Soil Seed Banks and Vegetation Dynamics in an *Acacia papyrocarpa* Open Woodland




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Cover images: *Acacia papyrocarpa* (LHS), *Brachyscome ciliaris* var*. ciliaris* and *Cephalipterum drummondii* (top RHS), *Maireana turbinata* (middle RHS) and *Rhodanthe floribunda* (bottom RHS). Photos: E Steggles and L Pound.

CONTENTS

Declaration

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Thesis Summary

This PhD formed part of a research partnership between the University of Adelaide, Botanic Gardens of Adelaide and Iluka Resources Ltd. The project commenced in early 2008 and focused on improving our ecological understanding of *Acacia papyrocarpa* (Western Myall) open woodlands. The study site had no or little history of stock grazing and whilst there are similar studies in this type of ecosystem, they have all been conducted in areas subject to domestic stock grazing. Mining activities are increasing in arid parts of South Australia, and mid-way through the project a mineral sands mine commenced adjacent to the study site. Research outcomes were therefore also aimed at informing post-mine restoration efforts.

Three key research areas were studied:

1. Spatial and temporal patterns within the germinable soil seed bank;
2. Effects of the biological soil crust (BSC) on seedling emergence;
3. Seed germination of selected species under salinity and water stress conditions.

Soil seed banks are key components of arid ecosystems as they buffer plant populations against stochastic events such as prolonged droughts, and they play an important role in shaping the dynamics of a plant community. Annual plant species exist predominantly as stored seeds within the soil seed bank and are dependent on specific environmental cues to overcome dormancy and germinate. Relationships between seed dispersal, seed accumulation in the soil, microenvironment properties and seedling establishment are poorly understood, yet such information is needed to inform the management and restoration of arid ecosystems.

To investigate spatial and temporal patterns within the germinable soil seed bank, soil samples were collected seasonally from four different patch types over a two year period. Samples were collected beneath the canopies of *A. papyrocarpa* (Western Myall), *Atriplex vesicaria* ssp. *variabilis* (Bladder Salt Bush) and *Maireana sedifolia* (Pearl Blue Bush), as well as in open inter-shrub areas. Nomenclature is according to Jessop and Toelken (1986). As episodic rainfall and flooding can stimulate seedling emergence in a range of arid zone plants, the soil was treated experimentally with two watering regimes (moist and submerged) to study effects of water saturation on the composition of seedlings. To supplement the research, soil nutrient, soil moisture, soil temperature and in situ seedling emergence data were collected from each of the four patch types.

Research results show evidence of both spatial and temporal variation in the germinable soil seed bank. Soil samples beneath the canopies of *A. vesicaria* ssp. *variabilis* produced highest seedling numbers and diversity when compared with most other patch types, indicating potential differences in the way seeds accumulate spatially within the soil. Submerging soil samples did not affect seedling composition; however, the study only tested responses to the high end of the water availability spectrum. Total seedling numbers and taxa were

highest in summer and autumn collections, reflecting seasonal influences on seed accumulation as well as seed dormancy and germination cues. There was a strong indication that canopy presence may provide suitable conditions to enable seeds to overcome dormancy in seasons other than autumn, thus expanding opportunities for seedling emergence throughout the year.

Investigating the BSC and its influence on seedling emergence is important to understand ecosystem processes within *A. papyrocarpa* open woodlands. Crusts are important components of arid ecosystems in that they influence nutrient cycling, water infiltration, surface evaporation and moisture storage, as well as protect soils against erosion. As such, the BSC helps determine landscape structure and function. Very little is known about BSC effects on seedling emergence, particularly within relatively undisturbed *A. papyrocarpa* open woodlands. Such information is pertinent for managing and restoring ecosystems where the BSC has been removed or disturbed through activities such as mining.

A series of experiments were designed to study interactions between BSC and seedling emergence. Initially, quadrats were established in open inter-shrub areas at the study site, where soil crusts predominantly occur. Seedling emergence was compared between areas originally with or without crust as well as between crust/surfaces left intact or shallowly and lightly scratched to simulate disturbance. Seedling abundance, diversity and composition were recorded towards the end of winter (August) when seedling emergence commences and in late spring (November) after peak seedling emergence. This experiment was also replicated in a glasshouse using intact soil cores. Seeds of selected species were later inserted into fresh cores through pre-drilled side holes in order to study their species-specific response to the various surfaces.

Results from the quadrat experiment indicate that seedling emergence and species richness were higher in inter-shrub areas where BSC was absent. Disturbance did not affect seedling emergence in either surface type. Seed extraction and seed germination experiments were then used to determine whether the variability was due to differences in seed accumulation or whether the BSC actually inhibited seedling emergence through allelopathic effects (i.e. chemical leachates from organisms making up the crust). Results from these experiments showed that late successional stage BSC negatively influences seed accumulation and that leachate effects on seed germination are species specific and depend on the successional stage of the crust.

The final area of research was to investigate the germination response of a selection of arid plant species to salinity and water stress. Groundwater is highly saline and its use in mining operations results in the accumulation of saline waste materials beneath reconstructed soil profiles. There was concern that salts may rise through the soil profile by capillary action, potentially inhibiting seed germination, seedling establishment and the long-term survival of plants. In addition to the toxicity effects of salts such as sodium chloride (NaCl), salinity affects seed germination by reducing soil water potential. Species vary in their ability to

germinate under saline conditions and have critical water content requirements for seed germination.

This research investigated germination responses of six plant species that grow in *A. papyrocarpa* open woodland: *Enneapogon cylindricus* (Gramineae), *Eriochiton sclerolaenoides* (Chenopodiaceae), *Eucalyptus oleosa* ssp*. ampliata* (Myrtaceae), *Lepidium phlebopetalum* (Cruciferae), *Maireana trichoptera* (Chenopodiaceae) and *Rhodanthe floribunda* (Compositae). Species were selected to represent a range of plant families and life forms that were locally abundant at the study site.

Preliminary experiments were needed to ascertain methods for overcoming physiological dormancy and promoting seed germination. A series of pre-treatments were investigated, including different concentrations of gibberellic acid (GA_3) and potassium nitrate (KNO_3) as well as dry heat treatments. From these preliminary experiments, the six species listed above were identified as suitable for studying the effects of salinity and water stress. Different concentrations of sodium chloride (NaCl) and polyethylene glycol (PEG-8000) were then used to produce a range of water potentials to assess germination responses.

Results from this component of the research showed that species vary in their germination response to salinity and water stress, displaying high to medium levels of tolerance or extreme sensitivity. Depending on the species, seed germination was affected through high toxicity levels, low water potentials or a combination of these two factors. Salinity and water stress was found to affect the temperature range over which some species (*E. cylindricus*, *L. phlebopetalum* and *M. trichoptera*) were capable of germinating, and low water potentials caused delays in the seed germination of others (*E. sclerolaenoides* and *R. floribunda*). Two species (*E. sclerolaenoides* and *M. trichoptera*) showed evidence of the selective accumulation of ions.

Overall, this research provides important insight into a selection of key ecological processes in a remote and intact arid ecosystem. In particular, the results add to our understanding of ecological processes within *A. papyrocarpa* open woodland, highlighting the importance of trees and shrubs in patterning and conserving understorey plant diversity and demonstrating the role of BSCs in influencing patterns of seed accumulation and seedling emergence. The research was undertaken within the context of increasing human activities within Australian arid zones, in particular mining, which was reflected in the seed germination component of the project.

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List of Figures

List of Tables