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Basal area increment is unaffected by thinning intensity in young *Eucalyptus dunnii* and *Corymbia variegata* plantations across different quality sites

Kevin Glencross [a,b], Graeme Palmer [a,b], Marie-Chantale Pelletier [a,b], J. Doland Nichols [a,b], R. Geoff B. Smith [b,c,*]

[a] Cooperative Research Centre for Forestry, University of Tasmania, Hobart Tasmania, Australia
[b] Forest Research Centre, School of Environment, Science and Engineering, Southern Cross University, Lismore 2480, Australia
[c] Institute for Rural Futures, University of New England, Armidale 2350, Australia

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ABSTRACT

The subtropical eucalypt plantation estate in Australia now comprises more than 100,000 hectares in north-east New South Wales (NSW) and south-east Queensland (QLD). If a significant proportion of this resource is to be used for sawlog production, it is necessary to design effective silvicultural systems, particularly thinning procedures. A thinning trial was carried out at two sites in QLD and two in NSW. Each was planted with two species, *Eucalyptus dunnii* and *Corymbia citriodora* ssp. *variegata*. The original stocking density of the plantations at planting was 1000–1300 trees per hectare. When the trees were 6–8 years of age, three treatments were applied in randomised complete block designs: an unthinned control, 550 and 300 stems per hectare residual stocking. Basal area increment after thinning was affected by site quality but was not affected by thinning treatments for either species. Mean diameter increment was significantly greater in the thinned stands of both species for all trees in the stand and for the largest 250 trees per hectare. The similarity of basal area growth and difference in diameter growth gives good management flexibility as all treatments at all sites were fully utilising site resources. Analysis of financial factors is needed to determine optimum management under different market scenarios.

1. Introduction

Eucalypt species native to eastern Australia are some of the most widely planted plantation species in the world. *Eucalyptus dunnii* has been widely planted throughout the world and is one of nine eucalypt species that account for over 90% of plantation area (Booth, 2013; Jovanovic et al., 2000). *E. dunnii* is mostly planted for pulp although there is interest in growing for solid wood. *Corymbia citriodora subsp variegata* (*C. variegata*), has not been as widely planted as it is not favoured for pulp regimes; however, as a solid wood species, it is superior and has great potential. It also has a much wider natural distribution into areas of low rainfall, which is of interest to forest managers in terms of climate change. Subtropical eucalypt plantations represent about 12% of Australia's plantation eucalypts (Gavran and Parsons, 2009). Approximately 54,000 ha of *E. dunnii* and *C. variegata* now account for just under half the subtropical estate (Nichols et al., 2010). As there is little previous experience growing these species in plantations for solid wood products (Carnegie, 2007; Lee, 2006; Smith and Brennan, 2006), the impacts of thinning on growth are not well understood.

Compared with other tree genera, *Eucalyptus* and *Corymbia* have a strong competitive ability in resource-limited situations (Florence, 1996). However, species within these genera differ in their tolerance to competition for light, nutrients and water. Therefore, careful matching of species to sites and application of appropriate silviculture are critical to commercial success (West, 2006). While the most competition intolerant species have a strong tendency to self-thin, stand dominance and self-thinning is delayed in more shade-tolerant species (Florence, 1996). While it is generally the case that thinning response increases with increasing thinning intensity there are several aspects that are not clear (Forrester et al., 2013a). The limit of thinning intensity at which stand growth will decline is difficult to predict, and thinning response across different site qualities also varies (Forrester et al., 2013a). Thinning response on lower quality sites may be expected

* Corresponding author at: Institute for Rural Futures, University of New England, Armidale 2350, Australia. Tel.: +61 437 310 812.
E-mail address: Geoff.Smith@une.edu.au (R.G.B. Smith).

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to be greater than on higher quality sites if light is limiting to stand growth, as often occurs on high quality sites, then thinning response of retained larger trees may not be great, as the extra light afforded larger trees by removal of smaller trees is minimal. In contrast on lower quality sites where soil resources may be limiting, thinning response may be expected to be greater due to the availability of resources once a significant proportion of smaller trees have been removed. Although there is little data *E. dunnii* might be expected to be less tolerant than *C. variegata* in water limited situations due to its more limited distribution. However, the range of site qualities and the drought conditions under which this experiment was undertaken suggest that water would be limiting to growth and therefore thinning responses would not be expected to vary across sites.

Thinning reduces competition, allowing retained stems a greater share of site resources, therefore realising larger individual tree sizes within a reduced rotation length (Smith and Brennan, 2006; West, 2006; Beadle et al., 2013). Thinning is essential for the profitability of solid wood regimes as there are three non-linear factors operating together. Log value increases non-linearly with diameter, larger logs being disproportionately more valuable than smaller logs due to the greater recovery that is possible. Discount rates act non-linearly on value over time such that harvest income from shorter rotations become disproportionately more valuable, and tree diameter growth increases dramatically after thinning.

In solid wood regimes, thinning is also used to improve stand quality by removing defective trees before they become dominant. This is important for unimproved stock where a high proportion of defective stems can be present (Smith and Brennan, 2006; Binkley et al., 2002). As pointed out by Smith and Brennan (2006), the optimal thinning regime may involve a trade-off between fully utilising the site resources and maximising growth of the most commercially valuable individual trees in the stand. Therefore, the optimal thinning regime will maintain stand rates of basal area increment, while distributing that growth increment over a small number of commercially valuable trees. This will ensure the most rapid increase in overall stand value. Cassidy et al. (2012) showed that reduction of basal area increment can still increase overall stand value if log value increases enough (disproportionately) with size.

In addition to growth response the intensity and timing of thinning can effect canopy dynamics and therefore wood quality, risks such as wind throw, and products available throughout the rotation. Subtropical eucalypt species have shown a tendency to self-prune lower branches (Smith et al., 2006) as light intensity declines due to inter-tree competition (Alcorn et al., 2008). Rates of occlusion of dead branches are similar in pruned and unpruned trees in several subtropical species (Smith et al., 2006). Thus, if clear-wood production is a plantation objective, efficient branch shedding characteristics can be exploited (Kearney et al., 2007). However, if thinning is delayed, the rise in crown height and loss of leaf area that result may reduce the increase in diameter growth normally associated with thinning release (Smith and Brennan, 2006; West, 2006). For this reason an early non-commercial thinning has been recommended to maximise the thinning response (Gerrand et al., 1997). Although a decline in growth due to thinning response is not always the case, retained trees will be smaller due to the extra time at higher stocking (Forrester et al., 2013b). Heavy thinning causes greater exposure to light in the lower canopy, which can induce larger branch sizes and associated knot defects, and increase risk from wind damage such as stem breakage and growth stresses (Medhurst and Beadle, 2001; Smith and Brennan, 2006).

Most of the recent subtropical eucalypt plantation expansion in Australia has been established primarily for pulpwood (Nichols et al., 2010). Declining world pulp prices and the need for diversification have seen some shift to managing pulp plantations for solid and engineered wood products (Montagu et al., 2003). New processing technologies may provide an opportunity for the development of round wood and engineered wood products from young plantation wood (McGavin et al., 2006), and that wood from young subtropical species may have a competitive advantage over softwood and temperate eucalypts, due to higher density and superior mechanical properties. The development of products from thinning material is a critical issue for forest growers in the subtropics, where pulpwood and residue markets are not well developed (Nichols et al., 2010).

E. dunnii and *C. variegata* are native species being grown in plantations for the first time for solid wood products. The productivity of sites and thinning response of species is unknown and the market for intermediate products not well developed. Therefore several different strategies have been used by plantation growers. Some have pruned and thinned early, others have waited for a later age thinning so a pulp crop can be commercial. Others have delayed without pruning or thinning, relying on self-pruning of species. The thinning treatments evaluated in this study are based on silvicultural regimes proposed by FEA, the owners of the study sites. FEA's intention was to undertake commercial thinning for pulpwood at age 8–9 years and final harvest of small sawlogs and pulpwood at age 13–15 years (FEA, 2009). The growth response was evaluated for different intensities of commercial thinning in *E. dunnii* and *C. variegata* at three sites of different quality for each species. The paper aims to compare the basal area and tree growth response of two contrasting subtropical species, on three sites of contrasting quality, to a range of thinning intensities.

2. Methods

2.1. Site description

Locations of the sites were selected to represent contrasting site types within the plantation estate in subtropical eastern Australia (Glencross et al., 2011). For each species, three sites with known and similar management histories were chosen. The sites were Kings plantation located 6 km west of Coraki, northern NSW, Reids plantation at Ellangowan located 50 km south-west of Lismore in northern NSW, Barron plantation located 15 km south-west of Kingaroy in south-east QLD, and Tingoora plantation, located 40 km north of Kingaroy, QLD. The NSW and QLD locations were selected to provide contrasting higher-rainfall and lower-rainfall sites respectively (Table 1). Annual rainfall data recorded at both locations for the period 2001–2010 is presented in Fig. 1. The mean

Table 1
Summary information for the trial sites.

Site	Soil type	Mean annual rainfall (mm)	Mean daily min temp. coldest month (°C)	Mean daily max. temp warmest month (°C)	Lat (°S)	Long (°E)	Elevation (m asl)
King	Kurosol	1290	6.6	31.3	29.031	153.215	30
Reids	Kurosol	1096	6.6	31.3	29.044	153.093	52
Barron	Ferrosol	783	4.0	29.6	26.573	151.755	465
Tingoora	Ferrosol	783	4.0	29.6	26.371	151.809	449