



**Demonstration of the potential effects
of nursery nutrients –**

Tropical Cabinet Timber Trees

**A report for the RIRDC/LWRRDC/FWPRDC Joint Venture
Agroforestry Program**

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Foreword

For the most part, tree production systems in north Queensland involve two industries: the nursery industry, and the plantation or rehabilitation industry. While it might seem to be in the commercial interest of both industries to produce/obtain the best quality planting stock at a minimum of cost, from a nutritional viewpoint this may not be the best strategy in terms of early establishment and growth.

This report describes the benefits to establishment and early growth of cabinet-timber species, of investing more nutritional resources than is standard in the nursery phase in the humid tropics. It also goes further to demonstrate that, in the humid tropics, there may be unrecognised losses in growth potential through inadequate field nutrition.

This report, a new addition to RIRDC's diverse range of over 500 research publications, forms part of our Agroforestry and Farm Forestry R&D program, which aims to integrate sustainable and productive agroforestry within Australian farming systems. This project was funded by three R&D Corporations — RIRDC, LWRRDC and FWPRDC. These Corporations are funded principally by the Federal Government.

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Peter Core

Managing Director

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Executive Summary

This report describes the results of a number of field trials, established in the humid tropics, to demonstrate the benefits to tree growth that can be derived from improving techniques in nutrient delivery to establishing trees.

However, the nutrient formulations described in this report should not be taken as any sort of recommendation because of differing species requirements and tolerances, and different climatic and edaphic conditions that might be encountered in different regions. Instead, these formulations should be viewed as a basis or a concept for further experimentation and local adaptation.

The research that underpins these trials was developed originally in a number of western Pacific countries with the support of the Forestry Program of the Australian Centre for International Agricultural Research (ACIAR). In essence, nursery media was modified so that it contained more nutrients than were required for the nursery phase of production. However, following planting out into the field, these “excess” nutrients in the potting media provided a continuing supply of nutrients to the establishing seedlings. This contrasts with various current standard techniques in which there is often a *hiatus* in nutrient supply available to the tree following planting. This *hiatus* arises either because the nursery fertilisers only last for the duration of the nursery phase, the nutrients in the nursery media and the media itself are not planted intact with the roots, or field fertilisers that are surface-applied take some time to reach the roots.

The above work, funded by ACIAR, focussed on technologies and production systems applicable to the overseas collaborators. This project was thus an opportunity to maximize the benefits for Australia of this previous research by demonstrating the applicability of these new systems to northern Australian conditions and demonstrating their benefit to growers. Appropriately adapted, this technology should also be widely applicable to other industries (eg horticulture) and other regions (eg seasonally-dry tropics).

During the 12 month duration of this project, five trial sites were established across the humid tropics of north Queensland (from Townsville to Daintree to Atherton), whilst monitoring was continued on another trial established previously. The sites were typical of those available for farm forestry and rehabilitation in the region and were located on a range of soil types. Timber trees that are widely used in the region were used in these trials.

In most species and at all sites, this “ACIAR” technique showed some advantage over the standard techniques within the first few months after planting (from 20% to 3-fold increases in growth). Thus better early growth can be achieved through attention to nursery conditions rather than through the more expensive and less efficient standard practices of field fertilisation.

When a complete field fertiliser was supplied in the planting hole below the seedlings (in addition to the ACIAR nursery techniques), there were, on some occasions, further increases in growth within the first few months. That the trees which did not receive field fertiliser appeared perfectly healthy, implies that there may be situations in commercial plantings in which there is an unrecognised loss in growth potential. The extent of this loss would be largely unknown.

1 Introduction

The inclusion of trees on farms - whether for timber production or improvement of farm productivity (eg through windbreak, river bank stabilisation, ground water control etc) is a rapidly developing industry in Australia (see *Australian Farm Journal*, Jan 1998, *Trees on Farms*) including north-eastern Queensland (Applegate and Bragg 1988). Currently more than 500 ha / yr of rainforest trees are planted on farms each year in north Queensland under the auspices of the NQAJB (eg. Wet Tropics Tree Planting Scheme, and various community and regional groups) and it would appear that this planting rate will increase rapidly as new joint ventures between the NQAJB, Queensland DPI, local landcare and catchment care groups and landholders are developed.

Techniques to optimise tree establishment and nutrition in order to increase growth rates and to ensure profitability and sustainability of production have been well researched in temperate and sub-tropical environments for many years (Miller 1981, Bowen and Nambiar 1984, Grey *et al.* 1984). This has resulted in the development of a range of operational strategies for management of (a) fertiliser applications for the life of forest stands (eg. Birk 1994, Hunter and Smith 1996) and (b) nutrients in thinnings and harvest residues (Beets *et al.* 1994). However, the same has not been done for northern Australian conditions - especially in the humid tropics.

This lack of research has allowed two nutritional problems to develop:

1. A lack of appreciation of the nutritional constraints to the establishment and growth of high-valued cabinet-timber trees.
2. A *hiatus* in the nutritional management of seedlings between nursery and field.

For the most part, tree production involves two industries, the nurseries and the growers. Although tree production is the ultimate result of both industries, there may be limited knowledge by the nurseries of the subsequent requirements of the growers, and equally, limited demand by the growers on the nurseries to fulfil these requirements; possibly because such requirements are unknown. The time of planting is undoubtedly when trees experience substantial stress and are most vulnerable. It would thus seem sensible to devote some considerable effort into improving this phase of tree production.

Nutritional Constraints to Growth

The soils available for new plantings in the humid tropics are often highly weathered and intrinsically low in plant nutrients (Kauffman *et al.* 1995, Webb *et al.* 1997) and it is known that a variety of nutritional constraints significantly limit the productivity of timber trees in much of the humid tropics, including northern Australia (Zhong and Reddell 1994, Webb *et al.* 1997, Keenan *et al.* 1998, Lamb and Borschmann 1998). These inherent nutritional limitations to tree growth are also frequently exacerbated by the effects of previous logging and/or agricultural pursuits which have resulted in compaction, the loss of soil organic matter and erosion of topsoils. Consequently, the restoration of soil fertility and the provision of adequate tree nutrition is critical to the successful establishment and long-term productivity of many forest plantings in the humid tropics (Nambiar and Brown 1995). Although some general strategies to address these issues can be drawn from work in temperate and sub-tropical forests, the strong leaching environment that is characteristic of most soils of the humid tropics (due to their highly weathered nature and the high, and frequently intense, rainfall) requires novel forest fertilisation strategies that optimise nutrient placement and minimise nutrient-loss beyond the root zone of establishing trees.

However, current fertiliser application strategies used in the region largely fail to alleviate these problems (Webb *et al.* 1995, Keenan *et al.* 1998, Reddell *et al.* 1999). Surprisingly, this is **not** through a lack of fertiliser usage *per se*, with some 250 g/tree of DAP being surface-applied soon after planting. This failure to alleviate these problems is through ineffective delivery of the surface-applied nutrients to the root zone of young trees (probably due to rapid leaching beyond the root zone, adsorption onto strongly fixing soil surfaces and/or uptake by competing weedy species).

One option would be to simply apply more fertiliser; but this could have negative financial and environmental implications. A better approach is to develop a more efficient and effective technique for delivering nutrients to young trees.

It is well recognised that attention to nursery nutrition is an important component of nursery management for the production of good quality seedlings, whether they are for the flower market or industrial timber plantations. Recently, these studies have also given attention to the environmental consequences of over-fertilising in nurseries (Huett 1997a, 1997b).

However, there are only a handful of reports that have dealt with tropical species and even fewer have specifically dealt with the consequence of nursery fertiliser strategies on the longer-term survival and growth of trees after planting out rather than just the health of the tree seedling at the end of the nursery cycle *per se*. For example, Simpson (1978) had found that increased use of nursery fertiliser on bare-rooted stock increased height growth of pines for a couple of years after planting. Similarly, van den Driessche (1984, 1988) has shown increased survival and height growth of bare-rooted conifers some years after planting. Both of these results were presumably as a result of the nutrients carried within the planting stock. Similar results were also found when container-grown stock were used (Kannan and Paliwal 1995).

From work in the Solomon Islands, we developed a novel technique of adding high levels of long-term slow-release fertiliser to the nursery media. These amounts of fertiliser are greater than that which is required for nursery production but they continue to benefit the tree long after planting out; especially when the slow-release fertilisers are mixed with the potting medium and particular care was taken to ensure that the potting medium was planted intact with the roots (Webb *et al.* 1996, Woods *et al.* 1998, Reddell *et al.* 1999).

So convincing were these results in that situation that our technology has already been adopted as standard practice by the largest commercial plantation forestry company (Kolombangara Forestry Products Ltd) in the Solomon Islands (see Figure 1 & Webb *et al.* 1996, Reddell *et al.* 1999) and is being locally-refined for routine use by the Ministry of Agriculture, Forestry, Fisheries and Meteorology in Samoa (Woods *et al.* 1998).

Thus, although only reported on a small number of occasions, there is strong evidence that judicious use of long-term slow-release fertilisers - beyond that which is required just to produce adequate seedlings - is of benefit to field plantings in the humid tropics for a considerable time after planting.

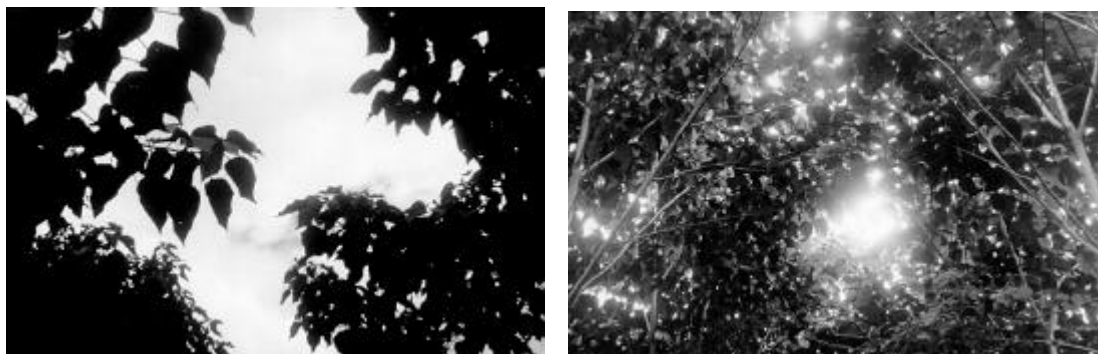


Figure 1: Canopy cover of *Gmelina arborea* 18 months after planting. No fertilisers were added in the field. Left, original nursery nutrition; Right, new nursery nutrition.

Constraints from the hiatus between Nursery and Field Nutrient Management

Both nursery and planting operations attempt to produce the best quality product for the minimum cost. Considering the industry as a whole, it may be more efficient, from both a nutritional and financial viewpoint, to increase nutrient inputs in the nursery phase even though it will have no immediate benefit to the nursery manager.

Interestingly, across the humid tropics, nursery nutrient management varies considerably; with each nursery usually having its own (sometimes secret) nutrient regime. Thus there are probably nurseries that have already experimented with higher rates of fertiliser and subsequently adopted similar regimes to those described in this report. However, many nurseries have quite low levels of added fertiliser – often less than 5g slow-release fertiliser per litre of nursery media. The reason for this level of nutrient input is probably driven by economics but may also be the result of perceptions that tropical rainforest species are sensitive to high levels of nutrients because of their ability to grow well in low nutrient environments. While this is certainly true for some species it is not a general feature of all tropical rainforest species.

The main aims of this project were:

1. By comparison with (various) current practices in the humid tropics, demonstrate the advantages to early field growth of cabinet-timber species of providing nursery nutrients in excess of nursery requirements.

2. Demonstrate that there may be substantial and unrecognised losses in field growth potential through lack of fertiliser usage.

This report describes the results of a number of trials (in the humid tropics of north Queensland) which demonstrate the potential to improve field growth of trees through improved nutrition (both nursery and field). Although details of nutrient formulations are provided for completeness, they should not be seen as a recommendation that will be appropriate for all combinations of species, climate, nursery, or field soil.

2 Objectives

The objectives of this project were:

1. To demonstrate, across a wide range of edaphic and climatic conditions, the potential to improve early field growth of timber species through improved nursery nutrition.
2. To demonstrate that even in apparently healthy trees, there is sometimes the potential to increase growth with additional fertiliser; suggesting that in many plantings there could be an unrecognised loss in growth potential

3. Methodology

3.1 General Approach

The treatments imposed were designed to simulate a “whole-of-system” approach to tree production in that they included both nursery and field treatments. These treatments covered current systems used for tree planting as well as different approaches developed before and during this project. One important feature of these different approaches is the use of relatively large amounts of slow-release fertiliser (up to 18 months release time as well as shorter release times) which include both macronutrients and micronutrients. Another important feature is the incorporation of the whole of the nursery potting media into the planting hole. This technique thus provides a continuing supply of nutrients (with the minimum disturbance to the root system) at the time of planting.

Because of the whole-of-system approach, there has been no attempt to experimentally separate nursery effects from field effects of treatments imposed; although some results at the end of the nursery phase are presented. Nor has there been an attempt to separate the individual components of the nursery effects on subsequent growth (viz. nutrients, media, pots size etc) however it is considered that it is the nutrient effect that is of major influence.

3.2 Nursery Treatments

There were two main treatments imposed in the nursery: one which represented various nursery production systems currently in use in north-eastern Australia, and one which has been developed during an ACIAR project. In addition, a somewhat adventurous nursery treatment, which uses much higher than normal concentrations of fertilisers was also included in some of the trials.

For simplicity, the various current approaches to nursery production are all referred to as “standard”. Because of the desire to follow routine nursery practice, these “standard” systems varied depending on the particular nursery involved. They are largely based on the systems in practice at Walkamin Forest Nursery near Atherton, the Hinchinbrook Wet Tropics Tree Planting Scheme Nursery at Ingham, and the Douglas Shire Wet Tropics Tree Planting Scheme Nursery at Mossman.

The alternative approaches are generally referred to as “ACIAR” but the exact details varied in order to accommodate routine procedures in use at the various nurseries where the trees were raised. In general, these contained large amounts of long-acting slow-release fertilisers. They included both macro- and micronutrients.

The “adventurous” nursery treatment contained twice the amount of fertiliser as that in the ACIAR mix and is referred to as “Double ACIAR”. However, in order to accommodate current nursery practice, this amount of fertiliser was in a small volume of potting media and thus had an effective concentration of five-fold that of the ACIAR mix.

In the nursery phase, all treatments were set out in a randomised complete block design of four replicates. Where more than one species was grown, each species was treated as a separate experiment.

3.3 Field Treatments

Similar to the nursery treatments, there were, in most cases, two main field treatments; namely, no fertiliser and added fertiliser. The fertiliser used and its placement were dependent on whether they were designed to simulate current practice, or an alternative approach. Similar to the nursery treatments, these were designated as “standard” or “ACIAR” respectively.

The combination of these treatments on top of the nursery treatment resulted in four (or five if Double ACIAR was included) treatments being represented in the field (Table 1).

Table 1: Nursery and field treatments employed in most experiments

Nursery Fertiliser	Field Fertiliser
Standard	Nil
Standard	Standard
ACIAR	Nil
ACIAR	ACIAR
(Double ACIAR)	(Nil)

A key feature of the ACIAR field fertiliser was that it was placed in the bottom of the planting hole before the trees were planted to ensure that it would be available to the growing roots soon after planting. In order to avoid damage to the young roots, this fertiliser was well mixed with the soil at the bottom of the hole then covered with about 5 cm of soil before the trees were planted above it. At 3 monthly intervals after planting, further doses of fertiliser were added (see appendices). However, for this report, except for the Townsville and Atherton sites, and the older Daintree site, only the initial dose at planting had been applied at the time trees were measured.

As in the nursery phase, all treatments were set out in a randomised complete block design of four replicates. Where more than one species was grown, each species was treated as a separate experiment (except at the Daintree site).

3.4 Field Sites

The seven sites chosen are all in the wet tropics from Townsville to the Daintree region. They all represent sites that were once covered by rainforest (except Townsville) and were previously in agricultural production. They also represent sites that are typical of those available for farm-forestry or rehabilitation. Although the actual soils were not analysed during this project, details of the soil series (and references) are given in the appendices. These references contain soil physical and chemical information relevant to soil types similar to those on which the trees were grown. The soils generally have low fertility because of their highly weathered nature. The CEC's are less than 12 cmol(c)/kg, pH less than 6 (and sometimes less than 5), and available P less than 20 mg/kg, unless they have been in recent agricultural production. Other general information is in the following site descriptions.

Daintree: The soils are derived from metasediments and the region receives an annual rainfall of 1992 mm. The soils are well drained and have a clay loam texture. This privately owned site was once a cattle property and is now being used for growing cabinet timbers. The experiment was planted prior to this project and was the basis of the proposal for this project. The plantings here are currently 2 years old.

Forest Creek: The soils are derived from alluvium and this site is close to the Daintree site. The soils are well drained and have a loam texture. This land is an Aboriginal holding and is being rehabilitated to protect the riparian zone.

Mossman: The soils are derived from metasediments and the region receives an annual rainfall of 2222 mm. The soils are well drained and have a light clay texture. This private property was once a cane farm which is now being used for growing cabinet timbers.

Atherton: The soils are derived from basalt and the region receives an annual rainfall of 1413 mm. The soils are well drained and have a clay texture. This land is owned by CSIRO and is representative of many agricultural soils in the region.

Babinda: The soils are derived from alluvium and the region receives an annual rainfall of 3553 mm. The soils are poorly drained and have a heavy clay texture. This private property was once a cane farm which is now being used for growing cabinet timbers.

Hinchinbrook: Four sites were planned for planting. This region has an annual average rainfall of 2020 mm. Unfortunately, record rains during the wet season and continual rain since has made it impossible to plant; even the planned planting activities of the WTTPS have been delayed several months (Figure 2).

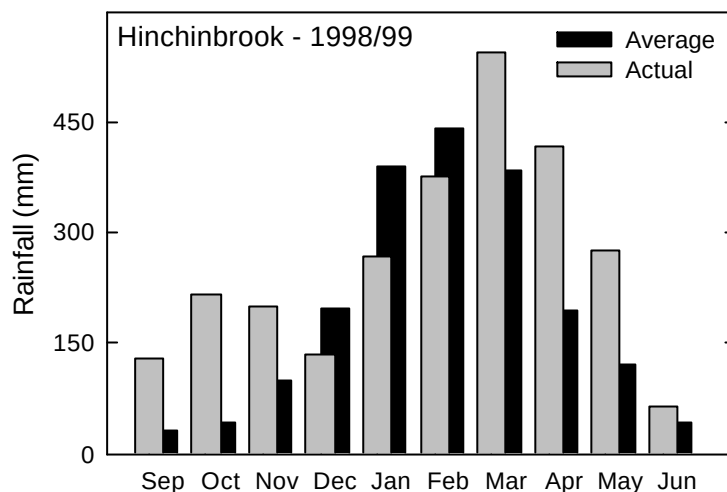


Figure 2: Average and actual rainfall for the Hinchinbrook region during the project.

Townsville: The soils are derived from alluvium and the region receives an annual rainfall of 1108 mm. The soils are well drained and have a sandy loam texture. This site has been used for various experimental trials on *Leucaena*.

3.5 Species

The species chosen are all ones that have potential for timber production or rehabilitation. The species used were influenced by the preferences of the landholder or tree-planting scheme. They are:

Acacia aulacocarpa, *A. mangium*, *Agathis robusta*, *Alphitonia petriei*, *Elaeocarpus angustifolius*, *Eucalyptus pellita*, *E. cloeziana*, *Flindersia brayleyana*, *Grevillea baileyana*, *Meliocope elleryana*, and *Nauclea orientalis*

As mentioned, the project was designed to demonstrate alternative methods of tree production from a whole-of-system approach. Thus, the possible interacting effects of potting media, fertiliser, and pot volume are not considered. However, experimental integrity is maintained by the fact that, between each nursery-field site combination, climatic conditions and species were consistent.

3.6 Planting

The exact method of planting depended on the operational practice of the landholder and is detailed in the appendices. However, in all treatments, at all sites, the entire nursery mix was planted with the tree.

At all sites except Babinda, when fertiliser was added to the planting hole, it was mixed with the soil in the bottom of the hole and covered with a layer of soil without fertiliser before the trees were planted. At the Babinda site, the soil was so heavy and sticky that it was difficult to dig a decent hole. In this case, the fertiliser was mixed with soil immediately below the planted tree.

3.7 Chemical, Biochemical, and Physiological Analysis

Chemical: Leaf material was dried at 60°C for at least 48hr and then ground to less than 2mm. Samples were analysed for N by a combustion technique (Matejovic 1996) and other nutrient elements by inductively coupled plasma optical emission spectrometry (Zarcinas *et al.* 1987).

Biochemical: Ten disks (5mm diam) were collected using a cork borer from five youngest mature leaves of each treatment immediately after leaves were detached. The disks were immediately placed in 7 ml cold *N,N*-dimethylformamide in a sealed vial. The vial was immediately placed in the dark in an insulated container at approximately 4°C. As soon as possible the vials were transferred to a refrigerator at 4°C. Chlorophyll was analysed spectrophotometrically (Porra *et al.* 1989).

Physiological: Chlorophyll fluorescence ratio (F_v/F_0) was measured with a Hansatech Plant Efficiency Analyser (Hansatech Industries Ltd) after dark adapting youngest mature leaves for 20 mins.

Results

3.8 Nursery Growth

When it was possible to do so, growth measurements were made at the end of the nursery phase, either on a representative sample of nursery stock or at planting.

In most cases, the ACIAR nursery protocol produced trees with greater dry weight or height compared to those grown in by a standard protocol (Table 2). Where this did not occur, trees were often quite small at the time of planting. In all cases, the Double ACIAR protocol suppressed dry weight compared to the ACIAR nursery protocol, possibly reflecting an oversupply of nutrients.

Where both dry weight and height were measured, dry weight was far more responsive than height. In *Eucalyptus cloeziana*, this appeared to be a result of increased size and number of branches; in *Flindersia brayleyana*, this appeared to be a results of increased size and number of leave.

Table 2: Comparison of tree growth in different nursery mixes.

Site	Growth Measure	Species	Nursery Treatment		
			Standard	ACIAR	Double ACIAR
Daintree	Field Height (m)	<i>Eucalyptus pellita</i>	0.24 b ¹	0.49 a	-
		<i>Acacia mangium</i>	0.17 a	0.20 a	-
Atherton	Nursery Dry Weight (g/tree)	<i>Eucalyptus cloeziana</i>	3.13 b	8.23 a	1.80 c
		<i>Flindersia brayleyana</i>	0.41 b	1.08 a	0.43 b
	Field Height (m)	<i>Eucalyptus cloeziana</i>	0.33 b	0.41 a	0.27 c
		<i>Flindersia brayleyana</i>	0.15 a	0.12 a	0.14 a
Babinda	Nursery Dry Weight (g/tree)	<i>Eucalyptus pellita</i>	4.3 c	30.1 a	10.9 b
		<i>Flindersia brayleyana</i>	1.62 b	3.37 a	1.36 b

¹ In each row, numbers not followed by the same letter are significantly different ($P < 0.05$; Fisher's Pairwise Comparison).

3.9 Early Field Growth - Height

In most situations, when no field fertiliser was added (first and third columns in each graph), the ACIAR nursery and field protocol (with the nursery mix subsequently planted with the tree (third column)) increased field growth (Figure 3 to Figure 11; Plate 1 to Plate 3 – panels A & C). These increases ranged from about 20 % (Figure 9) to more than 3-fold (Figure 10) as a consequence of nursery protocol alone. There were two exceptions to this effect of the ACIAR protocol; *Acacia mangium* at 9 months at Daintree (Figure 4) and at the Forest Creek site (data not shown).

In some situations, young trees grown with the ACIAR nursery protocol without field fertiliser (third column in the graph; panel C in plates) were still superior to those grown with both standard nursery and standard field fertilisers (second column in graph, panel B in plates). These results clearly show the early advantage of good nursery nutrition, even without added field fertilisers compared to the standard practice of field fertiliser placed soon after planting on trees receiving a less-than-adequate nutrient supply in the nursery.

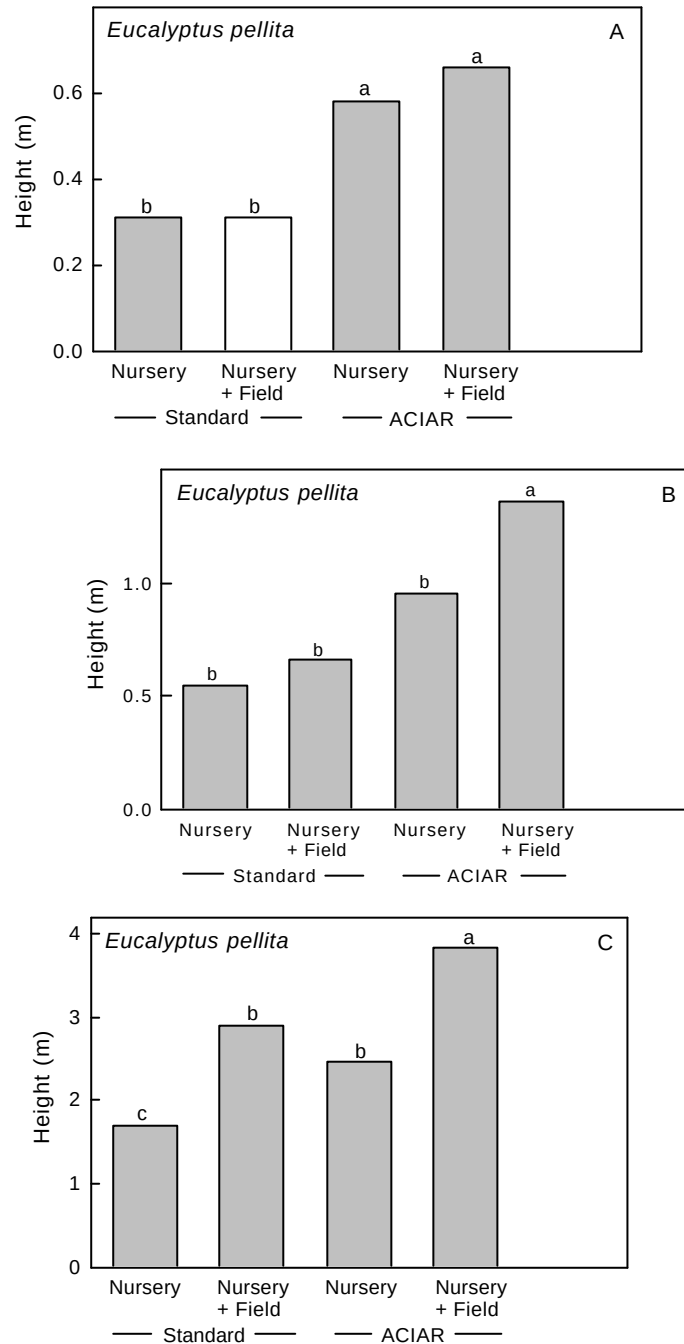


Figure 3: Growth of *Eucalyptus pellita* (A) 1 month, (B) 3 months, and (C) 9 months after planting at Daintree. The second column in Figure A, “Standard Nursery + Field” had the field fertiliser applied at the time of measurement. Thus, at the time of measurement, this treatment was the same “Standard Nursery” (first column). In all figures, columns with different letters are significantly different ($P < 0.05$; Fisher’s Pairwise Comparison).

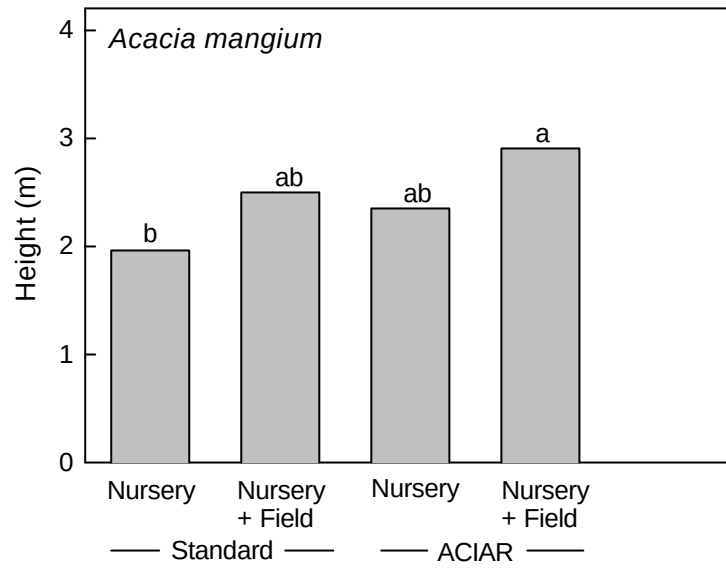


Figure 4: Growth of *Acacia mangium* 9 months after planting at Daintree.

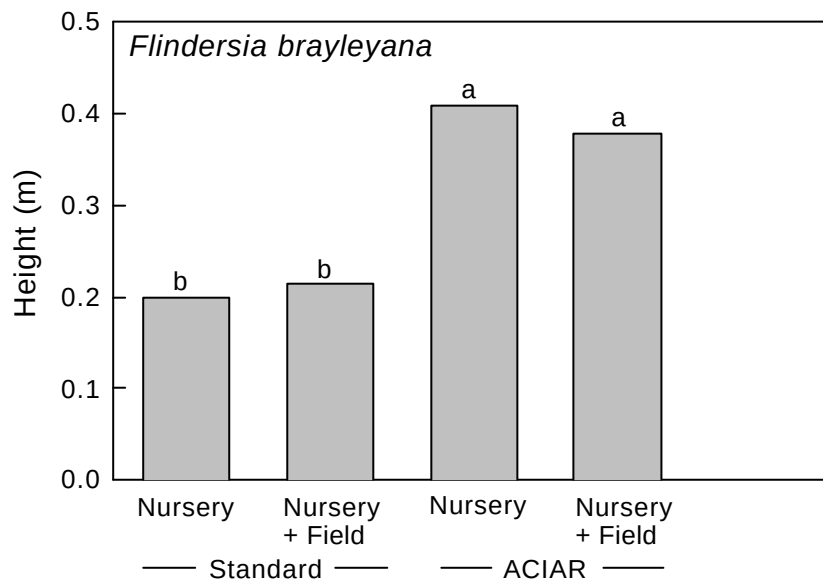


Figure 5: Growth of *Flindersia brayleyana* 2 months after planting at Mossman.

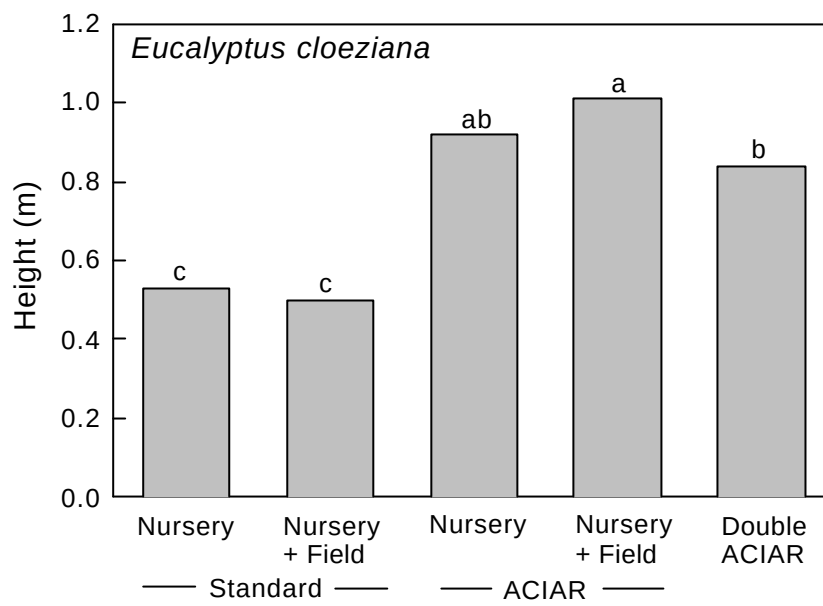


Figure 6: Growth of *Eucalyptus cloeziana* 3 months after planting at Atherton.

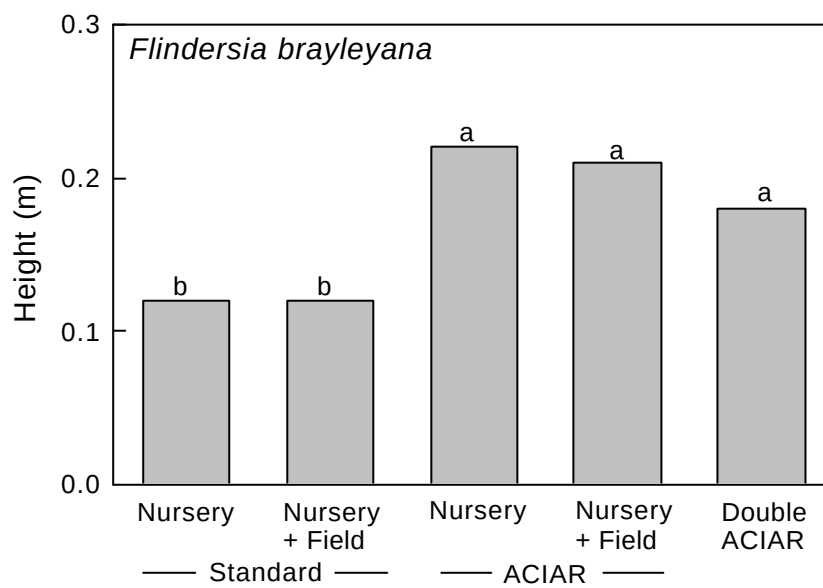


Figure 7: Growth of *Flindersia brayleyana* 3 months after planting at Atherton.

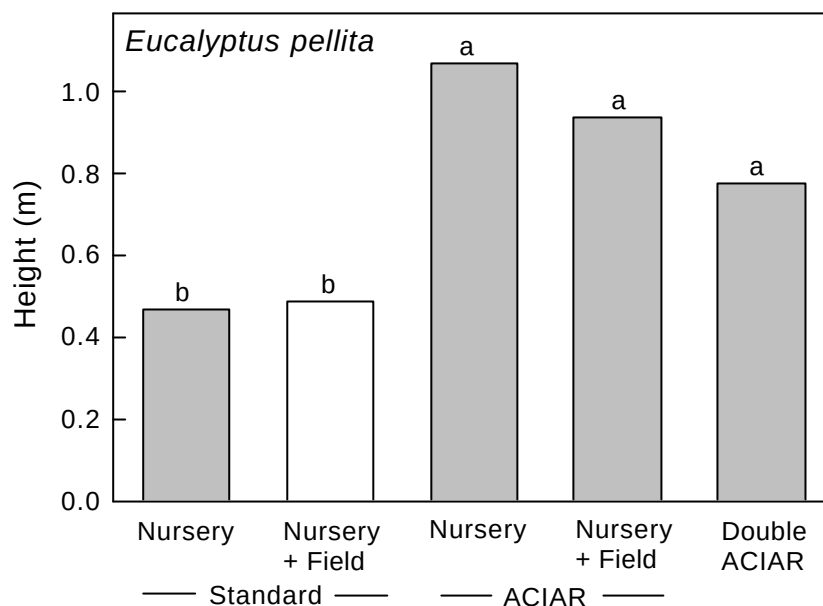


Figure 8: Growth of *Eucalyptus pellita* 2 months after planting at Babinda. The second column “Standard Nursery + Field” had the field fertiliser applied at the time of measurement. Thus, at the time of measurement, this treatment was the same “Standard Nursery” (first column).

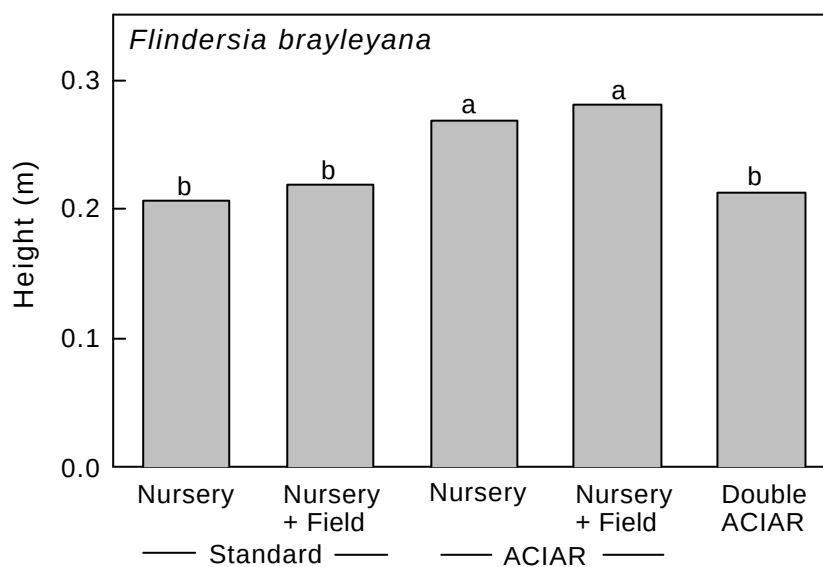


Figure 9: Growth of *Flindersia brayleyana* 2 months after planting at Babinda.

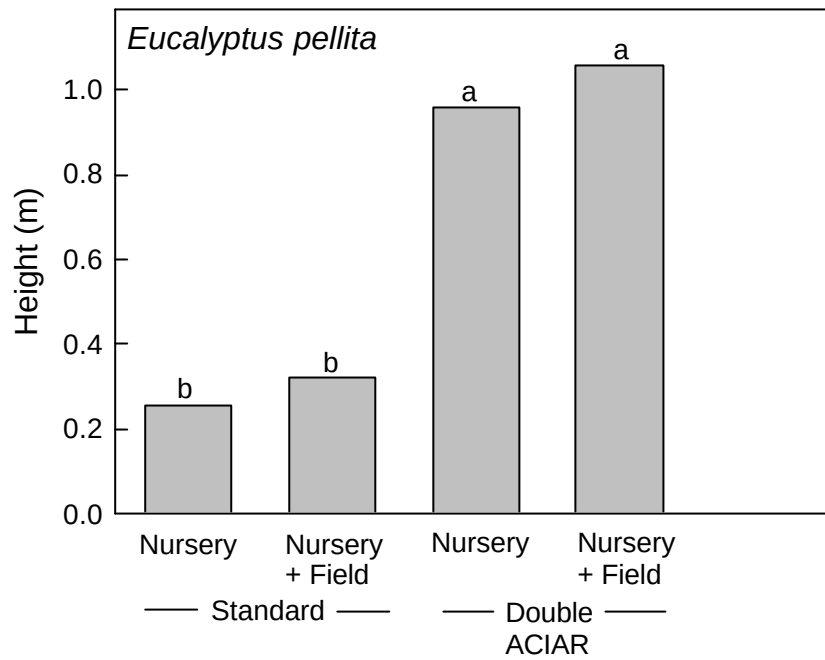


Figure 10: Growth of *Eucalyptus pellita* 1 month after planting at Townsville.

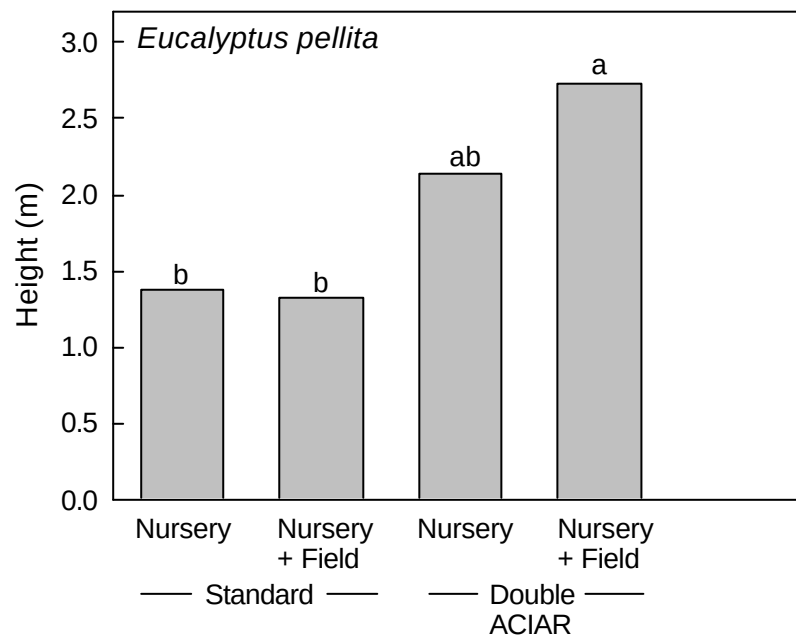


Figure 11: Growth of *Eucalyptus pellita* 6 months after planting at Townsville.



A. Seedling was raised in a standard potting media currently used in the industry. No field fertilisers were added.



B. Seedling was raised as in plate A. An industry-standard field fertiliser was applied after 1 month (250g DAP / tree).



C. Seedling was raised using the ACIAR nursery protocol designed to supply nutrients over a long period of time.



D. Seedling raised as in plate C. A “complete” nutrient fertiliser was also applied at planting.

Plate 1: *Eucalyptus pellita* grown in a metamorphic soil in the Daintree. Coloured bands = 20cm. Three months after planting



A. Seedling was raised in a standard potting media currently used in the industry. No field fertilisers were added.



B. Seedling was raised as in plate A. An industry-standard field fertiliser was applied after 1 month (250g DAP / tree).



C. Seedling was raised using the ACIAR nursery protocol designed to supply nutrients over a long period of time.



D. Seedling raised as in plate C. A “complete” nutrient fertiliser was also applied at planting.

Plate 2: *Eucalyptus cloeziana* grown in a basaltic soil at Atherton. Three months after planting



A. Seedling was raised in a standard potting media currently used in the industry. No field fertilisers were added.



B. Seedling was raised as in plate A. An industry-standard field fertiliser was applied (See QFRI standard).



C. Seedling was raised using the ACIAR nursery protocol designed to supply nutrients over a long period of time.



D. Seedling raised as in plate C. A “complete” nutrient fertiliser was also applied at planting.

Plate 3: *Eucalyptus pellita* grown in an old alluvial soil at Townsville. Seven months after planting. Note that the measuring pole is 1.5m in plates A & B, and is 4.5m in plates C & D.

In the older planting at Daintree, the addition of ACIAR field fertiliser further enhanced the beneficial effect of ACIAR nursery protocol, producing far superior stock (Figure 3 B & C). Again this clearly shows how beneficial good field nutrition

and nursery protocol are to the early establishment of trees in the field. Thus, it would be of interest to follow the performance of this treatment with time at the other sites.

At one site, Babinda, the addition of the ACIAR field fertiliser was detrimental to the trees. Although not affecting height (Figure 8 & Figure 9) the addition of field fertiliser caused visible burning of the leaves, and in some cases death. In this situation it appears that the large amount of fertiliser that was added was not mixed well enough with the underlying soil (which was physically difficult to dig by hand) and probably caused some nutrient excess stress. This also occurred in the standard nursery + field treatment for *F. brayleyana* which received the field fertiliser at planting.

The Double ACIAR mix performed reasonably well in most cases (outperforming the standard procedures) in spite of its suppression of growth in the nursery. This indicates that modification of this technique could be even superior to the ACIAR mix. Again, it would be of interest to follow the longer term effects (up to 24 months) of adding large amounts of slow-release fertiliser (up to 18 months release time).

3.10 Later Field Growth – Height

At the Daintree site, which was planted before this project began, growth has been monitored until 24 months after planting. It is clear that the continued application of field fertiliser in the ACIAR nursery + field treatment produced taller trees than the standard nursery + field treatment (Figure 12). Furthermore, although the initial gains from ACIAR nursery (without field fertiliser) compared to the standard nursery + field fertiliser were diminished with time, the ACIAR nursery treatment has replaced the need for the field fertilisation required by the standard method.

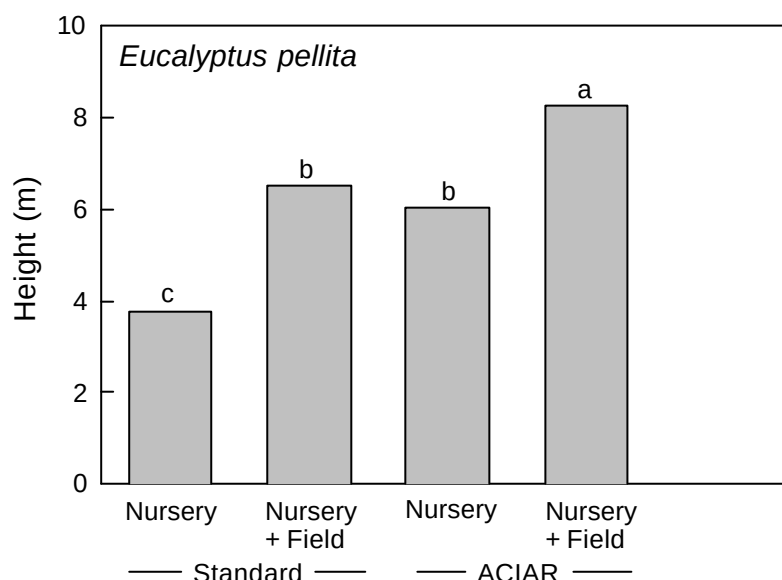


Figure 12: Growth of *Eucalyptus pellita* 24 months after planting at Daintree.

At the Atherton site, the similar to the Daintree site, field fertiliser also continued to increase growth (Figure 13). However, by contrast, the effect of the ACIAR nursery (without field fertiliser) compared to the standard nursery + field fertiliser was NOT lost with time.

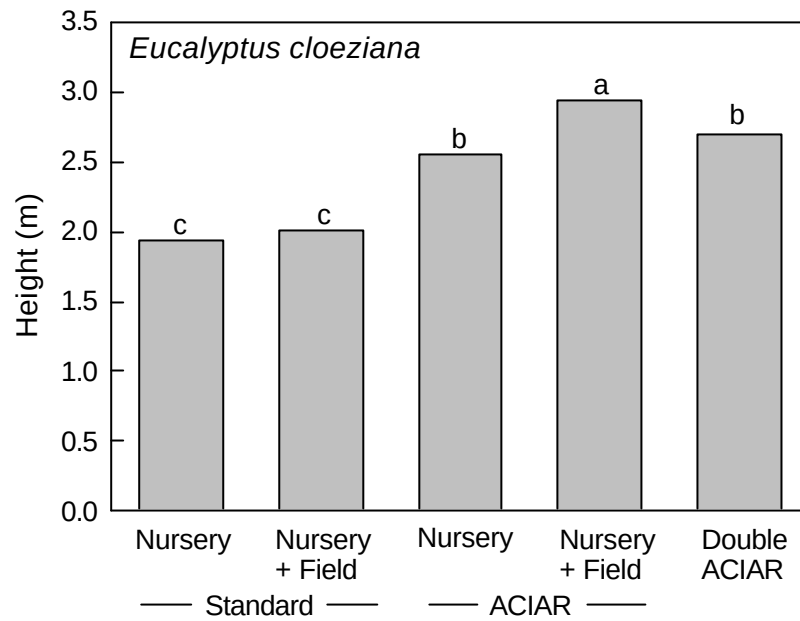


Figure 13: Growth of *Eucalyptus cloeziana* 9 months after planting at Atherton.

The growth rates at Daintree were also comparable to those found in the wet tropical regions of South-east Asia and the western Pacific (Figure 14). Indeed the best growth rates from the Daintree site were equivalent to the best for the region.

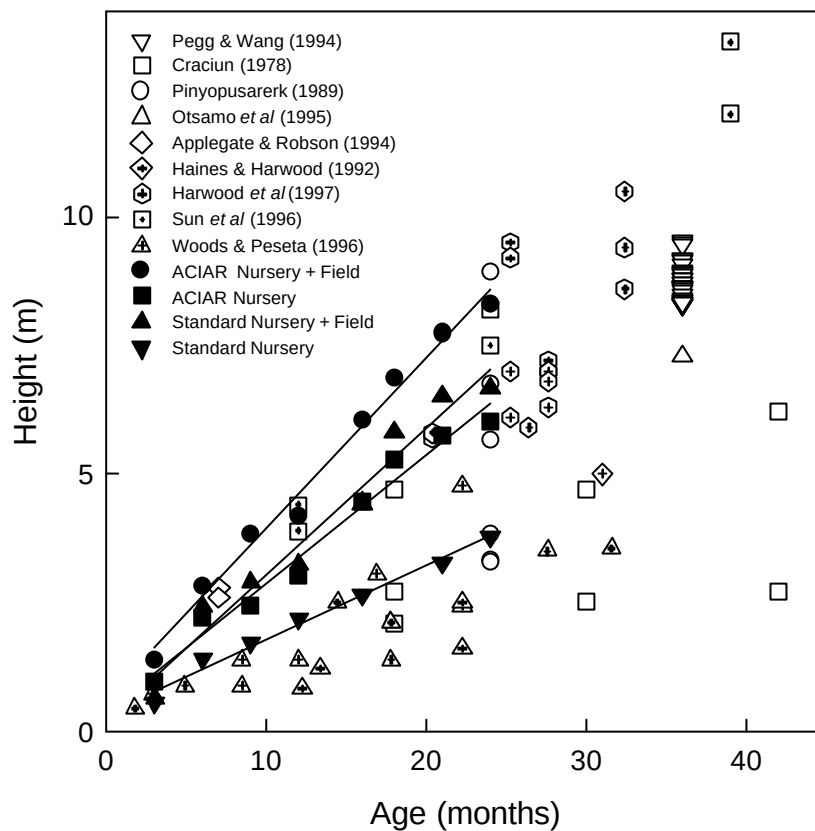


Figure 14: Comparative growth rates of *Eucalyptus pellita* Solid symbols are from the Daintree site; open symbols from published data.

3.11 Other Measurements of Growth

Although height is a common method for assessing the growth of trees it is often less responsive than other measures. At Daintree, Atherton and Townsville, other parameters of growth were measured (Figure 15 to Figure 19). Clearly for *E. pellita* and *E. cloeziana*, either volume index ($ht_{(m)} \times (stem_diameter_{(cm)})^2$), stem diameter, or crown width are more responsive than height (cf Figure 3, Figure 6 & Figure 11). Indeed, at the Atherton site (Figure 15), the use of these parameters for growth assessment suggests that *E. cloeziana* is responding to the ACIAR field fertiliser (column 4) after only 3 months – a response that would not have been realised if height was used as the measure of growth.

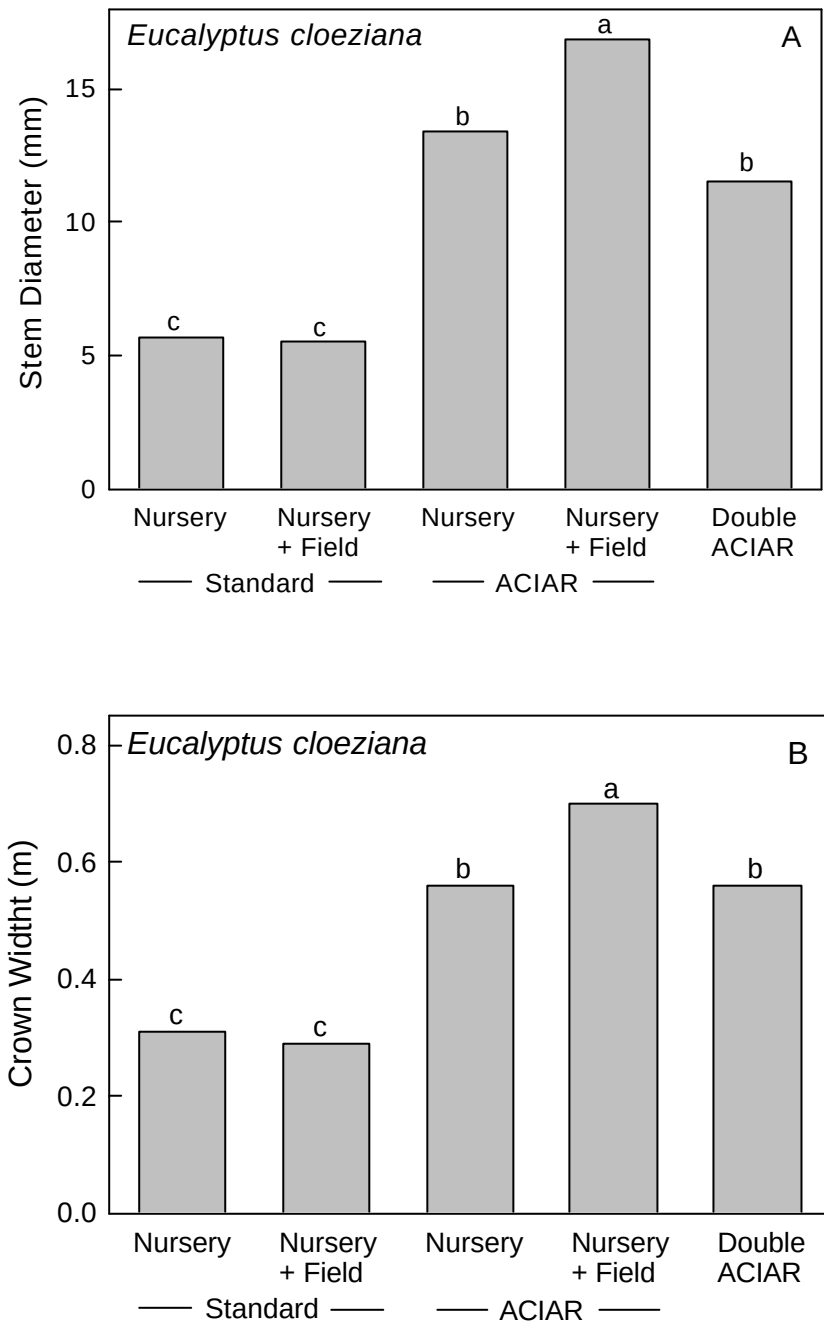


Figure 15: Stem diameter (10 cm above ground level) (A) and crown width (B) of *Eucalyptus cloeziana* 3 months after planting at Atherton.

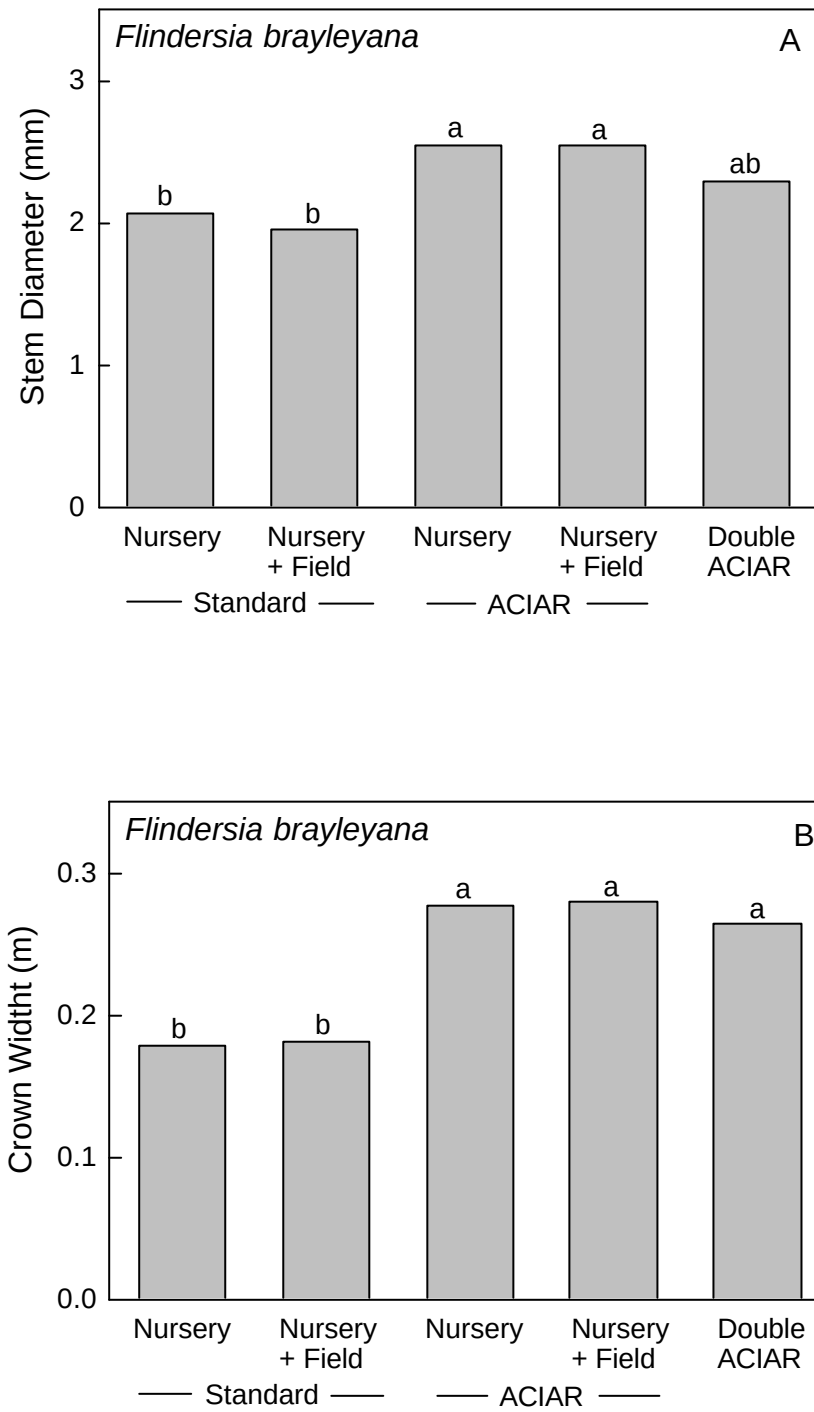


Figure 16: Stem diameter (10 cm above ground level) (A) and crown width (B) of *Flindersia brayleyana* 3 months after planting at Atherton.

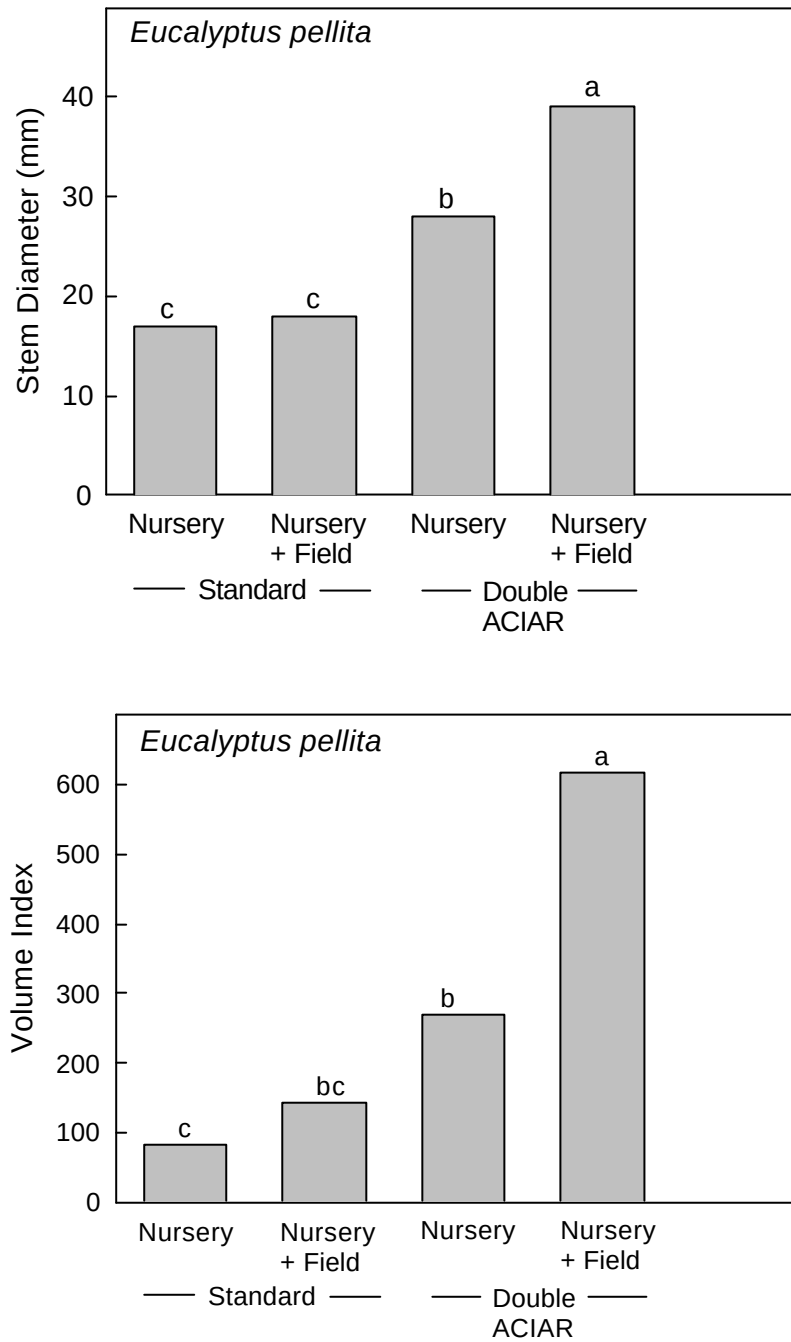


Figure 17: Stem diameter (10 cm above ground level) (A) and volume index (B) of *Eucalyptus pellita* 6 months after planting at Townsville. Volume index is proportional to the height of the tree and the square of the diameter.

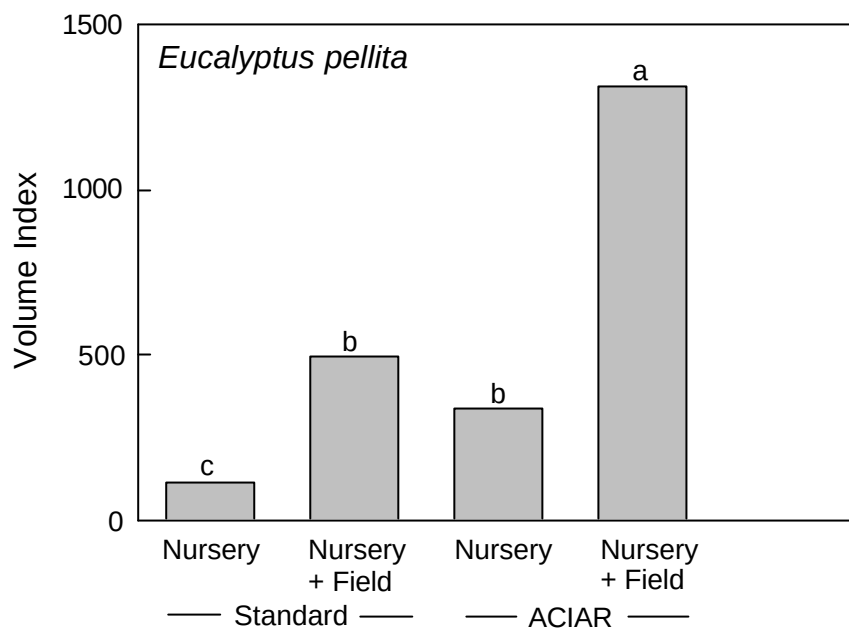


Figure 18: Volume index of *Eucalyptus pellita* 24 months after planting at Daintree.

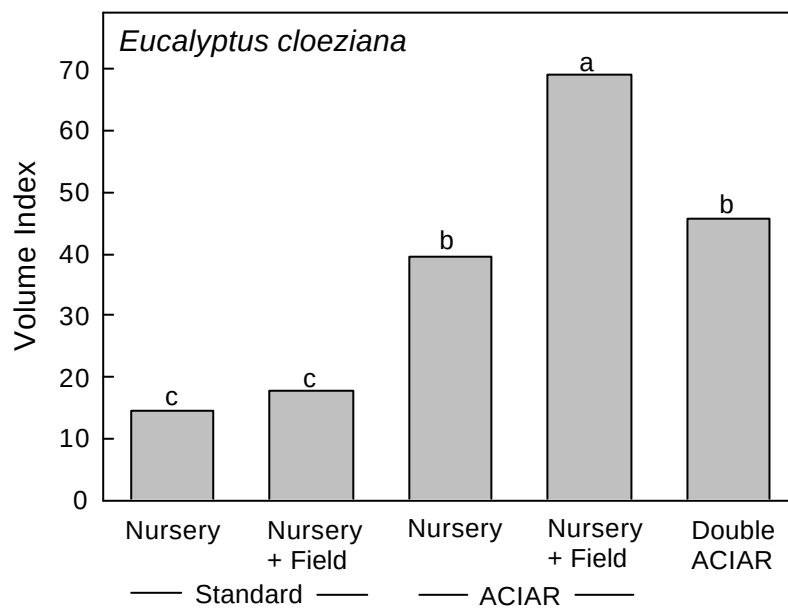


Figure 19: Volume index of *Eucalyptus cloeziana* 9 months after planting at Atherton.

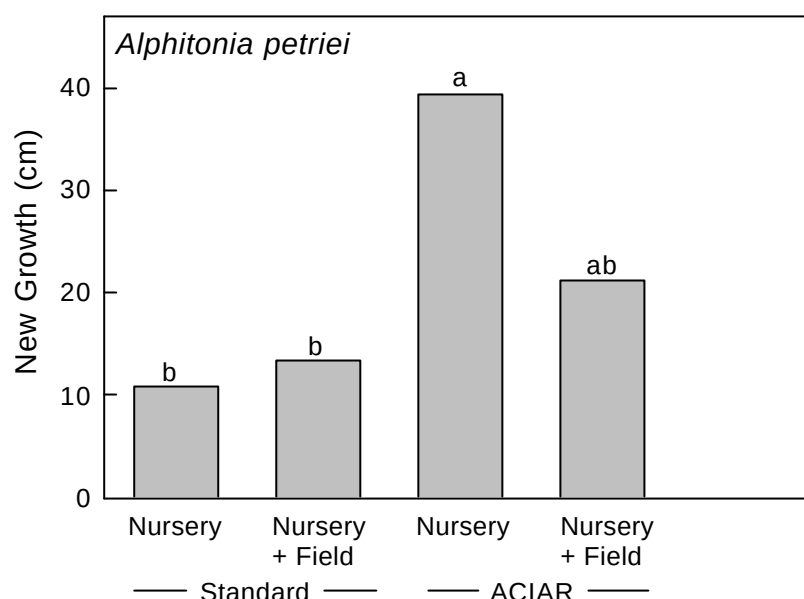


Figure 20: Growth new leader of *Alphitonia petriei* 3 months after planting at Forest Creek.

Similarly, measuring the growth of the new leader of *A. petriei* at the Forest Creek site reveals a marked response to the ACIAR nursery treatment (Figure 20). Height measures did not show any response (data not shown). However, this was probably a result of using reasonably mature planting stock which, due to its height and abundant foliage, was pruned back soon after planting to facilitate better establishment. Taking this result into consideration means that every site tested showed some response to improved nursery protocol for at least one species.

3.12 Unrecognised Loss of Potential Growth Rates

One of the outcomes of this and previous research is the realisation of what we have termed “unrecognised loss of potential growth rates”. It was noticed that, in some cases, there was a growth response to added field fertiliser even though trees which had not received fertiliser still appeared perfectly healthy. This was particularly evident in the trials at Daintree and Atherton. At Daintree, other parameters such as nutrient status (Table 3), chlorophyll concentration (Figure 21), and photosynthetic efficiency (Figure 22) were used to determine the health of the trees. There were no biologically important differences found in any of these parameters in spite of the growth responses (Figure 23). Similarly, at Atherton, chlorophyll concentration (Figure 24) could not differentiate between treatments even though there was a clear growth response (see Figure 15).

Importantly, because there was a growth response which could only be attributed to the added fertiliser, even though all other measured parameters would appear to indicate that these plants were adequate in their nutrients, they must, by definition, be considered nutrient deficient. This implies that it may be impossible to determine whether a particular tree or stand is growing at its maximum potential through standard diagnostic techniques. Thus, in any planting that “appears” healthy, these deficiencies could easily go unrecognised – even by the most vigilant observer.

This unrecognised growth potential was not only a feature of young trees. Even 24 months after planting, trees whose growth was suppressed through lack of fertiliser (see Figure 12 & Figure 18), still appeared healthy and had seemingly adequate chlorophyll levels (Figure 25).

Table 3: Nutrient concentrations in the youngest mature leaf of *Eucalyptus pellita* (9 months after planting) grown under various nursery and field nutrient supplies.

Treatment	Macroutrient Concentration					
	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)
Standard Nursery	2.1	0.11	1.4	0.14	0.9	0.26
Standard Nursery + Field	3.7	0.23	1.3	0.23	0.6	0.33
ACIAR Nursery	2.3	0.13	1.5	0.17	0.6	0.25
ACIAR Nursery + Field	2.6	0.15	1.3	0.18	0.5	0.21
Adequate range ¹	1.8 - 3.4	0.1 - 0.3	0.6 - 1.8	0.1 - 0.3	0.3 - 1.0	0.1 - 0.35

Treatment	Microutrient Concentration				
	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)	Fe (mg/kg)	B (mg/kg)
Standard Nursery	5	32	423	39	18
Standard Nursery + Field	7	40	841	47	20
ACIAR Nursery	6	34	523	41	22
ACIAR Nursery + Field	5	21	418	39	20
Adequate range ¹	6 - 15	14 - 46	220 - 700	60 - 130	15 - 30

¹For *Eucalyptus grandis* (Boardman *et al.*, 1997).

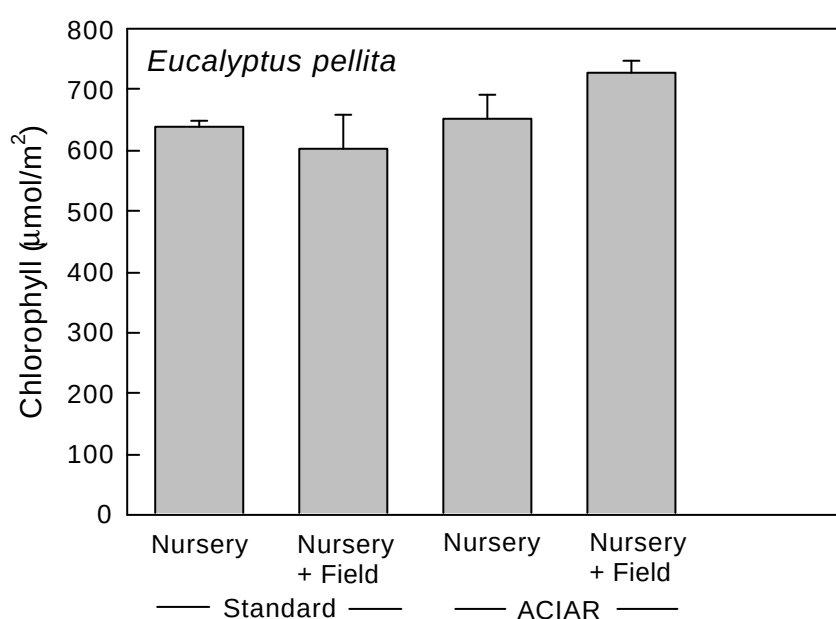


Figure 21: Chlorophyll (a + b) concentration in the youngest mature leaf of *Eucalyptus pellita* 6 months after planting at Daintree.

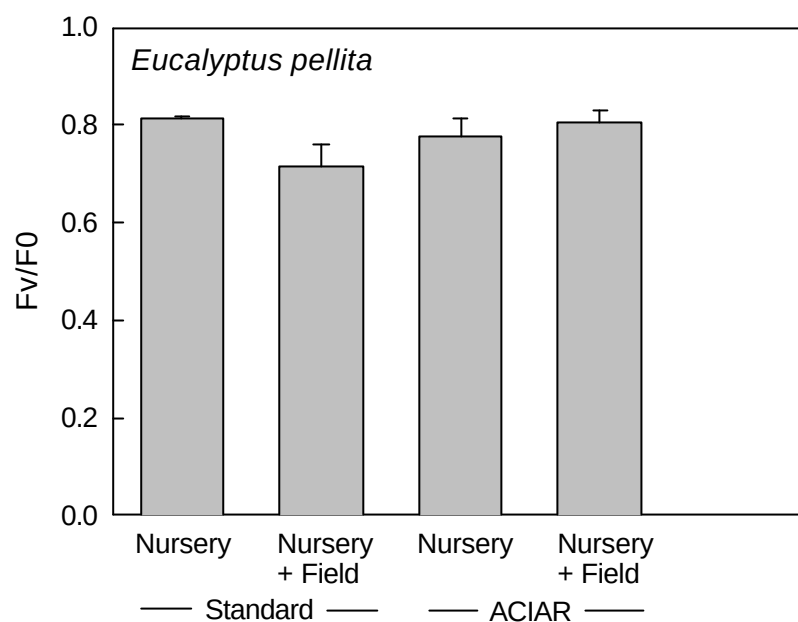


Figure 22: Chlorophyll fluorescence ratio (Fv/F0) from the youngest mature leaf of *Eucalyptus pellita* 6 months after planting at Daintree. Theoretical maximum is 0.83.

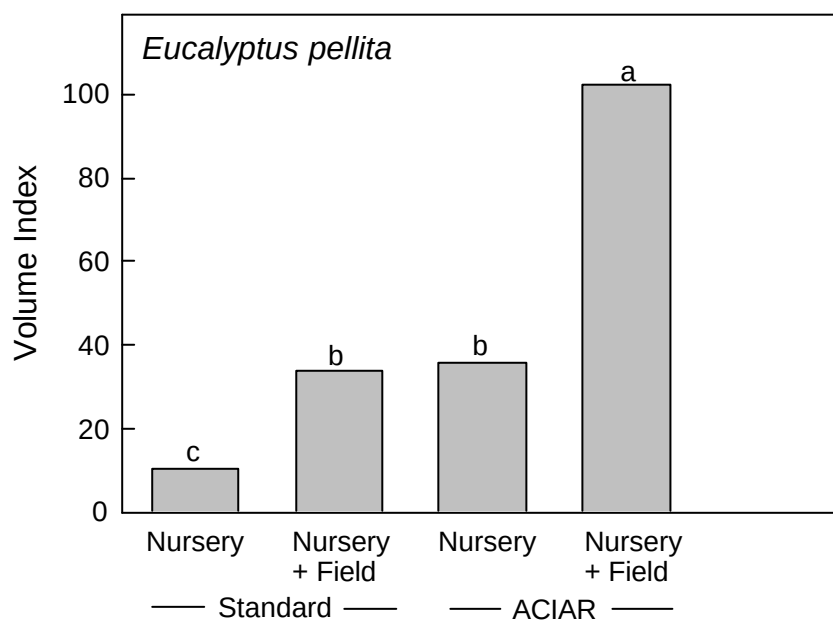


Figure 23: Volume Index of *Eucalyptus pellita* 6 months after planting at Daintree.

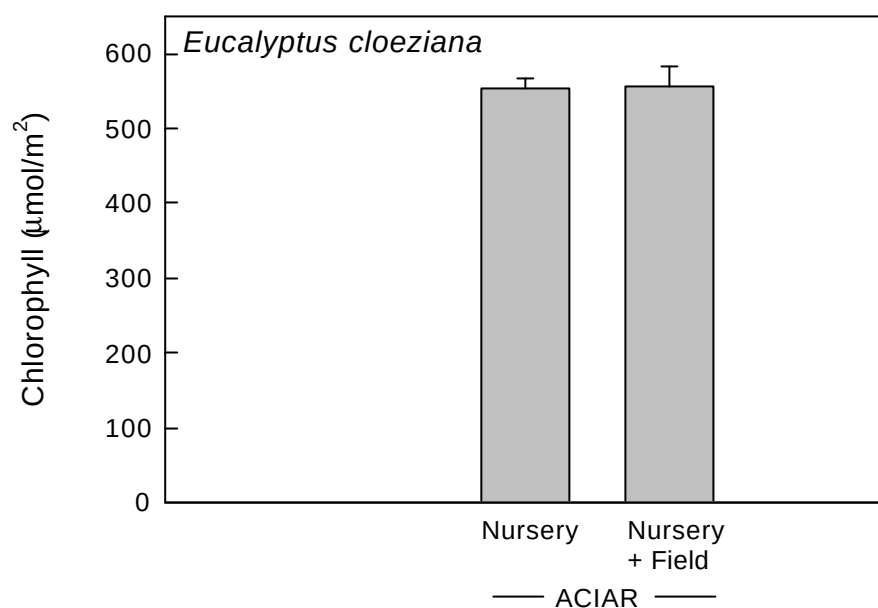


Figure 24: Chlorophyll (a + b) concentration in the youngest mature leaf of *Eucalyptus cloeziana* 6 months after planting at Atherton.

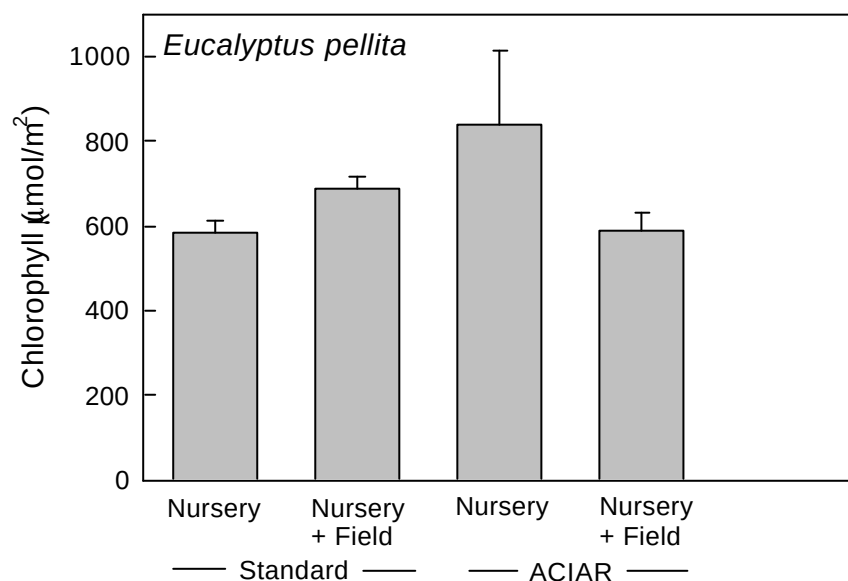


Figure 25: Chlorophyll (a + b) concentration in the youngest mature leaf of *Eucalyptus pellita* 24 months after planting at Daintree.

4. Discussion

Because of the “whole-of-system” approach, it has not always been possible to isolate the observed responses to any one factor. Thus, in many cases, the standard nursery protocol and the ACIAR nursery protocol differed in media, pot size, and nutrient supply. For this reason, most responses cannot strictly be attributed to improved nutrition alone. However, for the most part, it is believed that improved nutrition has an important and major role in these responses for reasons outlined in the following discussion. Nonetheless, it is acknowledged that these other factors will probably also affect establishment and early growth and will contribute, in part, to the differences between the standard and ACIAR protocols.

4.1 ACIAR Nursery Techniques Without Field Fertiliser

The results clearly show that the ACIAR nursery technique (of incorporating nutrients in excess of nursery requirements into the nursery media) we have developed overseas (as part of an ACIAR Forestry project) for improved early growth of cabinet-timber trees is applicable to Australian conditions. This ACIAR nursery technique, which results in early rapid growth compared with standard techniques will reduce the early maintenance resources required - such as weed control - either by shortening the time required to for canopy closure, or by increasing the ease of maintenance operations such as herbicide application.

It is also likely that this technique increases the ability of trees to compete with other vegetation for site resources thereby facilitating a faster growth rate (Reddell *et al.* 1999).

As mentioned, it is not always possible to attribute the response to fertiliser because of other operational differences in media, pot size, fertiliser type, hole preparation etc. However, at one site (Forest Creek) the pot size, hole preparation and planting techniques were identical. This implies that only the media or the fertiliser could be responsible for the improved growth at age 3 months.

Thus it is clear that, in the absence of field fertilisers, improving the nursery protocol can convey substantial advantages.

Moreover, even when standard field fertilisers are used in conjunction with the standard nursery techniques, the ACIAR protocol can produce larger plants even without additional field fertiliser.

Indeed, even after 9 months the growth of *Eucalyptus cloeziana* is markedly improved by using the ACIAR nursery protocol (even without field fertilisers) compared to the standard nursery practice with standard field fertiliser (see Figure 13 & Figure 19).

In spite of the observation in one experiment that these initial gains from this nACIAR nursery technique compared to the standard nursery + field fertiliser technique were diminished with time (see Figure 3 & Figure 12), this ACIAR technique has replaced the need for inefficient and expensive field fertilisation required by the standard method. For example, if only the components are considered, estimates of cost for the ACIAR protocol is \$0.36 per tree and the estimates for the standard nursery is \$0.17 plus field fertiliser \$0.11 (= \$0.28 per tree). That is, there is only a saving of approximately 8 cents per tree in terms of media and fertiliser. However, the added requirement of labour costs in field fertilising (\$140 per ha; 1000 trees per ha), plus possibly an additional weeding operation (\$350 per ha) because of the initial smaller size of the trees grown under the standard practice, would make the cost of the ACIAR protocol similar or maybe even cheaper than the standard practice.

Whether there are any benefits beyond 24 months is, of course, unknown. However, others have shown that increases in early growth rate resulted in longer term gains in productivity (Snowdon and Waring 1984; Schönau and Herbert 1989).

4.2 Effect of Field Fertiliser

In many cases, the addition of field fertiliser has had little effect because of the shortness of the project and thus the limited time for the trees to respond. However, in some experiments, where it was possible to measure older trees, it is clear that field fertiliser has enhanced growth (eg Figure 3, Figure 12, Figure 15, Figure 17, Figure 18 & Figure 23; Plate 1 & Plate 3). That is, **within** each nursery protocol, any enhancement in growth through the addition of field fertiliser can be attributed to the nutrients added in that fertiliser as all other aspects of the treatments were identical.

Thus it is clear that field fertilisation can increase growth in most situations – even in the presence of an improved nursery protocol. This also indicates that most of the soils planted can be regarded as nutrient deficient for tree growth.

4.3 ACIAR Nursery Techniques With Field Fertiliser

In almost every case, the use of the total ACIAR package of nursery and field protocols, produced trees substantially larger than any other technique – especially in older trees.

This demonstrates two important points:

1. Although this ACIAR technique (without field fertiliser) has operational advantages over the standard technique, it is clearly not adequate without some additional field fertiliser (as shown above), and
2. The improved growth that can be obtained by using the total package of ACIAR nursery protocol and field fertiliser compared with the standard practices clearly shows that some standard practices are inadequate if maximum growth is desired.

However, because the number of differences in techniques it is not always possible to attribute the response to any particular factor. But again, as it has been shown that some responses can be attributed solely to additional fertiliser, it is most likely that the responses observed are, for the most part, a result of improved nutrition.

4.4 Unrecognised Loss of Growth Potential

Possibly more important than showing improved growth through fertiliser addition is the observation that trees growing at less than the fastest rate may still appear healthy (chemically¹, biochemically, physiologically, and visually). Admittedly, there are no recognised standards by which to judge these parameters. However, as they differed only slightly between treatments and, where information is available, fell within ranges considered biologically adequate², it is difficult to assess these trees as other than “healthy”.

In other words, just because a tree “appears” healthy, it does not necessarily mean that it is growing at its maximum potential. This implies that there may be a substantial amount of unrecognised loss in growth potential of many of our plantation systems. Not only might it be unrecognised, but it may also be unrecognisable by any tests that we have available other than fertiliser application experiments.

From a conceptual viewpoint, the enigma is that these trees which are growing at less than the maximum rate, appear perfectly healthy. Yet, as their growth responded to a further supply of nutrients, by definition, they must be considered nutrient deficient.

4.5 Applicability of Results

That the nursery and field techniques employed produced trees with growth rates typical of those planted in the region indicates that these results, and therefore the implications, should be generally applicable across the region.

However, it would be unrealistic to expect to get the same benefits at every site and with every species. For example, when trees are planted on high fertility sites (in the tropics or elsewhere) it could be expected that the additional nursery fertiliser might only provide little or no benefit, as the soil may be capable of supplying all essential nutrients in adequate amounts (see also Snowden and Waring 1984). For species which are capable of fixing their own nitrogen, this technique may have minimal benefit where nitrogen is the major limiting nutrient. Indeed for some species, such as those from the Proteaceae family, this nutrient regime may well be toxic.

For this reason, this report has not been prescriptive in recommending a specific formulation. Although the formulations used are given in the appendices they should only be viewed as a starting point for experimentation; they should not be viewed as a recommendation. It is up to the individual nursery managers or tree growers to use these results in a conceptual way to develop, through experimentation, their own formulation suited to their climate, soil and species.

¹ It is not known whether the youngest mature leaf is the most appropriate tissue for this species as there is no known information for *Eucalyptus pellita*. However, this tissue has been shown to be the most appropriate for a large number of other species.

For example, it may well be irrelevant whether some nursery media other than coir is used as long as it has suitable properties. Similarly, the brand of slow-release fertiliser is probably also irrelevant, again, as long as it has suitable properties. Indeed, some nurseries may wish to experiment initially simply by increasing the rate of fertiliser used in the nursery media or by increasing the amount and longevity of slow-release fertilisers already in use.

5. Implications

These results could have wide reaching implications for the nursery industry. They imply that even though healthy nursery stock is supplied to tree-planters, it may not be optimal in terms of subsequent tree growth. While it is understandable that any nursery manager may not wish to “waste” resources on nutrients considered in excess of nursery requirements, the growers may wish to demand higher nursery inputs in order to achieve improved early growth. This may well be cheaper and more effective than the (rather inefficient) alternative of applying fertilisers soon after planting.

The implications of unrecognised losses in potential growth rates are also wide-reaching and possibly of major economic significance. They imply that there may well be large areas of plantings that are not achieving their maximum potential simply because there may be no method of determining that they are under-performing. That they simply appear “healthy” or have an “adequate” nutrient status may no longer be a reason for complacency.

The benefit of increasing early growth rates (through fertiliser or other techniques) to longer term productivity has been addressed on a number of occasions (Snowdon and Waring 1984; Schönau and Herbert 1989; Reddell *et al.* 1999). For example, Snowdon and Waring (1984) have shown the benefits of fertilising and weeding on long-term productivity in terms of total volume produced or time to reach maturity for *Pinus radiata*; Schönau and Herbert (1989) have cited many examples, mainly with Eucalypts, where early fertilisation has had a long-term and lasting benefit on growth; and Reddell *et al.* (1999) have shown the long-term benefits of improved nursery nutrition on the growth of the tropical species *Gmelina arborea* and *Acacia mangium*. Thus, it is highly likely that the increased early growth in these trials will result in long-term increases in productivity.

Importantly, Schönau and Herbert (1989) have suggested that it is economically justified to increase growth through addition of fertiliser because of benefits such as shorter rotation time and earlier canopy closure (reducing weed control requirements).

6. Recommendations

1. That tree growers take a more active role in determining the nutrient composition of the nursery media in which trees are supplied
2. That the extent of “unrecognised loss of growth potential” be determined in an economic framework.

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8. Appendices

Appendix 1: Details of Experimental Plans

Details of Experimental Plans

Experimental Plan
(Daintree)

Purpose:

To compare current practice with possible alternatives.

Experiment:

Species: *Eucalyptus pellita* (Seedlot 291 DPI Forestry, Beerwah, Q [collected from State Forest 1229 Kuranda, 16°46'S, 145°34'E, 440 m.a.s.]), *Acacia mangium* (Seedlot 228 DPI Forestry, Beerwah, Q [collected from Mission Beach, 17°55'S, 146°06'E, 10 m.a.s.])

Four Treatments

Pots	Nursery Fertiliser	Field Fertiliser
Forestry	Walkamin Standard	None
Forestry	Walkamin Standard	Walkamin Standard
150 mm	ACIAR	None
150 mm	ACIAR	ACIAR

Layout:

Each treatment contained 1 tree

Each treatment was replicated 4 times using a randomised complete block design.

Trees were spaced 3m by 2m.

Field Preparation:

Weeds were treated with glyphosate.

Planting:

Holes were dug with a spade for the Walkamin treatment and a 150 mm auger for the ACIAR treatment.

Soil association:

Mountainous Unit 1, possibly Bicton (see Murtha 1989). Soil formed on metamorphic material

Experimental Plan
(Forest Creek)

Purpose:

To compare current practice with possible alternatives

Experiment:

Three Species: *Alphitonia petriei*, *Acacia mangium*, *Elaeocarpus angustifolius*

Site: Daintree

Four Treatments:

Pots	Nursery Fertiliser	Field Fertiliser
1 L bags	Walkamin Standard	None
1 L bags	Walkamin Standard	Douglas Shire Standard
1 L bags	ACIAR	None
1 L bags	ACIAR	ACIAR

Layout:

Each treatment contained 5 trees.

Each treatment was replicated 4 times using a randomised complete block design

Trees were spaced 1.5m by 1.5m.

Field Preparation:

Weeds were treated with glyphosate.

Planting:

All holes were dug with a 300mm auger.

Soil association:

Liverpool (see Murtha 1989). Well drained soil formed on alluvium

Experimental Plan (Mossman)

Purpose:

To compare current practice with possible alternatives

Experiment:

Species: *Flindersia brayleyana* (Seedlot 10131 DPI Forestry, Beerwah, Q [collected from Atherton Tablelands, 17°17'S, 145°27'E, 752 m.a.s.])

Four treatments

Pots	Nursery Fertiliser	Field Fertiliser
Forestry	Walkamin Standard	None
Forestry	Walkamin Standard	QFRI Standard
150 mm	ACIAR	None
150 mm	ACIAR	ACIAR

Layout:

Each treatment contained 3 trees. Each treatment was replicated 4 times using a randomised complete block design. Trees were spaced 3m by 3m.

Field Preparation:

No field preparation was needed, as the site was relatively weed free.

Planting:

The planting holes were dug with a mattock for the Walkamin Standard and with a 150-mm auger for the ACIAR treatments.

Soil association:

Ponzo (see Murtha 1989). Well drained soil formed on alluvium

Experimental Plan
(Atherton CSIRO)

Purpose:

To compare current practice with possible alternatives.

Experiment:

Species: *Flindersia brayleyana* (Seedlot 10131 DPI Forestry, Beerwah, Q [collected from Atherton Tablelands, 17°17'S, 145°27'E, 752 m.a.s.]), *Eucalyptus cloeziana* (Seedlot #7 DPI Forestry, Beerwah, Q [collected from State Forest 28 Coomanglah, 24°45'S, 151°00'E, 400 m.a.s.]

Five Treatments

Pots	Nursery Fertiliser	Field Fertiliser
Forestry	Walkamin Standard	None
Forestry	Walkamin Standard	Walkamin Standard
150 mm	ACIAR	None
150 mm	ACIAR	ACIAR
100 mm	Double ACIAR	None

Layout:

Each treatment contained 7 trees. Each treatment was replicated 4 times using a randomised complete block design. Each species was treated as a separate experiment. Trees were spaced 3m by 3m.

Field Preparation:

Weeds were treated with a herbicide.

Planting:

Planting holes were dug with a hoe for the Walkamin Standard or a 150 mm auger for the ACIAR treatments.

Soil association:

Pin Gin (see Laffan 1988). Soil formed on highly weathered basalt

Experimental Plan (Babinda)

Purpose:

To compare current practice with possible alternatives

Experiment:

Species: *Flindersia brayleyana* (Seedlot 10131 DPI Forestry, Beerwah, Q [collected from Atherton Tablelands, 17°17'S, 145°27'E, 752 m.a.s.]), *Eucalyptus pellita* (Qld Tree Seeds 1998, Moura, Q)

Five treatments

Pots	Nursery Fertiliser	Field Fertiliser
Forestry	Walkamin Standard	None
Forestry	Walkamin Standard	Walkamin/QFRI Standard ¹
150 mm	ACIAR	None
150 mm	ACIAR	ACIAR
100 mm	Double ACIAR	None

¹ Walkamin for *Eucalyptus pellita* ; QFRI for *Flindersia brayleyana*

Layout:

Each treatment contained 5 trees. Each treatment was replicated 4 times using a randomised complete block design. Each species was treated as a separate experiment. Trees were spaced 5m by 2.5m.

Field Preparation:

The field site was ripped, rows mounded and weeds treated with a herbicide.

Planting:

At planting all the holes were dug with a mattock

Soil association:

Ramleh (see Murtha *et al.* no date) Poorly drained soil formed on alluvium.

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Experimental Plan (Hinchinbrook)

Purpose:

To compare current practice with possible alternatives

Experiment A:

Mixed species planting

Nauclea orientalis, *Meliocope eleryana*, *Acacia mangium*, *Agathis robusta*, *Alphitonia petriei*, *Grevillea baileyana*, *Alstonia scholaris*, *Cananga odorata*, *Randia fitzalanii*, *Planchonella obovoidea*, *Blepharocarya involucre*, *Syzygium kuranda*.

Four Treatments:

Pots	Nursery Fertiliser	Field Fertiliser
Super Native	Hinchinbrook Standard	None
Super Native	Hinchinbrook Standard	Hinchinbrook Standard
Super Native	ACIAR	None
Super Native	ACIAR	ACIAR

Layout:

Each treatment contained 7 species and 4 trees of each species = 28 plants in a 4 * 7 arrangement. Each treatment was to be replicated 4 times using a randomised complete block design

Experiment B:

Single species – Plantation type

Six treatments

Pots	Nursery Fertiliser	Field Fertiliser
Super Native	Hinchinbrook Standard	None
Super Native	Hinchinbrook Standard	Hinchinbrook Standard
Super Native	ACIAR	None
Super Native	ACIAR	ACIAR
Super Native	ACIAR	Hinchinbrook Standard
Super Native	Double ACIAR	None

Layout:

Each treatment was to contain 8 trees. Each treatment replicated 4 times using a randomised complete block design. Each species to be treated as a separate experiment.

Experimental Plan
(Townsville CSIRO)

Purpose:

To compare current practice with possible alternatives

Experiment:

Species: *Eucalyptus pellita* (Qld Tree Seeds 1998, Moura, Q)

Four treatments

Pots	Nursery Fertiliser	Field Fertiliser
Forestry	Walkamin Standard	None
Forestry	Walkamin Standard	QFRI Standard
150 mm	Double ACIAR	None
150 mm	Double ACIAR	ACIAR

Layout:

Each treatment contained 4 trees. Each treatment was replicated 4 times using a randomised complete block design. Trees were spaced 2.25m by 1.5m.

Field Preparation:

The weeds were suppressed with a weedmat (1m wide). A small hole was cut in the mat to allow the trees to be planted

Planting:

At planting the holes for the Walkamin Standard were dug with a 100 mm auger and a 150 mm auger for the ACIAR treatment.

Soil association:

Healey (see Murtha 1982). Duplex soil formed on alluvial fans.

Details of Nursery Treatments:

Walkamin

<i>Nutrient</i>	<i>g/L</i>
Nutricote blue (140 d)	1.15
Nutricote blue (270 d)	1.15
Lime	1.9
Micromax	0.46

<i>Media</i>	<i>L/L</i>
Peat	0.5
Vermiculite	0.5

Hinchinbrook

<i>Nutrient</i>	<i>g/L</i>
Osmocote (3-4mth)	2
Osmocote (8-9mth)	2
Dolomite	0.1
Iron Chelate	0.2
Micromax	0.79

<i>Media</i>	
Pine bark	3 bales
Soil Wetter	40 ml
Coarse Sand	2 large Wheelbarrows
Black Peat	2 large Wheelbarrows

ACIAR

<i>Nutrient</i>	<i>g/L</i>
Osmocote Plus (5-6mth)	4
Osmocote Plus (16-18mth)	12
Gypsum	0.5
Ferrous sulphate	0.25
Micromax	0.25

<i>Media</i>	<i>L/L</i>
Coir	0.85
Sand	0.15

Double ACIAR

<i>Nutrient</i>	<i>g/L</i>
Osmocote Plus (5-6mth)	18.4
Osmocote Plus (16-18mth)	55.2
Gypsum	2.3
Ferrous sulphate	1.15
Micromax	1.15

<i>Media</i>	<i>L/L</i>
Coir	0.85
Sand	0.15

Details of slow-release and compound fertilisers

Nutricote blue: N 16%; P 4.4%; K 8.3%; Ca 4%

Nutricote black: N 16%; P 4.4%; K 8.3%; Ca 4%

Osmocote Plus (5-6mth): N 15%; P 4.4%; K 10%; Ca 3.7%; Mg 1.2%; S 4.0%; Fe 0.25%; Mn 0.06%; Cu 0.05%; Mo 0.02%; B 0.02%; Zn 0.015%

Osmocote Plus (16-18mth): N 15%; P 3.9%; K 8.2%; Mg 1.2%; S 2.3%; Fe 0.4%; Mn 0.06%; Cu 0.05%; Mo 0.02%; B 0.02%; Zn 0.015%

Micromax: S 15%; Fe 12%; Ca 5.5%; Mg 3.3%; Mn 2.5%; Zn 1.0%; Cu 0.5%; B 0.1%; Mo 0.005%.

Details of Field Planting and Fertilising

Planting:

The nursery mix from all treatments was planted with the tree!

Walkamin Nursery: all holes were dug with a spade, mattock or auger.

Walkamin Nursery + Field fertiliser:

Forest Creek site: Douglas Shire standard field fertiliser (a handful of organic pelletised fertiliser – Dynamic Lifter®) was added into the augered hole.

All other sites: Walkamin standard field fertiliser and QFRI standard fertiliser were added post planting as described below.

ACIAR Nursery:

Holes were augered to approximately 300 mm depth. The bottom of the hole was then disturbed in a similar way to that when fertilisers were added in the *ACIAR Nursery + Field fertiliser* treatment below.

ACIAR Nursery + Field fertiliser:

Holes were augered to approximately 300 mm depth. The fertiliser (see below) was placed in the hole and augered into the soil to mix, then soil was replaced on top to act as a buffer between the root ball of the potted tree and fertiliser.

Double ACIAR Nursery:

An auger was used to dig the hole as above but with no added field fertiliser.

Post Planting:

Walkamin Field Fertiliser: 250g DAP was spread around the tree 1 month after planting.

QFRI Field Fertiliser: 40g Nitram, 290g Triphos, 100g muriate of potash, 20g copper sulphate, 22g zinc sulphate (heptahydrate), 22g borax in a slit on either side of the tree at planting.

ACIAR Field Fertiliser: In addition to that added at planting, the fertiliser was to be spread around the tree and scratched into soil with a truffle fork. This was to be done at 3, 6, 9, 12 months.

ACIAR field fertiliser (ACIAR Nursery + field):

Fertiliser Application

Fertiliser	"Full" Fertiliser rate (g/tree)	At Planting (g/tree)	3 months (g/tree)	6 months (g/tree)	9 months (g/tree)
Proportion of "Full"->		0.25	0.25	0.25	0.25
Urea	261	65	65	65	65
Super	1667	417	417	417	417
K ₂ SO ₄	160	40	40	40	40
Dolomite	343	86	86	86	86
Bar-min-el*	150	38	38	38	38

* Mg, 6%; Fe, 5.7%; S, 4.5%; Mn, 3.9%; Cu, 1.5%; Zn, 0.26%; Mo, 0.19%; B, 0.13%; Co, 0.03%

From 12 months onwards it is planned to add a “half” dose every 3 months. For the trial at Daintree, this has happened up to 24 months of age.