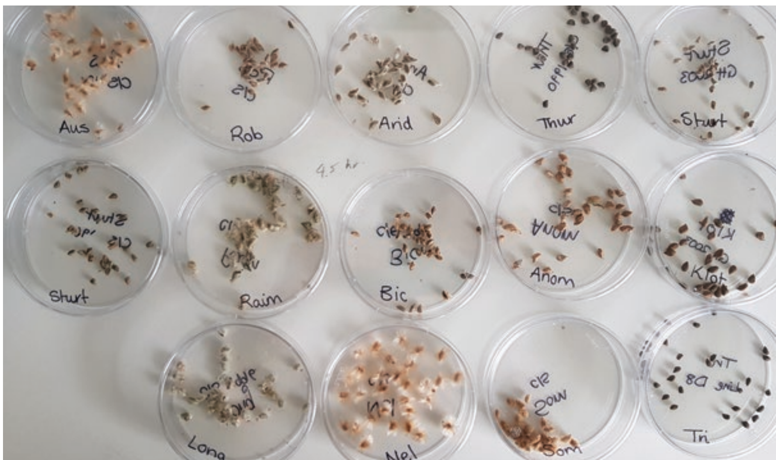
***Diploid organisms have two sets of chronosomes in each cell, while tetraploid organisms have four sets of chronosomes.**

1. Western Sydney University, Hawkesbury Institute for the Environment, Locked Bag 1797, Sydney NSW, 2753 Australia.
2. CSIRO Agriculture and Food, Locked Bag 59, Narrabri NSW, 2390 Australia.

Further reading:

Sharwood (2017) Engineering chloroplasts to improve Rubisco catalysis: prospects for translating improvements into food and fiber crops. New Phytologist.
Sharwood et al. (2016) Temperature responses of Rubisco from Paniceae grasses provide opportunities for improving C3 photosynthesis. Nature Plants.
Wu et al. (2018) Simulating daily field canopy photosynthesis: an integrated software package. Functional Plant Biology.

Multiple species are tested for their response to heat and drought.



Seeds of a number of different *Gossypium* species.