Mixed-species plantations of nitrogen-fixing and non-nitrogen-fixing trees

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A thesis submitted for the degree of Doctor of Philosophy of The Australian National University.

STATEMENT OF ORIGINALITY

This thesis is an original piece of work and does not contain the work of another individual except where acknowledged.

The results of Chapter 6 (Growth dynamics of a mixed-species plantation of *Eucalyptus globulus* ssp. *pseudoglobulus* and *Acacia mearnsii*) were published in Forrester et al., 2004 and the co-authors of the paper helped to write this chapter.

The statistical analyses of Chapter 8 (Effects of changing the supply of nitrogen, phosphorus and water on growth and interactions between *Eucalyptus globulus* and *Acacia mearnsii* in a pot trial) were carried out by Dr Jeff Wood (Statistical Consulting Unit, The Australian National University) after discussing the analyses with me.

Contributions including professional advice and help with data collection from others is detailed in the acknowledgments.

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June 28, 2004

Acknowledgments

I would like to thank my supervisors, Professor Jürgen Bauhus and Dr's Annette Cowie, Ryde James and John Evans. Jürgen has been a mentor to me, not only for this PhD but also prior to this when I was an undergraduate forestry student. I enjoyed and learnt a great deal from the time that we have worked together. Annette's supervision and guidance is also much appreciated. Annette's attention to detail and our discussions about experimental designs and methodologies for various sections of this thesis were particularly useful. Ryde and John also provided valuable advice and encouragement throughout the project.

Dr's Marcus Schortemeyer, John Brockwell, Partap Khanna and Chris O'Hara, Professor William Stock and Suzette Searle provided valuable professional advice that is greatly appreciated.

Thankyou also to Matt Forrester, Aaron van Winden, Robert Forrester, Heather Forrester, Kris Jacobsen, John Smith, Hery Suhartoyo, Wenhua Xiang, Julia Dordel, John Kane, Andrew Britton, John Marsh, Wanda Pienkowski, Julie Davis, Mauro Davanzo, Ljube Cvetkoski, Luke Wensing, for technical support with field and lab work.

I would like to thank the staff and students of the School of Resources, Environment and Society at The Australian National University who have helped me with this project. I would also like to thank the staff and students of the Institute for Silviculture at the University of Freiburg in Germany, who made me feel very welcome during the final stages of this work.

Thankyou also to FWPRDC (PG01.3102), CSIRO Forestry and Forest Products, the CRC for Greenhouse Accounting, CSIRO Plant Industry, South East NSW Private Forestry, ACT Forests and Harris Daishowa for financial assistance and the use of study sites.

Help with the statistical design and data analyses of parts of this study from Robert Forrester and Jeff Wood is most gratefully acknowledged.

Finally, thank you to my family, Jennifer, Matt, my parents Heather and Robert, relatives and friends for your support.

Abstract

Mixed-species plantations of eucalypts and acacias have the potential to improve stand productivity over that of respective monocultures through the facilitative effect of nitrogen-fixation by acacias, and increased resource capture through above- and belowground stratification. However, growth in mixed-species plantations may not be improved compared to that of monocultures when competitive interactions outweigh the effects of improved nutrient availability and resource capture. Careful selection of sites and species is therefore critical to successfully improving stand productivity using mixed-species plantations. This study set out to examine some of the processes and interactions that occur in mixed-species plantations, and the effect nutrient and water availability can have on the growth of mixtures.

In three out of four mixed-species field trials examined in this study, growth was not increased in mixtures compared to monocultures. However, in the fourth field trial, heights, diameters, stand volume and aboveground biomass were higher in mixtures of *E. globulus* and *A. mearnsii* from 3-4 years after planting.

The range in outcomes from mixing species in these four trials shows that a fundamental understanding of the underlying processes is required to enable a greater predictive capacity for the circumstances under which mixtures will be successful. Therefore the growth dynamics, processes and interactions were examined in the mixtures of *E. globulus* and *A. mearnsii*. The difference in productivity between mixtures and monocultures in this trial increased with time up to age 11 years, when 1:1 mixtures contained twice the aboveground biomass of *E. globulus* monocultures. The positive growth response of trees in mixture compared to monocultures was the result of accelerated rates of nutrient cycling, a shift in C allocation and reductions in light competition through canopy stratification.

Nitrogen contents of foliage and soil clearly showed that *A. mearnsii* influenced the N dynamics in this trial. If these changes in N contents were due to N fixation by *A. mearnsii,* then about 51 and 86 kg N ha^{-1} yr^{-1} was fixed in the 1:1 mixtures and *A. mearnsii* monocultures, respectively. Nitrogen fixation was also examined using the natural abundance method. The $\delta^{15}N$ values of foliage collected at 10 years were

grouped according to the mycorrhizal status of the host plant. Therefore the discrimination of ^{15}N during transfer from mycorrhizae to the host plant appeared to vary with mycorrhizal status, and the natural abundance of ^{15}N was not used to quantify N fixation.

Rates of N and P cycling in litterfall were significantly higher in stands containing at least 25% *A. mearnsii* (>31 kg N ha^{-1} yr^{-1} and >0.68 kg P ha^{-1} yr^{-1}) compared to *E. globulus* monocultures (24 kg N ha^{-1} yr^{-1} and 0.45 kg P ha^{-1} yr^{-1}). Rates of litter decomposition and N and P release were about twice as high in 1:1 mixtures compared to *E. globulus* monocultures and were even higher in *A. mearnsii* monocultures. It is therefore important to select N-fixing species that are capable of cycling nutrients quickly between the plant and soil, and that have readily decomposable litter.

The total belowground C allocation was not significantly different between mixtures and monocultures (14 to 16 Mg C ha^{-1} yr^{-1}). However, since aboveground net primary production was greater in 1:1 mixtures, the changes in nutrient availability appears to have increased total productivity (both above- and belowground), and reduced the proportion of C allocated belowground in mixtures compared to *E. globulus* monocultures.

In a pot trial containing mixtures of *E. globulus* and *A. mearnsii* both species grew larger in mixture than in monoculture at low N levels, and mixtures were more productive than monocultures. However, at high N levels, *E. globulus* suppressed *A. mearnsii* and mixtures were less productive than *E. globulus* monocultures. Similar effects were found for high and low levels of P.

Therefore resource availability can have a strong influence on the interactions and growth of mixtures. The productivity of mixtures may only be increased on sites where the resource for which competition is reduced in mixture is a major limiting growth resource. For example, if N is not a limiting growth factor then an increase in N availability from N-fixation may not increase growth, and the N-fixing species may compete for other resources such as soil P, moisture or light.

This study has shown that mixtures containing a N-fixing trees and a non-N-fixing trees can be more productive than monocultures, but that this increase in productivity will only occur on certain sites. Examination of the growth, interactions and processes that occurred in mixtures in this study provide useful information that can aid the selection of species combinations and sites.

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