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Faster growth of *Eucalyptus grandis* and *Eucalyptus pilularis* in mixed-species stands than monocultures

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ABSTRACT

Eucalyptus plantations cover more than 20 Mha worldwide and are almost exclusively monospecific. However, in native forests *Eucalyptus* species often grow in mixtures. Mixed species stands of trees can be more productive than monospecific stands but despite the implications of this effect, for plantations and native *Eucalyptus* forests, the effects of mixing eucalypts has received little attention. The aim of this study was to examine whether two species that naturally coexist (*Eucalyptus grandis* W. Hill and *Eucalyptus pilularis* Sm.) grow faster in mixtures than their respective monocultures. Monocultures and 1:1 mixtures, and stands of two initial planting densities (1250 and 2500 trees ha^{-1}), were used to compare the productivity and stand structures of mixtures and monocultures and to quantify inter- and intra-specific competition. Interactions between these *Eucalyptus* species increased their relative yields in mixtures by 10–30%. This was associated with changes in stand structure where the diameter distributions of both species became less positively skewed (lower proportions of small trees). Mixing effects were relatively consistent as the stands developed suggesting that if this complementarity effect is used in plantations there is considerable silvicultural flexibility, such that these mixed plantations could be used on both shorter rotations for biomass or pulp-logs as well as longer rotations for solid wood products. This study also suggests that interactions between co-occurring *Eucalyptus* species in natural forests might actually facilitate individual tree growth, in addition to simply enabling co-existence.

1. Introduction

Eucalyptus is the dominant tree genus of Australian forests and woodlands. No other continent has a comparable genus that dominates ecosystems from alpine tree lines to rainforest ecotones and desert river water courses (Noble, 1989). Distributions of individual eucalypt species are largely related to water availability (Noble, 1989; Adams, 1996; Merchant et al., 2006), but are also influenced by soil fertility and fire regimes (Florence, 1996). Members of the *Eucalyptus* genera frequently occur in natural mixtures with other *Eucalyptus* species. Often the associated species come from different sub-genera (e.g. *Symphyomyrtus* with *Monocalyptus*) thereby preventing interbreeding (Pryor, 1959; Austin et al., 1983). While many species can also occur in large monospecific stands, e.g. *Eucalyptus marginata*, most species co-exist with at least one other *Eucalyptus* species somewhere within their natural range (Boland et al., 1992).

Mechanisms that enable co-existence are well documented (Wright, 2002; Brooker et al., 2008; Thorpe et al., 2011). With regards to eucalypts, subtle differences in shade tolerance could enable different species to make use of the varying light intensities that occur in canopy gaps where eucalypts regenerate (Gravel et al., 2010). Differences in root architecture and distribution can allow water and nutrient uptake from different depths or regions of the soil, thereby reducing competition (Neave and Florence, 1994; Schmid and Kazda, 2002; Jose et al., 2006). Contrasting fine root architectures and associations with different mycorrhizae can enable the uptake of different forms of a given nutrient (Schulze et al., 1994; Kranabetter and MacKenzie, 2010). Pests and diseases that focus on a given host eucalypt can keep it from outcompeting and excluding an associated eucalypt species (Chilvers and Brittain, 1972; Morrow, 1977; Pacala and Crawley, 1992; Gurevitch et al., 2000).

More than enabling co-existence, inter-specific interactions can also result in increased productivity of mixed-species compared with monospecific stands when intense intra-specific competition is replaced with less intense inter-specific competition or even facilitative interactions (Kelty, 1992; Richards et al., 2010). For example, Forrester et al. (2006) showed that mixtures of eucalypts and

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