Eucalypt Seedling Hardiness to Low Temperature: A Synthesis©

Dugald C. Close, Phil H. Brown and Mark J. Hovenden
Cooperative Research Centre for Sustainable Production Forestry, University of Tasmania, Private Bag 252-12, Hobart, TAS 7001

Chris L. Beadle
CSIRO Forestry and Forest Products, Private Bag 252-12, Hobart, TAS 7001

This review describes research into the effects of low temperature induced photodamage on seedling performance and survival in the nursery and soon after planting. Photodamage to seedlings is more common after planting than in the nursery, but cases of severe damage have been recorded in nurseries. In one case, seedlings of *Eucalyptus globulus* were damaged in the nursery between 1000 and 1030 h after overnight frost, when light flux density was high but air temperature was still low. Seedlings within the tray bed that were shaded at this time by the shadehouse infrastructure did not suffer photodamage. The nursery now has an automated system where the extendable shadecloth is moved into place once air temperature drops below 10 °C. Management to reduce photodamage in the nursery may not be needed in all situations, but nursery managers need to be aware that production practices in the nursery can have a major impact on seedling susceptibility to photodamage when planted in the field.

A frost event after planting caused moderate and severe photodamage, respectively, to *E. nitens* and *E. globulus*. *Eucalyptus globulus* had 25% mortality. Shadecloth tree shelters did not affect minimum temperature but prevented photodamage by reducing exposure to bright morning sunlight after frosts. Nutrient deprived "red" seedlings had no photodamage.

Red leaves have accumulated anthocyanin that is located immediately below the leaf epidermis and screens light between 400 and 590 nm that would otherwise contribute to photodamage. Anthocyanin accumulation was also an indicator of greater activity of excess light-energy dissipating xanthophyll-cycle and antioxidant production. Nutrient-deprivation in the nursery reduced photosynthetic capacity and induced acclimation to photodamage, hardening them to potential photodamage soon after planting onto cold sites. The nursery practice of nutrient-deprivation is a useful tool for managing photodamage risk.

INTRODUCTION

In recent years, production of eucalypt seedlings in Tasmania has moved to containerized systems in nurseries situated at mild sites. Frost events in September/October (spring) 1997 led to complete mortality of seedlings on some sites and required expensive re-planting. This raised concerns about the survival and performance of containerized seedlings planted onto cold sites. Previously, production was in nurseries at relatively high altitude: the seedlings were relatively large and considered robust and cold hardy relative to the containerized seedlings produced at sea level. While water stress and frost damage were originally thought to be the main processes contributing to loss of container-grown seedlings, photodamage has now been demonstrated to be a principal mechanism of tissue death in transplanted seedlings.

Shading reduces visible frost damage, termed photodamage, to *Picea abies* seedlings when excess light absorbed during the morning following overnight frosts cannot be utilized for photosynthesis (Örlander, 1993). Photodamage is caused by free radical production that bleaches and kills leaf tissues (Wise, 1995).

Eucalyptus globulus and *E. nitens* are the major hardwood species planted in Australia. *Eucalyptus globulus* occurs naturally on or near the coast in Tasmania (Tibbits et al., 1997), has low frost tolerance, and is therefore only planted on mild sites. *Eucalyptus nitens* occurs naturally on the Great Dividing Range near the Victorian and New South Wales border between 800 and 1350 m above sea level (asl) (Tibbits et al., 1997). It has good frost tolerance and is planted on sites too cold for *E. globulus*. This review synthesises our research on the effects of photodamage to these species following low temperature events in the nursery or soon after planting and describes nursery practices that can prevent or ameliorate photodamage.

PHOTODAMAGE IN THE NURSERY

In July 1997, retractable shadecloth was not in place overnight over 7-week-old *E. globulus* seedlings. A mild frost occurred. Within a week, photodamage was apparent. This damage was restricted to particular strips within the tray bed whilst in between, the seedlings were minimally damaged. It was observed that on sunny mornings, the damaged strips were of similar size to the area of tray bed not shaded by the shadehouse infrastructure (Close et al., 1999). Tracking the shaded areas indicated that the strips of undamaged seedlings were coincident with the position of shade between 1000 and 1030 HR At this time, incident light flux density was close to the diurnal maximum of 750 $\mu mol \cdot m^{-2} \cdot s^{-1}$. However, the air temperature when photodamage occurred was ca. 8 °C. Thus a combination of high light and low temperature caused the photodamage. Eight weeks after this event, photodamaged seedlings had significantly greater percent leaf area damage and lower height growth (Close et al., 1999). An automated system that extends shadecloth over young seedlings in the nursery whenever air temperature falls below 10 °C is now in place.

PHOTODAMAGE IN THE FIELD

A spring-planted field trial at 350 m investigated the effects of photodamage in “conventional” seedlings of *E. nitens* and *E. globulus* newly transplanted to cold sites (Close et al., 2000). This altitude is marginal for planting *E. globulus* in Tasmania because of frost incidence. Nutrient-deprived *E. nitens* seedlings only (Close et al., 2000) and seedlings surrounded by open-topped 50% shade-cloth tree shelters (Close et al., 2002) were included also in the trial. The nutrient-deprived seedlings have “red” coloured leaves that are viewed by industry as relatively frost tolerant. Shadecloth is hypothesised to reduce levels of incident light thereby preventing photodamage, reduced growth, and/or mortality. There were three mild frosts (the most severe around –2 °C) during the 2 weeks after planting. Conventional *E. nitens* and *E. globulus* seedling had moderate and severe photodamage, respectively: leaves of both species developed significant red pigmentation. There was 25% mortality in *E. globulus* but none in *E. nitens*. Shaded seedlings of both species had no photodamage or mortality, remained green, and had relatively greater height growth than conventional seedlings. Seedlings without shadecloth shelters were exposed to identical minimum overnight temperatures. The nutrient-deprived seedlings had no photodamage and similar growth to conventional seedlings. Conventional and nutrient-deprived seedlings gradually lost red leaf pigmentation with increasing spring temperatures.

The findings indicated that photodamage reduces seedlings growth and increases mortality of seedlings after planting onto cold sites. Photodamage, and not levels of frost tolerance, restricts the planting range of *E. globulus* to mild sites. *E. nitens* has relatively high tolerance to, and rapid recovery from, photodamage relative to *E. globulus*. Nutrient deprivation in the nursery confers seedling hardiness to photodamage.

PHYSIOLOGY OF ACCLIMATION TO PHOTODAMAGE: HARDENING THROUGH NUTRIENT DEPRIVATION IN THE NURSERY

The finding that nonshaded seedlings developed distinct red leaf pigmentation in tissues not killed by photodamage and the observation that nutrient-deprived seedlings that were red before planting suffered no photodamage, indicated a role of pigments in protection from photodamage. The red pigment was identified as anthocyanin. In eucalypt seedlings, anthocyanin accumulates immediately below the upper leaf epidermis. Investigation of the optical properties of high and low anthocyanin-containing leaves indicated that anthocyanin screened out light between 400 and 590 nm that would otherwise contribute to photodamage (Close et al., 2001a). In addition, the dissipation of excess light energy by the xanthopyll cycle and antioxidant production are adjusted to prevent photodamage, before the increased synthesis of foliar anthocyanin (Close et al., 2003). These processes are particularly efficient in *E. nitens* (Close et al., 2000; 2001a, b; Close and Beadle, 2003), possibly conferring greater tolerance to photodamage than that exhibited in *E. globulus*.

The practice of nutrient deprivation in the nursery induces nitrogen deficiency. This causes decreased photosynthetic capacity and thus increases the potential for photodamage even under the mild conditions in the nursery. In response the seedling adjusts the physiological processes described above which include, and is indicated by, anthocyanin accumulation. Thus the practice of nutrient-deprivation effectively hardens seedlings to photodamage by inducing acclimation to low temperature.

CONCLUSIONS

Nutrient-deprivation in the nursery is a tool for managing the risk of photodamage to eucalypt seedlings after planting onto cold sites. While this practice may not detrimentally affect seedling growth on cold sites it may significantly reduce the growth of seedlings planted onto mild sites where the potential risk of photodamage soon after planting is low (Close et al., 2003).

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