RESPONSE OF *EUCALYPTUS NITENS* AND *EUCALYPTUS REGNANS* SEEDLINGS TO APPLICATION OF VARIOUS FERTILISERS AT PLANTING OR SOON AFTER PLANTING

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ABSTRACT

A site which had previously carried a high quality *Eucalyptus regnans* F.Mueller forest, but which had marginal soil nutrient reserves, was selected to trial four fertiliser options for establishment of *Eucalyptus nitens* (Dean et Maiden) Maiden and *E. regnans* sawlog plantations. Apart from the fertiliser options, current operational plantation establishment practices were used.

Application of a nitrogen-phosphorus fertiliser shortly after planting produced increased growth for *E. nitens* amounting to 30 m^3/ha by age 7 years. *Eucalyptus regnans* also responded to fertiliser application, but overall growth was less than half that of the *E. nitens*. This slower growth was due to early severe and repeated insect attacks. Insect attack also caused increased double and multiple leadering in the *E. regnans*.

Normal rates of nitrogen-phosphorus fertiliser application (25 g N and 11 g P/tree) resulted in an increase in branch size compared with trees without fertiliser, and the mean largest branch diameter was increased by 6 mm for *E. nitens*. Multiple leadering also increased, from 2% to 10%. Very high rates of fertiliser addition over the first 6 months after planting caused substantially greater deterioration in branching habit in both species; the mean largest branch diameter was 10 mm larger than with normal fertiliser additions, and 27% of trees had multiple leaders. While most stems in stands treated with normal rates of fertiliser were suitable for pruning for sawlog production, very few stems in stands treated with high rates of fertiliser were suitable.

Despite substantial increased growth from fertiliser application, at age 7 years foliar-phosphorus levels were low and foliar-nitrogen levels were marginal in all treatments. Increased growth rates could be expected from further application of fertiliser. Results indicated that soil nutrient profiles together with foliar analysis might be useful in developing fertiliser regimes for eucalypt plantations.

Keywords: fertiliser; foliar analysis; forest growth; branching; insect damage; *Eucalyptus nitens*; *Eucalyptus regnans*.

INTRODUCTION

Although *Eucalyptus* spp. will grow on sites of low fertility, deep fertile soils are required for satisfactory rates of growth of plantations (Cromer 1984; Neilsen & Wilkinson 1990).

Even on fertile soils the availability of nutrients at time of planting may not be sufficient in the vicinity of seedling roots to provide for maximum growth. The degree and nature of response to fertiliser applied at time of planting will be affected by soil type and fertility, site preparation, cultivation, weed control, and site factors such as rainfall and temperature (Cromer *et al.* 1981; Herbert 1991; Noble & Herbert 1991).

Responses of eucalypts to fertiliser applied shortly after planting have been obtained on a range of soils (Cromer *et al.* 1975, 1993; Cromer & Henderson 1981; Schonau & Herbert 1989; Birk & Turner 1992). Substantial responses to nitrogen fertilisers have been most common (Cromer 1971; Ballard 1978; McKimm & Flinn 1979) but responses to phosphorus and interactions between nitrogen and phosphorus fertilisers have also been noted (Cromer *et al.* 1981; Schonau 1983). Herbert (1983) found responses to nitrogen, phosphorus, and potassium fertilisers for *E. grandis* W. Hill ex Maiden, with complex interaction effects on growth and tree form. Response has been related to the quantity of fertiliser applied and has generally lasted for 2 to 4 years, although responses of much greater duration have been obtained with high rates of fertiliser (Cromer *et al.* 1975). Responses to both nitrogen and phosphorus have been obtained in trials with *Eucalyptus globulus* Labill. in Tasmania (Neilsen & Wilkinson 1990).

Although applications of fertiliser within 2 months of planting have given optimum response in some trials (Schonau & Herbert 1989) experience in Tasmania indicates that application as late as 4 months after planting did not lead to reduced growth response. Applications of any but small quantities of fertiliser at time of planting or shortly after risked a high rate of seedling mortality (Neilsen 1990). No particular method of applying fertiliser close to seedlings has proved any better than another (Schonau & Herbert 1989).

A trial was established to compare the effects, for two temperate-climate eucalypt species, of treating with (a) a standard nitrogen-phosphorus fertiliser, (b) a lower level of application at time of planting, (c) an application of nitrogen-phosphorus fertiliser in combination with potassium, and (d) a multiple-application regime. The site was treated with what was considered optimum cultivation and weed control.

METHOD

Site

The planting site was located in north-eastern Tasmania at 120 m altitude and has been described by Wilkinson & Neilsen (1990). Soils were yellow podsolics formed on adamellite granites. The upper horizon generally comprised a coarse, free-draining, dark-grey, gravelly quartz soil to 20–30 cm in depth, overlying a deep yellow clay with high quartz content. Chemical properties were determined (Table 1). The levels of nitrogen and phosphorus were low relative to most Tasmanian forest soils (Grant *et al.* 1995).

The climate was temperate with annual precipitation of approximately 980 mm with a winter peak and periods of summer moisture deficit. The site formerly carried *E. regnans* forest of 34–41 m mean dominant height (MDH).

Establishment Preparation

The soil was cultivated by discing, and mound-ploughed with tandem off-set discs of 600 mm diameter, producing mounds of 150 mm height. For weed control the area was

TABLE 1–Soil chemical* and physical properties for trial area in north-east Tasmania. Analyses are the means of a series of results from intact cores taken across the trial site.

Horizon	Depth (cm)	Texture	Organic carbon (%)	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Calcium (%)
A1	0–10	Loamy-sand	5.1	0.272	0.021	0.071	0.139
A2	10–25	Sandy loam	2.5	0.150	0.016	0.076	0.070
B	25–75	Sandy loam	1.7	0.072	0.014	0.110	0.032
C	75+	Sandy loam	1.1	0.037	0.017	0.154	0.019

* Organic carbon was Walkley-Black, and chemical analyses were Kjeldahl nitrogen and hot nitric acid extract for other elements.

broadcast sprayed with a mixture of amitrole at 1.3 kg a.i./ha and atrazine at 3 kg a.i./ha. The plantation was fenced to exclude browsing animals.

Trial Design

Two stock types, open-rooted and paper-potted, of *E. regnans* and *E. nitens* were used for the trial. Planting rate was 1428 stems/ha, with 3.5 m between rows and 2.0 m along rows. There were five treatments—four fertiliser treatments plus control—replicated in three blocks. Each species × fertiliser treatment consisted of four rows of 10 trees, with two rows of each stock type as split plots.

Fertiliser Treatments

Four fertiliser treatments were applied, in addition to a control. Treatments were:

- NP, 235 g/tree of an 11:5:0 (N:P:K) mixture of ammonium sulphate and superphosphate applied 2–4 months after planting (25 g N, 11 g P). This was the normal nitrogen-phosphorus treatment used by Forestry Tasmania (Neilsen 1990);
- NPK, 295 g/tree of an 8:4:10 mixture containing muriate of potash, together with nitrogen and phosphorus as above, applied 2–4 months after planting (25 g N, 11 g P, 29 g K);
- Fertiliser tablet, one 10-g fertiliser tablet (21:5:4) placed in the planting hole at time of planting (2 g N, 0.5 g P, 0.4 g K);
- Repeat applications of one 10-g fertiliser tablet as above, 295 g of 8:4:10 at 2–4 months, and 1000 g of 8:4:10 (N:P:K) 6–8 months after planting (106 g N, 52 g P, 130 g K).

Fertilisers applied at 2–4 months were applied by hand as a spot application 15 cm on the downhill side of the seedlings 16 weeks after planting of open-rooted stock and 9 weeks after planting of paper-potted stock. The application at 6 months was broadcast by hand. For application at planting, the fertiliser tablet was placed in the hole and covered with soil before the seedling was planted, and so there was no direct root-fertiliser contact.

Seedlings

Stock used for the trial were routine open-rooted and paper-potted *E. nitens* and *E. regnans* seedlings. Open-rooted seedlings averaged 34.5 cm in height and paper-potted seedlings 8.2 cm. There were two dates of planting—6 August 1986 for open-rooted and 23 September 1986 for paper-potted seedlings.

Measurement

Heights of all trees were measured at ages 6 months, 1 year, and 2 years, and sample heights were taken at subsequent measurement times. Diameter at breast height (dbh) was taken for all trees at ages 2, 3, 4, 5, and 7 years.

The volume of the sample for which tree heights were measured was calculated using a suitable tree volume equation (Opie 1976). Volumes of other trees were assigned using volume/basal-area relationships derived for both *E. regnans* and *E. nitens* from the sample of tree heights (Wilkinson & Neilsen 1995).

Assessment of Stem Form, Branching, and Multiple Leadering

At age 7 years, stem form, branching, and multiple leadering were assessed. For each tree the largest branch diameter in the bottom 6 m of stem was measured, and the number of branches over 35 mm, the size above which knots became a serious structural defect, was assessed. The branch diameter measurement was taken close to the bole of the tree and at right angles to the branch. Measurement was taken over bark and rounded to the 5 mm below.

For each tree the number of leaders was counted and the height of the first fork was measured. Stem form was assessed as the straightness of the first 6 m of the main stem.

Foliar Sampling

Foliar sampling was carried out in the autumn at age 7.5 years to determine the nutrient status of the trees. From each plot, samples were taken of fully expanded leaves, from the top third of the crown of trees of approximately mean diameter. Samples were dried and prepared for analysis which was carried out as described by Neilsen *et al.* (1992).

Data Analysis

Analysis of variance and regression analysis were used to determine the effect of fertiliser treatments. Tukey's cross classification was used for testing differences in survival. Group regression analysis was used for comparing branch size/dbh and volume/basal area (BA) regressions.

RESULTS

Survival

Survival at age 1 year was satisfactory for all treatments and averaged over 95%. The *E. nitens* had a slightly but significantly higher survival than the *E. regnans*, but there was no difference between fertiliser treatments (Table 2). By age 7 years a further 6% of the *E. nitens* had died, mainly due to suppression, but there were still no treatment differences. With slower growth of the *E. regnans*, development of weeds, particularly *Muehlenbeckia adpressa* (Labill.) Meisn. (Macquarie vine), caused substantial mortality, averaging an additional 14% by age 7 years. The *E. regnans* plots with repeated fertiliser application were most severely affected, averaging only 67.5% survival, significantly below any other treatment (Table 2).

TABLE 2–Survival for *E. nitens* and *E. regnans* at ages 1, 5, and 7 years after treatment at planting with various fertilisers.

Species	Fertiliser treatment	Survival at age 1 year (%)	Survival at age 5 years (%)	Survival at age 7 years (%)
E. nitens	Control	100.0 a	95.0 ab	95.0 ab
E. nitens	Fertiliser tablet	100.0 a	96.7 a	90.0 abc
E. nitens	NP	98.3 ab	93.3 ab	91.7 abc
E. nitens	NPK	98.3 ab	97.5 a	97.5 a
E. nitens	Repeat	100.0 a	95.8 ab	92.5 abc
E. regnans	Control	94.2 c	86.7 c	85.0 cd
E. regnans	Fertiliser tablet	94.2 c	90.8 b	80.8 d
E. regnans	NP	95.0 bc	92.5 ab	88.3 bcd
E. regnans	NPK	96.5 bc	93.3 ab	84.2 cd
E. regnans	Repeat	93.3 c	85.8 c	67.5 e

Within columns, values followed by the same letter do not differ significantly at the 5% probability level.

Growth

By the first measurement, at age 6 months, *E. nitens* had grown significantly better than *E. regnans* (Table 3). This continued through to age 4 years from which time covariate analysis indicated comparable relative growth. The *E. nitens* continued to have a large advantage and by age 7 years averaged 130 m^3/ha compared to 45 m^3/ha for *E. regnans* (Table 4).

There was a significant difference in growth between stock types and an interaction between species and stock type during the first 6 months. The *E. nitens* open-rooted plants had significantly better height growth in the 6 months than did the paper-potted *E. nitens*. For *E. regnans* the reverse was true as the *E. regnans* open-rooted stock showed very little growth, losing leaves and suffering dieback after planting. Beyond 6 months there was no effect of stocktype as the open-rooted *E. regnans* stock overcame its initial setback.

At age 6 months seedlings of both species in the nitrogen-phosphorus and nitrogen-phosphorus-potassium treatments were significantly taller than the respective control

TABLE 3–Height growth for *E. nitens* and *E. regnans* to age 24 months after treatment at planting with various fertilisers.

Species	Fertiliser treatment	Height at 6 months (cm)	Height at 12 months (cm)	Height at 24 months (cm)
E. nitens	Control	77.9 c	146.2 c	428.9 c
E. nitens	Fertiliser tablet	87.0 b	165.6 b	469.9 b
E. nitens	NP	88.7 ab	178.9 a	495.9 a
E. nitens	NPK	93.2 a	181.6 ab	489.8 ab
E. nitens	Repeat	82.1 c	160.2 d	382.4 d
E. regnans	Control	49.6 e	89.2 f	299.7 f
E. regnans	Fertiliser tablet	50.6 e	85.7 f	274.5 g
E. regnans	NP	58.1 d	117.7 d	336.7 e
E. regnans	NPK	57.3 d	111.5 d	327.6 e
E. regnans	Repeat	50.5 e	102.1 e	284.0 g

Within columns, values followed by the same letter do not differ significantly at the 5% probability level.

TABLE 4—Growth of *E. nitens* and *E. regnans* at age 7 years after treatment at planting with various fertilisers.

Species	Fertiliser treatment	Total volume (m^3/ha)	Mean diameter (cm)	Plot height (m MDH)
E. nitens	Control	113.0 c	13.9 c	11.3 bcd
E. nitens	Fertiliser tablet	132.2 abc	15.2 ab	12.4 abc
E. nitens	NP	146.7 a	15.8 a	13.3 a
E. nitens	NPK	136.8 ab	14.9 abc	12.3 abc
E. nitens	Repeat	119.3 bc	14.4 bc	11.1 cd
E. regnans	Control	44.2 de	10.2 d	11.7 bcd
E. regnans	Fertiliser tablet	39.9 de	10.0 d	10.4 d
E. regnans	NP	59.4 d	11.3 d	12.6 ab
E. regnans	NPK	47.5 de	10.5 d	12.2 abc
E. regnans	Repeat	32.0 e	10.6 d	11.2 bcd

Within columns, values followed by the same letter do not differ significantly at the 5% probability level.

treatment seedlings (Table 3). For *E. nitens* the seedlings in the fertiliser tablet treatment were also significantly taller than the control treatment seedlings at age 6 months, and at age 1 year all fertiliser treatments were significantly taller than the control treatment. By age 2 years, however, the *E. nitens* seedlings in the repeat fertiliser treatment had fallen behind the control treatment in height growth (Table 3). There was no interaction of species or stock type with fertiliser response. At age 7 years the *E. nitens* plots in the nitrogen-phosphorus treatment were still taller than those in the control treatment.

For both species, trees in the repeat fertiliser treatment were a different shape to the trees in the other treatments, being shorter for a given diameter, and so separate volume/basal area equations were prepared for assigning volume to that treatment. For the equations, r^2 were: *E. nitens* repeat fertiliser treatment 0.94, other treatments 0.95; *E. regnans* repeat fertiliser treatment 0.96, other treatments 0.97. No stem analysis was carried out to see if tree form factor differed between the repeat fertiliser and other treatments.

Volume growth of all *E. nitens* treatments with fertiliser remained significantly above the control treatment from first measurement at age 2 years through to age 5 years. Covariate analysis indicated no additional response due to treatment beyond age 3 years, although absolute differences continued to increase to age 7 years. Responses in *E. regnans* were less clear but covariate analysis indicated a treatment response only in the first year.

For *E. nitens* mean annual increment (MAI) of all treatments increased substantially until age 4 years after which it increased more slowly to just over 20 m^3/ha for the best treatment (Fig. 1). MAI for *E. regnans* was much lower and, although increasing through age 7, was still only 8.5 m^3/ha for the best treatment.

The growth advantage gained was maintained through to age 7 years when *E. nitens* plots in the nitrogen-phosphorus and nitrogen-phosphorus-potassium treatments carried significantly more volume (Fig. 2A). For *E. nitens* this result was also reflected in mean diameter (Table 4, Fig. 2B). There was no additional response to potassium with the nitrogen-phosphorus-potassium treatment over the nitrogen-phosphorus treatment. For *E. regnans* the repeat fertiliser plots had significantly less volume than other treatments at age 7 years, due to higher mortality (Fig. 2C). There were no differences between mean diameters of surviving trees for *E. regnans* (Table 4).

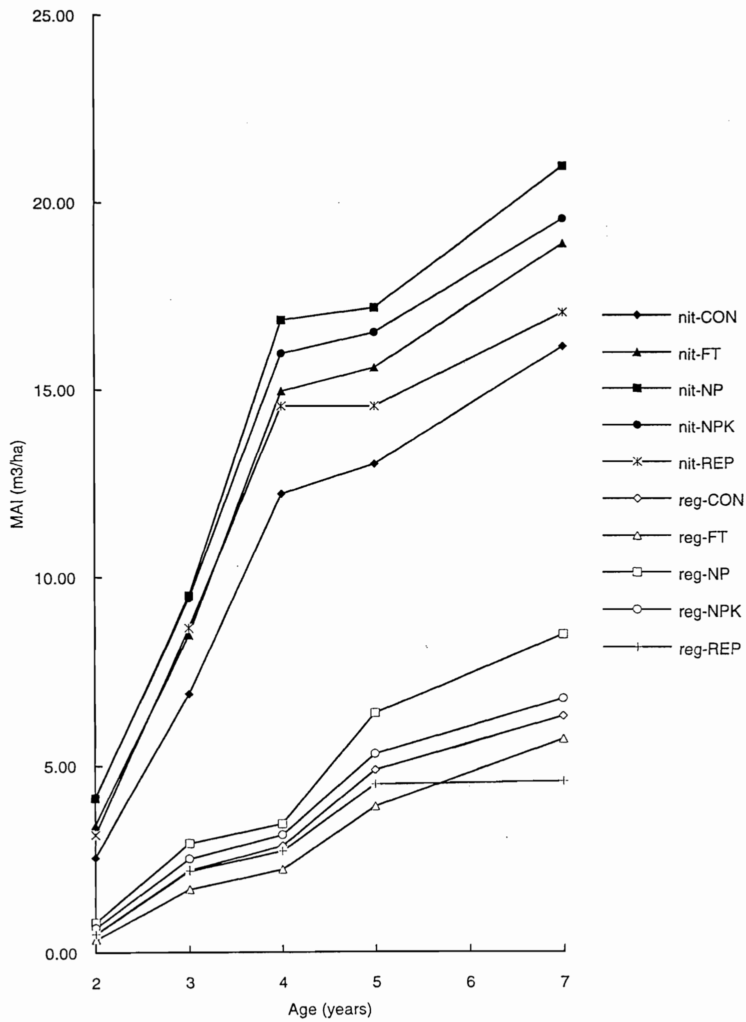

FIG. 1–Stand mean annual increment (MAI) volume growth to age 7 years for *E. nitens* (nit) and *E. regnans* (reg), untreated and treated with different fertilisers.

Stem Straightness

The main leader for most stems of both *E. regnans* and *E. nitens* was reasonably straight and there was no significant difference between treatments for this trait.

Branch Size, Number of Large Branches, and Multiple Leaders

Fertiliser treatment had a significant effect on branching and development of multiple leaders (Fig. 3 and 4).

Mean largest branch diameter and number of branches over 35 mm were strongly correlated for both species ($r^2 = 0.81$). For *E. nitens* multiple leadering was also correlated with branch size ($r^2 = 0.52$), but not for *E. regnans* ($r^2 = -0.01$).

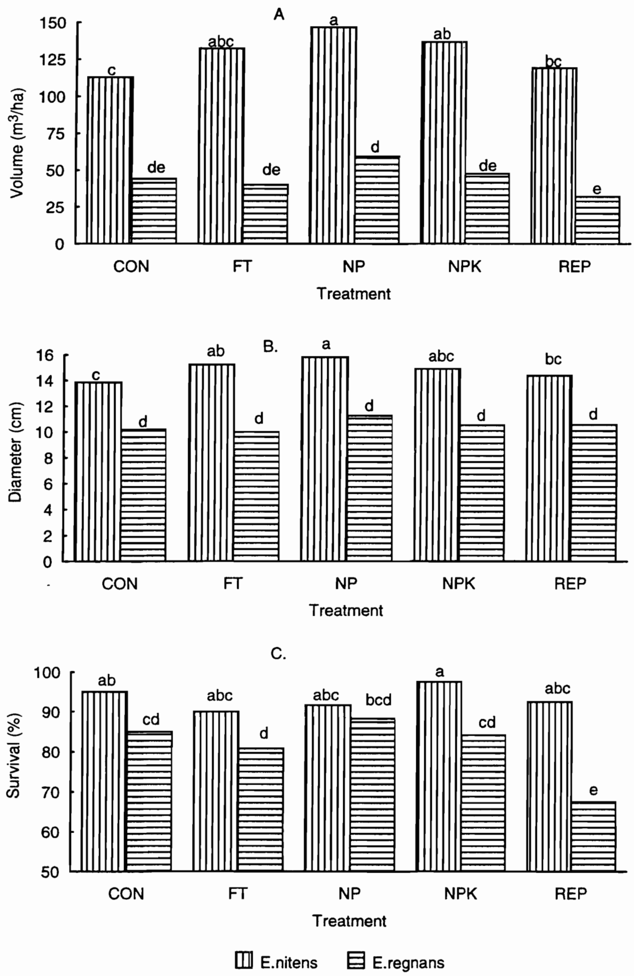

FIG. 2–Total stand volume **A**, mean tree diameter **B**, and percentage survival **C**; at age 7 years for *E. regnans* and *E. nitens*, untreated control (CON) and treated with different fertilisers: fertiliser tablet FT; NP; NPK; and repeated application REP. (Identical letters indicate subsets not significantly different at the 5% probability level).

For *E. nitens*, the mean largest branch per tree increased with fertiliser treatment although it was still below the 35-mm target size, except for the repeat fertiliser plots where it was over 40 mm (Fig. 5A). For *E. regnans*, the mean largest branch was less than for the *E. nitens*, but this was related to a smaller mean dbh. The repeat fertiliser treatment again produced the largest branches. For both species, group regression analysis indicated a significant difference of about 10 mm in size of branch for a given stem diameter (Fig. 6). Similar differences were evident in the number of branches over 35 mm. In *E. nitens* the number increased from 0.5 for the control treatment, to about 1.5 for normal fertiliser treatments, and to 3.7 for the repeat fertiliser treatment (Fig. 5B).

Multiple leaders in *E. nitens* were few in the control treatment plots, being around 2%, and with nitrogen-phosphorus fertiliser reached 10%. However, in the repeat fertiliser

FIG. 3–*Eucalyptus nitens* at age 6 years with nitrogen-phosphorus fertiliser applied at establishment.

FIG. 4–*Eucalyptus nitens* at age 6 years treated with repeated applications of fertiliser in the first 6 months after planting.

treatment 27% of trees had multiple leaders. For *E. regnans* the level of multiple-leader trees was higher than for the *E. nitens*, running at 12% in the control treatment. It increased to 28% in the repeat fertiliser treatment (Fig. 5C).

The deterioration in branching habit of the trees with high doses of fertiliser was consistent for both species and across all replicates. The repeat fertiliser treatment produced trees of poorest branching habit. This was reflected in multiple leaders in about 27% of stems compared with 10% for nitrogen-phosphorus treatment plots.

Foliar Nutrient Levels

The *E. nitens* had significantly lower levels of nitrogen and phosphorus than the *E. regnans* but differences between treatments were small. The repeat fertiliser treatment had the highest level of phosphorus for both species, but not substantially so. Foliar nitrogen levels were marginal but foliar phosphorus levels were low (Table 5).

DISCUSSION

Treatment with nitrogen-phosphorus fertiliser, on well-prepared soils with good weed control, produced increased growth response in *E. nitens* for 3 years. Similar early responses in diameter and height growth to fertiliser application in Tasmania have been obtained by

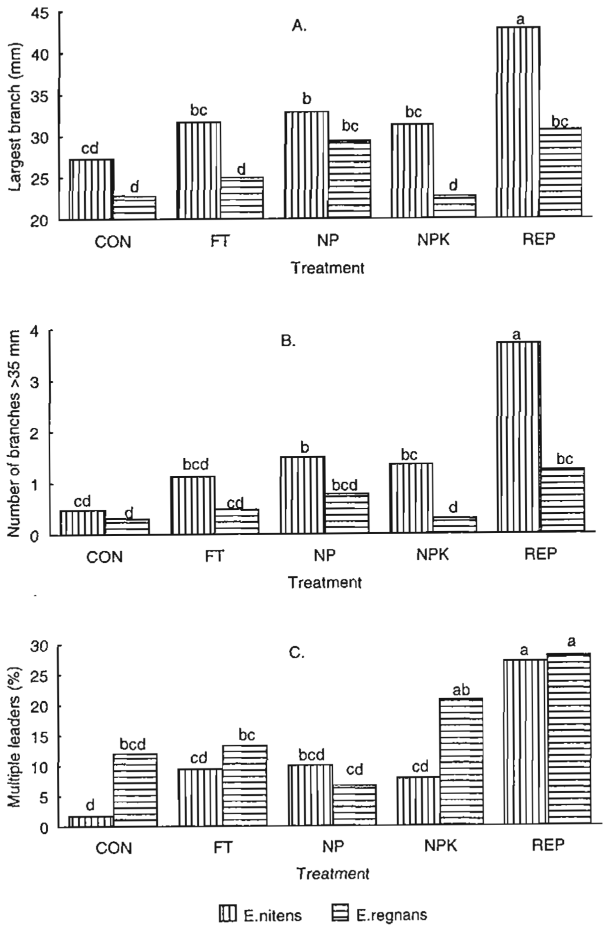

FIG. 5–Mean largest branch **A**, average number of branches per tree >35mm **B**, and percentage of trees with double or multiple leaders **C** at age 7 years for *E. regnans* and *E. nitens*, untreated control (CON) and treated with different fertilisers: fertiliser tablet FT; NP; NPK; and repeated application REP. (Identical letters indicate subsets not significantly different at the 5% probability level).

Turnbull *et al.* (1994). This early increase in growth resulted in substantial advantages by age 7 years. *Eucalyptus nitens* in the nitrogen-phosphorus treatment plots had an advantage of 30 m^3/ha over the control plots, a response of about 30%. MAI for the control treatment was 16.1 m^3/ha, and for the nitrogen-phosphorus treatment 20.9 m^3/ha.

Application of a low level of fertiliser as a tablet produced substantial increased growth in *E. nitens*. Although not as good as the normal nitrogen-phosphorus application, this offers a useful alternative where fertiliser must be applied at time of planting.

For *E. regnans* the fertiliser response lasted only 1 year, and at age 7 years the advantage for the nitrogen-phosphorus treatment over the control was 15 m^3/ha, about 30%. MAI for the control treatment was 6.3 m^3/ha, and for the nitrogen-phosphorus treatment 8.5 m^3/ha.

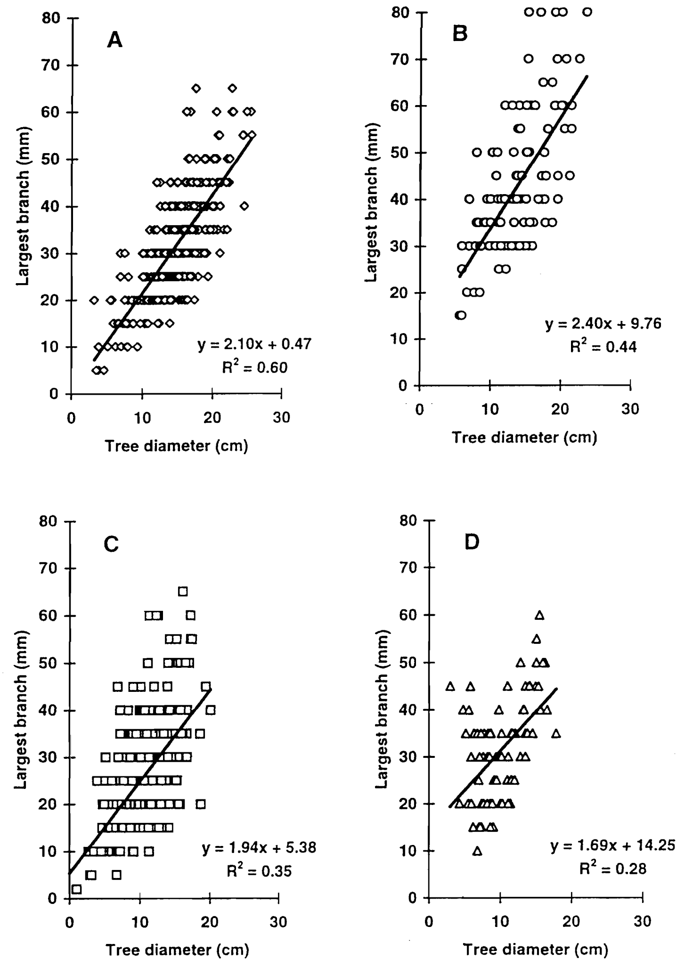

FIG. 6–Largest branch against tree diameter for *E. nitens* and *E. regnans*, respectively, untreated or treated with fertiliser tablet, NP, or NPK, **A** and **C**; or treated with repeated applications of fertiliser, **B** and **D**.

TABLE 5–Foliar nutrient levels for *E. nitens* and *E. regnans* at age 7.5 years after treatment at planting with various fertilisers.

Species	Fertiliser treatment	Phosphorus (%)	Nitrogen (%)	Potassium (%)
E. nitens	Control	0.068 bc	1.42 c	0.705 bc
E. nitens	Fertiliser tablet	0.068 bc	1.36 c	0.651 bc
E. nitens	NP	0.059 c	1.26 c	0.728 bc
E. nitens	NPK	0.059 c	1.28 c	0.618 bc
E. nitens	Repeat	0.074 ab	1.32 c	0.686 bc
E. regnans	Control	0.068 bc	1.57 ab	0.717 bc
E. regnans	Fertiliser tablet	0.074 ab	1.67 a	0.777 ab
E. regnans	NP	0.074 ab	1.55 ab	0.694 bc
E. regnans	NPK	0.066 bc	1.49 b	0.577 c
E. regnans	Repeat	0.082 a	1.58 ab	0.905 a

Within columns, values followed by the same letter do not differ significantly at the 5% probability level.

The poor early growth of *E. regnans* compared to *E. nitens* was largely due to insects. Attack of the former by coreid bugs, *Amorbus obscuricornis* (Westwood) and *Gelonus tasmanicus* (Le Guillou), caused leader wilt and dieback in the first year (Bashford 1992). Loss of growth by coreid attack followed by chrysomelid damage in year two has been documented by Bashford (1992) for this area. This repeated attack led to loss of terminal vigour and development of multi-leadering, as described by Leon (1989).

Attack by the chrysomelid, *Chrysophtharta bimaculata* Olivier, also occurred on the adult foliage of *E. nitens* (Elliott *et al.* 1990) and was noticeable on *E. nitens* in this trial from age 4 years onwards, the age at which MAI increase slowed.

Chrysomelid attacks can be expected to be most severe in large uniform stands of young trees (Leon 1989). The plots in the fertiliser trial represent a mixed species stand of *E. regnans* and *E. nitens*. In the surrounding plantation where extensive areas of pure stands of these species were planted on similar sites, treated similarly and with fertiliser applied, the MAI of *E. regnans* averaged 1.4 m^3/ha (Neilsen & Wilkinson 1995), only 17% of that on the plots. Growth of *E. nitens* averaged 14.4 m^3/ha, 70% of that on the plots. Although severity may decline, chrysomelid attacks can be expected to have a continuing effect on the growth of these stands as heavy defoliation has been measured on much older *E. regnans* in regrowth stands in Tasmania (Kile 1974).

The interaction of insect attack with fertiliser response was not determined. Response to fertiliser additions was considerable despite attack.

The low level of double and multiple leaders in the control *E. nitens* plots (2%) increased substantially after application of nitrogen-phosphorus fertiliser to about 10%. This level was in line with the populations studied by Pederick (1979) who measured about 5% of *E. nitens* with double or multiple leaders. Normal applications of fertiliser in this trial brought an increase in branch size and the development of double and multiple leaders. The effect of the early application of very high rates of fertiliser was a dramatic deterioration of branching habit, with a 16-fold increase in multiple leaders and a large increase in branch size leading to an 8-fold increase in number of branches >35 mm diameter. Higher levels of double and multiple leadering in *E. regnans* were aggravated by early insect attack.

To produce acceptable eucalypt sawlogs in plantations, stands need to be pruned (Neilsen & Wilkinson 1990; Waugh & Li Yang 1994). The poor branching habit of the repeat fertiliser stands resulted in few stems suitable for final-crop sawlog production and would increase pruning costs substantially. This deterioration of branching with high rates of nutrient availability has been observed on some highly productive sites, resulting in stands unsuitable for sawlog production. The nutrient status of sites must be managed to avoid deterioration due to fertiliser additions.

Application of fertiliser had no effect on early survival of *E. nitens* or *E. regnans*, neither reducing it due to toxicity nor improving it due to enhanced early growth and dominance over weeds. On this site, effective weed control and site preparation ensured satisfactory establishment even without fertiliser application. However, later mortality levels were affected by tree growth and by competition from weeds re-establishing on the site. The *E. nitens* grew well enough to occupy the site and combat the weeds but the *E. regnans* did not cope as well. In particular, the heavy branching of *E. regnans* in the repeat fertiliser treatment provided better purchase for Macquarie vine to grow and compete with the trees. Consequently, this treatment had lowest long-term survival.

The effect of fertiliser on height growth was evident at 6 months with the nitrogen-phosphorus and nitrogen-phosphorus-potassium treatment plots being significantly taller than the control. Early application was important because responses occur early, as has previously been pointed out by Pennefather & MacGillivray (1971). However, toxicity must be avoided. The plants in the repeat fertiliser treatment were significantly behind other fertiliser treatments at 6 months, indicating some toxicity at that early stage.

Foliar nutrient levels have been related to soil and to climatic factors and have proved satisfactory for predicting nutrient response in eucalypts (Ballard 1978). Fertiliser response has been related to mineralisable nitrogen (Herbert 1991) and to soil organic carbon levels as well (Noble & Herbert 1991). With low organic matter levels a nitrogen-phosphorus response was generally obtained. Foliar levels were considered a useful guide to nutrient status. The optimum level of nitrogen was considered to be about 2.0% and for phosphorus the level was 0.16%. Frederick *et al.* (1985) measured mean nitrogen levels of about 1.6% and phosphorus levels of 0.14%. The foliar nitrogen levels in this trial were marginal and foliar phosphorus levels were low.

Despite the site originally carrying high-quality *E. regnans* forest, organic matter levels and nutrient reserves in the soil were marginal. On a similar soil in north-eastern Tasmania, with poor reserves of nutrients, Adams & Atiwill (1988) found similar levels of nitrogen and phosphorus in the foliage of mature native trees to those found in this trial. They showed low levels of nitrogen and phosphorus mineralisation and low levels of availability on their study areas (Adams *et al.* 1989). The soil nutrient profile on the site used for this trial pointed to long-term marginal nutrient supply and the prospect of restrictions on growth. Foliar analysis at age 7 years indicated that after good early response to early fertiliser treatment it was likely that increased growth could be obtained by further applications of fertiliser. However, little information was available on later-age response of eucalypts to fertiliser application.

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