New tools for determining incidence and severity of Mycosphaerella Leaf Disease in Eucalypt plantations.

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For Mum and Dad
who gave me the opportunity to go to University.

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Abstract

Plantation forests are susceptible to many pests, which can reduce the quality and value of the wood products they source. Certain species of the fungal genus *Mycosphaerella* are a concern in eucalyptus plantations around the world. *Mycosphaerella* leaf disease (referred to as MLD from here in) can cause significant leaf necrosis, discolouration and defoliation. In Australia severe outbreaks of MLD have been observed in various eucalyptus plantations. The three aspects of MLD research targeted in this Thesis were factors influencing its atmospheric ascospore concentrations, the effect of its symptoms on leaf spectral properties, and the use of remote sensing to detect MLD's symptom distribution and severity.

Research into establishing the conditions required for high-risk infection periods in eucalyptus plantation forestry has been limited to a few studies that lack sufficient detail required for building a forecasting system. In this Thesis data from the ascospore trapping of *Mycosphaerella* ascospores in a juvenile *Eucalyptus globulus* Labill. plantation in northwest Tasmania indicated the presence of diurnal periodicities in ascospore densities. The meteorological variables influencing the pattern of atmospheric ascospore presence and absence were defined in terms of rainfall events, ambient temperature and relative humidity. The interactions of climatic variables and ascospore density with tree age were also investigated. The patterns of atmospheric ascospores over time indicated a higher probability of

observing ascospores when trees in the plantation were younger, however, the density of the ascospore event was likely to be small. As trees in the plantation became older this pattern was reversed. Mathematical functions were applied to describe the patterns identified. These were used to predict the probability and density of an ascospore event, both excluding and including meteorological data. The prototype predictive ascospore model is the first model developed for a disease in eucalyptus plantations, but requires validation at other sites, locations and years before adoption by the plantation forest industry.

The use of remote sensing (referred to as RS from here in) technologies for the evaluation of crown health in eucalyptus plantations will be a future option for forest managers as technologies improve and become cost effective for use in forestry. RS should offer assessment methodology and digitised data that is precise, non-subjective, providing to be integrated with existing geographical information systems (GIS) for further analysis and spatial modelling.

One step on the path towards developing successful RS forest health surveillance is robust spectral reflectance analysis of leaves from stressed and healthy tree crowns. The spectral reflectance response of foliage along the electromagnetic wavelength has a number of distinct features that can help characterise the symptoms of a fungal infection, such as *Mycosphaerella* leaf disease. Spectral reflectance measurements were made on healthy and diseased *E. globulus* foliage in the visible and near-infrared wavelengths (400 - 1000 nm). The wavelength most sensitive to infection severity was *R*678 nm. The wavelengths near *R*708 nm and *R*550 nm appeared relatively insensitive to disease severity. The reflectance index best correlated to leaf severity

was *R*678/*R*550 (r = 0.841, P < 0.001). This index was used in a linear regression model for predicting disease severity of leaves from an independent data set (r = 0.95, P < 0.0001). This work was used to identify potential spectral algorithms for testing remotely at the canopy scale.

Digital multi-spectral imagery (DMSI) was acquired over an *E. globulus* plantation in northwest Tasmania. The DMSI data together with ground based crown measurements of severity were used to develop regression models to predict MLD injury at the crown scale. A model was produced for defoliation and another for crown necrosis. The spatial distribution of symptoms was accurately represented by the maps derived from the RS imagery, and clearly showed where crown defoliation and necrosis were most severe. The results show that a post-stress assessment of eucalyptus health is possible at a plantation scale using remote sensing technology. With successful independent verification of the methods that were developed, this technology could be applied operationally to survey and assess plantation health.

This work represents the first attempt at developing models suitable for decision support software relevant to pest and disease management in eucalyptus plantations. The models will help guide intervention systems through specialized monitoring and disease warning systems, providing managers time to intervene before high levels of damage are incurred.

Preface

This PhD Thesis is composed of 3 papers (which have been either published, submitted or in preparation), two additional chapters and four appendices. Please note that some repetition does occur throughout the Thesis, e.g. study site details. To improve the flow of the Thesis the following changes have been made:

- References have been compiled into a single list at the end of the Thesis,
- Acknowledgements for each publication are listed separately (see below),
- Figures and tables have been renumbered according to the chapter,
- Additional information that was not originally a part of the papers but considered important to the Thesis have been included as appendices.

Publications arising from this Thesis include:

E. Pietrzykowski, C. Stone, E. Pinkard, C. Mohammed. (2006). Effects of Mycosphaerella leaf disease on the spectral reflectance properties of juvenile *Eucalyptus globulus* foliage. Forest Pathology 36: 334-348.

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Pietrzykowski, E., Sims, N., Stone, C., Pinkard, L., Mohammed, C. (2006). Mapping Mycosphaerella leaf disease severity in a *Eucalyptus globulus* plantation using Digital Multi-Spectral Imagery. Southern Hemisphere Forestry Journal. In press.

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Pietrzykowski, E., Foster, S., Pinkard, L., Mohammed, C. (2006). Mycosphaerella leaf disease atmospheric spore concentration patterns and the affect of meteorological variables in a *Eucalyptus globulus* plantation. In preparation.

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Additional Publications:

Smith, A. H., Wardlaw, T. J., Pinkard, E. A., Battaglia, M., **Pietrzykowski, E. A.** Mohammed, C. L. (2003). Is the Crown Damage Index damaged by scorer variation? Poster at CRC-SPF Annual Meeting, Cradle Mountain, Tasmania, 21st-23rd October 2003.

Smith, A. H., Wardlaw, T. J., Pinkard, E. A., **Pietrzykowski, E. A.** Mohammed, C., Battaglia, M. (2003). Is the Crown Damage Index damaged by scorer variation? Poster abstract In: Book of abstracts of the 15th Biennial Australasian Plant Pathology Society Conference. 26-29th September, 2005. Deakin University, Geelong, Australia.

Mohammed, C.L., Battaglia, M., Pinkard, L., Glen, M., Tommerup, I., Smith, A., **Pietrzykowski, E.**, Barry, K., Eyles, A., Beadle, C. (2004). New tools for cost effective health management in eucalypt plantations. In 'Proc. IUFRO Conf. Eucalypts in a changing world'. Aveiro, Portugal. (Eds. Borralho, N.M.G., Pereira, J. S., Marques, C., Coutinho, J., Madeira, M., Tomé, M.) pp. 606-613. (RAIR, Instituto Investigação da Floresta e Papel, Portugal).

Oral and poster presentations:

Pietrzykowski, E., Stone, C., Pinkard, E., Sims, N., Mohammed, C. (2005). From leaf to landscape. Identifying Mycosphaerella leaf blight in eucalyptus globulus plantations using digital multispectral imagery. Poster abstract In: Book of abstracts of the 15th Biennial Australasian Plant Pathology Society Conference. 26-29th September, 2005. Deakin University, Geelong, Australia, p 138.

Pietrzykowski, E. (2005). Leaf to landscape: Remote sensing of Mycosphaerella leaf disease in eucalypt plantations. Seminar at the *Mycosphaerella* Workshop of the 15th Biennial Australasian Plant Pathology Society Conference. 26-29th September, 2005. Deakin University, Geelong, Australia.

Pietrzykowski, E., Booth, T., Battaglia, M., Stone, C., Mohammed, C., Pinkard, L., Wardlaw, T., Smith, A. (2003). Is the risk on an epidemic too high? Case Study: Risk and Remote Sensing of *Mycosphaerella* leaf blight. Techniques for modelling disease risk, forecasting epidemics and monitoring disease symptom spread using remote sensing. Poster presentation at the Cooperative Research Centre for Sustainable Production Forestry Annual Meeting, Cradle Mountain, Tasmania, 21st-23rd October 2003 and at a Forest Health Workshop in Albany (24th/25th Nov. 2003) and Manjimup (26th/27th Nov. 2003).

Pietrzykowski, E. (2003). Remote sensing and epidemiology of Mycosphaerella leaf blight. 'Loss Fest' 25-26 February. Oral presentation. Hobart, Tasmania.

Pietrzykowski, E. (2003). Risk and remote sensing of *Mycosphaerella* leaf blight. Oral presentation at Forest Health Workshop. Albany (24th/25th Nov. 2003) and Manjimup (26th/27th Nov. 2003).

Prizes:

15th Biennial Australasian Plant Pathology Conference 2005-Winner of the best student poster in the section titled "Innovations for sustainable plant health".

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