

Abstract

The germination and early growth of Australian rainforest cabinet timber species were examined. The species were chosen from shade sensitive early secondary to shade tolerant climax successional groups. The germination of 35 Queensland rainforest timber species and effectiveness of pre-germination treatments were studied. Five distinct patterns of germination are outlined and linked to fruiting season and geographic location. Twenty Queensland cabinet timber species seedlings were subsequently grown in three light regimes and two nutrient treatments. Growth and photosynthetic responses to light and nutrient treatments were examined. The quantity and quality of solar radiation were altered by the use of painted polyfilm in order to simulate natural rainforest light regimes. Growth responses were variable across treatments and between species. A factorial analysis of variance was conducted to evaluate the effects of light (high-80% full sunlight and R:FR 1.01, low-8% full sunlight and R:FR 0.63), nitrogen (control, added nitrogen) and successional status (early secondary, late secondary, climax). Under high light conditions the cabinet timber species significantly increased their total number of leaves, branching, rate of photosynthesis, transpiration and stomatal conductance. Under low light conditions a significant increase in internode length, single leaf area, leaf blade length, slenderness (height/diameter ratio) and relative crown depth was observed. The light treatments did not have a significant effect on stem elongation rate, relative stem elongation rate or total leaf area. The added nitrogen treatment produced a significant increase in stem elongation rate, relative stem elongation rate, internode length, single leaf area, total leaf area, leaf blade length and relative crown depth. Additional nitrogen did

not have a significant effect on slenderness (height/diameter ratio), branching, rate of photosynthesis and stomatal conductance. The combination of high light conditions and added nitrogen treatment significantly increased diameter increment rate, relative diameter increment rate and water use efficiency in the species being trialed. Low light conditions combined with added nitrogen significantly increased specific leaf area.

Early secondary species exhibited the greatest stem elongation rate, relative stem elongation rate, diameter increment rate and relative diameter increment rate compared to late secondary and climax species. Early secondary species had the lowest total number of leaves at the end of the experiment. Climax species had significantly lower stem elongation rate, relative stem elongation rate, diameter increment rate, relative diameter increment rate, leaf blade length and height/diameter ratio than secondary species. Under low light conditions, early secondary species exhibited the highest mean specific leaf area whilst climax species had the lowest specific leaf area.

The potential application of these findings to rainforest cabinet timber farm forestry is discussed.

**Aspects of Seed Germination and Early Growth in
Rainforest Cabinet Timber Species**

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Declaration

I hereby declare that the main text in this thesis is an original work and no part of this thesis has been previously submitted for the award of any other degree.

I also declare that to the best of my knowledge any assistance I received in the experimentation presented in this thesis and all sources of information used in this thesis have been acknowledged.



N.J.C. Smith

Chapter 1 Introduction

1.1 Introduction

“The force that through the green fuse drives the flower drives my green age....”

(Dylan Thomas 1934).

Solar radiation through the unique process of photosynthesis drives the forest sapling upwards. This force through carbon accumulation has the potential to drive timber production to meet the challenges of sustainability in a future green age. Nicholas Dattner (1991), Melbourne furniture manufacturer, extols the virtues of timber “ *... a material which has endless capacity for self generation at virtually no cost, with no one in attendance, comes in thousands of varieties and has almost infinite uses – and with a life expectancy well in excess of three hundred years, it is extraordinarily enduring. It is being produced in the World’s single largest production plant, the pollution controls of which are so effective that the primary by-product is pure oxygen*”.

The integration of tree growing in whole farm planning has the potential to increase farm productivity and income, improve natural resource management and conservation values, as well as produce raw material for timber products (Guijt and Race 1998). Australian rainforest cabinet timber species produce some of the finest timber in the world and have a broad range of end uses including high quality furniture (Herbohn *et al.* 1996). Cabinet timber plantation design has focused on mixed species rather than monoculture plantings because of the perceived and known advantages that include good early growth rates and tree form, greater biomass production, better site utilization, reduced risk of insect

damage and disease problems (Keenan 1996) diversity of forest products and flexibility in product marketing (Montagnini *et al.* 1995).

The objectives of this thesis are to improve knowledge of the growth characteristics of valuable Australian rainforest cabinet timber species. A greater knowledge of the individual species will enable a better understanding of their likely role in mixed species plantings and will aid the forester in prescribing species for stratified mixed species plantings. The individual species to be examined were chosen from across a broad spectrum of rainforest timber trees, from short-lived (20 – 50 years) secondary species to long-lived (> 80 years) shade tolerant climax species. This thesis takes a physiological approach and looks at aspects of growth physiology from seed to sapling and attempts to define guilds of species that have the potential to be used in a mixed species rainforest silviculture. Chapter one reviews rainforest cabinet timber farm forestry in Australia as well as providing a literature review of the individual species under investigation in this thesis. Chapter two examines the seed germination of 33 Australian rainforest timber species and efficacy of pre-germination treatments. In Chapter three the experimental growth facilities that simulate natural shade through modification of shadehouse light quality and quantity are examined. Chapter four analyses the early growth of 20 Australian rainforest cabinet timber species in contrasting light and nutrient environments. The potential application of the germination and early growth results to farm forestry are examined in Chapter five.

1.2 Rainforest cabinet timber farm forestry in Australia

Tropical and subtropical rainforests are recognised as highly diverse ecosystems, characterised by diversity in species and microenvironments. Such forests cover only 7% of the world's land surface (Press *et al.* 1996). In Australia tropical and subtropical rainforests cover approximately 0.4% of the continent today (Australian Bureau of Agricultural and Resource Economics 2001). Land clearing has reduced this area from just over 1% 200 years ago (Frawley 1991).

In the early years of Queensland settlement, the prime concern of the public and politicians was the settling and clearing of land. The first settlement in 1824 was in the Brisbane area and as urban development expanded, combined with the clearing of "fertile scrub" (equivalent to rainforest) lands, the indigenous forest resources (chiefly araucarian rainforest) were seriously depleted (Watson 1989). Concerned sawmillers lobbied the government to preserve forests for future timber supplies, resulting in the declaration in 1906 of a system of state forests. By 1918 the annual cut of hoop pine (*Araucaria cunninghamii*) was around 600,000 m³. Over the following 15 years reforestation commenced due to concern at the depletion of the native hoop pine resource and an inability to successfully regenerate commercial quantities of this valuable species in natural stands (Queensland Forest Service (QFS) 1991). The hoop pine plantation estate now covers 180,000 ha, representing approximately 26% of Queensland's plantation resources (Nikles 1996).

The most important source for high quality cabinet timbers came from the rainforests of northeast Queensland. About 150 timber species were regarded as merchantable species. The annual quota of logs allowed for removal from north Queensland rainforest was set by state foresters at 207,000 m³ in post World War

11 years but was significantly reduced to less than 60,000 m³ by 1987 in an attempt to maintain a long-term sustainable yield (Adam 1992). World Heritage listing in much of the rainforests of north Queensland resulted in further decline of the north Queensland rainforest timber industry and current supplies are sourced predominantly from freehold rainforest areas or overseas. Traditionally, Australian rainforest cabinet timbers have been used by the high quality furniture industry in the form of boards or peeled and sliced for high quality plywood or veneer (Herbohn *et al.* 1996). Over the last 60 years, trial plantings of some of the more promising species (*Grevillea robusta*, *Flindersia brayleyana*, *Toona ciliata*) have been undertaken, though results from many of the older trials are largely unreported. Some results from pure, mixed and underplanted stands have been recorded on Treedat, a data system established by the CSIRO and the QFS (Brown *et al.* 1991). Results have been mixed but the general consensus amongst Australian foresters has been that hoop pine is the only successful rainforest plantation species to date.

A number of authors (Cameron and Jermyn 1991; Shea 1992; Gough *et al.* 1993; Russell *et al.* 1993) have set out to reappraise the potential for rainforest silviculture in Queensland. They suggest that a number of Queensland rainforest timber species have silvicultural and economic potential and that the use of mixed species plantings needs to be explored further. Under the Community Rainforest Reforestation Program (CRRP), established in 1992, local councils, community and Landcare groups became involved in the establishment of rainforest cabinet timber plantings (Creighton and Sexton 1998). However, environmental (water quality and land degradation), erosion and employment objectives were given higher priority than timber production. Attempts to appraise the silvicultural

success of these cabinet timber plantings are likely to prove difficult due to variable management of the timber resource. Early management including weed control and pruning of lower branches to create knot-free timber is usually required in order to produce high-grade timber.

Conditions are now more economically favourable for commercial tree planting than in the past (Russell *et al.* 1993). Harvesting of the world's rainforest for quality timber is likely to decline to a fraction of its present level over the next 30 years, due to current unsustainable logging practices. Present-day prices are expected to rise considerably as the resource becomes scarce and demand increases with rising world population (Shea 1992). Both state and federal governments predict a massive shortfall in Australian hardwood timber production over the next 20-30 years and have issued policy statements, Plantations and Farm Forestry (Commonwealth of Australia 1995), Plantations 2020 Vision (Commonwealth of Australia 1997) and Plantations, Forests and Future Directions (Government of Queensland 1995), to stimulate the private sector plantation industry. Over the last decade there have been a number of tree growing conferences promoting wood production and there are now over 20 self-help farm forestry groups in Queensland (Queensland Forestry Network News 2001).

Tropical and subtropical rainforest silviculture has concentrated on the exploitation of natural forest resources. Whilst a large variety of species were harvested for their valuable timbers in north Queensland, foresters have focused on species amenable to plantation forestry, generally fast growing pioneer species. More recently, research into the processes involved in rainforest ecosystems and a revival in interest in mixed species planting for timber products has occurred.

Silvicultural interest has focused on *Flindersia brayleyana*, *Elaeocarpus grandis*, *Agathis robusta*, *Grevillea robusta*, *Toona ciliata* and their suitability as plantation species. However, interest in the use of high value rainforest cabinet timbers in farm forestry projects has led to the trialing of a greater diversity of species. In mixed species planting silvicultural management has focused on stocking rates. High stocking rates encourage height growth, reduction in lateral branching and early canopy closure (Kooyman 1996). However, long-term processes including stagnation and thinning are not well understood. Lower stocking rates increase the potential to manage wood production but require greater input into management of early growth. The mixed species planting is often characterized by a combination of species with differing growth rates. This inevitably leads to stratification within the planting (Kooyman 1996). Similar stratification is commonly found in regenerating rainforests.

Stocking rates and species composition will have a major effect on growth and stratification. If mixed Australian rainforest timber plantings are adopted, it is important to establish a wealth of knowledge concerning a broad range of species suitable for silviculture. Few trials have been made of mixed species plantings and fully understanding this type of ecosystem is not without its difficulties. Growth rates can be established for individual species in monoculture, but in mixed species plantings the interaction of planting density, species mix, site and climate are difficult to quantify.

There is little published information concerning the biology and ecology of potential plantation species. A useful approach can be to search for guilds of species that grow successfully in particular niches within the mixed species planting system. There has been much debate (Whitmore 1996) concerning the

identification of ecological groups within tropical and subtropical rainforest tree species, for example; pioneer and climax trees *sensu stricto* (Swaine and Whitmore 1988); pioneer, secondary, mature phase and nomads *sensu stricto* (Hopkins 1978). Pioneers require full light for both germination and establishment. They are generally shade intolerant, fast growing short-lived species with small seeds. Climax species exhibit some shade tolerance and are able to germinate and establish under forest shade. Within the climax guild of species (including late secondary and mature phase species), seedlings exhibit a broad range of shade tolerance. Attempts to define meaningful groups within this continuum are proving difficult due to the diversity of physiological response of climax species to sun and shade (Whitmore 1996). Detailed research into the seedling ecology of many tropical timber species is still scarce. Researchers undertaking ecological studies must weigh up the advantages and disadvantages of experimental trials in forests or plantations where the natural light includes sunflecks and low R:FR diffuse irradiance, or controlled growth environments where natural sunflecks are difficult to reproduce (Whitmore 1996) but control of light intensity, watering and competition is easier.

1.3 Literature review of rainforest cabinet timber species selected for trial

1.3.1 Overview

In the rainforests of eastern Australia, species with attractive figure, grain and colour suitable for use in the high value timber industry are relatively common. As a result of over-logging and over-clearing few natural stands are available for timber production, seed collection and scientific research. The ecology and suitability to silviculture of many species is not well understood despite sporadic

interest over the last 100 years. Apart from *Araucaria cunninghamii*, no other Australian rainforest species has been successfully adapted to commercial timber production in Australia. A renewed interest in rainforest rehabilitation and farm forestry during the 1980's and 1990's has led to further interest in high value cabinet timber species (Russell *et al.* 1993, Shea 1992). Interest in mixed species plantings has increased due to a variety of perceived advantages and the failure of valuable species (eg *Toona ciliata*) to grow successfully in monoculture (Keenan 1996). No planned species mix has yet reached commercial timber production status. Despite the lack of scientific and silvicultural data on mixed species plantings and their management, including uncertainty of timber production at harvest, farm foresters and rainforest reforesters continue to trial mixed species designs.

1.3.2 Seed collection, storage, treatment and germination

Floyd's (1989) "Rainforest trees of mainland south eastern Australia" provides valuable ecological information including distribution of southern species and their germination rates. When examining procedures for germination of native Australian species, Cavanagh (1987) tested *Acacia aulacocarpa* and *Acacia melanoxylum*. Both species substantially increased percentage germination (to 50 %) following treatment with boiling water. Fox *et al.* (1987) recorded low average germination rates for *Agathis robusta*. Searle (1989) documented the flowering and germination of *Acacia aulacocarpa*, *Acacia melanoxylum*, *Alphitonia excelsa*, *Melia azederach* var. *australasica* and *Rhodosphaera rhodanthema*. The use of an electric seed thresher to clean and scarify seed resulted in moderate to high germination (≥ 40 %) of *Acacia aulacocarpa*, *Acacia melanoxylum* and

Rhodosphaera rhodanthema seed. Sporadic germination of *Acacia melanoxylum* and *Alphitonia excelsa* seed over 36 weeks was recorded in a study of soil seed banks in regenerating forest in south-east Queensland (Abdulhadi and Lamb 1987). General nursery practice including pre-treatment and patterns of germination were reported by Doran (1997) for Australian tree species. The hard seedcoats of *Acacia aulacocarpa*, *Acacia melanoxylon* and *Alphitonia excelsa* required manual scarification or boiling water treatment to break seedcoat-imposed dormancy. Germination of fresh *Melia azedarach* var. *australasica* seed may be assisted by careful cracking of its endocarp. *Grevillea robusta* seed did not require treatment and 66 % germination was achieved.

One of the few studies to focus on Australian rainforest cabinet timber species examined the effects of storage on the viability of wind-dispersed seeds of *Agathis robusta*, *Flindersia brayleyana* and *Toona ciliata* (Sanderson 1998). Seeds that were air-dried at ambient temperatures and subsequently refrigerated (5 to 10 °C) or frozen (-5 to -10 °C) retained greater than 50% of their original (post-harvest) germinability.

Direct seeding is a cost effective method of revegetating degraded land. In Greening Australia and Queensland forestry trials *Acacia aulacocarpa*, *Acacia melanoxylum*, *Castanospermum australe* and *Toona ciliata* were direct sown successfully whilst *Flindersia australis* and *Melia azedarach* var. *australasica* failed (Vanderwoude *et al.* 1996). Seed and fruit attributes have been used to study the ecology of 89 woody species from north Queensland including *Castanospermum australe* and *Flindersia brayleyana* (Osunkoya 1994). The strongest indicators of species shade tolerance were the large size of fruit and

seeds, soft seed coat, non-photosynthetic cotyledons and lengthy fruit maturation period.

In order to produce healthy, hardy and uniform seedlings nurseries must have a good understanding of storage, treatment and patterns of germination for all species. Correct storage is necessary if seed is to remain viable. Appropriate pre-germination treatment can break seed dormancy, increase uniformity of germination and improve percentage germination. Knowledge of the pattern of germination, including the time to onset of germination, the rate of germination and the final percentage germination helps nurseries plan the timing and production of uniform seedlings.

1.3.3 *Early growth*

The physiological responses of individual species to irradiance and shade enable researchers to gain a better understanding of the species ecology. A shadehouse pot trial examined the effects of irradiance quantity on the morphological attributes of 12 north Queensland rainforest tree species (Osunkoya *et al.* 1994). In *Castanospermum australe* differences in seedling height, number of leaves, leaf length and leaf area between 37% daily PAR, 10 % daily PAR and 2.5% daily PAR were small and generally not significant whereas the difference in total seedling biomass was large and significant between 10 % daily PAR and 2.5% daily PAR. In *Flindersia brayleyana* differences in seedling height and number of leaves were only significant between 37% daily PAR and 10% daily PAR, whilst differences in leaf area and total seedling biomass were significant between either 37% daily PAR or 10% daily PAR and 2.5% daily PAR. Stomatal conductance in *Flindersia brayleyana* but not *Castanospermum australe* was significantly

reduced in the lower light environments. In a shadehouse trial studying the acclimation potential of Australian rainforest trees (Osunkoya and Ash 1991), specific leaf weight and total seedling biomass in *Flindersia brayleyana* were significantly higher in the 37% full sunlight treatment compared to the 2.5% full sunlight treatment. Photosynthetic studies examining the effects of light and nutrients on potted seedlings, including *Toona ciliata* and *Flindersia brayleyana* were undertaken by Thompson *et al.* (1992b). Both species showed a strong positive response in rate of photosynthesis to an increase in nutrient supply. They also increased their SLA under low light conditions. In glasshouse trials (Langenheim *et al.* 1984) growth and photosynthetic responses to irradiance quantity were studied for *Agathis robusta*. They report a significant increase in primary stem length, number of leaves, specific leaf weight and rate of photosynthesis under full sunlight compared to shade (6% full sunlight). The acclimation ability of *Flindersia brayleyana* seedlings on transfer from shade (16% full sunlight) to full sun was greatest in those individuals with larger root systems and thicker leaves (Claussen 1996). In these experiments the quality of irradiance (R:FR) was not altered at low irradiance levels. Cameron and Jermyn (1991) reviewed trial plot performance data from north Queensland and reported height (H) and diameter (D) increments for *Castanospermum australe* (H = 0.5 m yr⁻¹, D = 1.0 cm yr⁻¹), *Dysoxylum Muelleri* (H = 0.4 m yr⁻¹, D = 0.8 cm yr⁻¹), *Elaeocarpus grandis* (H = 1.0 m yr⁻¹, D = 1.5 cm yr⁻¹), *Flindersia brayleyana* (H = 0.5 m yr⁻¹, D = 0.8 cm yr⁻¹), *Flindersia schottiana* (H = 1.5 m yr⁻¹, D = 1.2 cm yr⁻¹), *Gmelina leichardtii* (H = 0.6 m yr⁻¹, D = 1.3 cm yr⁻¹), *Grevillea robusta* (H = 1.0 m yr⁻¹, D = 1.0 cm yr⁻¹), and *Toona ciliata* (H = 1.3 m yr⁻¹, D = 2.0 cm yr⁻¹).

Using data collated from 250 permanent sample plots in Queensland forests, Vanclay (1991) attempted to differentiate species (including *Acacia aulacocarpa*, *Agathis robusta*, *Blepharocarya involucrigera*, *Castanospermum australe*, *Dysoxylum muelleri*, *Elaeocarpus grandis*, *Flindersia brayleyana*, *Flindersia schottiana*, *Melia azederach* var. *australasica*, *Podocarpus elatus* and *Toona ciliata*) into groups using diameter increment measurements. Taxonomy and ecology did not provide a good indication of diameter growth. Specific leaf area (for example in *Castanospermum australe*) was higher in rainforest understorey compared to canopy and open sites (Myers *et al.* 1987).

The photosynthetic gas exchange responses of *Castanospermum australe* and *Toona ciliata* under natural forest conditions were examined by Pearcy (1987). Canopy leaves of both species exhibited higher light saturated photosynthetic rates and stomatal conductances, and lower specific leaf weights than the understorey leaves. Two-year-old seedlings of *Castanospermum australe* exhibited significantly greater maximum rates of photosynthesis under low light levels in a lowland rainforest compared to upland rainforest (Swanborough *et al.* 1998).

Grevillea robusta is an Australian rainforest cabinet timber species that has been successfully integrated into agroforestry in Africa and south-east Asia. Much work has been done on its ecology and silviculture (Harwood 1992). Provenance had a significant effect on the early growth of *Grevillea robusta* in Rwanda (Kalinganire and Hall 1993). In India, the growth of potted seedlings of *Grevillea robusta* was greater under full sunlight than under natural shade (25% full sunlight) (Saju *et al.* 2000). In a similar experiment the growth performance of *Toona ciliata* was greater in 50 % shade than full sunlight (Gopikumar and Bindu

1999). Bowen and Whitmore (1980) report differential growth response between *Agathis* species and provenances, in a greenhouse trial under three shade treatments. Slow release fertilisers improved early growth of field planted *Flindersia brayleyana* and *Toona ciliata* seedlings in Hawaii (Walters 1975). The use of tree shelters in establishment and management of *Toona ciliata* plantings has been studied by Applegate and Bragg (1989). The rate of height growth was greatest in the 3 m growtubes (clear plastic tree shelters). The rate of stem diameter growth increased markedly when the crown emerged from the growtube.

This thesis examines the germination of 35 Queensland rainforest timber species and the efficacy of pre-germination treatments (Chapter 2) The early growth characteristics of twenty high value cabinet timber species grown under contrasting light and nitrogen treatments are reported (Chapter 4). There is a lack of published information on the early growth of some of these species (*Blepharocarya involucrigera*, *Dysoxylum fraserianum*, *Flindersia bennettiana*, *Flindersia xanthoxyla*, *Nauclea orientalis*, *Pleiogynium timorense*, *Podocarpus elatus* and *Rhodosphaera rhodanthema*). The potential applications of the germination and early growth results to the nascent farm forestry industry are discussed (Chapter 5).

Chapter 2 Comparative germination responses of 35 tropical and subtropical rainforest species

2.1 Introduction

Australian rainforest cabinet timber species are being grown for timber production and rainforest reforestation in northern New South Wales and eastern Queensland. They have the potential to form a high value niche market within hardwood timber production and a valuable replacement of existing high imports of rainforest cabinet timbers (Russell *et al.* 1993). Many forestry rainforest cabinet timber trials favour the use of mixed species plantings, using as many as 20 different species. Examples of mixed species plantings are found in the Community Rainforest Reforestation Program in north Queensland (Creighton and Sexton 1998), Mulgrave Shire north Queensland (Guijt and Race 1998), Surrey Park in Brisbane, Noosa Shire southeast Queensland (Guijt and Race 1998) and Rocky Creek Dam in northern New South Wales (Kooyman 1996). A survey of Queensland landholders by Harrison *et al.* (1996) suggested that mixed native species plantings are strongly preferred. The design of cabinet timber plantations has focused on species mixtures rather than monoculture because of the perceived and known advantages, including good early growth rates and tree form, greater biomass production, better site utilization and less risk of insect damage and disease problems (Keenan 1996, Montagnini *et al.* 1995).

The production process of seedlings for farm forestry, plantations and reforestation include the following steps: seed production, harvest, processing, storage, pre-germination treatments and germination. Whilst much of the practical information is known to individual nurseries (and valued as competitive

advantage), little has been published on collection, storage, treatment and germination of Australian cabinet timber species. Difficulties with harvest, storage and germination of rainforest species have been noted by Nicholson (1991), Sanderson (1998), Searle (1989) and Smith (1998). One of the major costs of growing trees for farm forestry is the purchase of seedlings (Harrison and Herbohn 1996), thus individuals' collection of seed and on-farm propagation can reduce their establishment costs (Kooyman 1996).

Published accounts on the germination of rainforest tree species have focused on species chosen for their ecological successional characteristics (Osunkoya *et al.* 1994) rather than their cabinet timber status. Other studies have examined the soil seed banks of rainforests (Abdulhadi and Lamb 1987, Hopkins and Graham 1984). These authors conclude that pioneer and secondary successional species dominate viable soil seed banks in gaps and disturbed areas of rainforest. Seeds of many of these species retained their viability after two years whereas those of many climax species were not viable after six weeks. Sanderson (1998) has studied the effects of storage on wind dispersed cabinet timber species (four genera) from north Queensland. Air-drying seed at ambient temperatures followed by refrigeration or freezing extended the storage life of the seeds. Floyd (1989) provides valuable germination data including likely germination percentages and seed weights for rainforest species of southeast Australia. Whilst individual aspects of seed collection, seed storage, pre-germination treatments and germination data can be found across a number of published texts, no author has specifically focused on the germination patterns of a broad range of Australian cabinet timber species. This information is vital to nurseries and farm foresters who intend to propagate species suitable for mixed species cabinet timber

plantings. Accurate information regarding patterns of germination and early seedling growth is necessary in order to plan seedling production. Healthy and vigorous seedlings (60 – 90 cm in height, grown in 200 mm deep pots) are required for a single optimum-planting phase during the wet season (Kooyman 1996).

The aim of this study has been to examine the germination characteristics of a broad range of cabinet timber species (27 genera), suitable for planting in the 1000-1500 mm rainfall areas of tropical and subtropical Queensland. In particular, the following characteristics were analysed: germination percentages, days to onset of germination, germination index, effectiveness of pre-germination treatments, comparisons between species, and possible associations between successional status and patterns of germination. In order to develop a culture of farm forestry, farmers require the knowledge to design and implement their own plantations (Reid 1998). This chapter provides some of the information required to initiate farm forestry plantings.

2.2 Materials and methods

2.2.1 Seed source

Seeds of 35 Australian rainforest species (16 families, 27 genera) were collected from large rainforest remnants and isolated trees, or purchased from reliable seed suppliers (see Appendix A for details). Species were chosen on the basis of availability, status as highly valued cabinet timber, and potential for growth in the 1000-1500 mm annual rainfall zone (even though some of the species occur naturally in higher rainfall areas). It should be noted that viable seeds of some rainforest cabinet timber species are only available for short periods around

harvest time as they cannot be stored successfully. Collection difficulties (isolated trees, canopy heights, insect damage and poor fruit set) further compound availability (Smith 1998).

2.2.2 Storage

Seeds from rainforest remnants and isolated trees were collected, placed in paper bags, stored at 9°C and sown within two weeks of collection. There were no details of date of harvest and subsequent storage for purchased seed.

2.2.3 Pre-germination treatment

Seeds were visually inspected prior to inclusion in the trial. Any obviously damaged, immature or empty seeds were excluded from further testing. All seeds were treated with a fungicide prior to being sown in steam sterilised washed river sand (Murray 1998). Seeds were washed for five minutes in a 0.05% solution of Thiram (active ingredient; tetramethylthiuram disulphide) to combat fungal growth, and then surface dried.

Seeds were subjected to one or more treatments (Table 2.1). The treatments using boiling water were designed to break the coat-imposed dormancy of very dry seeds. Not all treatments were applied to seeds of some species due to limited seed supplies.

2.2.4 Germination experiment

A completely randomised design was employed, with each treatment replicated three times. Data were recorded weekly and regularly transferred to an Excel database, checking for potential data errors. Germination tests were conducted by

placing 20 seeds per replicate (with the exception of *Castanospermum australe* when eight seed were used) on the surface of moist steam sterilized washed river

Table 2.1 Description of pre-germination treatments applied to Australian rainforest timber species

Code	Type	Description
T1	Control	Removal of any fruit or capsule covering the seed.
T2	Nicking	Nicking: Seeds were scarified manually by cutting a small portion of the seed coat at the end opposite the plumule.
T3	Boiling water	Seeds were placed in boiling water (> 10 times seed volume) for 60 seconds and then allowed to cool in the same water for one hour
T4	Maternal fruit	Seed covered in maternal fruit were left intact
T5	Darkness	In order to simulate conditions of seed burial light was excluded (Fenner 1985) from the seed germination containers (by the use of heavy black plastic) for the duration of the trial. This treatment was implemented in the controlled growth room and was subject to similar diurnal light/ temperature regime as all other treatments
T6	Maternal and boiling water	Combination of treatments T3 and T4
T7	Maternal and darkness	Combination of treatments T3 and T5
T8	Nicking and darkness	Combination of treatments T2 and T5
T9	Fermentation	Fleshy fruit were fermented in water for three days followed by repeated washing to remove all traces of the pulp/seed covering

sand, in a clear plastic 1000 ml container. Clear plastic perforated lids were fitted to reduce evaporation and the spread of fungal diseases. Germination containers were placed randomly in a controlled growth room at Central Queensland University, with an alternating temperature and light regime of 30°C, 12 hours light and 25°C, 12 hours dark. A bank of fluorescent tubes provided a photon flux density of 50 $\mu\text{mol m}^{-2} \text{s}^{-1}$ at the height of the containers. Similar regimes have been successfully used in other germination trials (Ashwath *et al.* 1994).

Individual germination containers were inspected at seven-day intervals until either germination ceased, fungal disease made germination unlikely, or 378 days elapsed. Germination was considered to have occurred upon emergence of the radicle through the seed coat. The germination containers were moistened as

necessary (approximately every 50 days) with demineralised water in order to maintain adequate moisture levels. In situations with zero germination, seeds were tested with tetrazolium (Moore 1973) to ascertain viability. Evaluation of these tests indicated the absence of viable seeds. The data from seedlots that failed to germinate were not included in the analysis.

The three characteristics used to quantify germination patterns comprise: maximum germination (G) - the maximum percentage germination achieved over the duration of the experiment; days to onset of germination (DG) - the time (days) to the onset of germination; germination index (S_{50}) - the time (days) to reach 50% maximum percentage germination, from the onset of germination. Successional status of each species was ascribed according to Kooyman (1996), Shea (1992) and this author, and is presented in Table 2.2.

2.2.5 *Statistical analysis*

The SPSS (version 10) software package was used in statistical analysis of the data according to Francis (1999). A factorial (treatment x succession) analysis of variance was conducted for maximum germination (G), days to onset of germination (DG) and germination index (S_{50}). Germination percentages were arcsine transformed and delayed germination and speed of germination were log transformed following normality test. Levene's test was employed to assess homogeneity of variance. Tuckey's HSD post-hoc test was used, where appropriate, when Levene's test was not significant, whilst Dunnett's T3 post-hoc test was used, where appropriate, when Levene's test was significant. Hierarchical cluster analysis was also employed (using SPSS) to group species according to their germination characteristics in the control (T1) treatment.

2.3 Results

2.3.1 Species comparisons without pre-germination treatment (T1)

Total percentage germination varied widely for the 35 rainforest species trialed (Table 2.2). Seven species (*Dysoxylum muelleri*, *Elaeocarpus kirtonii*, *Euroschinus falcata*, *Gmelina leichardtii*, *Owenia venosa*, *Paraserianthes toona*, *Pittosporum undulatum*) failed to germinate and did not respond to any of the pre-germination treatments. These species were excluded from further statistical analysis of germination, as their ability to germinate was unknown. Two species (*Castanospermum australe*, *Flindersia australis*) produced germination levels of 100%.

A one-way analysis of variance was conducted to assess the relationship between successional status and germination for species without pre-germination treatment. Successional status (see Table 2.2), the independent variable, comprised four levels: pioneer, early secondary, late secondary, and climax species. The dependent variable, mean germination, was arcsine transformed to improve normality. The one-way ANOVA was significant, $F(3,78) = 5.5$, $p = 0.002$. T-tests (Tuckey HSD) were conducted to evaluate the pair-wise differences among the treatment means. The results of these tests indicate that early secondary (S2-61%) and climax species (S4-71%) have significantly higher mean germination compared to pioneer species (S1-17%). Mean germination for late secondary species (S3-53%) did not significantly differ from any of the other successional groups.

A 4 (succession) by 6 (pre-germination treatment) factorial analysis of variance was conducted on germination (arcsine transformed). The main effects of pre-

Table 2.2 Germination characteristics of 35 rainforest tree species from eastern Queensland

Family	Species	Ecology	Seed Weight	Treat-ment	G	DG	S ₅₀
Anacardiaceae	<i>Blepharocarya involucrigera</i>	S4	12	T1	98 (1.7)	3	12
				T2	82 (4.4)	1	14
				T5	92 (4.4)	7	14
	<i>Pleiogynium timorense</i>	S4	13070*	T1	87 (13.3)	14	107
				T2	100 (0.0)	14	44
				T3	73 (14.5)	14	14
				T5	37 (17.4)	40	9
				T7	0	n.a.	n.a.
	<i>Rhodosphaera rhodanthema</i>	S4	340	T1	5 (n.a.)	88	95
				T2	47 (6.0)	1	12
T3				32 (6.0)	16	54	
T4,				0	n.a.	n.a.	
Araucaraceae	<i>Agathis robusta</i>	S4	55	T1	85 (2.9)	1	7
				T2	63 (10.9)	1	7
				T5	90 (5.8)	1	7
Combretaceae	<i>Terminalia sericocarpa</i>	S4	131	T1	63 (6.7)	7	16
				T4	32 (1.7)	19	12
Elaeocarpaceae	<i>Elaeocarpus grandis</i>	S3	13720*	T1	15 (n.a.)	294	11
				T2	25 (n.a.)	280	112
				T4	33 (4.4)	268	268
				T5	0	n.a.	n.a.
Fabaceae	<i>Castanospermum australe</i>	S4	23600	T1	100 (0.0)	28	33
Icacinaceae	<i>Citronella moorei</i>	S4	1230	T5	97 (3.3)	60	67
				T1	22 (6.0)	189	7
Meliaceae	<i>Toona ciliata</i>	S3	2	T2	7 (1.7)	203	7
				T4	5 (n.a.)	189	7
				T1	45 (15.3)	1	12
Mimosaceae	<i>Acacia aulacocarpa</i>	S1	12	T1	7 (1.7)	26	19
				T2	90 (2.9)	1	7
				T3	97 (1.7)	1	21
				T8	93 (1.7)	1	7
	<i>Acacia bakeri</i>	S2	40	T1	18 (1.7)	10	37
				T2	58 (9.3)	1	7
				T3	38 (1.7)	3	16
	<i>Acacia melanoxylon</i>	S1	8	T8	68 (11.7)	1	7
				T1	27 (1.7)	9	40
				T2	93 (1.7)	1	7
T3				97 (1.7)	3	16	
Pittosporaceae	<i>Pittosporum venulosum</i>	S2	120	T5	32 (8.3)	1	19
				T8	100 (0.0)	1	7
				T1	92 (6.0)	33	19
				T3	0	n.a.	n.a.
				T4	95 (0.0)	37	14

Podocarpaceae	<i>Podocarpus elatus</i>	S4	1860	T1	78 (14.2)	23	51
				T2	92 (1.7)	9	23
				T5	70 (11.5)	16	56
Proteaceae	<i>Grevillea hilliana</i>	S3	17	T1	30 (5.0)	12	16
				T2	87 (3.3)	5	14
				T5	33 (4.7)	16	21
				T8	43 (15.9)	9	23
	<i>Grevillea robusta</i>	S3	15	T1	77 (6.7)	1	14
				T2	97 (1.7)	1	7
				T5	10 (2.9)	5	9
				T8	60 (5.0)	1	9
<i>Stenocarpus sinuatus</i>	S4	64	T1	73 (4.4)	7	9	
			T5	72 (3.3)	7	14	
			T1	28 (1.7)	1	9	
Rhamnaceae	<i>Alphitonia excelsa</i>	S2	13	T2	48 (8.3)	1	12
				T3	62 (1.7)	7	7
				T1	72 (6.0)	44	28
Rutaceae	<i>Euodia elleryana</i>	S2	29	T1	72 (6.0)	44	28
				T1	100 (0.0)	1	14
	<i>Flindersia australis</i>	S4	77	T5	100 (0.0)	1	12
				T1	45 (5.8)	1	14
	<i>Flindersia brayleyana</i>	S3	92	T1	58 (1.7)	1	12
				T5	72 (4.4)	1	7
	<i>Flindersia schottiana</i>	S3	48	T1	92 (4.4)	1	7
				T5	82 (7.3)	1	7
T1				75 (5.0)	1	12	
Sapindaceae	<i>Harpullia pendula</i>	S3	636	T1	82 (1.7)	3	12
				T1	78 (1.7)	1	7
Sterculiaceae	<i>Argyrodendron trifoliolatum</i>	S4	610	T1	60 (11.5)	14	14
				T2	15 (0.0)	9	14
Ulmaceae	<i>Trema orientalis</i>	S2	6	T3	0	n.a.	n.a.
				T4	53 (7.3)	47	40
				T6	0	n.a.	n.a.
				T7	0	n.a.	n.a.
				T8	12 (1.7)	19	7
				T9	48 (6.0)	16	12

Ecology as defined (Kooyman 1996, Shea 1992 and this author) by successional status: S1 = pioneer; S2 = early secondary; S3 = late secondary; S4 = climax. Seed weight (n > 50) in milligrams (+ indicates weight of woody capsule containing multiple seed). Treatment: see Table 2.1. G = mean % germination (n = 20 x 3 replicates) standard errors in parentheses. DG = number of days from the start of the experiment to the onset of germination. S₅₀ = number of days following the onset of germination for 50% of total germination to occur. n.a. = not available.

germination treatment and succession were significant and there was a significant (F(12,193) = 5.8, p < 0.001) succession by pre-germination treatment interaction.

Examination of this interaction revealed that pre-germination treatment (nicking, boiling water and the combination of nicking and darkness) markedly increased germination in pioneer species. Factorial analysis conducted on (DG) days to onset of germination (log transformed) revealed significant main effects for succession ($F(3,187) = 6.7, p < 0.001$) and pre-germination treatment ($F(3,187) = 6.5, p < 0.001$). The time to onset of germination was significantly lower in pioneer species (5 ± 9.9 days) compared to early secondary (14 ± 7.6 days) and climax (35 ± 7.5 days) successional groups. Maternal fruit pre-germination treatment (T4) markedly increased time to onset of germination compared to all other treatments. Factorial analysis conducted on germination index (S_{50}) revealed a significant ($F(12,187) = 2.2, p = 0.012$) succession by pre-germination treatment interaction. Pre-germination treatments reduced S_{50} in pioneer species compared to the control T1 (no pre-germination treatment).

One-way analysis of variance was conducted to assess the relationship between seed weight (log transformed) and succession. The ANOVA was significant ($F(3,23) = 3.4, p = 0.034$), and the T-tests (Tuckey's HSD) showed significant difference ($p \leq 0.010$) between climax species (3.7 ± 2.3 g) and pioneer (10 ± 2.0 mg) and early secondary (81 ± 53.9 mg) species. One-way analysis of variance was conducted to assess the relationship between successional status and onset of germination, and the relationship between successional status and germination index but the results were not significant.

2.3.2 *Species and within species comparisons of pre-germination treatments*

Following pre-germination treatment, germination of seven species (*Acacia aulacocarpa*, *A. bakeri*, *A. melanoxylon*, *Alphitonia excelsa*, *Grevillea hilliana*, *G.*

robusta, *Rhodosphaera rhodanthema*) was significantly ($p < 0.05$) increased compared to that of species without pre-germination treatment. The most effective treatments were nicking (five species) and boiling water (four species), which gave on average 597% and 652%, increases respectively. Some pre-germination treatments significantly ($p < 0.05$) reduced germination in five species (*Citronella moorei*, *Grevillea robusta*, *Pittosporum venulosum*, *Terminalia sericocarpa*, *Trema orientalis*). Leaving the fleshy fruit on the seed (T4) and boiling water treatment (T3) significantly reduced mean germination of *Terminalia sericocarpa* and *Trema orientalis* whilst nicking (T2), dark (T5), maternal fruit presence and boiling water (T6), maternal fruit presence and darkness (T7) and the combination of nicking and darkness (T8) treatments significantly reduced mean germination percentage at least in one species (Table 2.2). One-way analysis of variance was conducted to examine the relationship between treatment and onset of germination and the relationship between treatment and the germination index for individual species. The mean number of days to onset of germination (DG) was significantly different between treatments ($F(4,10) = 10.6, p = 0.001$). DG decreased following pre-germination treatment (scarification, dark, and combined scarification and dark) compared to no pre-germination treatment for *Acacia melanoxylon* from 9 days to 1 day. Similarly, DG was significantly decreased ($p < 0.001$) for *Rhodosphaera rhodanthema* by nicking (T2) and boiling water (T3) pre-treatments. The mean number of days to onset of germination significantly increased following the maternal fruit presence treatment (T4) for *Terminalia sericocarpa* ($p = 0.002$) and following dark treatment for *Castanospermum australe* ($p = 0.023$) compared to no pre-germination treatment. The mean number of days to reach 50% of maximum germination following the onset of germination

(S_{50}), significantly decreased after scarification for *Rhodosphaera rhodanthema* ($p = 0.040$) and *Podocarpus elatus* ($p = 0.001$) compared to no pre-germination treatment. The dark treatment significantly increased ($p = 0.044$) S_{50} compared to no pre-germination treatment for *Castanospermum australe*.

2.3.3 Patterns of germination

The onset of germination (DG) for species without pre-germination treatments (T1) varied widely, from < 7 days to > 250 days (Table 2.2). Fifty percent of the species (T1) germinated in 7 days or less whilst 14% of the species took more than 50 days to begin germination. Where effective in enhancing germination, treating the seed tended to reduce the time to onset of germination (eg *Acacia* spp. treated by nicking).

Similarly, the germination index as measured by S_{50} (the time to reach 50% of the total germination, following the onset of germination), varied widely for seed without pre-germination treatment. Forty-three percent of the species exhibited rapid germination ($S_{50} < 15$ days) whilst 11% had slow germination ($S_{50} > 190$ days).

Hierarchical cluster analysis, an agglomerative procedure using squared Euclidean distance to measure proximity of individuals and Ward's method of clustering individuals into groups, was used to identify five major groups of species with similar patterns of germination (without pre-germination treatment - Table 2.3).

2.4 Discussion

Collection, storage, treatment and germination are important tasks in nursery production of rainforest cabinet timber seedlings, and data from these trials could

have a direct application to the industry and to farmers wishing to implement their own farm forestry projects. The germination of 35 rainforest trees varied widely, from 0% to 100%. Similar variation has been noted for Australian rainforest species by Floyd (1989) and Jones (1986) and other authors. Many species germinated

Table 2.3 Germination characteristics for five major groups of Australian rainforest timber species.

Type	Species	Description
Rapid-High	<i>Agathis robusta</i> , <i>Argyrodendron trifoliolatum</i> , <i>Blepharocarya involucrigera</i> , <i>Flindersia australis</i> , <i>F. xanthoxyla</i> , <i>Grevillea robusta</i> , <i>Harpullia pendula</i> , <i>Toechima tenax</i> .	Mean days to onset of germination 2 days (s.e. = 0.3), mean germination high 86% (s.e. = 3.5), mean germination index (S_{50}) 11days (s.e. = 1.1), see Fig. 2.1.
Rapid-Moderate	<i>Alphitonia excelsa</i> , <i>Flindersia brayleyana</i> , <i>F. schottiana</i> , <i>Toona ciliata</i> .	Mean days to onset of germination 1 days (s.e. = 0.0), mean germination moderate 44% (s.e. = 6.2), mean germination index (S_{50}) 12 days (s.e. = 1.0), see Fig. 2.2.
Delayed-High	<i>Castanospermum australe</i> , <i>Euodia elleryana</i> , <i>Pittosporum venulosum</i> , <i>Pleiogynium timorense</i> , <i>Podocarpus elatus</i> .	Mean days to onset of germination 28 days (s.e. = 5.0), mean germination high 86% (s.e. = 5.0), mean germination index (S_{50}) 48 days (s.e. = 15.7), see Fig. 2.3.
Delayed-Moderate	<i>Acacia aulacocarpa</i> , <i>A. bakeri</i> , <i>A. melanoxylon</i> , <i>Grevillea hilliana</i> , <i>Stenocarpus sinuatus</i> , <i>Terminalia sericocarpa</i> , <i>Trema orientalis</i> .	Mean days to onset of germination 12 days (s.e. = 2.5), mean germination moderate 40% (s.e. = 9.6), mean germination index (S_{50}) 22 days (s.e. = 4.5), see Fig. 2.4.
Very Delayed-Low	<i>Citronella moorei</i> , <i>Elaeocarpus grandis</i> , <i>Rhodospaera rhodanthema</i> .	Mean days to onset of germination 190 days (s.e. = 59.5), mean germination low 14% (s.e. = 4.9), mean germination index (S_{50}) 38 days (s.e. = 28.7), see Fig. 2.5.

readily and germination was further enhanced following pre-germination treatments (manual scarification, boiling water).

Species with high germination (>85%), whether inherent or following pre-germination treatment could be used for direct seeding into pots, streamlining the

nursery production process. These species may also be candidates for direct seeding into the field. There are however, many factors (eg. growth rates, hardiness, competition, availability of bulk seed lots) that condition the success of direct seeding in regeneration projects.

Low to moderate natural germination levels may be improved with pre-germination treatments, as was shown for *Acacia aulacocarpa*, *A. bakeri*, *A. melanoxylon*, *Alphitonia excelsa*, *Grevillea hilliana*, *G. robusta*, and *Rhodosphaera rhodanthema*.

Fresh seed of Silver Quandong (*Elaeocarpus grandis*), a highly regarded farm forestry timber species, had maximum germination of 33% and required in excess of 250 days to commence germination. Nurserymen often wait 6-12 months for fresh seed to germinate. Seed collectors specifically harvest last years seed from beneath parent trees in order to overcome lengthy delays in the commencement of germination. Effective pre-germination treatments have not been reported in the literature.

Some pre-germination treatments can have a detrimental effect on germination.

The pre-germination treatments using boiling water (T3, T6 and T7) may have exposed the seed of some species (non-Acacias) to unusually high temperatures.

Failure to remove the fleshy fruit covering the seed significantly reduced germination in *Citronella moorei*, *Terminalia sericocarpa* and *Trema orientalis*.

Manual scarification can prove difficult and time consuming when seed is very small (eg *Trema orientalis*). *Dysoxylum muelleri*, *Euroschinus falcata*, *Gmelina leichardtii*, *Paraserianthes toona* and *Pittosporum undulatum* failed to germinate, probably due to poor quality seed. *Elaeocarpus kirtonii* and *Owenia venosa* which also failed to germinate have been reported (Floyd 1989, Jones 1986) as very

difficult to germinate. Seed weights vary widely from the tiny (< 6 mg) seed of *Toona ciliata* and *Trema orientalis* to the robust (> 13 g) seed of *Elaeocarpus grandis* and *Castanospermum australe*. Floyd (1989) reports similar seed weights for the species trialed.

The results from this study confirm germination characteristics reported by other authors (Floyd 1989; Jones 1986; Sanderson 1998; and Searle 1989) that many rainforest timber species germinate readily and that selective pre-germination treatment can enhance germination.

The overall pattern of germination for species trialed (excluding those which failed to germinate) were separated into five major groups (Table 2.3 and Figs 2.1-2.5):

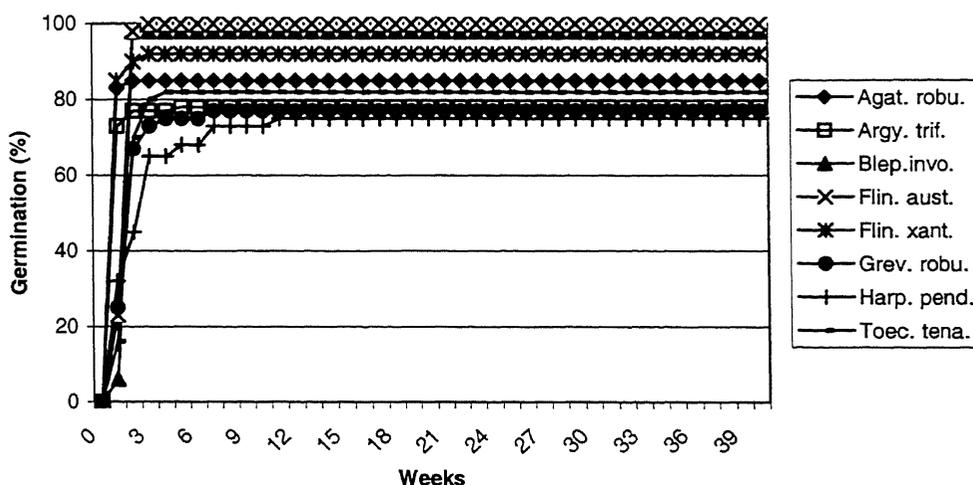


Figure 2.1 Rapid-High germination pattern (See Table 2.3 for definition of terms). (Agat. robu. = *Agathis robusta*; Argy. trif. = *Argyrodendron trifoliolatum*; Blep. invo. = *Blepharocarya involucrigera*; Flin. aust. = *Flindersia australis*; Flin. xant. = *Flindersia xanthoxyla*; Grev. robu. = *Grevillea robusta*; Harp. pend. = *Harpullia pendula*; Toec. tena. = *Toechima tenax*)

Rapid-High. The species associated with this group (Fig. 2.1) are long-lived, late secondary and climax rainforest trees found in the rainforests of southeast Queensland (with the exception of *Blepharocarya involucrigera* found in north Queensland). Their seeds mature in spring and summer, prior to the onset of the

wet season.

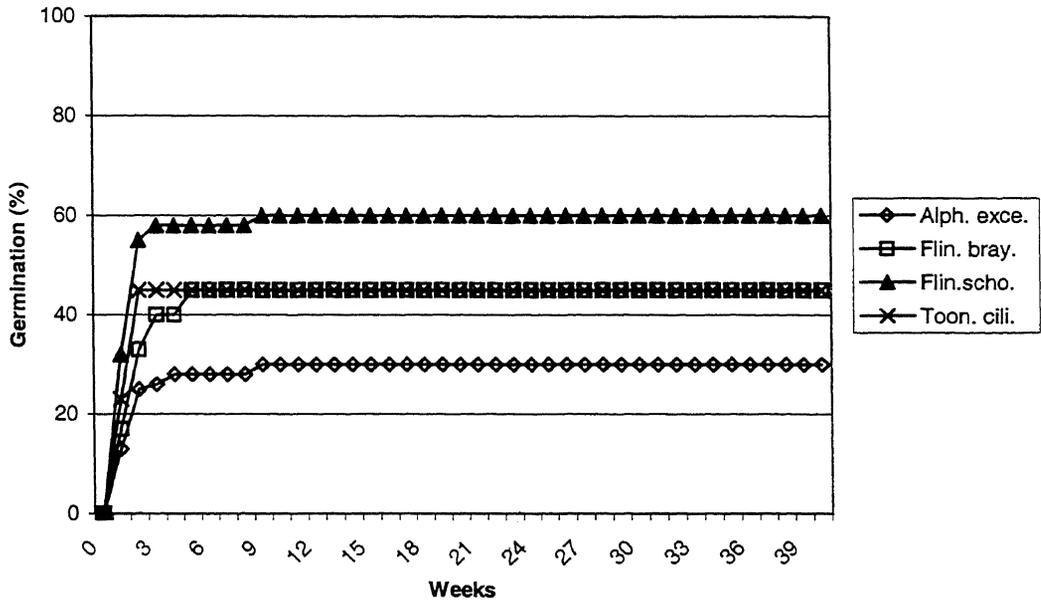


Figure 2.2 Rapid-Moderate germination pattern (Table 2.3).

(Alph. exce. = *Alphitonia excelsa*; Flin. bray. = *Flindersia brayleyana*; Flin. scho. = *Flindersia schottiana*; Toon. cili. = *Toona ciliata*.)

Rapid-Moderate. This group (Fig. 2.2) of species are found in north Queensland rainforest and are part of early to late secondary succession species.

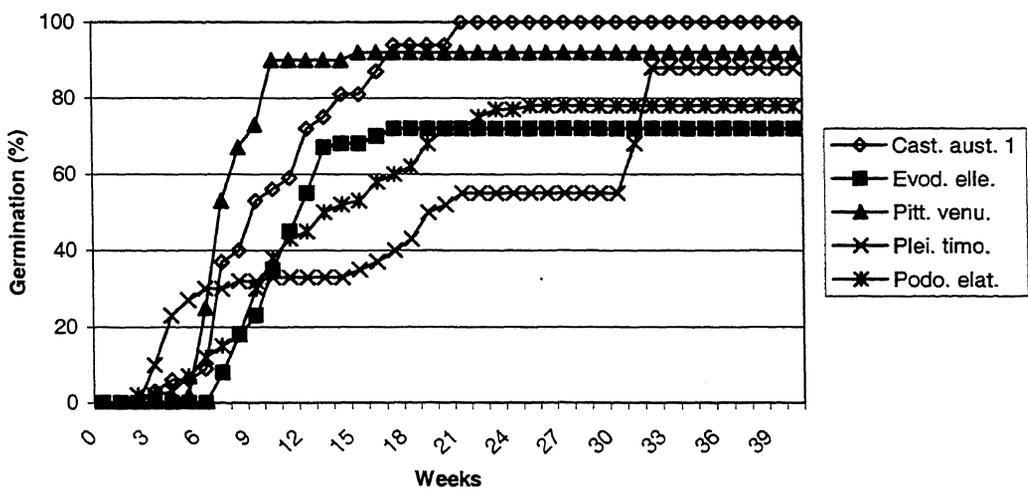


Figure 2.3 Delayed-High germination pattern (Table 2.3).

(Cast. aust. = *Castanospermum australe*; Evod. elle. = *Euodia elleryana*; Pitt. venu. = *Pittosporum venulosum*; Plei. timo. = *Pleiogyinium timorense*; Podo. elat. = *Podocarpus elatus*.)

Delayed-High. Three species are long-lived climax trees (*Castanospermum australe*, *Pleiogynium timorense*, *Podocarpus elatus*) whose seed is mature at the end of the wet season. Two early secondary successional species (*Euodia elleryana*, *Pittosporum venulosum*) have seeds that mature in winter. High rates of germination staggered over many weeks (Fig. 2.3) are likely to ensure that some seed encounter favourable conditions for germination and growth.

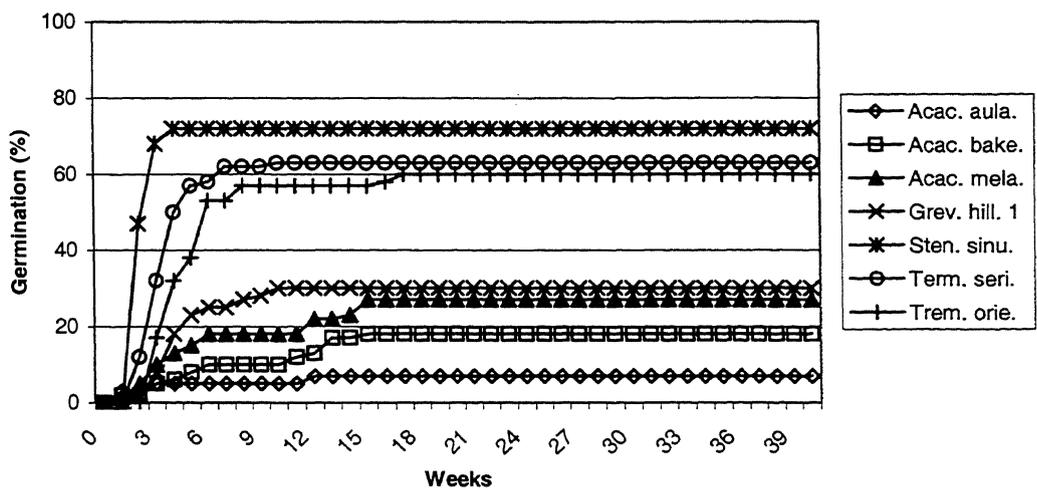


Figure 2.4 Delayed-Moderate germination pattern (Table 2.3).

(Acac. aula. = *Acacia aulacocarpa*; Acac. bake. = *Acacia bakeri*; Acac. mela. = *Acacia melanoxylum*; Grev. hill. = *Grevillea hilliana*; Sten. sinu. = *Stenocarpus sinuatus*; Term. seri. = *Terminalia sericocarpa*; Trem. orie. = *Trema orientalis*)

Delayed-Moderate. These species germinate readily when their seedcoat-imposed dormancy is broken (Fig. 2.4). Once broken, they germinate faster than species from other delayed germination groups but slower than those from the rapid germination groups.

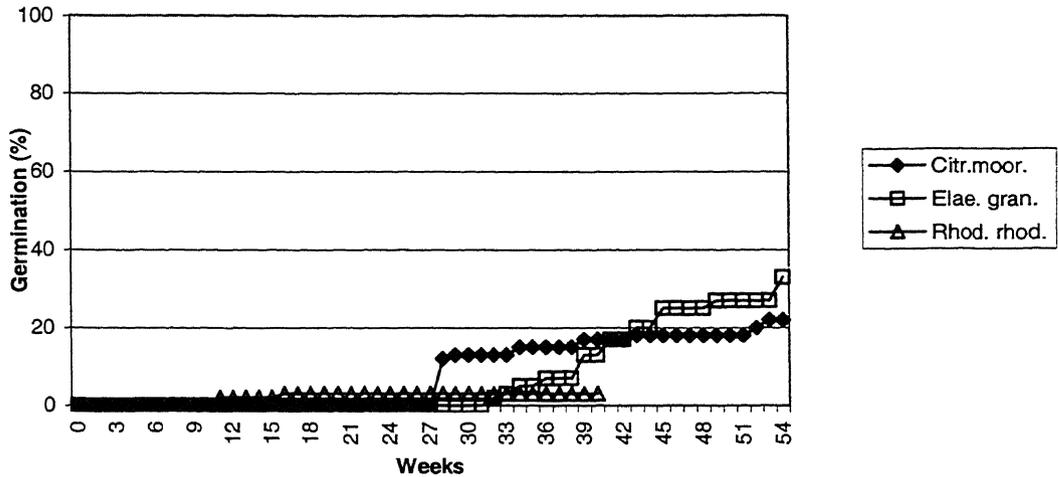


Figure 2.5 Very Delayed-Low germination pattern (Table 2.3).

(Citr. moor. = *Citronella moorei*; Elae. gran. = *Elaeocarpus grandis*; Rhod. rhod. = *Rhodospaera rhodantha*.)

Very delayed-Low. These species (Fig. 2.5) are long-lived late secondary and climax trees with hard seed coats. They produce seed in summer, around the beginning of the wet season, but require breakdown of their seedcoat before germination can proceed. This may well occur in more favourable conditions following the dispersal of seed.

The germination trials commenced within two weeks of seed acquisition (harvest from rainforest remnants and isolated trees or purchase from reliable seed merchants) in an attempt to reduce error related to 'time of storage' differences between species.

2.5 Conclusions

Tropical rainforest seed ecology is diverse reflecting the diversity of this plant community (Yanes and Segovia 1993). Australian rainforest timber species displayed great variation in patterns of germination (Table 2.2). These patterns

reflect reproduction strategies designed to optimise the distribution and successful germination of species. Selective pre-germination treatments were an effective method of increasing germination levels in some species. Rainforest cabinet timber seed is available from reputable seed merchants in Queensland, including the Department of Primary Industries (DPI Seeds). Whilst some seed stores well, and is available year round, others are recalcitrant and must be sown soon after harvest. Recalcitrant seed has a short shelf life, is subject to availability only at harvest time and must be ordered in advance. Nursery production of tree seedlings for mixed species plantings requires a variety of species for a single phase of planting, often the wet season. The ability to predict high levels of germination enables nurseries to sow directly into pots, reducing transplant shock and labour costs. Knowledge of germination ecology enables nurseries to accurately plan seedling production.

Following successful seed germination, seedlings require a suitable environment to maintain growth. Light requirement is an important component of rainforest plant growth and artificial modification of this will be examined in Chapter three and the response of seedlings to light and nitrogen treatments in Chapter four.

Chapter 3 Alteration of solar radiation quality and quantity in a shadehouse to simulate natural shade for plants.

3.1 Introduction

3.1.1 Solar radiation in rainforest ecosystems

Solar radiation is a highly variable and often limiting resource within the rainforest community (Yates *et al.* 1988). Leaves in the upper canopy receive 50-200 times more photosynthetically active radiation (PAR) than those beneath a closed canopy on the forest floor. In this thesis PAR is used to refer to irradiance measured in energy units (W m^{-2}) for wavelengths from 400 to 700 nm and PPFD (photosynthetic photon flux density) refers to the number of photons per unit area per unit time ($\mu\text{mol m}^{-2} \text{s}^{-1}$), for wavelengths between 400 to 700 nm (Salisbury and Ross 1992). The leaves of understorey plants receive 50-80% of their daily PAR levels in the form of sunflecks (direct beams of sunlight with high red/far-red ratios (R:FR)) varying in intensity and duration measured from seconds to minutes (Turnbull *et al.* 1993). The remainder of the PAR they receive is in the form of diffuse light of low intensity and low R:FR. This is because the quality of light changes due to the differential absorption of different wavelengths as light passes through the canopy. Radiation beneath a closed canopy is characterized by a low R:FR (0.2-0.5) compared to high R:FR (>0.9) for the upper canopy (Turnbull and Yates 1993).

Disturbance within the rainforest is capable of producing gaps of varying sizes within the canopy resulting in an increase in the amount of direct light reaching the forest floor. Average radiation levels increased from 0.5-2% of full sunlight

for the forest floor beneath a closed canopy to 2-6% for a small gap (50 m²) and to 39-53% for a large gap (500 m²) within a Mexican rainforest (Pompa and Bongers 1988). Similar radiation levels have been measured in the understorey and gaps within Australian subtropical rainforest (Turnbull and Yates 1993).

3.1.2 Ecophysiological responses to changes in PAR intensity and spectral quality

Variations in the quantity and quality of solar radiation within natural environments have a significant effect on plant productivity and plant development processes (Turnbull and Yates 1993). Far red light has a pronounced effect on stem elongation (Smith 1982) and specific leaf area (Newton *et al.* 1996). Under simulated shade environments morphological responses in rainforest sapling growth for height (Ashton 1995; Lee *et al.* 1996; Newton *et al.* 1996), stem diameter and internode length (Lee *et al.* 1996; Newton *et al.* 1996), leaf area, number and mass (Ashton 1995; Lee *et al.* 1996) have been studied.

Photosynthetic responses to various levels of solar radiation intensity have also been examined (Barker *et al.* 1997; Chow *et al.* 1988; Kwesiga *et al.* 1986; Lee *et al.* 1996; Thompson *et al.* 1988; Turnbull 1991).

Knowledge of the variation in growth characteristics of species in response to contrasting light environments can be applied to mixed species rainforest plantings. Differential growth (height) rates can lead to stratification within the plant community. Following canopy closure, understorey plants will receive a marked reduction in light intensity as well as a shift in the spectral quality of the incoming radiation. Cabinet timber species that are able to maintain moderate to

high growth rates in this understorey environment can be incorporated into any afforestation project, thereby increasing potential timber resources.

3.1.3 The altering of solar radiation intensity and spectral quality in plant research

In plant research, the alteration of solar radiation intensity and spectral quality has been achieved using a variety of approaches e.g. shadecloth, shade film, photographic light filters, and incandescent/fluorescent light. Small experiments in controlled growth rooms have used expensive photographic light filters (Kwesiga *et al.* 1986; Turnbull 1991) or incandescent/fluorescent lights (Chow *et al.* 1988). Larger experiments have used expensive coated film applied to glass or durable plastic (Lee *et al.* 1996). Ashton (1995), Lee (1988), and Lee *et al.* (1996) describe shadehouse experiments using painted polyfilm to alter solar radiation intensity and spectral quality in order to simulate natural forest shade. In large shadehouse experiments light intensity was modified using a range of shade cloths (Augspurger 1984; Maruyama *et al.* 1997) and plastic sheeting (Huante and Rincon 1998) but induced modifications of spectral quality were not reported. Such ecophysiological research that has studied the effects of solar radiation intensity but not spectral quality may not relate directly to the natural shade environment (Press *et al.* 1996). Some ecologists have chosen to conduct experiments within natural rainforest. Contrasting light environments were created by differential removal of the canopy, creating 'natural' light environments, which were characterized by reduced light intensity and reduced R:FR as well as the presence of sunflecks.

Healy and Rickert (1998) examined the proportion of diffuse radiation under commercial shading materials but did not report data on R:FR levels. Lee (1985) examined solar radiation intensity and spectral quality for a variety of shadefilms, including commercial shade cloth and painted plastic sheeting. He was able to reduce solar radiation intensity and alter spectral quality by the use of paint pigments applied to plastic sheeting. Commercial shade cloth whilst altering solar radiation intensity, had little effect on R:FR.

Coloured plastic sheeting has also been used as reflective mulch in capsicum (Kaul and Kasperbauer 1992), tomato (Decoteau *et al.* 1989) and in trials of other species (Hunt *et al.* 1989), to alter the spectral composition of light absorbed by plants.

3.1.4 *Aims of the experiment*

The aims of this experiment were:

- 1) to build inexpensive growth facilities in which to examine the effects of solar radiation intensity and spectral quality on growth characteristics of Australian rainforest cabinet timber species.
- 2) to produce three shade environments (4 replicates) that closely simulate natural conditions (1. Control, clear film 80% full sunlight, R:FR 1.0; 2. Moderate shade, blue film 15% full sun, R:FR 0.7; 3. Heavy shade, dark green film, 5% full sun, R:FR 0.5).

3.2 Materials and Methods

3.2.1 Construction

Four tunnel shadehouses were constructed on campus at Central Queensland University, Rockhampton in 1998 and maintained over the period 1998-2000. The tunnel shadehouses were constructed using 7 mm reo steel (F72) and wire ties. Central poles on each doorway, wire guys and steel star pickets provided extra stability. The shadehouses were covered in 150 μ m polyfilm and divided internally into three compartments. These structures were positioned in open sunlight, however large distant neighbouring trees caused a shading effect at low solar angles (notably replicates 1 and 3 after 2 pm daily).

Each shadehouse, with the relevant shadefilm, had a maximum height of 1.9 m and a floor dimension of 4.5 m x 3.8 m. A 0.6 m wide vent at the top, along the length of the shadehouse, provided ventilation. A shadefilm covered steel frame construction 1.2 m x 4.5 m positioned 0.2 m above the vent, maintained shade over the vent. Black plastic sheeting was laid over a dirt floor to reduce the effect of reflected light and to maintain a seal from the outside environment.

3.2.2 Shade compartments

Shadehouses were divided internally into three integral compartments using polyfilm sheeting and painted with exterior water based household paint in order to create blue and dark green compartments. The third was left clear as a control. The pigments recommended by Lee (1985) were unavailable locally and attempts to obtain similar pigments in Australia were unsuccessful. A wide variety of paints and dyes were tested for their transmitted light quality in comparison with natural solar radiation spectral quality (Table 3.1). Transmitted light quality

through the various dyes and painted film was measured by a Skye SDL S190 Datalogger 2 datalogger integrated with a 660 nm/730 nm sensor, placed in a light proof box, 10 cm beneath a painted polyfilm lid. The paint mixture that produced the best results was 75:25 “Ashley Blue”/ water for the blue compartment and 50:50 mixture “Ashley Blue”/”Flavus” for the green compartment. The clear polyfilm was painted using a roller to ensure an even coverage of paint prior to being secured to the shadehouse structures.

Table 3.1 R:FR measurements for natural light environments and beneath painted and dyed plastic sheeting

Light environment	R:FR
Clear day	1.01
Cloudy day	1.44
Heavy mango shade	0.15
Rainforest understorey at Kershaw Gardens, Rockhampton	0.24
Paint type	
Spray paint “Dark green”- White Knight Paints, Seven Hills, Australia	0.80
Spray paint “Light green”- White Knight Paints, Seven Hills, Australia	0.98
Permaset fabric dye “Red Violet”- Colourmaker Industries, Brookvale, Australia.	0.95
Permaset fabric dye “Blue”- Colourmaker Industries, Brookvale, Australia.	0.44
Permaset fabric dye “Yellow”- Colourmaker Industries, Brookvale, Australia.	1.00
50:50 mixture of Blue/Yellow, Permaset fabric dyes	0.42
33:33:33 mixture of Red/Blue/Yellow, Permaset fabric dyes	0.32
33:33:33 mixture of Red violet/ Red/Dark Red, Permaset fabric dyes	0.68
75:25 mixture “Ashley Blue”/water – Accent solar low sheen acrylic paint, ICI Australia, South Melbourne, Australia.	0.69
50:50 mixture of “Ashley Blue”/ “Flavus” Yellow Accent solar low sheen acrylic paint, ICI Australia, South Melbourne, Australia.	0.50
Fence paint Viva “Pinewood” green- Wattyl Australia, Canada bay, Australia.	0.44

On four occasions (24.11.98, 18.12.98, 29.06.99, 17.07.99) the shadehouses suffered storm damage and parts of the plastic sheeting had to be reattached or replaced.

3.2.3 Light experiment

The experiment was conducted over a 17-month period from September 1998 to January 2000. The shadehouses were orientated North-South and light readings were taken at the centre of each compartment on a horizontal surface 0.4 m above floor height, equating approximately to average maximum canopy height of saplings at 100 days after the commencement of the growth experiment (Chapter 4). Light quality was recorded for the duration of the experiment, using a Skye SDL S190 Datalogger 2 datalogger fitted with a 660/730 nm sensor.

Solar radiation intensity (PPFD) was recorded using a Licor LI-1000 datalogger fitted with a LI-190SA quantum sensor (400 to 700 nm waveband) and positioned horizontally, adjacent to the Skye R/FR sensor, for short periods (one week) from 15.07.99 to 26.11.99 in order to establish the relationship between R waveband and PPFD. Light readings were also taken at different positions within the compartment to assess the homogeneity of the light environment. Temperatures were recorded using a shielded maximum/minimum thermometer positioned in the center of each compartment, 0.4 m above floor height.

3.3 Results

3.3.1 Variation in transmitted light within compartments

The variation in photosynthetic photon flux density (PPFD) and R:FR during the course of representative cloud-free days, within a 55 day period, for the clear, blue and green compartments is summarized in Figures 3.1, 3.2 and 3.3.

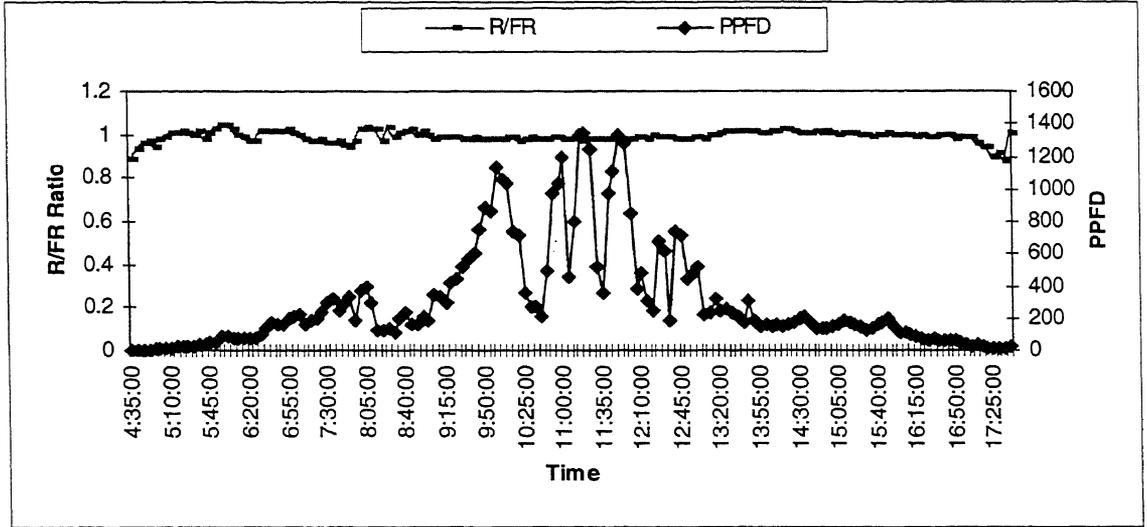


Fig. 3.1 Variation during the course of the day in PPFD ($\mu\text{mol m}^{-2} \text{s}^{-1}$) sampled every 10 seconds, averaged every five minutes and R:FR, sampled every 10 seconds, averaged every five minutes for the clear compartment (replicate 3) on 24.11.99

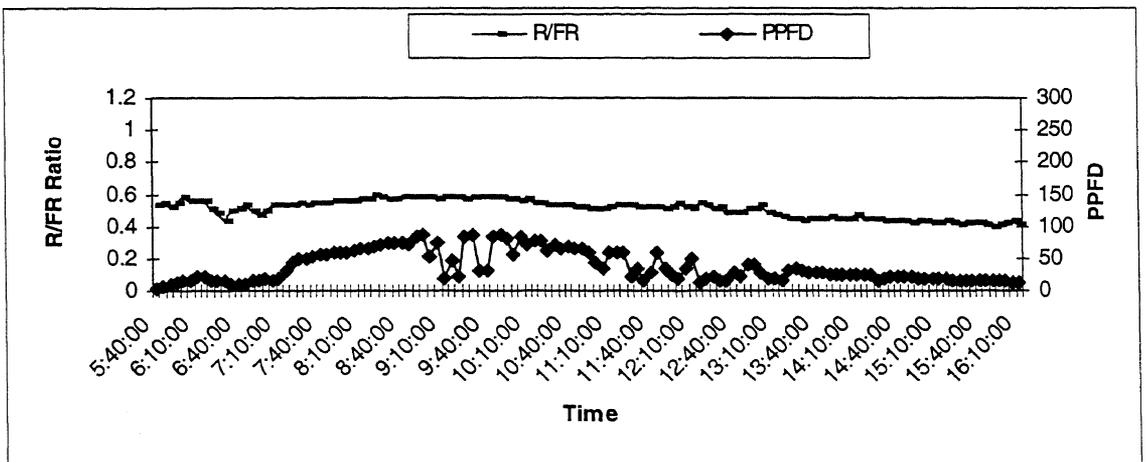


Fig. 3.2 Variation during the course of the day in PPFD ($\mu\text{mol m}^{-2} \text{s}^{-1}$) sampled every 10 seconds, averaged every five minutes and R:FR, sampled every 10 seconds, averaged every five minutes for the blue compartment (replicate 4) on 13.11.99

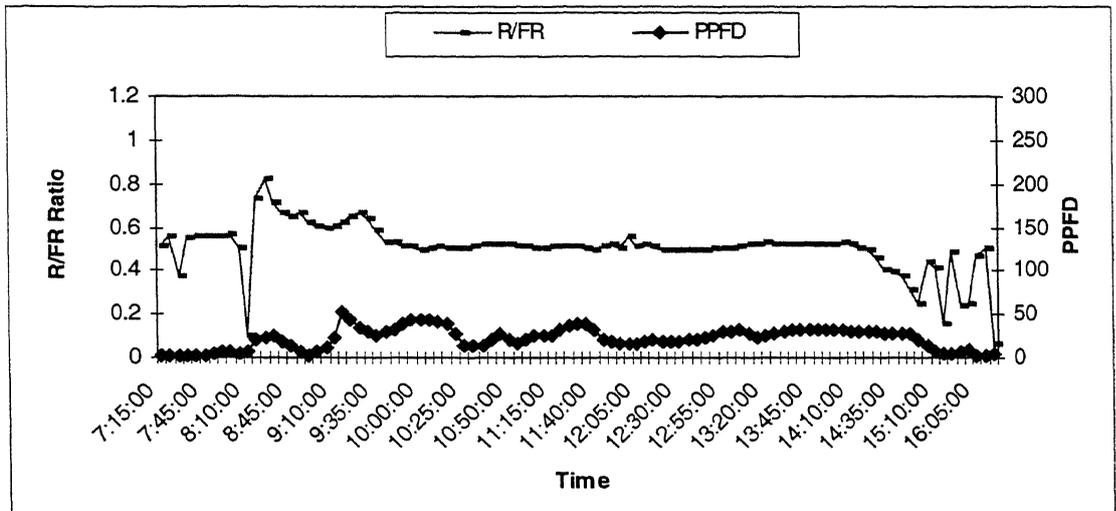


Fig. 3.3 Variation during the course of the day in PPFD ($\mu\text{mol m}^{-2} \text{s}^{-1}$) sampled every 10 seconds, averaged every five minutes and R:FR, sampled every 10 seconds, averaged every five minutes for the green compartment (replicate 4) on 02.10.99

There was little variation in R:FR during the course of a given day for the clear, blue and green compartments. The green compartment exhibited the greatest variation in the early morning and late afternoon when solar angles were low and the chamber was marginally shaded by tall trees. The diurnal trend of PPFD in the clear and blue compartments exhibited greatest variation between the hours of 9 AM and 2 PM, due to interference of light by the supporting poles of the shadehouse. The total 5-min PPFD averages for each compartment indicate that the blue received 9.8% and the green 4.5% of the total light received by the clear compartment for the days indicated.

3.3.2 Relationship between daily total PPFD and the daily total R (660 nm)

The relationship between the daily total incoming irradiance in the (660 nm) R waveband ($\mu\text{mol m}^{-2} \text{day}^{-1}$) and the daily total PPFD ($\mu\text{mol m}^{-2} \text{day}^{-1}$) was determined from readings taken in the clear, blue and green compartments during

October and November 1999 (Fig. 3.4). The PPFD and R data were log transformed prior to regression analysis.

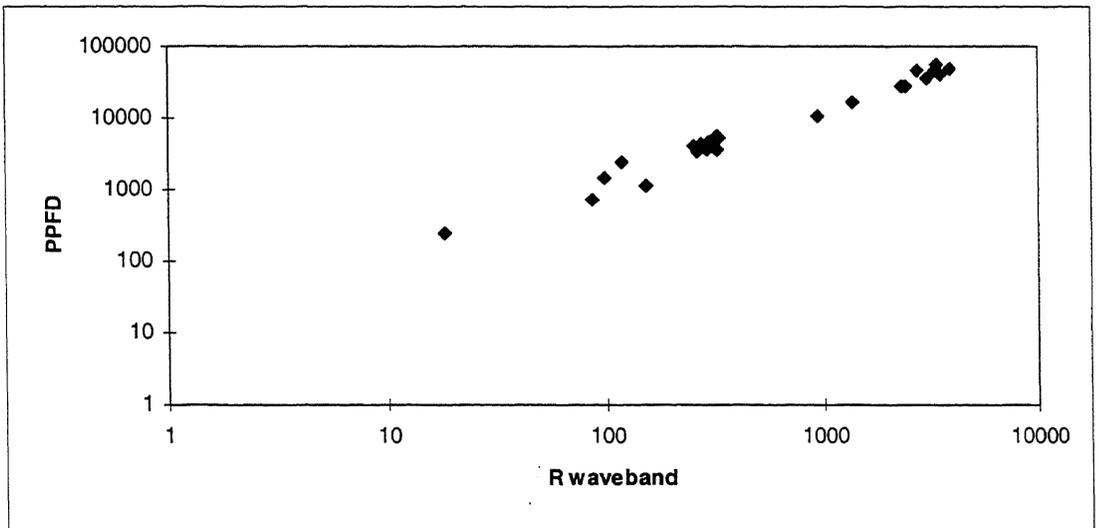


Fig 3.4 The relationship between daily total PPFD ($\mu\text{mol m}^{-2} \text{day}^{-1}$) and daily total R waveband ($\mu\text{mol m}^{-2} \text{day}^{-1}$).

There was a strong relationship between the daily total Log R incoming irradiance and the daily total Log PPFD as indicated by Fig. 3.4 ($r^2 = 0.97$, $Y = 1.12 + 1.00X$, $p < 0.001$).

3.3.3 Variation in light between compartments and replicates

On the strength of the relationship between Log R and Log PPFD, daily total

Table 3.2 Daily total PPFD ($\text{mol m}^{-2} \text{day}^{-1}$) means calculated with the model $Y = 1.12 + 1.00 X$ ($Y = \text{Log daily total PPFD } (\mu\text{mol m}^{-2} \text{day}^{-1})$, $X = \text{Log daily total R waveband } (\mu\text{mol m}^{-2} \text{day}^{-1})$) for all compartments (4 replicates). Standard errors in parentheses. n = number of days recorded.

Replicate 1			Replicate 2		
Clear (n = 22)	12.72	(se = 0.483)	Clear (n = 23)	13.55	(se = 0.732)
Blue (n = 17)	3.80	(se = 0.386)	Blue (n = 7)	0.85	(se = 0.123)
Green (n = 19)	1.27	(se = 0.167)	Green (n = 25)	0.99	(se = 0.085)
Replicate 3			Replicate 4		
Clear (n = 33)	10.56	(se = 0.870)	Clear (n = 32)	13.54	(se = 1.031)
Blue (n = 30)	0.92	(se = 0.156)	Blue (n = 39)	1.58	(se = 0.132)
Green (n = 9)	0.84	(se = 0.078)	Green (n = 11)	0.66	(se = 0.079)

PPFD's were calculated for all compartments (Table 3.2). The results (Table 3.2) give an indication of the daily total amount of light (PPFD) received within each compartment.

The variation in R:FR ratio as daily averages of logged results (sampled every 10 seconds averaged every five minutes) between compartments and replicates is summarized in Table 3.3.

Table 3.3 R:FR ratio means (as daily averages of logged results) for shadehouse compartments (4 replicates). Standard errors in parentheses. n = number of days recorded.

	Replicate 1		Replicate 2	
Clear (n = 28)	0.92	(± 0.0169)	Clear (n = 28)	0.98 (± 0.0098)
Blue (n = 26)	0.60	(± 0.0319)	Blue (n = 16)	0.53 (± 0.0123)
Green (n = 23)	0.55	(± 0.0150)	Green (n = 29)	0.57 (± 0.0200)
	Replicate 3		Replicate 4	
Clear (n = 42)	0.93	(± 0.0132)	Clear (n = 37)	0.97 (± 0.0115)
Blue (n = 50)	0.46	(± 0.0117)	Blue (n = 45)	0.57 (± 0.0154)
Green (n = 22)	0.51	(± 0.0243)	Green (n = 13)	0.49 (± 0.0062)

3.3.4 Simulated natural environments

The blue and green compartments in all replicates successfully reduced the solar irradiance and R:FR to levels found within rainforest ecosystems. Two-way ANOVA was conducted to assess the relationship between replicate (1-4), compartment type (clear, blue or green) and R:FR values. The difference between treatments was significant ($F(2,356) = 726.1, p < .001$) and T-tests ((Tukey's HSD) indicated that mean R:FR for the clear compartment (0.95 ± 0.008) was significantly different from the blue (0.54 ± 0.009) and green (0.53 ± 0.010) compartments but the blue and green compartments were not significantly different. Two-way ANOVA was conducted to assess the relationship between replicate (1-4), compartment type (clear, blue or green) and PPFD ($\text{mol m}^{-2} \text{day}^{-1}$)

values. The ANOVA was significant ($F(2,255) = 439.8, p < 0.001$) and T-tests (Dunnnett's T3) indicated that mean PPFD ($\text{mol m}^{-2} \text{ day}^{-1}$) for the clear (12.6 ± 0.29) compartment was significantly different from the blue (1.8 ± 0.39) and green (0.9 ± 0.41) compartments but the blue and green compartments were not significantly different. In order to maintain a balanced design in the statistical analysis of growth responses across light treatments (Chapter four), two significantly different transmitted solar radiation environments were employed:

- A). Clear compartment replicates 1-4, total yearly integral PPFD 4595 ± 107.1 (s.e.) $\text{mol m}^{-2} \text{ yr}^{-1}$, R:FR 0.95 ± 0.008 (s.e.). These values are similar to those of the upper canopy in full sun.
- B). Blue compartment replicates 3 and 4 and green compartment replicates 1 and 2 (were the most similar of the 8 compartments) total yearly integral PPFD 439 ± 35.7 (s.e.) $\text{mol m}^{-2} \text{ yr}^{-1}$, R:FR 0.54 ± 0.009 (s.e.). These values are similar to a gap edge in Australian sub tropical rainforest (Turnbull and Yates 1993).

3.4 Discussion

This shadehouse experiment was able to simulate the natural shade beneath plant canopies using relatively inexpensive materials. Indeed, twenty rainforest cabinet timber species were successfully grown in the clear and shaded compartments (Chapter 4). The painted polyfilm produced a significant reduction in solar radiation and R:FR to levels found in rainforest understoreys. Commercial shading materials tested by Healy and Rickert (1998) and Lee (1985) were unable to significantly reduce R:FR levels. Many researchers have altered the intensity but not the quality of solar radiation and failed to duplicate natural shade

conditions. Measurements of incoming irradiance in the R (660 nm) waveband (as recorded by the Skye datalogger) were used to predict a quantitative estimate of the daily PPF. In a recent study (Olsen 2000) the 530 nm waveband provided the best estimate of total incident PPF under contrasting light conditions. This type of narrowband sensor could provide an inexpensive lightweight alternative to traditional PPF sensors, of particular use with R and FR sensors in studies that require quantification of PPF and light quality.

3.5 Conclusions

Painted polyfilm can be used by researchers to reduce PPF and R:FR in order to duplicate natural foliage shade, in particular that characteristic of understory rainforest light regimes. The precise application of paint to the polyfilm is critical if replication of shading is to be achieved. The impregnation of appropriate dyes into the polyfilm during manufacture could provide researchers with a valuable tool for studying the effects of natural shade on plant development but this is likely to be of high cost compared to the use of commercially available hardware paints. Incorporation of narrow bands of clear film in the painted polyfilm, or a checkerboard approach to painted and non-painted sectors on the polyfilm, might allow the transmission of sunflecks (short bursts of intense sunlight that have proved difficult to duplicate).

Chapter 4 Physiological responses of 20 cabinet timber species to solar radiation and spectral quality

4.1 Introduction

4.1.1 Overview

Mixed species rainforest cabinet timber plantings have the potential to produce high value products for the farm forester. Species selection is usually based on 'best bet' species and fast growing 'local' species recommended by forestry groups. Growth rates of individual species within mixed species plantings are not commonly reported and comparisons between species prove difficult when design, site and early management have a profound effect on growth rates. Farm foresters commonly combine fast growing species with slower growing long-lived species in rainforest cabinet timber plantings with high stocking rates. Canopy closure can occur between three and seven years, leading to stratification within the planting. Slower growing species are then expected to grow in a modified light environment beneath the fast growing species canopy. Few trials have examined juvenile growth rates of Australian rainforest cabinet timber species in light environments characterized by reduced intensity and altered spectral quality of solar irradiance.

The rainforest environment is complex, dynamic and in a state of change. Rainforests are characterized by strongly contrasting light environments. At the top of the canopy and in large forest gaps, the quantity of solar radiation received and temperatures are high whilst humidity is low. In contrast, the forest floor is characterized by reduced quantities of solar radiation (as low as 5% full sun),

bursts of intermittent light termed sunflecks, increased humidity, lowered temperatures and reduced R:FR (< 0.5).

Rainforest species have been classified (Swaine and Whitmore 1988) into two major groups: pioneers requiring full sun for germination and establishment, and climax or late successional species that are able to germinate and establish below a forest canopy. Further study of successional patterns has led to further subdivisions: pioneer; early secondary; late secondary; climax and emergents (Hopkins 1978). Whitmore (1996) reviewed ecophysiological research attempting to define and test these ecological guilds.

Some authors (Barker *et al.* 1997, Press *et al.* 1996) question the validity of subdividing successional groups beyond pioneer and climax groups and point to the wide range of physiological response within climax species to contrasting light and nutrient environments.

Seedling morphology has an important bearing on the survival, establishment and growth of seedlings in a silvicultural planting. The ability of species to allocate plant resources in order to increase height relative to competing species can place individuals in a more favourable growing environment (notably increased light levels). In order to develop long straight boles with large diameters, timber species need to dominate part of the canopy during their life cycle.

4.1.2 Review of the ecophysiology of rainforest species

Cameron and Jermyn (1991) report mean annual height and diameter increments for high value rainforest species in northern Australia. Rates of growth are often greater than 1.0 m/yr height increment and 1.0 cm/yr diameter increment. In their study of Asian tropical rainforest seedlings, Lee *et al.* (1996) found that plant

height was strongly influenced by PPF_D and R:FR whilst stem diameter was primarily influenced by PPF_D. Stem height is linearly related to stem diameter when trees are juveniles (Bongers and Sterck 1998). Stem diameter increments are positively associated with rainfall, for broad-leaved dry rainforests in Thailand (Kamo *et al.* 1995). Growth of stems in height and diameter were either periodic or ever-growing depending on species and are linked to leaf production. Pioneer species tend to have an ever-growing leaf production. In periodic growers, stem diameter increments are associated with quiescence in leaf production.

Allocation of plant resources to leaf production increases at low light levels and is usually lower in pioneer species. Patterns of leaf production in the tropics form three groups: evergreen and ever-growing; evergreen and periodic growth; deciduous (Ackerly 1995). Givinish (1984) discusses the relationship of leaf size to leaf temperature, photocapacity and carbon gain. Mean leaf area has been found to increase with nutrient supply in shade tolerant species (Burslem 1996).

Rainforest species display a broad range of responses to shade, though shade intolerant species appear to respond more strongly to changes in R:FR (Lee *et al.* 1996). Biomass allocation to leaves was generally reduced in low R:FR environments but also varied between species (Lee *et al.* 1996). In low R:FR environments leaves are larger and thinner (Kwesiga and Grace 1986).

Tree architecture determines in part the ability of species to intercept light as well as providing mechanical stability. The architecture (branching pattern and shape of the crown) varies widely among tropical and subtropical tree species (Halle *et al.* 1978). The sapling branching pattern of the Australian cabinet timber species being trialed, typically bear nearly horizontal branches on a vertical stem and can be subdivided into two groups; tiered (e.g. *Agathis robusta*, *Elaeocarpus grandis*,

Podocarpus elatus) or non-tiered (e.g. *Castanospermum australe*, *Gmelina leichardtii*). Relative crown depth (RCD)((total height minus height to lowest node with either leaf or branch)/total height), is known to increase with tree height and increasing light levels, though variability is large. Light from above, favours wide shallow crowns whilst lateral light favours deep narrow crowns (Bongers and Sterck 1998). However Lee *et al.* (1996), in his study of Asian tropical rainforest seedlings, found that branching was not strongly influenced by the light environment.

Stem allometry is the relationship between tree height and stem diameter, and reflects the allocation of resources to mechanical support under a given set of environmental conditions (Claussen and Maycock 1995). Significant differences in stem allometry were found across successional groups in a north Queensland rainforest. Slenderness, the height/stem diameter ratio (H/D), has an effect on mechanical stability and the ability of the main stem to remain vertical and is known to decrease with tree height (Bongers and Sterck 1998). However a single allometric function may oversimplify the relationships, as it has been noted that H/D also changes with time (Claussen 1996). Changes in environment over time, especially light, wind, falling debris and changes in wood density with age may all have a great effect on stem diameter.

Whitmore (1996) reviews the photosynthetic responses of tropical rainforest species to changing light environments. Pioneers characteristically have higher mesophyll conductance, apparent quantum efficiencies and light compensation points. Shade tolerant species show lower rates of light saturated photosynthesis and dark respiration. In pioneer species the adult leaves have recorded maximum photosynthetic rates exceeding $20 \mu\text{mol m}^{-2} \text{s}^{-1}$. However the differences in

maximum photosynthetic rate between pioneers and shade tolerant species may be quite small (Kitajima 1994).

The R:FR photon ratio is a standardized measure of light quality

$$\text{R:FR} = \frac{\text{photon irradiance between 655 and 665 nm}}{\text{Photon irradiance between 725 and 735 nm}} \quad (\text{Smith 1986a}).$$

Vegetation absorbs R (655-665 nm) whilst it is transparent to FR (725-735 nm), thus light passing through a canopy has an R:FR ratio proportional to the amount of leaf material through which the light passes. Canopy and leaf architecture and leaf density can all have marked effects on R:FR ratios, for example deep mango shade has R:FR of 0.15 and understorey rainforest has a value of 0.24 (Table 3.1, Chapter 3). A number of experiments have clearly indicated that R:FR has a profound effect on patterns of growth and development. Leaf morphology, stomatal frequency, leaf epinasty, plastid pigment levels, nitrate reductase activity, seed germination and stem elongation are all affected by levels of R:FR (Smith 1986a). However many studies investigating early growth of rainforest seedlings in contrasting light environments have failed to significantly alter R:FR levels (Langenheim *et al.* 1984, Thompson *et al.* 1992a, Huante and Rincon 1998), their observed responses being almost entirely due to differences in light quantity. Impregnated plastic film or painted plastic sheeting has been used in some shadehouse trials to alter R:FR levels (Lee 1988, Kitajima 1994, Lee *et al.* 1996). Whilst successfully simulating natural R:FR levels, these trials have been unable to replicate sunflecks, which are capable of providing substantial increases (30%-60%) in total carbon gain in the forest understorey (Whitmore 1996). Because of the difficulty in replicating sunflecks in controlled environments,

Whitmore suggests that future ecophysiological trials need to be conducted within natural rainforests in order to duplicate natural light conditions.

This chapter examines the early growth of 20 species of Australian rainforest cabinet timbers across a range of light environments and two nitrogen treatments, as a prelude to providing the nascent farm forestry industry with relevant information on nursery and early field management practices. The objectives of the early growth trial are to: (a) describe growth conditions suitable for seedling production in the nursery and establishment in the field; (b) predict competition between species; (c) examine the usefulness of ecological groups, based on successional status, in predicting patterns of growth in response to light and nitrogen treatments. The 20 species were chosen for their timber value and suitability for rainforest mixed species plantings. All these species are found within and around the edge of Australian rainforests and have the potential to grow into large canopy trees. Many of the species are long lived. Non-destructive growth and photosynthetic measurements were used for assessment of species and treatment combinations, as potted seedlings were required for a farm forestry field trial following the experiment.

4.2 Materials and methods

The early growth trials were conducted in specially constructed shadehouses (see Chapter three for details), between September 1998 and December 1999. Each shadehouse was designed to provide three contrasting light environments:

1. Control, full sunlight (FS), clear film 80% full sunlight, R:FR 1.0;
2. Moderate shade (MS), blue film 15% full sun, R:FR 0.7;
3. Heavy shade (HS), dark green film, 5% full sun, R:FR 0.5

Seedlings of all species, maximum height 50 cm and less than six months old, were purchased from nurseries, repotted into 255 mm diameter pots, soil depth 200mm, pot height 235 mm, using a commercial garden soil. Soil analysis reported pH 6.6, electrical conductivity 0.4 mS cm^{-1} , NO_3^- 35 ppm, PO_4^{2-} 71 ppm, K^+ 118 ppm, Ca^{2+} 1789 ppm, Mg^{2+} 414 ppm, Na^+ 175 ppm, SO_4^{2-} 81,000 ppm, Zn 2.5 ppm, Cu 0.6 ppm, Fe 9.9 ppm, Mn 0.7 ppm, B 0.2 ppm, organic matter 2.2%. Fertiliser was not added to the soil mix. In order to improve pot drainage coarse river sand was added to the potting mix in the proportion one part sand to three parts soil. Nitrogen treatments comprised: (a) control, no added nitrogen over the duration of the experiment; (b) added nitrogen at a rate of 100 mg of urea dissolved in 250 ml of water per plant, applied once a week for the duration of the experiment. Pots were watered using a microprocessor automated water allocator via a 25 mm main line and 4 mm feed lines to each pot. Timing and volume of applied water were balanced to provide daily watering to field capacity. In summer watering was twice daily (early morning and late afternoon) for five minutes, at 0.18 litres/min, whilst in winter it was reduced to a single early morning watering at the same rate. Pots were placed in a square pattern, with 40 cm spacing between the centre of each pot, on black plastic sheeting to avoid possible contact with the soil. Drain holes in the sheeting were required to prevent water collecting in pools.

One seedling of each species per nitrogen treatment was randomly assigned to every light compartment. Light treatments were replicated four times, and each species by nitrogen combination was therefore represented in each light treatment x block. To reduce the confounding effects of shading by nearest neighbours, seedlings were rearranged on a monthly basis, with the tallest plants against the

southern wall. Prior to the commencement of the experiment there was a settling-in period of two weeks for the potted plants in their new environments.

Some species grew rapidly and reached the shadehouse roof (1.8 to 2.0 m) after 150 days. As plants reached this height they were removed from the experiment for final analysis. Height, stem diameter and number of branches were measured for each species at the beginning of the experiment. Height and stem diameters were measured at 4-5 week intervals for the duration of the experiment. Leaf blade length (LBL), total number of leaves per plant (TLN) and total number of leaflets per plant (TLFN), relative crown depth (RCD), maximum leaflet number per pinnate leaf (LFNmax), total number of branches (B), height, stem diameter and internode length (IL) were measured at the end of the experiment or when plants were removed from the compartments, whichever came first. For the two conifers (*Agathis robusta* and *Podocarpus elatus*) the number of whorls, number of branches per whorl, and length of branches were also measured at the end of the experiment. Leaf area (LA) of a single leaf and specific leaf area (SLA_{large}) were calculated after the removal, area measurement, drying and weighing of the largest undamaged leaf. An estimate of the total leaf area of each seedling, following removal from the compartment or at the end of the experiment, was calculated by multiplying the total number of leaves per plant (TLN) by 2/3 maximum individual area per leaf (LA) (based on personal observation).

Plant height was measured as the distance from the top of the pot to the apical bud (to the nearest 5 mm). Stem diameter was measured at the level of the top of the pot using calipers (to the nearest 0.05 mm). The distance to the lowest node with either leaf or branch was measured enabling the calculation of relative crown depth (RCD), ie sapling height minus height to lowest node with either leaf or

branch, divided by sapling height. Stem elongation rate (SER) was calculated as the rate of stem elongation (cm yr^{-1}) and relative stem elongation rate (RSER) as the height at the end of the experiment minus height at the beginning of the experiment, divided by the height at the start of the experiment, expressed per year ($\text{cm cm}^{-1} \text{yr}^{-1}$). Stem diameter increment rate (SDIR) was calculated as the diameter increment per year (mm yr^{-1}) and relative stem diameter increment (RSDIR) as the diameter at the end of the experiment minus the diameter at the start of the experiment, divided by the diameter at the start of the experiment, expressed per year ($\text{mm mm}^{-1} \text{yr}^{-1}$)

Maximum and minimum weekly temperatures were recorded for each shadehouse compartment (Appendix B). The shielded thermometer was placed adjacent to the datalogger (400 mm above ground level). A Skye datalogger was used to record R:FR measurements every 10 seconds, averaged over a five-minute period. The datalogger and thermometer were moved between shadehouse compartments every 5-7 days and were replicated every 12-15 weeks. A Licor (Lincoln, Nebraska, USA) LI-190SA PPFDF sensor (400-700 nm waveband) was attached to the Skye (Fowys, Wales) SDL S190 Datalog 2 datalogger and placed close to the R:FR sensor for a period of 3-5 days per light compartment, in order to establish the relationship between PPFDF and, R and FR output. This enabled an approximate daily photon rate to be calculated for each compartment.

Gas exchange of the most recent fully expanded leaf was measured on each plant using a portable ADC infrared gas analysis (IRGA) system. Measurements were recorded within two hours of noon, on clear days. During operation, air was collected from outside the shadehouse (3 m above ground level) and dried using Drierite before being pumped through the leaf chamber (11.35 cm^2 opening). The

leaf chamber was orientated to maximize incoming radiation, PPFD (400-700 nm) being measured by a sensor mounted adjacent to the leaf chamber. Gas exchange measurements were recorded following the stabilization of readings (1-5 mins depending on conditions). Rate of photosynthesis (A), stomatal conductance (Gs), transpiration (E), leaf temperature, humidity, atmospheric pressure, photosynthetic photon flux density (PPFD), time of day and date were logged by the IRGA and subsequently transferred to an excel data file for further analysis. The measured leaf was then detached and SLA was calculated. Measurements were made over the period 2nd May 1999 to 18th January 2000, at least once on individual seedlings within their assigned compartment, prior to removal for end of experiment measurements. Data were collected for groups of three to four species over 1-2 days, as they outgrew the height of the light compartment. Leaf area and specific leaf area (large) were calculated by photocopying the largest leaf as each species was removed from the experiment, cutting out the leaf shape, weighing leaf shape and residual paper and calculating proportion by weight of leaf shape to total A4 (A3 for large pinnate leaves) sheet. The leaf area was then calculated as that proportion of the total area of an A4 (or A3) sheet. Following photocopying, the leaf was dried at 80 °C for 24 hours and then weighed. Specific leaf area (SLA_{large}) was calculated for all seedlings as leaf area/leaf weight with units $cm^2 g^{-1}$. Water use efficiency (WUE) was calculated as the rate of photosynthesis divided by the transpiration rate (Maruyama *et al.* 1997). The pot-based experiment enabled 454 individual seedlings to be grown successfully in shade compartments, however there are a number of potential difficulties in running a pot experiment over a long time frame (> 1 year). Failure of automatic watering systems can lead to drought and possible plant death. The

use of drippers can isolate applied water to a narrow cylinder directly beneath the dripper. Regularly moving large pots can lead to increased settling of the soil, compaction and reduced drainage. This is aggravated when pots have recently been watered. Long-term shadehouse-based experiments can be detrimentally affected by outbreaks of insect infestation, wind and storm damage.

Growth was variable across the light and nutrient treatments. Some species grew exceptionally fast and the shadehouse roof impeded growth, consequently these individuals were removed from the trial and final measurements were conducted. There were some losses of stock due to transplanting shock, disease, waterlogging and drought over the twelve-month trial.

This study has not deconfounded the relative importance of R:FR and photon fluence rate (Chapter 3) but has simulated levels of natural shading conditions found in rainforests and some mixed species plantings. The shadehouse environments (blue and green compartments) were unable to be replicated with sufficient precision to significantly distinguish between moderate shade (15% daily PAR) and heavy shade (5% daily PAR)(Chapter 3). Consequently, these treatments are combined for factorial analysis and the two contrasting light treatments are defined as: High light (HL) 80% daily PAR, R:FR 0.94; Low light (LL) 8% daily PAR, R:FR 0.53.

Using SPSS (version 10) statistical package and following the procedures outlined by Francis (1999) a 4 (replicate/block) by 2 (light regime) by 2 (nitrogen) by 3 (succession groups) factorial analysis of variance was conducted on data derived from each growth characteristic. The grouping of species into successional types (see Appendix G) followed Kooyman (1996) and Shea (1992). Data were transformed where necessary (following examination for Skewness and Kurtosis)

in order to improve the normality of the distribution. Missing values were excluded from further analysis and when missing values exceeded 40 % of the data set for individual species, data for that species were excluded from further analysis. This resulted in treatment groups having different numbers of subjects in each group. Type II sum of squares were used in analysis of variance as a method of adjusting for unequal group sizes (Francis 1999). Levene's test examined the equality of variance across the treatment groups. Dunnett's T3 post-hoc test was used when Levene's test was significant.

4.3 Results

4.3.1 Comparative analysis of growth characteristics (height, stem diameter, internode length and branching)

An examination (Figure 4.1) of the rate of stem elongation (m yr^{-1}) reveals that in high light (80% full sun, R:FR 0.94) treatment, *Grevillea robusta* grew at $> 2 \text{ m yr}^{-1}$ and *Alphitonia excelsa*, *Elaeocarpus grandis*, *Melia azederach* var. *australasica*, *Nauclea orientalis*, *Pleiogynium timorense*, *Rhodosphaera rhodanthema* and *Toona ciliata* grew at $> 1 \text{ m yr}^{-1}$. In the low light treatment (8% full sun, R:FR 0.53) *Grevillea robusta* and *Melia azederach* var. *azederach* grew at $> 2 \text{ m yr}^{-1}$ and *Elaeocarpus grandis*, *Flindersia brayleyana*, *Nauclea orientalis*, *Pleiogynium timorense*, *Rhodosphaera rhodanthema* and *Toona ciliata* grew at $>$

1 m yr⁻¹.

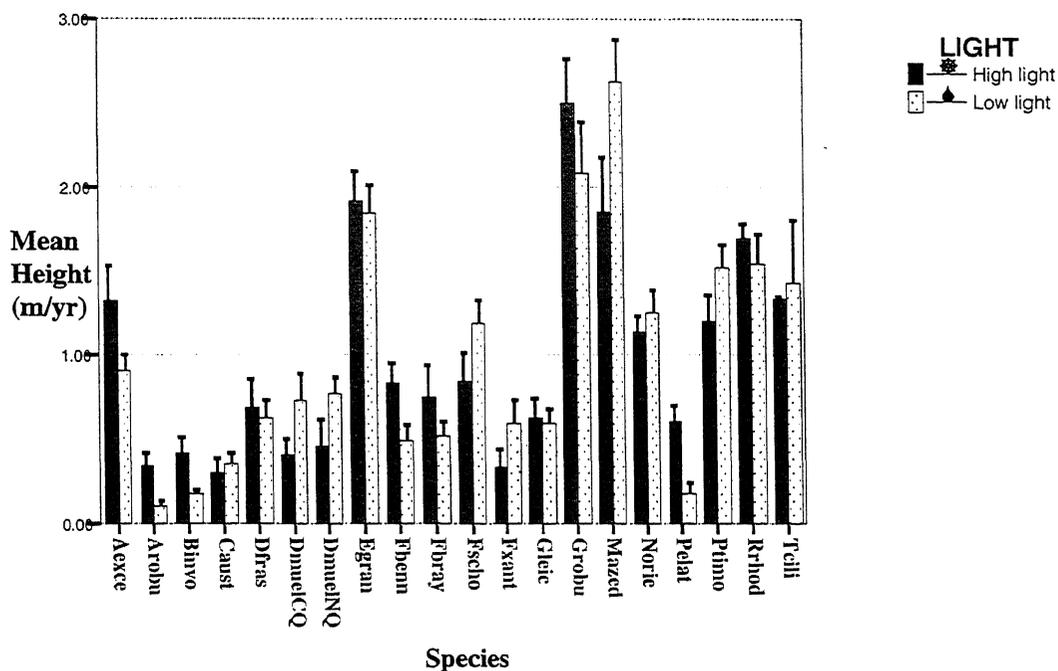


Figure 4.1 Mean height increment for Australian cabinet timber species grown under high and low light treatments. (Error bars represent + 1 s.e., Species key: Aexce = *Alphitonia excelsa*; Arobu = *Agathis robusta*; Binvo = *Blepharocarya involucrigera*; Caust = *Castanospermum australe*; Dfras = *Dysoxylum fraserianum*; DmuelCQ = *Dysoxylum muelleri* – Central Queensland provenance; DmuelNQ = *Dysoxylum muelleri* – North Queensland provenance; Egran = *Elaeocarpus grandis*; Fbenn = *Flindersia bennettiana*; Fbray = *Flindersia brayleyana*; Fscho = *Flindersia schottiana*; Fxant = *Flindersia xanthoxyla*; Gleic = *Gmelina leichardtii*; Grobu = *Grevillea robusta*; Mazed = *Melia azedarach* var. *australasica*; Norie = *Nauclea orientalis*; Pelat = *Podocarpus elatus*; Ptimo = *Pleiogynium timorense*; Rrhod = *Rhodosphaera rhodanthema*; Tcili = *Toona ciliata*.)

Similarly, the rate of stem diameter increment (Figure 4.2) for *Elaeocarpus grandis*, *Grevillea robusta* and *Nauclea orientalis* was >1.5 cm yr⁻¹, and *Gmelina leichardtii*, *Melia azedarach* var. *azedarach*, *Pleiogynium timorense*, *Rhodosphaera rhodanthema* and *Toona ciliata* was > 1 cm yr⁻¹ in the high light treatment. Only *Nauclea orientalis* achieved diameter increments > 1 cm yr⁻¹ in the low light, whilst *Alphitonia excelsa*, *Dysoxylum muelleri* - Central Queensland provenance (CQ), *Elaeocarpus grandis*, *Gmelina leichardtii*, *Grevillea*

robusta, *Melia azederach* var. *azederach*, *Pleiogynium timorense* and *Rhodospaera rhodantha* grew at $> 0.5 \text{ cm yr}^{-1}$ in the low light treatment.

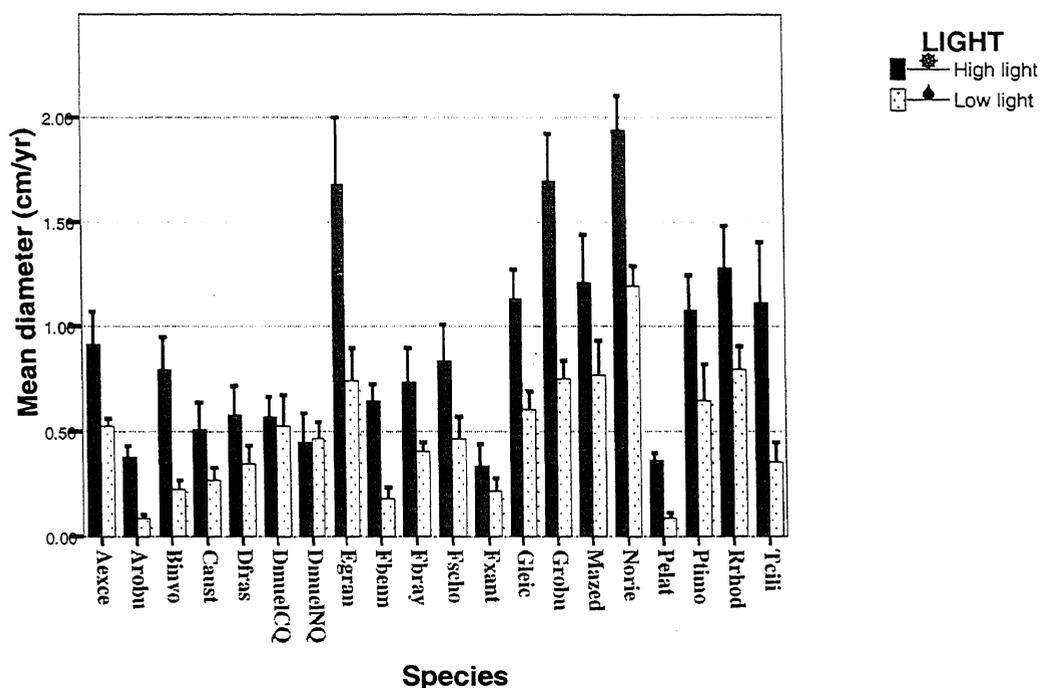


Figure 4.2 Mean diameter increments for Australian cabinet timber species grown under high and low light conditions. (Species key see Fig. 4.1, Error bars represent + 1 s.e.)

Silviculturally, species with height and diameter increments $> 1 \text{ m yr}^{-1}$ and $> 1 \text{ cm yr}^{-1}$ respectively are considered fast growers (Marcar *et al.* 1995).

At the start of the shadehouse growth trials the seedlings were not all the same height, consequently relative stem elongation $(H_{\text{final}} - H_{\text{initial}}) / H_{\text{initial}}$ and relative diameter increment $(D_{\text{final}} - D_{\text{initial}}) / D_{\text{initial}}$ are useful measures to compare growth rates across light treatments and among species. Relative stem elongation rates ($\text{cm cm}^{-1} \text{ yr}^{-1}$) for *Dysoxylum muelleri*-Central Queensland provenance (CQ), *Dysoxylum muelleri*- North Queensland provenance (NQ), *Flindersia schottiana*,

Flindersia xanthoxyla, *Nauclea orientalis* and *Pleiogynium timorense* were higher in the low light treatment than in the high light treatment (Figure 4.3).

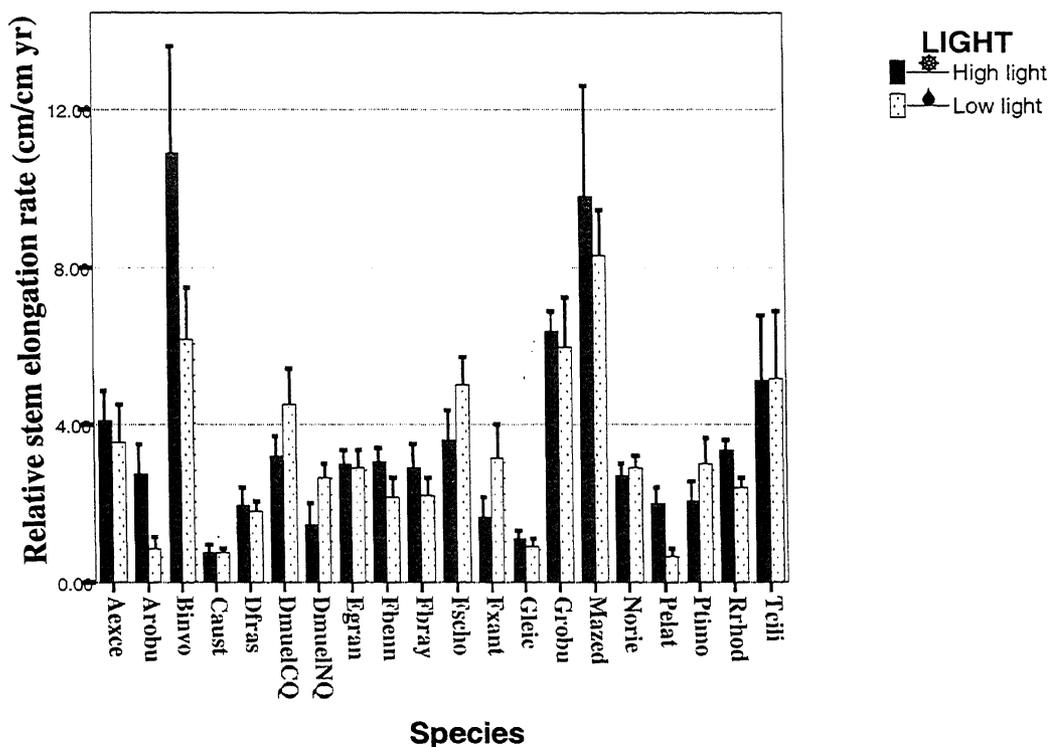


Figure 4.3. Relative stem elongation rates for 20 Australian cabinet timber species seedlings grown in contrasting light environments. (Species key see Fig. 4.1, error bars represent + 1 s.e.)

In contrast, *Agathis robusta*, *Podocarpus elatus*, *Rhodospaera rhodanthema* and *Blepharocarya involucrigera* had noticeably lower relative stem extension rates in the low light than in the high light. Two species, *Blepharocarya involucrigera* and *Melia azederach* var. *azederach* had noticeably larger average relative stem extension rates ($>9.5 \text{ cm cm}^{-1} \text{ yr}^{-1}$) in high light treatment than the rest of the species. Relative diameter increment rates were greater under high light treatment

compared to low light treatment (Figure 4.4).

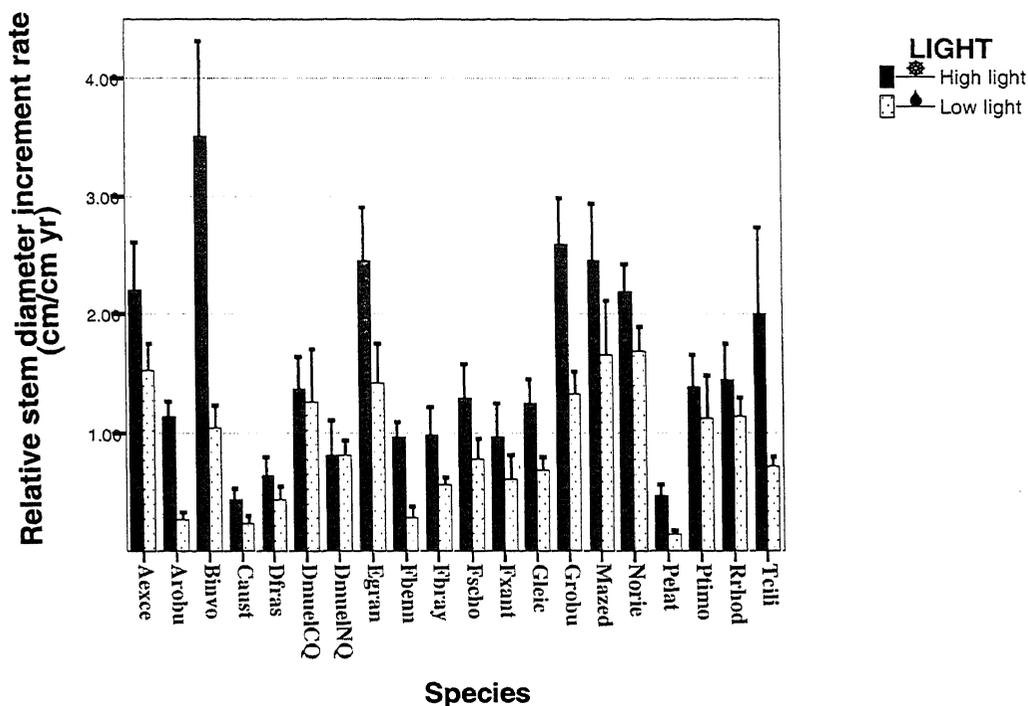


Figure 4.4 Relative diameter increment rates for 20 Australian cabinet timber species seedlings grown in contrasting light environments. (Species key see Fig. 4.1, error bars represent + 1 s.e.)

Growth was not constant over the length of the experiment. The number of days to the point where the maximum rate of relative stem extension (RSE_{max}) occurred varied among species. The maximum rate of relative stem diameter increment tended to occur in the five-week period following RSE_{max} . The length of the growth trials was insufficient to assess seasonal variation in growth. Water was unlikely to be a limiting factor, however temporal variation in temperature, incoming irradiance and day-length may have influenced periodicity of growth. Factorial analysis of variance on stem elongation rate indicated significant main effects for nitrogen ($F(1,33) = 20.5, p < 0.005$) and succession ($F(2,33) = 21.3, p$

< 0.005) factors (Table 4.1). Mean stem elongation rates were significantly higher with the added nitrogen treatment. Post-hoc (Dunnett's T3) tests revealed that early (S2) and late secondary (S3) species had significantly higher mean stem elongation rates than climax (S4) species. There were no significant interaction effects.

Factorial analysis of variance on relative stem elongation rate indicated similar main effects for nitrogen ($F(1,33) = 22.7, p < 0.005$) and succession ($F(2,33) = 42.9, p < 0.005$). Mean relative stem elongation rates were significantly higher with the added nitrogen treatment. Post-hoc (Dunnett's T3) tests revealed that early secondary (S2) had significantly higher mean relative stem elongation rates than late secondary (S3) species that in turn were significantly higher than climax (S4) species (Table 4.1).

Factorial analysis of variance conducted on diameter increment rates indicated significant main effects (Table 4.1) for light, nitrogen and succession and a significant interaction for light by nitrogen ($F(1,33) = 5.0, p < 0.05$). Post-hoc (Dunnett's T3) tests revealed that mean diameter increment rates were significantly higher in early (S2) and late (S3) secondary species compared to climax (S4) species. Examination of the light by nitrogen interaction (Table 4.2) revealed that the effects of added nitrogen were greater on diameter increment rates under high light conditions.

Factorial analysis of variance for relative diameter increment rates indicated significant main effects for light, nitrogen and succession and a significant interaction for light by nitrogen ($F(1,33) = 7.4, p < 0.025$). Post-hoc (Dunnett's T3) tests indicated that mean relative diameter increment rates were significantly higher in early (S2) secondary than late (S3) secondary species, which in turn

Table 4.1 Results from a light, nitrogen and succession 2x2x3 factorial ANOVA, mean values for main effects, n.s. main effect not significant $p > 0.05$, SED = Standard error of difference, at 33 df, between any values within the treatment.

Growth parameter	Light		Nitrogen		Succession			Transformation	Interaction $p < 0.05$
	High	Low	Control	added	S2	S3	S4		
Stem elongation rate (cm yr ⁻¹)	98	97	84	111	117	113	63	log	n.s.
	n.s.		SED = 1.28		SED = 1.4				
Relative stem elongation rate cm cm ⁻¹ yr ⁻¹	3.9	3.3	2.9	4.3	5.7	3.0	2.0	log	n.s.
	n.s.		SED = 1.0		SED = 1.31				
Diameter increment rate (mm yr ⁻¹)	9.4	5.1	5.6	8.9	9.0	7.8	4.8	log	L*N
	SED = 1.28		SED = 1.28		SED = 1.34				
Relative diameter increment rate (mm mm ⁻¹ yr ⁻¹)	1.6	0.9	1.0	1.5	1.9	1.2	0.8	log	L*N
	SED = 1.31		SED = 1.31		SED = 1.39				
H/D ratio (cm/cm)	78	106	90	94	97	101	77		n.s.
	SED = 6.9		n.s.		SED = 8.4				
Internode length (cm)	5.1	5.8	4.7	6.2	6.3	5.3	4.8		L*N
	SED = 0.69		SED = 0.69		SED = 0.84				
Area per leaf (cm ²)	152	233	166	219	212	195	170	log	L*N
	SED = 1.2		SED = 1.2		SED = 1.2				
Est. total leaf area (10 ³ .cm ²)	16.5	25.4	14.2	27.8	16.4	18.2	28.3	log	L*N L*S
	n.s.		SED = 1.32		SED = 1.37				
Leaf length (cm)	19.8	22.2	19.5	22.5	24.3	22.2	15.4	log	L*N L*S
	SED = 1.07		SED = 1.07		SED = 1.09				
Leaf number	120	89	76	133	67	101	146	Square root	L*N, L*S, N*S, L*N*S
	SED = 0.36		SED = 0.36		SED = 0.54				
Branching	5.0	2.9	3.2	4.7	2.6	4.9	4.4		L*N, L*S, N*S
	SED = 0.90		SED = 0.90		SED = 1.10				
SLA _{large} (cm ² g ⁻¹)	123	222	171	173	201	158	158		L*N L*S
	SED = 8.8		n.s.		SED = 10.8				
SLA (cm ² g ⁻¹)	129	248	182	195	218	187	161		L*N, L*S, N*S, L*N*S
	SED = 11.2		SED = 11.2		SED = 13.7				
RCD (cm cm ⁻¹)	0.67	0.74	0.67	0.74	0.62	0.77	0.73		L*S L*N*S
	SED = 0.05		SED = 0.05		SED = 0.06				
Photosynthetic rate A (μmol m ⁻² s ⁻¹)	4.5	1.5	2.8	3.3	3.1	3.0	3.0	log	n.s.
	SED = 1.3		n.s.		n.s.				
Transpiration rate E (mol m ⁻² s ⁻¹)	2.7	1.5	2.1	2.0	2.0	1.9	2.3	log	n.s.
	SED = 1.21		n.s.		n.s.				
G _s (mol m ⁻² s ⁻¹)	0.13	0.12	0.11	0.13	0.17	0.10	0.09	log	n.s.
Stomatal conductance	SED = 1.36		n.s.		n.s.				
WUE (μmol mol ⁻¹)	1.85	1.18	1.41	1.62	1.59	1.55	1.4	log	L*N L*S
Water use efficiency	SED = 1.25		n.s.		n.s.				

were significantly higher than climax (S4) species. Examination of the light by nitrogen interaction (Table 4.2) revealed that the effect of added nitrogen on

relative diameter increment rate, was more pronounced under high light conditions compared to low light conditions.

Table 4.2 Results from significant interactions between light and nitrogen treatments following factorial analysis (Table 4.1). SED = standard error of the difference, at 33 df, between any values within the light by nitrogen matrix.

Growth Parameter	Nitrogen	Light	
		High	Low
Diameter (mm yr ⁻¹) SED = 1.41	Control	6.8	4.5
	Added	12.0	5.7
Relative diameter (mm mm ⁻¹ yr ⁻¹) SED = 1.46	Control	1.2	0.9
	Added	2.1	1.0
Internode length (cm) SED = 0.97	Control	4.0	5.4
	Added	6.1	6.3
Area per leaf (cm ²) SED = 1.22	Control	119	214
	Added	186	252
Estimated total leaf area (10 ³ cm ²) SED = 1.44	Control	10.1	18.3
	Added	23.0	32.5
Leaf length (cm) SED = 1.10	Control	17.6	21.5
	Added	22.0	22.9
Branching SED = 1.27	Control	3.8	2.6
	Added	6.3	3.1
SLA _{large} (cm ² g ⁻¹) SED = 12.5	Control	126	217
	Added	120	226
WUE (μmol mol ⁻¹) SED = 1.37	Control	1.57	1.25
	Added	2.13	1.11

Factorial analysis of variance for the H/D (slenderness) ratio values indicated significant main effects for light ($F(1,33) = 87.5, p < 0.005$) and succession ($F(2,33) = 24.7, p < 0.005$) treatments. Slenderness was greatest under low light conditions (Table 4.1). Early (S2) and late (S3) secondary species had higher H/D ratios than climax (S4) species (Table 4.1).

Factorial analysis of variance for internode length indicated significant main effects for light, nitrogen and succession and a significant interaction for light by nitrogen ($F(1,33) = 4.3, p < 0.05$). Post-hoc (Dunnett's T3) tests indicated that mean internode lengths were significantly higher in early (S2) secondary than climax (S4) species (Table 4.1). Examination of the light by nitrogen interaction

revealed that the effects (increase in mean internode length) of added nitrogen were greater under high light conditions than low light conditions (Table 4.2).

4.3.2 *Comparative analysis of leaf and canopy characteristics.*

The main effects of light, nitrogen and succession on area per leaf were significant (Table 4.1) and there was a significant light by nitrogen interaction ($F(1,33) = 5.0$, $p < 0.05$). Mean area per leaf was larger for early (S2) secondary compared to climax (S4) species (Table 4.1). Examination of the light by nitrogen interaction revealed that the effect of added nitrogen in increasing area per leaf was proportionally greater under high light conditions than low light conditions (Table 4.2).

Estimated total leaf area was increased by nitrogen ($F(1,33) = 28.1$, $p < 0.005$) and affected by succession ($F(2,33) = 4.25$, $p < 0.025$) and there were significant light by nitrogen ($F(1,33) = 4.55$, $p < 0.05$) and light by succession ($F(2,33) = 4.63$, $p < 0.025$) interactions (Table 4.1). Examination of the light by nitrogen interaction revealed that the effect of added nitrogen was proportionally greater under high light conditions than low light conditions (Table 4.2). Examination of the light by succession interaction revealed that the effect of low light conditions in increasing estimated total leaf area was greater for climax species than for early secondary species and that late secondary species exhibited a reduction in estimated total leaf area under low light conditions (Table 4.3).

Maximum leaf length was influenced by light ($F(1,33) = 34.8$, $p < 0.005$), nitrogen ($F(1,33) = 29.4$, $p < 0.005$) and succession ($F(2,33) = 98.5$, $p < 0.005$) and there were significant light by nitrogen ($F(1,33) = 9.7$, $p < 0.005$) and light by succession ($F(2,33) = 5.3$, $p < 0.025$) interactions. Examination of the light by

nitrogen interaction revealed that once again the effect of added nitrogen was proportionally greater under high light conditions than low light conditions (Table 4.2). Examination of the light by succession interaction revealed that the effect of low light conditions in increasing leaf length was greater for climax species compared to early and late secondary species (Table 4.3).

Table 4.3 Results of significant interactions between light and succession indicated by factorial analysis of variance (Table 4.1). SED = Standard error of the difference, at 33 df, between any values within the light by succession matrix.

Growth parameter	Successional group	Light	
		High	Low
Estimated total leaf area (10 ³ cm ²) SED = 1.56	S2	12.5	20.3
	S3	19.7	16.7
	S4	17.4	39.2
Leaf length (cm) SED = 1.13	S2	23.7	24.9
	S3	22.1	24.3
	S4	13.6	17.3
Branching SED = 1.56	S2	2.8	2.4
	S3	6.3	3.4
	S4	6.0	2.9
SLA _{large} (cm ² g ⁻¹) SED = 15.3	S2	134	268
	S3	118	198
	S4	118	197
WUE (μmol mol ⁻¹) SED = 1.47	S2	1.98	1.21
	S3	2.04	1.05
	S4	1.52	1.28

Factorial analysis of variance for total leaf number (at the end of the experiment) indicated significant main effects for light, nitrogen and succession, and a significant light by nitrogen by succession ($F(2,33) = 4.1, p < 0.05$) interaction (Table 4.1). Examination of the light by nitrogen by succession interaction revealed that the increase in total leaf number was greater under the combination of added nitrogen and high light conditions for climax species than for early or late secondary successional groups (Table 4.5).

The number of branches (number of branches at end of experiment minus the number of branches at the start of the experiment) was affected by light ($F(1,33) = 36.5, p < 0.005$), nitrogen ($F(1,33) = 16.7, p < 0.005$) and succession ($F(2,33) =$

11.8, $p < 0.005$) and there were significant light by nitrogen ($F(1,33) = 8.5, p < 0.01$), light by succession ($F(2,33) = 4.3, p < 0.025$) and nitrogen by succession ($F(2,33) = 4.5, p < 0.025$) interactions. Examination of the light by nitrogen interaction revealed that the positive effect of added nitrogen was greater under high light conditions than low light conditions (Table 4.2). Examination of the light by succession interaction revealed that the increase in branching under high light conditions was greater for climax and late secondary successional species than for early successional species (Table 4.3). Examination of the nitrogen by succession interaction revealed that the effect of added nitrogen was greater for late secondary species than for early secondary or climax species (Table 4.4).

Table 4.4 Results for the nitrogen by succession interaction indicated by factorial analysis of variance (Table 4.1). SED = Standard error of the difference, at 33 df, between any values within the nitrogen by succession matrix.

Growth parameter	Successional group	Nitrogen	
		Control	Added
Branching SED = 1.56	S2	2.5	2.7
	S3	3.3	6.4
	S4	3.9	5.0

Specific leaf area, SLA_{large} (the largest leaf at the end of the experiment), was greater under low light ($F(1,33) = 502.4, p < 0.005$) and in the early secondary succession species ($F(2,33) = 38.6, p < 0.005$) and significant interactions were evident for light by nitrogen ($F(1,33) = 5.3, p < 0.05$) and for light by succession ($F(2,33) = 14.9, p < .$). Examination of the light by nitrogen interaction (Table 4.2) revealed that the effect of added nitrogen was greater under low light conditions than high light conditions. Examination of the light by succession interaction revealed that the effect of low light conditions was greater for early secondary than for late secondary and climax species (Table 4.3).

Factorial analysis of variance for specific leaf area of the most recent fully expanded leaf indicated significant main effects (Table 4.1) for light, nitrogen and

succession. There were significant interactions for light by nitrogen, light by succession, nitrogen by succession and light by nitrogen by succession ($F(2,33) = 4.6, p < 0.05$). Examination of the light by nitrogen by succession interaction revealed that early secondary species markedly increased specific leaf area under the combined effects of added nitrogen and low light conditions (Table 4.5).

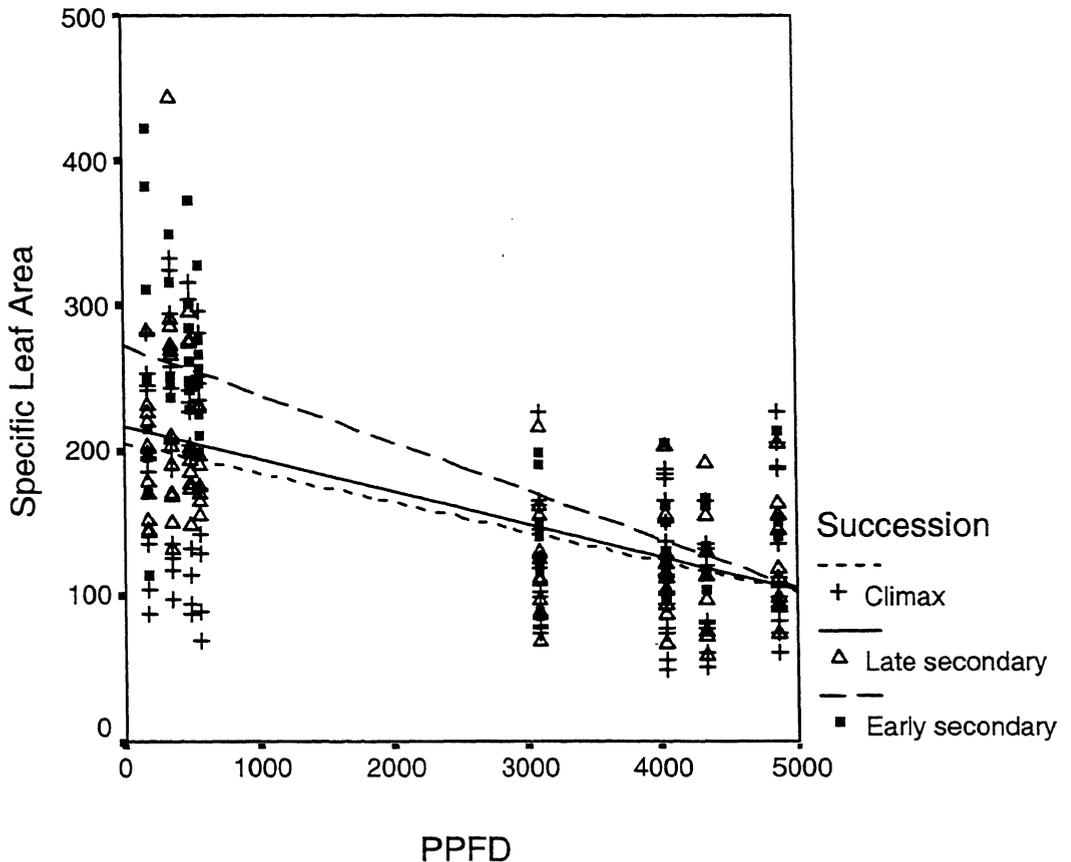


Fig. 4.5 Specific leaf area ($\text{cm}^2 \text{g}^{-1}$) v PPFD ($\mu\text{mol m}^{-2} \text{dy}^{-1}$) for three successional groups.
 (Linear regression equations ($p < 0.001$): Climax, $\text{SLA} = 272 - 0.033 \text{ PPFD}$; Late secondary, $\text{SLA} = 217 - 0.023 \text{ PPFD}$; Early secondary, $\text{SLA} = 205 - 0.020 \text{ PPFD}$)

Relative crown depth was influenced by all treatments (light reduced it ($F(1,33) = 9.5, p <$), nitrogen increased it ($F(1,33) = 14.2, p < 0.005$) and it was diminished in early secondary succession species ($F(2,33) = 11.8, p < 0.005$)) and a significant light by nitrogen by succession interaction ($F(2,33) = 3.8, p < 0.05$) was evident (Table 4.1). Examination of the light by nitrogen by succession

interaction (Table 4.5) revealed that the effect of combined high light and added nitrogen in increasing mean relative crown depth was proportionally greater in climax species compared to the other successional groups.

Table 4.5 Results for the light by nitrogen by succession interaction indicated by factorial analysis of variance (Table 4.1). SED = Standard error of the difference, at 33 df, between any values within the nitrogen by succession matrix.

Growth parameter	Light	Nitrogen	Succession		
			S2	S3	S4
Total leaf number at end of experiment SED = 2.17	High	Control	50	112	79
		Added	98	147	231
	Low	Control	50	58	106
		Added	69	85	166
SLA (cm ² g ⁻¹) SED = 27.5	High	Control	145	123	127
		Added	136	126	119
	Low	Control	255	245	196
		Added	334	253	204
Relative crown depth (cm cm ⁻¹) SED = 0.12	High	Control	0.52	0.79	0.55
		Added	0.55	0.80	0.79
	Low	Control	0.69	0.69	0.76
		Added	0.72	0.78	0.80

4.3.3 Comparative analysis of photosynthetic characteristics (net rate of photosynthesis, stomatal conductance and transpiration)

Maximum rate of photosynthesis (A_{\max}) indicated a significant main effect (Table 4.1) for light ($F(1,33) = 75.8, p < 0.005$); mean maximum rate of photosynthesis was significantly higher under high light than low light conditions (Table 4.1).

When individual values of A_{\max} were plotted against incident PPFD (Figure 4.6), there was a suggestion that A_{\max} for all successional groups was saturated at moderate PPFD (indeed, there was some indication of suppression of A_{\max} at high PPFD).

The rate of transpiration (E) was affected by light ($F(1,33) = 51.8, p < 0.005$); mean transpiration rate was significantly higher under high light than low light conditions (Table 4.1).

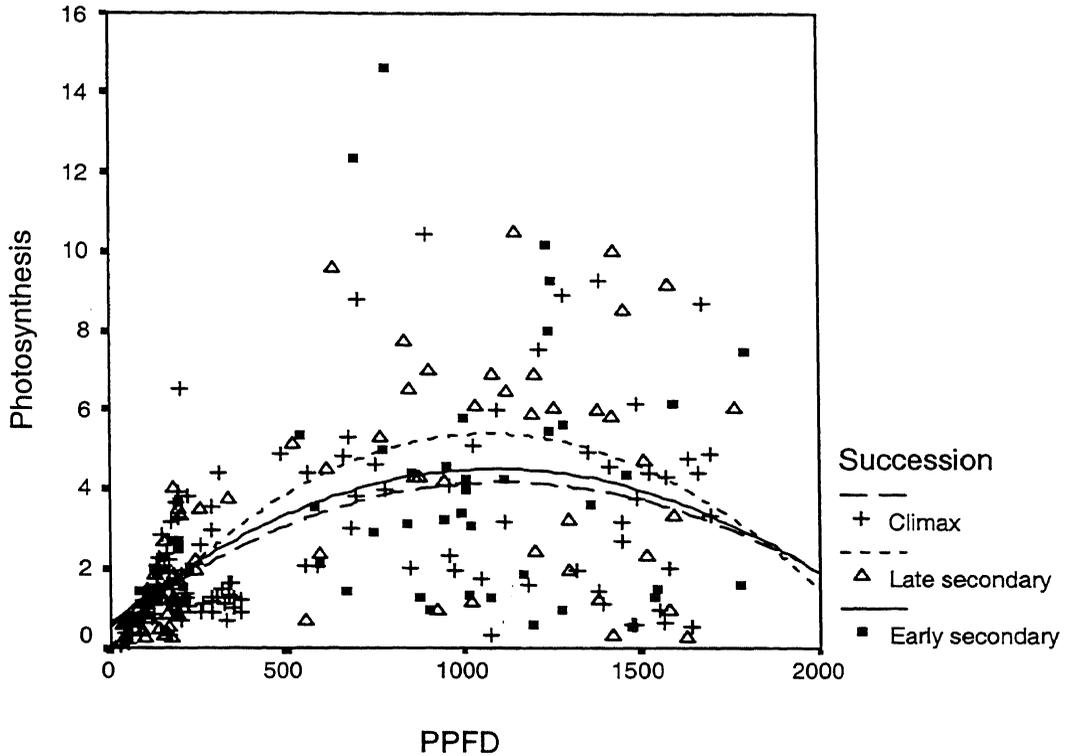


Fig. 4.6 Photosynthesis ($\mu\text{mol m}^{-2} \text{s}^{-1}$) v PPFD ($\mu\text{mol m}^{-2} \text{s}^{-1}$) for three successional groups. (Quadratic regression equations ($Y = \text{photosynthesis}$, $X = \text{PPFD}$) for fitted curves ($p < 0.001$) are: early secondary – $Y = 0.62 + 0.0071X + 0.000003X^2$; late secondary – $Y = 0.05 + 0.0099X + 0.000005X^2$; climax – $Y = 0.55 + 0.0065X + 0.000003X^2$).

Stomatal conductance (G_s) was influenced by light ($F(1,33) = 9.5$, $p < 0.005$).

Mean stomatal conductance was significantly higher under high light conditions (Table 4.1).

The effects of light ($F(1,33) = 17.6$, $p < 0.005$) and interactions between light and nitrogen ($F(1,33) = 4.6$, $p < 0.05$) and between light and succession ($F(2,33) = 4.4$, $p < 0.05$) were significant (Table 4.1) for water use efficiency (WUE).

Examination of the light by nitrogen interaction (Table 4.2) revealed that the effect of added nitrogen markedly increased WUE under high light conditions, whereas under low light conditions the effect of added nitrogen was to reduce mean WUE. Examination of the light by succession interaction (Table 4.3) revealed that the effect of high light conditions in increasing WUE was

proportionally greater for late secondary (S3) species than for early (S2) and climax (S4) species (Table 4.3).

4.4 Discussion

The species examined in this trial are from a range of successional groups found in Australian rainforests. These species were subjected to contrasting light conditions and nitrogen treatments in order to better understand their likely responses and preferred management practices following field planting. Early management of Australian cabinet timber plantings often utilises high stocking rates and a single phase of planting during the wet season. During this establishment phase, the individual seedlings grow in a high light environment. Rapid growth of some secondary successional species can lead to canopy closure within three to seven years. The light environment for slower growing species if planted with fast growing secondary species, changes to one of reduced light intensity and altered spectral quality. The morphological traits of individual species in sun and shade provide valuable information to the forester attempting to prescribe a species mix suitable for mixed species plantings.

Stem elongation rates (height and relative height) can be used to predict the species likely to form the first canopy in a mixed species planting. The results from this cabinet timber trial indicated that early and late successional groups had significantly higher stem elongation rates than climax species. Added nitrogen significantly increased stem elongation rates whilst the light environment was not a significant factor. Stem elongation rates were not significantly different under high or low light environments. Fast growing species were able to maintain fast growth under low light (8 % full sunlight) conditions. All species trialed therefore

demonstrated some shade tolerance at this light intensity, and light intensity needed to be further reduced in order to differentiate species tolerance to shade. Kitajima (1994) in his study of 13 tropical trees of contrasting shade tolerance from Barro Colorado Island, found that the fastest growing species under high light (23 % full sunlight) were also the fastest growing species under low light (2 % full sunlight) conditions. Lee *et al.* (1996) reports a similar finding amongst Asian tropical rainforest trees.

Stem diameter growth rates (diameter and relative diameter) are correlated with stem volume and carbohydrate storage for future growth (Lee *et al.* 1996). The combination of high light conditions and added nitrogen significantly increased diameter increment rates for the cabinet timber species trialed. Early secondary successional species exhibited significantly higher diameter increment rates than climax species. High nutrient supply combined with high irradiance significantly increased growth (seedling dry weight) in rain forest dipterocarps from south-east Asia (Bungard *et al.* 2000) and in Australian rainforest trees (Thompson *et al.* 1992a).

The slenderness (H/D) ratio was significantly higher (more slender) under low light compared to high light conditions reflecting the ability of seedlings to preferentially allocate resources to height growth over diameter increment. Early and late secondary species were more slender than climax species.

Internode length was significantly higher under low light conditions and variation between successional groups was evident. Lee *et al.* (1996) reports a similar response within Asian tropical trees. Added nitrogen also significantly increased internode length, a result reflected in the association between height growth

measurements (height and relative height) and the added nitrogen treatment (Table 4.1).

Leaf area and leaf blade length were significantly influenced by light, additional nitrogen and successional group status. Givinish (1984) in his review of leaf and canopy adaptation in tropical forests concluded that leaf area increased with decreasing solar radiation, with increasing nitrogen supply and with early successional status. Ackerly and Bazzaz (1995) record a similar response to light and nutrients in a tropical pioneer tree species. The ability to increase leaf area, thereby increasing photosynthetic capacity, under low light conditions enables the seedling to compensate for the reduction in light intensity and corresponding reduction in the maximum rate of photosynthesis.

The total number of leaves retained by individual seedlings at the end of the experiment increased with increasing irradiance, a trend observed in other tropical rainforest trees (Langenheim *et al.* 1984, Ackerly and Bazzaz 1995).

The total amount of plant resources invested in leaf production, measured as (estimated) total leaf area, was not significantly influenced by the light environment or successional group status. As solar radiation decreased, total leaf number decreased whilst individual leaf area increased. A similar pattern was observed with successional groups; those with largest mean individual leaf area (early secondary) retained fewest leaves whilst climax species with lowest mean individual leaf area retained the greatest number of leaves. Additional nitrogen had a marked effect on total leaf area as leaf area and retention of leaves increased with increasing nitrogen supply.

Branching was significantly increased under high light conditions, a pattern observed in many Australian rainforest plants grown in open sunny situations (Jones 1986).

Specific leaf area increased markedly with decreasing light. This effect was most evident in early secondary species following added nitrogen treatment.

The rate of photosynthesis was greater for all successional groups in the high light treatment, in part due to the higher intensity of solar radiation (Fig. 4.6).

Stomatal conductance increased with increasing irradiance but was not significantly affected by nitrogen treatment or successional group status. African tropical timber tree seedlings increased stomatal conductance in response to higher photon flux density (Kwesiga *et al.* 1986).

Water use efficiency (WUE, the ratio of photosynthetic rate and transpiration rate) reflects the balance between CO₂ uptake and the release of water vapour. It has been used (Maruyama *et al.* 1997) to assess susceptibility to initial transplantation shock of field planted seedlings. WUE was significantly higher with combined high light and added nitrogen treatment. In the relatively humid conditions in the shadehouse compartments, increase in solar irradiance increased photosynthesis proportionally more than the rate of transpiration (Table 4.1). High leaf nitrogen is also known to result in higher rates of photosynthesis (Bungard *et al.* 2000). Early and late secondary successional species had significantly higher WUE's only under high light treatment. WUE was highest in *Gmelina leichardtii*, *Alphitonia excelsa*, *Flindersia xanthoxyla* and *Dysoxylum fraserianum* and lowest in *Castanospermum australe*, *Grevillea robusta*, *Dysoxylum muelleri*-NQ and *Dysoxylum muelleri*-CQ under high light conditions (Appendix E).

A number of authors (Whitmore 1996, Valladares *et al.* 2000) have suggested that phenotypic plasticity in response to the light environment (the ratio of sun values to shade values) is greater for pioneer species than for climax species. Examining the plasticity ratios (Appendix G) for A_{\max} and $G_{S_{\max}}$, a broad range of values were found across the species trialed, and did not correspond closely to successional status. However the A_{\max} plasticity ratio may reflect the ability of a species to capitalize on an overall increase in solar radiation. Species with high ratios may be able to dramatically increase photosynthetic rates when more favourable conditions occur. The maximum rate of photosynthesis (A_{\max}) was more than three times greater in the high light environment compared to shade (plasticity ratios in parentheses) in the following species: *Elaeocarpus grandis* (6.8); *Flindersia bennettiana* (5.0); *Grevillea robusta* (3.8); *Rhodosphaera rhodanthema* (3.7); *Agathis robusta* (3.5); *Alphitonia excelsa* (3.4); *Dysoxylum muelleri*-CQ (3.1). These species do not correspond closely with a single successional group. In a study of 13 tropical tree seedlings on Barro Colorado Island Kitajima (1994) found no correlation between shade tolerance and photosynthetic plasticity.

4.5 Conclusions

The species trialed are all valuable timber species found in Australian tropical and subtropical rainforests. Most of the species are currently being utilized in mixed species cabinet timber plantings in Queensland. Species selected commonly include fast growing secondary succession species and slower growing climax species. Newly planted seedlings are required to grow under high light conditions.

Fertilisers are commonly applied during this establishment phase. After canopy closure, taking three to seven years (depending on growth and stocking density), slower growing species are required to grow in low light environments. This study has examined the role of light, nitrogen and successional status in the early growth of twenty Australian cabinet timber species.

Under high light conditions the cabinet timber species markedly increased their total number of leaves, branching, rate of photosynthesis and rate of transpiration. Under low light conditions a noteworthy increase in internode length, area per leaf, specific leaf area, leaf blade length, slenderness (H/D ratio) and relative crown depth was observed. The light treatments did not have a significant effect on stem elongation rate or relative stem elongation rates.

The added nitrogen treatment produced a significant increase in stem elongation rate, relative stem elongation rate, internode length, leaf area, total leaf area, leaf blade length and relative crown depth. Additional nitrogen did not have a significant effect on slenderness (H/D ratio), branching, rate of photosynthesis and stomatal conductance. The combination of high light conditions and added nitrogen treatment significantly increased diameter increment rates, relative diameter increment rates and water use efficiency in the species being trialed. Low light conditions combined with added nitrogen significantly increased specific leaf area.

Clearly, the combination of added nitrogen with a high light environment promotes vigorous seedling growth that is required for the production of quality nursery stock and for the establishment of successful farm forestry enterprises.

Reducing available nitrogen reduces growth and has been successfully applied to seedlings in a nursery in order to suspend growth until required (Nicholson 1991).

This enables nurseries to maintain, at a reasonable size, stock of rainforest species whose seed does not store well and is only available for short periods every year. Early secondary (S2) species exhibited greater stem elongation rate, relative stem elongation rate and diameter and relative diameter increment rate than late secondary (S3) and climax (S4) species. Early secondary (S2) species had the lowest total number of leaves at the end of the experiment. Climax (S4) species had significantly lower stem elongation rate, relative stem elongation rate, diameter and relative diameter increment rate, leaf blade length and H/D ratio than secondary (S2 and S3) species. Under low light conditions, early secondary species exhibited higher mean specific leaf area than climax species that had the lowest specific leaf area. Late secondary (S3) species exhibited an intermediate (between S2 and S4) response in growth characteristics (except relative crown depth, branching and slenderness ratio).

Rainforest tree species have been divided into guilds (pioneer and climax) based on their light requirements for germination and establishment (Swaine and Whitmore 1988). Within the early secondary, late secondary and climax successional groups a wide range of growth responses to light and shade were observed.

The physiological growth characteristics of the Australian cabinet timber species examined in this study are applied to silvicultural design and management of rainforest plantings in Chapter 5.

Chapter 5 Potential application of these findings to farm forestry

5.1 Introduction

5.1.1 Farm forestry in Australia

Farm forestry has been defined as “ the incorporation of commercial tree growing into farming systems. It can take many forms: plantations; woodlots; timberbelts, alleys and widespread trees as well as on-farm native forests” (Greening Australia 1996). Farm forestry differs from the narrow conservative approach of forestry plantations that endeavour to maximise timber production and economic returns, to a broader approach that embraces a wide variety of planting systems, designs and outcomes (Reid 1996). Farm forestry in Australia has the potential to provide wide-ranging benefits (Guijt and Race 1998). Timber products range from low value firewood, pulpwood and posts to high value sawn timber and veneer. By-products can include nuts, seeds, oils, foliage and honey. Landholders often prioritise planting of trees for shade, shelter, environmental management and conservation above that simply for timber production (Harrison *et al.* 1996). Over the last ten years, federal and state governments in Australia have identified the need for trees on farms in order to expand commercial plantations of softwoods and hardwoods, rehabilitate cleared agricultural land and address environmental and conservation objectives.

Notable increases in the number of conferences on tree-growing, regional farm forestry associations and committees, and the proliferation of farm forestry self-

help groups testify to the growing interest in putting trees back into the farming landscape.

5.1.2 *Rainforest cabinet timber plantings*

Australian rainforest cabinet timber species produce some of the finest timber in the world and have a broad range of end uses including high quality furniture.

Timber quality (colour and grain) is important. In Queensland the cabinet timber industry has difficulty obtaining a regular supply of these timbers. Value-adding from standing timber to processed boards can increase economic returns 40-fold

(Herbolm *et al.* 1996). A survey of Queensland landholders suggests that

plantings of mixed species rainforest trees including cabinet timbers have been

primarily for environmental reasons (Harrison *et al.* 1996). Timber values and

economic returns are given a lower priority. Queensland local government

authorities promoting farm forestry, however, place a high priority on developing

a local timber industry with associated employment creation (Harrison *et al.*

1996).

Hoop Pine remains the only successful Australian rainforest timber species to be

utilised in plantations. Trial plantings of other promising species have had

variable results. In the last ten years a number of authors (Shea 1992, Russell *et*

al. 1993, Harrison and Herbohn 1996) have reassessed the potential for rainforest

cabinet timber plantings, with interest focussing on mixed species plantings.

Rainforest cabinet timber trial plantings are predominantly located in the medium

to high rainfall areas of south-east Queensland and north-east Queensland. As yet,

no such planting has reached commercial timber production and assessment of

potential economic returns remains difficult.

5.1.3 *Mixed species plantings*

The silviculture and ecology of mixed species plantings have been reported for temperate species in Europe (Burkhart and Tham 1992) but there are few published accounts of tropical and sub-tropical multi-species timber plantings. Cabinet timber plantation design has focussed on mixed species plantings rather than monospecific plantations because of the perceived and known advantages including good early growth rates and tree form, greater biomass production, better site utilisation, reduced risk of insect damage and disease problems (Keenan 1996) diversity of forest products and flexibility in product marketing (Montagnini *et al.* 1995). There are many valuable cabinet timber species in sub-tropical and tropical Australian rainforests for which there is little available data on growth and productivity. Examining plant attributes in order to aggregate a large number of species into a small number of well defined groups can aid the forester in species selection and predictions of growth. Vanclay *et al.* (1994) used plant functional attributes to study site productivity and growth patterns for a broad range of species in north Queensland rainforests. The best predictors of site productivity were canopy height, mean leaf size and the number of species with vertical leaf inclination. Diameter growth group membership (species with similar diameter growth rates) was best defined by reference to data on leaf inclination, leaf size, lenticels and chlorophyllous tissue on the main stem, and furcation index (relative height to first fork or branch in the main stem axis).

Mixed species plantings (eg Rocky Creek Dam plantation, New South Wales) can involve up to 30 timber species (Rous County Council 1994). Selection of species is based on site assessment, availability of planting stock and desired silvicultural

outcomes (Keenan 1996). Planting in southeast Queensland and northern New South Wales takes place from mid-summer to winter (Kooyman 1996, Mitchell 1996) whilst in north Queensland planting occurs following the onset of the wet season (Keenan 1996).

Stratified mixtures combine fast growing overstorey species with higher value shade tolerant species in the understorey and have the potential to increase total productivity above levels for shade intolerant monospecific plantations (Smith 1986b). The overstorey matures fastest and is removed first, whilst attempting to minimise understorey damage. The removal of overstorey (thinning) produces large diameter logs in contrast to normal thinning operations where reduction in stocking rates produces low value small diameter logs. The understorey microclimate provides benefits to the slower growing climax successional species that are not adapted to establishment in full sunlight as well as improving form and bole length in the understorey species.

An increase in our knowledge of the physiology of individual species and our understanding of the processes and interactions of mixed species plantings may lead to the design, trialing and assessment of specific types of multi-species plantations.

5.2 Application of germination and early growth data to farm forestry

The germination data from 27 rainforest tree species provides the farm forester with essential information for nursery production of seedlings. Viability of seed, maximum germination levels and patterns of germination enable farm foresters to carefully plan seedling production for specific plantings. For example, up to thirty

species of vigorous healthy seedlings, 60-90 cm in height, may be required for a single planting phase during the wet season. Germination needs to be organised well in advance of the planting phase due to availability of seed and differential speed of germination. Obtaining seed from state forests requires permits, detailed location of individual accessible trees and careful timing of harvest (and is likely to be too difficult for many farm foresters). Seed for cabinet timber species are available from DPI Seeds and other seed suppliers, however some seed has a limited storage life, requires pre-ordering and must be sown soon after harvest. The results from the germination trials (Chapter 2) indicated that selective pre-germination treatments were an effective method of increasing germination levels in some species.

In the shadehouse trials (Chapter 4), seedlings grown under the combination of low light conditions and no added nitrogen treatment, exhibited reduced growth (stem elongation rate, diameter increment rate, leaf number and total leaf area). Nurserymen have applied this combined treatment in order to hold seedlings at a juvenile stage of growth, with subsequent release when required (Nicholson 1991).

The differential growth rates exhibited by the rainforest cabinet timber species under trial can be applied by the farm forester to promote stratification in the mixed species planting. The combination of fast growing trees and high stocking rates in the species mixture can promote height growth and tree boles with a high proportion of knot free timber. Knowledge of individual species growth characteristics under low light levels can help the forester predict the effects of species mixtures. The relative merits of the individual species trailed are

summarised in the mixed species rainforest cabinet timber silvicultural design (see Appendix F).

The use of nitrogenous fertilisers may provide valuable benefits (in terms of growth and development) during the seedling to sapling phase of forestry planning. This study has indicated that added nitrogen significantly increases height, diameter, leaf area and relative crown depth. Its use may be of particular importance during the establishment phase prior to canopy closure when all individual seedlings are exposed to a high light environment. Under these conditions, added nitrogen significantly increases diameter growth and transpirational water use efficiency. Following canopy closure (three to seven years), tree requirements for added nitrogen are reduced as nitrogen is returned to the soil via leaf litter (CSIRO 1996). However added nitrogen may again be of benefit when applied just prior to thinning of the canopy and release of understorey trees. Bungard *et al.* 2000 have observed that added nitrogen reduces photodamage and increases photosynthetic capacity per unit leaf area following the transfer of seedlings from low to high light environments. In field trials of three Australian cabinet timber species there was a significant growth response to additional phosphorus applications in *Agathis robusta* but not *Castanospermum australe* and *Flindersia brayleyana* (Webb *et al.* 2000). Routine broad-scale application of high nitrogen and/or phosphorus fertilisers during early management of mixed cabinet timber plantings may not always substantially increase growth. However, degraded lands that once supported rainforest are candidates for farm forestry in north Queensland, and soil from these sites are found to be deficient in major nutrients (Webb *et al.* 1997). Clearly, site and

species specific fertilisers are required to improve the growth rates of mixed species plantings.

Farm forestry trials using sewerage effluent for irrigation require tree species to take up nutrient-rich water. There may be potential to use rainforest cabinet timber species that exhibited high rates of transpiration in full sunlight in the current studies (*Podocarpus elatus*, *Melia azedarach* var. *australasica*, *Dysoxylum muelleri* (CQ and NQ), *Grevillea robusta*) and shade (*Podocarpus elatus*, *Elaeocarpus grandis* and *Grevillea robusta*). Similarly, species with a significant positive growth response (relative height and relative diameter) to added nitrogen in sun (*Blepharocarya involucrigera*, *Melia azedarach* var. *australasica* and *Grevillea robusta*) and shade (relative height *Melia azedarach* var. *australasica*, *Grevillea robusta*, *Flindersia xanthoxyla* and *Dysoxylum Muelleri* (CQ), relative diameter *Nauclea orientalis* and *Melia azedarach* var. *australasica*) may be useful.

Species with high WUE, in the present study, may be adapted to seasonal drought whilst species with low WUE might be prone to wilting following field planting (Maruyama *et al.* 1997). Climax species were found to have (Chapter 4) lower WUE than other successional groups under high light conditions and they may be more susceptible to seasonal drought and transplanting shock (wilt) following planting into high light environments. Additional nitrogen treatment under high light conditions, as shown in the present study, has the potential to raise WUE thereby reducing the potential for wilt following field planting.

5.3 Areas for future research

Many Queensland rainforest timber species remain untested for use in farm forestry designs. Difficulties with the development of suitable seed storage protocols and the breaking of seed dormancy still require attention. The physiological adaptation of many timber species to sun and shade is also not well documented. Planting designs need to be tested in the field in order to observe relative growth rates, light environments, nutrient cycling, stratification, competition and mycorrhizal associations. As mentioned before, there are few published accounts of field plantings of mixed species design. Specific trials are required to test species composition, stratification and management practises including thinning and harvest. Specially designed mixed species models are required to quantitatively evaluate biological growth and economic viability (Burkhart and Tham 1992). Research is needed on site-specific species selection, the role of soil characteristics and mycorrhiza, and the optimum solar radiation environment for individual species (Otsamo *et al.* 1996). Whilst analyses can reveal nutrient deficiencies in the soil, the response of many Australian rainforest cabinet timber species to nutrient application during early growth has not been documented.

5.4 From planning to sustainable harvest: a mixed species rainforest cabinet timber silviculture design

Farm forestry and agroforestry systems should not be an extension of conventional forestry practises but embrace a wide range of designs and encourage multi-purpose planting designs (Reid 1996). The challenge for landholders is to determine their own farm forestry design and explore possible

outcomes and benefits. As many farmers have limited forestry experience it may be advisable to commence with a small trial planting (less than one hectare). Valuable information necessary for successful plantings by landholders with limited forestry experience is presented as the brochure “Cabinet Timber Farm Forestry for Moderate to High rainfall areas of Eastern Queensland” (Appendix F).

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Appendix A

Summary of silvicultural characteristics of Queensland rainforest timber species and seed source for the germination experiment

Authors quoted are listed in Bibliography

Acacia aulacocarpa

Habit A tree mostly to 15 m tall and 40 cm dbh (Floyd 1989), occasionally up to 30 m tall and 100 cm dbh in Queensland rainforests (Boland *et al.* 1984).

Habitat Littoral rainforests and riverine subtropical rainforest (Floyd 1989).

Distribution From northern New South Wales to north Queensland (Floyd 1989).

Standard Trade Name Brown Salwood (Cause *et al.* 1989).

Timber and uses Dark red, hard, heavy, tough and durable. Texture is rather coarse but even and the grain is straight (Bootle 1983). It has been used for fence rails, **cabinet** work (Floyd 1989), framing, weatherboards and joinery (Boland *et al.* 1984), furniture, veneer and turnery (Bootle 1983).

Fruit Pod straight or wavy, thick and woody, rounded at both ends, 3 - 7 cm long and 1 - 2 cm wide.

Seed Black, oval, 5 mm long and 2 mm thick. 80,000 seeds per kilogram. Seed was obtained from DPI Forestry (Seedlot No. 5153), sourced from 3 trees at Caboolture, 27° 05' S, 152° 05' E, altitude 30 m, annual rainfall 1100 mm.

Acacia bakeri

Habit A straight tree up to 40 m in height and 90 cm dbh (Floyd 1989).

Habitat Lowland subtropical rainforest on volcanic and alluvial soils (Floyd 1989).

Distribution From Brunswicks Heads, New South Wales to Maryborough, Queensland (Floyd 1989).

Standard trade name White Wattle (Cause *et al.* 1989).

Timber and uses Pale yellow heartwood and marble-like figuring on the tangential face. The texture is coarse but even (Bootle 1983). the timber is suitable for flooring and cabinet work (Floyd 1989).

Fruit The pod is straight and flat, 12 - 20 cm long and about 13 mm wide.

Seed Black, flat, shiny, oval, 6 - 10 mm long. 25,000 seeds per kilogram. Seed was obtained from Queensland Tree Seeds (QTS2), source unknown.

Acacia melanoxylon

Habit A medium to large tree attaining a height of 45 m and 120 cm dbh in the Otway Ranges, Victoria (Floyd 1989).

Habitat Found in all types of rainforest (Floyd 1989).

Distribution From Tasmania to north Queensland (Floyd 1989).

Standard trade name Blackwood (Cause et al. 1989).

Timber and uses Heartwood is golden brown, grain is usually straight but sometimes wavy producing a fiddleback figure, and texture is medium and even (Bootle 1983). The timber is used for decorative veneer, furniture, panelling, flooring, and boatbuilding (Bootle 1983). It has good acoustic qualities and is suitable for violin backs (Floyd 1989).

Fruit Brown flat pod, much twisted, up to 120 mm long and 8 mm wide (Floyd 1989).

Seed Oval black seeds 3mm x 2mm with a thin red thread connection to the pod. 125,000 seeds per kilogram. Seed was obtained from DPI Forestry (Seedlot No. 5546), sourced from 5 parent trees in SF 792 Conondale 26° 42' S, 152° 42' E, altitude 635 m., annual rainfall 1080 mm.

Agathis robusta

Habit A large tree attaining a height of 50 m and 180 cm dbh (Boland *et al.* 1984).

Habitat Found as an emergent in some tropical and subtropical rainforests but forming a dominant part of the stand in dry marginal rainforest types on the edge of the rainforest zone (Boland *et al.* 1984).

Distribution It has a disjunct distribution occurring in south-east Queensland and in north-east Queensland (Boland *et al.* 1984).

Standard Trade Name Queensland Kauri Pine (Cause *et al.* 1989).

Timber and uses Heartwood is cream to pale brown, texture is even (Boland *et al.* 1984). It is used for cabinet work, pannelling and indoor fittings (Francis 1981).

Fruit Mature cones are globular to cylindric, up to 150 mm x 105 mm (Boland *et al.* 1984).

Seed Winged seed up to 30 mm in length (Boland *et al.* 1984), seed brown 10 mm x 7 mm. 18,000 seed per kilogram. Seed was obtained from DPI Forestry (Seedlot No.

4986), sourced from five parents at Byfield 22° 45' S, 150° 45' E, altitude 50 m., annual rainfall 1650 mm.

Alphitonia excelsa

Habit A small to medium sized tree, but occasionally attaining a height of 35 m and 125 cm dbh. It has a crown of medium density (Floyd 1989).

Habitat Dry, littoral, subtropical and warm temperate rainforests (Floyd 1989).

Distribution From New south Wales to north Queensland (Floyd 1989).

Standard trade name Red Ash (Cause *et al.* 1989).

Timber and uses Pink when freshly cut, darkening to a rich orange red with age. Stripes of varying hue often occur. Texture even and relatively fine. Grain is straight. Requires careful drying to avoid surface checks. It can be used for decorative veneer, turnery, panelling, joinery, and flooring (Bootle 1983).

Fruit Black globular, 6-10 mm diameter, containing two hard cells with a powdery red covering.

Seed Fruit contains two oval brown seeds about 3 mm long. 77,000 seeds per kilogram. Seed was obtained from DPI Forestry (Seedlot No. 4685), sourced from 7 trees at Danbulla State Forest 185, 17° 09' S 145° 09' E, altitude 700 m, annual rainfall 1600 mm.

Argyrodendron trifoliolatum

Habit A large tree to 45 m in height and 200 cm dbh, with a dense crown (Floyd 1989).

Habitat Lowland sub tropical rainforest.

Distribution Northern New south Wales to Bulburin, Central Queensland with isolated occurrences at Eungella and Atherton, North Queensland (Floyd 1989).

Standard trade name Brown Tulip Oak (Cause *et al.* 1989).

Timber and uses Dark brown to red brown, straight grain, coarse texture and prominent rays giving a silky oak appearance (Bootle 1983). It is used for cabinet work, pannelling, flooring and furniture (Floyd 1989).

Fruit Brown seed attached to a thin flat silvery brown scaly wing 40 mm x 25 mm x 1 mm. 1500 fruit per kilogram.

Seed Spherical seed, 8.5 mm diameter. 1700 seed per kilogram. Seed was collected from Bulburin State Forest (BB03) on 2nd and 3rd December 1997 from 10 parents over a 5 km transect, 24° 32' S, 151° 28' E, altitude 580 m., annual rainfall 1491 mm.

Blepharocarya involucrigera

Habit A large tree attaining a height of 36 m and 80 cm dbh (Francis 1981). It is fast growing and develops a spreading lacy crown (Jones 1986).

Habitat Tropical rainforests (Jones 1986).

Distribution North Queensland (Jones 1986).

Standard trade name Rose Butternut (Cause *et al.* 1989).

Timber and uses Heartwood is pinkish brown, texture is fine and even, grain is often wavy producing an attractive figure. It can be used for decorative veneer, furniture and pannelling (Bootle 1983).

Fruit Woody capsule, 25 mm diameter (Francis 1981).

Seed Several light brown seed in each fruit (Jones 1986). The seeds are flattened, 12mm diameter, with a distinctive fringe of dense marginal hairs (Francis 1981). Seed was obtained from DPI Forestry (Seedlot No. 10126), sourced from unknown parents at Atherton, 17° 17' S, 145° 28' E., 85,000 seed per kilogram.

Cardwellia sublimis

Habit A large tree attaining a height of 30 m and 150 cm dbh (Francis 1981).

Habitat North Queensland rainforests (Bootle 1983).

Distribution North Queensland rainforests (Francis 1981).

Standard Trade Name Northern Silky Oak (Cause *et al.* 1989).

Timber and uses Pinkish brown heartwood, with coarse texture, straight grain and prominent rays (Bootle 1983). It is used for cabinet making (Francis 1981), furniture and joinery and is the most readily available of the silky oaks (Bootle 1983).

Fruit A woody folicle 160 mm x 120 mm (Jones 1986).

Seed The seed is enclosed in a light brown thin papery capsule 80 mm x 30 mm. The seed is approximately 70 mm x 25 mm and there are 1,500 seeds per kilogram. Seed was obtained from DPI Forestry (Seedlot No. 5613), sourced from 6 parent trees at Malanda, 17° 20' S, 145° 20' E, altitude 760 m, annual rainfall 1666 mm.

Castanospermum australe

Habit A large tree attaining a height of 35 m and 100 cm dbh (Floyd 1989).

Habitat Riverine rainforest (Floyd 1989).

Distribution From northern New South Wales to north Queensland (Floyd 1989).

Standard trade name Black Bean (Cause *et al.* 1989).

Timber and uses Heartwood dark brown to black, texture moderately coarse, grain usually straight (Bootle 1983). It is used for decorative veneer, furniture and pannelling (Bootle 1983).

Fruit A woody dark brown shiny pod 150 mm x 50 mm x 45 mm containing up to five seeds. 50 fruits per kilogram.

Seed Brown round to compressed seed 50 mm x 35 mm x 25mm. Seed was collected from street plantings in Rockhampton (R01), from five parents, 23° 23' S, 150° 31' E, altitude 20 m., annual rainfall 850 mm. 200 seed per kilogram.

Citronella moorei

Habit A large tree attaining a height of 50 m and 200 cm dbh, with a large dense crown (Floyd 1989).

Habitat Sub tropical and warm temperate rainforest (Floyd 1989).

Distribution From southern New South Wales to North Queensland (Floyd 1989).

Standard trade name Silky Beech (Cause *et al.* 1989).

Timber and uses Heartwood pale yellow with a grey-green tinge. Texture moderately fine. Grain often interlocked. The rays are prominent, giving an attractive figure to the radial surface. It is suitable for decorative veneer, furniture and turnery (Bootle 1983).

Fruit Black oval-globular, about 2 cm long containing a single seed. 300 fruit per kilogram.

Seed Light brown, 1.5 cm long with longitudinal ridges. In cross-section the seed has a deep vertical furrow. 800 seed per kilogram. Seed was collected (20/2/1997) from Bulburin State Forest (BU4), sourced from four parent trees, 24° 32' S, 151° 28' E, altitude 580 m., annual rainfall 1491 mm.

Dysoxylum muelleri

Habit A large tree attaining a height of 35 m and 120 cm dbh. (Floyd 1989).

Habitat Subtropical, riverine and littoral rainforests (Floyd 1989).

Distribution Northern New South Wales to north Queensland (Floyd 1989).

Standard trade name Miva Mahogany (Cause *et al.* 1989).

Timber and uses Heartwood reddish brown, texture moderately fine and even, grain sometimes interlocked (Bootle 1983). It is used for veneer, furniture, panneling (Bootle 1983), cabinet work and boatbuilding (Floyd 1989).

Fruit A fawn brown globular capsule, 20 mm diameter, containing two to five cells. 450 fruit per kilogram.

Seed Red to brown seed 10 mm x 6 mm. 3,700 seed per kilogram. Seed was obtained from DPI Forestry (Seedlot No. 10123), sourced from unknown parents from Yungaburra, north Queensland 17° 16' S, 145° 34' E.

Elaeocarpus grandis

Habit A large tree attaining a height of 35 m and 200 cm dbh, with a large sparsely leaved crown (Floyd 1989).

Habitat A riverine tree commonly dominant on alluvial flats and gullies in lowland subtropical rainforest.

Distribution From north New South Wales to Cape York, north Queensland (Floyd 1989).

Standard trade name Silver Quandong (Cause *et al* 1989).

Timber and uses White to pale brown, straight grained, light relatively strong and bends well. Prized for boat building, as well as furniture and flooring (Floyd 1989).

Fruit Blue globular drupe, 18-30 mm in diameter. Edible fleshy outer layer enclosing a very hard stone containing five seeds (Floyd 1989). 142 fruit per kilogram.

Seed Narrow oval seed to 10 mm long. 270 seed per kilogram. Five seed compartments per fruit often only two with viable seed. Seed was obtained (28/09/97) from Polka Creek, Byfield, 22° 49' S, 150° 37' E, altitude 200 m, annual rainfall 1650 mm.

Elaeocarpus kirtonii

Habit A large tree with straight bole, attaining a height of 45 m and 200 cm dbh (Floyd 1989).

Habitat Temperate and cool sub-tropical rainforest in the mountains in moister sites (Floyd 1989).

Distribution Central New South Wales to Eungella Range, central Queensland (Floyd 1989).

Standard trade name Brown-hearted Quandong (Floyd 1989)

Timber and uses Pale brown, straight grained and relatively strong. Used for flooring, furniture and aircraft manufacture (Floyd 1989).

Fruit Olive green to blue drupe with pale spots, 11 mm long and 10 mm in width. 1845 fruit per kilogram.

Seed Unable to extract the seed from the woody fruit. Collected on 02/12/1997 from Bulburin State Forest (BB02), sourced from a single parent tree, 24° 32' S, 151° 28' E, altitude 580 m., annual rainfall 1491 mm.

Euroschinus falcata var. falcata

Habit A large tree attaining height of 45 m and 90 cm dbh (Floyd 1989).

Habitat Found in all types of rainforest but especially in littoral, riverine and dry rainforests (Floyd 1989).

Distribution From south-east New South Wales to north Queensland (Floyd 1989).

Standard Trade Name Pink Poplar (Cause *et al.* 1989).

Timber and uses Heartwood pinkish grey with yellow streaks, texture fine and even, grain slightly interlocked. The timber has a distinctive silken sheen (Bootle 1983). It is used for furniture, internal joinery, plywood (Floyd 1989) and flooring (Francis 1981).

Fruit Black egg-shaped drupe, 6-9 mm long. 37,000 fruits per kilogram (Floyd 1989).

Seed Flattened egg-shaped seed 6 mm x 4 mm x 2 mm. 43,000 seed per kilogram. Seed was collected in mid January from one parent in Yeppoon (YP4), 23° 8' S, 150° 44' E, altitude 20 m., annual rainfall 1100 mm.

Flindersia australis

Habit A large tree attaining a height of 40 m and 180 cm dbh (Floyd 1989).

Habitat Dry rainforest (Floyd 1989).

Distribution From northern New South Wales to Mackay, Queensland (Floyd 1989).

Standard Trade Name Crow's Ash (Cause *et al.* 1989).

Timber and uses Heartwood golden yellow, texture medium and even, grain often interlocked. It has a very greasy surface (Bootle 1983). It can be used for flooring (especially dance floors), boatbuilding and outdoor furniture (Floyd 1989).

Fruit A woody capsule covered with stout blunt prickles, splitting into 5 boat shaped valves containing two or three winged seeds (Floyd 1989).

Seed Flat brown seed, 13 mm x 8 mm, with papery wing 20 - 30 mm long. 12,500 seeds per kilogram. Seed was obtained from DPI Forestry (Seedlot No. 3601), sourced from 4 parent trees east of Gympie 26° 10' S, 152° 10' E, altitude 95 m., annual rainfall 1200 mm.

Flindersia brayleyana

Habit A large tree attaining a height of 30 m and 120 cm dbh. (Francis 1981). It is fairly fast growing and develops a spreading crown (Jones 1986).

Habitat North Queensland rainforests (Bootle 1983)

Distribution North Queensland (Bootle 1983).

Standard Trade Name Queensland Maple (Cause *et al.* 1989).

Timber and uses Decorative veneer, furniture, panelling (Bootle 1983).

Fruit A woody capsule up to 100 mm in length, splitting into 4 or 5 narrow boat shaped valves (Francis 1981).

Seed Dark brown papery wings 65 mm x 15 mm, enclosing a seed 30 mm x 9 mm. The seed was obtained from DPI Forestry (Seedlot No. 56360), sourced from 5 parent trees on the Atherton Tableland 17° 17' S, 145° 17' E, altitude 760 m., annual rainfall 1425 mm. 10,800 seed per kilogram.

Flindersia schottiana

Habit A large fast growing tree attaining a height of 45 m and 100 cm dbh (Floyd 1989)

Habitat Riverine and subtropical rainforest (Floyd 1989)

Distribution From northern New South Wales to north Queensland (Floyd 1989).

Standard trade name Southern Silver Ash (Cause *et al.* 1989).

Timber and uses Heartwood pale yellow, texture medium and even, grain variable (Bootle 1983). It is used for decorative veneer, furniture, panelling, boatbuilding, flooring (Bootle 1983), and cabinet work (Floyd 1989).

Fruit Brown woody capsule with short stout prickles, separating into five narrow boat shaped valves, each containing up to six seeds (Floyd 1989).

Seed Brown thin papery winged seed 50 mm x 17 mm x 2 mm. Seed was obtained from DPI Forestry (Seedlot No. 10214). 20,900 seed per kilogram.

Flindersia xanthoxyla

Habit A large tree attaining a height of 45 m and dbh 90 cm (Floyd 1989).

Habitat Dry rainforest, occasionally riverine and littoral rainforest (Floyd 1989).

Distribution From northern New South Wales to Gympie, Queensland (Floyd 1989).

Standard Trade Name Yellowwood (Cause *et al.*).

Timber and uses Pale yellow heartwood, texture medium and even, grain sometimes interlocked (Bootle 1983). It can be used for decorative veneer, furniture, boatbuilding (Bootle 1983), flooring and cabinet making (Floyd 1989).

Fruit A woody capsule covered with short blunt prickles, splitting into 5 boat shaped valves containing two or three winged seeds (Floyd 1989).

Seed Papery winged seed 50 mm x 12 mm, the seed being 20 mm x 6 mm. The seed was obtained from DPI Forestry (Seedlot No. 4362), sourced from 8 parent trees at 67 V Cooyar 26° 50' S, 151° 50' E, altitude 500 m., annual rainfall 715 mm.

Gmelina leichardtii

Habit A large tree attaining a height of 30 m and 200 cm dbh (Boland *et al.* 1984). It has an open crown and is semi-deciduous, leaves falling in late spring (Boland *et al.* 1984).

Habitat Found in sub tropical and tropical rainforests (Boland *et al.* 1984).

Distribution From south-east New South Wales to north Queensland (Boland *et al.* 1984),

Standard Trade Name White Beech (Cause *et al.*).

Timber and uses Heartwood pale brown, texture medium and even, grain often interlocked. It is used for furniture, boatbuilding and patternmaking (Bootle 1983).

Fruit White to purple globular fruit 36 mm x 24 mm turning to yellow brown with storage. 85 fruit per kilogram.

Seed Light brown seed. 430 seed per kilo. Collected from Maleny (DPI seeds Seedlot No. 10232), southern Queensland, 26° 47' S, 152° 47' E, altitude 250 m., annual rainfall 1700 mm.

Grevillea hilliana

Habit A tree attaining a height of 30 m and 35 cm dbh (Floyd 1989).

Habitat Littoral and riverine rainforest (Floyd 1989).

Distribution From northern New South Wales to North Queensland (Floyd 1989).

Standard Trade Name Hill's Silky Oak (Cause *et al.* 1989).

Timber and uses Reddish brown with silky oak figure (Floyd 1989). It can be used for veneer, cabinet work and violins (Floyd 1989).

Fruit A green woody folicle turning black at maturity, 28 mm x 14 mm x 12 mm, containing two seed. 570 fruit per kilogram.

Seed Greyish brown oval seed, 8 mm x 6 mm x 1 mm, surrounded by a papery wing 17 mm x 11 mm. 57,500 seed per kilo (Floyd 1989). Seed was collected in mid-February from three parent trees in Bulburin State Forest (BU3), sourced from three parent trees, 24° 32' S, 151° 28' E, altitude 580 m., annual rainfall 1491 mm.

Grevillea robusta

Habit A large tree attaining a height of 35 m and dbh 90 cm. It is fast growing (Floyd 1989).

Habitat Riverine, subtropical and dry rainforest (Floyd 1989).

Distribution From northern New South Wales to south-east Queensland (Floyd 1989).

Standard Trade Name Southern Silky Oak (Cause *et al.* 1989).

Timber and uses Heartwood pinkish brown, texture medium, grain straight, and a typical silky oak figure (Bootle 1983). It has been used for furniture (Bootle 1983) and cabinet work (Floyd 1989).

Fruit A brown woody folicle up to 20 mm long, containing 2 seed (Floyd 1989).

Seed Thin brown seed surrounded by a papery capsule 12 mm x 8 mm. 66,000 seed per kilogram. Seed was obtained from DPI Forestry (Seedlot No. 5158), sourced from three parent trees between Conondale and Kenilworth, 26° 40' S, 152° 40' E, altitude 150 m., annual rainfall 1200 mm.

Harpullia pendula

Habit A small to medium tree attaining a height of 24 m and 60 cm dbh (Floyd 1989).

Habitat Riverine, subtropical and dry rainforests (Floyd 1989)

Distribution From northern New South Wales to north Queensland (Floyd 1989).

Standard Trade Name Tulipwood (Cause *et al.* 1989)

Timber and uses Heartwood is dark brown, texture is fine. The timber is highly figured with dark brown bands and pale or yellowish areas. It is used for cabinet work and turnery (Floyd 1989).

Fruit A two lobed yellow to red papery capsule 13 - 18 mm in diameter (Floyd 1989).

Seed Black egg shaped seed 13 mm x 9 mm. 1600 seed per kilogram. Seed was collected (03/12/1997) at Bulburin State Forest (BB05), sourced from a single parent tree, 24° 32' S, 151° 28' E, altitude 580 m., annual rainfall 1491 mm.

Melia azederach var. australasica

Habit A large tree attaining a height of 45 m and 120 cm dbh. It is fast growing and is deciduous (Floyd 1989).

Habitat Riverine, littoral and dry rainforests (Floyd 1989).

Distribution From southern New South Wales to north Queensland (Floyd 1989)

Standard Trade Name White Cedar (Cause *et al.* 1989).

Timber and uses Heartwood pale brown, texture very coarse and uneven, grain is straight (Bootle 1983). It has been used for cabinet work, veneer and panelling (Floyd 1989).

Fruit Yellow drupe 16 mm x 10 mm, occurring in bunches. 930 fruit per kilogram.

Seed Ribbed light brown seed case containing five cells each with a small seed. Seed was collected in late February (BF1) from one parent at Byfield, 22° 50' S, 150° 38' E, altitude 200 m, annual rainfall 1650 mm.

Nauclea orientalis

Habit Medium to tall tree attaining a height of 30 m and 100 dbh (Boland *et al* 1984).

Habitat Riverine and alluvial flats in gallery and lowland rainforest (Boland *et al* 1984).

Distribution Granite Creek, Miriam Vale, central Queensland to Cape York, north Queensland (Jones 1986).

Standard Trade Name Cheesewood.

Timber and uses Heartwood yellow to orange, used for flooring, internal joinery and novelty (Boland *et al* 1984).

Fruit Fleshy globular to irregular fruit up to 50 mm in diameter. 27 fruit to the kilogram.

Seed Seed tiny, 1.5 x 1 mm, collected (15/02/1998) in Rockhampton, central Queensland, (R04), 23° 23' S, 150° 31' E, altitude 20 m., annual rainfall 850 mm.

Paraserianthes toona

Habit A large tree attaining a height of 30 m and 60 cm dbh. It is fast growing and has a spreading canopy (Jones 1986). It may be deciduous in winter and early spring (Francis 1981).

Habitat Found in open forest as well as rainforest (Francis 1981).

Distribution From Sarina, Central Queensland to Cooktown, north Queensland (Francis 1981).

Standard Trade Name Red Siris (Cause *et al.* 1989)

Timber and uses Heartwood is red with streaky yellow variegations. It has been used for cabinet work and flooring (Francis 1981).

Fruit A flattened pod up to 130 mm long with 4 - 6 seeds in each pod (Francis 1981).

Seed Dark brown oval flattened seed 9 mm x 11 mm x 2 mm. 13,500 seed per kilogram. Seed was obtained from Queensland Tree Seeds, sourced from unknown parents, unknown location.

Pittosporum undulatum

Habit A medium sized tree attaining a height of 25 m and 75 cm dbh (Floyd 1989).

Habitat Dry rainforest (Floyd 1989).

Distribution From Victoria to Central Queensland (Floyd 1989).

Standard Trade Name Pittosporum (Cause et al. 1989).

Timber and uses Heartwood cream to pale yellow, texture fine and even, grain usually straight. It is used for turnery and marquetry (Bootle 1983).

Fruit A globular yellow capsule 8 - 12 mm diameter containing numerous dark angular seeds in an orange musilage. 1700 fruit per kilogram.

Seed Small dark angular seed. 38,000 seed per kilogram. Seed (BY7) was collected in late September from one parent at Byfield, 22° 50' S, 150° 38' E, altitude 200 m, annual rainfall 1650 mm.

Planchonella australis

Habit A large tree attaining a height of 30 m and 120 cm dbh (Floyd 1989).

Habitat Semi-dry rainforest to sub-tropical rainforest (Floyd 1989).

Distribution From southern New South Wales to Gympie, southern Queensland (Floyd 1989).

Standard Trade Name Black Apple (Cause et al. 1989).

Timber and uses Heartwood pale yellow with darker streaks, texture very fine and even, grain sometimes interlocked. It is used for turnery and marquetry (Bootle 1983).

Fruit Black succulent egg shaped fruit 45 mm x 35 mm. 40 fruit per kilogram.

Seed Dark brown glossy seed 25 mm x 14 mm x 9 mm. 770 seed per kilogram. Seed (BBO4) was collected in early December from three parents at Bulburin SF391, 24° 32' S, 151° 28' E, altitude 500 m, annual rainfall 1491 mm.

Pleiogynium timorense

Habit A small tree to 12 m with a rounded bushy crown (Jones 1986)

Habitat Riverine and depauperate rainforest (Jones 1986).

Distribution Central Queensland to far north Queensland (Jones 1986).

Standard Trade Name Tulip Plum (Cause *et al.* 1989).

Timber and uses Used for turnery.

Fruit Round deep purple fruit with edible flesh surrounding a red-brown woody capsule. 77 fruit per kilogram.

Seed Unable to extract individual seed from woody capsule, 8-10 seed per capsule, collected from street plantings in Rockhampton (RO3), from five parents, 23° 23' S, 150° 31' E, altitude 20 m., annual rainfall 850 mm.

Podocarpus elatus

Habit A large tree attaining a height of 40 m and 90 cm dbh

Habitat Littoral, riverine, subtropical (Floyd 1989) and dry rainforest.

Distribution From southern New South Wales to northern Queensland (Floyd 1989).

Standard Trade Name Brown Pine (Cause *et al.* 1989).

Timber and uses Heartwood golden brown, texture very fine and even, grain straight. It has been used for furniture, musical instruments, turnery (Bootle 1983) and boat building (Floyd 1989).

Fruit A fleshy plum, bluish black stalk with a resinous globular seed attached. The edible stalk is 20 mm in diameter and average weight is 2g. 240 fruit per kilogram.

Seed Spherical seed, 15 mm diameter, green with a purplish hue. 540 seed per kilogram. Seed (BU10) was collected in mid-April from five parents at Bulburin SF 391, 24° 32' S, 151° 28' E, altitude 500 m, annual rainfall 11491 mm.

Rhodosphaera rhodanthema

Habit A medium sized tree attaining a height of 27 m and 75 cm dbh (Floyd 1989).

Habitat Subtropical and dry rainforests (Floyd 1989).

Distribution From northern New South Wales to southern Queensland (Floyd 1989).

Standard Trade Name Tulip Satinwood (Cause et al. 1989).

Timber and uses Heartwood is yellowish bronze with a silky lustre. Texture is fine and the timber is beautifully figured. It can be used for cabinet work (Floyd 1989).

Fruit Dry brown globular fruit hanging in dense bunches.

Seed Hard brown globular seed 10 mm diameter. 3000 seed per kilogram. Seed was obtained from DPI Forestry (Seedlot No. 5177), sourced from one parent at SF1355 Mount Glorious, 27° 19' S, 152° 19' E, altitude 120 m., annual rainfall 1200 mm.

Stenocarpus sinuatus

Habit A medium sized tree attaining a height of 40 m and 75 cm dbh (Floyd 1989).

Habitat Subtropical, littoral, riverine and warm temperate rainforest (Floyd 1989).

Distribution Northern New South Wales to north Queensland (Floyd 1989).

Standard Trade Name White Silky Oak (Cause *et al.* 1989).

Timber and uses White with a figure like silky oak. It is suitable for veneer and cabinet work (Floyd 1989).

Fruit A grey-brown curved capsule containing numerous flattened seeds (Floyd 1989).

Seed A brown papery wing 43 mm x 11 mm, enclosing a squarish seed 13 mm x 12mm. Seed was obtained from DPI Forestry (Seedlot No. 5415), sourced from a single parent at Atherton 17° 16' S, 145° 16' E, altitude 760 m., annual rainfall 1404 mm.

Terminalia sericocarpa

Habit A large tree attaining a height of 30 m and 100 cm dbh (Boland et al. 1984)

Habitat Riverine and gallery rainforest (Boland et al 1984).

Distribution From Rockhampton, Central Queensland to Cape York and across the Northern Territory to the Kimberleys, Western Australia (Boland et al. 1984)

Standard trade name Damson (Cause et al. 1989)

Timber and uses Heartwood yellow-brown, medium and even texture (Bootle 1983), with interlocked grain (Boland et al. 1984).

Fruit Thin pink to red fruit 16 mm x 8 mm x 6 mm, covering a hard nut like endocarp. 4243 fruit per kilogram.

Seed Dark brown endocarp 12 mm x 8 mm x 5 mm. Seed was obtained from DPI Forestry (Seedlot No. 10145), sourced from unknown parents (10/2/98) from Yungaburra, North Queensland, 17° 16' S 145° 34' E. 7600 seed per kilogram.

Toechima tenax

Habit A small to medium tree attaining a height of 18 m and 30 cm dbh (Floyd 1989).

Habitat Dry rainforest (Floyd 1989).

Distribution From northern New South Wales to southern Queensland (Floyd 1989).

Standard Trade Name None.

Timber and uses Pinkish to red (Floyd 1989), used in turnery.

Fruit A yellow pear shaped two to three lobed capsule 10 mm x 20 mm.

Seed Black ovoid seed 9 mm x 6 mm x 4 mm. 7500 seed per kilogram. Seed was collected in October from Kershaw Gardens, Rockhampton (R02), 23° 23' S, 150° 31' E, altitude 20 m, annual rainfall 850 mm with supplementary watering from the gardens.

Toona ciliata

Habit A large tree attaining a height of 45 m and 210 cm dbh. It has a wide spreading crown and is deciduous (Floyd 1989).

Habitat Subtropical and riverine rainforests (Floyd 1989) occasionally dry rainforests.

Distribution From central New South Wales to north Queensland (Floyd 1989).

Standard Trade Name Red Cedar (Cause et al. 1989).

Timber and uses Heartwood is pale to dark red, depending on maturity. Texture is coarse, grain is straight or slightly interlocked. The timber is used for decorative veneer, furniture, boatbuilding, panelling (Bootle 1983) and cabinet work (Floyd 1989).

Fruit A dry light brown capsule splitting into five valves, each seed containing four or five winged seeds.

Seed Light brown winged seed 13 - 18 mm long. 440,000 seed per kilogram. Seed was obtained from DPI Forestry (Seedlot No. 4385), sourced from three parent trees at SF1355 Mount Glorious, 27° 19' S, 152° 19" E, altitude 120 m., annual rainfall 1200 mm.

Trema orientalis

Habit A large tree attaining a height of 25 m and 80 cm dbh. It is very fast growing and has a large spreading open canopy (Francis 1981).

Habitat Occurs as a pioneer in disturbed rainforest.

Distribution From central Queensland to Cape York (Francis 1981).

Standard Trade Name Peach Cedar (Cause *et al.* 1989).

Timber and uses Heartwood is pale pink, timber is soft. It can be used for internal joinery (Francis 1981) and boatbuilding.

Fruit Small green ovoid 5 mm x 3mm fruit turning black on maturity. 63,000 fruit per kilogram.

Seed Small brown to grey seed, ovoid 2 mm diameter, 160,000 seed per kilogram. Seed was collected from one parent at Byfield (BY2), 22° 49' S, 150° 37' E, altitude 200 m, annual rainfall 1650 mm.

Appendix B

Table of data and results of solar irradiance quality within compartments.

Compartment: Data code for shadehouse compartment, CL = clear, BL = blue, GR = green, Replicates 1 – 4.

Date: Date of reading.

Replicate: Four free standing shadehouses (replicates 1-4) sited at Plant Sciences compound, Central Queensland University on a 2 x 2 grid orientated North- South. Replicate 1 = north-west grid position, 2 = north-east grid position, 3 = south-west grid position, 4 = south-east grid position.

Light: 1 = Clear polyfilm covered shadehouse compartment, 2 = Blue polyfilm covered shadehouse compartment, 3 = green polyfilm covered shadehouse compartment.

Mean R:FR: Skye Datalogger data of R (660 ± 5 nm) waveband ($\mu\text{mol m}^{-2} \text{s}^{-1}$) divided by FR (730 ± 5 nm) waveband ($\mu\text{mol m}^{-2} \text{s}^{-1}$) sampled every 10 seconds, averaged every five minutes. Mean R:FR is the daily average of five-minute averages of R/FR.

SE Mean: Standard error of the Mean R:FR.

N: N = number of five-minute averages recorded by the Datalogger for a given date.

TR: TR = Aggregate total of the five-minute averages of the R (660 ± 5 nm) waveband ($\mu\text{mol m}^{-2} \text{s}^{-1}$) for a given date.

TFR: TFR = Aggregate total of the five-minute averages of the FR (730 ± 5 nm) waveband ($\mu\text{mol m}^{-2} \text{s}^{-1}$) for a given date.

Licor PPFD: Licor PPFD = Aggregate total of the five-minute averages (sampled every 10 seconds) of the 400-700 nm waveband ($\mu\text{mol m}^{-2} \text{s}^{-1}$) for a given date using a LI-COR. LI-1000 fitted with a LI-190SA quantum sensor.

Temp. max: Maximum temperature recorded using a shielded max-min thermometer for a week (depending on location of Skye datalogger) preceding the given date.

Temp. min: Minimum temperature recorded using a shielded max-min thermometer for a week (depending on location of Skye datalogger) preceding the given date.

Compartment	Date	replicate	light	Mean			TR	
				R:FR	SEMean	N		
CL1	26.04.99	1	1	0.8961	0.0266	59	462.459	
CL1	27.04.99	1	1	0.7839	0.0123	134	2775.42	
CL1	28.04.99	1	1	0.7555	0.0141	136	2888.8	
CL1	29.04.99	1	1	0.7737	0.0224	135	2835.31	
CL1	30.04.99	1	1	0.7773	0.0107	132	2845.87	
CL1	01.05.99	1	1	0.8036	0.0099	134	2901.12	
CL1	02.05.99	1	1	0.7798	0.0175	42	526.933	
CL1	24.11.98	1	1	1.0553	0.0373	79	2306.97	
CL1	25.11.98	1	1	1.0446	0.0072	146	3354.07	
CL1	26.11.98	1	1	1.0124	0.0123	162	4293.84	
CL1	27.11.98	1	1	0.98661	0.0091	162	4036.82	
CL1	28.11.98	1	1	1.019	0.0127	159	4440.13	
CL1	29.11.98	1	1	1.0341	0.0162	162	3940.04	
CL1	30.11.98	1	1	1.0079	0.0096	160	3713.92	
CL1	01.12.98	1	1	0.9828	0.0139	162	3388.66	
CL1	02.12.98	1	1	0.97635	0.00944	51	1227.61	
DG4	24.09.99	4	3	0.4717	0.018	37	52.421	
DG4	25.09.99	4	3	0.51427	0.00839	108	185.568	
DG4	26.09.99	4	3	0.4998	0.00985	115	179.272	
DG4	27.09.99	4	3	0.4711	0.0124	104	111.602	
DG4	28.09.99	4	3	0.48092	0.0096	118	123.916	
DG4	29.09.99	4	3	0.50033	0.0078	114	110.89	
DG4	30.09.99	4	3	0.50473	0.00746	114	141.127	
DG4	01.10.99	4	3	0.49416	0.00922	109	85.611	
DG4	02.10.99	4	3	0.5032	0.0117	100	151.948	
DG4	03.10.99	4	3	0.4673	0.029	20	6.927	
CL3	30.06.99	3	1	0.90143	0.00833	124	700.573	
CL3	01.07.99	3	1	0.84156	0.00686	124	721.169	
CL3	29.06.99	3	1	1.085	0.178	22	38.312	
CL3	02.07.99	3	1	0.78565	0.00683	126	1502.51	
CL3	03.07.99	3	1	0.83944	0.0047	125	699.321	
CL3	04.07.99	3	1	0.8237	0.00936	99	450.806	
DG1	02.12.98	1	3	0.6584	0.00868	97	591.673	
DG1	03.12.98	1	3	0.5845	0.00454	149	869.044	
DG1	04.12.98	1	3	0.61814	0.00633	95	705.202	
BL3	29.12.98	3	2	0.48668	0.00489	46	65.759	
BL3	30.12.98	3	2	0.4637	0.00368	131	250.34	
BL3	31.12.98	3	2	0.45604	0.0034	131	282.642	
BL3	01.01.99	3	2	0.48736	0.00451	131	121.548	
BL3	02.01.99	3	2	0.46365	0.00315	128	195.836	
BL3	03.01.99	3	2	0.51386	0.00233	126	88.856	
BL3	04.01.99	3	2	0.49914	0.00581	120	83.302	
BL3	05.01.99	3	2	0.46355	0.00806	84	177.043	
DG3	02.09.98	3	3	0.4995	0.0131	53	45.169	
DG3	03.09.98	3	3	0.54724	0.00693	98	112.465	
DG3	04.09.98	3	3	0.51586	0.00643	100	125.694	
DG3	05.09.98	3	3	0.5336	0.016	43	59.749	
BL3	31.05.99	3	2	0.36325	0.00538	71	77.643	

BL3	01.06.99	3	2	0.34453	0.00641	84	93.263
BL3	02.06.99	3	2	0.35906	0.005	83	77.923
BL3	03.06.99	3	2	0.41957	0.00563	88	48.425
BL3	04.06.99	3	2	0.36585	0.00269	76	84.948
BL3	05.06.99	3	2	0.4293	0.00811	66	24.076
BL3	06.06.99	3	2	0.35873	0.00879	48	24.076
CL2	30.10.98	2	1	1.0189	0.0042	102	2544.79
CL2	31.10.98	2	1	1.0847	0.0114	151	2428.31
CL2	01.11.98	2	1	1.0922	0.0273	152	2250.89
CL2	02.11.98	2	1	1.0258	0.0144	152	3369.15
CL2	03.11.98	2	1	0.99209	0.00498	156	3997.75
CL2	04.11.98	2	1	0.969	0.00792	157	4449.79
CL2	05.11.98	2	1	0.96256	0.00525	156	4472.66
CL2	06.11.98	2	1	0.94857	0.003	74	2074.2
DG2	01.03.99	2	3	0.45123	0.00334	116	148.689
DG2	02.03.99	2	3	0.46481	0.00459	129	193.219
DG2	03.03.99	2	3	0.44443	0.00545	120	170.175
DG2	04.03.99	2	3	0.46098	0.00554	101	116.238
DG2	05.03.99	2	3	0.45206	0.00536	121	153.32
DG2	06.03.99	2	3	0.42915	0.00484	116	153.614
DG2	07.03.99	2	3	0.47795	0.00553	83	106.87
BL1	29.09.98	1	2	0.82498	0.00414	139	1558.95
BL1	30.09.98	1	2	0.82224	0.00391	141	1330.31
BL1	01.10.98	1	2	0.79338	0.00392	142	1484.7
BL1	02.10.98	1	2	0.80345	0.00399	143	1235.82
BL1	03.10.98	1	2	0.8102	0.00372	141	1078.73
BL1	04.10.98	1	2	0.80336	0.00481	141	1295.47
BL1	05.10.98	1	2	0.78428	0.00486	140	1427.22
BL1	06.10.98	1	2	0.83637	0.0064	142	1395.76
BL1	07.10.98	1	2	0.86957	0.00646	71	618.642
BL2	01.11.99	2	2	0.55775	0.00664	123	226.059
BL2	02.11.99	2	2	0.58538	0.00447	128	232.025
BL2	03.11.99	2	2	0.56045	0.00375	137	225.234
BL2	04.11.99	2	2	0.5747	0.00428	137	280.924
BL2	05.11.99	2	2	0.58187	0.0033	133	322.935
BL2	06.11.99	2	2	0.59468	0.00606	119	119.051
BL2	07.11.99	2	2	0.6104	0.0125	48	97.301
CL2	04.12.98	2	1	0.9272	0.0105	59	1286.98
CL2	05.12.98	2	1	0.98845	0.00378	160	5012.28
CL2	06.12.98	2	1	0.9869	0.0053	163	4176.34
CL2	07.12.98	2	1	0.9871	0.00716	162	4743.97
CL2	08.12.98	2	1	1.0086	0.0045	52	1167.47
CL2	03.05.99	2	1	0.89384	0.00871	134	3422.65
CL2	04.05.99	2	1	0.92674	0.00856	132	3145.54
CL2	05.05.99	2	1	0.92361	0.00598	133	2528.4
CL2	06.05.99	2	1	0.91317	0.00896	133	2436.58
CL2	07.05.99	2	1	0.90745	0.00796	133	2999.5
CL2	08.05.99	2	1	0.96444	0.00533	132	2561.72
CL2	09.05.99	2	1	0.94786	0.00713	86	2083.51
DG3	02.09.98	3	3	0.4995	0.0131	53	45.169
DG3	03.09.98	3	3	0.54966	0.00656	97	112.378

DG3	04.09.98	3	3	0.51586	0.00643	100	125.694
CL4	30.11.99	4	1	0.9933	0.0119	37	686.066
CL4	01.12.99	4	1	1.0327	0.0039	159	3959.15
CL4	02.12.99	4	1	1.0051	0.004	160	4875.82
CL4	03.12.99	4	1	1.0035	0.0066	160	4942.46
CL4	04.12.99	4	1	0.98042	0.00307	161	5376.65
CL4	05.12.99	4	1	1.0036	0.0056	161	4848.82
CL4	06.12.99	4	1	1.0005	0.005	161	4931.24
CL4	07.12.99	4	1	1.0104	0.0041	161	4717.54
CL4	08.12.99	4	1	1.0498	0.0054	158	3833.83
CL4	09.12.99	4	1	1.0323	0.0071	48	952.612
BL4E	09.12.99	4	2	0.56187	0.00547	34	161.965
BL4E	10.12.99	4	2	0.6425	0.0101	147	663.052
BL4E	11.12.99	4	2	0.62911	0.00965	146	706.641
BL4E	12.12.99	4	2	0.7272	0.00472	102	91.302
BL4E	13.12.99	4	2	0.64682	0.00957	141	173.85
BL4E	14.12.99	4	2	0.57304	0.0084	144	555.609
BL4E	15.12.99	4	2	0.57235	0.00771	144	352.037
BL4E	16.12.99	4	2	0.57672	0.00849	140	437.332
BL4E	17.12.99	4	2	0.61245	0.00549	145	529.311
BL4E	18.12.99	4	2	0.63943	0.00427	141	297.622
BL4E	19.12.99	4	2	0.6877	0.00223	137	185.605
BL4E	20.12.99	4	2	0.57743	0.00807	145	692.469
BL4E	21.12.99	4	2	0.58557	0.00689	137	419.382
BL4E	22.12.99	4	2	0.57593	0.00888	147	552.645
BL4E	23.12.99	4	2	0.64253	0.00226	143	199.257
BL4E	24.12.99	4	2	0.63706	0.00354	147	294.835
BL4E	25.12.99	4	2	0.63921	0.00556	142	246.632
BL4E	26.12.99	4	2	0.65375	0.0063	126	271.38
BL4E	27.12.99	4	2	0.68397	0.00527	131	148.576
BL4E	28.12.99	4	2	0.59735	0.00615	141	353.904
BL4E	29.12.99	4	2	0.56434	0.00827	143	669.815
BL4E	30.12.99	4	2	0.57932	0.00581	146	746.39
BL4E	31.12.99	4	2	0.54747	0.00786	143	685.925
BL4E	01.01.00	4	2	0.57429	0.00609	145	560.791
BL4E	02.01.00	4	2	0.56273	0.00866	154	636.081
BL4E	03.01.00	4	2	0.56339	0.00808	122	307.898
BL4E	04.01.00	4	2	0.56789	0.00768	142	285.158
BL4E	05.01.00	4	2	0.59169	0.00595	139	398.195
BL4E	06.01.00	4	2	0.67988	0.00773	18	32.718
DG3	03.10.99	3	3	0.68966	0.00711	97	207.611
DG3	04.10.99	3	3	0.67057	0.00721	122	159.557
DG3	05.10.99	3	3	0.60593	0.00579	129	250.154
DG3	06.10.99	3	3	0.59534	0.00663	128	229.561
DG3	07.10.99	3	3	0.66484	0.00579	133	235.647
DG3	08.10.99	3	3	0.61411	0.00668	129	265.348
DG3	09.10.99	3	3	0.57368	0.00697	131	254.631
DG3	10.10.99	3	3	0.55223	0.0085	126	269.778
BL4	05.01.99	4	2	0.37	0.01	22	17.285
BL4	06.01.99	4	2	0.37967	0.00336	132	151.932
BL4	07.01.99	4	2	0.36637	0.00674	128	150.554

BL4	08.01.99	4	2	0.37886	0.00411	135	162.95
BL4	09.01.99	4	2	0.37582	0.00398	133	140.873
BL4	10.01.99	4	2	0.38342	0.0036	127	129.723
BL4	11.01.99	4	2	0.39701	0.00629	80	109.395
BL3	07.11.99	3	2	0.4661	0.0107	71	122.464
BL3	08.11.99	3	2	0.53145	0.00475	111	151.704
BL3	09.11.99	3	2	0.45515	0.00576	128	250.419
BL3	10.11.99	3	2	0.4358	0.00391	131	270.618
BL3	11.11.99	3	2	0.45317	0.00335	21	18.578
CL1	05.07.99	1	1	0.91896	0.00819	127	2767.05
CL1	06.07.99	1	1	0.93069	0.00644	128	2688.73
CL1	07.07.99	1	1	0.93234	0.00679	129	2963.34
CL1	08.07.99	1	1	0.9323	0.0136	131	3239.28
CL1	09.07.99	1	1	0.94282	0.00383	127	2358.36
CL1	10.07.99	1	1	0.9337	0.0116	129	3158.76
CL1	11.07.99	1	1	0.95917	0.00863	129	2977.46
CL1	12.07.99	1	1	0.9911	0.0116	64	1615.97
BL3	07.10.98	3	2	0.66491	0.00633	64	176.395
BL3	08.10.98	3	2	0.6435	0.00321	135	457.485
BL3	09.10.98	3	2	0.65283	0.00724	128	481.083
BL3	10.10.98	3	2	0.65208	0.00676	130	380.273
BL3	11.10.98	3	2	0.63101	0.00541	136	669.063
BL3	12.10.98	3	2	0.66773	0.00472	136	633.905
DG4E	11.01.00	4	3	0.51834	0.0074	126	170.087
DG4E	12.01.00	4	3	0.4384	0.0143	138	260.949
DG4E	13.01.00	4	3	0.4968	0.0122	121	304.633
BL3	06.02.99	3	2	0.41964	0.00549	110	105.889
BL3	07.02.99	3	2	0.43083	0.00566	98	117.067
BL3	08.02.99	3	2	0.418	0.00704	103	94.238
BL3	09.02.99	3	2	0.41272	0.00424	100	73.9
BL3	10.02.99	3	2	0.4688	0.00533	103	71.522
BL3	11.02.99	3	2	0.42414	0.00377	82	57.093
BL3	12.02.99	3	2	0.42298	0.00411	108	106.575
BL3	13.02.99	3	2	0.41707	0.00427	111	65.834
BL3	14.02.99	3	2	0.41457	0.0037	81	69.714
DG3	08.03.99	3	3	0.37361	0.00495	84	42.487
DG3	09.03.99	3	3	0.35687	0.00694	90	48.969
DG3	10.03.99	3	3	0.36785	0.00521	84	59.771
DG3	11.03.99	3	3	0.36007	0.00389	85	61.152
DG3	12.03.99	3	3	0.35028	0.00774	79	48.027
DG3	13.03.99	3	3	0.35609	0.00489	82	61.507
DG3	14.03.99	3	3	0.37244	0.00829	49	27.017
BL2	06.06.99	2	2	0.49035	0.00636	8	5.266
BL2	07.06.99	2	2	0.49801	0.00502	89	117.782
BL2	08.06.99	2	2	0.48698	0.00815	95	114.57
BL2	09.06.99	2	2	0.49582	0.0062	96	127.788
BL2	10.06.99	2	2	0.537	0.00737	104	93.891
BL2	11.06.99	2	2	0.47825	0.00721	89	137.796
BL2	12.06.99	2	2	0.46649	0.00841	91	138.057
BL2	13.06.99	2	2	0.50072	0.00452	89	124.518
BL2	14.06.99	2	2	0.47348	0.00758	44	76.45

CL4	09.12.98	4	1	0.97422	0.00609	159	4591.75
CL4	10.12.98	4	1	1.0574	0.0099	159	2002.23
CL4	11.12.98	4	1	0.98701	0.00521	162	3674.22
CL4	12.12.98	4	1	0.97825	0.00417	161	2414.32
CL4	13.12.98	4	1	1.0321	0.0196	157	3349.07
CL4	14.12.98	4	1	1.0121	0.0112	56	930.833
BL4	11.11.99	4	2	0.51338	0.00522	99	211.557
BL4	12.11.99	4	2	0.52258	0.00417	125	230.931
BL4	13.11.99	4	2	0.50062	0.00595	132	298.856
BL4	14.11.99	4	2	0.4931	0.00575	131	328.82
CL3	10.05.99	3	1	0.96239	0.00304	125	360.537
CL3	11.05.99	3	1	0.931	0.00316	125	1644.69
CL3	12.05.99	3	1	0.87556	0.00924	128	1952.31
CL3	13.05.99	3	1	0.8529	0.00864	129	1835.89
CL3	14.05.99	3	1	0.8413	0.0113	127	2265.5
CL3	15.05.99	3	1	0.9353	0.0299	59	1081.88
CL1	13.07.99	1	1	0.91828	0.00441	128	2412.05
CL1	14.07.99	1	1	0.8984	0.0114	130	3427.39
CL1	15.07.99	1	1	0.8693	0.0106	130	3374.98
CL1	16.07.99	1	1	0.9436	0.0101	87	2748.64
BL4	13.10.98	4	2	0.71797	0.00974	125	618.429
BL4	14.10.98	4	2	0.65256	0.00909	136	734.022
BL4	15.10.98	4	2	0.73002	0.00638	141	485.094
BL4	16.10.98	4	2	0.71036	0.00757	138	648.459
BL4	17.10.98	4	2	0.67973	0.00941	94	673.569
DG2	09.09.98	2	3	0.71075	0.00467	85	161.896
DG2	10.09.98	2	3	0.77873	0.00507	113	138.531
DG2	11.09.98	2	3	0.68143	0.00337	126	337.471
DG2	12.09.98	2	3	0.66694	0.00354	126	421.838
DG2	13.09.98	2	3	0.67919	0.00306	125	333.234
DG2	14.09.98	2	3	0.68344	0.00343	127	315.959
DG2	15.09.98	2	3	0.67715	0.00552	123	217.467
DG2	16.09.98	2	3	0.61824	0.00406	124	463.417
DG2	17.09.98	2	3	0.62591	0.0042	126	484.306
DG2	18.09.98	2	3	0.69033	0.00443	125	235.345
DG2	19.09.98	2	3	0.67688	0.00877	58	185.572
BL3	06.02.99	3	2	0.40891	0.00816	114	106.021
BL3	07.02.99	3	2	0.43083	0.00566	98	117.067
BL3	08.02.99	3	2	0.41115	0.00769	107	94.894
BL3	09.02.99	3	2	0.40459	0.00581	104	74.49
BL3	10.02.99	3	2	0.45176	0.0086	109	72
BL3	11.02.99	3	2	0.401	0.00878	90	57.745
BL3	12.02.99	3	2	0.41258	0.00658	112	106.879
BL3	13.02.99	3	2	0.40808	0.00606	115	66.16
BL3	14.02.99	3	2	0.41161	0.0047	82	69.757
CL3	14.02.99	3	1	0.8642	0.0114	33	89.317
CL3	15.02.99	3	1	0.97419	0.00468	153	1181.46
CL3	16.02.99	3	1	0.94356	0.00309	146	1971.44
CL3	17.02.99	3	1	0.85891	0.00963	152	3371.77
CL3	18.02.99	3	1	0.86084	0.0079	150	3453.91
CL3	19.02.99	3	1	0.8352	0.00865	150	3342.11

CL3	20.02.99	3	1	0.83446	0.00853	151	3071.63
CL3	21.02.99	3	1	0.8339	0.0172	81	2379.99
BL1	15.06.99	1	2	0.4309	0.0103	99	349.667
BL1	16.06.99	1	2	0.4549	0.0122	100	406.645
BL1	17.02.99	1	2	0.4394	0.0116	99	393.981
BL1	18.02.99	1	2	0.4397	0.0114	99	395.828
BL1	19.02.99	1	2	0.445	0.0118	100	393.827
BL1	20.02.99	1	2	0.4508	0.0115	99	396.482
BL1	21.02.99	1	2	0.48586	0.00998	98	394.334
BL1	22.02.99	1	2	0.46679	0.00477	25	36.224
CL2	15.11.99	2	1	0.94018	0.00949	120	3551.57
CL2	16.11.99	2	1	0.96373	0.0073	156	4559.93
CL2	17.11.99	2	1	0.98903	0.00942	157	2412.52
CL2	18.11.99	2	1	1.0016	0.0068	159	2311.18
CL2	19.11.99	2	1	1.0208	0.0046	157	3969.89
CL2	20.11.99	2	1	1.0231	0.0028	156	3914.32
CL2	21.11.99	2	1	1.0372	0.0034	157	3515.96
CL2	22.11.99	2	1	1.063	0.0285	66	1364.59
BL1	14.12.98	1	2	0.57287	0.00789	84	452.198
BL1	15.12.98	1	2	0.48614	0.00855	147	761.317
BL1	16.12.98	1	2	0.50692	0.00848	149	617.822
BL1	17.12.98	1	2	0.48367	0.00937	146	726.554
BL1	18.12.98	1	2	0.52155	0.00665	146	611.345
BL1	19.12.98	1	2	0.5374	0.00789	142	694.949
BL1	20.12.98	1	2	0.52717	0.00745	149	640.469
BL1	21.12.98	1	2	0.52548	0.0076	129	694.387
BL1	22.12.98	1	2	0.56636	0.00457	68	170.56
DG2	11.10.99	2	3	0.54681	0.00383	133	307.026
DG2	12.11.99	2	3	0.57407	0.00487	132	291.574
DG2	13.11.99	2	3	0.56832	0.00436	135	303.336
DG2	14.11.99	2	3	0.60694	0.005	133	242.389
DG2	15.11.99	2	3	0.57104	0.00536	136	279.81
DG2	16.11.99	2	3	0.60126	0.00483	136	200.108
DG2	17.11.99	2	3	0.53634	0.00572	137	303.246
DG2	18.11.99	2	3	0.55332	0.00558	135	274.885
CL3	06.11.98	3	1	0.95184	0.00473	68	1689.35
CL3	07.11.98	3	1	0.98245	0.00538	158	4661
CL3	08.11.99	3	1	1.0044	0.004	157	4875.41
CL3	09.11.98	3	1	0.99497	0.0077	158	4351.92
CL3	10.11.98	3	1	1.0526	0.0094	158	3807.37
CL3	11.11.98	3	1	1.0522	0.0194	159	4418.51
CL3	12.11.98	3	1	1.0616	0.0051	157	3506.35
CL3	13.11.98	3	1	1.1019	0.0036	154	2723.43
CL3	14.11.98	3	1	1.023	0.0083	159	4623.76
CL4	15.11.98	4	1	0.9988	0.0109	159	5072.27
CL4	16.11.98	4	1	1.0153	0.0104	159	4837.04
CL4	17.11.98	4	1	1.0171	0.0054	157	4972.51
CL4	18.11.98	4	1	1.0392	0.0194	157	3988.27
CL4	19.11.98	4	1	0.97607	0.00663	158	5096.17
CL4	20.11.98	4	1	0.983	0.00236	156	3507.69
CL4	21.11.98	4	1	0.9964	0.0101	161	4060.79

CL4	22.11.98	4	1	1.0119	0.0149	159	4578.85
CL4	23.11.98	4	1	0.99632	0.00974	160	4356.11
CL4	24.11.98	4	1	1.0071	0.0053	61	1514.13
DG1	13.01.00	1	3	0.60818	0.00862	14	25.63
DG1	14.01.00	1	3	0.52	0.0104	139	156.315
DG1	15.01.00	1	3	0.538	0.011	140	238.208
DG1	16.01.00	1	3	0.53338	0.00698	137	154.74
DG1	17.01.00	1	3	0.55135	0.00632	140	197.974
DG1	18.01.00	1	3	0.5483	0.00818	131	248.734
DG1	19.01.00	1	3	0.5147	0.0108	137	247.74
DG1	20.01.00	1	3	0.53975	0.00985	138	294.72
DG1	21.01.00	1	3	0.53911	0.0036	136	550.948
DG1	22.01.00	1	3	0.53465	0.00437	120	489.081
DG1	23.01.00	1	3	0.52534	0.00496	129	444.992
DG1	24.01.00	1	3	0.54222	0.00507	145	500.281
DG1	25.01.00	1	3	0.56216	0.00287	102	269.924
CL4	16.05.99	4	1	0.8181	0.0128	130	1841.64
CL4	17.05.99	4	1	0.8713	0.0103	129	1395.15
CL4	18.05.99	4	1	0.8693	0.0149	129	1474.76
CL4	19.05.99	4	1	0.8674	0.0172	126	1663.94
CL4	20.05.99	4	1	0.84836	0.00978	126	1357.57
CL4	21.05.99	4	1	0.8936	0.0173	126	1382.55
CL4	22.05.99	4	1	0.8967	0.0122	126	1389.18
CL4	23.05.99	4	1	0.8469	0.0113	127	1835.27
CL4	24.05.99	4	1	0.828	0.017	127	1834.3
CL4	25.05.99	4	1	0.8648	0.0144	127	1363.02
CL4	26.05.99	4	1	0.91839	0.0059	54	516.568
CL3	22.11.99	3	1	1.0341	0.0078	58	756.448
CL3	23.11.99	3	1	1.0477	0.0032	155	1991.78
CL3	24.11.99	3	1	0.98905	0.00226	159	3288
CL3	25.11.99	3	1	1.0122	0.004	158	3002.11
CL3	26.11.99	3	1	0.93407	0.00931	59	938.82
DG2	06.02.99	2	3	0.40891	0.00816	114	106.021
DG2	07.02.99	2	3	0.43083	0.00566	98	117.067
DG2	08.02.99	2	3	0.40111	0.00948	110	94.959
BL3	09.02.99	3	2	0.40074	0.00693	105	74.49
BL3	10.02.99	3	2	0.45176	0.0086	109	72
BL3	11.02.99	3	2	0.39708	0.00952	91	57.766
BL3	12.02.99	3	2	0.41258	0.00658	112	106.879
BL3	13.02.99	3	2	0.40552	0.00653	116	66.225
BL3	14.02.99	3	2	0.41161	0.0047	82	69.757
CL3	14.02.99	3	1	0.8642	0.0114	33	89.317
CL3	15.02.99	3	1	0.97419	0.00468	153	1181.46
CL3	16.02.99	3	1	0.94356	0.00309	146	1971.44
CL3	17.02.99	3	1	0.85891	0.00963	152	3371.77
CL3	18.02.99	3	1	0.8738	0.013	152	3454.36
CL3	19.02.99	3	1	0.8352	0.00865	150	3342.11
CL3	20.02.99	3	1	0.8469	0.0123	153	3071.78
CL3	21.02.99	3	1	0.9674	0.0358	105	2395.43
DG1	22.02.99	1	3	0.52174	0.00366	132	370.901
DG1	23.02.99	1	3	0.49896	0.00396	132	315.235

DG1	24.02.99	1	3	0.52785	0.00324	113	236.755
DG1	25.02.99	1	3	0.56876	0.00208	116	131.93
DG1	26.02.99	1	3	0.52806	0.00567	128	263.025
DG1	27.02.99	1	3	0.56811	0.00231	129	121.163
DG1	28.02.99	1	3	0.6117	0.013	41	28.205
Compartment	Date	Replicate	Light	TFR	Licor PPFD	Temp. max	Temp. min
CL1	26.04.99	1	1	530.365			
CL1	27.04.99	1	1	3230.45			
CL1	28.04.99	1	1	3379.35			
CL1	29.04.99	1	1	3335.59			
CL1	30.04.99	1	1	3363.69			
CL1	01.05.99	1	1	3356.36			
CL1	02.05.99	1	1	675.151		42	17
CL1	24.11.98	1	1	2337.63			
CL1	25.11.98	1	1	3285.36			
CL1	26.11.98	1	1	4373.73			
CL1	27.11.98	1	1	4148.54			
CL1	28.11.98	1	1	4475.99			
CL1	29.11.98	1	1	3965.09			
CL1	30.11.98	1	1	3744.14			
CL1	01.12.98	1	1	3484.9			
CL1	02.12.98	1	1	1267.79		44.5	21
DG4	24.09.99	4	3	102.74			
DG4	25.09.99	4	3	346.926			
DG4	26.09.99	4	3	338.475			
DG4	27.09.99	4	3	217.075			
DG4	28.09.99	4	3	241.991			
DG4	29.09.99	4	3	207.437			
DG4	30.09.99	4	3	269.296			
DG4	01.10.99	4	3	164.171	713		
DG4	02.10.99	4	3	279.162	1157		
DG4	03.10.99	4	3	14.141		35	15
CL3	30.06.99	3	1	796.152			
CL3	01.07.99	3	1	835.374			
CL3	29.06.99	3	1	42.647			
CL3	02.07.99	3	1	1799.32			
CL3	03.07.99	3	1	813.98			
CL3	04.07.99	3	1	537.736			
DG1	02.12.98	1	3	900.423			
DG1	03.12.98	1	3	1409.28			
DG1	04.12.98	1	3	1099.45			
BL3	29.12.98	3	2	134.611			
BL3	30.12.98	3	2	548.746			
BL3	31.12.98	3	2	618.881			
BL3	01.01.99	3	2	247.664			
BL3	02.01.99	3	2	436.932			
BL3	03.01.99	3	2	173.638			
BL3	04.01.99	3	2	165.532			
BL3	05.01.99	3	2	365.745		37	23
DG3	02.09.98	3	3	96.549			

DG3	03.09.98	3	3	213.328			
DG3	04.09.98	3	3	245.505			
DG3	05.09.98	3	3	112.214			
BL3	31.05.99	3	2	209.047			
BL3	01.06.99	3	2	261.224			
BL3	02.06.99	3	2	216.734			
BL3	03.06.99	3	2	115.615			
BL3	04.06.99	3	2	232.533			
BL3	05.06.99	3	2	55.723			
BL3	06.06.99	3	2	55.723		34	13
CL2	30.10.98	2	1	2525.89			
CL2	31.10.98	2	1	2321.65			
CL2	01.11.98	2	1	2116.44			
CL2	02.11.98	2	1	3373.76			
CL2	03.11.98	2	1	4072.11			
CL2	04.11.98	2	1	4585.12			
CL2	05.11.98	2	1	4605.69			
CL2	06.11.98	2	1	2161.32			
DG2	01.03.99	2	3	328.247			
DG2	02.03.99	2	3	418.439			
DG2	03.03.99	2	3	376.234			
DG2	04.03.99	2	3	247.291			
DG2	05.03.99	2	3	335.859			
DG2	06.03.99	2	3	354.331			
DG2	07.03.99	2	3	219.016		40.5	25
BL1	29.09.98	1	2	1877.86			
BL1	30.09.98	1	2	1609.94			
BL1	01.10.98	1	2	1843.59			
BL1	02.10.98	1	2	1510.85			
BL1	03.10.98	1	2	1346.01			
BL1	04.10.98	1	2	1611.27			
BL1	05.10.98	1	2	1783.98			
BL1	06.10.98	1	2	1685.97			
BL1	07.10.98	1	2	730.336			
BL2	01.11.99	2	2	404.786			
BL2	02.11.99	2	2	394.864			
BL2	03.11.99	2	2	399.992			
BL2	04.11.99	2	2	486.995			
BL2	05.11.99	2	2	546.545	5764		
BL2	06.11.99	2	2	199.608	2483		
BL2	07.11.99	2	2	155.119	1495	41	18
CL2	04.12.98	2	1	1337.28			
CL2	05.12.98	2	1	5089.25			
CL2	06.12.98	2	1	4233.61			
CL2	07.12.98	2	1	4847.84			
CL2	08.12.98	2	1	1165.09			
CL2	03.05.99	2	1	3642.48			
CL2	04.05.99	2	1	3320.75			
CL2	05.05.99	2	1	2663.88			
CL2	06.05.99	2	1	2606.51			
CL2	07.05.99	2	1	3192.44			

CL2	08.05.99	2	1	2663.46		
CL2	09.05.99	2	1	2167.44	42	14
DG3	02.09.98	3	3	96.549		
DG3	03.09.98	3	3	213.05		
DG3	04.09.98	3	3	245.505		
CL4	30.11.99	4	1	683.126		
CL4	01.12.99	4	1	3910		
CL4	02.12.99	4	1	4898.61		
CL4	03.12.99	4	1	4999		
CL4	04.12.99	4	1	5484.54		
CL4	05.12.99	4	1	4906.11		
CL4	06.12.99	4	1	4980.98		
CL4	07.12.99	4	1	4734.66		
CL4	08.12.99	4	1	3778.19		
CL4	09.12.99	4	1	944.502	43	18
BL4E	09.12.99	4	2	281.734		
BL4E	10.12.99	4	2	1106.53		
BL4E	11.12.99	4	2	1174.51		
BL4E	12.12.99	4	2	126.89		
BL4E	13.12.99	4	2	275.72		
BL4E	14.12.99	4	2	906.812		
BL4E	15.12.99	4	2	583.96		
BL4E	16.12.99	4	2	724.336		
BL4E	17.12.99	4	2	857.322		
BL4E	18.12.99	4	2	464.379		
BL4E	19.12.99	4	2	274.659		
BL4E	20.12.99	4	2	1125.26		
BL4E	21.12.99	4	2	685.999		
BL4E	22.12.99	4	2	907.557		
BL4E	23.12.99	4	2	309.516		
BL4E	24.12.99	4	2	461.974		
BL4E	25.12.99	4	2	381.651		
BL4E	26.12.99	4	2	407.455		
BL4E	27.12.99	4	2	221.75		
BL4E	28.12.99	4	2	586.111		
BL4E	29.12.99	4	2	1114.84		
BL4E	30.12.99	4	2	1250.05		
BL4E	31.12.99	4	2	1170.11		
BL4E	01.01.00	4	2	935.421		
BL4E	02.01.00	4	2	1064.31		
BL4E	03.01.00	4	2	532.009		
BL4E	04.01.00	4	2	480.784		
BL4E	05.01.00	4	2	662.228		
BL4E	06.01.00	4	2	48.277	45	18
DG3	03.10.99	3	3	308.088		
DG3	04.10.99	3	3	244.38		
DG3	05.10.99	3	3	405.086		
DG3	06.10.99	3	3	374.159		
DG3	07.10.99	3	3	348.026		
DG3	08.10.99	3	3	424.285		
DG3	09.10.99	3	3	426.741		

DG3	10.10.99	3	3	447.41			
BL4	05.01.99	4	2	45.627			
BL4	06.01.99	4	2	398.094			
BL4	07.01.99	4	2	402.69			
BL4	08.01.99	4	2	424.531			
BL4	09.01.99	4	2	370.896			
BL4	10.01.99	4	2	339.196			
BL4	11.01.99	4	2	278.479		39	23
BL3	07.11.99	3	2	254.325			
BL3	08.11.99	3	2	294.816			
BL3	09.11.99	3	2	535.428	3964		
BL3	10.11.99	3	2	601.556	4360		
BL3	11.11.99	3	2	41.587	239	43	15
CL1	05.07.99	1	1	2916.18			
CL1	06.07.99	1	1	2844.63			
CL1	07.07.99	1	1	3126.82			
CL1	08.07.99	1	1	3439.02			
CL1	09.07.99	1	1	2469.76			
CL1	10.07.99	1	1	3340.28			
CL1	11.07.99	1	1	3131.89			
CL1	12.07.99	1	1	1670.1			
BL3	07.10.98	3	2	256.974			
BL3	08.10.98	3	2	700.606			
BL3	09.10.98	3	2	717.154			
BL3	10.10.98	3	2	558.925			
BL3	11.10.98	3	2	1016.47			
BL3	12.10.98	3	2	937.354			
DG4E	11.01.00	4	3	309.938			
DG4E	12.01.00	4	3	484.667			
DG4E	13.01.00	4	3	536.3			
BL3	06.02.99	3	2	251.104			
BL3	07.02.99	3	2	272.058			
BL3	08.02.99	3	2	215.968			
BL3	09.02.99	3	2	180.53			
BL3	10.02.99	3	2	148.573			
BL3	11.02.99	3	2	133.732			
BL3	12.02.99	3	2	248.488			
BL3	13.02.99	3	2	155.389			
BL3	14.02.99	3	2	170.422			
DG3	08.03.99	3	3	112.245			
DG3	09.03.99	3	3	133.064			
DG3	10.03.99	3	3	162.262			
DG3	11.03.99	3	3	168.723			
DG3	12.03.99	3	3	132.784			
DG3	13.03.99	3	3	171.568			
DG3	14.03.99	3	3	71.331		37	22
BL2	06.06.99	2	2	10.668			
BL2	07.06.99	2	2	234.978			
BL2	08.06.99	2	2	229.01			
BL2	09.06.99	2	2	256.288			
BL2	10.06.99	2	2	176.652			

BL2	11.06.99	2	2	284.195			
BL2	12.06.99	2	2	292.457			
BL2	13.06.99	2	2	245.428			
BL2	14.06.99	2	2	160.353		34	5
CL4	09.12.98	4	1	4695.21			
CL4	10.12.98	4	1	1925.03			
CL4	11.12.98	4	1	3699.83			
CL4	12.12.98	4	1	2435.59			
CL4	13.12.98	4	1	3359.16			
CL4	14.12.98	4	1	935.608		43	20
BL4	11.11.99	4	2	395.301			
BL4	12.11.99	4	2	432.003			
BL4	13.11.99	4	2	563.098	4757		
BL4	14.11.99	4	2	631.505	5109	42	15
CL3	10.05.99	3	1	372.938			
CL3	11.05.99	3	1	1764.52			
CL3	12.05.99	3	1	2168.98			
CL3	13.05.99	3	1	2076.45			
CL3	14.05.99	3	1	2559.93			
CL3	15.05.99	3	1	1176.76		40	17
CL1	13.07.99	1	1	2543.63			
CL1	14.07.99	1	1	3643.12			
CL1	15.07.99	1	1	3627.66	55197		
CL1	16.07.99	1	1	2866.69	46775		
BL4	13.10.98	4	2	825.1			
BL4	14.10.98	4	2	1052.43			
BL4	15.10.98	4	2	643.059			
BL4	16.10.98	4	2	854.01			
BL4	17.10.98	4	2	932.467			
DG2	09.09.98	2	3	227.681			
DG2	10.09.98	2	3	180.215			
DG2	11.09.98	2	3	505.901			
DG2	12.09.98	2	3	644.264			
DG2	13.09.98	2	3	496.262			
DG2	14.09.98	2	3	473.774			
DG2	15.09.98	2	3	321.504			
DG2	16.09.98	2	3	736.468			
DG2	17.09.98	2	3	763.135			
DG2	18.09.98	2	3	342.012			
DG2	19.09.98	2	3	276.176			
BL3	06.02.99	3	2	252.579			
BL3	07.02.99	3	2	272.058			
BL3	08.02.99	3	2	218.557			
BL3	09.02.99	3	2	183.259			
BL3	10.02.99	3	2	151.551			
BL3	11.02.99	3	2	137.656			
BL3	12.02.99	3	2	250.827			
BL3	13.02.99	3	2	157.449			
BL3	14.02.99	3	2	170.672			
CL3	14.02.99	3	1	103.636			
CL3	15.02.99	3	1	1201.65			

CL3	16.02.99	3	1	2075.71			
CL3	17.02.99	3	1	3723.13			
CL3	18.02.99	3	1	3788.25			
CL3	19.02.99	3	1	3725.2			
CL3	20.02.99	3	1	3392.7			
CL3	21.02.99	3	1	2639.08		45	20
BL1	15.06.99	1	2	696.327			
BL1	16.06.99	1	2	754.031			
BL1	17.02.99	1	2	762.531			
BL1	18.02.99	1	2	763.675			
BL1	19.02.99	1	2	760.832			
BL1	20.02.99	1	2	760.554			
BL1	21.02.99	1	2	733.11			
BL1	22.02.99	1	2	78.618			
CL2	15.11.99	2	1	3681.63			
CL2	16.11.99	2	1	4713.6			
CL2	17.11.99	2	1	2489.63	28036		
CL2	18.11.99	2	1	2365.73	27930		
CL2	19.11.99	2	1	3950.02			
CL2	20.11.99	2	1	3870.8	48224		
CL2	21.11.99	2	1	3424.22	41415		
CL2	22.11.99	2	1	1325.16	16582	42	19
BL1	14.12.98	1	2	750.17			
BL1	15.12.98	1	2	1474.23			
BL1	16.12.98	1	2	1154.68			
BL1	17.12.98	1	2	1394.27			
BL1	18.12.98	1	2	1170.87			
BL1	19.12.98	1	2	1263.61			
BL1	20.12.98	1	2	1168.66			
BL1	21.12.98	1	2	1259.54			
BL1	22.12.98	1	2	311.61		44	20
DG2	11.10.99	2	3	576.055			
DG2	12.11.99	2	3	530.305			
DG2	13.11.99	2	3	556.608			
DG2	14.11.99	2	3	422.084			
DG2	15.11.99	2	3	509.301			
DG2	16.11.99	2	3	349.719			
DG2	17.11.99	2	3	568.811			
DG2	18.11.99	2	3	508.88			
CL3	06.11.98	3	1	1740.75			
CL3	07.11.98	3	1	4740.21			
CL3	08.11.99	3	1	4916.19			
CL3	09.11.98	3	1	4401.1			
CL3	10.11.98	3	1	3734.53			
CL3	11.11.98	3	1	4359.05			
CL3	12.11.98	3	1	3346.51			
CL3	13.11.98	3	1	2481.92			
CL3	14.11.98	3	1	4628.4			
CL4	15.11.98	4	1	5171.25			
CL4	16.11.98	4	1	4894.83			
CL4	17.11.98	4	1	5030.07			

CL4	18.11.98	4	1	3995.82			
CL4	19.11.98	4	1	5224.8			
CL4	20.11.98	4	1	3553.58			
CL4	21.11.98	4	1	4115.91			
CL4	22.11.98	4	1	4657.6			
CL4	23.11.98	4	1	4440.93			
CL4	24.11.98	4	1	1523.51			
DG1	13.01.00	1	3	41.37			
DG1	14.01.00	1	3	262.872			
DG1	15.01.00	1	3	390.536			
DG1	16.01.00	1	3	285.387			
DG1	17.01.00	1	3	350.508			
DG1	18.01.00	1	3	430.559			
DG1	19.01.00	1	3	438.05			
DG1	20.01.00	1	3	508.868			
DG1	21.01.00	1	3	1038.35			
DG1	22.01.00	1	3	931.221			
DG1	23.01.00	1	3	850.508			
DG1	24.01.00	1	3	948.664			
DG1	25.01.00	1	3	491.62		45	23
CL4	16.05.99	4	1	2171.99			
CL4	17.05.99	4	1	1579.93			
CL4	18.05.99	4	1	1685.67			
CL4	19.05.99	4	1	1947.2			
CL4	20.05.99	4	1	1524.2			
CL4	21.05.99	4	1	1566.61			
CL4	22.05.99	4	1	1533.55			
CL4	23.05.99	4	1	2111.83			
CL4	24.05.99	4	1	2163.49			
CL4	25.05.99	4	1	1554.69			
CL4	26.05.99	4	1	551.242		39	11
CL3	22.11.99	3	1	753.716			
CL3	23.11.99	3	1	1896.91			
CL3	24.11.99	3	1	3328.7	47752		
CL3	25.11.99	3	1	2986.22	36317		
CL3	26.11.99	3	1	987.375	10894	47	19
DG2	06.02.99	2	3	252.579			
DG2	07.02.99	2	3	272.058			
DG2	08.02.99	2	3	220.032			
BL3	09.02.99	3	2	183.844			
BL3	10.02.99	3	2	151.551			
BL3	11.02.99	3	2	138.129			
BL3	12.02.99	3	2	250.827			
BL3	13.02.99	3	2	158.034			
BL3	14.02.99	3	2	170.672			
CL3	14.02.99	3	1	103.636			
CL3	15.02.99	3	1	1201.65			
CL3	16.02.99	3	1	2075.71			
CL3	17.02.99	3	1	3723.13			
CL3	18.02.99	3	1	3788.55			
CL3	19.02.99	3	1	3725.2			

CL3	20.02.99	3	1	3392.78		
CL3	21.02.99	3	1	2650.66	45	20
DG1	22.02.99	1	3	690.101		
DG1	23.02.99	1	3	604.727		
DG1	24.02.99	1	3	440.624		
DG1	25.02.99	1	3	232.903		
DG1	26.02.99	1	3	477.615		
DG1	27.02.99	1	3	213.089		
DG1	28.02.99	1	3	45.982	41	22

Appendix C

Table of stem growth characteristics measured at the end of the experiment, for seedlings of twenty Queensland rainforest tree species.

Replicate: As for replicate in Appendix B.

Treatment: 1 = clear compartment and no added nitrogen, 2 = blue compartment and no added nitrogen, 3 = green compartment and no added nitrogen, 4 = clear compartment with added nitrogen, 5 = blue compartment with added nitrogen, 6 = green compartment and added nitrogen.

Species: 1 = *Agathis robusta*, 2 = *Alphitonia excelsa*, 3 = *Castanospermum australe*, 4 = *Dysoxylum fraserianum*, 5 = *Dysoxylum muelleri* CQ (Central Queensland provenance), 6 = *Dysoxylum muelleri* NQ (North Queensland provenance), 7 = *Elaeocarpus grandis*, 8 = *Flindersia bennettiana*, 9 = *Flindersia brayleyana*, 10 = *Flindersia schottiana*, 11 = *Flindersia xanthoxyla*, 12 = *Gmelina leichardtii*, 13 = *Grevillea robusta*, 14 = *Melia azedarach* var. *australasica*, 15 = *Nauclea orientalis*, 16 = *Pleiogynium timorense*, 17 = *Podocarpus elatus*, 18 = *Rhodosphaera rhodanthema*, 19 = *Blepharocarya involucrigera*, 20 = *Toona ciliata*.

SER: Stem elongation rate (cm/yr).

SDIR: Stem diameter increment rate ($\text{mm } 10^{-1}/\text{yr}$).

H/D: Height (cm) divided by diameter (cm) measured on individual seedling at the end of the experiment, slenderness ratio (cm/cm).

RSER: Relative stem elongation rate (cm/cm yr), height at end of experiment minus height at beginning of experiment, divided by height at the start of the experiment, expressed per year.

RSDIR: Relative stem diameter increment rate (cm/cm yr), diameter at end of experiment minus diameter at beginning of experiment, divided by diameter at the start of the experiment, expressed per year.

SERmax: Maximum rate of stem elongation (cm/yr), measured over a four to five week interval between measurements.

SDIRmax: Maximum rate of diameter increment (cm/yr), measured over a four to five week interval between measurements.

RSERmax: Maximum relative stem elongation rate (cm/cm yr), measured over a four to five week interval between measurements.

RSDIRmax: Maximum relative stem diameter increment (cm/cm yr), measured over a four to five week interval between measurements.

IL: Internode length (cm), average of the three internodes directly below the youngest fully expanded leaf.

RIL: Relative internode length (cm/cm), IL divided by seedling height at time of measurement.

B: Number of branches produced over the duration of the experiment.

RB: Number of new branches divided by number of initial branches ($B_{\text{new}} - B_{\text{initial}} / (B_{\text{initial}} + 1)$).

DyRHmax: Number of days to reach maximum relative stem increment rate (dys) from beginning of the experiment.

DyRDmax: Number of days to reach maximum relative stem diameter increment rate (dys) from beginning of the experiment.

Replicate	Treatment	Species	SER	SDIR	H/D	RSER	RSDIR	SERmax	SDIRmax	
1	1	1	1	48	41.3	84.4	4	1.12	71	133
1	4	1	1	74	58.5	95.6	7.42	1.5	132	146
1	2	1	1	19	25.7	53.4	3.12	1.03	104	144
1	5	1	1	37	46	68.3	5.25	2	156	111
1	3	1	1	1	2.3	36.8	0.12	0.07	12	122
1	6	1	1	0.1	4.7	50	0.01	0.17	13	43.8
2	1	1	1	15	27.8	48.4	1.39	0.96	51	75.3
2	4	1	1	42	50.8	75	2.67	1.59	122	96.3
2	2	1	1	21	9.5	91.2	1.64	0.29	71	66.4
2	5	1	1	10	12.7	59.2	0.71	0.38	70	88.5
2	3	1	1	15	15.1	74.5	1.02	0.54	37	73
2	6	1	1	5	11.1	38.5	0.67	0.44	52	44.3
3	1	1	1	19	26.2	65.1	1.17	0.87	94	122
3	4	1	1	28	35.7	72	1.36	0.97	61	220
3	2	1	1	0.75	9.5	45.5	0.04	0.3	78	73
3	5	1	1	14	7.8	68.8	1.02	0.21	35	122
3	3	1	1	0.1	0.1	34.3	0.01	0.01	106	11.4
3	6	1	1	0.1	1.6	13.6	0.01	0.04	52	39.9
4	1	1	1	14	20.3	53.6	1.31	0.68	45	44.2
4	4	1	1	38	44.5	74.7	2.52	1.5	80	103
4	2	1	1	11	5.5	67.2	0.96	0.18	26	66.4
4	5	1	1	26	6.2	95.8	2.15	0.16	60	77.4
4	3	1	1	4	5.5	48.6	0.29	0.18	41	155
4	6	1	1	5	1.6	62.2	0.28	0.05	37	79.6
1	1	2	2	141	130	130.7	6.72	3.42	241	1981
1	4	2	2	223	150	132.8	6.75	3.06	432	178.7
1	2	2	2	126	93.6	140	3.14	3.12	371	730
1	5	2	2	163	102	165	3.63	3.39	404	178.7
1	3	2	2	74	45.6	148.6	2	1.47	258	73
1	6	2	2	96	49.1	166.2	3.09	1.69	202	104.3
2	1	2	2	118	59.7	155.8	3.02	1.49	225	199.1
2	4	2	2	154	62.9	126.7	5.13	1.57	207	91.3
2	2	2	2	137	45.8	214.7	4.03	1.31	232	156.4
2	5	2	2	59	28.6	157.8	1.29	0.73	132	625.7
2	3	2	2	69	49.2	142.3	1.87	1.76	294	573.6
2	6	2	2	64	48.1	136.5	1.52	1.5	163	312.9
3	1	2	2	121	82.4	131.7	2.63	1.72	270	132.7
3	4	2	2	23	33.2	91.3	0.44	0.65	158	212.4
3	2	2	2	133	65.2	159.6	6.99	2.04	270	365
3	5	2	2	120	35.5	181.2	8.57	0.13	324	312.9
3	3	2	2	13	0.1	118.5	0.46	0.01	16.6	55.3
3	6	2	2	11	1.1	153.1	0.28	0.04	91.3	188
4	1	2	2	118	70.9	136.6	4.06	1.82	236	208.6
4	4	2	2	166	145	117.7	4.26	3.93	314	417.1
4	2	2	2	67	60.6	125.6	1.31	1.64	158	469.3
4	5	2	2	104	66.4	145.6	2.96	2.07	185	260.7
4	3	2	2	100	12.6	280.4	2.79	0.36	306	53
4	6	2	2	84	12.6	201.7	2.16	0.31	174	182.3
1	1	3	3	8	16.7	37.1	0.2	0.16	58	116.8
1	4	3	3	24	33.4	34.1	1.24	0.33	61	175.2
1	2	3	3	13	9.5	40	0.36	0.1	24.9	53.2
1	5	3	3	56	22.9	75.4	1.59	0.21	198	214.2
1	3	3	3	18	9.7	55.6	0.37	0.09	55.5	43.8
1	6	3	3	51	29.9	75.2	0.86	0.24	162	79.3
2	1	3	3	22	47.5	32.1	0.66	0.37	84.2	279.5
2	4	3	3	47	95	42.4	1.43	0.93	106	168

2	2	3	9	21.6	55.6	0.19	0.26	70.6	73
2	5	3	43	28.3	70.9	0.88	0.26	143	86.3
2	3	3	18	19.3	51.3	0.45	0.2	49.8	95.2
2	6	3	39	34.3	61.8	0.9	0.33	95.6	87.6
3	1	3	15	40.5	42.2	0.3	0.35	85.2	73
3	4	3	73	79.2	66.2	1.26	0.61	170	165.4
3	2	3	40	30.8	65.1	0.79	0.26	156	97
3	5	3	58	62.4	70.3	1.07	0.6	158	190.4
3	3	3	8	0.1	54.7	0.24	0.01	60.8	55.3
3	6	3	1	1.8	50	0.02	0.02	16.6	31.7
4	1	3	4	1.8	49.2	0.08	0.01	43.5	51.3
4	4	3	48	94.1	48.1	0.84	0.72	146	165.9
4	2	3	16	10.6	69.1	0.28	0.11	112	59.7
4	5	3	48	12.3	68.5	1.07	0.09	183	91.3
4	3	3	7	6.2	48.5	0.17	0.07	23.8	39.7
4	6	3	28	11.4	63.8	0.49	0.09	71.4	103.2
1	1	4	15	1.04	64.6	0.41	0.01	76.8	188
1	4	4	109	84	83.1	2.87	0.87	212	234
1	2	4	56	42.5	74.8	1.68	0.55	122	83.6
1	5	4	115	69.5	101.3	2.74	0.78	202	199
1	3	4	64	47.7	77.2	2.15	0.62	101	130
1	6	4	44	0.1	79.6	1.45	0.01	133	7.6
2	1	4	34	14.4	81.8	0.89	0.2	67.4	43.8
2	4	4	110	87.6	82.3	3.34	0.97	256	191
2	2	4	40	25.8	60.9	1.47	0.3	202	92.7
2	5	4	56	36.1	85.2	1.54	0.49	130	144
2	3	4	65	40.2	91.2	1.72	0.54	177	104
2	6	4	78	46.4	85.2	2.18	0.52	140	87.6
3	1	4	24	45.4	45.5	0.94	0.5	73	155
3	4	4	88	108	69.7	1.88	1.2	365	232
3	2	4	60	52.6	74.8	1.57	0.66	124	161
3	5	4	106	47.4	121.8	2.79	0.65	207	204
3	3	4	54	1	101.1	1.49	0.01	116	22.1
3	6	4	132	0.1	138.8	3.38	0.01	153	29.2
4	1	4	31	27.8	62.2	0.81	0.33	84.2	59.7
4	4	4	138	90.7	98.3	4.18	1.04	280	204
4	2	4	26	6.2	80.3	0.83	0.1	95.6	55.3
4	5	4	97	0.1	91.4	2.77	0.01	83	0.1
4	3	4	88	0.1	124.8	2.39	0.01	163	29.2
4	6	4	24	12.4	62.6	0.72	0.16	74.7	11.8
1	1	5	32	31.3	62.9	2.02	0.6	75.3	57
1	4	5	92	82.8	79.5	4.19	1.13	264	265
1	2	5	24	0.1	69.6	0.84	0.01	24.9	0.1
1	5	5	101	116	80.6	3.49	1.89	235	146
1	3	5	84	0.1	96.8	1.9	0.01	140	22.8
1	6	5	8	0.1	68.3	0.3	0.01	8.3	29.2
2	1	5	15	29	40	2.2	0.91	34.8	79.8
2	4	5	54	87	55.8	5.36	2.72	84.2	111
2	2	5	95	38.2	81.8	11	0.78	93.8	97
2	5	5	47	15.1	67.6	3.91	0.47	67.4	45.6
2	3	5	15	14.5	68.1	1.4	0.52	44.9	34.2
2	6	5	93	96.3	96.5	7.77	3.21	188	249
3	1	5	39	71.8	45.7	2.43	1.31	61.8	139
3	4	5	53	83.6	58.2	4.05	2.39	84.2	200
3	2	5	91	56.6	108.3	5.08	1.04	183	133
3	5	5	125	92.9	102.9	5.45	1.48	170	148
3	3	5	6	11.8	41.9	0.36	0.25	16.6	57.9
3	6	5	68	24.5	125.6	2.34	0.4	191	254

4	1	5	37	47.3	57.8	4.08	1.18	63.6	125
4	4	5	7	22.8	20.6	1.34	0.81	8.3	22.8
4	2	5	70	44.3	114.4	4.36	1.14	141	79.8
4	5	5	43	11.7	78.9	3.01	0.24	99.5	43.8
4	3	5	25	16	78.1	1.56	0.37	78.6	234
4	6	5	71	38.9	112	4.75	0.79	93.8	87.6
1	1	6	82	48.1	122.3	2.28	0.83	185	204
1	4	6	42	84	103.1	1.16	1.65	60	125
1	2	6	71	61.9	94	1.6	0.91	165	103
1	5	6	110	117	90.1	3.34	2.34	306	234
1	3	6	78	49.6	106.8	2.22	0.74	122	131
1	6	6	84	48.9	118.7	2.72	0.83	177	111
2	1	6	0.1	0.1	32.7	0.01	0.01	10.1	52.1
2	4	6	109	97.7	97.8	4.18	1.95	330	155
2	2	6	98	71.8	99.3	9.84	1.41	256	175
2	5	6	109	56.5	116.3	4.97	0.77	219	91.3
2	3	6	32	10.7	105.5	0.93	0.18	200	51.3
2	6	6	60	35.1	110.5	2.62	0.72	268	97
3	1	6	10	9.2	58.2	0.29	0.14	24.9	94.4
3	4	6	66	57.3	95.6	1.69	0.95	167	131
3	2	6	93	55	116	3.56	0.93	256	177
3	5	6	106	64.9	126.1	3.53	1.22	243	139
3	3	6	22	0.76	79.7	0.88	0.01	36.5	55.3
3	6	6	45	9.9	115.2	1	0.13	73	57.9
4	1	6	0.1	6.1	36.5	0.01	0.11	6.7	45.6
4	4	6	16	15.2	56.5	0.44	0.23	16.6	15.2
4	2	6	47	0.1	52.9	2.04	0.01	67.4	87.6
4	5	6	88	63.4	104.2	3.04	1.06	218	147
4	3	6	55	34.4	122.1	1.34	0.69	106	144
4	6	6	84	30.5	125.5	3.67	0.44	150	133
1	1	7	221	76.1	151.9	3.75	1.06	332	175
1	4	7	234	313	126.9	4.18	4.48	302	219
1	2	7	242	159	120.7	3.37	2.3	324	240
1	5	7	300	193	128.2	3.89	3.06	340	316
1	3	7	196	119	138.8	3.26	2.64	245	204
1	6	7	274	128	151.4	5.37	2.45	428	148
2	1	7	133	99	116.2	1.82	1.43	225	118
2	4	7	120	66	129.9	1.82	1.02	306	131
2	2	7	200	90.7	147.8	2.74	1.31	307	456
2	5	7	198	86.6	170.7	3.04	1.52	290	365
2	3	7	198	45.4	221.5	3.73	1.06	216	60.8
2	6	7	198	84.5	161	2.9	1.43	359	183
3	1	7	224	123	126.9	3.8	1.92	249	175
3	4	7	240	217	95.9	3.38	2.9	331	256
3	2	7	141	53.7	170.2	1.56	0.9	262	91.3
3	5	7	123	29.1	152.6	1.73	0.45	165	175
3	3	7	55	0.1	188.1	1.03	0.01	158	15.2
3	6	7	44	0.1	181.8	0.52	0.01	58.1	0.1
4	1	7	155	196	97.5	2.01	2.97	274	821
4	4	7	213	254	90.5	3.32	3.84	282	365
4	2	7	193	14.3	193.3	2.61	0.29	245	166
4	5	7	152	118	136.4	1.98	2.22	249	821
4	3	7	152	80.4	145.5	2.12	1.34	265	639
4	6	7	170	84.5	156	2.2	1.43	325	639
1	1	8	41	46.4	61.3	1.95	0.77	101	76
1	4	8	61	29.1	113.8	2.1	0.53	183	79.8
1	2	8	44	0.1	49.1	2.9	0.01	50.5	73
1	5	8	19	5.5	54.9	1.12	0.08	91.3	161

1	3	8	16	0.1	59.4	0.68	0.01	48.7	79.8
1	6	8	12	0.1	49.3	0.58	0.01	33.2	88.5
2	1	8	84	71	81.6	3.12	0.96	183	133
2	4	8	115	85.6	98.8	3.48	1.17	212	177
2	2	8	52	23.7	98.7	3.07	0.46	113	88.5
2	5	8	37	20.9	79	1.66	0.36	78.2	62.7
2	3	8	58	28.2	104.4	2.08	0.47	185	125
2	6	8	59	31.9	108.5	1.74	0.54	122	137
3	1	8	104	77.4	88.8	3.36	0.91	158	205
3	4	8	120	75.5	116.3	3.63	1.18	251	171
3	2	8	59	8.2	91.7	2.95	0.09	101	44.2
3	5	8	12	8.2	62.5	0.47	0.15	49.8	88.5
3	3	8	16	0.1	33.3	0.68	0.01	16.6	144
3	6	8	13	0.1	41.8	0.67	0.01	24.9	22.1
4	1	8	44	36.4	76	1.77	0.61	140	133
4	4	8	103	93.8	87.5	4.92	1.64	157	190
4	2	8	47	0.1	50	2.34	0.01	49.8	3.8
4	5	8	59	14.6	100	3.48	0.21	228	125
4	3	8	41	21.8	73.6	2.04	0.33	108	88.5
4	6	8	86	0.1	69.9	2.75	0.01	124	19
1	1	9	131	104	93.6	4.51	1.41	314	199
1	4	9	133	145	82.5	3.69	1.86	376	154
1	2	9	131	93.1	101.2	3.45	1.18	343	219
1	5	9	140	113	94.3	4.99	1.69	274	166
1	3	9	18	23	48	0.58	0.29	71	39.8
1	6	9	82	50.2	82.3	3.43	0.61	152	155
2	1	9	46	41.8	62.7	1.98	0.6	70.6	83
2	4	9	102	77.4	76.8	3.93	0.82	159	173
2	2	9	29	27.2	45.7	2.05	0.4	47.1	86.3
2	5	9	20	18.8	55.8	0.86	0.32	48.7	74.7
2	3	9	16	25.1	43.6	0.57	0.33	146	91.3
2	6	9	73	52.3	95.1	1.71	0.72	165	111
3	1	9	24	15.2	38.3	1.11	0.27	24.9	15.2
3	4	9	28	35.6	39	1.39	0.4	219	99.5
3	2	9	50	41.8	75	1.98	0.7	122	108
3	5	9	57	35.6	80.8	2.46	0.55	172	73
3	3	9	10	1.2	33.3	0.39	0.02	16.6	43.8
3	6	9	7	0.1	41.8	0.25	0.01	16.6	11.4
4	1	9	20	42.9	39.6	0.83	0.61	73	98.5
4	4	9	122	125	78.8	5.55	1.91	312	243
4	2	9	67	56.5	67.7	4.22	0.81	219	87.6
4	5	9	55	36.6	69.4	2.73	0.5	219	99.5
4	3	9	31	27.2	51.5	1.54	0.37	95.5	63.7
4	6	9	62	7.2	56.8	2.96	0.11	146	44.2
1	1	10	40	57.4	51.8	1.48	0.87	112	110
1	4	10	105	0.1	49.3	4.22	0.01	108	34.2
1	2	10	54	30.8	60.1	2.25	0.48	149	43.8
1	5	10	121	109	100	6.04	1.98	402	166
1	3	10	50	14.4	111.6	2.65	0.25	94	66.4
1	6	10	82	49.1	102.5	2.92	0.83	174	99.5
2	1	10	107	33.2	57.9	4.66	0.55	207	133
2	4	10	120	140	83	5.45	2.37	329	307
2	2	10	94	9.5	82	4.26	0.18	124	34.2
2	5	10	135	85	113.7	5.61	1.57	216	144
2	3	10	167	6	111.3	8.81	0.09	247	73
2	6	10	159	29.9	114.1	6.93	0.51	303	204
3	1	10	57	76.6	57.2	2.29	1.09	232	177
3	4	10	135	130	89.5	5.61	1.86	331	161

3	2	10	114	64.6	123.4	5.17	1.17	257	146
3	5	10	134	102	115	4.46	1.67	315	234
3	3	10	112	3.9	135.6	3.99	0.07	153	44.2
3	6	10	37	1.5	67.2	1.4	0.02	50	46.3
4	1	10	47	64.6	59.1	2.23	1.08	166	103
4	4	10	65	0.1	54.5	2.95	0.01	66.4	0.1
4	2	10	123	40.7	143.2	4.9	0.71	399	177
4	5	10	121	62.2	100	4.31	1	265	288
4	3	10	136	47.9	165.3	4.53	0.8	286	166
4	6	10	121	0.1	84.3	5.24	0.01	207	43.8
1	1	11	8	30.2	40.5	0.48	0.94	8.3	30.4
1	4	11	71	59.4	105.4	3.24	1.7	113	177
1	2	11	33	33.6	80.7	1.43	0.84	66.4	131
1	5	11	64	3	104.3	2.19	0.07	141	53.2
1	3	11	60	21.9	150.8	3.33	0.59	132	55.9
1	6	11	30	0.1	72.5	1.44	0.01	44.9	26.6
2	1	11	2	0.78	50	0.13	0.02	10.1	17.1
2	4	11	50	50	91.5	2.64	1.67	122	99.5
2	2	11	21	6.3	102.7	2.1	0.22	132	44.2
2	5	11	65	30.5	139.7	2.96	0.78	193	96.8
2	3	11	34	14.1	124.5	1.72	0.4	81.9	51.3
2	6	11	116	52.4	170.3	6.83	1.54	160	89.4
3	1	11	15	9.4	78.8	0.63	0.23	41.5	58.4
3	4	11	59	68	78.6	2.96	1.74	130	243
3	2	11	40	14.9	157.1	1.76	0.5	122	119
3	5	11	60	0.1	102.9	3.01	0.01	84	41.8
3	3	11	2	31.2	67.5	0.08	0.59	20.3	122
3	6	11	22	3.1	107.7	0.86	0.07	74.5	51.3
4	1	11	5	1.2	46.9	0.23	0.02	23.5	34.8
4	4	11	30	18.1	75	1.44	0.46	33.7	73
4	2	11	29	6.3	142.2	1.17	0.17	58.1	39.8
4	5	11	80	16.6	110	4.02	0.5	107	26.6
4	3	11	1	0.1	73.5	0.04	0.01	12.2	44.2
4	6	11	47	75.9	82.9	3.94	1.9	78.6	29.2
1	1	12	77	91	63.8	1.66	0.93	162	183
1	4	12	115	185	62.3	1.75	1.78	271	730
1	2	12	100	94.5	78	1.45	0.88	177	133
1	5	12	86	133	65.9	1.19	1.22	134	137
1	3	12	72	73	88.3	0.95	0.82	132	151
1	6	12	54	92	80	0.66	1.1	98	114
2	1	12	16	70.6	59	0.21	0.73	73	160
2	4	12	79	112	71.1	1.01	1.12	183	168
2	2	12	79	41.9	113.8	1.08	0.47	280	186
2	5	12	62	69.4	89.2	0.76	0.88	170	292
2	3	12	40	43.1	85.5	0.6	0.54	173	104
2	6	12	58	52.7	98.4	0.9	0.7	172	146
3	1	12	64	86.2	56.5	1.06	0.72	146	118
3	4	12	58	126	52.8	1.6	2.28	149	285
3	2	12	94	65.8	87.8	1.4	0.69	176	177
3	5	12	39	85	64.4	0.55	1.04	73	103
3	3	12	21	11.7	90.8	0.42	0.17	56.9	33.2
3	6	12	41	4.8	117.9	0.55	0.05	101	44.2
4	1	12	17	81.4	50.3	0.26	0.98	195	125
4	4	12	77	154	56.7	1.04	1.53	142	190
4	2	12	22	20.3	76.9	0.28	0.21	60.8	38
4	5	12	95	51.5	96.1	1.8	0.49	179	111
4	3	12	53	20.3	113.8	0.74	0.23	128	66.4
4	6	12	86	31.1	126.2	1.62	0.37	122	66.4

1	1	13	164	123	88	6.08	2.12	141	152
1	4	13	373	268	104.1	8.67	3.58	483	496
1	2	13	219	15.4	173.8	6.84	0.26	258	95
1	5	13	339	207	113.2	7.21	2.58	440	259
1	3	13	219	108	171.1	5.62	2.34	414	125
1	6	13	125	74.8	135.4	2.98	1.29	348	110
2	1	13	159	134	92.2	4.82	2.07	224	258
2	4	13	235	192	107.7	5.87	3.69	314	248
2	2	13	141	12.8	157.7	4.85	0.28	257	57
2	5	13	154	91.8	128.4	5.49	2.42	195	118
2	3	13	81	47	139.1	2.31	1.19	130	53.2
2	6	13	227	72.6	142.4	13.34	1.25	340	161
3	1	13	248	152	105.4	5.27	1.95	424	277
3	4	13	300	226	101.9	8.57	4.12	376	365
3	2	13	172	63.8	118.1	3.82	0.84	390	88
3	5	13	219	46.2	137.4	5.09	0.59	440	64.6
3	3	13	96	0.1	134.3	1.72	0.01	207	0.1
3	6	13	91	11.9	147.4	1.9	0.2	166	30.4
4	1	13	206	62.4	122.5	5.42	0.83	337	133
4	4	13	315	199	113.5	6.07	2.37	371	209
4	2	13	266	94.7	151	7	1.72	292	122
4	5	13	362	97	179.3	7.55	1.41	432	146
4	3	13	242	60.1	159	6.06	1.05	348	66.4
4	6	13	258	90.1	147.5	5.16	1.45	448	122
1	1	14	41	39	64	2.15	0.81	50.5	131
1	4	14	246	158	126	13.75	3.16	299	186
1	2	14	282	115	177.8	11.73	2.67	489	148
1	5	14	342	36.9	183.6	7.94	0.75	373	106
1	3	14	325	65.6	147.2	13.53	1.64	465	144
1	6	14	292	150	133.6	10.43	4.05	489	217
2	1	14	161	74.1	98.4	7.32	1.51	188	177
2	4	14	149	115	77.4	12.4	1.94	256	155
2	2	14	227	3	218	10.31	0.06	465	34.2
2	5	14	201	49.4	139.7	7.18	0.99	224	49.4
2	3	14	147	58.2	164.4	3.97	1.45	274	110
2	6	14	174	0.1	187.5	7.26	0.01	382	43.8
3	1	14	225	88.2	161.7	4.8	1.73	318	118
3	4	14	307	191	107.6	23.62	3.67	424	179
3	2	14	248	73.8	150.6	6.69	1.51	448	219
3	5	14	208	6.2	200	6.92	0.09	419	183
3	3	14	96	0.1	205.4	2.47	0.01	158	34.2
3	6	14	117	0.1	237.5	2.79	0.01	224	0.1
4	1	14							
4	4	14	170	185	97.7	4.61	4.39	231	217
4	2	14	322	98.7	187.4	9.48	1.8	489	131
4	5	14	296	84.6	166.7	6.88	1.09	393	160
4	3	14	328	67	241.6	10.93	1.31	487	164
4	6	14							
1	1	15	78	178	48.3	1.7	2.74	206	555
1	4	15	93	215	49.2	2.58	3.08	389	289
1	2	15	140	182	52.8	4.66	1.76	193	319
1	5	15	164	253	53.7	4.67	2.98	394	445
1	3	15	168	74.2	76	3.99	1.43	171	183
1	6	15	154	132	94.6	3.2	2.09	341	245
2	1	15	130	213	62.4	2.76	2.67	388	376
2	4	15	87	147	53.4	1.68	1.28	165	297
2	2	15	39	12.1	85.7	0.78	0.18	86	87.6
2	5	15	64	150	51.8	1.29	2.06	83	221

2	3	15	86	116	78.1	1.65	1.7	207	176
2	6	15	73	159	49.5	1.87	2.37	170	321
3	1	15	117	139	64.6	2.5	1.47	235	199
3	4	15	159	263	44.8	2.9	2.27	285	365
3	2	15	144	118	69.1	3.06	0.96	336	380
3	5	15	70	0.1	85.1	0.87	0.01	282	33.2
3	3	15	35	0.1	55.6	0.76	0.01	29	19
3	6	15	4	0.1	76.4	0.09	0.01	25	102
4	1	15	115	153	60	3.72	1.76	195	281
4	4	15	134	245	48.1	3.84	2.29	271	361
4	2	15	113	125	82.3	2.83	2.12	308	213
4	5	15	140	113	94.2	3.59	1.18	314	467
4	3	15	66	37	99	1.37	0.51	134	98.9
4	6	15	131	119	92.3	3.96	2.13	279	194
1	1	16			87.8				
1	4	16			100				
1	2	16	168	61.3	144	2.86	0.9	241	85.2
1	5	16	57		94	1.42		58	
1	3	16	194	79.9	135.2	5.39	1.38	348	131
1	6	16			91.7				
2	1	16	89	61.3	99.1	1.29	0.72	259	219
2	4	16	103	109	94.9	1.54	1.44	141	263
2	2	16	154	0.01	189.7	2.41	0.01	241	
2	5	16	32		84.6	0.52		33	
2	3	16	122	24	162.3	2.03	0.4	247	95.1
2	6	16	129	42.6	154.1	2.18	0.73	185	117
3	1	16			109.3				
3	4	16			109.5				
3	2	16							
3	5	16	248	0.14	151.2	3.22	1.94	348	163
3	3	16	87	0.1	164.8	1.34	0.01	116	11.4
3	6	16	166	0.1	170.2	7.71	0.01	197	11.4
4	1	16	159	141	92.7	3.46	2.02	241	204
4	4	16	129	120	94.7	1.84	1.38	191	228
4	2	16	162	123	117.7	3.17	2.45	180	161
4	5	16	156	53.3	132.7	2.23	0.68	236	160
4	3	16	8		121.8	0.12		8.3	
4	6	16			97.1				
1	1	17	61	40.7	108.3	1.95	0.03	122	77.4
1	4	17	98	49.4	125.6	3.38	0.82	141	264
1	2	17	46	5.2	132.8	1.6	0.09	139	81.1
1	5	17	27	4.3	81.3	1.33	0.07	142	43.8
1	3	17	2	14.7	94.4	0.74	0.27	132	58.4
1	6	17	3	4.3	52.7	0.13	0.09	26.1	44.2
2	1	17		21.3	51.5		0.36	28.1	34.2
2	4	17	27	33.2	53.6	0.89	0.6	33.7	103
2	2	17	40	7.8	127.5	1	0.13	139	66.4
2	5	17	24	0.1	115	0.6	0.01	191	102
2	3	17	11	0.1	96	0.31	0.01	91.3	60
2	6	17	7	0.1	50.8	0.31	0.01	40.5	77.4
3	1	17	2	0.86	53.1	0.05	0.01	12.2	69.5
3	4	17	55	36.4	92.2	1.37	0.5	183	146
3	2	17	27	6.1	93.2	0.72	0.09	112	88.5
3	5	17	44		87.58	1.39		74.7	161
3	3	17	17		87.5	0.36		21.1	131
3	6	17	9		70.5	0.24		71	144
4	1	17	58	36.9	83.3	1.71	0.53	122	68.4
4	4	17	66	35.5	93.7	2.77	0.51	172	155

4	2	17	21	2.6	93.4	0.65	0.04	91.3	77.4
4	5	17	9	14.6	58.1	0.23	0.21	61.8	87.6
4	3	17	17	0.1	87.5	0.5	0.01	66.4	88.5
4	6	17	17	0.1	88.7	0.47	0.01	78.6	56.2
1	1	18	187	149	82	4.06	2.16	219	204
1	4	18	204	188	82.1	3.52	2.48	264	307
1	2	18	260	134	116.7	6.66	2.28	365	285
1	5	18	236	169	100.6	4.82	2.42	340	263
1	3	18	107	50.7	102.8	1.39	0.74	118	141
1	6	18	202	137	102.6	3.36	1.99	270	217
2	1	18	142	103	70.9	2.58	1.04	183	137
2	4	18	170	162	98	2.78	2.41	231	186
2	2	18	94	45.5	118.2	1.11	0.47	199	92.9
2	5	18	213	86.2	153.1	2.8	0.93	274	161
2	3	18	118	62.2	134.6	2	1.24	183	155
2	6	18	195	74	111.3	3.05	0.83	264	144
3	1	18	176	81.4	94.3	2.52	0.78	213	104
3	4	18	191	209	55.2	4.44	1.68	290	431
3	2	18	88	58.6	111.5	1.47	0.9	149	177
3	5	18	180	77.8	108.6	2.91	1.11	249	146
3	3	18	105	5.86	150.6	1.37	0.07	183	55.3
3	6	18	73	0.1	125	1.2	0.01	74.7	11.1
4	1	18	159	50.3	61.8	3.88	0.39	243	111
4	4	18	133	80	71.2	2.83	0.73	236	152
4	2	18	191	94.5	105.4	2.42	1.2	224	152
4	5	18	55	0.1	88.1	0.81	0.01	235	0.1
4	3	18	159	140	121	2.89	1.63	195	88.5
4	6	18	189	13.2	132.5	3.05	0.13	307	44.2
1	1	19	11	45.3	24.4	2.25	1.89	44.9	131
1	4	19	77	121	59.7	15.44	4.66	126	238
1	2	19	11	20.3	41.9	3.75	1.2	37.2	70.8
1	5	19							
1	3	19	11	10.9	45.5	3	0.36	28.1	87.6
1	6	19	3	0.1	14.7	0.84	0.01	10.1	33.2
2	1	19	45	52.4	68.1	14.99	2.09	194	197
2	4	19	61	112	48	10.16	2.94	162	166
2	2	19	7	14.3	32.5	1.71	0.65	132	114
2	5	19	7	20.6	27.6	0.98	0.64	14.9	77.4
2	3	19	18	19.8	60.5	5.84	1.1	52.1	114
2	6	19	25	38.1	53.5	5.03	1.66	67	137
3	1	19	1	13.5	17.1	0.37	0.75	11.8	117
3	4	19	47	136	34.6	23.61	7.98	172	285
3	2	19	15	13.2	48.4	7.26	0.66	30.4	44.2
3	5	19	12	27.7	35.2	2.04	1.07	34.8	77.4
3	3	19		0.1	25		0.01	10.1	44.2
3	6	19	4	0.1	25	2.1	0.01	19.9	66.4
4	1	19	27	66.1	38.5	6.86	3.3	55.9	144
4	4	19	69	92	69.3	13.72	4.6	186	207
4	2	19	25	31.5	59.3	12.57	1.66	44.7	111
4	5	19	22	16.5	80	7.37	0.87	74.5	39.9
4	3	19	23	34.6	54.7	4.57	1.73	71	177
4	6	19	2	0.1	27.6	0.59	0.01	14.9	55.3
1	1	20			82.7				
1	4	20							
1	2	20			60.9				
1	5	20	194	15.2	167.2	4.13	0.23	473	15.2
1	3	20							
1	6	20							

2	1	20								
2	4	20	135	140	86.3	6.76	2.74	426	978	
2	2	20	16		60	0.52		16.6		
2	5	20	275	160	127.2	7.84	3.19	299	160	
2	3	20			55.4					
2	6	20			75					
3	1	20			75					
3	4	20								
3	2	20	82	25.1	174.6	2.5	0.66	233	210	
3	5	20								
3	3	20			50					
3	6	20	8		44.2	0.37		8.3		
4	1	20								
4	4	20	132	83.2	108	3.48	1.28	268	949	
4	2	20	135	44.9	134.2	4.49	0.8	304	68.4	
4	5	20	211		118.6	8.44		216		
4	3	20			68					
4	6	20								

Replicate	Treatment	Species	RSERmax	RSDIRmax	IL	RIL	BInc	RBInc	RHmaxDy
1	1	1	3.46	2.95	8.27	0.108	16	3.2	45
1	4	1	5.7	2.92	15.17	0.139	28	4	109
1	2	1	6.13	4.79	4.7	0.152	11	1.6	352
1	5	1	5.59	3.69	7.3	0.13	27	3.4	352
1	3	1	1.63	4.87	1.6	0.114	9	2.3	109
1	6	1	1.63	1.56			15	3.8	109
2	1	1	4.67	2.23	4.23	0.137	11	1.4	109
2	4	1	3.12	1.19	11.33	0.157	31	31	388
2	2	1	2.45	1.7	4.57	0.111	11	2.2	388
2	5	1	4.36	2.77	4	0.138	11	1.6	352
2	3	1	3.65	2.28	5.43	0.155	19	9.5	170
2	6	1	4.36	1.77	2.5	0.167	7	1.4	352
3	1	1	7.25	3.48	6.67	0.163	16	2.3	140
3	4	1	2.43	4.4	9.03	0.153	20	2	206
3	2	1	5.21	1.92	2.17	0.108	6	0.9	352
3	5	1	2.21	3.11	4.1	0.124	12	1.3	140
3	3	1	0.71	0.38	2.4	0.2	0	0	109
3	6	1	13.04	1.6	1.1	0.183	0	0	352
4	1	1	4.99	1.2	4.83	0.161	11	1.6	109
4	4	1	4.68	5.2	8.83	0.136	21	2.6	261
4	2	1	1.63	7.3	3.03	0.121	16	16	352
4	5	1	5.07	2.21	7	0.152	18	18	109
4	3	1	3.19	6.45	2.97	0.165	4	0.7	45
4	6	1	2.48	2.75	2.83	0.123	7	1	310
1	1	2	11.46	17.9	3.4	0.023	7	1.8	45
1	4	2	8.04	3.95	4.1	0.017	13	13	45
1	2	2	7.24	7.6	4.47	0.029	8	8	109
1	5	2	6.84	5.96	3.33	0.017	9	9	109
1	3	2	5.14	1.72	5.5	0.053	8	8	109
1	6	2	5.13	3.11	4.8	0.041	12	12	109
2	1	2	5.53	2.73	3.73	0.025	10	10	45
2	4	2	6.91	2.23			0	0	45
2	2	2	6.83	2.82	3.67	0.023	3	3	45
2	5	2	1.91	15.6	3.77	0.037	3	3	206
2	3	2	4.33	11.7	3.07	0.03	6	6	140
2	6	2	3.45	6.22	4.8	0.048	5	1.3	109
3	1	2	4.33	2.69	2.97	0.019	21	21	45
3	4	2	3.44	3.54	2.87	0.039	6	6	170
3	2	2	10.04	4.87	3.93	0.028	9	4.5	45

3	5	2	23.11	5.49	4.6	0.037	10	10	45
3	3	2	0.57	2.05			7	7	45
3	6	2	2.17	6.27	3.97	0.081	0	0	338
4	1	2	5.43	2.53	2.8	0.02	6	1.5	45
4	4	2	5.7	4.01	2.63	0.014	10	10	109
4	2	2	3.09	6.52	4.7	0.042	6	6	45
4	5	2	5.07	3.26	4.67	0.036	9	9	261
4	3	2	3.92	1.52	6.4	0.05	0	0	45
4	6	2	4.47	3.58	3.3	0.028	6	6	45
1	1	3	1.57	1.02	1.2	0.025	0	0	45
1	4	3	3.1	1.67	1.53	0.033	0	0	140
1	2	3	0.67	0.53			0	0	45
1	5	3	4.7	2	3.57	0.035	0	0	352
1	3	3	0.9	0.37	2.9	0.043	0	0	434
1	6	3	1.69	0.53	3.47	0.028	0	0	388
2	1	3	2.19	2.12	1.4	0.023	2	2	109
2	4	3	2.16	1.33	1.53	0.017	2	2	140
2	2	3	1.86	0.91	2.17	0.036	2	2	140
2	5	3	2.25	0.13	3.07	0.031	3	3	170
2	3	3	1.28	0.91	1.17	0.019	0	0	45
2	6	3	3.32	0.77	2.37	0.027	1	1	352
3	1	3	1.52	0.52	2.93	0.043	1	1	170
3	4	3	1.76	0.92	2.4	0.017	1	0.5	170
3	2	3	2	0.72	5.43	0.055	1	1	352
3	5	3	2.55	1.26	3.23	0.026	0	0	170
3	3	3	1.74	0.13	1.67	0.041	0	0	170
3	6	3	0.34	0.06	1.43	0.029	1	1	45
4	1	3	0.75	0.45	1.1	0.018	3	3	352
4	4	3	2.09	1.07	1.7	0.015	1	1	170
4	2	3	2.14	0.62	2.97	0.039	2	2	206
4	5	3	2.81	0.66	3.2	0.031	1	1	388
4	3	3	1.77	0.51	1.33	0.028	0	0	109
4	6	3	1.02	0.81	3.23	0.036	0	0	45
1	1	4	1.94	2.98	1.5	0.029	0	0	371
1	4	4	3.6	2.29	2.57	0.017	0	0	109
1	2	4	2.77	1.07	3.1	0.035	1	1	45
1	5	4	3.73	1.75	3.8	0.024	1	1	109
1	3	4	2.21	1.56	4.4	0.046	0	0	45
1	6	4	4.42	0.14			0	0	45
2	1	4	2.67	0.56	1.77	0.025	0	0	109
2	4	4	3.36	1.72	3.4	0.024	5	5	170
2	2	4	6.84	1.09	5.23	0.078	3	3	109
2	5	4	4.13	1.53	4.1	0.045	0	0	140
2	3	4	2.72	1.04	3.93	0.038	0	0	140
2	6	4	3.46	0.92	2.5	0.022	0	0	45
3	1	4	1.81	1.41	3	0.049	0	0	109
3	4	4	4.56	1.89	3.3	0.024	2	2	170
3	2	4	3.06	1.8	3.77	0.038	3	3	109
3	5	4	3.24	2.56	4.47	0.031	0	0	109
3	3	4	3.23	0.25	3.03	0.034	0	0	45
3	6	4	3.28	0.36	4.07	0.037	0	0	109
4	1	4	2.04	0.59	1.8	0.026	0	0	109
4	4	4	5.03	1.95	3.93	0.023	0	0	45
4	2	4	2.17	0.8	4.6	0.081	0	0	352
4	5	4	2.41	0.01	1.3	0.033	0	0	109
4	3	4	3.31	0.29	4.37	0.035	2	2	109
4	6	4	2.26	0.15	2.57	0.045	0	0	45
1	1	5	3.63	0.81	4.27	0.076	2	2	45

1	4	5	4.12	2.98	2.77	0.02	0	0	206
1	2	5	0.86	0.01			0	0	45
1	5	5	4.62	2.12	8.3	0.054	0	0	140
1	3	5	3.48	0.33			0	0	109
1	6	5	0.31	0.75			0	0	45
2	1	5	2.37	1.6	0.07	0.003	0	0	45
2	4	5	4.15	2.05			0	0	109
2	2	5	7.78	1.86	3.87	0.048	0	0	109
2	5	5	4.89	1.43			0	0	109
2	3	5	4.15	0.98	1.33	0.042	0	0	109
2	6	5	4.15	2.53	7.7	0.055	0	0	45
3	1	5	3.14	1.31	3.33	0.052	0	0	109
3	4	5	3.83	2.32	2.63	0.034	2	2	45
3	2	5	4.89	1.66	7.07	0.054	0	0	109
3	5	5	4.15	1.19	7.5	0.042	0	0	170
3	3	5	0.92	1.14	1.17	0.045	0	0	45
3	6	5	2.59	4.39	6.8	0.06	0	0	109
4	1	5	3.69	1.96	2.4	0.041	0	0	45
4	4	5	1.66	0.81			0	0	45
4	2	5	4.28	1.09	7.2	0.065	0	0	109
4	5	5	4.63	0.78			0	0	109
4	3	5	4.44	5.08	1.07	0.021	0	0	109
4	6	5	5.39	1.48	5.63	0.05	0	0	109
1	1	6	3.76	3.19	2.4	0.016	0	0	109
1	4	6	1.49	1.61			0	0	388
1	2	6	2.91	0.99	5.17	0.037	0	0	109
1	5	6	6.63	3.16	4.1	0.022	0	0	109
1	3	6	2.53	1.67	6.57	0.047	0	0	109
1	6	6	2.99	1.24	6.1	0.042	0	0	170
2	1	6	0.72	1.13	0.43	0.027	0	0	206
2	4	6	9.16	2.13	2.07	0.012	0	0	140
2	2	6	11.41	2.97	6.63	0.046	0	0	109
2	5	6	5.7	0.87	6.4	0.037	0	0	109
2	3	6	6.46	0.81	3.67	0.048	0	0	140
2	6	6	7.23	1.31	5.3	0.05	1	1	170
3	1	6	0.75	1.41	0.037	0.008	0	0	45
3	4	6	2.29	1.66	4.73	0.037	2	2	497
3	2	6	5.88	2.18	6.53	0.043	0	0	109
3	5	6	2.71	1.76	9.03	0.052	0	0	388
3	3	6	1.63	0.86	2.53	0.046	0	0	140
3	6	6	1.26	0.91	3.83	0.036	0	0	140
4	1	6	0.34	0.91	0.033	0.001	0	0	497
4	4	6	0.45	0.23			0	0	45
4	2	6	2.74	1.25			0	0	109
4	5	6	3.87	1.49	7.6	0.051	0	0	388
4	3	6	2.48	2.93	4.87	0.042	0	0	140
4	6	6	4.07	1.92	7.3	0.053	0	0	109
1	1	7	5.62	1.88	4.1	0.025	5	1.3	45
1	4	7	3.85	2.09	4.17	0.025	5	1.3	45
1	2	7	4.49	3.47	5.67	0.034	0	0	45
1	5	7	4.42	5.01	5.4	0.028	0	0	45
1	3	7	3.1	3.3	5.67	0.042	3	3	109
1	6	7	5.55	2.85	7.23	0.044	5	5	109
2	1	7	2.81	1.71	3.17	0.023	2	0.4	109
2	4	7	3.19	1.44	6.07	0.048	1	0.1	170
2	2	7	4.2	4.22	6.17	0.037	8	4	45
2	5	7	4.47	3.8	7.17	0.042	0	0	45
2	3	7	4.07	1.41	4.4	0.031	3	3	45

2	6	7	4.49	2	6.17	0.038	0	0	109
3	1	7	4.22	2.07	4.33	0.029	12	2	45
3	4	7	3.48	3.42	4.53	0.027	22	5.5	109
3	2	7	2.65	1.52	4.93	0.034	1	0.5	109
3	5	7	1.95	2.61	6.17	0.052	3	1	109
3	3	7	2.97	0.3			0	0	45
3	6	7	0.68	0.01	4.16	0.042	0	0	45
4	1	7	3.56	5.48	4	0.025	10	2.5	45
4	4	7	4.4	3.97	4.9	0.029	13	3.3	45
4	2	7	2.76	2.28	5.1	0.03	5	5	109
4	5	7	3.23	8.13	6.73	0.045	3	1	45
4	3	7	3.69	6.94	5.23	0.036	3	1.5	45
4	6	7	3.25	6.87	6.83	0.068	5	1	109
1	1	8	3.56	1.27	3.63	0.053	0	0	45
1	4	8	2.46	1.24	9.4	0.095	0	0	352
1	2	8	2.7	1.14			0	0	109
1	5	8	4.39	2.59	3.23	0.082	0	0	45
1	3	8	1.52	1.29	2.67	0.065	0	0	170
1	6	8	1.58	1.45	3.13	0.09	0	0	45
2	1	8	6.76	1.34	3.8	0.031	0	0	45
2	4	8	6.28	1.67	5.1	0.031	0	0	45
2	2	8	4.88	1.73	6.2	0.081	0	0	45
2	5	8	1.84	0.88	4.2	0.066	0	0	140
2	3	8	6.97	1.79	5.97	0.063	0	0	109
2	6	8	1.95	1.67	6.97	0.039	0	0	45
3	1	8	5.08	1.64	3.47	0.023	0	0	45
3	4	8	4.02	1.84	9.23	0.054	0	0	45
3	2	8	4.98	0.51	8.27	0.094	0	0	45
3	5	8	1.91	1.43	3.77	0.094	0	0	45
3	3	8	0.69	2.57			0	0	45
3	6	8	1.24	0.42			0	0	45
4	1	8	4.31	1.7	4.43	0.058	0	0	45
4	4	8	5.93	2.83	4.43	0.032	0	0	45
4	2	8	2.49	0.05			0	0	45
4	5	8	4.39	1.77	5.77	0.068	0	0	45
4	3	8	5.39	1.25	5.1	0.076	0	0	45
4	6	8	4.44	0.26			0	0	45
1	1	9	7.44	1.76	8.97	0.056	0	0	45
1	4	9	7.35	2.16	8.03	0.045	0	0	109
1	2	9	5.61	1.99	8.9	0.052	0	0	109
1	5	9	4.65	1.31	9.97	0.06	0	0	109
1	3	9	1.87	0.42	5.4	0.11	0	0	206
1	6	9	3.61	1.82	7.37	0.069	0	0	109
2	1	9	2.52	0.83	4.3	0.062	0	0	45
2	4	9	3.11	1.41	5.47	0.042	0	0	109
2	2	9	2.37	1.11	3.4	0.079	0	0	45
2	5	9	1.95	1.1	3.93	0.091	0	0	170
2	3	9	2.28	1	4.13	0.094	0	0	368
2	6	9	2.64	1.27	7.27	0.062	0	0	170
3	1	9	1.13	0.27			0	0	45
3	4	9	3.26	0.9	4.5	0.094	0	0	368
3	2	9	2.59	1.24	7.33	0.097	0	0	206
3	5	9	4.01	0.89	4.7	0.059	0	0	206
3	3	9	0.64	0.58			0	0	45
3	6	9	0.61	0.19			0	0	45
4	1	9	1.28	1.19	3.13	0.071	0	0	261
4	4	9	4.72	2.7	6.93	0.048	0	0	206
4	2	9	3.89	1.14	8.17	0.097	0	0	109

4	5	9	3.07	1.12	6.07	0.081	0	0	109
4	3	9	3.59	0.79	5.8	0.114	0	0	109
4	6	9	3.84	0.64	4.5	0.107	0	0	170
1	1	10	3.07	1.34	4.33	0.059	0	0	45
1	4	10	4.31	0.53			0	0	45
1	2	10	6.22	0.57	8.06	0.094	0	0	45
1	5	10	9.13	1.87	10.3	0.065	0	0	45
1	3	10	3.14	1.12	4.06	0.053	0	0	140
1	6	10	4.74	1.36	9.93	0.081	0	0	45
2	1	10	9.02	2.22			0	0	45
2	4	10	10.18	2.64	7.5	0.045	0	0	45
2	2	10	5.66	0.63			0	0	45
2	5	10	8.99	2.11	13.2	0.072	0	0	45
2	3	10	10.04	1.18			0	0	109
2	6	10	9.06	2.88			0	0	45
3	1	10	9.29	1.75	3.6	0.04	0	0	109
3	4	10	8.64	1.68	14.1	0.079	0	0	45
3	2	10	11.69	2.09	11	0.072	0	0	45
3	5	10	10.51	2.96	9.63	0.052	0	0	45
3	3	10	3.3	0.8			0	0	109
3	6	10	1.91	0.76			0	0	45
4	1	10	7.9	1.71	2.97	0.04	0	0	45
4	4	10	3.02	0.01			0	0	45
4	2	10	9.29	2.49	7.93	0.048	0	0	45
4	5	10	9.48	3.51	8.77	0.058	0	0	45
4	3	10	6.06	2.59	9.37	0.056	0	0	109
4	6	10	9.02	0.63			0	0	45
1	1	11	0.49	0.95			0	0	45
1	4	11	6.04	3.28	2.33	0.02	0	0	109
1	2	11	2.89	2.68	2.47	0.037	0	0	45
1	5	11	4.86	1.18			0	0	45
1	3	11	2.53	1.12	4.3	0.044	0	0	388
1	6	11	2.07	0.62			0	0	109
2	1	11	0.68	0.55	0.33	0.019	0	0	206
2	4	11	4.51	2.77	1.8	0.021	0	0	206
2	2	11	6.59	1.26	2.8	0.074	0	0	388
2	5	11	3.01	1.86	3.13	0.029	0	0	388
2	3	11	2.43	1.6	4.03	0.061	0	0	170
2	6	11	4.85	1.93	4.87	0.028	0	0	109
3	1	11	1.73	1.27	1.13	0.028	0	0	45
3	4	11	3.8	3.63	1.77	0.018	0	0	109
3	2	11	2.97	3.23	3.67	0.048	0	0	109
3	5	11	3.72	1.19			0	0	109
3	3	11	0.85	2.83	0.73	0.027	0	0	206
3	6	11	2.05	1.35	4.17	0.074	0	0	388
4	1	11	1.02	0.81			0	0	140
4	4	11	1.19	1.83			0	0	45
4	2	11	1.66	0.97	2.23	0.035	0	0	45
4	5	11	4.33	0.81			0	0	109
4	3	11	0.53	1.16	0.37	0.015	0	0	170
4	6	11	3.47	0.75			0	0	109
1	1	12	5.81	1.86	6.17	0.056	19	3.8	109
1	4	12	3	4.83	7.2	0.043	40	4.4	140
1	2	12	2.56	1.24	6	0.038	23	2.1	140
1	5	12	1.64	1.26	6	0.039	36	2.8	140
1	3	12	1.64	1.3	4.1	0.029	6	0.7	109
1	6	12	2.33	1.36	4.4	0.032	19	3.8	109
2	1	12	0.94	1.65	4	0.043	17	1.9	261

2	4	12	1.82	1.56	4.73	0.031	32	2.9	109
2	2	12	3.54	1.98	7.47	0.05	19	19	170
2	5	12	1.83	2.43	6.13	0.043	22	22	170
2	3	12	3.57	1.16	6.77	0.064	7	0.9	261
2	6	12	2.5	1.95	7.17	0.056	0	0	206
3	1	12	1.75	0.99	7.3	0.065	17	1.3	140
3	4	12	4.22	5.18	5.67	0.066	23	2.1	109
3	2	12	2.62	1.43	4.43	0.031	7	1	109
3	5	12	0.83	1.25	8.57	0.076	26	3.7	170
3	3	12	1.12	0.45	5.4	0.078	3	1	109
3	6	12	1.35	0.49	4.53	0.04	5	1	109
4	1	12	3.04	1.51	5.83	0.072	20	4	170
4	4	12	1.91	1.43	8.03	0.054	44	5.5	109
4	2	12	0.79	0.39	7.07	0.071	6	1.2	109
4	5	12	2.59	0.98	7.17	0.049	30	10	109
4	3	12	1.8	0.65	7.93	0.064	3	0.6	109
4	6	12	2.3	0.75	7.4	0.055	10	2.5	109
1	1	13	5.22	2.62	2.33	0.027	0	0	45
1	4	13	7.33	3.29	7.83	0.038	3	1.5	45
1	2	13	7.26	1.61	5.07	0.045	2	2	45
1	5	13	9.35	3.23	5.6	0.028	2	1	45
1	3	13	8.51	2.73	6	0.037	1	1	45
1	6	13	8.3	2.25	5.07	0.047	2	2	45
2	1	13	3.98	2.4	2.5	0.021	0	0	109
2	4	13	6.65	4.1	4.77	0.031	4	4	109
2	2	13	8.87	1.24			0	0	45
2	5	13	6.22	3.1	5.03	0.048	2	2	45
2	3	13	2.35	1.27	3.63	0.041	0	0	140
2	6	13	7.9	2.01	5.6	0.043	3	3	45
3	1	13	4	2.31	3.2	0.021	0	0	140
3	4	13	7.08	4.98	4.87	0.03	6	6	109
3	2	13	8.66	1	5.37	0.043	7	7	45
3	5	13	10.22	0.83	5.83	0.043	4	4	45
3	3	13	3.7	0.01			0	0	45
3	6	13	3.46	0.51			0	0	45
4	1	13	5.59	1.77	3.47	0.028	2	1	109
4	4	13	4.76	2.49	4.37	0.023	1	1	109
4	2	13	6.11	2.21	4.6	0.032	0	0	45
4	5	13	8.3	1.93	5.67	0.028	0	0	45
4	3	13	6.64	0.93	6.17	0.047	5	5	45
4	6	13	8.96	1.96	4.93	0.033	7	7	45
1	1	14	2.23	2.19	1.27	0.031	0	0	109
1	4	14	11.06	3.73	4.83	0.03	0	0	45
1	2	14	20.39	3.45	5.1	0.029	0	0	45
1	5	14	8.68	2.17			0	0	45
1	3	14	19.36	3.61			0	0	45
1	6	14	14.52	5.86	9.36	0.057	1	1	45
2	1	14	7.92	2.49	1.07	0.012	0	0	45
2	4	14	12.26	2	2.67	0.028	0	0	109
2	2	14	21.12	0.7			0	0	45
2	5	14	8	0.99			0	0	45
2	3	14	7.4	2.76	5.83	0.049	3	3	45
2	6	14	15.9	1.18			0	0	45
3	1	14	4.41	2.31	5.2	0.034	0	0	45
3	4	14	15.62	3.44	8.07	0.052	0	0	109
3	2	14	12.11	3.04	7.87	0.061	6	6	45
3	5	14	8.85	3.09	7.3	0.051	0	0	45
3	3	14	4.04	0.83			0	0	45

3	6	14	5.33	0.01			0	0	45
4	1	14			3.17	0.035	0	0	
4	4	14	4.04	5.16	3.23	0.025	0	0	45
4	2	14	14.4	2.07	4.67	0.022	2	2	45
4	5	14	13.31	1.61	5.5	0.026	3	3	45
4	3	14	14.1	2.03	4	0.019	1	1	45
4	6	14			5.17	0.038	2	2	
1	1	15	2.62	4.4	8	0.08	0	0	140
1	4	15	6.95	4.13	5.83	0.049	4	4	140
1	2	15	4.98	3.1	10.7	0.081	7	7	45
1	5	15	7.03	5.23	12.8	0.083	0	0	109
1	3	15	3.72	3.51			0	0	109
1	6	15	3.87	2.45	13.2	0.083	0	0	109
2	1	15	5.25	2.77	10.67	0.068	1	1	140
2	4	15	3.03	2.58	3.5	0.028	9	9	45
2	2	15	1.58	1.33			0	0	109
2	5	15	1.69	1.92	9	0.087	1	1	45
2	3	15	2.71	1.98	8.67	0.069	0	0	45
2	6	15	2.67	3.35	7.5	0.076	0	0	109
3	1	15	3.35	2.1	10.3	0.078	1	1	45
3	4	15	3.95	3.15	11.2	0.076	9	9	109
3	2	15	5.28	2.22	12	0.08	4	4	109
3	5	15	3.53	0.21	13.7	0.104	2	2	45
3	3	15	0.72	0.2			0	0	45
3	6	15	0.54	1.57			0	0	45
4	1	15	3.75	3.23	10.2	0.079	2	2	45
4	4	15	5.93	3.38	10	0.067	4	2	45
4	2	15	5.7	3.61	11.2	0.083	3	3	109
4	5	15	5.92	3.09	13.5	0.075	0	0	109
4	3	15	2.14	1.35	7.3	0.071	0	0	109
4	6	15	7.17	3.46	12.7	0.088	1	0.5	109
1	1	16					0	0	
1	4	16					0	0	
1	2	16	3.23	1.25	4.33	0.033	4	4	109
1	5	16	1.45				0	0	45
1	3	16	9.67	1.8	5.07	0.043	0	0	45
1	6	16					10	10	
2	1	16	3.16	2.13	3.3	0.031	4	1	45
2	4	16	1.86	3.13	4.2	0.038	3	0.2	45
2	2	16	3.66				0	0	109
2	5	16	0.54				0	0	45
2	3	16	2.98	1.58	6.17	0.055	3	0.8	140
2	6	16	2.69	1.8	4.47	0.039	0	0	109
3	1	16					0	0	
3	4	16					0	0	
3	2	16					0	0	
3	5	16	4.52	2.34	7.9	0.043	10	1.7	45
3	3	16	1.79	0.2	5.63	0.063	1	0.2	45
3	6	16	2.65	0.13	6.33	0.044	2	0.5	45
4	1	16	5.23	2.02	4.47	0.039	5	0.8	45
4	4	16	2.62	1.87	5.97	0.048	8	1.1	109
4	2	16	8.3	2.28	6.17	0.055	4	0.7	45
4	5	16	3.07	1.75	4.33	0.033	2	0.3	109
4	3	16	0.13				0	0	45
4	6	16					0	0	
1	1	17	2.94	1.29	9.47	0.091	20	2	45
1	4	17	4.86	3.94	18.7	0.127	40	5	45
1	2	17	3.17	1.33	15.6	0.183	11	1.2	261

1	5	17	3.74	0.7	13.7	0.263	21	2.3	388
1	3	17	2.4	0.99	8.23	0.121	9	1	388
1	6	17	1	0.92	7	0.241	1	0.1	352
2	1	17	0.95	0.58			0	0	109
2	4	17	1.07	1.87			0	0	109
2	2	17	2.44	1.04	10.33	0.117	14	3.5	352
2	5	17	5.03	1.68	14.5	0.21	4	0.3	352
2	3	17	2.34	1	7.83	0.163	5	0.5	388
2	6	17	1.45	1.06	9.17	0.278	0	0	388
3	1	17	0.37	0.97	4.47	0.131	15	2.5	170
3	4	17	2.28	1.9	10.5	0.099	31	2.6	440
3	2	17	2.23	1.32	9.67	0.14	10	0.8	388
3	5	17	2.23	2.51			0	0	45
3	3	17	2.23	2.19	11.3	0.231	1	0.2	440
3	6	17	1.97	2.4	10.7	0.248	2	0.2	388
4	1	17	1.63	0.84	9.33	0.098	25	2.3	261
4	4	17	3.12	2.24	13.5	0.13	24	4.8	352
4	2	17	2.07	1.41	7.67	0.135	4	0.4	45
4	5	17	1.61	1.31	9.5	0.19	3	0.3	109
4	3	17	1.9	1.45	11	0.196	2	0.3	45
4	6	17	1.95	1.04	7.07	0.128	1	0.1	109
1	1	18	3.97	2.59	3.5	0.023	3	3	45
1	4	18	3.35	3.95	2.5	0.013	0	0	109
1	2	18	9.36	4.83	4	0.022	0	0	45
1	5	18	6.94	3.48			0	0	45
1	3	18	1.36	2.04	3.67	0.025	0	0	109
1	6	18	3.47	3.14	2.67	0.013	0	0	109
2	1	18	2.38	1.38	2	0.014	0	0	109
2	4	18	2.3	2.78			3	1.5	109
2	2	18	2.34	0.77	2.33	0.012	5	5	45
2	5	18	3.6	1.36	3.2	0.019	2	1	45
2	3	18	2.11	2.21	4.67	0.019	1	0.3	45
2	6	18	3.76	1.3	3.93	0.023	3	1.5	45
3	1	18	2.46	0.7	1.83	0.011	0	0	109
3	4	18	6.75	2.14	2.67	0.016	2	1	45
3	2	18	2.49	2.34	7.33	0.054	6	6	45
3	5	18	4.01	1.72	5.93	0.039	6	6	45
3	3	18	2.37	0.63	3.23	0.024	2	2	45
3	6	18	1.22	0.2			0	0	45
4	1	18	4.05	0.85	2.83	0.024	0	0	45
4	4	18	3.63	1.4			0	0	109
4	2	18	2.84	1.93	4.1	0.023	1	1	45
4	5	18	3.41	0.01			0	0	140
4	3	18	3.62	0.88	3.97	0.028	3	3	45
4	6	18	4.95	0.4	4	0.024	5	5	45
1	1	19	6.52	2.99	1.83	0.092	0	0	109
1	4	19	12.61	9.5	13.5	0.125	0	0	261
1	2	19	16.9	2.95	3.43	0.191	0	0	388
1	5	19					0	0	
1	3	19	8.55	3.02	1.67	0.083	0	0	109
1	6	19	2.53	1.75	0.57	0.226	0	0	206
2	1	19	20.86	4.68	6.47	0.104	0	0	486
2	4	19	6.91	2.06	9.33	0.108	0	0	45
2	2	19	5.99	3.26	0.77	0.059	0	0	388
2	5	19	2.41	1.99	1.5	0.094	0	0	486
2	3	19	4.68	6	3.53	0.136	0	0	486
2	6	19	3.61	6.84	4.07	0.107	0	0	486
3	1	19	2.35	3.77	0.66	0.111	3	3	140

3	4	19	10.14	3.66	10.1	0.155	0	0	206
3	2	19	8.3	1.77			0	0	45
3	5	19	2.85	2.58			0	0	109
3	3	19	2.53	2.77	0.63	0.127	0	0	388
3	6	19	9.95	4.74			0	0	261
4	1	19	5.7	3.2	4.4	0.11	0	0	109
4	4	19	19.91	2.5	7.6	0.08	0	0	45
4	2	19	8.55	5.27	3.2	0.091	0	0	109
4	5	19	8.55	1.6	4.17	0.13	0	0	109
4	3	19	3.32	7.08	4.13	0.118	0	0	45
4	6	19	3.72	2.13	1.33	0.167	0	0	310
1	1	20					0	0	
1	4	20					0	0	
1	2	20					0	0	
1	5	20	10.06	0.23			0	0	45
1	3	20					0	0	
1	6	20					0	0	
2	1	20					0	0	
2	4	20	16.29	19.2	4.07	0.022	0	0	109
2	2	20	0.54				0	0	45
2	5	20	8.53	3.19	2.5	0.024	0	0	45
2	3	20					0	0	
2	6	20					0	0	
3	1	20					0	0	
3	4	20					0	0	
3	2	20	9.36	6.57			0	0	170
3	5	20					0	0	
3	3	20					0	0	
3	6	20	0.38				0	0	45
4	1	20			3.57	0.016	0	0	
4	4	20	5.68	13.6			0	0	45
4	2	20	4	1.22			0	0	170
4	5	20	8.63				0	0	45
4	3	20					0	0	
4	6	20					0	0	

Replicate	Treatment	Species	RDmaxDy
1	1	1	173
1	4	1	140
1	2	1	206
1	5	1	206
1	3	1	206
1	6	1	140
2	1	1	269
2	4	1	487
2	2	1	206
2	5	1	206
2	3	1	140
2	6	1	173
3	1	1	206
3	4	1	269
3	2	1	324
3	5	1	206
3	3	1	388
3	6	1	388
4	1	1	206
4	4	1	173
4	2	1	140
4	5	1	173

4	3	1	173
4	6	1	324
1	1	2	331
1	4	2	115
1	2	2	331
1	5	2	115
1	3	2	115
1	6	2	331
2	1	2	206
2	4	2	115
2	2	2	206
2	5	2	338
2	3	2	338
2	6	2	206
3	1	2	115
3	4	2	324
3	2	2	338
3	5	2	338
3	3	2	206
3	6	2	173
4	1	2	115
4	4	2	115
4	2	2	338
4	5	2	338
4	3	2	115
4	6	2	338
1	1	3	140
1	4	3	140
1	2	3	115
1	5	3	434
1	3	3	140
1	6	3	434
2	1	3	388
2	4	3	269
2	2	3	140
2	5	3	324
2	3	3	434
2	6	3	140
3	1	3	324
3	4	3	388
3	2	3	388
3	5	3	434
3	3	3	173
3	6	3	434
4	1	3	388
4	4	3	206
4	2	3	324
4	5	3	388
4	3	3	434
4	6	3	434
1	1	4	206
1	4	4	140
1	2	4	115
1	5	4	173
1	3	4	140
1	6	4	115
2	1	4	140
2	4	4	269

2	2	4	269
2	5	4	206
2	3	4	373
2	6	4	140
3	1	4	206
3	4	4	206
3	2	4	140
3	5	4	140
3	3	4	173
3	6	4	140
4	1	4	324
4	4	4	140
4	2	4	173
4	5	4	
4	3	4	140
4	6	4	173
1	1	5	388
1	4	5	173
1	2	5	115
1	5	5	140
1	3	5	115
1	6	5	140
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2	3	6	388
2	6	6	388
3	1	6	173
3	4	6	388
3	2	6	206
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3	3	6	173
3	6	6	269

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4	5	6	497
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1	2	7	115
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4	2	7	115
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4	3	7	177
4	6	7	177
1	1	8	115
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2	4	8	206
2	2	8	173
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4	2	8	115
4	5	8	388
4	3	8	173
4	6	8	115
1	1	9	206
1	4	9	140
1	2	9	140
1	5	9	115

1	3	9	324
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2	1	9	368
2	4	9	324
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2	5	9	368
2	3	9	368
2	6	9	206
3	1	9	115
3	4	9	368
3	2	9	368
3	5	9	324
3	3	9	140
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4	4	9	206
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4	3	9	269
4	6	9	206
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1	4	10	115
1	2	10	140
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3	4	10	115
3	2	10	140
3	5	10	140
3	3	10	173
3	6	10	269
4	1	10	115
4	4	10	
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4	6	10	140
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1	4	11	206
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1	5	11	115
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2	1	11	388
2	4	11	269
2	2	11	206
2	5	11	486
2	3	11	388
2	6	11	269
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3	2	11	324
3	5	11	115
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3	6	11	388
4	1	11	269
4	4	11	140
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4	5	11	115
4	3	11	206
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4	3	13	226
4	6	13	

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1	2	14	115
1	5	14	115
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1	6	14	115
2	1	14	206
2	4	14	115
2	2	14	115
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4	2	14	115
4	5	14	140
4	3	14	226
4	6	14	
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1	2	15	115
1	5	15	115
1	3	15	115
1	6	15	173
2	1	15	173
2	4	15	115
2	2	15	140
2	5	15	173
2	3	15	173
2	6	15	140
3	1	15	140
3	4	15	140
3	2	15	140
3	5	15	173
3	3	15	115
3	6	15	140
4	1	15	115
4	4	15	115
4	2	15	115
4	5	15	140
4	3	15	115
4	6	15	115
1	1	16	
1	4	16	
1	2	16	115
1	5	16	
1	3	16	140
1	6	16	
2	1	16	140
2	4	16	140
2	2	16	
2	5	16	

2	3	16	115
2	6	16	140
3	1	16	
3	4	16	
3	2	16	
3	5	16	115
3	3	16	115
3	6	16	115
4	1	16	140
4	4	16	156
4	2	16	115
4	5	16	156
4	3	16	
4	6	16	
1	1	17	173
1	4	17	140
1	2	17	269
1	5	17	140
1	3	17	140
1	6	17	206
2	1	17	115
2	4	17	115
2	2	17	206
2	5	17	140
2	3	17	324
2	6	17	173
3	1	17	269
3	4	17	140
3	2	17	173
3	5	17	173
3	3	17	140
3	6	17	173
4	1	17	388
4	4	17	173
4	2	17	173
4	5	17	140
4	3	17	173
4	6	17	440
1	1	18	115
1	4	18	115
1	2	18	115
1	5	18	115
1	3	18	115
1	6	18	115
2	1	18	115
2	4	18	115
2	2	18	324
2	5	18	140
2	3	18	206
2	6	18	173
3	1	18	269
3	4	18	173
3	2	18	115
3	5	18	140
3	3	18	206
3	6	18	173
4	1	18	115
4	4	18	115

4	2	18	115
4	5	18	
4	3	18	173
4	6	18	173
1	1	19	140
1	4	19	269
1	2	19	486
1	5	19	
1	3	19	140
1	6	19	173
2	1	19	486
2	4	19	324
2	2	19	388
2	5	19	206
2	3	19	388
2	6	19	486
3	1	19	140
3	4	19	388
3	2	19	206
3	5	19	173
3	3	19	173
3	6	19	206
4	1	19	206
4	4	19	486
4	2	19	206
4	5	19	388
4	3	19	173
4	6	19	206
1	1	20	
1	4	20	
1	2	20	
1	5	20	115
1	3	20	
1	6	20	
2	1	20	
2	4	20	140
2	2	20	
2	5	20	115
2	3	20	
2	6	20	
3	1	20	
3	4	20	
3	2	20	206
3	5	20	
3	3	20	
3	6	20	
4	1	20	
4	4	20	140
4	2	20	115
4	5	20	
4	3	20	
4	6	20	

Appendix D

Table of leaf characteristics for seedlings of twenty Queensland rainforest tree species.

Replicate: As for replicate in Appendix B.

Treatment: 1 = clear compartment and no added nitrogen, 2 = blue compartment and no added nitrogen, 3 = green compartment and no added nitrogen, 4 = clear compartment with added nitrogen, 5 = blue compartment with added nitrogen, 6 = green compartment and added nitrogen.

Species: 1 = *Agathis robusta*, 2 = *Alphitonia excelsa*, 3 = *Castanospermum australe*, 4 = *Dysoxylum fraserianum*, 5 = *Dysoxylum muelleri* CQ (Central Queensland provenance), 6 = *Dysoxylum muelleri* NQ (North Queensland provenance), 7 = *Elaeocarpus grandis*, 8 = *Flindersia bennettiana*, 9 = *Flindersia brayleyana*, 10 = *Flindersia schottiana*, 11 = *Flindersia xanthoxyla*, 12 = *Gmelina leichardtii*, 13 = *Grevillea robusta*, 14 = *Melia azedarach* var. *australasica*, 15 = *Nauclea orientalis*, 16 = *Pleiogynium timorense*, 17 = *Podocarpus elatus*, 18 = *Rhodosphaera rhodanthema*, 19 = *Blepharocarya involucrigera*, 20 = *Toona ciliata*.

LA: Leaf area of largest leaf at end of experiment (cm²).

SLA: Specific leaf area for largest leaf (cm²/g)

SLA-yfel: Specific leaf area for youngest fully expanded leaf (cm²/g).

LBL: Leaf blade length (cm).

TLN: Total leaf number at end of experiment.

TLFN: Total number of leaflets at end of experiment.

TLA (est.): An estimate of total leaf area at end of experiment TLN x 2/3 LA (cm²).

RCD: Relative crown depth (height-height to first leaf)/height, (cm/cm).

LFNmax: Maximum leaflet number per individual leaf at end of experiment.

Replicate	Treatment	Species	Leaf Area	SLA	SLA-yfel	LBL	TLN	TLFN	TLA (est.)
1	1	1	65	77	89.19		12	123	7995
2	1	1	40	83	108.54		10	80	3200
3	1	1	50	84	90.05		10	93	4650
4	1	1	46	81	89.36		11	62	2852
1	2	1	58	111	128.32		11	69	4002
2	2	1	61	138	146.1		11	51	3111
3	2	1			122.53		10	49	
4	2	1	56	142	149.92		14	41	2296
1	3	1	54	132			11	32	1728
2	3	1	68	118	130.19		12	88	5984
3	3	1	39	107	140.94		10	13	507
4	3	1	32	124	139.58		8	21	672
1	4	1	58	75	97.01		12	233	13514
2	4	1	56	74	70.41		14	222	12432
3	4	1	61	79	95.69		13	160	9760
4	4	1	62	77	95.88		15	161	9982
1	5	1	59	114			12	156	9204
2	5	1	48	127	137.38		11	44	2112
3	5	1	47	104	137.41		11	48	2256
4	5	1	48	129	145.47		14	66	3168
1	6	1	35	115			9	39	1365
2	6	1	47	136	141.5		9	37	1739
3	6	1	47	95	141.43		10	13	611
4	6	1	31	139	155.83		10	38	1178
1	1	2	53	113	102.91		18	42	2226
2	1	2	53	142	166.36		14	12	636
3	1	2	33	140	118.84		13	40	1320
4	1	2	48	115	142.4		15	34	1632
1	2	2	75	204	217.25		18	46	3450
2	2	2	101	223	298.52		21	21	2121
3	2	2	36	215	205.06		18	48	1728
4	2	2	86	327	391.09		22	39	3354
1	3	2	109	301	294.91		24	42	4578
2	3	2	95	350	335.53		18	43	4085
3	3	2							
4	3	2	89	210	296.33		20	31	2759
1	4	2	50	122	103.85		15	188	9400
2	4	2							
3	4	2	31	125	114.72		11	12	372
4	4	2	52	115	114.56		13	136	7072
1	5	2	107	192	223.7		19	100	10700
2	5	2	123	332	417.33		25	26	3198
3	5	2	130	422	405.66		21	53	6890
4	5	2	133	267	419.79		23	72	9576
1	6	2	115	372	427.78		21	81	9315
2	6	2	108	317	337.81		23	61	6588
3	6	2	43	470	543.33		16	16	688
4	6	2	91	237	461.86		19	30	2730
1	1	3	106	137	142.74		9	95	10070
2	1	3	172	135			12	215	28
3	1	3	74	126	157.64		10	241	37
4	1	3			119.74		9	59	10
1	2	3							
2	2	3	148	215			10	175	24
3	2	3	404	193	212.81		14	224	24
4	2	3			202.47		12	200	22
1	3	3	356	233	240.63		14	145	20
									51620

2	3	3	278	205		14	116	17	32248
3	3	3	236	243	245.34	14	50	7	11800
4	3	3			298.52	13	55	9	
1	4	3	206	150	167.76	12	195	22	40170
2	4	3	159	108		12	355	45	56445
3	4	3	151	120	113.03	12	520	88	78520
4	4	3			132.77	11	594	59	
1	5	3	261	214	203.79	14	379	42	98919
2	5	3	264	217		14	268	38	70752
3	5	3	563	196	195.39	17	209	23	117667
4	5	3			334.6	17	234	26	
1	6	3	363	227	243.68	19	357	39	129591
2	6	3	228	200		15	295	33	67260
3	6	3	238	242	287.25	15	40	5	9520
4	6	3			341.76	16	204	24	
1	1	4	56	102	106.13	9	82	13	4592
2	1	4	34	100	112.03	6	134	22	4556
3	1	4	54	100	95.79	9	84	11	4536
4	1	4	184	121	123.23		79	15	14536
1	2	4	187	126	149.57	13	127	21	23749
2	2	4	177	161	204.48	13	120	18	21240
3	2	4	151	135	163.98	13	292	50	44092
4	2	4	278	282	287.41	18	64	10	17792
1	3	4	214	195	216.06		139	21	29746
2	3	4	212	125	235.22	16	133	17	28196
3	3	4	332	298	286.13	19	85	14	28220
4	3	4	321	273	258.7	20	148	24	47508
1	4	4	82	94	116.99	10	280	35	22960
2	4	4	60	62	121.1	8	648	81	38880
3	4	4	322	74	91.41	9		48	
4	4	4	205	82	127.28	13		59	
1	5	4	182	138	195.71		274	41	49868
2	5	4	332	193	211.86	19	164	21	54448
3	5	4	238	186	221.15		285	30	67830
4	5	4							
1	6	4							
2	6	4			195.56	18	229	28	
3	6	4	179	272		16	134	20	23986
4	6	4	165	254	276.22	12	112	13	18480
1	1	5	119	187	224.08	8		25	
2	1	5	48	205		6	107	8	5136
3	1	5	224	166	190.74	8		8	
4	1	5	189	165	161.49	10	160	12	30240
1	2	5							
2	2	5	293	279		14	219	13	64167
3	2	5	309	254	242.68	11		13	
4	2	5	268	296	329.67	10	129	8	34572
1	3	5							
2	3	5				9	119	10	
3	3	5	208	424	422.22	13		10	
4	3	5	131	437	379.8	11	299	18	39169
1	4	5	403	183	177.26	12		25	
2	4	5							
3	4	5	227	145	142.83	9		16	
4	4	5							
1	5	5	515	186	233.28	14		27	
2	5	5							
3	5	5	707	282	299.68	16		25	

4	5	5							
1	6	5							
2	6	5	585	295		16	317	18	185445
3	6	5	334	384	354.15	15		23	
4	6	5	351	333	368	13	274	17	96174
1	1	6	261	181	165.38	10	63	5	16443
2	1	6	17	226		3	45	4	765
3	1	6	42	226	154.63	4	57	4	2394
4	1	6			195.67	3	35	3	
1	2	6	313	173	204.2	11	63	5	19719
2	2	6	198	191		11	345	26	68310
3	2	6	373	199	282.79	17	206	15	76838
4	2	6							
1	3	6	298	241		12	322	19	95956
2	3	6	256	243		11	130	8	33280
3	3	6	133	249	433.33	12	127	9	16891
4	3	6	431	330	441.43	14	307	19	132317
1	4	6	291	166	133.17	10	214	12	62274
2	4	6	423	106		13	162	13	68526
3	4	6	189	163	191.36	11	497	40	93933
4	4	6							
1	5	6	401	105	190.28	14	259	29	103859
2	5	6	448	225		13	457	34	204736
3	5	6	379	196	278.08	16	378	27	143262
4	5	6	517	247	340	14	376	23	194392
1	6	6	158	305	242.71	15	500	38	79000
2	6	6	200	258		10	111	6	22200
3	6	6	361	240	388.81	15	183	10	66063
4	6	6	535	342	497.88	16	375	21	200625
1	1	7	55	155		19	110		6050
2	1	7	30	155		18	152		4560
3	1	7	40	217		16	220		8800
4	1	7	50	192		22	322		16100
1	2	7	20	162		11	2		40
2	2	7	55	293		20	56		3080
3	2	7	56	283		18	24		1344
4	2	7	89	230		24	89		7921
1	3	7	95	275		29	60		5700
2	3	7	99	270		24	39		3861
3	3	7							
4	3	7	75	301		28	83		6225
1	4	7	74	204		23	157		11618
2	4	7	55	206		19	149		8195
3	4	7	70	156		20	235		16450
4	4	7	82	156		23	296		24272
1	5	7	47	245		18	83		3901
2	5	7	73	221		23	107		7811
3	5	7	93	204		27	43		3999
4	5	7	49	231		19	80		3920
1	6	7	63	276		22	64		4032
2	6	7	45	274		20	46		2070
3	6	7	43	338		18	14		602
4	6	7	107	236		26	85		9095
1	1	8	137	95	81.01	9	88	14	12056
2	1	8	252	99	127.15	14	148	26	37296
3	1	8	121	69	104.33	13	173	37	20933
4	1	8	227	73	91.22	16	64	11	14528
1	2	8							

2	2	8	230	167	166.52	16	79	25	18170
3	2	8	280	146	146.99	14	28	16	7840
4	2	8							
1	3	8	157	177	173.28	13	35	7	5495
2	3	8	201	132	147.16	17	75	14	15075
3	3	8							
4	3	8	352	176	189.9	19	69	13	24288
1	4	8	174	123	74.89	16	95	19	16530
2	4	8	314	93	99.65	15	132	41	41448
3	4	8	310	131	165.84	19	232	40	71920
4	4	8	270	97	101.95	16	206	36	55620
1	5	8	212	139	104.31	14	38	8	8056
2	5	8	317	215	195.48	17	58	18	18386
3	5	8				8	20	10	
4	5	8	281	197	177.29	17	79	16	22199
1	6	8	144	174	167.73	9	36	7	5184
2	6	8	223	170	192.25	15	97	19	21631
3	6	8							
4	6	8							
1	1	9	164	129	140.07	40	224	28	36736
2	1	9			137.12	34	57	15	
3	1	9							
4	1	9	362	131	138.65	37	38	10	13756
1	2	9	236	89	155		144	18	33984
2	2	9	592	160	174.03	45	50	10	29600
3	2	9	475	170	372.45	44	53	11	25175
4	2	9	701	166	262.2	43	74	14	51874
1	3	9	596	185	346.91	49	47	6	28012
2	3	9	577	210	266.12	42	37	7	21349
3	3	9			255.06		52	13	
4	3	9	285	240	310.76	39	52	13	14820
1	4	9	232	88	95.6	38	192	24	44544
2	4	9	429	112	191.36	49	124	24	53196
3	4	9	347	126	103.97	31	57	14	19779
4	4	9	391	115	122.7	41	77	25	30107
1	5	9	598	131	258.46	60	103	17	61594
2	5	9	361	178	315.93	35	20	7	7220
3	5	9	391	144	287.86		30	7	11730
4	5	9	624	170	226.57	45	77	14	48048
1	6	9	1035	202	322.57	51	109	16	112815
2	6	9	583	150	301.2	46	128	20	74624
3	6	9							
4	6	9	166	224	429.8	34	43	9	7138
1	1	10	146	131	177.28	17	143	18	20878
2	1	10							
3	1	10	288	191	139.52	14	182	23	52416
4	1	10	150	163		14	174	27	26100
1	2	10	452	182	169.24	17	131	16	59212
2	2	10							
3	2	10	310	171	155.63	20	131	21	40610
4	2	10	430	225	194.11	17	241	27	103630
1	3	10	472	229	174.47	23	54	9	25488
2	3	10							
3	3	10							
4	3	10	297	294	310.32	21	133	28	39501
1	4	10							
2	4	10	335	151	112.52	16	133	35	44555
3	4	10	419	121	106.95	17	201	35	84219

4	4	10							
1	5	10	330	218	130.62	14	104	21	34320
2	5	10	446	156	174.04	17	177	26	78942
3	5	10	483	114	141.91	17	200	30	96600
4	5	10	454	247	303.69	19	200	36	90800
1	6	10	628	249	254.56	21	165	19	103620
2	6	10							
3	6	10							
4	6	10							
1	1	11							
2	1	11	11	120	174.4	4	5		55
3	1	11	18	163		3	4		72
4	1	11							
1	2	11	90	189	235.31	9	7		630
2	2	11	38	296	306.74	6	20		760
3	2	11	84	227	212.22	8	8		672
4	2	11			262.5	7	16		
1	3	11	118	297	253.05	9	30		3540
2	3	11	82	292	324.09	8	21		1722
3	3	11	19	270	256.15	5	11		209
4	3	11	28	269	363.59	7	3		84
1	4	11	132	155	147.92	7	21		2772
2	4	11	68	164	133.88	7	19		1292
3	4	11	84	131	120.48	8	29		2436
4	4	11							
1	5	11							
2	5	11	144	246	272.74	10	33		4752
3	5	11							
4	5	11							
1	6	11							
2	6	11	197	267	244.03	10	43		8471
3	6	11			237.5	7	18		
4	6	11							
1	1	12		116	88.77	14	134		
2	1	12	46	99	159.83	15	100		4600
3	1	12	45	111	140.07	16	177		7965
4	1	12			122.57	11	124		
1	2	12	46	162	175.27	16	252		11592
2	2	12	66	295	229.76	19	145		9570
3	2	12	53	153	207.48	17	145		7685
4	2	12			223.43	24	89		
1	3	12	69	149	219.07	17	132		9108
2	3	12	69	203	258.93	19	121		8349
3	3	12	86	182	271.51	21	11		946
4	3	12			410.22	26	23		
1	4	12	44	105	134.34	15	316		13904
2	4	12			161.47	18	378		
3	4	12	38	113	95.08	18	238		9044
4	4	12			146.03	16	102		
1	5	12	44	132	153.19	17	333		14652
2	5	12	80	341	268.07		146		11680
3	5	12	80	179	272.95	24	176		14080
4	5	12			302.9	19	210		
1	6	12	57	193	254.67	16	216		12312
2	6	12	81	169	247.3	19	110		8910
3	6	12	111	278	312.37	22	33		3663
4	6	12				20	64		
1	1	13	91	68		31	32		2912

2	1	13	108	95		32	38	4104
3	1	13	109	90		31	52	5668
4	1	13	65	60		27	61	3965
1	2	13				28	18	
2	2	13						
3	2	13	116	220		33	81	9396
4	2	13	128	176		31	33	4224
1	3	13	103	186		30	47	4841
2	3	13	46	286		21	45	2070
3	3	13						
4	3	13	138	235		33	42	5796
1	4	13	238	112		45	118	28084
2	4	13	167	75		38	81	13527
3	4	13	182	98		36	81	14742
4	4	13	110	76		35	55	6050
1	5	13	114	104		38	106	12084
2	5	13	55	186		25	36	1980
3	5	13	144	232		34	49	7056
4	5	13	178	191		38	45	8010
1	6	13	123	199		31	69	8487
2	6	13	100	190		31	61	6100
3	6	13						
4	6	13	184	208		32	62	11408
1	1	14	84	150	176.67	30	10	840
2	1	14				30	10	
3	1	14	112	151		39	16	1792
4	1	14			170.5		3	
1	2	14	320	253		41	13	4160
2	2	14						
3	2	14	106	311		35	44	4664
4	2	14	112	198		35	17	1904
1	3	14						
2	3	14	81	246		30	16	1296
3	3	14					20	
4	3	14	280	265		48		
1	4	14	275	162		51	21	5775
2	4	14	161	154		45	21	3381
3	4	14	351	198		60	27	9477
4	4	14	220	168		45	12	2640
1	5	14						
2	5	14						
3	5	14	193	382		39	20	3860
4	5	14	204	254		41	73	14892
1	6	14	211	285		44	74	15614
2	6	14						
3	6	14						
4	6	14	250	459		35		
1	1	15	180	126	193.87	29	15	2700
2	1	15	209	92	164.5	25	29	6061
3	1	15	157	86	109.95	28	26	4082
4	1	15	257	134	148.44	31	21	
1	2	15	320	140	233.26	42	33	10560
2	2	15						
3	2	15	468	195	197.81	43	30	14040
4	2	15	254	249	310.5	34	24	6096
1	3	15						
2	3	15	312	268	300.76	36	15	4680
3	3	15						

4	3	15	290	347	386.73	33	12		3480
1	4	15	168	101	168.97	26	40		6720
2	4	15	171	140	188.97	27	54		9234
3	4	15	227	87	176.1	30	68		15436
4	4	15	233	114	118.41	28	57		13281
1	5	15	390	203	280.54	37	40		15600
2	5	15	396	228	381.96	38	32		12672
3	5	15	149	250	357.63	24	11		1639
4	5	15	522	257	290.13	40	38		19836
1	6	15	200	262	341.21	32	19		3800
2	6	15	427	237	304.37	41	14		5978
3	6	15							
4	6	15	421	269	376.94	41	22		9262
1	1	16							
2	1	16	123	187		16	66		8118
3	1	16							
4	1	16	113	135		15	79		8927
1	2	16	159	186		25	35		5565
2	2	16							
3	2	16							
4	2	16	181	235		27	73		13213
1	3	16	194	317		29	70		13580
2	3	16	133	325		17	63		8379
3	3	16	96	415		22	26		2496
4	3	16							
1	4	16							
2	4	16	150	189		20	143		21450
3	4	16							
4	4	16	88	133		13	127		11176
1	5	16							
2	5	16							
3	5	16	272	241			98		26656
4	5	16	216	251		26	44		9504
1	6	16							
2	6	16	141	333		24	68		9588
3	6	16	205	354		29	31		6355
4	6	16							
1	1	17	20	50	47.16	11	29	7	580
2	1	17							
3	1	17			61.91	8	20	6	
4	1	17	24	62	55.23	10	35	14	840
1	2	17	25	70	134	12	19	5	475
2	2	17	27	78		13	17	7	459
3	2	17	20	88	95.59	12	21	8	420
4	2	17	36	89	79.88	12	12	6	432
1	3	17	25	94	98.17	13	17	6	425
2	3	17	31	98		11	14	6	434
3	3	17	35	102	93.57	11	5	4	175
4	3	17	46	86	97.33	15	9	6	414
1	4	17	18	57	100.19	12	47	9	846
2	4	17							
3	4	17	20	77	58.3	11	42	10	840
4	4	17	30	51	55.15	14	28	6	840
1	5	17	27	74	73.66	12	29	5	783
2	5	17	29	85		11	15	5	435
3	5	17							
4	5	17	39	70	54.19	11	13	7	507
1	6	17	41	88	97.55	10	7	4	287

2	6	17				16	7	4	
3	6	17	34	102	107.46	10	10	5	340
4	6	17	38	91	88.39	12	8	5	304
1	1	18	131	115	135.17	28	17		2227
2	1	18	121	113	159.67	29	26		3146
3	1	18	114	126	131.33	27	33		3762
4	1	18	172	121	127.3	39	7		1204
1	2	18	168	163	177.17	31	44		7392
2	2	18	195	214		38	63		12285
3	2	18	179	245	209.71	33	34		6086
4	2	18	149	174	201.01	39	41		6109
1	3	18							
2	3	18	176	209	242.33	40	27		4752
3	3	18	90	474	686.43	22	13		1170
4	3	18	154	243	351.15	43	28		4312
1	4	18	190	112	142.83	33	63		11970
2	4	18	276	93	170.77	43	68		18768
3	4	18	141	103	129.86	31	72		10152
4	4	18							
1	5	18							
2	5	18	191	175		33	102		19482
3	5	18	219	282	234.55	36	70		15330
4	5	18							
1	6	18	302	204	190	41	64		19328
2	6	18	97	187	190.34	33	73		7081
3	6	18							
4	6	18	239	242	274.34	45	67		16013
1	1	19	74	98	114.1	11	29		2146
2	1	19	241	214	155.85	18	95		22895
3	1	19	13	89	156.89	8	11		143
4	1	19	248	105	125.4	14	76		18848
1	2	19	75	221	229.73	11	26		1950
2	2	19				8	15		
3	2	19							
4	2	19	175	211	221.01	12	31		5425
1	3	19	114	242	251.52	11	22		2508
2	3	19			309.41	12	39		
3	3	19	6	205	242.86	8	4		24
4	3	19	149	270	275.14	12	42		6258
1	4	19	1074	205	134.79	22	170		182580
2	4	19			134.48	14	250		
3	4	19	853	117	116.69	23	113		96389
4	4	19	308	130	173.6	18	154		47432
1	5	19							
2	5	19			296.5	12	34		
3	5	19							
4	5	19	203	277	352.5	12	50		10150
1	6	19			362.5	6	2		
2	6	19	187	252	398.6	13	71		13277
3	6	19							
4	6	19			509.17	7	18		
1	1	20							
2	1	20							
3	1	20							
4	1	20							
1	2	20							
2	2	20							
3	2	20							

4	2	20	218	155	146.83	9		20		
1	3	20								
2	3	20	258	444	497.88	12	192	15	49536	
3	3	20								
4	3	20								
1	4	20								
2	4	20	404	145	225.69	12	347	19	140188	
3	4	20								
4	4	20								
1	5	20								
2	5	20								
3	5	20								
4	5	20								
1	6	20								
2	6	20								
3	6	20								
4	6	20								
Replicate	Treatment	Species	RCD	LFNmax	RFR	PPFD	SLA	RFR	SLA-yfel	
1	1	1	0.97			1	4047	77	1	89.19
2	1	1	1			1.02	4863	83	1.02	108.54
3	1	1	1			1.02	3100	84	1.02	90.05
4	1	1	0.97			1.01	4334	81	1.01	89.36
1	2	1	1			0.82	1120	111	0.82	128.32
2	2	1	0.85			0.66	251	138	0.66	146.1
3	2	1	1			0.65	170		0.65	122.53
4	2	1	1			0.62	568	142	0.62	149.92
1	3	1	0.93			0.57	495	132	0.57	
2	3	1	1			0.67	352	118	0.67	130.19
3	3	1	1			0.52	219	107	0.52	140.94
4	3	1	0.83			0.53	371	124	0.53	139.58
1	4	1	0.96			1	4047	75	1	97.01
2	4	1	0.97			1.02	4863	74	1.02	70.41
3	4	1	0.98			1.02	3100	79	1.02	95.69
4	4	1	0.97			1.01	4334	77	1.01	95.88
1	5	1	1			0.82	1120	114	0.82	
2	5	1	0.97			0.66	251	127	0.66	137.38
3	5	1	0.91			0.65	170	104	0.65	137.41
4	5	1	1			0.62	568	129	0.62	145.47
1	6	1	0.88			0.57	495	115	0.57	
2	6	1	0.99			0.67	352	136	0.67	141.5
3	6	1	1			0.52	219	95	0.52	141.43
4	6	1	1			0.53	371	139	0.53	155.83
1	1	2	0.43			1	4047	113	1	102.91
2	1	2	0.53			1.02	4863	142	1.02	166.36
3	1	2	0.13			1.02	3100	140	1.02	118.84
4	1	2	0.49			1.01	4334	115	1.01	142.4
1	2	2	0.6			0.82	1120	204	0.82	217.25
2	2	2	0.68			0.66	251	223	0.66	298.52
3	2	2	0.44			0.65	170	215	0.65	205.06
4	2	2	0.82			0.62	568	327	0.62	391.09
1	3	2	0.82			0.57	495	301	0.57	294.91
2	3	2	0.7			0.67	352	350	0.67	335.53
3	3	2				0.52	219		0.52	
4	3	2	0.93			0.53	371	210	0.53	296.33
1	4	2	0.32			1	4047	122	1	103.85
2	4	2				1.02	4863		1.02	
3	4	2	0.5			1.02	3100	125	1.02	114.72
4	4	2	0.35			1.01	4334	115	1.01	114.56

1	5	2	0.53		0.82	1120	192	0.82	223.7
2	5	2	0.5		0.66	251	332	0.66	417.33
3	5	2	0.85		0.65	170	422	0.65	405.66
4	5	2	0.92		0.62	568	267	0.62	419.79
1	6	2	0.92		0.57	495	372	0.57	427.78
2	6	2	0.82		0.67	352	317	0.67	337.81
3	6	2	0.9		0.52	219	470	0.52	543.33
4	6	2	1		0.53	371	237	0.53	461.86
1	1	3	0.22	11	1	4047	137	1	142.74
2	1	3	0.56	12	1.02	4863	135	1.02	
3	1	3	0.68	9	1.02	3100	126	1.02	157.64
4	1	3	0.1	9	1.01	4334		1.01	119.74
1	2	3			0.82	1120		0.82	
2	2	3	0.75	11	0.66	251	215	0.66	
3	2	3	0.52	14	0.65	170	193	0.65	212.81
4	2	3	0.83	9	0.62	568		0.62	202.47
1	3	3	0.64	11	0.57	495	233	0.57	240.63
2	3	3	0.42	9	0.67	352	205	0.67	
3	3	3	0.29	9	0.52	219	243	0.52	245.34
4	3	3	0.19	9	0.53	371		0.53	298.52
1	4	3	0.66	11	1	4047	150	1	167.76
2	4	3	0.63	13	1.02	4863	108	1.02	
3	4	3	0.95	11	1.02	3100	120	1.02	113.03
4	4	3	0.82	13	1.01	4334		1.01	132.77
1	5	3	0.95	11	0.82	1120	214	0.82	203.79
2	5	3	0.74	13	0.66	251	217	0.66	
3	5	3	0.55	13	0.65	170	196	0.65	195.39
4	5	3	0.69	11	0.62	568		0.62	334.6
1	6	3	0.79	11	0.57	495	227	0.57	243.68
2	6	3	0.54	13	0.67	352	200	0.67	
3	6	3	0.4	9	0.52	219	242	0.52	287.25
4	6	3	0.82	10	0.53	371		0.53	341.76
1	1	4	0.25	7	1	4047	102	1	106.13
2	1	4	0.49	9	1.02	4863	100	1.02	112.03
3	1	4	0.39	9	1.02	3100	100	1.02	95.79
4	1	4	0.45	9	1.01	4334	121	1.01	123.23
1	2	4	0.64	9	0.82	1120	126	0.82	149.57
2	2	4	0.9	7	0.66	251	161	0.66	204.48
3	2	4	0.66	9	0.65	170	135	0.65	163.98
4	2	4	0.46	7	0.62	568	282	0.62	287.41
1	3	4	0.69	8	0.57	495	195	0.57	216.06
2	3	4	0.63	11	0.67	352	125	0.67	235.22
3	3	4	0.66	9	0.52	219	298	0.52	286.13
4	3	4	0.74	9	0.53	371	273	0.53	258.7
1	4	4	0.74	9	1	4047	94	1	116.99
2	4	4	0.76	9	1.02	4863	62	1.02	121.1
3	4	4	0.71		1.02	3100	74	1.02	91.41
4	4	4	0.81	9	1.01	4334	82	1.01	127.28
1	5	4	0.81	9	0.82	1120	138	0.82	195.71
2	5	4	0.65	11	0.66	251	193	0.66	211.86
3	5	4	0.73	9	0.65	170	186	0.65	221.15
4	5	4			0.62	568		0.62	
1	6	4		9	0.57	495		0.57	
2	6	4	0.64	9	0.67	352		0.67	195.56
3	6	4	0.68	9	0.52	219	272	0.52	
4	6	4	0.42	11	0.53	371	254	0.53	276.22
1	1	5	0.91	17	1	4047	187	1	224.08
2	1	5	0.32	15	1.02	4863	205	1.02	

3	1	5	0.28	21	1.02	3100	166	1.02	190.74
4	1	5	0.61	17	1.01	4334	165	1.01	161.49
1	2	5			0.82	1120		0.82	
2	2	5	0.68	19	0.66	251	279	0.66	
3	2	5	0.85	20	0.65	170	254	0.65	242.68
4	2	5	0.32	19	0.62	568	296	0.62	329.67
1	3	5			0.57	495		0.57	
2	3	5	0.38	17	0.67	352		0.67	
3	3	5	0.35	15	0.52	219	424	0.52	422.22
4	3	5	0.72	19	0.53	371	437	0.53	379.8
1	4	5	0.38	19	1	4047	183	1	177.26
2	4	5			1.02	4863		1.02	
3	4	5	0.62	18	1.02	3100	145	1.02	142.83
4	4	5			1.01	4334		1.01	
1	5	5	0.72	24	0.82	1120	186	0.82	233.28
2	5	5			0.66	251		0.66	
3	5	5	0.87	22	0.65	170	282	0.65	299.68
4	5	5			0.62	568		0.62	
1	6	5			0.57	495		0.57	
2	6	5	0.81	20	0.67	352	295	0.67	
3	6	5	0.74	21	0.52	219	384	0.52	354.15
4	6	5	0.87	19	0.53	371	333	0.53	368
1	1	6	0.1	19	1	4047	181	1	165.38
2	1	6	0.13	13	1.02	4863	226	1.02	
3	1	6	0.04	17	1.02	3100	226	1.02	154.63
4	1	6	0.09	13	1.01	4334		1.01	195.67
1	2	6	0.21	18	0.82	1120	173	0.82	204.2
2	2	6	0.86	19	0.66	251	191	0.66	
3	2	6	0.64	19	0.65	170	199	0.65	282.79
4	2	6			0.62	568		0.62	
1	3	6	0.77	19	0.57	495	241	0.57	
2	3	6	0.32	19	0.67	352	243	0.67	
3	3	6	0.36	17	0.52	219	249	0.52	433.33
4	3	6	0.67	20	0.53	371	330	0.53	441.43
1	4	6	0.41	20	1	4047	166	1	133.17
2	4	6	0.34	22	1.02	4863	106	1.02	
3	4	6	0.93	19	1.02	3100	163	1.02	191.36
4	4	6			1.01	4334		1.01	
1	5	6	0.36	17	0.82	1120	105	0.82	190.28
2	5	6	0.81	21	0.66	251	225	0.66	
3	5	6	0.64	21	0.65	170	196	0.65	278.08
4	5	6	0.81	21	0.62	568	247	0.62	340
1	6	6	0.8	18	0.57	495	305	0.57	242.71
2	6	6	0.39	21	0.67	352	258	0.67	
3	6	6	0.34	23	0.52	219	240	0.52	388.81
4	6	6	0.81	21	0.53	371	342	0.53	497.88
1	1	7	0.92		1	4047	155	1	
2	1	7	0.79		1.02	4863	155	1.02	
3	1	7	1		1.02	3100	217	1.02	
4	1	7	0.54		1.01	4334	192	1.01	
1	2	7	0.6		0.82	1120	162	0.82	
2	2	7	0.6		0.66	251	293	0.66	
3	2	7	0.44		0.65	170	283	0.65	
4	2	7	0.59		0.62	568	230	0.62	
1	3	7	0.63		0.57	495	275	0.57	
2	3	7	0.67		0.67	352	270	0.67	
3	3	7			0.52	219		0.52	
4	3	7	0.54		0.53	371	301	0.53	

1	4	7	0.68		1	4047	204	1	
2	4	7	0.98		1.02	4863	206	1.02	
3	4	7	0.83		1.02	3100	156	1.02	
4	4	7	0.65		1.01	4334	156	1.01	
1	5	7	0.67		0.82	1120	245	0.82	
2	5	7	0.68		0.66	251	221	0.66	
3	5	7	0.97		0.65	170	204	0.65	
4	5	7	0.58		0.62	568	231	0.62	
1	6	7	0.62		0.57	495	276	0.57	
2	6	7	0.7		0.67	352	274	0.67	
3	6	7	0.7		0.52	219	338	0.52	
4	6	7	0.56		0.53	371	236	0.53	
1	1	8	0.74	7	1	4047	95	1	81.01
2	1	8	0.81	8	1.02	4863	99	1.02	127.15
3	1	8	0.85	7	1.02	3100	69	1.02	104.33
4	1	8	0.7	7	1.01	4334	73	1.01	91.22
1	2	8			0.82	1120		0.82	
2	2	8	1	6	0.66	251	167	0.66	166.52
3	2	8	0.77	7	0.65	170	146	0.65	146.99
4	2	8			0.62	568		0.62	
1	3	8	0.51	7	0.57	495	177	0.57	173.28
2	3	8	0.77	7	0.67	352	132	0.67	147.16
3	3	8			0.52	219		0.52	
4	3	8	0.75	7	0.53	371	176	0.53	189.9
1	4	8	0.75	7	1	4047	123	1	74.89
2	4	8	0.82	7	1.02	4863	93	1.02	99.65
3	4	8	0.82	7	1.02	3100	131	1.02	165.84
4	4	8	0.88	9	1.01	4334	97	1.01	101.95
1	5	8	0.79	7	0.82	1120	139	0.82	104.31
2	5	8	0.91	5	0.66	251	215	0.66	195.48
3	5	8	0.88	5	0.65	170		0.65	
4	5	8	0.8	7	0.62	568	197	0.62	177.29
1	6	8	0.46	7	0.57	495	174	0.57	167.73
2	6	8	0.7	7	0.67	352	170	0.67	192.25
3	6	8			0.52	219		0.52	
4	6	8			0.53	371		0.53	
1	1	9	0.85	10	1	4047	129	1	140.07
2	1	9	0.67	5	1.02	4863		1.02	137.12
3	1	9			1.02	3100		1.02	
4	1	9	0.48	7	1.01	4334	131	1.01	138.65
1	2	9	0.81		0.82	1120	89	0.82	155
2	2	9	0.72	7	0.66	251	160	0.66	174.03
3	2	9	0.67	7	0.65	170	170	0.65	372.45
4	2	9	0.8	9	0.62	568	166	0.62	262.2
1	3	9	0.45	9	0.57	495	185	0.57	346.91
2	3	9	0.39	6	0.67	352	210	0.67	266.12
3	3	9			0.52	219		0.52	255.06
4	3	9	0.78	7	0.53	371	240	0.53	310.76
1	4	9	0.8	9	1	4047	88	1	95.6
2	4	9	0.78	9	1.02	4863	112	1.02	191.36
3	4	9	0.44	7	1.02	3100	126	1.02	103.97
4	4	9	0.85	9	1.01	4334	115	1.01	122.7
1	5	9	0.82	9	0.82	1120	131	0.82	258.46
2	5	9	0.47	5	0.66	251	178	0.66	315.93
3	5	9	0.71	8	0.65	170	144	0.65	287.86
4	5	9	0.76	8	0.62	568	170	0.62	226.57
1	6	9	0.86	11	0.57	495	202	0.57	322.57
2	6	9	0.68	10	0.67	352	150	0.67	301.2

3	6	9			0.52	219		0.52	
4	6	9	0.55	8	0.53	371	224	0.53	429.8
1	1	10	0.68	9	1	4047	131	1	177.28
2	1	10			1.02	4863		1.02	
3	1	10	0.8	9	1.02	3100	191	1.02	139.52
4	1	10	0.76	9	1.01	4334	163	1.01	
1	2	10	0.83	11	0.82	1120	182	0.82	169.24
2	2	10			0.66	251		0.66	
3	2	10	0.92	9	0.65	170	171	0.65	155.63
4	2	10	0.9	11	0.62	568	225	0.62	194.11
1	3	10	0.74	7	0.57	495	229	0.57	174.47
2	3	10			0.67	352		0.67	
3	3	10			0.52	219		0.52	
4	3	10	0.88	7	0.53	371	294	0.53	310.32
1	4	10			1	4047		1	
2	4	10	0.94	9	1.02	4863	151	1.02	112.52
3	4	10	0.9	9	1.02	3100	121	1.02	106.95
4	4	10			1.01	4334		1.01	
1	5	10	0.91	11	0.82	1120	218	0.82	130.62
2	5	10	0.89	9	0.66	251	156	0.66	174.04
3	5	10	0.8	9	0.65	170	114	0.65	141.91
4	5	10	0.85	9	0.62	568	247	0.62	303.69
1	6	10	0.81	12	0.57	495	249	0.57	254.56
2	6	10			0.67	352		0.67	
3	6	10			0.52	219		0.52	
4	6	10			0.53	371		0.53	
1	1	11			1	4047		1	
2	1	11	0.12	5	1.02	4863	120	1.02	174.4
3	1	11	0.05	7	1.02	3100	163	1.02	
4	1	11			1.01	4334		1.01	
1	2	11	0.19	9	0.82	1120	189	0.82	235.31
2	2	11	1	7	0.66	251	296	0.66	306.74
3	2	11	0.32	7	0.65	170	227	0.65	212.22
4	2	11	0.47	8	0.62	568		0.62	262.5
1	3	11	0.85	9	0.57	495	297	0.57	253.05
2	3	11	0.73	7	0.67	352	292	0.67	324.09
3	3	11	1	5	0.52	219	270	0.52	256.15
4	3	11	0.12	6	0.53	371	269	0.53	363.59
1	4	11	0.31	11	1	4047	155	1	147.92
2	4	11	0.45	13	1.02	4863	164	1.02	133.88
3	4	11	0.65	9	1.02	3100	131	1.02	120.48
4	4	11			1.01	4334		1.01	
1	5	11			0.82	1120		0.82	
2	5	11	0.79	9	0.66	251	246	0.66	272.74
3	5	11			0.65	170		0.65	
4	5	11			0.62	568		0.62	
1	6	11			0.57	495		0.57	
2	6	11	0.9	9	0.67	352	267	0.67	244.03
3	6	11	0.89	7	0.52	219		0.52	237.5
4	6	11			0.53	371		0.53	
1	1	12	0.94		1	4047	116	1	88.77
2	1	12	0.71		1.02	4863	99	1.02	159.83
3	1	12	88		1.02	3100	111	1.02	140.07
4	1	12	0.84		1.01	4334		1.01	122.57
1	2	12	0.89		0.82	1120	162	0.82	175.27
2	2	12	0.9		0.66	251	295	0.66	229.76
3	2	12	0.76		0.65	170	153	0.65	207.48
4	2	12	0.82		0.62	568		0.62	223.43

1	3	12	0.56		0.57	495	149	0.57	219.07
2	3	12	0.75		0.67	352	203	0.67	258.93
3	3	12	0.45		0.52	219	182	0.52	271.51
4	3	12	0.3		0.53	371		0.53	410.22
1	4	12	0.95		1	4047	105	1	134.34
2	4	12	0.63		1.02	4863		1.02	161.47
3	4	12	0.93		1.02	3100	113	1.02	95.08
4	4	12	0.67		1.01	4334		1.01	146.03
1	5	12	0.93		0.82	1120	132	0.82	153.19
2	5	12	0.87		0.66	251	341	0.66	268.07
3	5	12	0.87		0.65	170	179	0.65	272.95
4	5	12	0.84		0.62	568		0.62	302.9
1	6	12	0.82		0.57	495	193	0.57	254.67
2	6	12	0.69		0.67	352	169	0.67	247.3
3	6	12	0.38		0.52	219	278	0.52	312.37
4	6	12	0.74		0.53	371		0.53	
1	1	13	0.77	24	1	4047	68	1	
2	1	13	0.76	22	1.02	4863	95	1.02	
3	1	13	0.75	26	1.02	3100	90	1.02	
4	1	13	0.98	24	1.01	4334	60	1.01	
1	2	13	0.67	24	0.82	1120		0.82	
2	2	13			0.66	251		0.66	
3	2	13	0.94	28	0.65	170	220	0.65	
4	2	13	0.77	25	0.62	568	176	0.62	
1	3	13	0.84	25	0.57	495	186	0.57	
2	3	13	1	16	0.67	352	286	0.67	
3	3	13			0.52	219		0.52	
4	3	13	1	22	0.53	371	235	0.53	
1	4	13	1	32	1	4047	112	1	
2	4	13	1	25	1.02	4863	75	1.02	
3	4	13	0.78	26	1.02	3100	98	1.02	
4	4	13	0.81	28	1.01	4334	76	1.01	
1	5	13	0.87	26	0.82	1120	104	0.82	
2	5	13	0.98	20	0.66	251	186	0.66	
3	5	13	0.9	29	0.65	170	232	0.65	
4	5	13	0.82	28	0.62	568	191	0.62	
1	6	13	0.94	29	0.57	495	199	0.57	
2	6	13	0.95	26	0.67	352	190	0.67	
3	6	13			0.52	219		0.52	
4	6	13	0.99	26	0.53	371	208	0.53	
1	1	14	0.24	15	1	4047	150	1	176.67
2	1	14	0.11	16	1.02	4863		1.02	
3	1	14	0.28	13	1.02	3100	151	1.02	
4	1	14			1.01	4334		1.01	170.5
1	2	14	0.24	17	0.82	1120	253	0.82	
2	2	14			0.66	251		0.66	
3	2	14	0.9	13	0.65	170	311	0.65	
4	2	14	0.51	13	0.62	568	198	0.62	
1	3	14			0.57	495		0.57	
2	3	14	0.43	15	0.67	352	246	0.67	
3	3	14			0.52	219		0.52	
4	3	14	0.47	13	0.53	371	265	0.53	
1	4	14	0.33	17	1	4047	162	1	
2	4	14	0.49	15	1.02	4863	154	1.02	
3	4	14	0.92	19	1.02	3100	198	1.02	
4	4	14	0.29	15	1.01	4334	168	1.01	
1	5	14			0.82	1120		0.82	
2	5	14			0.66	251		0.66	

3	5	14	0.81	13	0.65	170	382	0.65	
4	5	14	0.51	15	0.62	568	254	0.62	
1	6	14		17	0.57	495	285	0.57	
2	6	14			0.67	352		0.67	
3	6	14			0.52	219		0.52	
4	6	14	0.88	13	0.53	371	459	0.53	
1	1	15	0.72		1	4047	126	1	193.87
2	1	15	0.83		1.02	4863	92	1.02	164.5
3	1	15	0.79		1.02	3100	86	1.02	109.95
4	1	15	0.41		1.01	4334	134	1.01	148.44
1	2	15	0.73		0.82	1120	140	0.82	233.26
2	2	15			0.66	251		0.66	
3	2	15	0.7		0.65	170	195	0.65	197.81
4	2	15	0.7		0.62	568	249	0.62	310.5
1	3	15			0.57	495		0.57	
2	3	15	0.38		0.67	352	268	0.67	300.76
3	3	15			0.52	219		0.52	
4	3	15	0.45		0.53	371	347	0.53	386.73
1	4	15	0.5		1	4047	101	1	168.97
2	4	15	0.54		1.02	4863	140	1.02	188.97
3	4	15	0.51		1.02	3100	87	1.02	176.1
4	4	15	0.67		1.01	4334	114	1.01	118.41
1	5	15	0.71		0.82	1120	203	0.82	280.54
2	5	15	0.65		0.66	251	228	0.66	381.96
3	5	15	0.75		0.65	170	250	0.65	357.63
4	5	15	0.53		0.62	568	257	0.62	290.13
1	6	15	0.55		0.57	495	262	0.57	341.21
2	6	15	0.43		0.67	352	237	0.67	304.37
3	6	15			0.52	219		0.52	
4	6	15	0.83		0.53	371	269	0.53	376.94
1	1	16			1	4047		1	
2	1	16	1	9	1.02	4863	187	1.02	
3	1	16			1.02	3100		1.02	
4	1	16	0.99	9	1.01	4334	135	1.01	
1	2	16	0.95	11	0.82	1120	186	0.82	
2	2	16			0.66	251		0.66	
3	2	16			0.65	170		0.65	
4	2	16	1	9	0.62	568	235	0.62	
1	3	16	0.98	11	0.57	495	317	0.57	
2	3	16	0.91	9	0.67	352	325	0.67	
3	3	16	0.97	11	0.52	219	415	0.52	
4	3	16			0.53	371		0.53	
1	4	16			1	4047		1	
2	4	16	1	9	1.02	4863	189	1.02	
3	4	16			1.02	3100		1.02	
4	4	16	1	9	1.01	4334	133	1.01	
1	5	16			0.82	1120		0.82	
2	5	16			0.66	251		0.66	
3	5	16	1	11	0.65	170	241	0.65	
4	5	16	1	9	0.62	568	251	0.62	
1	6	16			0.57	495		0.57	
2	6	16	0.96	11	0.67	352	333	0.67	
3	6	16	0.96	11	0.52	219	354	0.52	
4	6	16			0.53	371		0.53	
1	1	17	1	5	1	4047	50	1	47.16
2	1	17			1.02	4863		1.02	
3	1	17	0.91	3	1.02	3100		1.02	61.91
4	1	17	0.99	3	1.01	4334	62	1.01	55.23

1	2	17	1	5	0.82	1120	70	0.82	134
2	2	17	0.91	3	0.66	251	78	0.66	
3	2	17	0.96	4	0.65	170	88	0.65	95.59
4	2	17	0.89	2	0.62	568	89	0.62	79.88
1	3	17	1	3	0.57	495	94	0.57	98.17
2	3	17	0.98	4	0.67	352	98	0.67	
3	3	17	0.82	1	0.52	219	102	0.52	93.57
4	3	17	0.95	3	0.53	371	86	0.53	97.33
1	4	17	0.92	6	1	4047	57	1	100.19
2	4	17			1.02	4863		1.02	
3	4	17	0.99	5	1.02	3100	77	1.02	58.3
4	4	17	0.91	4	1.01	4334	51	1.01	55.15
1	5	17	1	4	0.82	1120	74	0.82	73.66
2	5	17	0.9	3	0.66	251	85	0.66	
3	5	17			0.65	170		0.65	
4	5	17	0.94	3	0.62	568	70	0.62	54.19
1	6	17	0.9	3	0.57	495	88	0.57	97.55
2	6	17		3	0.67	352		0.67	
3	6	17	0.98	3	0.52	219	102	0.52	107.46
4	6	17	0.95	3	0.53	371	91	0.53	88.39
1	1	18	0.46	10	1	4047	115	1	135.17
2	1	18	50	9	1.02	4863	113	1.02	159.67
3	1	18	0.49	11	1.02	3100	126	1.02	131.33
4	1	18	0.17	8	1.01	4334	121	1.01	127.3
1	2	18	0.75	9	0.82	1120	163	0.82	177.17
2	2	18	0.72	7	0.66	251	214	0.66	
3	2	18	0.88	7	0.65	170	245	0.65	209.71
4	2	18	0.6	9	0.62	568	174	0.62	201.01
1	3	18			0.57	495		0.57	
2	3	18	0.92	7	0.67	352	209	0.67	242.33
3	3	18	0.34	5	0.52	219	474	0.52	686.43
4	3	18	0.67	8	0.53	371	243	0.53	351.15
1	4	18	0.48	8	1	4047	112	1	142.83
2	4	18	0.71	12	1.02	4863	93	1.02	170.77
3	4	18	0.85	9	1.02	3100	103	1.02	129.86
4	4	18			1.01	4334		1.01	
1	5	18			0.82	1120		0.82	
2	5	18	0.75	9	0.66	251	175	0.66	
3	5	18	0.72	7	0.65	170	282	0.65	234.55
4	5	18			0.62	568		0.62	
1	6	18	0.69	9	0.57	495	204	0.57	190
2	6	18	0.65	7	0.67	352	187	0.67	190.34
3	6	18			0.52	219		0.52	
4	6	18	0.71	9	0.53	371	242	0.53	274.34
1	1	19	0.8	7	1	4047	98	1	114.1
2	1	19	0.92	10	1.02	4863	214	1.02	155.85
3	1	19	0.97	4	1.02	3100	89	1.02	156.89
4	1	19	0.83	12	1.01	4334	105	1.01	125.4
1	2	19	0.83	7	0.82	1120	221	0.82	229.73
2	2	19	0.23	7	0.66	251		0.66	
3	2	19			0.65	170		0.65	
4	2	19	0.66	9	0.62	568	211	0.62	221.01
1	3	19	0.2	8	0.57	495	242	0.57	251.52
2	3	19	0.96	7	0.67	352		0.67	309.41
3	3	19	0.46	1	0.52	219	205	0.52	242.86
4	3	19	0.94	6	0.53	371	270	0.53	275.14
1	4	19	0.79	14	1	4047	205	1	134.79
2	4	19	0.81	10	1.02	4863		1.02	134.48

3	4	19	0.91	11	1.02	3100	117	1.02	116.69
4	4	19	0.84	15	1.01	4334	130	1.01	173.6
1	5	19			0.82	1120		0.82	
2	5	19	0.81	8	0.66	251		0.66	296.5
3	5	19			0.65	170		0.65	
4	5	19	1	9	0.62	568	277	0.62	352.5
1	6	19	0.4	2	0.57	495		0.57	362.5
2	6	19	0.89	9	0.67	352	252	0.67	398.6
3	6	19			0.52	219		0.52	
4	6	19	0.75	5	0.53	371		0.53	509.17
1	1	20			1	4047		1	
2	1	20			1.02	4863		1.02	
3	1	20			1.02	3100		1.02	
4	1	20			1.01	4334		1.01	
1	2	20			0.82	1120		0.82	
2	2	20			0.66	251		0.66	
3	2	20			0.65	170		0.65	
4	2	20		22	0.62	568	155	0.62	146.83
1	3	20			0.57	495		0.57	
2	3	20	0.23	17	0.67	352	444	0.67	497.88
3	3	20			0.52	219		0.52	
4	3	20			0.53	371		0.53	
1	4	20			1	4047		1	
2	4	20	0.3	30	1.02	4863	145	1.02	225.69
3	4	20			1.02	3100		1.02	
4	4	20			1.01	4334		1.01	
1	5	20			0.82	1120		0.82	
2	5	20			0.66	251		0.66	
3	5	20			0.65	170		0.65	
4	5	20			0.62	568		0.62	
1	6	20			0.57	495		0.57	
2	6	20			0.67	352		0.67	
3	6	20			0.52	219		0.52	
4	6	20			0.53	371		0.53	

Appendix E

Table of response in photosynthetic characteristics to growth conditions for seedlings of twenty Queensland rainforest tree species, using ADC infrared gas analysis (IRGA) system.

Replicate: As for replicate in Appendix B.

Treatment: 1 = clear compartment and no added nitrogen, 2 = blue compartment and no added nitrogen, 3 = green compartment and no added nitrogen, 4 = clear compartment with added nitrogen, 5 = blue compartment with added nitrogen, 6 = green compartment and added nitrogen.

Species: 1 = *Agathis robusta*, 2 = *Alphitonia excelsa*, 3 = *Castanospermum australe*, 4 = *Dysoxylum fraserianum*, 5 = *Dysoxylum muelleri* CQ (Central Queensland provenance), 6 = *Dysoxylum muelleri* NQ (North Queensland provenance), 7 = *Elaeocarpus grandis*, 8 = *Flindersia bennettiana*, 9 = *Flindersia brayleyana*, 10 = *Flindersia schottiana*, 11 = *Flindersia xanthoxyla*, 12 = *Gmelina leichardtii*, 13 = *Grevillea robusta*, 14 = *Melia azedarach* var. *australasica*, 15 = *Nauclea orientalis*, 16 = *Pleiogynium timorense*, 17 = *Podocarpus elatus*, 18 = *Rhodosphaera rhodanthema*, 19 = *Blepharocarya involucrigera*, 20 = *Toona ciliata*.

PAR: Instantaneous measurement of photosynthetically active radiation ($\mu\text{mol m}^{-2} \text{s}^{-1}$).

Area-c: Projected leaf area as calculated by IRGA (cm^2).

E: Transpiration rate ($\text{mol m}^{-2} \text{s}^{-1}$).

G_s : Stomatal conductance to water vapour ($\text{mol m}^{-2} \text{s}^{-1}$).

A: Rate of photosynthesis ($\mu\text{mol m}^{-2} \text{s}^{-1}$).

N: Data record number.

T: Leaf surface temperature as calculated by IRGA ($^{\circ}$ C).

Area-m: Area of leaf enclosed in leaf chamber (cm^2).

AdjE: Adjusted transpiration rate for adjusted leaf area (when leaf did not completely fill leaf chamber) ($\text{mol m}^{-2} \text{s}^{-1}$).

AdjG_s: Adjusted stomatal conductance for adjusted leaf area (when leaf did not completely fill leaf chamber) ($\text{mol m}^{-2} \text{s}^{-1}$).

AdjA: Adjusted rate of photosynthesis for adjusted leaf area (when leaf did not completely fill leaf chamber) ($\mu\text{mol m}^{-2} \text{s}^{-1}$).

AdjWUE: Adjusted water use efficiency, adjA/adjE ($\mu\text{mol mol}^{-1}$).

Replicate	Treatment	Species	PPFD	Leaf Area	Area-c	Area-m	E	Gs	A	No.	Temp
1	1	1	1728	15.56	13.35	10.32307692	0.94	0.01	-0.67	112	46
1	1	1	1399	17.57	13.35	11.35	0.4	0.01	0.95	116	40.45
1	1	1	687	16.28	13.35	10.87692308	1.26	0.04	2.48	139	38.88
2	1	1	1449	11.18	13.35	6.953846154	1.9	0.04	1.65	85	41.23
3	1	1	1342	16.57	13.35	11.1	1.27	0.03	-0.26	121	45.01
3	1	1	589	15.54	13.35	10.30769231	0.97	0.03	1.58	135	37.04
4	1	1	1381	13.94	13.35	9.076923077	1.07	0.02	0.99	88	44.35
1	2	1	468		13.35	11.35	2.06	1.67	0.05	106	38.51
2	2	1	148	17.97	13.35	11.35	0.62	0.02	1.24	78	34.63
3	2	1	171	10.17	13.35	10.17	0.31	0.01	1.11	125	32.37
4	2	1	186	19.19	13.35	11.35	0.59	0.01	0.96	93	39.19
1	3	1	163	14.86	13.35	9.784615385	0.62	0.11	0.23	101	34.77
2	3	1	198	20.31	13.35	11.35	1.11	0.03	1.59	72	37.66
3	3	1	97	16.75	13.35	11.23846154	0.77	0.03	0.12	128	36.22
3	3	1	85	17.9	13.35	11.35	0.58	0.02	0.52	131	34.3
4	3	1	148	16.75	13.35	11.23846154	0.12	0	0.08	97	36.56
1	4	1	1535	21.85	13.35	11.35	1.47	0.02	-0.3	110	45
1	4	1	1449	15.91	13.35	10.59230769	0.61	0.02	2.14	117	41.2
1	4	1	563	16.39	13.35	10.96153846	1.21	0.04	3.62	138	38.63
2	4	1	1325	15.49	13.35	10.26923077	0.94	0.02	1.51	84	41.64
3	4	1	1422	11.1	13.35	6.892307692	0.87	0.02	-0.28	122	46.83
3	4	1	681	14.16	13.35	9.246153846	1.54	0.06	3.67	136	37.18
4	4	1	1494	16.3	13.35	10.89230769	2.23	0.04	3.09	89	43.79
1	5	1	604	17.02	13.35	11.35	2.63	0.34	0.28	107	40.92
2	5	1	142	16.76	13.35	11.24615385	0.5	0.02	1.02	79	35.07
3	5	1	163	15.94	13.35	10.61538462	0.43	0.01	0.89	124	41.73
3	5	1	201	18.61	13.35	11.35	0.28	0.01	0.6	126	33.76
4	5	1	210	13.82	13.35	8.984615385	0.59	0.01	0.92	92	39.74
1	6	1	160	11.87	13.35	7.484615385	0.92	0.25	0.43	103	35.18
2	6	1	168	18.82	13.35	11.35	0.58	0.02	0.98	73	37.47
3	6	1	106	16.83	13.35	11.3	0.33	0	0.2	129	37.21
3	6	1	65	14.85	13.35	9.776923077	0.28	0	0.51	132	35.09
4	6	1	151	16.83	13.35	11.3	0.23	0	0.44	98	36.18
1	1	2	1467	18.77	13.35	11.35	2.85	0.1	3.68	8	37.94
1	1	2	1778	17.07	13.35	11.35	1.24	0.02	1.34	179	39.17
2	1	2	583	19.7	13.35	11.35	1.53	0.05	3.01	48	35.93
2	1	2	1245	19.63	13.35	11.35	1.64	0.06	6.81	106	35.73
2	1	2	1049	18	13.35	11.35	3.32	0.27	7.18	114	36.93
3	1	2	841	18.38	13.35	11.35	0.9	0.04	2.66	29	31.84
3	1	2	1280	17.35	13.35	11.35	0.53	0.01	0.8	142	34.35
4	1	2	776	20.75	13.35	11.35	1.83	0.09	4.22	60	31.29
4	1	2	1245	21.93	13.35	11.35	1.68	0.09	4.64	137	29.95
1	2	2	204	22.52	13.35	11.35	1.12	0.04	1.84	15	34.68
1	2	2	109	17.38	13.35	11.35	0.71	0.03	1.32	174	29.65
2	2	2	17	20.52	13.35	11.35	0.07	0	0.31	53	31.03
2	2	2	118	18.21	13.35	11.35	1.26	0.1	1.44	103	28.74
3	2	2	85	21.5	13.35	11.35	0.26	0.01	0.68	36	30.58
3	2	2	148	18.25	13.35	11.35	1.67	0.09	1.68	154	31.88
4	2	2	133	21.51	13.35	11.35	0.89	0.04	1.64	69	30.58

4	2	2	124	18.97	13.35	11.35	1.91	0.13	1.7	125	33.31
1	3	2	133	21.83	13.35	11.35	0.29	0.01	0.97	22	33.38
1	3	2	47	16.22	13.35	10.83076923	0.37	0.01	0.22	167	29.39
2	3	2	44	25.5	13.35	11.35	0.62	0.03	0.51	88	29.89
3	3	2	8	7.25	13.35	7.25	0.05	0	0.06	41	28.79
4	3	2	59	17.78	13.35	11.35	0.52	0.02	0.34	75	31.45
4	3	2	26	18.62	13.35	11.35	0.74	0.03	0.24	122	34.23
1	4	2	1200	19.83	13.35	11.35	0.84	0.02	0.48	7	37.68
1	4	2	1796	17.55	13.35	11.35	2.4	0.06	6.35	180	39.05
3	4	2	542	20.12	13.35	11.35	0.98	0.05	4.56	30	31.82
3	4	2	1239	18.24	13.35	11.35	1.91	0.1	8.64	147	32.78
4	4	2	595	19.92	13.35	11.35	0.88	0.03	1.79	59	30.21
4	4	2	791	20.62	13.35	11.35	1.99	0.13	12.43	138	29.77
1	5	2	376	22.84	13.35	11.35	1.2	0.04	3.2	16	34.96
1	5	2	195	22.37	13.35	11.35	1.36	0.07	3.68	173	29.56
2	5	2	160	18.78	13.35	11.35	1.43	0.1	2.36	104	30.09
2	5	2	880		13.35	11.35	1.5	0.07	-0.24	105	33.25
3	5	2	26	20.32	13.35	11.35	0.01	0	0.28	37	30.22
3	5	2	109	21.5	13.35	11.35	1.8	0.1	1.23	152	32.2
4	5	2	142	20.15	13.35	11.35	1.65	0.09	1.93	68	30.19
4	5	2	109	21.87	13.35	11.35	0.82	0.03	0.92	124	33.94
1	6	2	94	19.89	13.35	11.35	0.45	0.02	0.8	21	33.36
1	6	2	53	19.25	13.35	11.35	0.88	0.04	0.54	168	29.04
2	6	2	50	21.62	13.35	11.35	0.65	0.03	0.39	87	29.77
3	6	2	8	20.9	13.35	11.35	0.08	0	-0.24	42	28.72
3	6	2	56	17.93	13.35	11.35	0.58	0.02	0.24	159	31.19
4	6	2	59	19.86	13.35	11.35	0.96	0.04	0.43	76	30.97
4	6	2	50	18.53	13.35	11.35	0.71	0.03	0.22	121	34.52
1	1	3	1553	10.42	13.35	6.369230769	0.95	0.02	0.45	6	42.85
3	1	3	1535	11.35	13.35	7.084615385	0.35	0	0.13	21	43.22
4	1	3	1642	13.41	13.35	8.669230769	0.68	0.01	0.36	63	42.88
3	2	3	222	18.94	13.35	11.35	0.61	0.01	0.9	35	38.72
4	2	3	290	18.83	13.35	11.35	0.64	0.02	1.1	56	36.57
1	3	3	115	19.25	13.35	11.35	0.65	0.02	0.62	17	38.29
3	3	3	83	17.91	13.35	11.35	0.37	0	0.05	38	38.93
4	3	3	32	18.21	13.35	11.35	0.31	0.01	0.06	47	29.34
1	4	3	1568	16.44	13.35	11	0.94	0.02	0.51	5	42.29
3	4	3	1485	17.52	13.35	11.35	1.58	0.03	0.49	25	44.27
4	4	3	1701	14.87	13.35	9.792307692	1.63	0.04	2.46	62	41.31
1	5	3	492	19.36	13.35	11.35	1.07	0.02	1.19	11	41.16
3	5	3	334	17.39	13.35	11.35	0.85	0.02	1.38	33	38.12
4	5	3	231	20.41	13.35	11.35	0.19	0	-0.16	55	36.38
1	6	3	115	18.52	13.35	11.35	0.72	0.02	0.62	18	38.03
3	6	3	183	19.82	13.35	11.35	0.69	0.02	1.03	39	38.74
4	6	3	103	17.43	13.35	11.35	0.19	0	0.26	46	37.29
4	6	3	47	18.86	13.35	11.35	0.44	0.02	0.34	48	30.55
4	6	3	246	17.7	13.35	11.35	0.58	0.02	1.02	57	36.83
1	1	4	1680	9.87	13.35	5.946153846	2.89	0.07	3.86	183	40.34
2	1	4	1256	7.73	13.35	4.3	1.98	0.1	2.93	110	35.76
3	1	4	486	13.89	13.35	9.038461538	1.35	0.06	3.3	141	31.42
4	1	4	1574	19.47	13.35	11.35	2.94	0.14	3.66	130	36.87

1	2	4	133	17.2	13.35	11.35	1.29	0.07	1.63	175	28.87
2	2	4	118	18.6	13.35	11.35	1.42	0.08	1.46	95	29.84
2	2	4	174	20.4	13.35	11.35	1.67	0.09	0.72	97	30.96
3	2	4	130	18.53	13.35	11.35	2.05	0.14	1.77	155	31.5
4	2	4	174	23.28	13.35	11.35	2.2	0.16	2.71	129	33.3
1	3	4	50	20.31	13.35	11.35	1.18	0.07	0.5	166	28.91
2	3	4	127	21.17	13.35	11.35	0.85	0.04	1.19	89	29.39
3	3	4	59	21.46	13.35	11.35	0.92	0.04	0.23	157	31.32
4	3	4	136	19.92	13.35	11.35	1.64	0.08	1.31	118	35.08
1	4	4	957	16.73	13.35	11.22307692	2.53	0.07	3.43	182	38.61
2	4	4	1470	9.93	13.35	5.992307692	2.32	0.12	4.68	111	36.68
3	4	4	1093	18.1	13.35	11.35	2.36	0.12	5.11	143	33.1
4	4	4	895		13.35	11.35	1.55	0.15	8.88	134	25.49
4	4	4	1289	19.22	13.35	11.35	2.16	0.09	7.58	132	35.73
4	4	4	192		13.35	11.35	1.35	0.06	3.32	133	33.2
4	4	4	705		13.35	11.35	2.67	0.15	7.49	131	35.36
1	5	4	329	20.55	13.35	11.35	2.05	0.17	4.43	169	28.85
2	5	4	154	18.22	13.35	11.35	1.51	0.08	0.28	96	30.74
3	5	4	192	23	13.35	11.35	1.94	0.11	2.79	150	32.42
2	6	4	145	21.12	13.35	11.35	1.82	0.13	2.44	90	29.28
4	6	4	97	20.44	13.35	11.35	1.53	0.08	0.83	120	34.35
1	1	5	1028	17.03	13.35	11.35	2.68	0.1	4.34	2	37
2	1	5	1387	6.22	13.35	3.138461538	1.61	0.04	2.18	150	41.92
3	1	5	752	12.97	13.35	8.330769231	3.97	0.14	2.87	24	40.77
4	1	5	1585	18.41	13.35	11.35	2.45	0.06	1.73	66	42.35
2	2	5	154	20.09	13.35	11.35	1.1	0.03	0.8	145	38.22
3	2	5	290	17.23	13.35	11.35	1.79	0.06	2.53	31	36.53
4	2	5	213	20.11	13.35	11.35	0.72	0.02	1.1	61	37.71
2	3	5	219	13.89	13.35	9.038461538	1.35	0.05	2.6	140	37.83
3	3	5	77	19	13.35	11.35	1.45	0.04	0.28	37	38.49
4	3	5	20	19.37	13.35	11.35	0.42	0.02	0.07	51	32.29
1	4	5	1663	12.94	13.35	8.307692308	2.77	0.08	2.72	3	39.4
3	4	5	1701	15.14	13.35	10	2.86	0.06	3.64	23	43.23
1	5	5	257	15.63	13.35	10.37692308	1.07	0.03	1.16	14	39.6
3	5	5	254	18.88	13.35	11.35	2.1	0.07	2.19	32	36.7
2	6	5	154	18.13	13.35	11.35	1.34	0.04	1.29	141	38.18
2	6	5	100	13	13.35	8.353846154	0.24	0	0.03	154	39.54
2	6	5	142	18.19	13.35	11.35	0.18	0	1.56	155	39.34
2	6	5	334	18.18	13.35	11.35	0.83	0.03	1.11	156	35.85
2	6	5	346	18.65	13.35	11.35	0.66	0.02	1.09	157	37.28
2	6	5	373	18.17	13.35	11.35	0.56	0.01	0.76	158	38.54
2	6	5	373	20.31	13.35	11.35	0.68	0.02	1.04	159	39.56
2	6	5	332	19.92	13.35	11.35	0.48	0.01	0.58	160	40.51
2	6	5	346	17.72	13.35	11.35	0.61	0.01	0.86	161	41.01
2	6	5	340	20.52	13.35	11.35	1.1	0.02	1.4	162	41.08
2	6	5	320	19.01	13.35	11.35	0.7	0.01	0.93	163	41.44
2	6	5	334	19.81	13.35	11.35	0.5	0	1.16	164	41.69
2	6	5	314	21.45	13.35	11.35	0.87	0.02	1.24	165	41.49
2	6	5	302	19.31	13.35	11.35	0.84	0.02	1.07	166	41.58
2	6	5	323	17.99	13.35	11.35	0.7	0.01	0.96	167	41.77
2	6	5	290	18.26	13.35	11.35	0.69	0.01	0.77	168	41.76

2	6	5	287	18.78	13.35	11.35	0.69	0.01	0.99	169	41.8
2	6	5	263	16.24	13.35	10.84615385	0.7	0.01	0.9	170	41.75
2	6	5	251	14.48	13.35	9.492307692	0.51	0.01	0.63	171	41.61
2	6	5	254	16.92	13.35	11.35	0.46	0	0.48	172	41.38
2	6	5	243	13.45	13.35	8.7	0.4	0	0.63	173	41.28
3	6	5	106	18.77	13.35	11.35	1.02	0.02	0.68	36	38.97
4	6	5	157	18.9	13.35	11.35	1.28	0.04	1.29	45	36.65
4	6	5	32	19.69	13.35	11.35	1.02	0.05	0.18	49	31.03
1	1	6	874	10.75	13.35	6.623076923	3.64	0.14	3.18	8	39.5
2	1	6	385	2.35	13.35	0.161538462	0.43	0	0.27	153	41.8
3	1	6	1639	6.34	13.35	3.230769231	2.32	0.04	1.15	27	44.82
4	1	6	1185	5.87	13.35	2.869230769	0.82	0.02	0.34	67	42.43
1	2	6	545	17.97	13.35	11.35	4.03	0.2	2.95	9	39.24
2	2	6	154	19.11	13.35	11.35	1.2	0.04	1.09	146	38.21
2	2	6	166		13.35	11.35	1.47	0.05	1.21	147	38.35
3	2	6	554	19.23	13.35	11.35	1.54	0.04	1.77	29	40.59
1	3	6	210	18.45	13.35	11.35	1.49	0.04	1.65	15	38.38
2	3	6	85	16.19	13.35	10.80769231	0.7	0.02	0.25	143	38.41
2	3	6	74	14.47	13.35	9.484615385	0.73	0.02	0.44	144	38.31
3	3	6	106	15.6	13.35	10.35384615	1.38	0.04	1.55	41	37.34
4	3	6	145	18.54	13.35	11.35	0.48	0.02	0.92	53	33.14
1	4	6	1221	7.99	13.35	4.5	2.41	0.06	2.53	7	41.29
2	4	6	1437	19.94	13.35	11.35	0.4	0	1.43	149	42.43
2	4	6	1046	16.99	13.35	11.35	1.51	0.04	1.47	151	42.19
2	4	6	975		13.35	11.35	1.83	0.05	1.68	152	41.95
3	4	6	1491	15.5	13.35	10.27692308	3.87	0.1	4.74	26	43.24
1	5	6	545	20.74	13.35	11.35	2.2	0.06	3.05	13	40.06
2	5	6	243	20.94	13.35	11.35	0.77	0.02	1.4	148	39.21
3	5	6	311	20.3	13.35	11.35	2.55	0.12	3.75	30	35.68
4	5	6	139	17	13.35	11.35	2.36	0.11	1.28	60	36.01
1	6	6	124	11.65	13.35	7.315384615	1.65	0.05	0.46	19	37.5
2	6	6	91		13.35	11.35	0.84	0.02	0.52	142	38.56
3	6	6	109	16.33	13.35	10.91538462	1.27	0.03	1.44	40	37.85
4	6	6	103	17.92	13.35	11.35	0.43	0.02	0.8	52	32.53
3	1	7	862		13.35	11.35	3.72	0.25	6.35		38.07
3	2	7	180		13.35	11.35	1.86	0.07	0.91		38.09
3	2	7	189		13.35	11.35	1.9	0.07	0.67		38.2
3	4	7	904		13.35	11.35	2.4	0.1	5.96		37.27
3	4	7	847		13.35	11.35	2.39	0.1	5.53		37.37
3	4	7	1031		13.35	11.35	2.06	0.07	5.18		38.74
3	5	7	168		13.35	11.35	2.3	0.1	0.23		38.29
3	5	7	166		13.35	11.35	2.37	0.1	0.44		38.35
3	5	7	160		13.35	11.35	2.57	0.11	0.71		38.55
1	1	8	1594	17.58	13.35	11.35	2.08	0.06	2.83	178	36.78
2	1	8	1627	20.09	13.35	11.35	1	0.02	0.24	116	40.7
3	1	8	1019	17.84	13.35	11.35	0.61	0.02	1	149	35.24
4	1	8	924	19.43	13.35	11.35	0.5	0.01	0.82	140	32.7
2	2	8	29	21.98	13.35	11.35	0.67	0.02	-0.06	98	31.24
3	2	8	136	19.55	13.35	11.35	0.88	0.03	1.18	156	32.22
1	3	8	68	20.1	13.35	11.35	1.34	0.08	0.57	165	28.85
2	3	8	151	18.69	13.35	11.35	0.93	0.04	2.3	92	29.99

4	3	8	50	19.94	13.35	11.35	0.52	0.02	0.2	123	33.71
4	3	8	106	22.87	13.35	11.35	1.74	0.11	1.33	126	33.05
1	4	8	945	20.37	13.35	11.35	2.72	0.08	3.55	181	38.04
2	4	8	1150	18.34	13.35	11.35	1.97	0.12	8.91	109	34.71
2	4	8	803	19.93	13.35	11.35	3.18	0.25	9.02	115	36.68
3	4	8	1304	18.74	13.35	11.35	0.93	0.03	1.65	148	34.98
4	4	8	1079	21.92	13.35	11.35	2.1	0.12	5.87	139	31.22
1	5	8	100	19.61	13.35	11.35	1.47	0.08	1.74	172	29.39
2	5	8	80	20.33	13.35	11.35	0.84	0.03	0.67	99	31.14
1	6	8	74	17.78	13.35	11.35	0.95	0.05	0.79	163	28.99
2	6	8	106	20.7	13.35	11.35	1.56	0.1	1.24	91	29.51
3	6	8	44	12.22	13.35	7.753846154	0.32	0.01	-0.12	161	30.78
1	1	9	1520	19.89	13.35	11.35	2.58	0.07	1.97	10	40.11
2	1	9	521	21.39	13.35	11.35	2.73	0.2	4.37	50	34.53
4	1	9	770	21.49	13.35	11.35	2.36	0.13	4.49	62	31.83
1	2	9	234	20.77	13.35	11.35	1.42	0.06	3.3	17	34.51
2	2	9	14	21.58	13.35	11.35	0.21	0.02	-0.07	56	29.74
3	2	9	29	19.74	13.35	11.35	0.21	0.01	0.08	38	29.72
4	2	9	106	23.86	13.35	11.35	0.61	0.02	0.64	67	30.68
1	3	9	91	23.59	13.35	11.35	0.11	0	0.37	24	33.18
2	3	9	50	22.62	13.35	11.35	1.62	0.1	0.52	86	29.62
3	3	9	11	20.15	13.35	11.35	0.1	0	-0.04	43	28.66
4	3	9	71	20.51	13.35	11.35	0.35	0.01	0.42	78	31.09
1	4	9	1381	20.65	13.35	11.35	1.85	0.04	1.04	9	39.59
2	4	9	880	22.58	13.35	11.35	1.83	0.07	3.63	49	36.2
2	4	9	14	18.64	13.35	11.35	0.19	0.01	-0.56	55	30.08
3	4	9	403	19.13	13.35	11.35	0.12	0	0.16	31	32.19
4	4	9	838	21.84	13.35	11.35	2.71	0.16	6.56	63	32.15
4	4	9	65		13.35	11.35	0.61	0.02	-5.74	64	29.78
1	5	9	340	23.52	13.35	11.35	1.41	0.06	3.24	18	34.91
3	5	9	32	22.74	13.35	11.35	0.74	0.05	0.5	39	29.13
4	5	9	88	22.43	13.35	11.35	1.47	0.08	0.7	66	30.07
1	6	9	97	22.58	13.35	11.35	0.56	0.03	0.94	23	33.03
2	6	9	139	22.59	13.35	11.35	0.54	0.02	0.41	85	30.48
4	6	9	71	21.49	13.35	11.35	1.33	0.07	0.06	77	30.55
1	1	10	1547	16.31	13.35	10.9	1.42	0.04	1.19	189	38.49
3	1	10	1022	17.3	13.35	11.35	2.06	0.07	2.63	191	38.17
1	2	10	222	17.77	13.35	11.35	1.07	0.04	1.63	188	33.61
3	2	10	222	21.01	13.35	11.35	0.41	0	0.34	193	37.86
4	2	10	166	17.47	13.35	11.35	0.8	0.02	1	203	38.86
1	3	10	171	17.97	13.35	11.35	1.16	0.09	2.31	185	27.13
4	3	10	91	19.24	13.35	11.35	0.28	0	-0.19	204	38.03
2	4	10	1076	12.92	13.35	8.292307692	2.3	0.07	0.78	198	38.31
2	4	10	945	17.44	13.35	11.35	2.01	0.06	2.75	199	38.41
3	4	10	999	17.86	13.35	11.35	2.2	0.07	4.92	192	38.79
1	5	10	545	18.94	13.35	11.35	1.18	0.04	3.17	187	33.5
2	5	10	177	23.23	13.35	11.35	1.13	0.05	2.22	100	31.13
2	5	10	198	19.84	13.35	11.35	1.64	0.07	1.89	196	34.89
3	5	10	210	18.59	13.35	11.35	1.03	0.03	1.03	194	37.19
4	5	10	151	19.74	13.35	11.35	1.75	0.05	0.38	202	38.09
1	6	10	192	20.11	13.35	11.35	1.06	0.06	2.13	186	28.97

2	1	11	1209	4.36	13.35	1.707692308	0.34	0	-0.06	83	41.36
1	2	11	598	11.53	13.35	7.223076923	1.54	0.42	1.28	105	37.97
2	2	11	154	13.19	13.35	8.5	1.74	0.09	1.58	77	33.59
3	2	11	337	13.37	13.35	8.638461538	0.82	0.03	2.45	127	35.15
4	2	11	204	18.9	13.35	11.35	0.73	0.02	0.85	94	38.55
1	3	11	148	14.93	13.35	9.838461538	1.04	0.34	0.83	104	35.9
2	3	11	254	14.26	13.35	9.323076923	1.73	0.06	2.44	71	38.17
3	3	11	50	6.66	13.35	3.476923077	0.34	0.01	0.06	134	36
4	3	11	166	14.18	13.35	9.261538462	0.43	0.01	0.4	99	35.93
1	4	11	1766	14.2	13.35	9.276923077	0.69	0.02	4.19	118	42.78
2	4	11	1384	8.97	13.35	5.253846154	1.65	0.05	2.35	80	38.47
3	4	11	1203	7.59	13.35	4.192307692	1.21	0.03	2.17	123	44.3
2	5	11	240	16.91	13.35	11.35	0.46	0.02	1.02	76	33.74
2	6	11	240	16.35	13.35	10.93076923	0.91	0.02	1.6	70	39.01
3	6	11	115	14.42	13.35	9.446153846	0.33	0	0.05	113	43.27
3	6	11	62	10.45	13.35	6.392307692	0.85	0.03	0.46	133	35.28
1	1	12	1428	17.31	13.35	11.35	0.59	0.01	0.26	176	34.76
1	1	12	1583	18.83	13.35	11.35	1.11	0.02	0.8	184	41.52
2	1	12	1458	18.58	13.35	11.35	1.27	0.07	7.24	108	33.82
2	1	12	1200	19.34	13.35	11.35	3.08	0.21	5	113	37.03
3	1	12	598	18.77	13.35	11.35	0.87	0.03	2.02	144	33.1
4	1	12	1304	20.47	13.35	11.35	1.04	0.05	2.74	136	29
1	2	12	320	19.63	13.35	11.35	1.53	0.09	4.94	170	29.63
2	2	12	68	19.3	13.35	11.35	1.21	0.05	1.43	101	30.94
3	2	12	237	21.37	13.35	11.35	0.77	0.03	1.91	151	33.33
4	2	12	201	22.12	13.35	11.35	1.78	0.1	2.84	128	33.51
1	3	12	47	21.25	13.35	11.35	0.24	0	0.02	164	29.31
2	3	12	189	19.42	13.35	11.35	1.41	0.07	2.96	94	30.39
3	3	12	65	23.35	13.35	11.35	0.81	0.03	0.33	160	30.8
4	3	12	139	18.46	13.35	11.35	1.24	0.06	1.42	119	35.05
1	4	12	554	19.21	13.35	11.35	0.58	0.02	0.58	177	33.89
2	4	12	1585	22.75	13.35	11.35	1.93	0.06	7.79	107	37.83
2	4	12	1517	17.6	13.35	11.35	2.31	0.1	4.03	112	37.61
3	4	12	1099	17.97	13.35	11.35	0.2	0	0.48	145	30.67
3	4	12	1203	19.16	13.35	11.35	0.7	0.03	2.09	146	32.72
4	4	12	112	20.89	13.35	11.35	2.09	0.12	0.63	117	35.51
4	4	12	640	21.32	13.35	11.35	1.65	0.19	8.15	135	25.34
1	5	12	278	17.31	13.35	11.35	1.38	0.07	4.61	171	29.9
2	5	12	180	22.25	13.35	11.35	0.86	0.03	1.73	102	31.19
3	5	12	74	21.29	13.35	11.35	1.13	0.05	0.61	153	32.26
4	5	12	177	20.9	13.35	11.35	1	0.04	1.58	127	33.71
1	6	12	124	22.92	13.35	11.35	1.16	0.07	1.57	162	28.87
2	6	12	177	22.01	13.35	11.35	1.9	0.13	3.41	93	29.68
3	6	12	62	18.43	13.35	11.35	0.45	0.02	0.29	158	31.55
3	1	13	616		13.35	11.35	3.44	0.17	3.81		39.8
3	1	13	865		13.35	11.35	3.52	0.16	3.67		40.26
3	1	13	352		13.35	11.35	3.59	0.22	3.42		39.01
3	2	13	148		13.35	11.35	1.29	0.04	0.28		37.28
3	4	13	1120		13.35	11.35	3.76	0.16	5.5		40.85
3	4	13	1422		13.35	11.35	4.01	0.16	4.95		41.59
3	5	13	177		13.35	11.35	1.91	0.06	0.99		39.3

3	5	13	180		13.35	11.35	1.9	0.06	1.07		39.37
3	5	13	192		13.35	11.35	1.82	0.06	1.46		39.55
1	1	14	699	6.36	13.35	3.246153846	1.64	0.05	3	190	36.45
4	1	14	1256	10.23	13.35	6.223076923	2.55	0.08	4.33	200	39.81
2	1	15	1114	21.22	13.35	11.35	1.72	0.07	3.6	44	33.92
3	1	15	747	21.44	13.35	11.35	1.28	0.05	2.46	25	35.47
3	1	15	1262		13.35	11.35	6.25	2.06	6.6		40.7
3	1	15	1491		13.35	11.35	6.88	0	5.8		40.95
4	1	15	990	22.86	13.35	11.35	1.38	0.07	2.9	58	29.06
1	2	15	308	21.46	13.35	11.35	1.37	0.05	2.31	12	35.52
3	2	15	83	24.33	13.35	11.35	0.97	0.07	0.94	32	30.41
3	2	15	195		13.35	11.35	2.11	0.1	3.13		37.32
3	2	15	189		13.35	11.35	2.58	0.15	2.28		37.14
4	2	15	124	18.63	13.35	11.35	1.05	0.05	1.69	71	30.57
2	3	15	85	23.76	13.35	11.35	1.62	0.14	1.23	81	28.07
3	3	15	53		13.35	11.35	2.62	0.14	0.34		36.26
3	3	15	65		13.35	11.35	2.57	0.13	0.85		36.32
3	3	15	85		13.35	11.35	2.64	0.14	0.2		36.43
4	3	15	94	20.11	13.35	11.35	0.23	0	0.35	74	31.48
1	4	15	859	19.77	13.35	11.35	2.06	0.16	3.75	2	29.12
1	4	15	865		13.35	11.35	2.17	0.15	-6.74	3	30.42
1	4	15	1120	19.77	13.35	11.35	0.33	0	-0.38	4	34.55
2	4	15	1286	25.7	13.35	11.35	2.4	0.1	4.77	45	35.57
3	4	15	1597	21.66	13.35	11.35	2.59	0.11	5.21	26	37.57
3	4	15	1150		13.35	11.35	3.97	0.32	8.55		39.05
3	4	15	1565		13.35	11.35	4.19	0.31	8.61		39.79
3	4	15	1568		13.35	11.35	4.43	0.37	8.83		39.87
3	4	15	1621		13.35	11.35	4.64	0.41	8.58		40.03
4	4	15	1007	23.09	13.35	11.35	1.31	0.08	3.59	57	27.08
1	5	15	323	26.09	13.35	11.35	0.45	0.01	0.26	11	36.43
2	5	15	23	21.39	13.35	11.35	0.43	0.02	-0.69	51	32.29
3	5	15	56	21.1	13.35	11.35	1.28	0.11	0.69	33	30.17
3	5	15	160		13.35	11.35	4.59	2.78	2.26		37.06
3	5	15	189		13.35	11.35	5.15	0	3.03		36.79
4	5	15	106	22.05	13.35	11.35	1.69	0.1	1.06	72	30.47
1	6	15	106	22.52	13.35	11.35	0.16	0	-0.04	19	34.22
2	6	15	38	21.61	13.35	11.35	0.35	0.01	0.21	82	29.33
4	6	15	56	23.37	13.35	11.35	0.34	0.01	0.25	73	31.23
1	1	17	1354	4.15	13.35	1.546153846	1.12	0.02	0.57	4	40.57
3	1	17	1666	2.91	13.35	0.592307692	0.08	0	0.01	28	40.65
4	1	17	1485	7.29	13.35	3.961538462	0.59	0	0.63	64	43.24
1	2	17	539	5.36	13.35	2.476923077	0.36	0	0.03	10	41.59
3	2	17	201	5.64	13.35	2.692307692	0.99	0.02	1.31	34	37.9
4	2	17	290	6.87	13.35	3.638461538	0.47	0.01	0.97	59	37.81
1	3	17	186	6.97	13.35	3.715384615	1.1	0.03	1.02	16	38.34
3	3	17	71	6.55	13.35	3.392307692	0.33	0	0.33	43	37.46
4	3	17	94	10.22	13.35	6.215384615	0.26	0	0.39	54	33.48
1	4	17	1221	5.31	13.35	2.438461538	0.3	0	0.33	1	37.29
3	4	17	1280	6.53	13.35	3.376923077	0.45	0	0.05	22	43.3
4	4	17	699	7.5	13.35	4.123076923	0.79	0.02	1.18	65	41.14
1	5	17	741	6.04	13.35	3	0.53	0	0.62	12	41.93

4	5	17	266	5.69	13.35	2.730769231	0.38	0	0.73	58	37.65
1	6	17	136	9.17	13.35	5.407692308	0.76	0.02	0.93	20	38.11
3	6	17	97	7.63	13.35	4.223076923	0.61	0.01	0.63	42	37.62
4	6	17	80	7.6	13.35	4.2	0.63	0.02	0.38	44	36.92
4	6	17	65	8.1	13.35	4.584615385	0.34	0.01	0.44	50	32.33
1	1	18	1482	23.52	13.35	11.35	0.67	0.01	0.51	6	37.65
2	1	18	847	14.39	13.35	9.423076923	0.66	0.02	1.43	46	36.5
2	1	18	14	19.46	13.35	11.35	0.14	0	0.06	54	30.65
3	1	18	782	11.82	13.35	7.446153846	0.89	0.03	2.23	28	37.36
3	1	18	1416		13.35	11.35	3.55	0.15	3.86		41.15
3	1	18	1529		13.35	11.35	3.64	0.15	3.73		41.51
4	1	18	957	14.13	13.35	9.223076923	1.51	0.05	1.62	61	32.82
1	2	18	171	20.02	13.35	11.35	1.72	0.07	1.82	13	34.67
3	2	18	47	22.02	13.35	11.35	0.28	0.01	0.33	34	30.8
3	2	18	168		13.35	11.35	0.75	0.02	0.93		37.05
3	2	18	163		13.35	11.35	0.61	0.02	1.6		37.28
4	2	18	127	19.9	13.35	11.35	1	0.04	1.36	70	30.61
2	3	18	47	21.81	13.35	11.35	0.46	0.02	0.07	83	29.72
3	3	18	14	19.22	13.35	11.35	0.6	0.04	-0.49	40	28.69
4	3	18	83	21.42	13.35	11.35	0.62	0.02	0.65	79	30.9
1	4	18	1076	17.14	13.35	11.35	0.47	0.01	0.25	5	35.67
2	4	18	664	14.15	13.35	9.238461538	2.03	0.08	3.35	47	36.08
2	4	18	26	22.52	13.35	11.35	0.26	0.01	0.04	52	31.42
3	4	18	1117	18.31	13.35	11.35	1.11	0.03	2.7	27	37.87
3	4	18	477		13.35	11.35	4.12	0.45	7.16		38.32
3	4	18	1159		13.35	11.35	4.25	0.32	7.54		39.72
3	4	18	1191		13.35	11.35	4.41	0.37	7.51		39.69
1	5	18	148	15.77	13.35	10.48461538	0.28	0	0.25	14	35.11
3	5	18	38	23.69	13.35	11.35	0.76	0.05	0.3	35	30.38
3	5	18	163		13.35	11.35	1.14	0.04	1.87		35.98
3	5	18	157		13.35	11.35	1.16	0.04	2.01		36.01
1	6	18	109	20.14	13.35	11.35	0.48	0.02	1.07	20	33.65
2	6	18	154	22.46	13.35	11.35	1.26	0.07	1.76	84	29.75
4	6	18	85	20.85	13.35	11.35	0.44	0.02	0.62	80	31.12
1	1	19	1680	17.81	13.35	11.35	1.34	0.02	-0.72	111	45
1	1	19	1013	15.37	13.35	10.17692308	0.36	0.01	1.02	114	36.62
2	1	19	1173	16.52	13.35	11.06153846	1.43	0.03	1.52	82	39.87
3	1	19	1479	18.67	13.35	11.35	1.15	0.03	0.47	120	44.46
4	1	19	904	18.81	13.35	11.35	1.31	0.02	0.8	86	43.52
1	2	19	545	16.77	13.35	11.25384615	2.93	0.94	0.67	108	40.11
2	2	19	216	19.5	13.35	11.35	0.51	0.02	1.54	75	32.41
4	2	19	204	19.67	13.35	11.35	1.74	0.05	1.3	91	39.52
1	3	19	163	16.6	13.35	11.12307692	0.58	0.09	1.34	100	34.31
2	3	19	192	15.78	13.35	10.49230769	0.66	0.02	0.64	68	39.49
3	3	19	85	17	13.35	11.35	0.28	0.01	0.38	130	33.61
4	3	19	174	19.26	13.35	11.35	0.37	0	0.67	95	37.18
1	4	19	954	19.27	13.35	11.35	2.29	0.16	3.87	109	41.85
1	4	19	874	19.68	13.35	11.35	0.46	0.02	1.08	115	38.26
1	4	19	672	20.71	13.35	11.35	1.19	0.04	1.22	137	38.78
2	4	19	1366	19.5	13.35	11.35	2.5	0.08	3.08	81	39
3	4	19	1004	18.32	13.35	11.35	1.25	0.03	3.4	119	43.07

4	4	19	1538	19.59	13.35	11.35	1.48	0.02	1.08	87	44.56
2	5	19	168	20.4	13.35	11.35	0.43	0.02	1.19	74	31.37
4	5	19	186	19.74	13.35	11.35	0.85	0.02	0.66	90	40.56
1	6	19	142	5.8	13.35	2.815384615	0.7	0.14	0.53	102	34.95
2	6	19	210	19.93	13.35	11.35	0.35	0	0.48	69	39.39
4	6	19	148	12.22	13.35	7.753846154	0.82	0.02	0.69	96	36.47
2	3	20	94	16.43	13.35	10.99230769	1.57	0.06	0.23	195	35.57
2	4	20	1262	16.25	13.35	10.85384615	2.49	0.09	4.93	197	37.69
4	4	20	1431	15.27	13.35	10.1	2.31	0.06	7.56	201	40.73

Replicate	Treatment	Species	AdjE	AdjGs	AdjA	AdjWUE
1	1	1	1.215625931	0.012932191	-0.866456781	-0.712765957
1	1	1	0.470484581	0.011762115	1.117400881	2.375
1	1	1	1.546485149	0.049094767	3.04387553	1.968253968
2	1	1	3.647621681	0.076792035	3.16767146	0.868421053
3	1	1	1.527432432	0.036081081	-0.312702703	-0.204724409
3	1	1	1.256294776	0.038854478	2.046335821	1.628865979
4	1	1	1.573716102	0.029415254	1.456055085	0.925233645
1	2	1	2.422995595	1.964273128	0.058810573	0.024271845
2	2	1	0.729251101	0.023524229	1.458502203	2
3	2	1	0.406932153	0.013126844	1.457079646	3.580645161
4	2	1	0.693964758	0.011762115	1.129162996	1.627118644
1	3	1	0.845919811	0.150082547	0.313808962	0.370967742
2	3	1	1.305594714	0.035286344	1.870176211	1.432432432
3	3	1	0.914671458	0.03563655	0.142546201	0.155844156
3	3	1	0.682202643	0.023524229	0.611629956	0.896551724
4	3	1	0.142546201	0	0.095030801	0.666666667
1	4	1	1.729030837	0.023524229	-0.352863436	-0.204081633
1	4	1	0.768812636	0.025206972	2.697145969	3.508196721
1	4	1	1.473652632	0.048715789	4.408778947	2.991735537
2	4	1	1.222	0.026	1.963	1.606382979
3	4	1	1.685139509	0.038738839	-0.54234375	-0.32183908
3	4	1	2.223519135	0.086630616	5.29890599	2.383116883
4	4	1	2.733167373	0.049025424	3.787213983	1.385650224
1	5	1	3.093436123	0.399911894	0.329339207	0.106463878
2	5	1	0.593536252	0.02374145	1.210813953	2.04
3	5	1	0.540771739	0.012576087	1.119271739	2.069767442
3	5	1	0.329339207	0.011762115	0.705726872	2.142857143
4	5	1	0.87666524	0.014858733	1.367003425	1.559322034
1	6	1	1.640966084	0.445914697	0.766973279	0.467391304
2	6	1	0.682202643	0.023524229	1.152687225	1.689655172
3	6	1	0.389867257	0	0.236283186	0.606060606
3	6	1	0.382328875	0	0.696384736	1.821428571
4	6	1	0.271725664	0	0.519823009	1.913043478
1	1	2	3.352202643	0.117621145	4.32845815	1.29122807
1	1	2	1.458502203	0.023524229	1.576123348	1.080645161
2	1	2	1.799603524	0.058810573	3.540396476	1.967320261
2	1	2	1.928986784	0.070572687	8.01	4.152439024
2	1	2	3.905022026	0.317577093	8.445198238	2.162650602
3	1	2	1.058590308	0.047048458	3.128722467	2.955555556
3	1	2	0.62339207	0.011762115	0.940969163	1.509433962
4	1	2	2.15246696	0.105859031	4.963612335	2.306010929

4	1	2	1.976035242	0.105859031	5.457621145	2.761904762
1	2	2	1.317356828	0.047048458	2.164229075	1.642857143
1	2	2	0.835110132	0.035286344	1.552599119	1.85915493
2	2	2	0.082334802	0	0.364625551	4.428571429
2	2	2	1.482026432	0.117621145	1.693744493	1.142857143
3	2	2	0.305814978	0.011762115	0.799823789	2.615384615
3	2	2	1.964273128	0.105859031	1.976035242	1.005988024
4	2	2	1.046828194	0.047048458	1.928986784	1.842696629
4	2	2	2.246563877	0.152907489	1.999559471	0.890052356
1	3	2	0.341101322	0.011762115	1.14092511	3.344827586
1	3	2	0.45606179	0.012325994	0.271171875	0.594594595
2	3	2	0.729251101	0.035286344	0.599867841	0.822580645
3	3	2	0.092068966	0	0.110482759	1.2
4	3	2	0.611629956	0.023524229	0.399911894	0.653846154
4	3	2	0.870396476	0.035286344	0.282290749	0.324324324
1	4	2	0.988017621	0.023524229	0.564581498	0.571428571
1	4	2	2.822907489	0.070572687	7.468942731	2.645833333
3	4	2	1.152687225	0.058810573	5.363524229	4.653061224
3	4	2	2.246563877	0.117621145	10.16246696	4.523560209
4	4	2	1.035066079	0.035286344	2.105418502	2.034090909
4	4	2	2.340660793	0.152907489	14.62030837	6.246231156
1	5	2	1.411453744	0.047048458	3.763876652	2.666666667
1	5	2	1.599647577	0.082334802	4.32845815	2.705882353
2	5	2	1.681982379	0.117621145	2.775859031	1.65034965
2	5	2	1.764317181	0.082334802	-0.282290749	-0.16
3	5	2	0.011762115	0	0.329339207	28
3	5	2	2.117180617	0.117621145	1.446740088	0.683333333
4	5	2	1.940748899	0.105859031	2.270088106	1.16969697
4	5	2	0.964493392	0.035286344	1.082114537	1.12195122
1	6	2	0.529295154	0.023524229	0.940969163	1.777777778
1	6	2	1.035066079	0.047048458	0.635154185	0.613636364
2	6	2	0.764537445	0.035286344	0.458722467	0.6
3	6	2	0.094096916	0	-0.282290749	-3
3	6	2	0.682202643	0.023524229	0.282290749	0.413793103
4	6	2	1.129162996	0.047048458	0.505770925	0.447916667
4	6	2	0.835110132	0.035286344	0.25876652	0.309859155
1	1	3	1.991213768	0.04192029	0.943206522	0.473684211
3	1	3	0.659527687	0	0.244967427	0.371428571
4	1	3	1.04715173	0.01539929	0.554374445	0.529411765
3	2	3	0.717488987	0.011762115	1.058590308	1.475409836
4	2	3	0.75277533	0.023524229	1.293832599	1.71875
1	3	3	0.764537445	0.023524229	0.729251101	0.953846154
3	3	3	0.435198238	0	0.058810573	0.135135135
4	3	3	0.364625551	0.011762115	0.070572687	0.193548387
1	4	3	1.140818182	0.024272727	0.618954545	0.542553191
3	4	3	1.858414097	0.035286344	0.576343612	0.310126582
4	4	3	2.222203456	0.0545326	3.35375491	1.509202454
1	5	3	1.258546256	0.023524229	1.39969163	1.112149533
3	5	3	0.999779736	0.023524229	1.623171806	1.623529412
4	5	3	0.223480176	0	-0.188193833	-0.842105263
1	6	3	0.846872247	0.023524229	0.729251101	0.861111111

3	6	3	0.811585903	0.023524229	1.211497797	1.492753623
4	6	3	0.223480176	0	0.305814978	1.368421053
4	6	3	0.51753304	0.023524229	0.399911894	0.772727273
4	6	3	0.682202643	0.023524229	1.199735683	1.75862069
1	1	4	6.488479948	0.157160414	8.666274256	1.335640138
2	1	4	6.147209302	0.310465116	9.096627907	1.47979798
3	1	4	1.993978723	0.088621277	4.874170213	2.444444444
4	1	4	3.458061674	0.164669604	4.304933921	1.244897959
1	2	4	1.517312775	0.082334802	1.91722467	1.263565891
2	2	4	1.670220264	0.094096916	1.717268722	1.028169014
2	2	4	1.964273128	0.105859031	0.846872247	0.431137725
3	2	4	2.41123348	0.164669604	2.081894273	0.863414634
4	2	4	2.587665198	0.188193833	3.18753304	1.231818182
1	3	4	1.387929515	0.082334802	0.588105727	0.423728814
2	3	4	0.999779736	0.047048458	1.39969163	1.4
3	3	4	1.082114537	0.047048458	0.270528634	0.25
4	3	4	1.928986784	0.094096916	1.540837004	0.798780488
1	4	4	3.009468814	0.083265936	4.080030843	1.355731225
2	4	4	5.168626444	0.267342747	10.42636714	2.017241379
3	4	4	2.775859031	0.141145374	6.010440529	2.165254237
4	4	4	1.823127753	0.176431718	10.44475771	5.729032258
4	4	4	2.54061674	0.105859031	8.915682819	3.509259259
4	4	4	1.587885463	0.070572687	3.905022026	2.459259259
4	4	4	3.140484581	0.176431718	8.809823789	2.805243446
1	5	4	2.41123348	0.199955947	5.21061674	2.16097561
2	5	4	1.776079295	0.094096916	0.329339207	0.185430464
3	5	4	2.28185022	0.12938326	3.281629956	1.43814433
2	6	4	2.140704846	0.152907489	2.869955947	1.340659341
4	6	4	1.799603524	0.094096916	0.976255507	0.54248366
1	1	5	3.152246696	0.117621145	5.104757709	1.619402985
2	1	5	6.848419118	0.170147059	9.273014706	1.354037267
3	1	5	6.361897507	0.22434903	4.599155125	0.722921914
4	1	5	2.881718062	0.070572687	2.034845815	0.706122449
2	2	5	1.293832599	0.035286344	0.940969163	0.727272727
3	2	5	2.105418502	0.070572687	2.975814978	1.413407821
4	2	5	0.846872247	0.023524229	1.293832599	1.527777778
2	3	5	1.993978723	0.073851064	3.840255319	1.925925926
3	3	5	1.705506608	0.047048458	0.329339207	0.193103448
4	3	5	0.494008811	0.023524229	0.082334802	0.166666667
1	4	5	4.451236111	0.128555556	4.370888889	0.981949458
3	4	5	3.8181	0.0801	4.8594	1.272727273
1	5	5	1.376564122	0.038595256	1.492349889	1.08411215
3	5	5	2.470044053	0.082334802	2.575903084	1.042857143
2	6	5	1.576123348	0.047048458	1.517312775	0.962686567
2	6	5	0.383535912	0	0.047941989	0.125
2	6	5	0.211718062	0	1.834889868	8.666666667
2	6	5	0.976255507	0.035286344	1.305594714	1.337349398
2	6	5	0.776299559	0.023524229	1.282070485	1.651515152
2	6	5	0.658678414	0.011762115	0.893920705	1.357142857
2	6	5	0.799823789	0.023524229	1.223259912	1.529411765
2	6	5	0.564581498	0.011762115	0.682202643	1.208333333

2	6	5	0.717488987	0.011762115	1.01154185	1.409836066
2	6	5	1.293832599	0.023524229	1.646696035	1.272727273
2	6	5	0.823348018	0.011762115	1.093876652	1.328571429
2	6	5	0.588105727	0	1.364405286	2.32
2	6	5	1.023303965	0.023524229	1.458502203	1.425287356
2	6	5	0.988017621	0.023524229	1.258546256	1.273809524
2	6	5	0.823348018	0.011762115	1.129162996	1.371428571
2	6	5	0.811585903	0.011762115	0.905682819	1.115942029
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2	6	5	0.861595745	0.012308511	1.107765957	1.285714286
2	6	5	0.717264992	0.014064019	0.886033225	1.235294118
2	6	5	0.541057269	0	0.564581498	1.043478261
2	6	5	0.613793103	0	0.966724138	1.575
3	6	5	1.199735683	0.023524229	0.799823789	0.666666667
4	6	5	1.505550661	0.047048458	1.517312775	1.0078125
4	6	5	1.199735683	0.058810573	0.211718062	0.176470588
1	1	6	7.337073171	0.282195122	6.409860627	0.873626374
2	1	6	35.53642857	0	22.31357143	0.627906977
3	1	6	9.586571429	0.165285714	4.751964286	0.495689655
4	1	6	3.815308311	0.0930563	1.581957105	0.414634146
1	2	6	4.740132159	0.235242291	3.469823789	0.732009926
2	2	6	1.411453744	0.047048458	1.282070485	0.908333333
2	2	6	1.729030837	0.058810573	1.423215859	0.823129252
3	2	6	1.811365639	0.047048458	2.081894273	1.149350649
1	3	6	1.752555066	0.047048458	1.940748899	1.10738255
2	3	6	0.864661922	0.024704626	0.308807829	0.357142857
2	3	6	1.027506083	0.028150852	0.619318735	0.602739726
3	3	6	1.779338782	0.051575037	1.998532689	1.123188406
4	3	6	0.564581498	0.023524229	1.082114537	1.916666667
1	4	6	7.149666667	0.178	7.505666667	1.049792531
2	4	6	0.470484581	0	1.681982379	3.575
2	4	6	1.776079295	0.047048458	1.729030837	0.973509934
2	4	6	2.15246696	0.058810573	1.976035242	0.918032787
3	4	6	5.027234281	0.129902695	6.157387725	1.224806202
1	5	6	2.587665198	0.070572687	3.587444934	1.386363636
2	5	6	0.905682819	0.023524229	1.646696035	1.818181818
3	5	6	2.999339207	0.141145374	4.410792952	1.470588235
4	5	6	2.775859031	0.12938326	1.505550661	0.542372881
1	6	6	3.011119874	0.091246057	0.839463722	0.278787879
2	6	6	0.988017621	0.023524229	0.611629956	0.619047619
3	6	6	1.553266385	0.036691332	1.761183932	1.133858268
4	6	6	0.505770925	0.023524229	0.940969163	1.860465116
3	1	7	4.375506608	0.294052863	7.468942731	1.706989247
3	2	7	2.187753304	0.082334802	1.070352423	0.489247312
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3	4	7	2.822907489	0.117621145	7.010220264	2.483333333
3	4	7	2.811145374	0.117621145	6.504449339	2.313807531
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3	5	7	2.705286344	0.117621145	0.270528634	0.1
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1	1	8	2.446519824	0.070572687	3.328678414	1.360576923
2	1	8	1.176211454	0.023524229	0.282290749	0.24
3	1	8	0.717488987	0.023524229	1.176211454	1.639344262
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2	2	8	0.788061674	0.023524229	-0.070572687	-0.089552239
3	2	8	1.035066079	0.035286344	1.387929515	1.340909091
1	3	8	1.576123348	0.094096916	0.670440529	0.425373134
2	3	8	1.093876652	0.047048458	2.705286344	2.47311828
4	3	8	0.611629956	0.023524229	0.235242291	0.384615385
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1	4	8	3.199295154	0.094096916	4.175550661	1.305147059
2	4	8	2.317136564	0.141145374	10.48004405	4.52284264
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3	4	8	1.093876652	0.035286344	1.940748899	1.774193548
4	4	8	2.470044053	0.141145374	6.904361233	2.795238095
1	5	8	1.729030837	0.094096916	2.04660793	1.183673469
2	5	8	0.988017621	0.035286344	0.788061674	0.797619048
1	6	8	1.117400881	0.058810573	0.929207048	0.831578947
2	6	8	1.834889868	0.117621145	1.458502203	0.794871795
3	6	8	0.550952381	0.017217262	-0.206607143	-0.375
1	1	9	3.034625551	0.082334802	2.317136564	0.763565891
2	1	9	3.211057269	0.235242291	5.140044053	1.600732601
4	1	9	2.775859031	0.152907489	5.281189427	1.902542373
1	2	9	1.670220264	0.070572687	3.881497797	2.323943662
2	2	9	0.247004405	0.023524229	-0.082334802	-0.333333333
3	2	9	0.247004405	0.011762115	0.094096916	0.380952381
4	2	9	0.717488987	0.023524229	0.75277533	1.049180328
1	3	9	0.12938326	0	0.435198238	3.363636364
2	3	9	1.905462555	0.117621145	0.611629956	0.320987654
3	3	9	0.117621145	0	-0.047048458	-0.4
4	3	9	0.411674009	0.011762115	0.494008811	1.2
1	4	9	2.175991189	0.047048458	1.223259912	0.562162162
2	4	9	2.15246696	0.082334802	4.269647577	1.983606557
2	4	9	0.223480176	0.011762115	-0.658678414	-2.947368421
3	4	9	0.141145374	0	0.188193833	1.333333333
4	4	9	3.18753304	0.188193833	7.715947137	2.420664207
4	4	9	0.717488987	0.023524229	-6.751453744	-9.409836066
1	5	9	1.65845815	0.070572687	3.81092511	2.29787234
3	5	9	0.870396476	0.058810573	0.588105727	0.675675676
4	5	9	1.729030837	0.094096916	0.823348018	0.476190476
1	6	9	0.658678414	0.035286344	1.105638767	1.678571429
2	6	9	0.635154185	0.023524229	0.482246696	0.759259259
4	6	9	1.564361233	0.082334802	0.070572687	0.045112782
1	1	10	1.739174312	0.048990826	1.457477064	0.838028169
3	1	10	2.422995595	0.082334802	3.093436123	1.276699029
1	2	10	1.258546256	0.047048458	1.91722467	1.523364486
3	2	10	0.482246696	0	0.399911894	0.829268293
4	2	10	0.940969163	0.023524229	1.176211454	1.25
1	3	10	1.364405286	0.105859031	2.717048458	1.99137931
4	3	10	0.329339207	0	-0.223480176	-0.678571429
2	4	10	3.702829314	0.112694805	1.255742115	0.339130435

2	4	10	2.364185022	0.070572687	3.234581498	1.368159204
3	4	10	2.587665198	0.082334802	5.786960352	2.236363636
1	5	10	1.387929515	0.047048458	3.728590308	2.686440678
2	5	10	1.329118943	0.058810573	2.611189427	1.96460177
2	5	10	1.928986784	0.082334802	2.223039648	1.152439024
3	5	10	1.211497797	0.035286344	1.211497797	1
4	5	10	2.058370044	0.058810573	0.446960352	0.217142857
1	6	10	1.246784141	0.070572687	2.505330396	2.009433962
2	1	11	2.657972973	0	-0.469054054	-0.176470588
1	2	11	2.84629393	0.776261981	2.365750799	0.831168831
2	2	11	2.732823529	0.141352941	2.481529412	0.908045977
3	2	11	1.267239537	0.046362422	3.78626447	2.987804878
4	2	11	0.858634361	0.023524229	0.999779736	1.164383562
1	3	11	1.411196247	0.461352619	1.126243159	0.798076923
2	3	11	2.477240099	0.085915842	3.493910891	1.410404624
3	3	11	1.305464602	0.038396018	0.230376106	0.176470588
4	3	11	0.619821429	0.014414452	0.576578073	0.930232558
1	4	11	0.992947761	0.028781095	6.029639303	6.072463768
2	4	11	4.192642753	0.12704978	5.971339678	1.424242424
3	4	11	3.85312844	0.09553211	6.910155963	1.79338843
2	5	11	0.541057269	0.023524229	1.199735683	2.217391304
2	6	11	1.111403941	0.02442646	1.954116819	1.758241758
3	6	11	0.466380293	0	0.070663681	0.151515152
3	6	11	1.775180505	0.06265343	0.960685921	0.541176471
1	1	12	0.693964758	0.011762115	0.305814978	0.440677966
1	1	12	1.305594714	0.023524229	0.940969163	0.720720721
2	1	12	1.493788546	0.082334802	8.515770925	5.700787402
2	1	12	3.622731278	0.247004405	5.881057269	1.623376623
3	1	12	1.023303965	0.035286344	2.375947137	2.32183908
4	1	12	1.223259912	0.058810573	3.222819383	2.634615385
1	2	12	1.799603524	0.105859031	5.810484581	3.22875817
2	2	12	1.423215859	0.058810573	1.681982379	1.181818182
3	2	12	0.905682819	0.035286344	2.246563877	2.480519481
4	2	12	2.093656388	0.117621145	3.340440529	1.595505618
1	3	12	0.282290749	0	0.023524229	0.083333333
2	3	12	1.65845815	0.082334802	3.481585903	2.09929078
3	3	12	0.952731278	0.035286344	0.38814978	0.407407407
4	3	12	1.458502203	0.070572687	1.670220264	1.14516129
1	4	12	0.682202643	0.023524229	0.682202643	1
2	4	12	2.270088106	0.070572687	9.162687225	4.03626943
2	4	12	2.717048458	0.117621145	4.740132159	1.744588745
3	4	12	0.235242291	0	0.564581498	2.4
3	4	12	0.823348018	0.035286344	2.458281938	2.985714286
4	4	12	2.458281938	0.141145374	0.741013216	0.301435407
4	4	12	1.940748899	0.223480176	9.586123348	4.939393939
1	5	12	1.623171806	0.082334802	5.422334802	3.34057971
2	5	12	1.01154185	0.035286344	2.034845815	2.011627907
3	5	12	1.329118943	0.058810573	0.717488987	0.539823009
4	5	12	1.176211454	0.047048458	1.858414097	1.58
1	6	12	1.364405286	0.082334802	1.846651982	1.353448276
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3	6	12	0.529295154	0.023524229	0.341101322	0.644444444
3	1	13	4.046167401	0.199955947	4.481365639	1.10755814
3	1	13	4.140264317	0.188193833	4.316696035	1.042613636
3	1	13	4.222599119	0.25876652	4.022643172	0.95264624
3	2	13	1.517312775	0.047048458	0.329339207	0.217054264
3	4	13	4.422555066	0.188193833	6.469162996	1.462765957
3	4	13	4.71660793	0.188193833	5.822246696	1.234413965
3	5	13	2.246563877	0.070572687	1.164449339	0.518324607
3	5	13	2.234801762	0.070572687	1.258546256	0.563157895
3	5	13	2.140704846	0.070572687	1.717268722	0.802197802
1	1	14	6.744597156	0.205627962	12.33767773	1.829268293
4	1	14	5.470364648	0.171619283	9.288893696	1.698039216
2	1	15	2.0230837	0.082334802	4.234361233	2.093023256
3	1	15	1.505550661	0.058810573	2.893480176	1.921875
3	1	15	7.351321586	2.422995595	7.762995595	1.056
3	1	15	8.092334802	0	6.822026432	0.843023256
4	1	15	1.623171806	0.082334802	3.411013216	2.101449275
1	2	15	1.611409692	0.058810573	2.717048458	1.686131387
3	2	15	1.14092511	0.082334802	1.105638767	0.969072165
3	2	15	2.481806167	0.117621145	3.68154185	1.483412322
3	2	15	3.034625551	0.176431718	2.681762115	0.88372093
4	2	15	1.235022026	0.058810573	1.987797357	1.60952381
2	3	15	1.905462555	0.164669604	1.446740088	0.759259259
3	3	15	3.081674009	0.164669604	0.399911894	0.129770992
3	3	15	3.022863436	0.152907489	0.999779736	0.3307393
3	3	15	3.105198238	0.164669604	0.235242291	0.075757576
4	3	15	0.270528634	0	0.411674009	1.52173913
1	4	15	2.422995595	0.188193833	4.410792952	1.82038835
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1	4	15	0.38814978	0	-0.446960352	-1.151515152
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3	4	15	3.046387665	0.12938326	6.128061674	2.011583012
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3	4	15	5.21061674	0.435198238	10.38594714	1.993227991
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4	4	15	1.540837004	0.094096916	4.222599119	2.740458015
1	5	15	0.529295154	0.011762115	0.305814978	0.577777778
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3	5	15	1.505550661	0.12938326	0.811585903	0.5390625
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1	6	15	0.188193833	0	-0.047048458	-0.25
2	6	15	0.411674009	0.011762115	0.247004405	0.6
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1	1	17	9.670447761	0.172686567	4.921567164	0.508928571
3	1	17	1.803116883	0	0.22538961	0.125
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1	2	17	1.940310559	0	0.161692547	0.083333333
3	2	17	4.908985714	0.099171429	6.495728571	1.323232323

4	2	17	1.7244926	0.036691332	3.559059197	2.063829787
1	3	17	3.952484472	0.107795031	3.665031056	0.927272727
3	3	17	1.298673469	0	1.298673469	1
4	3	17	0.55845297	0	0.837679455	1.5
1	4	17	1.642429022	0	1.806671924	1.1
3	4	17	1.778986333	0	0.197665148	0.111111111
4	4	17	2.557919776	0.064757463	3.820690299	1.493670886
1	5	17	2.3585	0	2.759	1.169811321
4	5	17	1.85771831	0	3.568774648	1.921052632
1	6	17	1.876216216	0.049374111	2.295896159	1.223684211
3	6	17	1.928333333	0.031612022	1.991557377	1.032786885
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1	1	18	0.788061674	0.011762115	0.599867841	0.76119403
2	1	18	0.935044898	0.028334694	2.025930612	2.166666667
2	1	18	0.164669604	0	0.070572687	0.428571429
3	1	18	1.595655992	0.053786157	3.998104339	2.505617978
3	1	18	4.175550661	0.176431718	4.540176211	1.087323944
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4	1	18	2.185658882	0.072372811	2.344879066	1.072847682
1	2	18	2.0230837	0.082334802	2.140704846	1.058139535
3	2	18	0.329339207	0.011762115	0.38814978	1.178571429
3	2	18	0.88215859	0.023524229	1.093876652	1.24
3	2	18	0.717488987	0.023524229	1.881938326	2.62295082
4	2	18	1.176211454	0.047048458	1.599647577	1.36
2	3	18	0.541057269	0.023524229	0.082334802	0.152173913
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2	4	18	0.305814978	0.011762115	0.047048458	0.153846154
3	4	18	1.305594714	0.035286344	3.175770925	2.432432432
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1	5	18	0.356522377	0	0.318323551	0.892857143
3	5	18	0.893920705	0.058810573	0.352863436	0.394736842
3	5	18	1.340881057	0.047048458	2.199515419	1.640350877
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1	6	18	0.564581498	0.023524229	1.258546256	2.229166667
2	6	18	1.482026432	0.082334802	2.070132159	1.396825397
4	6	18	0.51753304	0.023524229	0.729251101	1.409090909
1	1	19	1.576123348	0.023524229	-0.846872247	-0.537313433
1	1	19	0.472244898	0.013117914	1.338027211	2.833333333
2	1	19	1.725844924	0.036206537	1.834464534	1.062937063
3	1	19	1.352643172	0.035286344	0.552819383	0.408695652
4	1	19	1.540837004	0.023524229	0.940969163	0.610687023
1	2	19	3.475745044	1.115085441	0.794794942	0.228668942
2	2	19	0.599867841	0.023524229	1.811365639	3.019607843
4	2	19	2.04660793	0.058810573	1.52907489	0.747126437
1	3	19	0.696120332	0.108018672	1.608278008	2.310344828

2	3	19	0.839758065	0.025447214	0.81431085	0.96969697
3	3	19	0.329339207	0.011762115	0.446960352	1.357142857
4	3	19	0.435198238	0	0.788061674	1.810810811
1	4	19	2.693524229	0.188193833	4.551938326	1.689956332
1	4	19	0.541057269	0.023524229	1.27030837	2.347826087
1	4	19	1.39969163	0.047048458	1.434977974	1.025210084
2	4	19	2.940528634	0.094096916	3.622731278	1.232
3	4	19	1.470264317	0.035286344	3.999118943	2.72
4	4	19	1.740792952	0.023524229	1.27030837	0.72972973
2	5	19	0.505770925	0.023524229	1.39969163	2.76744186
4	5	19	0.999779736	0.023524229	0.776299559	0.776470588
1	6	19	3.319262295	0.663852459	2.513155738	0.757142857
2	6	19	0.411674009	0	0.564581498	1.371428571
4	6	19	1.411815476	0.034434524	1.187991071	0.841463415
2	3	20	1.906742477	0.072869139	0.2793317	0.146496815
2	4	20	3.062647059	0.110698086	6.063795181	1.979919679
4	4	20	3.053316832	0.079306931	10.01910891	3.281385281

Appendix F

Rainforest cabinet timber plantings

Species selection should reflect planning design. Models for timber production include:

Eco-forestry- mixed rainforest (including reforestation and cabinet timber) species from local provenance planted at very high stocking density (2m x 2m spacing, 2500 stems per hectare) with canopy closure in less than 3 years. Individual trees harvested when mature.

Stratified cabinet timber planting- fast and slower growing cabinet timber species planted at high stocking density (2.5m x 2.5m spacing, 1600 stems per hectare) with canopy closure in 3-5 years. Removal of overstorey produces large diameter thinnings resulting in some harvest damage. Multiple harvests of understorey upon maturity similar to enriched native forest silviculture.

Woodlots- cabinet timber plantings at moderate stocking densities (4m x 4m spacing, 625 stems per hectare) with canopy closure after 7 years. As stocking density decreases early management commitment to weed control and form pruning increases. Careful management of wide-spaced individual trees required and potential for some stock grazing.

Taungya- Interplanting of high value timber trees with agricultural crops. Stocking density varies considerably and is dependent on associated crops. This model is characterized by high labour inputs and a mixed range of outputs. It is often practiced by indigenous farmers and communities with small landholdings.

Plantation- a monoculture (single species planting). Stocking density initially high (3m x 3m spacing, 990 stems per hectare) followed by small diameter thinnings and a final clear fell harvest.

Collection, germination and nurseries

Rainforest seed can prove difficult to collect due to isolation of trees, timing of harvest and poor storage capability. Seed for some important species can be purchased from DPI Seeds and other seed merchants. Some short-viability seeds must be sown within four weeks of harvest. Many species exhibit high germination levels and require little or no treatment. However some important species are difficult to germinate. Nurseries require 6-12 months to obtain, germinate and ready seedlings for the required wet season or winter plantings.

Plantation design

A mixed species planting has the potential to become a multi-layered multi-aged diverse forest similar to rainforest and dominated by a high percentage of high value timber species. Suitable fast growing species that promote height and straight stems are interplanted with slower growing shade tolerant species. Initial harvest (thinning) begins with the removal of the overstorey (15-25 years), being careful to minimize damage to the understorey. Subsequent harvests are undertaken as trees mature (40-100 years). On-site management of early growth is very important in the first few years in order to establish site dominance (out competing weedy species) through crown closure and to ensure long straight tree boles by form pruning.

Outcomes and benefits

Farm forestry in Australia has a very promising future. Mixed species rainforest cabinet timber plantings have the potential to provide multiple diverse benefits to the landholder.

- **Timber** products including high value saw logs
- **Land management** including reforestation and catchment management
- **Biodiversity** of both flora and fauna
- **Conservation** of the rainforest ecosystem especially if local species are used
- **Sustainability** following long-lived successional cycles towards a timber enriched climax rainforest.
- **Adaptability.** Multiple products and niche marketing enable flexible outcomes.
- **Carbon accumulation** and storage as rainforest ecosystem.

The landholder may consider value-adding to the timber resource. Mobile saw mills enable logs to be sawn on-site and timber being stored locally for drying. A 40 fold increase in value can occur from log to air dried timber boards.

Further information

Central Queensland University: Plant Sciences Group, School of Biological and Environmental Sciences, Faculty of Arts, Health and Science, CQU, Rockhampton, QLD 4702.

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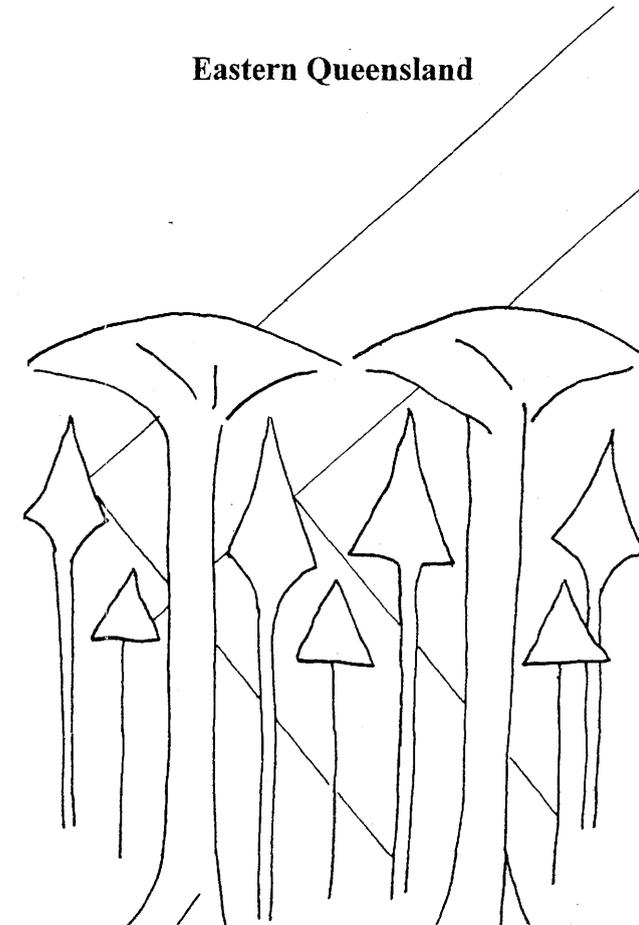
Cabinet Timber Farm Forestry

for

Moderate to High Rainfall Areas

of

Eastern Queensland



Farm forestry

The benefits of including forestry in farming systems are beginning to be accepted by landmanagers. Whole farm planning has encouraged landholders to assess the physical, biological and economic components of their farms. The challenge for farmers is to determine their own farm forestry design that reflects their aspirations and capabilities. The approach should begin with a review of land management systems and the recognition of problems and opportunities (Reid 1996). Appropriate designs should address individual farm situations and objectives. There is a vast range of possible designs including multi-purpose plantings.

With any farm forestry design, the following are

Important points to consider:

Planning	Timber production, shade and shelter, catchment management, conservation, reforestation.
Product	Timber for farm use, high volume low value wood chips, high value saw logs.
Species	Local provenance, regional, Australian or exotic species
Site	Location, climate, soil type and nutrient deficiencies, depth of soil, drainage.
Silviculture	Mixed species planting or monoculture, quality of stock, stocking density, access for planting, management and harvest, security of tenure, fire.

Many landholders have the farm resources to engage in farm forestry. Design and planning, seed or seedling purchase, planting, early management, harvest and value adding are practicable activities for many farms.

For landholders with limited farm forestry experience it is advisable to initiate a trial planting of one hectare or less. This would enable the farm forester to assess the practical implementation of species selection, purchase, planting and early management of trees on the farm.

Early management of trees is essential to all timber plantings. Weeds need to be controlled, followed by form pruning to ensure clear straight boles. Additional management may depend on plantation design.

Cabinet timber production is best suited to ex-rainforest lands with reasonable fertility and rainfall and some protection against wind and frost. The diversity of timber species enables individual designs to reflect local conditions. Many rainforest timber species have been grown successfully outside their natural range.

RAINFOREST TIMBER SPECIES

Elaeocarpus grandis (Silver Quandong)- low germination (33%) with a long delay to onset of germination, capable of rapid growth (height > 1.5 m yr⁻¹, diameter > 1.5 cm yr⁻¹), early site dominance, very large tree with light spreading canopy, self pruning at high density, valuable timber used for cabinet work and boatbuilding, found throughout Queensland in riverine rainforest.

Trema orientalis (Peach Cedar)- moderate germination (60%) capable of very rapid growth, early site dominance, large tree with light spreading canopy, may require form pruning, low density multipurpose timber, found in central and north Queensland in tropical rainforest, prefers high rainfall.

Rhodospaera rhodanthema (Tulip Satinwood)- germination improved by scarification (47%) or boiling water (32%), fast growing tree (height > 1.5 m yr⁻¹, diameter > 1.5 cm yr⁻¹) with bushy dense crown, may require form pruning, valuable yellow cabinet timber from southeast Queensland in subtropical and dry rainforests.

Grevillea robusta (Southern Silky Oak)- rapid germination (77%), capable of fast growth (height > 2.0 m yr⁻¹, diameter > 1.5 cm yr⁻¹), large tree with small bushy crown, much used ornamental cabinet timber from southeast Queensland in riverine, subtropical and dry rainforest.

Melia azedarach var australasica (White Cedar)- difficult to germinate, capable of fast growth (height > 1.5 m yr⁻¹, diameter > 1.0 cm yr⁻¹), very large tree with deciduous spreading canopy, some drought tolerance, pale brown light cabinet timber found throughout Queensland in riverine, dry, subtropical and tropical rainforest.

Alphitonia excelsa (Red Ash)- germination improved by scarification (48%) and boiling water (62%), fast growing (height > 1.0 m yr⁻¹, diameter > 0.5 cm yr⁻¹), occasionally large tree with open canopy, some drought tolerance, pink red cabinet timber found throughout Queensland in warm temperate, dry, subtropical and tropical rainforest, also forage for stock.

Toona ciliata (Red Cedar)- rapid germination (45%), fast growing (height > 1.0 m yr⁻¹, diameter > 1.0 cm yr⁻¹), very large tree with spreading deciduous canopy, debilitating pest problems, valuable cabinet timber (deep red colour only in mature trees), found throughout Queensland in riverine, subtropical and tropical rainforest.

Flindersia schottiana (Southern Silver Ash)- rapid germination (58%), fast growing (height > 1.0 m yr⁻¹, diameter > 0.5 cm yr⁻¹), very large tree, light yellow cabinet timber found throughout Queensland in riverine, subtropical and tropical rainforest.

Nauclea orientalis (Leichardt Pine)- germinates readily, fast growing (height > 1.0 m yr⁻¹, diameter > 1.5 cm yr⁻¹), large tree with dense canopy, prefers high rainfall, orange cabinet timber, found in north Queensland in riverine rainforests

Pleiogynium timoriense (Burdekin Plum)- delayed germination (87%), fast growing (height > 1.0 m yr⁻¹, diameter > 1.0 cm yr⁻¹) hardy tree with bushy crown, cabinet timber found in riverine rainforest, edible bush food fruit.

Dysoxylum fraserianum (Rose Mahogany)- moderate growth (height > 0.5 m yr⁻¹, diameter > 0.5 cm yr⁻¹), very large tree with dense spreading canopy, shade tolerant, red rose scented cabinet timber from southeast Queensland in subtropical rainforest.

Dysoxylum muelleri (Miva Mahogany)- fresh seed only, requires sowing within a few weeks of harvest, moderate growth (height > 0.5 m yr⁻¹, diameter > 0.5 cm yr⁻¹), very large tree with spreading canopy, shade tolerant, reddish brown cabinet timber (difficulties with toxicity of sawdust), found throughout Queensland in riverine, subtropical and tropical rainforests.

Flindersia bennettiana (Bennett's Ash)- moderate growth (height > 0.5 m yr⁻¹, diameter > 0.5 cm yr⁻¹), large tree with bushy crown, cabinet timber from southeast Queensland in riverine and subtropical rainforest.

Flindersia brayleyana (Queensland Maple)- rapid germination (45%) moderate growth (height > 0.5 m yr⁻¹, diameter > 0.5 cm yr⁻¹), large tree with bushy or spreading crown, valuable cabinet timber, found in northeast Queensland in tropical rainforest.

Gmelina leichardtii (White Beech)- fresh seed only, requires sowing within a few weeks of harvest, moderate growth (height > 0.5 m yr⁻¹, diameter > 0.5 cm yr⁻¹), very large tree with dense canopy, shade tolerant, valuable cabinet timber found throughout Queensland in riverine, subtropical and tropical rainforest.

Blepharocarya involucrigera (Rose Butternut)- rapid germination (98%), moderate growth (height < 0.5 m yr⁻¹, diameter > 0.5 cm yr⁻¹), tree with spreading crown, prefers high rainfall, valuable cabinet timber found in northeast Queensland.

Agathis robusta (Kauri Pine)- rapid germination (85%), slow growing (height < 0.5 m yr⁻¹, diameter < 0.5 cm yr⁻¹), large tree with narrow dense crown, valuable softwood with cabinet timber qualities, found in southeast and northeast Queensland in subtropical and tropical rainforests.

Castanospermum australe (Black Bean)- delayed germination (100%), slow growing (height < 0.5 m yr⁻¹, diameter > 0.5 cm yr⁻¹) legume, large tree with dense canopy, magnificent cabinet timber found throughout Queensland in riverine rainforest.

Flindersia xanthoxyla (Yellowwood)- rapid germination (92%), slow growing (height > 0.5 m yr⁻¹ in shade, diameter < 0.5 cm yr⁻¹) large tree with dense canopy, pale yellow cabinet timber found in southeast Queensland in riverine and dry rainforest.

Podocarpus elatus (Brown Pine)- delayed germination (78%), slow growing (height > 0.5 m yr⁻¹, diameter < 0.5 cm yr⁻¹), occasionally large tree with dense canopy, shade tolerant, valuable softwood with cabinet timber qualities found throughout Queensland in riverine, subtropical and tropical rainforest, produces valuable bush food fruit.

Other rainforest timber species include: *Acacia aulacocarpa* (Brown Salwood), *A. melanoxylon* (Blackwood), *Alangium villosum* (Canary Muskheart), *Albizia procera* (Forest Siris), *Araucaria bidwillii* (Bunya Pine), *Araucaria cunninghamii* (Hoop Pine), *Argyrodendron* sp. (Tulip Oak), *Beilschmiedia bancroftii* (Yellow Walnut), *Beilschmiedia obtusifolia* (Blush Walnut), *Cardwellia sublimis* (Northern Silky Oak), *Cassia brewsteri* (Cassia), *Ceratopetalum apetalum* (Coachwood), *Cinnamomum oliveri* (Camphorwood), *Doryphora sassafras* (Sassafras), *Ehretia acuminata* (Silky Ash), *Euroschinus falcata* (Pink Poplar), *Flindersia bourjotiana* (Silver Ash), *Flindersia iffliana* (Hickory Ash), *Flindersia pimenteliana* (Maple Silkwood), *Lophostemon confertus* (Brush Box), *Orites excelsa* (Mountain Silky Oak), *Paraserianthes toona* (Red Siris), *Planchonella australis* (Black Apple), *Polyscias elegans* (Silver Basswood), *Pseudoweinmannia lachnocarpa* (Mararie), *Sloanea australis* (Blush Alder).

Appendix G

Summary of phenotypic plasticity results

Species: Refer to Appendix E

AR: Ratio of high light values of A (rate of photosynthesis) divided by low light values of A.

GsR: Ratio of high light values of Gs (stomatal conductance) divided by low light values of Gs.

Succession: Successional ecology as defined by Kooyman (1996) and Shea (1992).

2 = Early Secondary, 3 = Late Secondary and 4 = Climax successional group

Species	AR	GsR	Succession
1	3.5	0.2	4
2	3.4	2.1	2
3	2.1	2.5	4
4	2	1.6	4
5	3.1	2.8	4
6	1.7	1.2	4
7	6.8	2.2	3
8	5	3.2	3
9	2	2.7	3
10	1.6	1.4	2
11	1.8	0.2	3
12	1.7	2.1	3
13	3.8	3.7	3
14	n.a.	n.a.	2
15	2.8	1.3	2
16	n.a.	n.a.	4
17	0.8	1.7	4
18	3.7	6.6	4
19	2.6	3.2	2
20	n.a.	n.a.	3