Effects of soil water and nitrogen on grass suppression of young *Eucalyptus globulus*

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Summary The effect of grass competition on the growth of young *Eucalyptus globulus* under contrasting levels of soil water and nitrogen was investigated in an experiment near Hobart, Australia. The objectives were to determine (1) the 'critical period' of competition, and (2) how the timing and duration of competition was related to resource availability. *E. globulus* growth was strongly suppressed in the presence of grass, with height and diameter growth of weedy trees being 52% and 40% of weed-free trees, respectively, at age two years. Most growth losses occurred during the first year. This effect was mediated by level of water and soil nutrient status. Where water was limiting, the impact of weeds on tree growth was greatest, compared to where soil water was readily available. The interaction between soil water and tree response to applied nitrogen was also evident, with high water availability increasing the response to nitrogen fertiliser in the presence of weeds. Even with high water availability, intensive fertiliser use did not completely compensate for slow growth in the presence of weeds. The relationship between site resource availability and weed competition requires further investigation and should enable weed management practices more appropriate to soil, site and species.

Keywords Weed control, *Eucalyptus globulus*, grass competition, water, nitrogen, critical period.

INTRODUCTION

The effective management of weeds during eucalypt plantation establishment is a major determinant of the success of new plantings in Australia. Failure to predict, plan for, and implement appropriate control methods often results in low survival and growth of the crop, with rotation-length consequences. Many plantation growers have developed successful weed control prescriptions based mainly on the use of herbicides. However, there is increasing environmental pressure and public scrutiny of forest management, particularly relating to catchment management and water quality. There is an ongoing need, therefore, to minimise the environmental impacts of herbicides while making them more effective and efficient.

The efficiency of herbicide use can be improved by various methods including: reducing the area treated (e.g. spots or strips), improving the application and formulation technology, improving weed forecasting and timing of application, and accepting lower levels of weed control and hence tree growth rates.

Plantation weed control research has mainly involved herbicides (Richardson 1993), focusing on tree responses, herbicide type, application rate, and degree of weed removal. The interfering weeds, their ecology, growth and behaviour have received much less attention (Nambiar 1990). However, further advances in weed management practices and the application of weed control appropriate to soil, site and species, requires greater consideration of the site quality and weed – tree interactions. The timing and duration of weed competition and the influence of resource availability are important aspects.

This study focused on the interaction between young *Eucalyptus globulus* Labill. (Tasmanian blue gum) trees and two common herbaceous weeds: a temperate, perennial grass *Holcus lanatus* L. (Yorkshire fog) and a rhizomatous broadleaf *Acetosella vulgaris* Fourr. (sheep sorrel). The main objective of the study was to measure the competitive effect of grass for below ground resources on the growth of *E. globulus* under contrasting levels of soil water and nitrogen availability.

MATERIALS AND METHODS

Site and treatments A 2.0 ha field experiment was established in 1996 on a low rainfall (500 mm y^{-1}), ex-pasture site with a moderately fertile sand, approximately 15 km north-east of Hobart, Australia. The soil is duplex (Podosol, Isbell 1996) with an aeolian derived sandy A horizon overlying a sandy clay to clay B horizon at 1.3 to 2 m depth. The clay B horizon was imperfectly drained and a seasonal water table was present. Original vegetation was degraded pasture dominated by *Medicago sativa* L. (lucerne) (up to 20% groundcover); *Acetosella vulgaris* (Fourr.) (up to 80% groundcover) with isolated patches of *Pteridium esculentum* (Forster f.) Cockayne (bracken fern).

Holcus lanatus seed was drilled to provide consistent grass coverage across the plots, while weed-free treatments were maintained by regular, careful application of glyphosate (Roundup®). Overtopping of tree seedlings by grass was prevented by occasional hand cutting within a 1 m radius of each seedling during the first year of growth.

To simulate a range of ex-pasture conditions, irrigation and nitrogen fertiliser was applied. Low irrigation (I_{Low}) was applied at 800 mm y^{-1} (including rainfall), while high irrigation (I_{High}) was applied at 1200 mm y^{-1}. Nitrogen fertiliser was applied at 0 (N_{Zero}) and 900 (N_{High}) kg N ha^{-1} over two years, while a basal dressing of other nutrients was also applied across the site.

The critical period method (Zimdahl 1988) was used to examine the timing and duration of weed interference, and to define the period during crop development when weed control should be carried out to prevent yield loss. The form, timing and length of a critical period is determined by many interacting factors, including resource availability, weed and crop species and management (Zimdahl 1988). In a subset of low irrigation plots, a range of weedy and weed-free periods were applied (Table 1). Critical periods of six or 12 months (in N_{High} or N_{Zero} respectively) were chosen to accommodate the potentially high rates of tree growth, the patterns of grass growth and seasonal effects.

Measurements Tree height and diameter of each tree was measured bi-monthly until age 17 months, then at 21 and 24 months of age. Measurements of stem diameter at 0.15 m above-ground (D_{15}) commenced at age five months. Assessment of *H. lanatus* and *A. vulgaris* percent groundcover (%) was carried out, along with weed biomass harvests on three occasions.

Experimental design Treatments were arranged in a split plot design in three blocks. Each plot contained 12 measurement trees surrounded by a 1.5 tree row buffer. Espacement was 2.5 m × 2.5 m (1600 stems ha^{-1}). Treatment details are provided in Table 1.

Data analysis Data analysis was via ANOVA (GENSTAT 5) to determine least significant differences (P<0.05) for comparison of treatments. The critical period of weed control was determined using regression (Cousens 1988), and solution of the equations to show when growth loss occurred. A minimum diameter reduction of 5% was used as the criterion.

Table 1. Treatment details.

Irrigation	Nitrogen	Weeds
I_{Low}	N_{Zero}	W12
		W24
		WF12
		WF24
	N_{High}	W6
		W12
		W18
		W24
		WF6
		WF12
		WF18
		WF24

W = weedy, WF = weed-free, Number = months.

RESULTS

Holcus lanatus was the dominant weed (Figure 1). Per cent ground cover was 83 (± 6) % (mean ± 1 SE) in all weed treatments eight months after sowing, after which treatment differences became evident (Figure 1a). This cover was maintained over the following winter and spring until flowering, and maturity in the second summer. Regrowth occurred in the second autumn. Grass growth was poorer in Block 3 where the sandy soil was deeper and water availability lower. Here, *A. vulgaris* formed a more significant component of the sward but only accounted for 20% ground cover. Thereafter *A. vulgaris* was only a minor component of the weed population (Figure 1b).

Where N fertiliser was applied *H. lanatus* responded strongly, with above-ground biomass increasing by as much as 56% compared to unfertilised plots. There was no significant response to high irrigation by the weeds.

The timing and duration of weed presence significantly affected *E. globulus* height and diameter growth (P<0.001). Two years of continuous grass presence reduced height and diameter to 52% and 40%, respectively, of trees growing in entirely weed-free conditions. Tree growth decreased as the duration of weed presence increased (Figure 2). In addition, there was a significant delay in recovery of growth after the application of weed removal treatments.

Tree recovery was delayed longer and suppressed to a greater degree in N_{Zero} treatments (Figure 2). At age two years, diameter growth was 50% and 80% smaller in N_{Zero} than N_{High} in W and WF treatments, respectively (Figure 2).

Analysis of the critical period curves shows that diameter growth increased with increasing duration

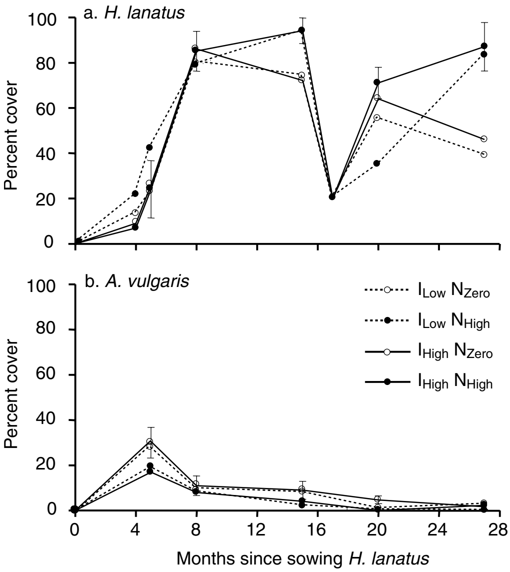

Figure 1. Temporal pattern of coverage of (a) *H. lanatus*, and (b) *A. vulgaris*. Error bars are LSD's (P<0.05).

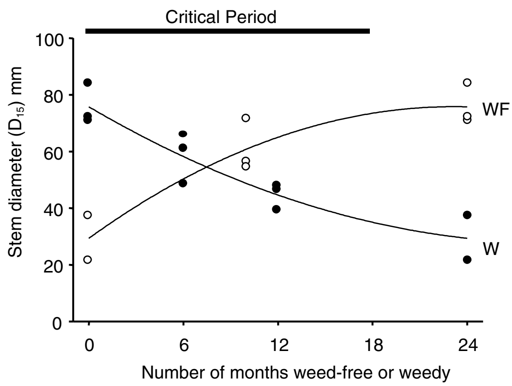

Figure 2. Effect of delaying grass removal on *E. globulus* diameter growth. All plots receiving I_{Low}. Error bars are LSD's (P<0.05).

of weed-free conditions (weed-free curve). Maximum diameter growth was approached (80%) after approximately one year of weed control. The weedy curve shows that diameter growth declines immediately after planting in the presence of grass and that this decline was still apparent at age two years. Using a minimum 5% reduction in diameter growth compared to that in continuous weed-free conditions as the criterion, the critical period of weed control at this site was from planting to age 20 months (Figure 3).

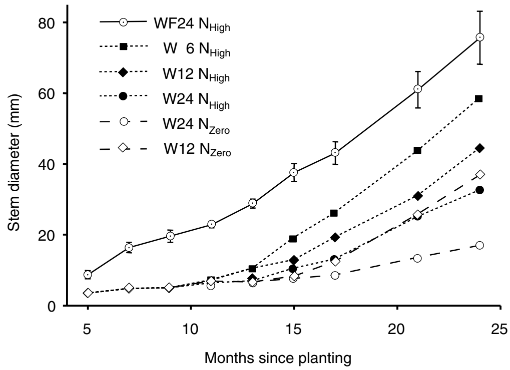

Figure 3. The critical period of grass interference with *E. globulus* based on stem diameter at age two years (all receiving I_{Low} and N_{High}).

DISCUSSION

This study demonstrated the importance of resource availability, particularly soil nitrogen, in the interaction between *E. globulus* and grass. Consistent with other studies (e.g. Fremlin and Misic 1999), up to 80% of the diameter growth of the trees at age two years was attributed to weed control during the first year. However, due to the vigour and dominance of the grass at this site, weed control during the first half of the second year also contributed to the maximisation of early tree growth.

The duration of grass weed control is important for *E. globulus*, but it is dependent on soil and site conditions (Fremlin and Misic 1999). Sites with high resource availability (nutrients and water) are less likely to respond to second-year control, especially where good weed suppression occurred during the first year. By the end of the second year of growth, the trees are usually of sufficient stature (2–4 m in height in eucalypt plantations in southern Australia) to exert a suppressive effect on weed growth. On water- and nutrient-limited sites, or with slower growing tree species, the length of time for weed interference will be longer (Wagner *et al.* 1999), dominance of the site will be delayed and therefore the duration of weed control will need to be extended.

There was a strong tree growth response to N_{High} in the presence of weeds, especially during the second year, indicating that availability of, and competition for, nitrogen was limiting tree growth. Trees were more suppressed by weeds in N_{Zero} treatments, than in N_{High} treatments, even though grass growth was also less vigorous. The application of high rates of fertiliser (900 kg N ha^{-1}) was unable to totally offset lost tree growth, partly because it also stimulated grass growth.

The slow response of trees to applied N in weedy treatments was probably associated with restricted tree root development reducing the ability of the trees to take up N, though N immobilisation and leaching also may have been important factors. The greater response during the second year of growth was probably associated with more developed and extensive tree root systems capable of increased nutrient capture and uptake. It is probable that the trees were better prepared, both morphologically and physiologically, for the favourable conditions (increased N availability) in the second year, compared to the first (Kirongo *et al.* 2002).

Although there was no significant growth response to irrigation by the trees, there was an increased tree growth response to N in weedy treatments under I_{High}, compared to I_{Low}, indicating a water × nitrogen interaction in the surface soil (Sands and Nambiar 1984). This suggests that trees were under nutrient stress due to lower water availability in the surface soil. Higher water availability provided by I_{High} could have increased nitrogen mineralisation, and enhanced root uptake of N via diffusion and mass flow (Nambiar and Sands 1993).

The level of soil fertility influenced the speed of recovery of tree growth after post-planting application of weed control. Trees in N_{High} treatments responded faster than trees in N_{Zero} treatments, indicating that access to increased levels of available nitrogen increased growth. In addition, weed control applied in spring when tree growth was increasing was associated with faster recovery than in autumn, when tree growth was slower.

This research indicates good prospects for utilising the relationship between site resource availability (soil water and nutrients), weeds and the intensity of weed control, to tailor weed control operations on a soil, site and species basis. Improved quantification of weed effects by site type and resource level is required. The trade-off will be increased management complexity.

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