Session 4: Acacia Species and Natural Resource Management
Paper 22

Silvicultural Management of Australian Blackwood (*Acacia melanoxylon*) in Plantations and Multi-Purpose Forests

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Abstract

Australian blackwood (*Acacia melanoxlyon*) is arguably one of the most challenging, yet rewarding, tree species to grow for high-quality sawlogs. Inherent genetic variability in stem form and its susceptibility to exposure suggests that growers should consider high initial stocking rates from which to select trees of good form and vigour for pruning. Once established, the species does not self-thin well so, without intervention, stands can become overstocked resulting in very slow diameter increment.

Based on data from both native and planted forests of blackwood, this paper proposes the use of Reineke-style stand density diagrams as an aid to designing appropriate management regimes that reflect growers' particular interests. The ratio of diameter to basal area is then presented as a simple, practical, yet effective tool for guiding the thinning of blackwood plantations.

Introduction

Australian blackwood (*Acacia melanoxylon*) is a useful species for inclusion in multi-purpose forests on farms and a promising commercial timber. Its propensity to sucker from exposed roots and spread by seed makes it an ideal tree to grow along an eroding creek or unstable slope for soil conservation. The dense foliage offers refuge for small birds and can help shade creek lines, thereby improving their habitat value. As a timber species, its high value suggests that it could be viable to selectively harvest and market in small volumes, thereby negating the need for invasive harvesting techniques. Regeneration from the stump or seed following harvesting can occur in relatively low-light conditions, leading to multi-aged, multi-value permanent forests.

Whilst multi-purpose forests strategically integrated in the agricultural landscape can be managed to produce commercial sawlogs, the mix of objectives and small scale mean that viable harvesting requires high individual log values to offset poor economies of scale. The most important factors that determine the standing value of blackwood sawlogs are likely to be tree diameter and knots. Nicholas and Brown (2002) recommend a target tree of 60 cm dbhob with a pruned butt log of 6 m. Because pruning is essentially a fixed cost per tree, the return on the investment is directly related to diameter increment and hence stocking rates. Being able to effectively manage the competition between trees is therefore critical to the viability of pruned sawlog management regimes.

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Stocking rates from planting to final crop

Data from natural and planted stands of blackwood provide a basis for understanding how diameter growth is affected by competition in single-species stands. Jennings (1991) provides measurements of native stands of blackwood in Tasmania (Fig. 1). Adding data from measurements of plantations provides some indi-

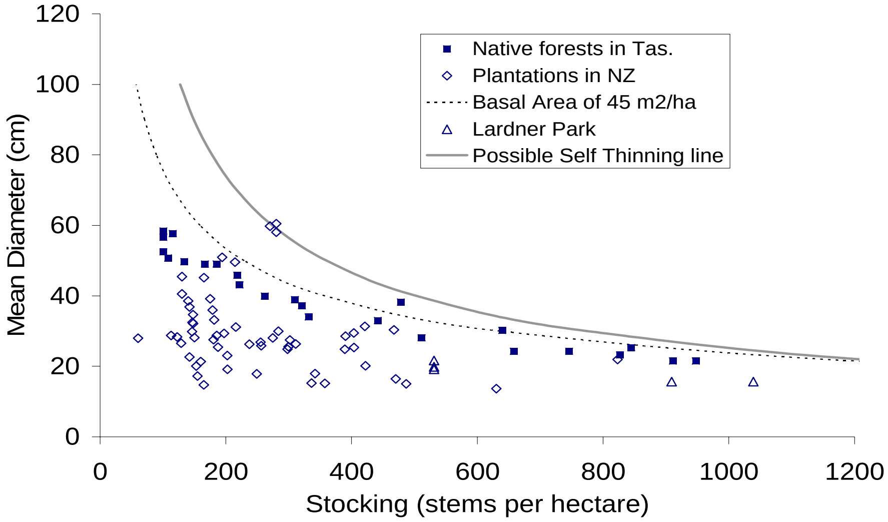

Figure 1. Measurements of both native and planted forests of blackwood

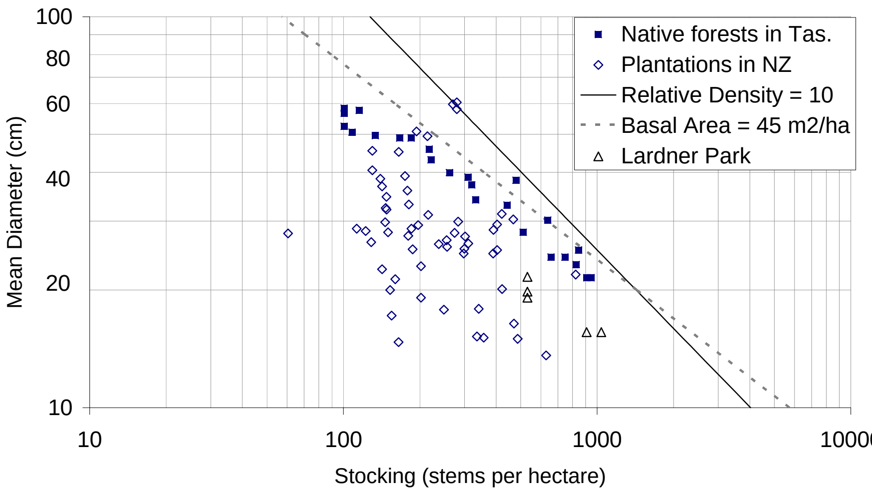

Figure 2. The same data as presented in Figure 1 plotted on a log-log scale along with a line representing a relative density (RD) equal to 10 (RD = BA/DBH$^{0.5}$) and a basal area of 45 m^2 ha^{-1}

cation of the position of the self-thinning curve for blackwood. As the stand approaches the self-thinning line, individuals must succumb in order for the mean diameter to increase.

Jennings (1991) suggests that a basal area limit of 45 m^2 ha^{-1} may approximate the self-thinning line and provide a useful guide for stand management. Although basal area incorporates both stocking rate and tree diameter and can be quickly assessed before and after a thinning operation, it is worth reviewing its effectiveness as a thinning guide for blackwood forests.

Stand density diagrams for blackwood

Reineke (1933) proposed that the natural self-thinning curves comparing quadratic mean diameter (Dg) and stocking rate (N) in even aged forests approximated a linear line when plotted on a log-log scale and that the gradient for different species was very similar (–0.625). Each species' self-thinning line was thought to be independent of site quality and management and that only the position of the line varied with species, thus indicating their relative tolerance of competition. Although the relationship may not be as robust as originally proposed by Reineke, many authors do argue that Reineke-style stand density diagrams provide a better basis for understanding competition in even-aged forests than basal area (Lonsdale 1990; Zeide 2005).

Curtis (1982) demonstrates how the Reineke model can be translated into a relationship between the basal area (BA) and quadratic mean diameter (Dg):

$$BA = a_1(Dg^b) \quad (1)$$

Whereas Reineke's model (self-thinning line gradient of –0.625) infers that b = 0.4, Curtis points out that for natural stands of Douglas-fir (*Pseudotsuga menziesii*) b is in the range of 0.45 to 0.5. Rounding out to b = 0.5, Curtis also suggests that the constant, a_1, might be a useful measure of both relative and absolute density:

$$RD = BA/(Dg^{0.5}) \quad (2)$$

where RD is the relative density. In a recent paper (Reid 2006) the author explored the use of stand density diagrams and equation 2 as a guide for thinning of eucalypt sawlog plantations, and found that using b = 0.5 provided a better match with the available data than did Reineke's model. Although there are fewer data available pertaining to blackwood, a similar approach may be useful. Figure 2 presents the same data as in Figure 1 plotted on a log-log scale along with a line of relative density (RD) equal to 10 (based on equation 2) and a line of basal area equal to 45 m^2 ha^{-1}.

The potential limit of blackwood growth appears to be well represented by a relative density of 10 (based on equation 2), particularly at stockings above 400 stems ha^{-1}. At lower stockings the line may be optimistic, particularly in natural stands. This could reflect the age of the lower-stocked natural stands (they are yet to reach their full potential) or their uneven spacing. The managed blackwood plantation near Rotorua which is now approaching 100 y of age is represented by the three data points close to where the relative density line intersects the 60-cm average-diameter line. Being managed, the mature trees are well distributed across the site and appear to have been able to achieve a higher yield for the same stocking than noted in the native forests of Tasmania.

Figure 2 does suggest that a plantation managed at a constant basal area will tend to become less competitive over time. This is because tree basal area includes the area of both sapwood and heartwood, whereas only the sapwood area is related to leaf area, tree growth and hence competition (Medhurst and Beadle 2002). As a stand develops it is therefore able to carry a higher basal area for the same growth potential (leaf area). It is for this reason that the value of basal area alone as a guide for managing stocking in plantations has been seriously questioned (Zeide 2005).

Competition zones

A number of authors, including Renieke (1933), suggest that it is possible to use the stand density diagrams to define the degree of competition in an even-aged forest using a series of lines drawn parallel to the self-thinning line (Dean and Baldwin 1996). Theoretically there are five competition zones for plantations ranging from a *zone of excessive exposure*, within which tree height growth is retarded due to a lack of mutual shelter, through to a *zone of imminent mortality* which is presumed to be unobtainable. Within the *zone of free growth* individual-tree diameter increment is maximized whereas in the *zone of full stocking* stand productivity is maximized. Once the forest passes into the fully-stocked zone, the volume increment is simply distributed over a greater number of stems. Between the free-growth and fully-stocked zones there is presumably a *zone of increasing competition* in which individual-tree growth is increasingly restricted.

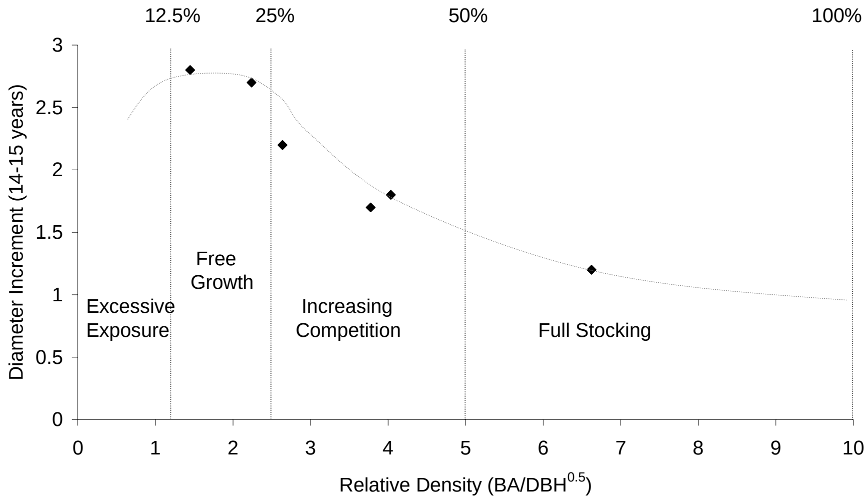

Figure 3. Annual increments (from age 14 to 15 y) of blackwood growing under different management regimes in New Zealand provide some indication of the different competition zones

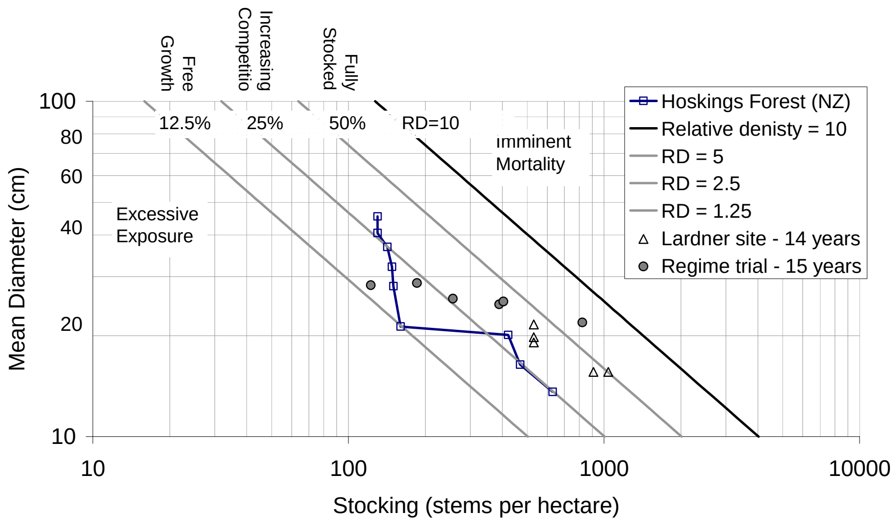

Figure 4. The competition zones shown on the log-log scale along with data showing the past management of the Hosking blackwood plantation in New Zealand and plot measurements of the Rotorua regime trial (NZ) and Lardner site (Gippsland)

Based on the limited available data it is difficult to judge at what RD a blackwood plantation may move from one competition zone to the next. Figure 3 presents the diameter increment between age 14 and 15 y for blackwood grown at a range of stocking rates in a trial near Rotorua (Nicholas and Kimberley 2002). The mean diameter in these stands varied from 22 to 29 cm at age 15 y. Assuming a maximum RD of 10, the lines delineating the theoretical zones have been arbitrarily drawn at 50%, 25% and 12.5% of the maximum. Figure 4 shows the same zones on a Reineke-style stand density diagram along with data showing the history of the 20-y-old Hosking's plantation in New Zealand (Gilchrist *et al.* 2002), the regime trial near Rotorua (Nicholas and Kimberley 2002) and the recent measurements of the 14-y-old Lardner trial in Gippsland (measured by Reid and Hirst in 2006).

Target stocking rates for blackwood sawlog plantations

Stand density diagrams provide a useful guide for the selection of appropriate initial and final-crop stocking rates. For example, a grower primarily focused on producing large pruned blackwood butt logs (of say 60 cm dbhob) may judge that a final stocking of about 150 stems ha^{-1} is not only feasible but will also ensure the forest is close to fully stocked at the time of harvest. To avoid excessive exposure, an initial stocking of at least seven times that expected at harvest may be required, particularly on poorly-sheltered sites. Overplanting also provides the opportunity to select the trees of best form and vigour through a series of thinning operations.

Diameter:basal area ratio (D:BA)

Whereas a plantation held at a constant basal area tends to become understocked over time, the opposite is true of a plantation held at a constant ratio of mean tree diameter to stand basal area (D:BA) (Fig. 5). For example, a blackwood plantation managed at a constant mean diameter (in cm) to basal area (in m^2 ha^{-1}) ratio of two might be free-growing until the trees are about 25 cm in diameter (stocking of around 250 stems ha^{-1}) after which time diameter growth and branch development will presumably be restricted by increasing competition.

In practice, maintaining a D:BA ratio of between two and three during the early years may be an ideal route for growers who intend to prune, since they are able to concentrate their pruning costs on a smaller number of free-growing trees than that required by a constant basal area regime. Having established sufficient trees to achieve mutual shelter and an adequate selection ratio, the stocking would be reduced to around 500 stems ha^{-1} at the time of the first pruning lift. Form pruning during this establishment phase is useful to improve the number of suitable trees for stem pruning (when the trees are 8–10 cm in diameter). Subsequent thinnings, timed to coincide with the selection of superior trees for pruning, would reduce the stocking to around 220 high-pruned stems ha^{-1} by the time the mean diameter was 20 cm (pruning phase). Allowing for natural mortality, wind damage and disease, these 220 stems would then be left to grow on and provide the basis for the final crop whether they are to be harvested as a clear fell or selectively logged.

Balancing harvesting and non-timber benefits

Whilst most plantation regimes assume the plantation will be clear felled at a particular age, farmers who have established the trees for multiple values may prefer to harvest small areas, or even individual trees, in an attempt to retain the non-timber values the forest provides. By aiming to produce 220 high-pruned stems ha^{-1}, the trees are expected to be relatively free growing until the mean diameter approaches 30 cm (basal area of about 15 m^2 ha^{-1}). The farmer could then begin selectively harvesting some of the largest trees as they reach a useful size (say 40–50 cm) to maintain a D:BA ratio of around two. At this stocking there would be

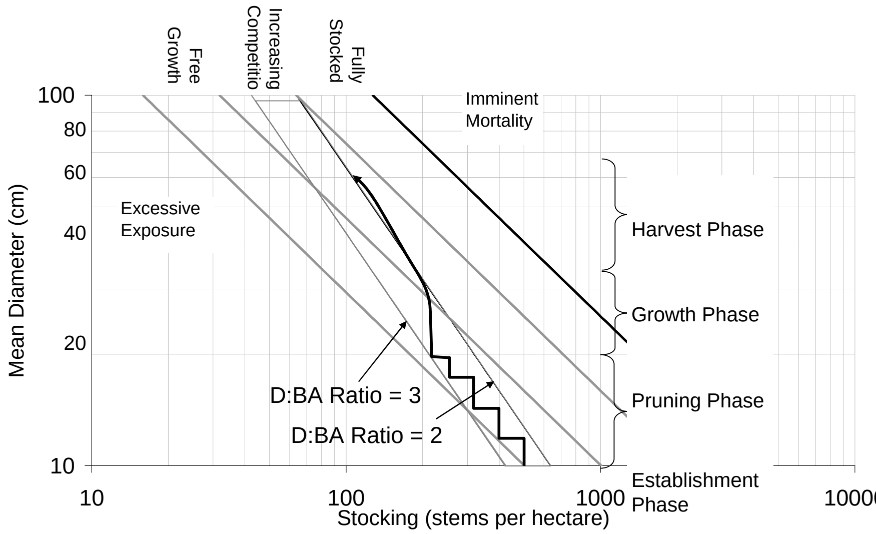

Figure 5. A possible management regime for blackwood based on thinning to maintain a diameter:basal area (D:BA) ratio of between two and three

sufficient light available at ground level to allow natural regeneration or replanting in order to develop an uneven-aged forest providing ongoing non-timber benefits as well as the opportunity for regular harvests of high-quality logs.

Spot measurements of D:BA ratios

Using the basal area sweep method (Reid and Stephen 2001) individual D:BA ratios can be estimated quickly for each tree in a stand by comparing tree diameter to the basal area around that individual. This is an especially useful technique in irregularly-shaped forests of the type commonly grown on farms and possibly even mixed-species plantings. Figure 6 compares the D:BA ratio of individual blackwood trees growing in an irregular, mixed-species riparian buffer strip on the author's own farm. In this case most of the competition is from taller eucalypts. Diameter increment measurements in future years will help build an understanding about how to manage the overstorey component in order to allow the blackwood to develop well.

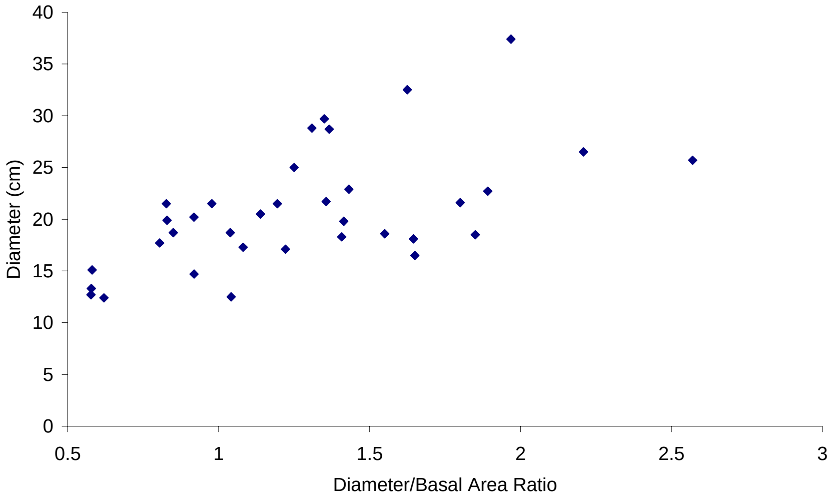

Figure 6. Individually-assessed diameter:basal area (D:BA) ratios for blackwood trees growing under a canopy of widely spaced, pruned eucalypts in a riparian buffer. Basal areas were measured around each tree using a two-factor basal area wedge.

Conclusion

Farmers committed to the management of blackwood plantations for commercial sawlog production have lacked practical tools for planning initial and final-crop stockings and for guiding stocking during the rotation. They seldom have access to detailed growth functions relevant to their tree species or sites and, if they do, such models are rarely adaptable to irregular farm plantings of the type farmers want to grow. The D:BA ratio is a simple and practical tool for guiding stocking management in such plantings.

Landholders can easily determine an appropriate ratio based on their target log diameter, whether they wish to prune or not, and the relative importance they place on either maximizing yield or maximizing the return on management costs such as pruning. As the forest grows, simple measurements of tree performance can be used to refine their choice of D:BA ratio. Use of the ratio promotes the establishment of sufficient trees to provide mutual shelter in the early years whilst encouraging growers to thin heavily during the pruning phase in order to concentrate their investment and the available site resources on the most promising individuals.

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