Honours Research Grant Report to the

National Climate Change Adaptation Research Facility – Terrestrial

Biodiversity Adaptation Research Network

Ecotypic variation and plasticity of morphological and physiological traits of *Eucalyptus loxophleba* ssp. *lissophloia* along a climate gradient in south-west Australia

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1.0 Background

The adaptive capacity of plant species will be important for increasing their resilience in a changing climate. By 2070, a change in rainfall of +10 to -40 % of current mean annual rainfall and warming of between +2 to +5 ˚C in south-west Western Australia, is predicted (CSIRO 2007). Plant species may cope with changing climatic characteristics through natural selection or phenotypic plasticity responses. Greater ecotypic variation in traits between stands of a single species may reduce its vulnerability in a changing climate as there is a greater selection of traits to increase fitness (Whisenant 1999, Lindenmayer & Burgman 2005). Phenotypic plasticity has been highlighted as a mechanism to potentially enhance resistance and resilience in a changing climate in the short-term (Prober et al. 2011). Given that the Mediterranean region of the south-west of Western Australia is considered to be the most vulnerable to contraction of all Mediterranean systems worldwide under predicted climate change scenarios, the region is a priority area for research into climate resilience and adaptive ecotypic variation in plant species (Klausemeyer & Shaw 2009).

2.0 Major Findings and Outcomes

This project examined variation in morphological and physiological traits between nine stands of the widespread species *E. loxophleba* ssp. *lissophloia* L.A.S. Johnson & K.D. Hill (Smooth-barked York Gum) across a climate gradient in south-western Australia. Morphological and physiological traits known to promote efficient water use and drought tolerance were compared across its natural range (450 km from W to E), with samples of the same provenances also grown in a common garden (plantation) which receives higher long-term average rainfall. Greater variation was expected to convey a higher adaptive capacity and resilience to a drying climate. Morphological traits measured were total leaf length, maximum leaf width, the ratio of leaf length to leaf width, area per leaf, dry mass, specific leaf area and wood density and the physiological traits measured were leaf nitrogen, carbon and nitrogen isotope ratios, instantaneous water use efficiency and maximum photosynthetic and transpiration rate. High plasticity of these traits reflected in this common garden experiment may facilitate the adaptation of the species to varying climatic conditions across Australia's south-west.

Results showed significant differences (one-way ANOVA) between the nine natural stands along the climate gradient for all of the traits measured, with the exception of wood density. This showed the high ecotypic variation present within the widespread species in both foliar morphological and physiological traits measured. However, there was no single, major climatic variable which was the primary cause of variation of all the traits, as determined by linear regression analysis. A multitude of climatic variables affected the traits differently, and with varying levels of influence. Thus, the consequences for plant species in a changing climate where a multitude of interrelated climatic variables are predicted to change, remains uncertain.

Comparison of the natural versus plantation stands showed high phenotypic plasticity in the physiological traits to prevailing climatic conditions, which should allow the species to cope with climate changes of a limited scale over the short-term. Morphological leaf traits showed a more conservative response, although the high ecotypic variation between stands suggests there is variation to facilitate change if given sufficient time. Stands towards the dry end of the gradient did not have a greater within-stand variation (as determined by the range between maximum and minimum trait values) than other stands along the gradient.

3.0 Significance to Adapting and Protecting Australia's Terrestrial Biodiversity

The clear variation between the natural stands of the widespread *E. loxophleba* ssp. *lissophloia* along the gradient as a result of ecotypic adaptation to specific, variable environments heightens the importance of selecting stands for revegetation based on their suitability in a changing climate. Currently, restoration efforts source genetic material from local populations or areas, assuming them to be the most successful as they are adapted to the local conditions. However, in a changing climate, it is advisable to instead source genetic material from stands which display traits with a higher fitness advantage in the predicted climatic changes. In this way, resilience of plants may be enhanced in a changing climate by sourcing genetic material from the warmer, drier end of the gradient.

The significant ecotypic variation in morphological traits between the natural stands suggests that there is variation to facilitate change to warming and drying conditions. However, species with distinct ectopic adaptations may be restricted in their ability to change and evolve under a rapidly changing climate due to the time delay in new adaptive mutations (Jump & Peñuelas 2005, Aitken et al. 2008, Hancock et al. 2011). However, the eucalypt studied in this research appeared to phenotypically adjust its physiological traits in particular, to the different environmental conditions in the plantation. This suggests that *E. loxophleba* ssp. *lissophloia* has the ability to grow in highly variable environments which should allow it to cope with climate changes of a limited scale over the short-term. Such knowledge of morphology, physiology and adaptive potential is crucial to inform climatic modelling of species range and distribution changes (Helmuth et al. 2005) and to optimise allocation of conservation and management resources to the least resilient species.

Some adaptive capacity of traits relating to drought tolerance and water conservation has been shown in a single species. Despite the ability to cope with a changing climate afforded by phenotypic responses and ecotypic variation within a species however, the necessity of mitigating climate change remains paramount.

4.0 Further Research Suggestions

Recent studies have shown a link between the phenotypic differentiation in an Alpine species in a common garden in Switzerland to the genetic differences in the widespread species adapted to different climatic conditions (Frei et al. 2011). Furthermore, Hancock et al. (2011) have recently shown that genetic markers on *Arabidopsis thaliana* can accurately identify loci in the plant that are related to climatic conditions. This implies that genome-wide scans can detect alleles adapted to a changing climate (Hancock et al. 2011). Thus, it is recommended that eco-physiological studies, such as this, be compared to the genetic analyses being undertaken by Byrne et al. to determine whether such eco-physiological studies are even necessary or if in-depth genetic studies can be undertaken directly to gauge the adaptive potential of a species in a changing climate. It would also be useful for future studies to focus on demonstrating that the leaf traits measured in this study affect fitness and increase capacity to persist in warmer environments.

In addition, this study examined the variation in, and plasticity of, a geographically widespread species. However, geographically restricted species may have lower phenotypic plasticity than widespread species (Hughes et al. 1996, Pohlman et al. 2005, Godoy et al. 2011). Therefore, complementary studies on variation in geographically restricted species are recommended. Indeed, current climatic modelling typically uses the environmental conditions of the past and current distribution of a species to generate the 'climatic envelope' it may occupy (Jeschke & Strayer 2008). However, restricted species may actually have a higher variability in traits and potential plasticity to respond to water deficit than their present distribution would suggest, but they are restricted in their geographic range owing to other factors, such as landscape clearing, dispersal abilities or biotic interactions (Loehle & LeBlanc 1996, Witkowski & Lamont 2006). Thus, it would be important to measure the relative plasticity of geographically restricted species to determine if the effects of climate change on their distribution are being over-estimated.

This research was presented at the Annual Conference of the Ecological Society of Australia 2011.

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