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Do hotter and drier regions harbour adaptive variation for climate change?

Ecosystem Science

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Project Team	granted
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Do hotter and drier regions harbour adaptive variation for climate change?

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Context

Understanding the capacity of trees to respond to climate change is essential for the maintenance of biodiversity, forest health and productivity. In south-west Australia, climate change has increased the frequency and intensity of droughts, which has resulted in tree death and negatively affected essential ecosystem services. Adaptive land management is required to mitigate the risk of large-scale drought mortality in a rapidly changing climate. Current forest regeneration practice provides for seed sourcing from land management units adjacent to the site based on a broad interpretation of local provenance in widespread semi-continuous species. Assisted gene migration has also been advocated as a tool for land managers and foresters in managing forests and establishing plantations for future climates. But there is little information to provide a basis for land-managers to implement assisted gene migration.

Marri (*Corymbia calophylla*) is an important component of the forest ecosystem providing nesting hollows and a food source for endangered cockatoo species. In addition to being an important timber tree, the fruit, seeds, flowers, leaves and wood of marri are all important sources of food for native fauna. The seeds are a major food source for nationally listed threatened birds (Baudin's black cockatoo and Carnaby's black cockatoo) and the maintenance of habitat and food resources is a key factor in forest management practice. In each of the forest and woodland ecosystems where marri is present, it is an important and integral keystone species. Consequently, a decline in its overall health, now being experienced due to drought and disease, will have significant long-term detrimental impacts on ecosystem function. Management of keystone species within forest ecosystems needs to have a strong scientific basis. This project will deliver a scientific basis for consideration of adoption of assisted gene migration in south-west forests, through a detailed understanding of genetic adaptation and physiological tolerance in marri, and the capacity for enhanced drought-resilience under future hotter and drier climates.

Aims

- Characterise neutral and adaptive genetic variation to estimate demographic (population size, migration) and evolutionary (adaptation to climate) processes.
- Estimate the heritability of plant functional traits associated with growth and resilience, and correlated traits, to determine the propensity for genetic adaptation.
- Determine the physiological and molecular capacity to respond to drought to elucidate the mechanisms enabling plants to persist under climate change.

Progress

- A paper on genetic adaptation to climate in marri has been submitted to *Molecular Ecology*. This genomic study of 23 populations across the range of marri, generating 10,000 SNP loci and showed low levels of genetic structure (F_{ST} = 0.05) with isolation by distance in a north-south orientation. After controlling for population structure, analysis identified greatest variation explained by associations with temperature (27%) rather than rainfall (6%) or aridity (5%). Variation occurred throughout the genome, and was found in gene coding and regulatory regions, including those known to regulate processes important in stressful climatic conditions,suggesting that both adaptive and plastic responses are involved in the response of the species to climate.
- A paper on variation in provenance trials has been submitted to the journal *Evolution*. Analysis of 18 provenances and 170 families planted at Mt Barker and Margaret River has been undertaken for tree growth (height, basal diameter) and disease resistance (shoot blight). Growth and disease resistance both show moderate levels of genetic heritability (0.2). There was strong associations with the climate of origin (temperature, rainfall) showing high growth and disease resistance in southern coastal populations experiencing cool and wet climatic conditions.

- A drought experiment has been undertaken for seedlings from 12 provenances growing at 100% and 50% soil water holding capacity for 4 months over summer. Analysis of the data has commenced.
- Data analysis has been undertaken for a heatwave experiment where seedlings from eight provenances were grown under 'cool' (26 ℃ maximum) and 'warm' (32 ℃ maximum) growth conditions in a glasshouse and exposed to two consecutive five day heatwaves at either 40 or 46 ℃ in a fully factorial reciprocal temperature design. Leaf gas exchange, growth and leaf damage were monitored throughout the experiment under conditions where soil water content was maintained at field capacity. Results suggest that plants from cooler provenances exposed to the 46 ℃ heatwave experienced the most severe impacts on growth and had the highest levels of leaf damage.

Management implications

Assisted gene migration has been suggested as a key climate change adaptation strategy for forests worldwide, and could be readily incorporated into current silvicultural practices in south-west forests through the inclusion of seed from dry adapted provenances in regeneration. This project will provide the scientific evidence required to determine effective assisted gene migration practices in southwest forests for resilience to changing climates, providing a basis for adoption of this practice by decision-makers and acceptance by the community and non-government organisations.

Future directions

- Analysis of glasshouse heatwave and drought experiments will be completed and papers written.