FACTORS AFFECTING GROWTH OF WILDLINGS IN THE FOREST AND NURTURING METHODS IN NURSERY

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MASTER OF SCIENCE
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GRADUATE SCHOOL
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A THESIS SUBMITTED TO THE GRADUATE SCHOOL IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN BIOLOGY

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11 February 2002

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Thesis Title Factors Affecting Growth of Wildlings in the Forest and Nurturing Methods in Nursery

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ABSTRACT

Forest restoration by planting nursery-raised seedling stock is relatively expensive. There are many technical problems involved in seedling production from seeds. Transplanting tree seedlings from forests into nurseries may reduce these problems. The objectives of this research were to determine which factors affect the growth of wildlings in the forest and to develop techniques to nurture wildlings transplanted from the forest in the nursery. This research was conducted in Doi Suthep-Pui National Park at the Forest Restoration Research Unit (FORRU). The species tested were: *Sarcosperma arboreum* Bth. (Sapotaceae), *Castanopsis tribuloides* (Sm.) A. DC. (Fagaceae), *Podocarpus neriifolius* D. Don (Podocarpaceae), and *Eugenia albiflora* Duth. *ex* Kurz (Myrtaceae).

This research was divided into 2 parts: i) wildlings of these 4 species were monitored in the forest to determine which factors affect their growth, including

distance from the parent tree, ground flora competition, canopy cover, and soil moisture; and ii) in the nursery, various treatments were tested on wildlings grown in plastic bags. Three size classes of wildlings were each subjected to 2 pruning methods.

For all species, most of the wildlings measured in the forest grew very slowly, on average approximately 4-5 cm in height, over 12 months. Most mortality occurred at the beginning of the rainy season (June-July, 10.17%). *P. neriifolius* wildlings had the highest mean mortality during 1 year, *viz.* 19.4%, followed by *C. tribuloides* 13.2%, *S. arboreum* 12.5% and *E. albiflora* 11.1%. Distance from parent tree showed a negative and significant correlation with the mortality rates of *P. neriifolius* and *C. tribuloides* wildlings ($r = -0.925$, $p = 0.024$ and $r = -0.903$, $p = 0.036$). Canopy cover was positively and significantly correlated with the mortality rates of *E. albiflora* and *C. tribuloides* ($r = 0.892$, $p = 0.042$ and $r = 0.976$, $p = 0.005$). Analysis of the effects of soil moisture revealed a significantly positive correlation with mortality rates of *P. neriifolius*, *E. albiflora*, and *C. tribuloides* wildlings ($r = 0.921$, $p = 0.009$, $r = 0.816$, $p = 0.047$ and $r = 0.935$, $p = 0.006$). Correlation analysis failed to detect a significant linear relationship between these factors and relative growth rate of wildlings for all species ($p > 0.05$).

The optimum height of wildlings for transfer was not more than 20 cm, since they could be dug up without injuring the roots, which reduces the transplanting shock. Pruning before potting significantly reduces mortality and promotes in a high relative growth rate. Optimum time of transfer should be done at the beginning of the rainy season.

ชื่อเรื่องวิทยานิพนธ์	ปัจจัยที่มีผลต่อการเจริญเติบโตของกล้าไม้ในป่าและวิธีการนำมาเลี้ยงในเรือนเพาะชำ
ชื่อผู้เขียน	นายเชิดศักดิ์ เกื้อรักษ์
วิทยาศาสตรมหาบัณฑิต	สาขาวิชาชีววิทยา

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ดร. สตีเฟน เอลเลียต	กรรมการ
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บทคัดย่อ

การฟื้นฟูป่าโดยใช้กล้าไม้ที่ผลิตจากเรือนเพาะชำมีค่าใช้จ่ายค่อนข้างสูงรวมทั้งมีปัญหาในขั้นตอนการผลิตมากมายโดยเฉพาะการผลิตกล้าไม้จากเมล็ด การนำกล้าไม้จากป่ามาเลี้ยงในเรือนเพาะชำก่อนนำไปปลูกเป็นอีกทางเลือกที่ช่วยลดปัญหาต่างๆเหล่านี้ งานวิจัยนี้มีวัตถุประสงค์เพื่อต้องการทราบถึงปัจจัยที่มีผลต่อการเจริญเติบโตของกล้าไม้ในป่าธรรมชาติและต้องการที่จะพัฒนาเทคนิควิธีในการนำกล้าไม้จากป่ามาเลี้ยงในเรือนเพาะชำ งานวิจัยนี้ได้ทำการศึกษาที่อุทยานแห่งชาติดอยสุเทพ-ปุยและหน่วยวิจัยการฟื้นฟูป่า ทำการศึกษากล้าไม้ 4 ชนิด ประกอบด้วย มะยาง (*Sarcosperma arboreum* Bth.) (Sapotaceae), ก่อใบเลื่อม (*Castanopsis tribuloides* (Sm.) A. DC.) (Fagaceae), พญาไม้ (*Podocarpus neriifolius* D. Don) (Podocarpaceae), และมะห้า (*Eugenia albiflora*

Duth. *ex* Kurz) (Myrtaceae) โดยวางแผนการทดลองออกเป็น 2 ส่วน ส่วนแรก ศึกษาติดตามถึงปัจจัยที่มีผลต่อการเจริญเติบโตของกล้าไม้ในป่าธรรมชาติทั้ง 4 ชนิด คือ ระยะห่างจากต้นแม่ อัตราการแข่งขันจากไม้พื้นล่าง ระดับของร่มเงาที่ถูกปกคลุมและปริมาณความชื้นในดิน ส่วนที่สอง ทำการทดลองในเรือนเพาะชำด้วยวิธีทดสอบที่แตกต่างกัน โดยแบ่งขนาดความสูงของกล้าไม้ขณะขุดออกเป็น 3 ขนาด และกรรมวิธีการตัดแต่งกล้าไม้ 2 วิธี

ผลการศึกษาพบว่า กล้าไม้ทุกชนิดในป่าธรรมชาติมีอัตราการเจริญเติบโตช้าโดยเฉลี่ย 4-5 ซม. ตลอดระยะเวลา 12 เดือน อัตราการตายส่วนใหญ่เกิดช่วงต้นฤดูฝน (มิ.ย- ก.ค 10.17 %) พญาไม้มีอัตราการตายสูงสุด 19.4 % ตามด้วย ก่อใบเลื่อม 13.2 %, มะยาง 12.5 % และมะห้า 11.1 % ระยะห่างจากต้นแม่ มีความสัมพันธ์ในทางลบอย่างมีนัยสำคัญทางสถิติกับอัตราการตายของพญาไม้และก่อใบเลื่อม ($r = -0.925$, $p = 0.024$ และ $r = -0.903$, $p = 0.036$) ระดับของร่มเงามีความสัมพันธ์ในทางบวกอย่างมีนัยสำคัญทางสถิติกับอัตราการตายของมะห้าและก่อใบเลื่อม ($r = 0.892$, $p = 0.042$ และ $r = 0.976$, $p = 0.005$) และปริมาณความชื้นในดินมีความสัมพันธ์ในทางบวกอย่างมีนัยสำคัญทางสถิติกับอัตราการตายของพญาไม้, มะห้าและก่อใบเลื่อม ($r = 0921$, $p = 0.009$, $r = 0.816$, $p = 0.047$ และ $r = 0.935$, $p = 0.006$) อย่างไรก็ดีปัจจัยต่างๆเหล่านี้ไม่มีสัมพันธ์อย่างมีนัยสำคัญทางสถิติกับอัตราการเจริญเติบโตของกล้าไม้ทุกชนิด ($p > 0.05$)

ขนาดของกล้าไม้ที่เหมาะในการนำมาเลี้ยงในเรือนเพาะชำควรมีขนาดความสูงไม่เกิน 20 ซม เพราะสะดวกในการขุด รากไม่กระทบกระเทือนมากนัก การตัดแต่งกล้าไม้ก่อนย้ายลงถุงสามารถช่วยลดอัตราการตายและช่วยส่งเสริมอัตราการเจริญเติบโตสัมพัทธ์ของกล้าไม้อย่างมีนัยสำคัญทางสถิติ ระยะเวลาที่เหมาะสมในการขุดย้ายกล้าไม้จากป่ามาเลี้ยงในเรือนเพาะชำควรกระทำในช่วงต้นฤดูฝน

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ABBREVIATIONS

ANOVA:	analysis of variance
BN:	big seedlings with no pruning
BP:	big seedlings with pruning
ANR:	assisted natural regeneration
cm:	centimeter
CMU:	Chiang Mai University
DSNP:	Doi Sutep-Pui National Park
FORRU:	Forest Restoration Research Unit
km^2:	square kilometers
LSD:	least significant difference
m:	meter
mm:	millimeter
MN:	medium seedlings with no pruning
MP:	medium seedlings with pruning
no:	number
p:	significant (2-tailed)
r:	Pearson Correlation
RGR:	Relative Growth Rate
SD:	standard deviation
SN:	small seedlings with no pruning
SP:	small seedlings with pruning

INTRODUCTION

Loss of forests and associated biodiversity is a serious issue in many tropical countries. In Thailand, forest cover has been reduced from about 53% in the early 1960s (Bhumibamon, 1986) to about 22.8% (FAO, 1997). Consequently today, Maxwell and Elliott (2001) estimates the remaining primary forest area to be about 15%. In northern Thailand, the main causes of forest destruction are logging, shifting cultivation, and infrastructure development projects (Blakesley *et al.*, 1999).

In 1993 a major restoration project was initiated in Thailand to mark His Majesty King Bhumibol Adulyadej's Golden Jubilee (OEPP, 1995). The long-term aim of this project was to plant a wide range of native forest tree species in deforested areas. A positive development of the project has been a rapid increase in public awareness of the problems caused by deforestation such as floods, droughts, damage to watersheds, and loss of biodiversity. The project has encouraged more organizations to undertake tree planting. Although many people have participated enthusiastically in many tree planting events, the results were often disappointing (FORRU, 1998).

If forest restoration projects are to recreate original forest ecosystems, it is essential to have a clear description of these ecosystems, specifically a forest inventory. The importance of basing topical forest restoration on an understanding of ecological processes is often emphasized. We need to understand how forests regenerate themselves naturally, identify the factors limiting regeneration, and develop effective methods to counteract them and thus accelerate regeneration (Hardwick *et al.*, 1997).

Planting nursery-produced seedlings is just one of many options. Unfortunately, tree nursery practices in Thailand are only for commercial plantation species. Knowledge of the habitat requirements and how to propagate native tree species in Thailand is still very limited (Blakesley *et al.*, 1999). There is a need to initiate research on the scientific and technical aspects of forest restoration, such as the development of means for studying the restoration of natural forest ecosystems and to develop methods to propagate appropriate tree species for experimental planting trials.

Rationale

Forest restoration by planting nursery-raised seedlings is costly because an input of labor is required at every stage of the nursery process, *viz.* collecting the seeds or seedlings, raising them in nurseries, preparing sites, planting seedlings, and maintaining them afterwards (Hardwick *et al.*, 1997). Transplanting seedlings from the forest is one way to solve propagation problems in the nursery by saving time, money, and nursery space since many species have long periods of seed dormancy, low germination rates, slow growth rates, or are difficult to collect as seeds. Research on natural seedlings involves their identification and the ability to cultivate them. The optimum time to dig them up and methods of transplanting into plastic bags in the nursery are necessary to develop appropriate methods to propagate these species. Such methods are applicable to all areas throughout the region so that the most effective methods of forest restoration can be developed and utilized.

Objectives and Hypotheses

This research was carried out 1) to determine which factors affect growth of natural seedlings (wildlings) in the forest and 2) to develop techniques to nurture wildlings transplanted from the forest to the nursery. This study tested the hypotheses that proximity to the mother tree, ground flora competition, soil moisture and shade affect growth of seedlings in the forests. The second hypothesis tested was that the size of wildlings selected for nursery propagation and whether they are pruned before potting affect mortality rates and seedling quality in the nursery.

Future implications of the study

My study provides original knowledge that will allow an alternative to the costly method of planting containerized seedlings for forest restoration projects. The results should improve management and seedling production in assisted natural regeneration projects.

Limitations of the study

My studied investigated 4 species from primary evergreen seasonal hardwood forests and two factors were tested in the nursery. The information obtained might not be applicable to every species and every forest type and saplings produced by this method should be monitored after planting in degraded areas.

LITERATURE REVIEW

TROPICAL FORESTS

Forests, especially tropical forests, are one of the most important bases for human life and national development. They also contain a substantial portion of Earth's biological resources, richness, and diversity. This is especially relevant in tropical forests because so little is known about species diversity, gene pools, and plant ecosystems there which we expect to need for conservation and restoration ecology in the future. Large areas of tropical forest have been lost in the last 40 years, mostly due to the activities of developed countries (Ishi, 1988).

The forests of northern Thailand are one of the Kingdom's most important natural resources. They provide habitats for numerous wildlife species, including 150 mammal species (Lekagul and McNeely, 1988), 383 birds (Round, 1988) and at least 3,450 vascular plants, of which 1,116 are trees (CMU Herbarium Database, 2001). Despite their importance, these forests have been widely degraded or destroyed in recent years. In 1961, forests covered 68.5% of the 17 provinces, which comprise the northern region. By 1995, logging, fire, and agricultural expansion had reduced this figure by 36.4% to only 73,886 km^2 (or 43.5% of the region's area) (Bhumibhamon, 1986). The consequences of deforestation are particularly serious in the mountainous north. As watersheds become degraded, flash floods occur in the rainy season, streams dry up in the dry season, and rivers become choked with slit (Kerby *et ai.*, 2000).

In the past, people accepted deforestation as an inevitable consequence of economic development. Now attitudes are changing. Since 1993, various tree-planting projects to celebrate the Golden Jubilee of His Majesty King Bhumibol Adulyadej have encouraged people from all walks of life to become involved in restoring the nation's forests. Such activities have raised hopes that deforestation might be reversible. The success of such tree planting projects is often limited by lack of skills and knowledge about how to grow, plant, and take care of native forest trees which have never before been planted on a large scale in Thailand (Kerby *et al.*, 2000).

In Doi Suthep-Pui National Park, has at least species 512 of trees included in the overall vascular flora of 2,247 species (Maxwell and Elliott, 2001). Very little is known about seed production, germination, and seedling growth of the vast majority these trees. Provided with a wide range of soil and climate conditions, this place could be a valuable seed source of native tree species in forest restoration projects. In order to restore natural forest ecosystems in degraded areas within national parks and wildlife sanctuaries, we need to have a much better under standing of how such ecosystems function. This requires a great deal of research (Elliott *et al.*, 1994).

FOREST RESTORATION

Recently, many community groups have organized tree planting events to restore forests. Such tree planting projects are often constrained by lack of knowledge on species selection and habitat requirements of the several hundred potential native tree species. Knowledge of how to germinate the seeds and raise healthy seedlings is also limited. Until very recently there was no manual for tree seedlings (FORRU, 1998, Kerby *et al.*, 2000). We must regenerate, restore, and rehabilitate the forests in order to avoid the loss and devastation of these ecosystems. Successful restoration requires a clear understanding of ecological processes, but rehabilitation of degraded tropical forest lands is expensive. Assisted or accelerated natural regeneration (ANR) is a relatively cheap method of reforestation (Hardwick, 2000). It requires very low inputs and is simple to implement at low cost (Dugan, 2000). ANR offers an efficient, technologically simple, and cost-effective approach to forest restoration. Comparisons carried out in Indonesia showed it to be 26-72% cheaper than traditional methods of intensive tree planting (Drilling, 1989). ANR can only work with the trees that are already established in deforested areas and may not be effective in areas far from tree seed sources.

Rapid restoration of a more complete forest tree community usually requires some tree planting. Restoring forests by planting trees is also very useful when there are not enough natural trees and saplings on the site (Longman and Wilson, 1995) or to ensure early representation of large-seeded, climax forest tree species (Elliott, 2000). In any tree planting program, primary concerns include selecting appropriate species to plant, identifying individual trees from which to obtain seeds or cuttings, and nursery production of planting material. Species selection and technologies for growing and planting seedlings are crucial to the success of any natural forest restoration program (Blakesley, 2000). This has led to the development of more intensive and more expensive systems of forest restoration. Tree planting, such as the "Miyawaki method" in Malaysia, which experimented with direct planting of up to 42 climax forest tree species, has helped to return the forests to their original condition as quickly as possible. In Vietnam, forest succession is mimicked by the "accelerated pioneer-climax series" or APCS method (Sou, 2000). With this method, pioneer trees are planted first and are later interplanted with climax tree species. In Queensland, Australia, the framework species method (Tucker, 2000) uses a mixture of 20-30 pioneer and climax species planted in the initial and single step. The framework species are selected for their ability to shade out competing weeds and attract wildlife into planted areas. The planted trees re-establish basic forest structure and function, while birds and bats add diversity to the forest by dispersing seeds of non-planted trees into the planted areas. This method is now being adapted for use in northern Thailand, with promising results (FORRU, 1998).

FACTORS AFFECTING THE GROWTH OF SEEDLINGS

The characteristic growth pattern of a tree in the wild may be affected by many factors. For plants to grow, they require food, water, light, and a suitable climate. The density of seedlings in the forest will most often be determined by the number of microsites available (Brickell and David, 1996).

Aguirre *et al.* (1991) studied the importance of light in affecting the spatial distribution of seedlings (natural regeneration) of *Pinus sylvestris* L. (Pinaceae) in the *Quercus pyrenaica* (Fagaceae) zone in Avila (Spain), where extensive pine stands now exist. The numbers of pine seedlings were determined on plots at roadsides, 10 and 20 m inside pine stands, and also in clearings within pine stands. The results showed that the distribution of the pine seedlings is closely correlated with the light conditions and that exploitation in the oak zone has favored expansion of pine.

Competition with weeds is one of the most important factors preventing forest regeneration in degraded areas (Kerby *et al.*, 2000). Weeds can grow in all plant communities, but most herbaceous weed species do not germinate or thrive under a closed canopy. The success of any tree planting is largely dependent upon controlling weeds (Goosem and Tucker, 1995).

In theory, seed density and the probability of seed survival are expected to change with increasing distance from the parent tree, because seed and seedling predation are greater near the parent (Jansen, 1970). Jansen (1970) and Connell (1971) proposed that recruitment of seedlings near adult trees might be limited by seed predation, thus seed and seedling survival would be near zero in the vicinity of the parent tree, but would tend to increase farther away.

Terborgh *et al.* (1993) tested the results for each species for evidence of the Jansen/Connell distance effect. Of the 5 species, only *Astrocaryum macrocalyx* (Palmae) showed a distance effect. This resulted from higher levels of invertebrate seed predation in plots near parent trees (5 m) compared with plots far (25 m) from parent trees. Synnott (1973) studied the regeneration of ***Entandrophragma utile*** (Dawe and Sprague) Sprague (Meliaceae) from Africa. He found that 70% of seeds were eaten by animals. Other loses were caused by seed rot, insect and fungal attacks, and seed drought. The survival rate after 2 years from seed fall was only 2%.

Most tropical rain forest tree species appear to depend on gaps in the forest canopy for successful regeneration (Hartshorn, 1978). Whitmore (1978) reported the importance of gap size in influencing species composition of gap regeneration. The larger the gap, the more its microclimate differs from that of closed forest. During germination, most plants require 40-50 % shade, though some species may require more or less than this.

With increasing plant age, shade should be reduced. Plants grown in too much shade are stunted and grow slowly, or they are tall and slender with a soft stem, which does not become woody. They are also susceptible to diseases or insect attack (Wightman, 1999).

Longman and Wilson (1995) reported that the right amount of light is critical for healthy development of seedlings since in heavy shade a tree may be producing less sugar than it uses. It will stop growing, run out of stored reserves, and then die. Shaded saplings, within natural forests, may often receive as little as 1% full sunlight. This might allow them just to survive, making little new growth unless a tree or large branch falls, making a gap in the canopy. Too much light leads to scorching, drying out of tender tissue, soil conditions being too hot for important organisms, and favouring of grasses or weeds over trees.

WILDLINGS

Jurik and Pleasants (1990) reported that seedlings are an especially sensitive stage in a plant's life cycle, yet we do not have a good understanding of how specific traits of individual species and characteristics of the environment affect seedling growth. Only a few studies have provided quantitative data on microsite and growth characteristics for young seedlings of rain forest trees in the field (Denslow and Gomez-Diaz, 1990).

One major constraint, currently limiting research on forest tree seedlings is the lack of an identification guide to seedlings or a complement botanist available to help determine seedlings identifications. To save time and nursery space, many seedlings used in current tree plantings projects are dug up from remaining areas of forest and nurtured in a nursery for a year, before being planted out (Elliott *et al.*, 1996).

Kawanabe (1990) studied the natural regeneration of *Pinus densiflora* Sieb. and Zucc. var. *umbraculifera* Mayr (Pinaceae) in a protected forest nature reserve in the southern part of Shiga Prefecture, Japan. He showed that 5-10% of fallen seeds germinated, but in areas of dense ground vegetation no seedlings survived by September. By keeping the shrub understorey to <50% cover ensured >50% seedling survival. Adequate survival and growth of seedlings can be ensured by weeding twice a year until seedling stem height is 40 cm.

Bartlett *et al.* (1991) studied natural seedlings of *Acer saccharum* Marshall (Aceraceae) in Ontario. Age structures of natural seedlings and saplings 1-25 years old were investigated over a three year period. Mortality rates were highest in 1year old seedlings and decreased gradually as age approached 10 years. Both spatial and seasonal environmental variation affected 1year old seedlings the most and these effects declined as seedling age increased. The distribution of types of visible injury preceding death in the 1year old seedlings suggested that both drought and herbivory were involved.

Cui and Smith (1991) studied the ecophysiology of natural seedling establishment in forest trees not associated with anthropogenic disturbance. Photosynthesis and water relations measurements were made on one to four year old seedlings of subalpine fir (*Abies lasiocarpa* Nutt., Pinaceae), establishing naturally in an understorey environment in SE Wyoming (elevation 2,672-2,950 m). First (current) year seedlings generally had only cotyledons, whereas most second year seedlings had both cotyledons and primary leaves. Mortality was high (>60%) in the first year seedlings with greatest mortality (>90%) measured in more open, sun-exposed sites within the understorey. Seedling mortality was negligible after the first year of growth at shaded microsites and after the second year of growth at sunny microsites. Abrupt increases in water status and photosynthetic capacity after the first or second year of growth appear to be crucial for survival to maturity. Moreover, differences in temperature and water relations according to specific microsites may be major factors determining seedling establishment and the distributional and successional patterns observed for adult trees of *Abies lasiocarpa.*

Bondarenko and Kopii, (1986) reported which factors affect mortality of seedling natural regeneration of *Quercus robur* L. (Fagaceae) in moist oak/hornbeam forest type in the western forest steppe in Russia. Light is one of the main factors governing the survival of this tree in natural regeneration and mortality was greatest in stands with a dense underwood of hazel and hornbeam advance growth.

Skolmen *et al.* (1980) reported the growth of *Acacia koa* Mill. (Leguminosae). Natural seedlings grew on average 0.96 cm in height over the first year, 2.88 cm in the second, and 4.8 cm in the third. The largest dbh after 2.5 years was 7.36 cm. The most serious disease present was the rust (*Uromyces koae*), found on 36% of the 3 year old trees (60% on the poorest site, 20% on the best). The most severe damage was caused by a drought in mid-1977. Although many natural seedling establishments may occur on natural litter, soil disturbance appears to greatly increase the rate of establishment. Litter removal alone does not increase establishment (Zobel, 1980).

Abdullajev (1975) reported comparative data for three species of maple (*Acer campestre* L., *Acer ibericum* L., and *Acer platanoides* L.; Aceraceae) on the numbers of natural seedlings and advanced growth from surveys made at 800, 1200 and 1600 m elevation in the forest zone of the Lesser Caucasus in Azerbaijan. The quantity of natural regeneration decreased with increasing elevation.

Bernier (1993) compared natural and planted seedling growth of *Picea mariana* (Mill.) BSP. (Pinaceae) in Quebec, Canada. First year relative growth rates of newly planted seedlings were significantly lower than those of natural seedlings, but the difference was smaller during their second season in the forest.

NATURAL SEEDLINGS USEFUL FOR FOREST RESTORATION

Studies using alternative methods of producing planting stock are essential to meet the need for large-scale replanting projects (Brown, 1993). Planting nursery-produced seedlings is just one of the options where natural regeneration is very poor. The nursery is the foundation for tree planting success since quality seedlings in the nursery are fundamental to having healthy trees in the field. Improving plant growth not only improves plant quality, but also means more efficient use of time, labour, and resources for the nursery. Speeding up production is important to get trees out of the nursery within one season (Wightman, 1999).

In Thailand, nursery technology for propagation of woody perennial species, both by seed and cuttings, is quite advanced. The development of this technology has largely focused on exotic and commercial plantation trees. Very little work has been carried out on native forest tree species in Thailand. Furthermore, the technological requirements for nursery production of native species for forest restoration must address issues concerned with lack of knowledge, the requirement for low-tech input, maintenance of genetic diversity, and handling of relatively small numbers of many different species (Blakesley, 2000).

Establishment of seedlings in gaps could be achieved by various methods including i) direct sowing of seeds into gaps, ii) germinating seeds in nurseries and transplanting the seedlings produced into gaps, iii) transplanting seedlings from forests directly into gaps, and iiii) nurturing seedlings collected from forests in nurseries before transplanting them into gaps. Collection of seedlings from forests often causes long-lasting damage to the root system, which many reduce seedling performance even after period of care in a nursery (Elliott *et al.*, 1996).

Framework tree species must be relatively easy to propagate in a low-technology tree nursery. It is essential that all nursery-produced seedlings have the best chance of survival following planting. It is very difficult to produce seedlings of 30-50 framework species of an acceptable quality, when they are required for planting. Production is made very difficult by seasonal variation in seed availability, dormancy, germination, and growth rates amongst the framework species (Blakesley, 2000). For alternative propagation methods, trees are not only raised directly from seed. Many nurseries obtain materials as naturally regenerated seedlings (wildlings) transplanted elsewhere (Blakesley *et al.*, 1998).

In Malaysia, planting stock was obtained from two sources *viz.* germinated seeds and collection of seedlings from the forest floor. The germination rates of collected seeds have been encouraging, but survival of seedlings collected from the forest floor were not satisfactory because wildlings have high rates of mortality (Brown, 1993).

Transplanting tree seedlings from forests to nurseries or directly to forest restoration sites may provide a cheap alternative to raising planting stock from seed, but these transplanting methods have not been tested. Such factors such as the optimum size of wildlings for transfer and pruning methods, to reduce the shock of transplantation, need to be developed (Elliott, 2000).

PRUNING METHODS

The objectives of pruning are maintenance of plant health and control of growth (Hudson, 1972). The aims of pruning are to ensure a healthy, soundly structured, properly shaped plant, and removal of any dead, diseased, and damaged tissue. Prompt action helps plants to remain healthy and appropriate pruning improves their chances of recovery from damage and disease. (Brickell and David, 1996).

Pruning in different ways produces different effects. In some situations, pruning to restrict size may be important to stimulate vigorous growth. Restricting shoot growth by pruning stimulates the production of new growth elsewhere on the plant (Brickell and David, 1996). When to prune is important,tropical tree species should be pruned in the rainy season when there is the least risk of infection from diseases. Every cut should be clean. Slanting cuts are usually preferable because they discourage fungal rots. The bottom of each cut should be just above the top of a healthy axillary bud (Brickell and David, 1996).

When transplanting seedlings, leaf pruning is often required because if seedlings have many leaves they require a lot of water and may grow slowly or even die because the roots cannot supply the leaves with enough water (Josiah, 1992). The reason for pruning is to compensate for transplanting shock. When plants are dug up for transplanting the roots are often severed. Consequently the plant will have trouble getting enough water to supply the leaves. As a result, the plants will wilt and can die unless something happens within the plant or its environment to reduce moisture loss. Transplanted plants can be pruned enough to reduce leaf area more or less in the same ratio as the loss the roots suffered when dug up (Sunset, 1983). If the seedlings have shock from transplanting or their environment suddenly changes and the growth rate may be retarded because the roots cannot absorb the nutrients and moisture necessary to make new growth. Pruning can solve this problem by cutting back strong buds or young shoots. Seedlings will then easily develop new leader shoot growth (Brickell and David, 1996). Root pruning makes seedlings deficient in water, so pruning should be immediately followed by watering (Jackson, 1987).

MATERIALS AND EQUIPMENT

Species studied

Eugenia albiflora Duth. *ex* Kurz (Myrtaceae)

Sarcosperma arboreum Bth. (Sapotaceae)

Podocarpus neriifolius D. Don (Podocarpaceae)

Castanopsis tribuloides (Sm.) A. DC. (Fagaceae)

Table 1. Reasons for selecting wildling species (Maxwell and Elliott, 2001 and Kuarak *et al*, 2000).

SPECIES	WILDLING DENSITY IN THE FOREST	FRAME-WORK SPECIES	NURSERY PROBLEMS	FRUIT TYPE	NOTES
E. albiflora	high	yes	difficult to collect seeds, slow seedling growth rate**	berry	common
S. arboreum	high	yes	difficult to collect seeds	berry	common
C. tribuloides	high	yes	slow seedling	nut	very

			growth rate** long periods of seed dormancy		common
*P. neriifolius**	low	no	slow seedling growth rate***	fleshy seed	in danger of extirpati-on

* = For conservation purposes

** = Ready for planting in the second planting season after seed collection (Kuarak *et al*, 2000)

*** = Ready for planting in the third planting season after seed collection (FORRU, 1998)

Equipment

1. In the forest

bamboo measuring sticks (50 cm)

metal labels

measuring tape (50 m)

string

soil pH & moisture tester

circle ring (radius 25 cm)

altimeter (m)

2. In the nursery

small hand spade

bamboo basket (diameter 50 cm)

gloves

pruning scissors

black plastic bags (2.5 x 9.0 inches) 576 bags

Equipment for data collection

calipers with a vernier scale

measuring tape (150 cm)

data sheet

pencils

camera

Materials

Forest soil from Doi Pui	(230,400 cm^3)
Peanut husk	(115,200 cm^3)
Coconut husk	(115,200 cm^3)

"Osmocote", slow releasing N-P-K fertilizer (14-14-14) (0.518 kg)

METHODOLOGY

Site Description

This study was conducted in Doi Suthep–Pui National Park, Chiangmai Province, northern Thailand (18° 50'N, 98° 50'E). Experiments in the forest were located in primary, evergreen, seasonal forest (Maxwell and Elliott, 2001). All work was carried out between elevations of 1,020 m and 1,450 m above mean sea level. The nursery experiment was carried out at the Forest Restoration Research Unit Nursery (FORRU) at the headquarters of Doi Suthep-Pui National Park, at approximately 1,050 m elevation in primary evergreen, seasonal, hardwood forest, granite bedrock. The average amount of annual rainfall at the base of Doi Suthep-Pui National Park (*c.* 350 m), is 1067.8 mm, the average amount of rainfall at the national park headquarters (*c.* 1050 m) is 1670.1 mm per year and 2095 mm at Puping village (*c.* 1375 m). August and September have the most rain with an average of 207.7 mm per month. The lowest amount of rainfall is during January-February with an average of 6.3 mm per month. Average lowland temperatures range from a low of 21.1°C during December-January and a high of 29 °C during April-May (Maxwell and Elliott, 2001).

Experimental Design

Monitoring Natural Seedlings in the Forest

Four species were studied and wildling voucher specimens were collected and deposited in the CMU herbarium; *Eugenia albiflora* Duth. *ex* Kurz (Myrtaceae) (Kuarak 325, Figure 4), *Sarcosperma arboreum* Bth. (Sapotaceae) (Kuarak 105, Figure 2), *Podocarpus neriifolius* D. Don (Podocarpaceae) (Kuarak 293, Figure 5), and *Castanopsis tribuloides* (Sm.) A. DC. (Fagaceae) (Kuarak 269, Figure 3). For each species, 6 mother trees were selected. Mother trees were selected at different locations and elevations to have as much variation as possible for each species (Table 2).

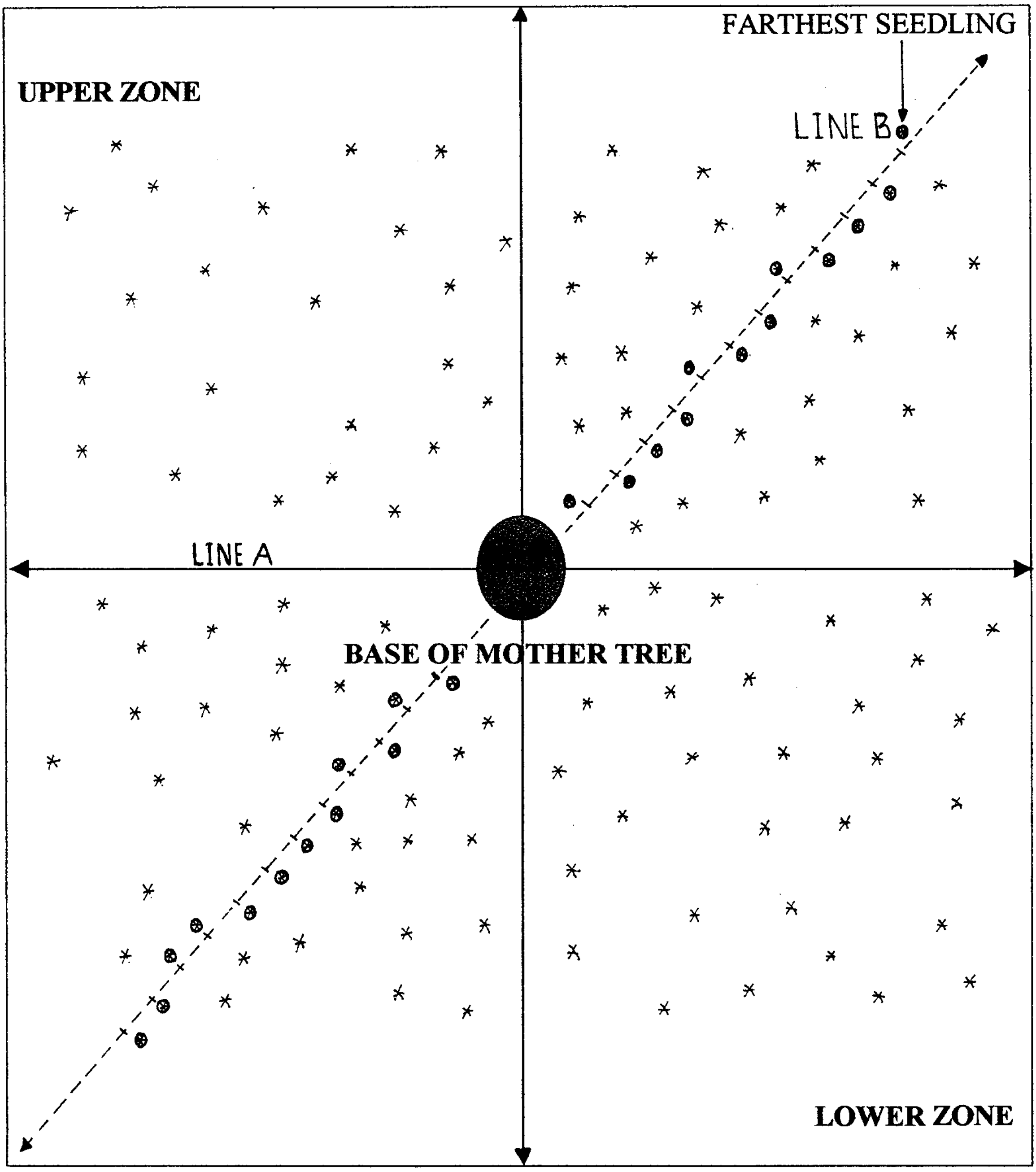
Table 2. Locations and elevation ranges of the mother trees of each species

SPECIES	TREE NO.	ELEVATION (M)	LOCATION
E. albiflora	1	1,020	Ru See Cave
	2	1,030	Ru see Cave
	3	1,150	road to Kawk Mah
	4	1,280	road to Kawk Mah
	5	1,365	road to Doi Pui
	6	1,440	road to Doi Pui
S. arboreum	1	1,050	road to Chang Kian
	2	1,110	road to Chang Kian
	3	1,250	road to Kawk Mah

	4	1,280	road to Kawk Mah
	5	1,320	road to Doi Pui
	6	1,360	road to Doi Pui
P. neriifolius	1	1,350	Kawk Mah
	2	1,350	Kawk Mah
	3	1,400	Kawk Mah
	4	1,400	Kawk Mah
	5	1,400	Kawk Mah
	6	1,400	Kawk Mah
C. tribuloides	1	1,050	Ru See Cave
	2	1,100	Ru see Cave
	3	1,200	road to Kawk Mah
	4	1,350	road to Kawk Mah
	5	1,400	road to Doi Pui
	6	1,450	road to Doi Pui

Twenty-four seedlings, situated at the full range of distances from each mother tree, were selected for *in situ* study in the following manner (Figure 1).

Figure 1. Method used to select wildlings under the mother trees



* = other natural seedlings

⊗= seedlings selected

A horizontal line (A) was constructed across the slope area, to divide the slope area into an upper zone (above the base of the tree) and a lower zone (below the base of the tree). Then another line (B) at 45° to line A was laid out with a tape measure running from the base of the mother tree to the farthest seedling of the same species. This line was divided into 12 equal lengths. The nearest species specific seedling to the tape measure on either side within each of the 12 lengths was selected for monitoring.

Wildling measurements included height (distance from ground level to the terminal bud); root collar diameter (measured using callipers with a vernier scale); plant width (at the widest point using a tape measure); health score (3 = perfect or nearly perfect health, 2 = slight insect damage or discoloration, 1 = severe insect damage or discoloration, and 0 = believed to be dead); ground flora score (measured on a 100 point scale from zero to full ground flora cover in a 50 cm circle around the base of each seedling) (Figure 6); seedling canopy cover score (measured on a 100 point scale from zero to full canopy cover, by estimating % cover in a 50 cm diameter ring projected above each seedling; soil moisture and pH (measured by using soil pH & moisture tester near the base of each seedling). These measurements were repeated every 2 months from February 2000 to January 2001.

Experimental Design in the Nursery

Natural seedlings of *Eugenia albiflora, Sarcosperma arboreum, Podocarpus neriifolius,* and *Castanopsis tribuloides* were dug up and the soil removed from the roots in the early morning. Seedlings were divided into 3 size classes (small = 0 to 20 cm tall, medium = 21-40, and big = 41-60) and transferred to the FORRU nursery in a bamboo basket.

The experiment tested 6 treatments on each species. Each treatment included 24 plants (Figure 9).

Treatment 1: big seedlings – pruning (BP)

Treatment 2: big seedlings – no pruning (BN)

Treatment 3: medium seedlings – pruning (MP)

Treatment 4: medium seedlings – no pruning (MN)

Treatment 5: small seedlings – pruning (SP)

Treatment 6: small seedlings – no pruning (SN)

Pruning methods:

Using sharp and clean pruning scissors before transplanting into plastic bags (Figures 7-8).

1) Stem pruning (at half of wildling height)

2) Cut slash at 45 □, about 5 mm above the axillary bud

3) Leaf pruning leaving 1-2 leaves

4) Root pruning of secondary roots, making it easier for putting into plastic bags

All seedlings were transplanted into black plastic bags 2.5 inches in diameter and 9 inches in deep. The potting mixture consisted of forest soil, peanut husk, and coconut husk mixed in the ratio of 2:1:1. Seedlings were shaded in the nursery under a plastic roof (approximately 20% sunlight), for about 6 weeks. After that, the seedlings were moved out of the nursery and placed under black shade netting (approximately 50% sunlight). All seedlings of all treatments were monitoring for health and measurement of relative growth rate of height, root collar diameter, and canopy. These measurements were repeated every 45 days. About 10 granules of "Osmocote" slow-release fertilizer (14-14-14) were placed on the media surface every 3 months.

Data analysis

Relationships between field parameters were examined using simple correlation or regression analyses. Data on height, basal diameter, canopy, and relative growth rate were tested for differences among the treatments for each species, using ANOVA (analysis of variance), T-test, and LSD test (least significant difference) using the SPSS computer program.

Seedling mortality was calculated by the formula :

$$\text{Percent mortality} = \frac{\text{Number of dead seedlings}}{\text{Total number of seedling}} \times 100$$

The Relative Growth Rates (RGR) were calculated using the formula:

Relative Growth Rates (RGR) percent per year

$$RGR = \frac{LN\ H2 - LN\ H1}{T2 - T1} \times 365 \times 100$$

H1 = Initial height (cm), basal diameter (mm) or canopy (cm)

H2 = Final height (cm), basal diameter (mm) or canopy (cm)

T1 = Start time (day): first monitoring (1.5 month after transplant into plastic bag)

T2 = Final time (day): at the end of monitoring (9 months after transplant into plastic bag)

Health average

$$Ha = (H1 + H2 + \ldots Hn) / n$$

Ha = Health average

H1 = Health score of seedling for the first monitoring

H2 = Health score of seedling for the second monitoring

Hn = Health score of seedling for the final monitoring

Figure 2. Wildlings of *Sarcosperma arboreum* in the forest (6 March 2000).

Figure 3. Wildlings of *Castanopsis tribuloides* in the forest (6 March 2000)

Figure 4. Wildlings of *E. albiflora* in the forest (6 March 2000)

Figure 5. Wildlings of *P. neriifolius* in the forest (6 March 2000)

Figure 6. Monitoring % ground flora competition in the forest

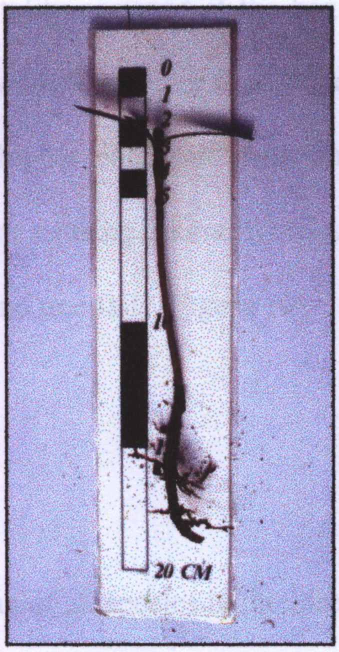


Figure 7. Figure 8. Figure 9.

Figure 7. Wildling of *Podocarpus neriifolius* before pruning

Figure 8. Wildling of *Podocarpus neriifolius* after pruning

Figure 9. All nursery treatments of *Sarcosperma arboreum* wildlings

RESULTS

In the Forest

Mortality

Podocarpus neriifolius wildlings had the highest mean mortality over 1 year 19.4% (SD 12.8), followed by ***Castanopsis tribuloides*** 13.2% (SD 8.1), ***Sarcosperma arboreum*** 12.5% (SD 9.9) and *Eugenia albiflora* 11.1% (SD 10.1). The differences in mortality rates among species were not statistically significant ($p<0.05$) (Figure 10). For all species, most mortality occurred at the beginning of the rainy season (June-July). The mean mortality of all species from June to July was 10.17% (SD 2.83), which was significantly higher compared with any other time (ANOVA, $p<0.05$) (Figure 11). Some factors causing mortality of wildlings of all species included diseases (Figures 12-16) and tree falls (Figure 16).

Seedling growth

The growth of wildling of all species in the forest was very slow. In general, most of the wildings measured in the forest grew on average approximately 4-5 cm in height over the course of the 1 year study. The mean heights of the wildlings when first measured (1 March 2000) and when last measured (4 January 2001) were, respectively, 34.91 and 38.47 cm. for ***Sarcosperma arboreum***, 15.81 and 19.18 cm.

for ***Podocarpus neriifolius***, 41.84 and 46.45 cm. for ***Eugenia albiflora*** and 24.65 and 29.54 cm. for ***Castanopsis tribuloides*** (Figure 17)

The relative height growth rate (%/year) was calculated for the period March 2000 to January 2001. Differences among species were not statistically significant (p <0.05) (Table 3). An analysis of variance showed significant interaction between relative height growth rate and time for all species. Mean % RGR was highest at the beginning of the rainy season (June-July, 32.56%), which was significantly higher than at other times of the year (ANOVA, p<0.05). The relative growth rate of height initially decreased then increased at the beginning of the cool-dry season (October-November). At this time most wildlings of all species produced new shoots and new leaves (Figure 18).

Factors Affecting Survival and Growth of Wildlings

Distance from parent tree. Analysis of variance showed significant interaction between the distance from the parent tree and mortality of ***Podocarpus neriifolius*** and ***Castanopsis tribuloides*** wildlings (r = -0.925, p = 0.024 and r = -0.903, p = 0.036). Mortality decreased with increasing distance from the parent trees, but the correlation was not statistically significant for ***Sarcosperma arboreum*** and ***Eugenia albiflora*** (r = -0.792, p = 0.111 and r = -0.170, p = 0.785) (Table 5, Figure 19). Within 5 m of mother trees, ***Podocarpus neriifolius*** and ***Castanopsis tribuloides*** wildlings suffered the highest mortality 26.58% and 20.0% compared with other distances (ANOVA, p <0.05). Correlation analysis fail to detect a significant linear relationship between distance from the parent tree and relative height growth rate for all species (Table 6).

Canopy cover. Analysis of the effects of canopy cover showed a positive and significant correlation with the mortality rate of ***Eugenia albiflora*** (r = 0.892, p = 0.042) and ***Castanopsis tribuloides*** (r = 0.976, p = 0.005). The mortality rate increased with increasing canopy cover, but the correlation with canopy cover was not statistically significant for ***Podocarpus neriifolius*** and ***Sarcosperma arboreum*** wildlings (r = 0.786, p = 0.115 and r = -0.002, p = 0.997) (Table 5). Canopy cover did not significantly correlate with the relative height growth rate for all species (Table 6).

Soil moisture. Analysis of the effects of soil moisture revealed a significantly positive correlation with mortality rate of ***Podocarpus neriifolius*** (r = 0.921, p = 0.009), ***Eugenia albiflora*** (r = 0.816, p = 0.047), and ***Castanopsis tribuloides*** (r = 0.935, p = 0.006) wildlings, but not for ***Sarcosperma arboreum*** (r = 0.719, p = 0.108) (Table 5). Soil moisture did not significantly correlated with the relative height growth rate for all species (Table 6).

Ground flora competition. Analysis of ground flora density showed that very few herbaceous ground floras occurred in the forest. The mean ground flora score for all species ranged from 16.08% to 24.98%. There were no significant correlations between ground flora cover and relative growth rate for height and mortality rate for all species (Tables 5 and 6). Analysis of the effects of ground flora revealed a significantly positive correlation with soil moisture (Table 4).

Figure 10. Percentage of mortality of 4 wildling species during 1 year in the forest

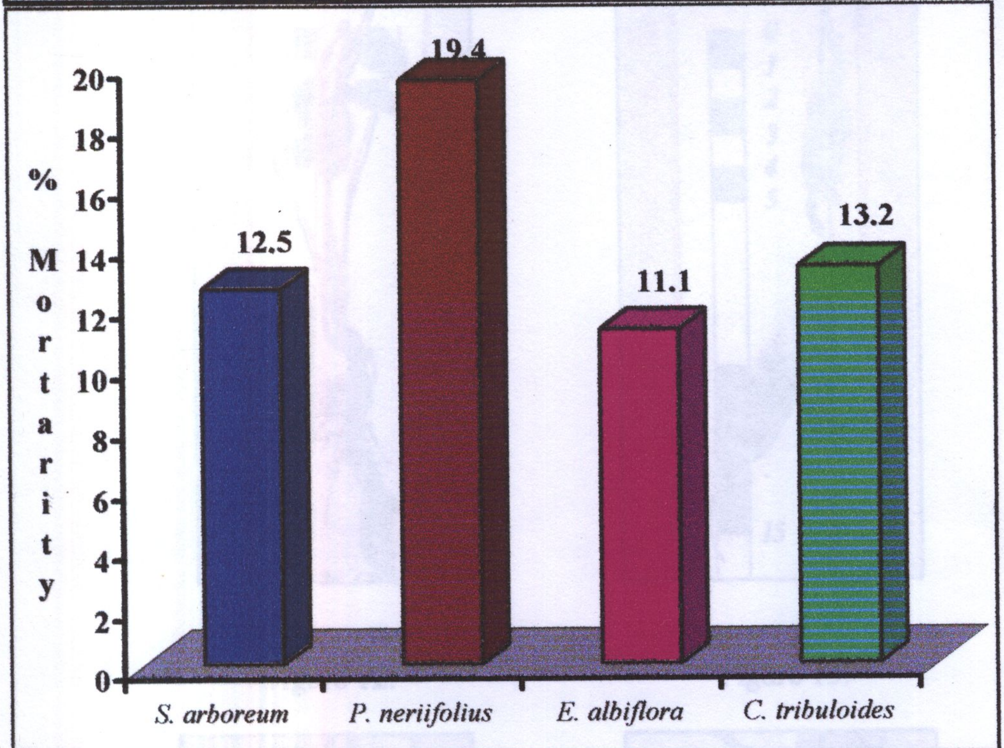
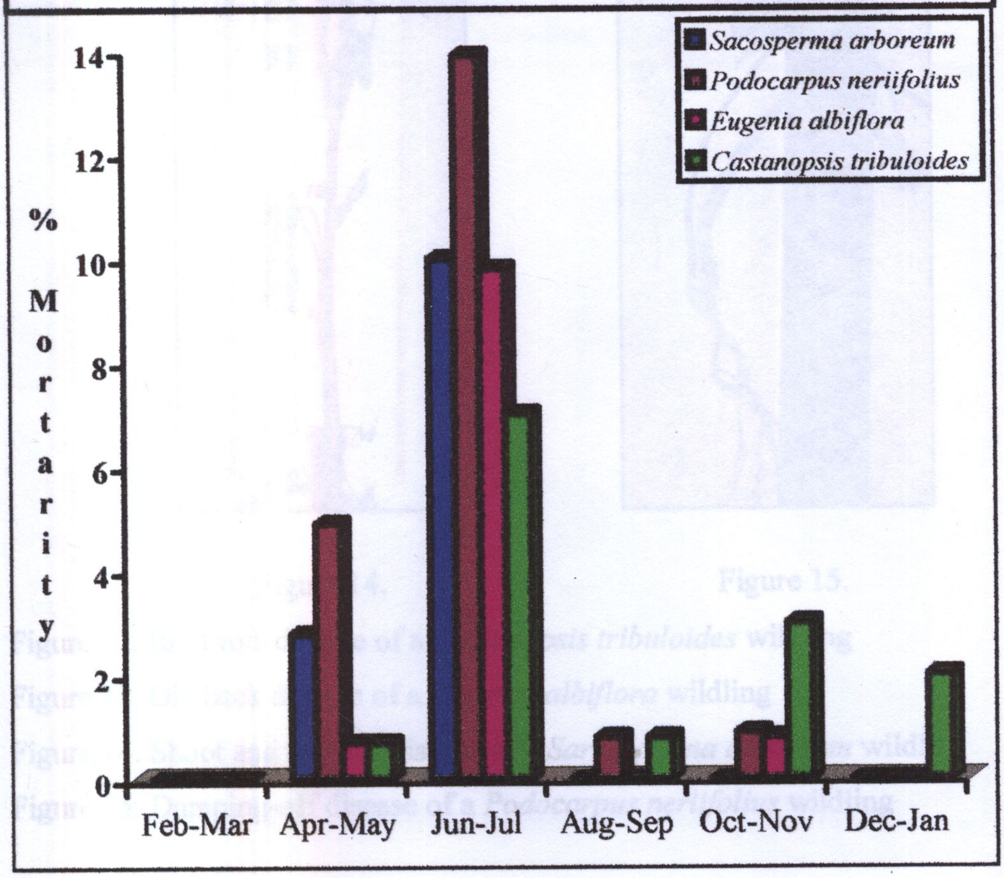


Figure 11. Percentage mortality according to month



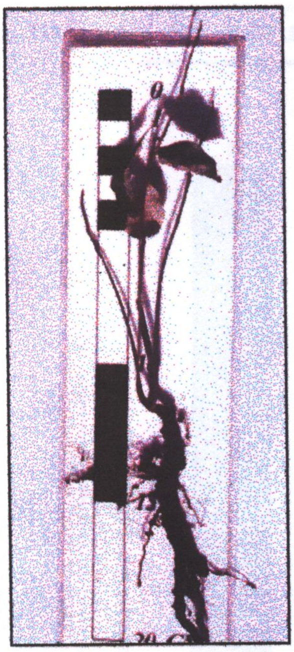


Figure 12.

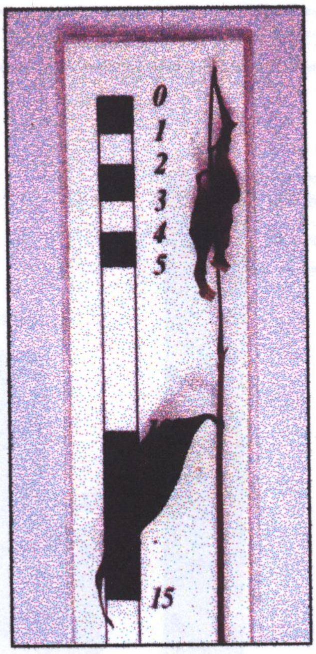


Figure 13.

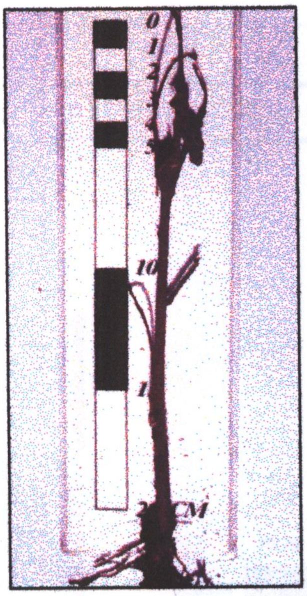


Figure 14.

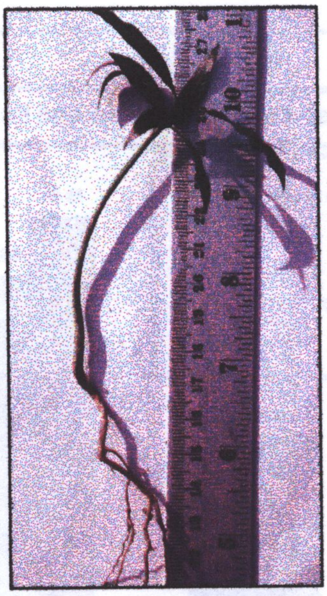


Figure 15.

Figure 12. Root rots disease of a *Castanopsis tribuloides* wildling

Figure 13. Die back disease of a *Eugenia albiflora* wildling

Figure 14. Shoot and root rot disease of a *Sarcosperma arboreum* wildling

Figure 15. Damping-off disease of a *Podocarpus neriifolius* wildling

Figure 16. Factors affecting mortality rates of wildlings in the forest

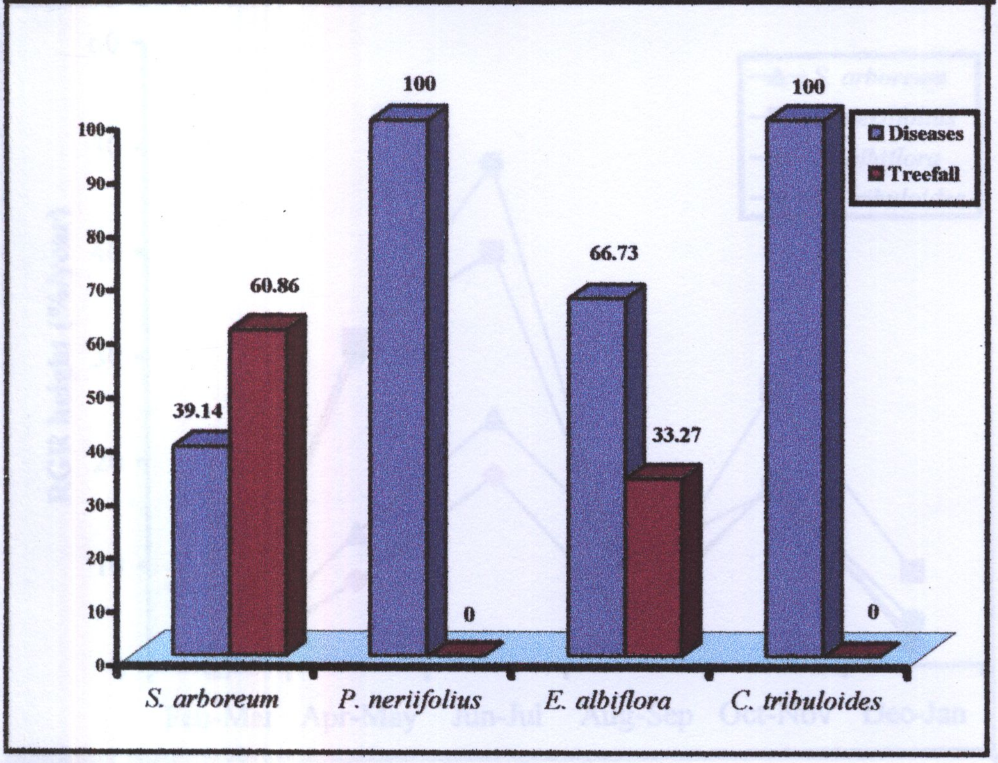


Figure 17. The mean height of wildlings when first and last measured in the forest

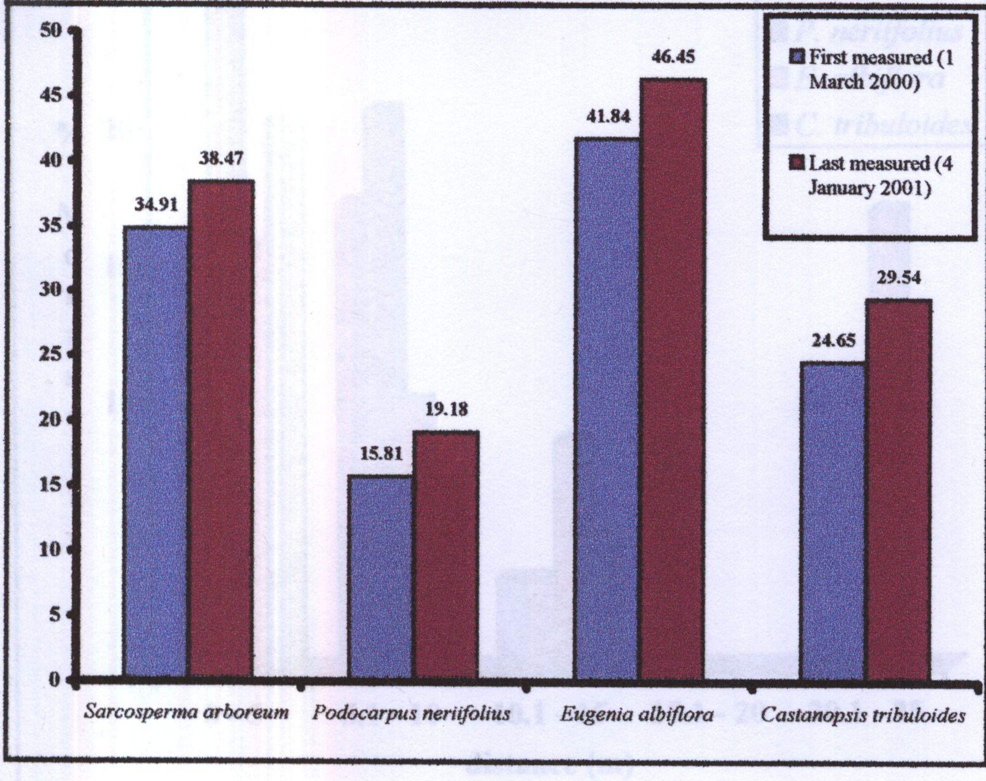


Figure 18. Mean relative growth rate of height through out the year

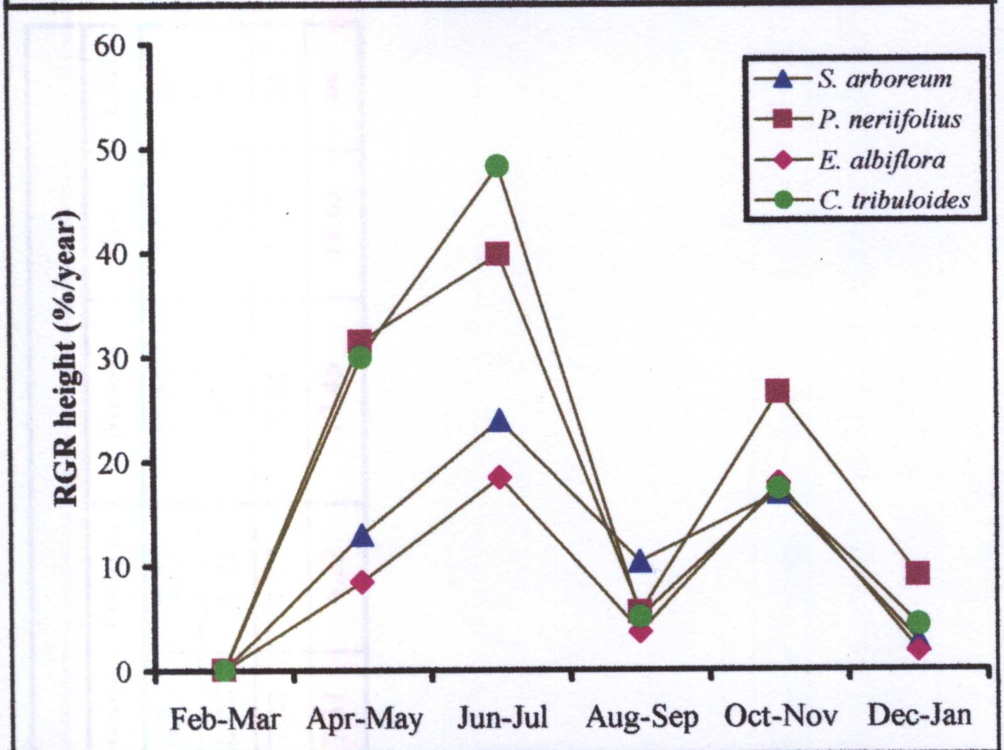


Figure 19. Percentage of mortality with distance from the mother tree

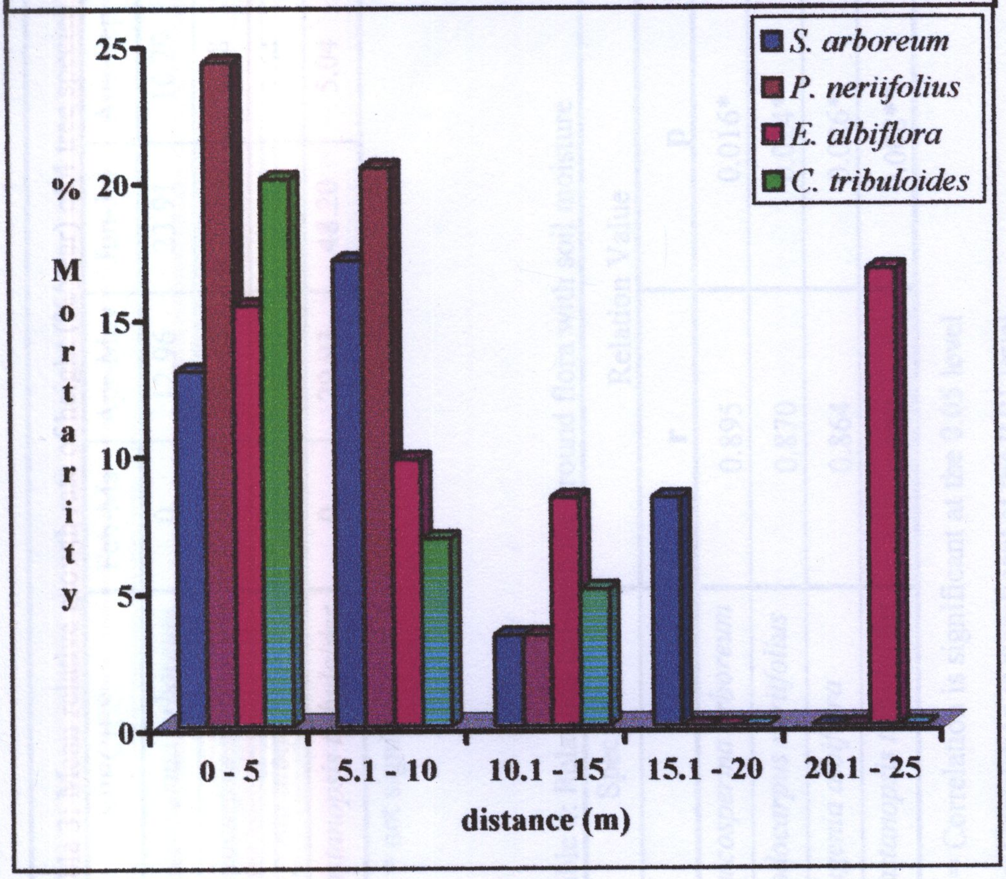


Table 3: Mean relative growth rate of height (%/year) of 4 tree species

SPECIES	Feb-Mar	Apr-May	Jun-Jul	Aug-Sep	Oct-Nov	Dec-Jan	**Mean**	SD	**LSD**
Sarcosperma arboreum	0	12.96	23.91	10.29	16.86	2.73	**11.12**	8.88	**ns**
Podocarpus neriifolius	0	31.36	39.76	5.48	26.48	8.93	**18.67**	16.03	**ns**
Eugenia albiflora	0	8.41	18.40	3.64	17.83	1.77	**8.34**	8.08	**ns**
Castanopsis tribuloides	0	29.93	48.20	5.04	17.31	4.22	**17.45**	18.63	**ns**

ns = not significant at the 0.05 level

Table 4: Relations between the ground flora with soil moisture

Species	Relation Value	
	r	**p**
Sarcosperma arboreum	0.895	0.016*
Podocarpus neriifolius	0.870	0.024*
Eugenia albiflora	0.864	0.026*
Castanopsis tribuloides	0.927	0.008**

* = Correlation is significant at the 0.05 level

**= Correlation is significant at the 0.01 level

Table 5: Relations between the field parameters with mortality rate

Species	distance		canopy cover		soil moisture		ground flora cover	
	r	**p**	**r**	**p**	**r**	**p**	**r**	**p**
Sarcosperma arboreum	-0.792	0.111	-0.002	0.997	0.719	0.108	-0.879	0.121
Podocarpus neriifolius	-0.925	0.024*	0.786	0.115	0.921**	0.009	-0.762	0.238
Eugenia albiflora	-0.170	0.785	0.892*	0.042	0.816*	0.047	-0.104	0.896
Castanopsis tribuloides	-0.903	0.036*	0.976**	0.005	0.935**	0.006	-0.340	0.660

* Correlation is significant at the 0.05 level

** Correlation is significant at the 0.01 level

Table 6: Relations between the field parameters with relative growth rate of height (%/year) in the forest

Species	distance		canopy cover		soil moisture		ground flora cover	
	r	**p**	**r**	**p**	**r**	**p**	**r**	**p**
Sarcosperma arboreum	-0.147	0.284	-0.137	0.323	0.591	0.094	0.088	0.563
Podocarpus neriifolius	-0.067	0.554	0.004	0.973	0.351	0.062	0.074	0.527
Eugenia albiflora	0.129	0.354	-0.138	0.319	0.517	0.103	0.042	0.767
Castanopsis tribuloides	0.105	0.384	-0.126	0.295	0.522	0.150	0.128	0.288

Nursery Experiments

Eugenia albiflora

Mean height of wildlings at first monitoring (15 March 2000): 24.1 $\pm$ 14.5 cm.

Mean height of wildlings at end of monitoring (10 December 2000): 44.8 $\pm$ 8.7 cm.

Percentage mortality of wildlings from potting to at end of monitoring (10 December 2000): 22.83 %

Mean health of wildlings at end of monitoring (10 December 2000): 2.7 (Table 12)

Relative growth rate

The **SN** treatment resulted in the highest relative growth rate of basal diameter (85.32 % yr^{-1}), significantly higher than all other treatments ($p<0.05$) (Table 7).

The **SP** and **SN** treatments resulted in the highest relative height growth rate (179.34 % yr^{-1} and 158.18 % yr^{-1}), significantly higher than all other treatments ($p<0.05$) (Table 7).

The **SP** treatment resulted in the highest relative growth rate of canopy (186.24 % yr^{-1}), significantly higher than all other treatments ($p<0.05$) (Table 7).

Castanosis tribuloides

Mean height of wildlings at first monitoring (13 March 2000): 23.7 $\pm$ 14.4 cm.

Mean height of wildlings at end of monitoring (8 December 2000): 26.1 $\pm$ 12.3 cm.

Percentage mortality of wildlings from potting to at end of monitoring (8 December 2000) 55.55 %

Mean health of wildlings at end of monitoring (8 December 2000): 2.4 (Table 12)

Relative growth rate

The **MP** and **SP** treatments resulted in the highest relative growth rate of basal diameter (38.81 % yr^{-1} and 31.94 % yr^{-1}), significantly higher than all other treatments ($p<0.05$) (Table 8).

The **SP** treatment resulted in the highest relative height growth rate (96.30 % yr^{-1}), significantly higher than all other treatments ($p<0.05$) (Table 8).

The **BP** treatment resulted in the highest relative growth rate of canopy (170.04 % yr^{-1}), significantly higher than all other treatments ($p<0.05$) (Table 8).

Sarcosperma arboreum

Mean height of wildlings at first monitoring (14 March 2000): 24.7 $\pm$ 13.5 cm.

Mean height of wildlings at end of monitoring (9 December 2000): 38.7 $\pm$ 9.6 cm.

Percentage mortality of wildlings from potting to at end of monitoring (9 December 2000): 27.07 %

Mean health of wildlings at end of monitoring (9 December 2000): 2.4 (Table 12)

Relative growth rate

The **SN** treatment resulted in the highest relative growth rate of basal diameter .88 % yr^{-1}), followed by **SP** (74.30 % yr^{-1}), **MN** (64.21 % yr^{-1}) and **MP** (61.41 % ^{1}). The results were statistically different ($p<0.05$) (Table 9).

The **SP** and **MP** treatments resulted in the highest relative height growth rate 20.73 % yr^{-1} and 99.73 % yr^{-1}), significantly higher than all other treatments (p .05) (Table 9).

The **MP** treatment resulted in the highest relative growth rate of canopy 33.66 % yr^{-1}), significantly higher than all other treatments ($p<0.05$) (Table 9).

docarpus neriifolius

ean height of wildlings at first monitoring (12 December 2000): 21.9 ± 12.9 cm.

ean height of wildlings at the end of monitoring (7 December 2000): 28.4 ±11.6 cm.

rcentage mortality of wildlings from potting to end of monitoring (7 December 00): 48.60 %

ean health of wildlings at the end of monitoring (7 December 2000): 2.7 (Table 12)

elative growth rate

The **SN** treatment resulted in the highest relative growth rate of basal diameter 4.59 % yr^{-1}), significantly higher than all other treatments ($p<0.05$) (Table 10).

The **SN** and **SP** treatments resulted in the highest relative height growth rate 08.22 % yr^{-1} and 78.00 % yr^{-1}), significantly higher than all other treatments (p 0.05) (Table 10).

The **SP** and **SN** treatments resulted in the highest relative growth rate of the canopy (154.91 % yr^{-1} and 140.21 % yr^{-1}), which was significantly higher than all other treatments ($p<0.05$) (Table 10).

EFFECTS OF TREATMENTS

Analyses were carried out on data collected at the end of monitoring (9 months after planting in plastic bags). The statistical test applied was ANOVA using the SPSS program. Results are stated as "significant" if $p<0.05$.

MORTALITY Mean mortality of all species for all treatments was 38.52 %. Averaging for all treatments, *Castanopsis tribuloides* had the highest mortality rate (55.55%), which was significantly higher compared with the other species, except for *Podocarpus neriifolius* (48.60 %). For individual treatments, averages for all species, the **SN** treatment resulted in the highest mortality (59.37 %), significantly higher compared with the **MP** and **SP** treatments, but not significantly higher compared with the other treatments (ANOVA, $p<0.05$) (Table 11).

RELATIVE GROWTH RATE Averaging for all species and treatments, the mean height % RGR yr^{-1} was 56.56 % yr^{-1} (Table 13). Averaging across treatments for individual species, *Eugenia albiflora* had the highest mean height % RGR (97.61 % yr^{-1}) (Table 7). It was not significantly higher compared with the other species, except for *Castanopsis tribuloides* (13.47 % yr^{-1}) (Table 8). Averaging for all species, the **SP** treatment resulted in the highest mean height %RGR (118.6 % yr^{-1}), but it was not significantly higher compared with other treatments, except for the **BN** and **MN** treatments (ANOVA, $p<0.05$) (Table 13).

Averaging across species and treatments, the mean % RGR of basal diameter was 37.23 % yr^{-1} (Table 14). Averaging across treatments, for individual species, *Sarcosperma arboreum* (58.76 % yr^{-1}) (Table 9) and *Eugenia albiflora* (53.5 % yr^{-1}) (Table 7) had the highest mean % RGR, significantly higher than for other species. Averaging across all species, the **SN** treatment resulted in the highest mean % RGR (62.52 % yr^{-1}), but was not significantly higher compared with other treatments, except for **BP** treatment (ANOVA, $p<0.05$) (Table 14).

Averaging across species and treatments, the mean % RGR of canopy was 124.97 % yr^{-1} (Table 15). Averaging across treatments, *Sarcosperma arboreum* resulted in, significantly, the highest mean % RGR (252.45 % yr^{-1}) (Table 9), compared with other species. Averaging across all species, the **MP** treatment resulted in the highest mean % RGR (193.4 % yr^{-1}), but this value was not significantly higher than all other treatments (ANOVA, $p<0.05$) (Table 15).

Mean height, averaged across all species and all treatments, was 34.49 cm (Table 16). *Eugenia albiflora* had the highest mean height (44.85 cm) (Table 16). Although at the end of the experiment it did not grow significantly taller compared with *Sarcosperma arboreum* (38.67 cm) (Table 16), the differences compared with other species were significant. For individual treatments, averaging across the species, the **BN** and **BP** treatments resulted in the highest mean height (47.18 cm and 43.90

cm), but seedlings not grow significantly taller compared with other treatments, except for the **SN** and **SP** treatments (ANOVA, $p<0.05$) (Table 16).

EFFECTS OF SEEDLING SIZE

Seedlings in the **small** size class (0-20 cm tall) had highest mortality (41.66 %), followed by **big** seedlings (41-60 cm tall) 40.1 % and **medium** seedlings (21-40 cm tall) 33.85 %, but the differences among size classes were not significant (ANOVA, $p<0.05$) (Table 17).

The **small** size class had the highest mean % RGR height (99.98 % yr^{-1}) significantly higher compared with other size class (ANOVA, $p<0.05$) (Table 17).

The **medium** size class had the highest mean % RGR of canopy (129.3 % yr^{-1}), followed by the **small** size class (128.96 % yr^{-1}) and the **big** size class (116.63 % yr^{-1}), but the differences were not statistically significant (ANOVA, $p<0.05$) (Table 17).

The **small** size class had the highest mean % RGR of basal diameter (54.71 % yr^{-1}) significantly higher compared with **big** seedlings, but it was not significantly higher compared with **medium** seedlings (ANOVA, $p<0.05$) (Table 17).

PRUNING

The statistical test used was Student's t-tests. Results are stated as "significant" if $p<0.05$.

Mortality

No pruning resulted in the highest mortality (51.03 %), compared with **Pruning** (26.03 %). The difference was statistically significant (at $p<0.05$) (T-test, $p=0.000$) (Table 18).

Relative height growth rate

Pruning resulted in the highest mean % RGR of height (85.06 % yr^{-1}), significantly higher (at $p<0.05$) (T-test, $p=0.002$), compared with **no pruning** (28.07 % yr^{-1}) (Table 18).

Relative growth rate of canopy

Pruning resulted in the highest mean % RGR of canopy (176.06 % yr^{-1}), significantly (at $p<0.05$) (T-test, $p=0.002$), compared with **no pruning** (73.88 % yr^{-1}) (Table 18).

Relative growth rate of basal diameter

No pruning resulted in the highest mean % RGR of basal diameter (38.78 % yr^{-1}), it was not significantly higher (at $p<0.05$) (T-test, $p=0.669$), compared with **pruning** (35.68 % yr^{-1}) (Table 18).

Table 7. Mean Relative Growth Rate (%/year) of *Eugenia albiflora* with 6 Treatments

TREAT	DIAMETER			HEIGHT			CANOPY		
MENTS	MEAN	SD	LSD	MEAN	SD	LSD	MEAN	SD	LSD
BN	**32.41**	31.6	**c**	**16.54**	32.40	**c**	**71.87**	85.01	**c**
MN	**56.80**	37.87	**bc**	**41.24**	58.07	**c**	**128.19**	67.48	**b**
SN	**85.32***	45.17	**a**	**158.18***	50.20	**a**	**156.52**	81.21	**ab**
BP	**29.20**	22.33	**c**	**83.80**	36.78	**b**	**132.77**	60.32	**b**
MP	**56.93**	40.38	**b**	**106.60**	54.17	**b**	**110.49**	83.69	**bc**
SP	**60.38**	32.03	**b**	**179.34***	45.82	**a**	**186.24***	55.8	**a**
MEAN	**53.5**			**97.61**			**131.01**		

Table 8. Mean Relative Growth Rate (%/year) of *Castanopsis tribuloides* with 6 Treatments

TREAT	DIAMETER			HEIGHT			CANOPY		
MENTS	MEAN	SD	LSD	MEAN	SD	LSD	MEAN	SD	LSD
BN	**16.13**	36.74	**ab**	**-44.37**	47.99	**c**	**8.00**	64.87	**bc**
MN	**-25.33**	92.09	**b**	**-75.76**	65.23	**c**	**-47.70**	58.27	**c**
SN	**21.30**	42.58	**ab**	**-17.28**	47.41	**c**	**-33.47**	67.78	**bc**
BP	**12.04**	55.08	**ab**	**49.25**	48.47	**b**	**170.04***	257.31	**a**
MP	**38.81***	35.60	**a**	**72.69**	51.45	**ab**	**66.92**	84.76	**bc**
SP	**31.94***	39.70	**a**	**96.3***	50.58	**a**	**86.22**	78.05	**ab**
MEAN	**15.81**			**13.47**			**41.66**		

Table 9. Mean Relative Growth Rate (%/year) of *Sarcosperma arboreum* with 6 Treatments

TREAT	DIAMETER			HEIGHT			CANOPY		
MENTS	MEAN	SD	LSD	MEAN	SD	LSD	MEAN	SD	LSD
BN	**30.76**	48.93	**b**	**-11.67**	60.32	**c**	**119.94**	50.40	**c**
MN	**64.21***	34.61	**a**	**44.48**	58.75	**b**	**149.75**	57.57	**c**
SN	**88.88***	17.88	**a**	**76.40**	18.84	**ab**	**146.94**	56.25	**c**
BP	**33.03**	44.35	**b**	**53.57**	66.73	**b**	**370.24**	377.20	**b**
MP	**61.41***	33.12	**a**	**99.73***	45.16	**a**	**533.66***	417.89	**a**
SP	**74.3***	41.80	**a**	**120.73***	47.17	**a**	**194.18**	74.69	**c**
MEAN	**58.76**			**63.87**			**252.45**		

Table 10. Mean Relative Growth Rate (%/year) of *Podocarpus neriifolius* with 6 Treatments

TREAT	DIAMETER			HEIGHT			CANOPY		
MENTS	MEAN	SD	LSD	MEAN	SD	LSD	MEAN	SD	LSD
BN	**22.95**	25.47	**b**	**19.55**	29.14	**b**	**15.58**	28.27	**b**
MN	**17.44**	24.44	**b**	**21.32**	42.23	**b**	**30.74**	28.63	**b**
SN	**54.59***	30.95	**a**	**108.22***	73.98	**a**	**140.21***	65.61	**a**
BP	**3.94**	24.03	**b**	**32.81**	23.61	**b**	**44.63**	47.22	**b**
MP	**5.15**	16.22	**b**	**47.94**	41.17	**b**	**62.42**	64.56	**b**
SP	**21.04**	19.52	**b**	**78***	35.71	**a**	**154.91***	44.44	**a**
MEAN	**20.81**			**51.30**			**74.74**		

Table 11. Percentage mortality of 4 tree spcies with 6 treatments in the nursery

Species	**Treatment**						**Species mean**	**LSD**
	BN	**MN**	**SN**	**BP**	**MP**	**SP**		
Eugenia albiflora	33.33	41.66	25.00	4.16	25.00	8.33	**22.83**	**c**
Podocarpus neriifolious	75.00	45.83	66.66	54.16	20.83	29.16	**48.60**	**ab**
Castanosis tribuloides	70.83	70.83	79.16	45.83	33.33	33.33	**55.55***	**a**
Sarcosperma arboreum	20.83	16.66	66.66	16.66	16.66	25.00	**27.07**	**bc**
Treatment means	**49.99**	**43.74**	**59.37***	**30.20**	**23.95**	**23.95**	**38.52**	
LSD	**ab**	**ab**	**a**	**ab**	**b**	**b**		

Table 12. Mean health of 4 tree spcies with treatments in the nursery

Species	**Treatment**						**Species mean**	**LSD**
	BN	**MN**	**SN**	**BP**	**MP**	**SP**		
Eugenia albiflora	2.8	2.7	2.9	2.8	2.2	2.8	**2.7***	**a**
Podocarpus neriifolious	2.7	2.7	2.6	2.7	2.6	2.9	**2.7***	**a**
Castanosis tribuloides	2.6	2.4	2.1	2.6	2.5	2.2	**2.4**	**b**
Sarcosperma arboreum	2.6	2.4	2.4	2.4	2.5	2.3	**2.4**	**b**
Treatment means	**2.7**	**2.6**	**2.5**	**2.6**	**2.5**	**2.6**		
LSD	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**		

* = significant at the 0.05 level

ns = not significant

Table 13. Mean relative growth rate of height (%/year) of 4 tree species at the end of monitoring with treatments

Species	Treatment												specie		
	BN	SD	MN	SD	SN	SD	BP	SD	MP	SD	SP	SD	means	SD	LSD
E. albiflora	16.54	32.40	41.24	58.08	158.2	50.21	83.80	36.78	106.6	54.18	179.3	45.82	**97.61***	63.82	a
P. neriifolious	19.55	29.15	21.32	42.24	108.2	73.98	32.81	23.61	47.94	41.17	78.00	35.71	**51.3**	35.25	ab
C. tribuloides	-44.4	47.99	-75.8	65.23	-17.3	47.42	49.25	48.48	72.69	51.45	96.30	50.58	**13.47**	69.13	b
S. arboreum	-11.7	60.32	44.48	58.75	76.40	18.84	53.57	66.74	99.73	45.16	120.7	47.17	**63.87**	46.61	ab
Treatment means	**-4.98**		**7.82**		**81.38***		**54.85**		**81.74***		**118.59***		**56.56**		
SD	29.78		56.65		73.88		21.26		26.87		44.11				
LSD	**b**		**b**		**a**		**ab**		**a**		**a**				

Table 14. Mean relative growth rate of basal diameter (%/year) of 4 tree species at the end of monitoring with treatments

Species	Treatment												specie		
	BN	SD	MN	SD	SN	SD	BP	SD	MP	SD	SP	SD	means	SD	LSD
E. albiflora	32.41	31.60	56.80	37.88	85.31	45.17	29.20	22.33	56.93	40.39	60.38	32.03	**53.5***	20.57	a
P. neriifolious	22.95	25.47	17.44	24.45	54.59	30.95	3.94	24.04	5.15	16.22	21.04	19.53	**20.85**	18.36	b
C. tribuloides	16.13	36.75	-25.3	92.09	21.30	42.58	12.04	55.09	38.81	35.61	31.94	39.7	**15.81**	22.47	b
S. arboreum	30.76	48.94	64.21	34.62	88.88	17.88	33.03	44.36	61.41	33.13	74.30	41.8	**58.76***	22.94	a
Treatment means	**25.56**		**28.28**		**62.52***		**19.55**		**40.57**		**46.91**		**37.23**		
SD	7.52		41.21		31.49		13.84		25.55		24.66				
LSD	**ab**		**ab**		**a**		**b**		**ab**		**ab**				

Table 15. Mean relative growth rate of canopy (%/year) of 4 tree species at the end of monitoring with treatments

Species	**Treatment**												**specie**		
	BN	SD	**MN**	SD	**SN**	SD	**BP**	SD	**MP**	SD	**SP**	SD	**means**	SD	**LSD**
E. albiflora	71.87	85.01	128.2	67.48	156.5	81.22	132.8	60.32	110.5	83.70	186.2	55.80	**131.01**	39.06	**b**
P. neriifolious	15.58	28.28	30.74	28.63	140.2	65.61	44.63	47.22	62.42	64.56	154.9	44.45	**74.74**	58.66	**b**
C. tribuloides	8.00	64.87	-47.7	58.27	-33.5	67.78	170.0	257.3	66.92	84.76	86.22	78.06	**41.66**	82.30	**b**
S. arboreum	119.9	50.40	149.8	57.57	146.9	56.26	370.2	377.2	533.7	417.9	194.2	74.70	**252.45***	164.7	**a**
Treatment means	**53.84**		**65.24**		**102.5**		**179.4**		**193.4**		**155.4**		**124.97**		
SD	52.47		91.37		90.92		137.7		227.9		49.12				
LSD	**ns**		**ns**		**ns**		**ns**		**ns**		**ns**				

Table 16. Mean height of 4 tree species at the end of monitoring with treatments

Species	**Treatment**												**specie**		
	BN	SD	**MN**	SD	**SN**	SD	**BP**	SD	**MP**	SD	**SP**	SD	**means**	SD	**LSD**
E. albiflora	55.75	12.02	44.50	16.88	41.83	16.07	54.87	14.41	37.40	14.17	34.77	10.94	**44.85***	8.7	**a**
P. neriifolious	49.16	10.53	29.69	8.84	20.75	9.03	31.27	5.13	23.21	6.80	16.11	3.99	**28.36**	11.63	**b**
C. tribuloides	37.14	13.08	16.71	7.93	12.30	5.78	42.61	15.58	30.12	12.85	17.81	6.29	**26.11**	12.31	**b**
S. arboreum	46.68	17.27	45.35	17.17	28.62	4.30	46.85	19.58	39.35	13.63	25.22	8.65	**38.67**	9.57	**ab**
Treatment means	**47.18***		**34.06**		**25.87**		**43.9***		**32.52**		**23.47**		**34.49**		
SD	7.71		13.62		12.55		9.83		7.36		8.50				
LSD	**a**		**ab**		**b**		**a**		**ab**		**b**				

Table 17. Mean of 4 wildling species with 3 difference sizes averaged across pruning method at the end of monitoring

Size of seedling	%Mortality			RGR height			RGR canopy			RGR diameter		
	Mean	SD	**LSD**	**Mean**	SD	**LSD**	**Mean**	SD	**LSD**	**Mean**	SD	**LSD**
Big seedling	**40.1**	25.77	**ns**	**24.93**	39.96	**b**	**116.63**	117.49	**ns**	**22.55**	10.8	**b**
Medium seedling	**33.85**	18.55	**ns**	**44.78**	56.98	**b**	**129.3**	174.71	**ns**	**34.42**	32.42	**ab**
Small seedling	**41.66**	25.48	**ns**	**99.98***	59.74	**a**	**128.96**	73.31	**ns**	**54.71***	27.48	**a**

Table 18. Mean of 4 wildling species with 2 pruning treatments averaged across size classes at the end of monitoring

Pruning treatments	%Mortality			RGR height			RGR canopy			RGR diameter		
	Mean	SD	**LSD**	**Mean**	SD	**LSD**	**Mean**	SD	**LSD**	**Mean**	SD	**LSD**
No pruning	**51.03***	23.03	**a**	**28.07**	64.69	**b**	**73.88**	75.86	**b**	**38.78**	32.52	**ns**
Pruning	**26.03**	14.44	**b**	**85.06***	39.94	**a**	**176.06***	142.3	**a**	**35.68**	23.35	**ns**

ns = non significant

* = Significant at 0.05 level

** = Significant at 0.01 level

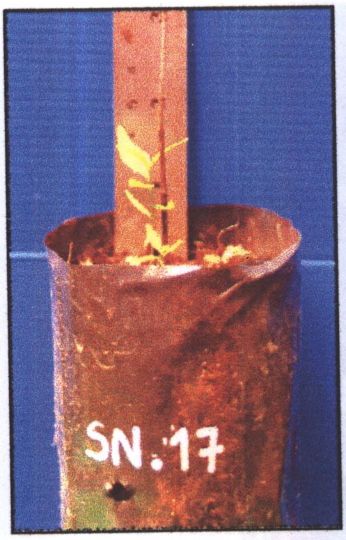


Figure 20.

Figure 21.

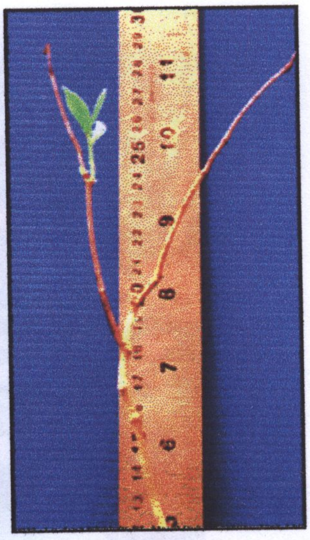


Figure 22.

Figure 23.

Figure 24.

Figure 25.

Figure 20. SN treatment of *E. albiflora* wildling 45 days after transplanting

Figure 21. MN treatment of *E. albiflora* wildling 45 days after transplanting

Figure 22. BN treatment of *E. albiflora* wildling 45 days after transplanting

Figure 23. SP treatment of *S. arboreum* wildling 45 days after transplanting

Figure 24. MP treatment of *S. arboreum* wildling 45 days after transplanting

Figure 25. BP treatment of *S. arboreum* wildling 45 days after transplanting

Figure 26. Canopy of MN treatment of *E. albiflora* wildling 9 months after transplanting

Figure 27. Canopy of MP treatment of *E. albiflora* wildling 9 months after transplanting

DISCUSSION

IN THE FOREST

Most of the wildlings of all four species measured in the forest grew very slowly, averaging approximately 4-5 cm in height, over the course of the study (Figure 17). For all species, most mortality occurred at the beginning of the rainy season (June-July) (Figure 11). Some factors causing this included diseases and tree falls (Figures 12-16). My results agree with those of Smith (1970), who reported that forest diseases are often related to soil moisture conditions. Common diseases, which damage or kill natural tree seedlings, are usually fungal and occurred during the rainy season. Another factor causing wildling mortality was tree and branch falls (Figure 16). This observation is in agreement with Whitmore (1978) who reported that most tree falls in tropical forests occur in the rainy season.

Podocarpus neriifolius is a rare species in northern Thailand (Maxwell and Elliott, 2001). The result showed wildlings had the highest mean mortality over 1 year 19.4 % (Figure 10) and most mortality occurred at a distance of less than 5 m from the parent tree (Figure 11). I suggest that further studies are needed to investigate the performance of seeds and seedlings, the efficiency of natural establishment and seed dispersal. One problem might be that animals, which are necessary for seed dispersal are no longer present in the area. Assisting recruitment of wildlings after germination is a challenge since this specie requires pristine upland seasonal evergreen forest, especially in water catchment valleys.

Relative growth rate was maximum at the beginning of the rainy season (June-July) for all species (Figure 18), because early rains stimulated wildling growth and triggered production of new leaves, branches and roots. During this time the young tissues are highly susceptible to infection by various diseases. Smith (1970) also reported that the beginning of disease infection usually occurs on the young parts of wildlings.

Factors Affecting Survival and Growth of Wildlings

Distance from parent tree

Wildling mortality significantly decreased with increasing distance from the parent tree for ***Podocarpus neriifolius*** and ***Castanopsis tribuloides*** (Figure 19 and Tables 5, 19). This supports the Jansen-Connell (1970,1971) model of optimum dispersal distance. They hypothesized that wildlings close to the parent tree occur in high densities with high competition, which cause slow growth rates and high mortality. Wildlings of ***Eugenia albiflora*** and ***Sarcosperma arboreum*** had no relationship between distance from parent tree and mortality (Figure 19 and Tables 5, 19). This contrasts with Jansen-Connell's model. I suggest that this was because other factors caused mortality of those species, including tree and branch falls (Figure 16).

Correlation analysis failed to detect a significant linear relationship between distance from the parent tree and relative growth rate of height of all species. This result is in disagreement with the Jansen-Connell model (Table 6). It may be that under the canopy of primary evergreen forest, seedlings growing far from the parent tree are in competition with other trees nearby. I think that the Jansen-Connell model of optimal dispersal distance should be tested only if the parent tree is isolated far from conspecifics and the density of other trees is low. This model is only a theory and has not been tested in Thailand, especially in Doi Suthep-Pui National Park. It may be true for some species, false for others. In addition to seedling/sapling diseases, tree and branch falls, which I know to be factors affecting seedling survival, I also think that predation and trampling by large animals, at least in other areas where the fauna has not been devastated as in my study area, must also be considered. The specific ecologies of each parent tree, i.e. condition of the forest, animal activity, wind, *etc.* and the Jansen-Connell model should be studied intensely. Since Doi Suthep-Pui National Park includes other distinct forest habitats, *e.g.* deciduous dipterocarp-oak, mixed evergreen + deciduous seasonal forest, pine areas, *etc.* more studies similar to my work should be done and the Jansen-Connell model tested.

Canopy cover

Canopy cover in the forest was not very variable (about 70-80%). Canopy cover showed a positive and significant correlation with mortality rates of ***Eugenia albiflora*** and ***Castanopsis tribuloides*** wildlings (Tables 5 and 19). This was probably because the parent trees of these species had more densely spreading crowns compared with those of ***Podocarpus neriifolius*** and ***Sarcosperma arboreum*** (Tables 5 and 19), causing deep shade and high humidity, which facilitated spread of diseases, especially in the rainy season.

There was no relationship between percent canopy cover and relative growth rate for height (Table 6). I suggest that this was because most of the species studied are primary evergreen forest tree species (shade-tolerant tree species). Canopy density would have a greater effect should on pioneer species (light-loving tree species). Another reason for no relationship might be the rather crude scale and subjectivity used to quantify canopy density. Improved methods and more sophisticated equipment should be developed for scientists to study the canopy effect of tropical forests.

Soil moisture

Soil moisture had a significantly positive correlation with the mortality rates of 3 species (except *Sarcosperma arboreum*) (Tables 5 and 19). This result agrees with Woods *et al.* (1957), who reported that forest diseases are often related to soil conditions, especially fungal diseases.

Soil moisture was not significantly correlated with relative growth rate of height for all species (Table 6). This result contrasts with the findings of Smith (1963), who reported that successful germination and seedling establishment in Malaysians forest require a constantly moist soil. One possible explanation for the lack of a relationship between soil moisture and wildling growth is that northern Thailand has a seasonal climate and totally different flora from which Smith studied. In my study areas ground flora increased where high soil moisture was inhibiting growth of wildlings, since there was a significant positive correlation between soil moisture and ground flora density (Table 4).

Ground flora competition

Ground flora in the forest was very sparse (<30% of ground flora cover) for all species. There was no significant correlation between ground flora cover and relative growth rate and mortality rate for all species (Tables 5-6 and 19). I suggest that ground flora are a serious problem in deforested areas, but not in the forest, because lack of light, especially in evergreen forest, which has deep shade and a closed canopy, limits ground flora growth and excludes weeds. Another reason for no relationship might be that the equipment used to measure ground flora competition only considered above-ground parts. Root competition under ground was not assessed.

IN THE NURSERY

Transplantating of wildlings from forests into nurseries should be done at the beginning of the rainy season, because at that time most natural mortality had not yet occurred. The soil is very soft, so seedlings are easily dug up, without injuring the roots. Great care should be taken when digging up seedlings, so that water loss by transpiration through the leaves is not greater than can be supplied by the injured root system (Adriance and Brison, 1995). Wildlings should be dug up at a distance of not more than 5 m from the parent tree, because of the high wildling density that occurs there. If wildlings are removed within this distance, wildling density is decreased near the parent tree, thus reducing intraspecific competition. Furthermore, removing wildling where density is high saves times and labor during collection.

EFFECTS OF SEEDLING SIZE AND PRUNING

The optimum height of wildlings for transfer was not more than 20 cm. Seedlings of that size have high relative growth rates, high survival, and the roots could be dug out of the ground relatively rapidly, with low root injury, which reduced the transplantating shock. Pruning substantially reduced wildling mortality following transfer to the nursery (Tables 17-18). This result was in agreement with Sunset (1983) who reported that pruning of leaves compensates for root damage during transplantating. Digging up wildlings severs many small roots, which reduces water supply to the leaves. This can cause wilting and eventual death of the plants. Pruning of leaves restores a balance between the reduced amount of water supplied by the damaged roots and the transpiration levels of the leaves. Another advantage of pruning was that it promoted branching causing the seedlings to develop a dense canopy (Table 18 and Figures 26-27), which would help to out-compete weeds after planting out.

Castanopsis tribuloides had the highest mortality rate and slowest relative growth rate (Tables 11 and Table 13). FORRU (2000) reported that for this species, production of seedlings from seed was problematic because germination was very slow, 86% over 27-144 days, asynchronous, and seedlings were not ready for planting in the first year after seed collection. Possibly, slow growth is natural for this species, because it produces a very hard, dense wood. I suggest that further research is necessary for this specie, especially about mycorrhizal infection factors. New methods of transplanting it from the forest to the nursery may be developed by digging up wildlings with soil.

From the results, in general the optimum height of wildlings for transfer was not more than 20 cm with pruning (cutback 50% of shoot) before transfer to plastic bags (SP). This treatment showed a high relative growth rate and high percentage of survival. During seedling production to restore forests, all seedlings must reach a plantable size (40-60 cm tall) at the planting season (May-June in northern, Thailand). Also it is not wanted to keep seedlings in nursery more than 1 year. Comparison about producing seedlings from wildlings and from seeds is different for each species.

Sarcosperma arboreum

To produce 100 seedlings, dig up 120 seedlings (to allow for 83 % survival) 41-60 cm tall in June, within 5 m of the parent tree. Prune (cutback 50% of shoot), then transfer to plastic bags. After approximately 1 year in the nursery, the saplings should have regrown to approximately 47 cm tall and be ready for planting (Table 20).

In contrast, to grow *Sarcosperma arboreum* seedlings from seed requires collection of 263 seeds (to allow for only 38 % survival) in July. Seedlings can be pricked out 2 months after sowing. Potted seedlings must be kept in the nursery a further 21 months before the saplings are ready for planting. Therefore, using wildlings reduces the time required to produce plantable saplings by 11 months (Table 20).

Castanopsis tribuloides

To produce 100 seedlings, dig up 185 seedlings (to allow for 54 % survival) 41-60 cm tall in June, within 5 m of the parent tree. Prune (cutback 50% of shoot), then transfer to plastic bags. After approximately 1 year in the nursery, the saplings should be approximately 43 cm tall and ready for planting (Table 20).

In contrast, to grow *Castanopsis tribuloides* seedlings from seed requires collection of 125 seeds (to allow for 80 % survival) in October. Seedlings can be pricked out 5 months after sowing. Potted seedlings must be kept in the nursery a further 15 months before the saplings are ready for planting. Therefore, using wildlings reduces the time required to produce plantable saplings by 8 months (Table 20).

Podocarpus neriifolius

To produce 100 seedlings, dig up 127 seedlings (to allow for 79 % survival) 21-40 cm tall in June, within 5 m of the parent tree. Prune (cutback 50% of shoot), then transfer to plastic bags. After approximately 2 years in the nursery, the saplings should be approximately 45 cm tall and ready for planting (Table 20).

In contrast, to grow *Podocarpus neriifolius* seedlings from seed requires collection of 250 seeds (to allow for 40 % survival) in August. Seedlings can be pricked out 2 months after sowing. Potted seedlings must be kept in the nursery a further 32 months before the saplings are ready for planting. Therefore, using wildlings reduces the time required to produce plantable saplings by 11 months (Table 20).

Eugenia albiflora

To produce 100 seedlings, dig up 104 seedlings (to allow for 96 % survival) 41-60 cm tall in June, within 5 m of the parent tree. Prune (cutback 50% of shoot), then transfer to plastic bags. After approximately 1 year in the nursery, the saplings should be approximately 55 cm tall and ready for planting (Table 20).

In contrast, to grow *Eugenia albiflora* seedlings from seed requires collection of 294 seeds (to allow for 34 % survival) in May. Seedlings can be pricked out 5 months after sowing. Potted seedlings must be kept in the nursery a further 8 months before the saplings are ready for planting. Therefore, using wildlings reduces the time required to produce plantable saplings by 1 month (Table 20).

Table 19. Relations between factors with mortality rate in the forest for all species

FACTORS	POSITIVE CORRE.	NEGATIVE CORRE.	NOT CORRE.
DISTANCE FROM MOTHER TREE		_P. neriifolius_*	_E. albiflora_
		_C. tribuloides_*	_S. arboreum_
CANOPY COVER	_E. albiflora_*		_P. neriifolius_
	C. tribuloides**		_S. arboreum_
SOIL MOISTURE	_E. albiflora_*		_S. arboreum_
	C. tribuloides**		
	P. neriifolius**		
GROUND FLORA COMPETITION			_E. albiflora_
			C. tribuloides
			P. neriifolius
			S. arboreum

* = correlation is significant at the 0.05 level (2-tailed)

** = correlation is significant at the 0.01 level (2-tailed)

Table 20. Production schedule compairing production of seedlings from seed and from wildlings

SPECIES	YEAR 1												YEAR 2												YEAR 3						JUNE YEAR 4
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	
S. arboreum																															
seed							**S**	*	**P**	*	*	*	*	*	*	*	*	**NR**	*	*	*	*	*	*	*	*	*	*	*	**R**	
wildling(BP)						**W**	*	*	*	*	*	*	*	*	*	*	*	**R**													
C. tribuloides																															
seed										**S**	*	*	*	*	**P**	*	*	**NR**	*	*	*	*	*	*	*	*	*	*	*	**R**	
wildling(BP)						**W**	*	*	*	*	*	*	*	*	*	*	*	**R**													
P. neriifolius																															
seed								**S**	*	**P**	*	*	*	*	*	*	*	**NR**	*	*	*	*	*	*	*	*	*	*	*	**NR**	**R**
wildling(MP)						**W**	*	*	*	*	*	*	*	*	*	*	*	**NR**	*	*	*	*	*	*	*	*	*	*	*	**R**	
E. albiflora																															
seed					**S**	*	*	*	*	**P**	*	*	*	*	*	*	*	**R**													
wildling(BP)						**W**	*	*	*	*	*	*	*	*	*	*	*	**R**													

S = collecting and sowings seeds

W = wildling collection

P = pricking out and potting seedlings

* = time in the nursery

NR = not ready for planting

R = ready for planting

CONCLUSIONS

1. For all species, most wildlings in the forest grew very slowly, averaging approximately 4-5 cm in height/year and most wildling mortality occurred at the beginning of the rainy season.
2. Factors causing mortality of wildlings in the forest of all species included seedling diseases and tree falls.
3. Distance from the parent tree, especially less than 5 meters, combined with dense canopy cover and high soil moisture were important factors decreasing survival of wildlings (not for *S. arboreum and E. albiflora*), but these factors in total, had no affect on growth.
4. Transplantation of wildlings from forests into nurseries should be done at the beginning of the rainy season and for conservation purposes wildlings possibly should be dug up at a distance of not more than 5 m from the parent tree.
5. The optimum height of wildlings for transfer should be not more than 20 cm
6. Pruning (stem and leaf) before transferring wildlings into plastic bags helped to reduce transplantating shock, increased survival percentage and growth rate of wildlings.

RECOMMENDATIONS

1. Further research is necessary for better understanding about seed, seedling diseases in nature and methods to stop the spread of diseases among wildlings.

2. Further studies are needed to investigate the performance of seed from seed fall until natural seedlings establishment, including seed dispersal, methods and mycorrhizal infection, especially in rare species to plan for their conservation.

3. These transplantation methods should be applied to other species, which grow slowly in the nursery, but which have many wildlings in the forest such as *Helicia nilagirica* Bedd. (Proteaceae), *Cinnamomum iners* Reinw. *ex* Bl. (Lauraceae), *Horsfieldia thorelii* Lec. (Myristicaceae).

4. Saplings produced by this method should be monitored after planting in degraded areas, to compare their field performance with planting stock raised from seed.

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APPENDIX I:

General characteristics of the 4 species studied in Doi Suthep-Pui National Park (Maxwell and Elliott, 2001)

Castanopsis tribuloides **(Sm.) A. DC. (Fagaceae)**

habit:	evergreen tree
habitat:	mixed evergreen + deciduous, seasonal forest; primary evergreen seasonal forest; evergreen seasonal forest with pine
elevation range:	650 – 1650 m
flower month:	April - May
fruit month:	August – October
leaf month:	January - December
bark:	thick, vertically cracked, dark grey to dark brown
cupule:	completely covering the fruit (nut), spiny, spines 3-5 mm long
fruit:	nut subglobose, glabrous, exocarp brown with thin vertical lines, unripe green, ripe brown
seed:	brown, 6-8 mm x 5 mm
abundance:	abundant

***Eugenia albiflora* Duth. *ex* Kurz (Mytaceae)**

habit:	evergreen tree
habitat:	seasonal evergreen forest with pine, mixed evergreen + deciduous, seasonal forest, primary evergreen seasonal forest
elevation range:	800 – 1525 m
flower month:	February - April
fruit month:	May – August
leaf month:	January - December
bark:	thin, slightly cracked, grey + brown
fruit:	green berry
seed:	cream to light brown, globose, 1.5 cm x 1.3 cm
Abundance:	medium

***Sarcosperma arboreum* Bth. (Sapotaceae)**

habit:	evergreen tree
habitat:	mixed evergreen + deciduous, seasonal forest; primary evergreen seasonal forest
elevation range:	650 – 1400 m
flower month:	December - February
fruit month:	April – June
leaf month:	January - December

bark:	thin, vertically cracked, light grey – brown, sap white
fruit:	berry, unripe light green, ripe purple - black
seed:	testa smooth, light brown, 1.8 cm x 1.2 cm
abundance:	medium

***Podocarpus neriifolius* D. Don**

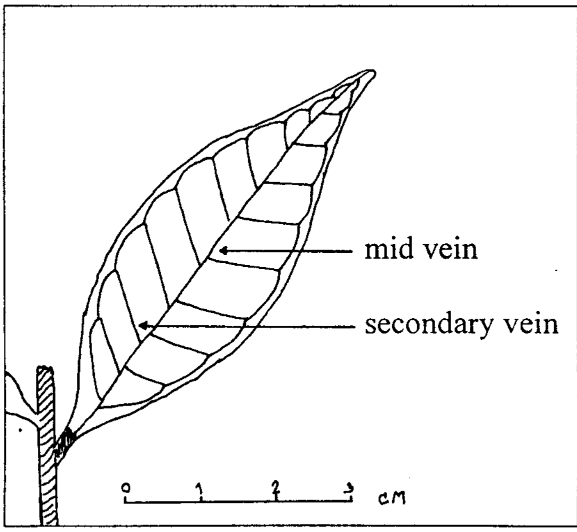
habit:	evergreen tree
habitat:	primary evergreen seasonal forest
elevation range:	1050 – 1400 m
flower month:	January - March
fruit month:	March – June (August)
leaf month:	January - December
bark:	roughly cracked, brown - grey
fruit:	seed with fleshy testa “berry-like”, green, ripening purple-blackish
seed:	hard, light brown, 0.5 mm x 0.3 mm
abundance:	down to a few individuals, in danger of extirpation

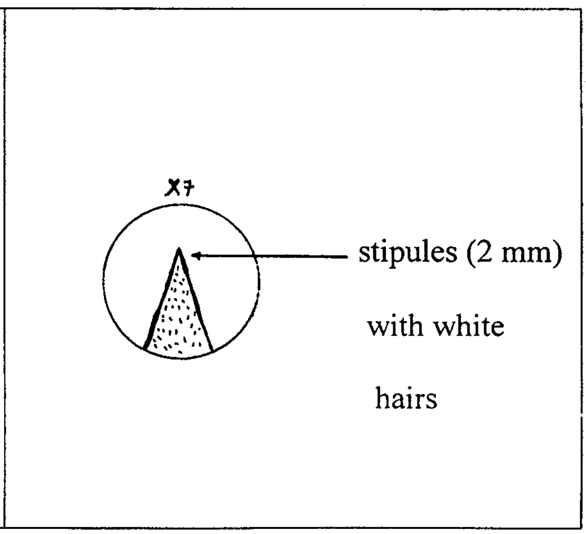
APPENDIX II:

Seedling Descriptions

Castanopsis tribuloides **(Sm.) A. DC. (Fagaceae)**

roots:	light to dark brown
stem:	terete, youngest parts with tiny white hairs; glabrescent
leaves:	spirally arranged, simple; blades subcoriaceus, oblong to lanceolate, apex acuminate, base acute and decurrent, margin entire; 7-13 x 2-4 cm; green above, dull light green below
venation:	pinnate, secondary veins subopposite to alternate, 7-9 on each side of the midrib, not reaching the margin and joined by a looping, intramarginal vein 2-3 mm below the margin; impressed above, raised below; midrib with fine scattered hairs, below finer venation reticulate
petiole:	2-4 mm long, with fine white hairs
stipules:	triangular, 2 mm long with fine white hairs, evanescent
terminal bud:	subulate, 1-2 mm long





Eugenia albiflora **Duth.** ***ex*** **Kurz (Mytaceae)**

roots: light to dark brown

stem: terete, glabrous, light to dark brown

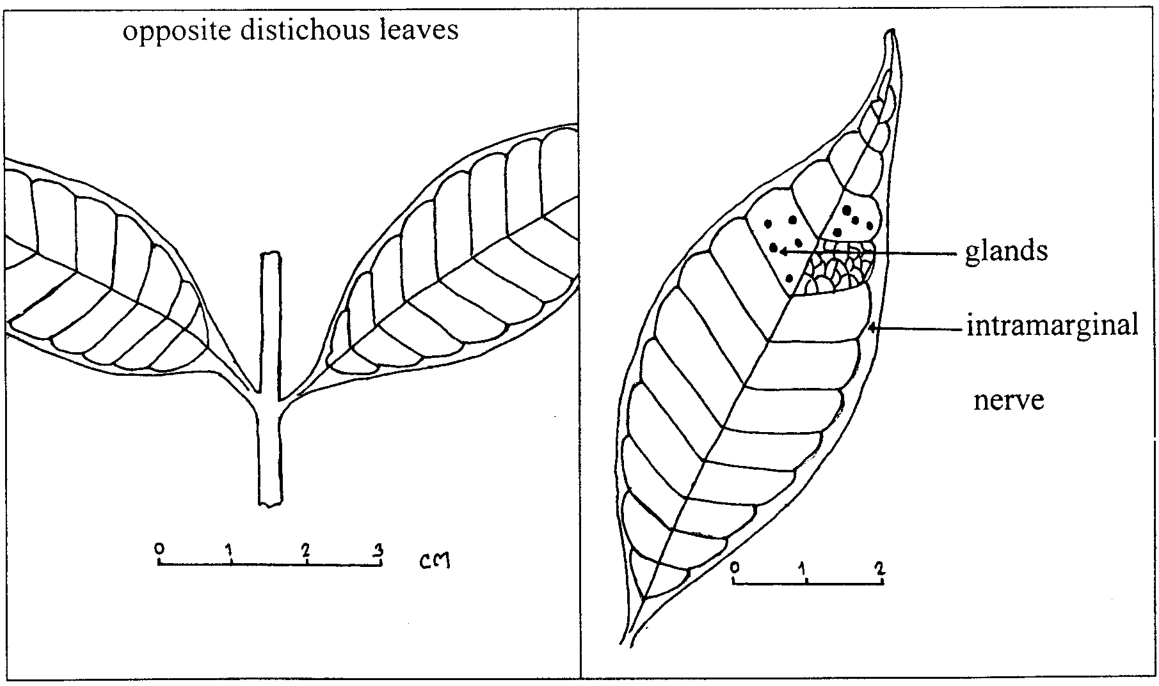
leaves: opposite distichous; glabrous, simple; blades lanceolate; apex acuminate, base acute; margin entire; 7.5-12 x 2-3.5 cm; green above, light green below; minutely brown glandular-punctate

venation: pinnate; secondary veins fine, alternate, 12-14 on each side of the midnerve, tips connected by a looping intramarginal nerve *c.* 1 mm below the margin; finer venation reticulate

petiole: 3-4 mm long, dark brown

stipules: none

buds: terminal bud subulate, 2 mm long, glabrous; axillary buds 1.5 mm, brown, glabrous



Sarcosperma arboreum Bth. (Sapotaceae)

roots: brown

stem: terete, finely brown puberulous, glabrescent

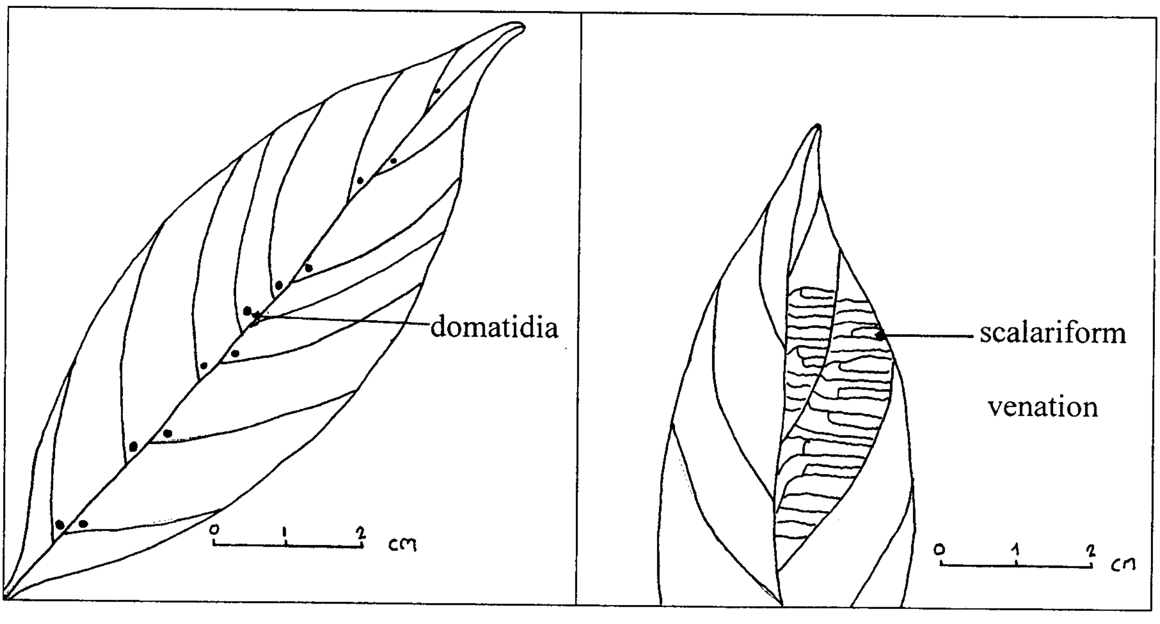
leaves: initially spiral, later alternate, simple; blades thin, lanceolate to obovate – lanceolate; apex acuminate, base acute; margin entire; 12-16 x 4-6 cm; dull green above, glabrous with sunken nerves; lower side with very fine, scattered, brown hairs, glabrescent, nerves raised, dull light green

venation: secondary veins pinnate, with 8-13 subopposite to alternate veins on each side of the midrib; light green, arching, many with basal domatidia; tertiary venation scalariform, finer venation reticulate

petiole: 12-14 mm long, with fine white hairs, glabrescent

stipules: subulate, 1.8 mm long, evanescent; scar circular

terminal bud: 2 mm long, brown puberulous



Podocarpus neriifolius **D. Don**

roots: nodular, light cream to yellow

stem: angular, lenticellate, glabrous, light green; becoming light brown, roughening with age

leaves: spiral, often in groups, intenodes of variable lengths; glabrous; blades: coriaceous, linear-lanceolate to linear – subulate; apex sharply acute, base acute; margin entire; dark green above; dull light green underneath; 4-13.5 cm x 7-12 mm

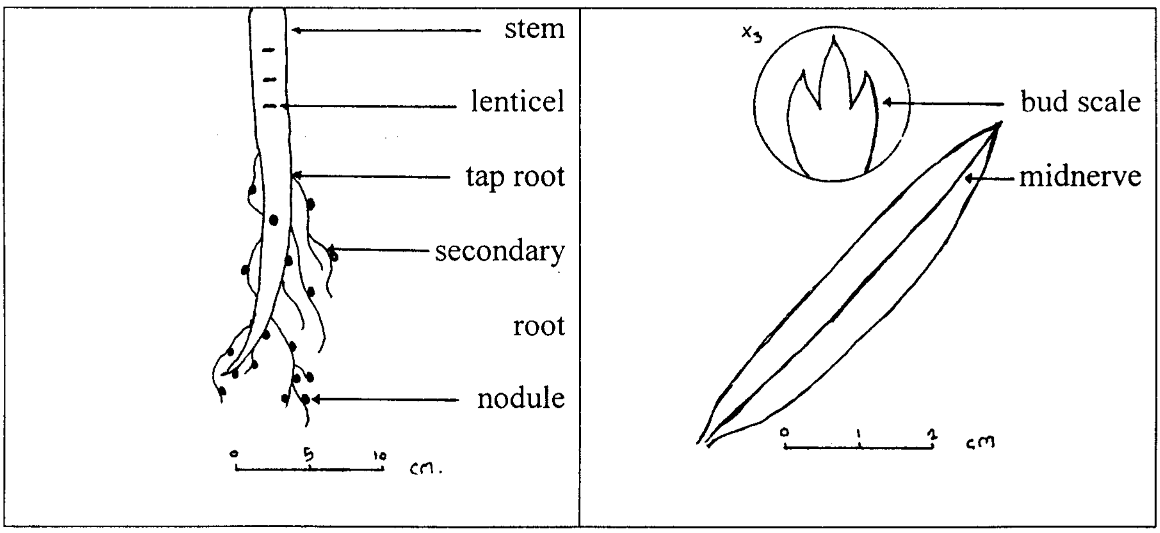
venation: midnerve distinct, sunken above, raised below; other venation indistinct

petiole: 2 - 4 mm long

stipules: none

bud scales: ovate, tip acute, glabrous, light brown, 3-5 x 2.5 mm, often elongating with age, caducous

terminal bud: not seen, enclosed in scales



APPENDIX III

ANOVA ANALYSIS

Table 1. ANOVA analysis of mortarity rate of 4 species in the forest over 1 year

Significant differences were further analyzed using the LSD Test

SPECIES	N	Mean	SD	LSD Test
Sarcosperma arboreum	6	**12.5**	9.9	**ns**
Podocarpus neriifolius	6	**19.4**	12.8	**ns**
Eugenia albiflora	6	**11.1**	10.1	**ns**
Castanopsis tribuloides	6	**13.2**	8.1	**ns**
Total	**24**	**14.1**	**10.2**	
Source of Varian	Sum of Squares	DF	F	Significant
Between Groups	245.3	3	0.763	**0.528**
Within Groups	2144.3	20		
Total	**2389.6**	**23**		

ns = The mean difference is non significant at the 0.05 level

Table 2. ANOVA analysis of mortarity rate across all species in

the forest over 1 year with difference times

Significant differences were further analyzed using the LSD Test

Source of Varian	N	Mean	SD	LSD Test
Feb - Mar	4	**0**	0	**b**
Apr - May	4	**2.27**	2	**b**
June - July	4	**10.17***	2.83	**a**
Aug - Sep	4	**0.4**	0.46	**b**
Oct - Nov	4	**1.17**	1.28	**b**
Dec - Jan	4	**0.5**	1	**b**
Total	**24**	**2.42**	**3.87**	
Source of Varian	Sum of Squares	DF	F	Significant
Between Groups	301.343	5	24.214	**0.000**
Within Groups	44.802	18		
Total	**346.145**	**23**		

* = The mean difference is significant at the 0.05 level

Table 3. ANOVA analysis of relative height growth rate
(%/year) among species in the forest over 1 year
Significant differences were further analyzed using the LSD Test

SPECIES	N	Mean	SD	LSD Test
Sarcosperma arboreum	6	**11.12**	8.88	**ns**
Podocarpus neriifolius	6	**18.67**	16.03	**ns**
Eugenia albiflora	6	**8.34**	8.08	**ns**
Castanopsis tribuloides	6	**17.45**	18.63	**ns**
Total	**24**	**13.89**	**13.48**	

Source of Varian	Sum of Squares	DF	F	Significant
Between Groups	443.611	3	0.791	**0.513**
Within Groups	3739.841	20		
Total	**4183.451**	**23**		

ns = The mean difference is non significant at the 0.05 level

Table 4. ANOVA analysis of relative height growth rate (%/year)
across all species with difference time in the forest over 1 year
Significant differences were further analyzed using the LSD Test

Source of Varian	N	Mean	SD	LSD Test
Apr - May	4	**20.66***	11.68	**ab**
June - July	4	**32.56***	13.8	**a**
Aug - Sep	4	**6.11**	2.89	**c**
Oct - Nov	4	**19.62**	4.59	**b**
Dec - Jan	4	**4.41**	3.17	**c**
Total	**20**	**16.67**	**13.09**	
Source of Varian	Sum of Squares	DF	F	Significant
Between Groups	2156.4	4	7.35	**0.002**
Within Groups	1100.144	15		
Total	**3256.544**	**19**		

* = The mean difference is significant at the 0.05 level

Table 5. ANOVA analysis of mortarity rate of ***Podocarpus neriifolius***

with distance from the parent tree

Significant differences were further analyzed using the LSD Test

Distance	N	Mean	SD	LSD Test
0 - 5 m	6	**24.26***	18.69	**a**
5.1 - 10 m	6	**20.41***	14.44	**a**
10.1 - 15 m	6	**3.33**	8.16	**b**
15.1 - 20 m	4	**0**	0	**b**
20.1 - 25 m	3	**0**	0	**b**
Total	**25**	**11.52**	15.68	
Source of Varian	Sum of Squares	DF	F	Significant
Between Groups	2780.871	4	4.450	**0.10**
Within Groups	3124.275	20		
Total	**5905.146**	**24**		

* = The mean difference is significant at the 0.05 level

Table 6. ANOVA analysis of mortarity rate of ***Sarcosperma arboreum***

with distance from the parent tree

Significant differences were further analyzed using the LSD Test

Distance	N	Mean	SD	LSD Test
0 - 5 m	6	**12.98**	12.13	**ns**
5.1 - 10 m	6	**17.03**	15.69	**ns**
10.1 - 15 m	6	**3.33**	8.16	**ns**
15.1 - 20 m	3	**8.33**	14.43	**ns**
20.1 - 25 m	3	**0**	0	**ns**
Total	**24**	**9.37**	**12.56**	
Source of Varian	Sum of Squares	DF	F	Significant
Between Groups	915.95	4	1.601	**0.215**
Within Groups	2717.66	19		
Total	**3633.62**	**23**		

ns = The mean difference is non significant at the 0.05 level

Table 7. ANOVA analysis of mortarity rate of ***Castanopsis tribuloides***
with distance from the parent tree
Significant differences were further analyzed using the LSD Test

Distance	N	Mean	SD	LSD Test
0 - 5 m	6	**20.0***	14.91	**a**
5.1 - 10 m	6	**6.85**	5.32	**b**
10.1 - 15 m	5	**5.0**	11.18	**b**
15.1 - 20 m	3	**0.0**	0	**b**
20.1 - 25 m	3	**0.0**	0	**b**
Total	**23**	**8.09**	**11.78**	
Source of Varian	Sum of Squares	DF	F	Significant
Between Groups	1300.743	4	3.337	**0.033**
Within Groups	1753.875	18		
Total	**3054.618**	**22**		

* = The mean difference is significant at the 0.05 level

Table 8. ANOVA analysis of mortarity rate of ***Eugenia albiflora***
with distance from the parent tree
Significant differences were further analyzed using the LSD Test

Distance	N	Mean	SD	LSD Test
0 - 5 m	6	**15.36**	19.87	**ns**
5.1 - 10 m	6	**9.73**	11.08	**ns**
10.1 - 15 m	6	**8.33**	20.41	**ns**
15.1 - 20 m	3	**0**	0	**ns**
20.1 - 25 m	3	**16.66**	28.86	**ns**
Total	**24**	**10.44**	**17.39**	
Source of Varian	Sum of Squares	DF	F	Significant
Between Groups	618.552	4	0.463	**0.762**
Within Groups	6340.387	19		
Total	**6958.938**	**23**		

ns = The mean difference is non significant at the 0.05 level

Table 9. Mean relative growth rate of basal diameter (%/year) of ***Eugenia albiflora*** with 6 treatments

Eugenia alblflora					
Treatments	N	Mean	SD	Std. Error	LSD Test
BN	16	**32.41**	31.6	7.9	**c**
MN	14	**56.8**	37.87	10.12	**bc**
SN	18	**85.32***	45.17	10.64	**a**
BP	23	**29.2**	22.33	4.65	**c**
MP	18	**56.93**	40.38	9.51	**b**
SP	22	**60.38**	32.03	6.82	**b**
Total	**111**	**53.5**	**39.18**	**3.71**	
	Sum of squares	DF	Mean Square	F	Sig.
Between groups	40291.953	5	8058.391	6.581	**0.00**
Within Groups	128580	105	1224.572		
Total	168872	110			

* = The mean difference is significant at the 0.05 level

Table 10. Mean relative growth rate of height (%/year) of ***Eugenia albiflora*** with 6 treatments

Eugenia alblflora					
Treatments	N	Mean	SD	Std. Error	LSD Test
BN	16	**16.54**	32.4	8.1	**c**
MN	14	**41.24**	58.07	15.52	**c**
SN	18	**158.18***	50.2	11.83	**a**
BP	23	**83.8**	36.78	7.66	**b**
MP	18	**106.6**	54.17	12.76	**b**
SP	22	**179.34***	45.82	9.76	**a**
Total	**111**	**97.61**	**73.29**	**6.95**	
	Sum of squares	DF	Mean Square	F	Sig.
Between groups	364701.2	5	72940.239	33.857	**0.00**
Within Groups	226206.2	105	2154.344		
Total	590907.4	110			

* = The mean difference is significant at the 0.05 level

Table 11. Mean relative growth rate of canopy (%/year) of ***Eugenia albiflora*** with 6 treatments

Eugenia alblflora					
Treatments	N	Mean	SD	Std. Error	LSD Test
BN	16	**71.87**	85.01	21.25	**c**
MN	14	**128.19**	67.48	18.03	**b**
SN	18	**156.52**	81.21	19.14	**ab**
BP	23	**132.77**	60.32	12.57	**b**
MP	18	**110.49**	83.69	19.72	**bc**
SP	22	**186.24***	55.8	11.89	**a**
Total	**111**	**131.01**	**78.94**	**7.49**	

	Sum of squares	DF	Mean Square	F	Sig.
Between groups	141385.8	5	28277.162	5.455	**0.00**
Within Groups	544254.5	105	5183.376		
Total	685640.3	110			

* = The mean difference is significant at the 0.05 level

Table 12. Mean relative growth rate of basal diameter (%/year) of ***C. tribuloides*** with 6 treatments

Castanopsis tribuloides					
Treatments	N	Mean	SD	Std. Error	LSD Test
BN	7	**16.13**	36.74	13.88	**ab**
MN	7	**-25.33**	92.09	34.8	**b**
SN	5	**21.3**	42.58	19.04	**ab**
BP	13	**12.04**	55.08	15.27	**ab**
MP	16	**38.81***	35.6	8.9	**a**
SP	16	**31.94***	39.7	9.92	**a**
Total	**64**	**15.81**	**51.72**	**6.46**	

	Sum of squares	DF	Mean Square	F	Sig.
Between groups	23223	5	4644.66	1.854	**0.117**
Within Groups	145317.2	58	2505.469		
Total	168540.5	63			

* = The mean difference is significant at the 0.05 level

Table 13. Mean relative growth rate of height (%/year) of ***C. tribuloides*** with 6 treatments

Castanopsis tribuloides					
Treatments	N	Mean	SD	Std. Error	LSD Test
BN	7	**-44.37**	47.99	18.13	**c**
MN	7	**-75.76**	65.23	24.65	**c**
SN	5	**-17.28**	47.41	21.2	**c**
BP	13	**49.25**	48.47	13.44	**b**
MP	16	**72.69**	51.45	12.86	**ab**
SP	16	**96.3***	50.58	12.64	**a**
Total	**64**	**13.47**	**77.99**	**9.74**	

	Sum of squares	DF	Mean Square	F	Sig.
Between groups	228624.7	5	45724.93	17.15	**0.00**
Within Groups	154637	58	2666.15		
Total	383261.7	63			

* = The mean difference is significant at the 0.05 level

Table 14. Mean relative growth rate of canopy (%/year) of ***C. tribuloides*** with 6 treatments

Castanopsis tribuloides					
Treatments	N	Mean	SD	Std. Error	LSD Test
BN	7	**8**	64.87	24.51	**bc**
MN	7	**-47.7**	58.27	22.02	**c**
SN	5	**-33.47**	67.78	30.31	**bc**
BP	13	**170.04***	257.31	71.36	**a**
MP	16	**66.92**	84.76	21.19	**bc**
SP	16	**86.22**	78.05	19.51	**ab**
Total	**64**	**65.86**	**147.38**	**18.42**	

	Sum of squares	DF	Mean Square	F	Sig.
Between groups	310779.4	5	62155.87	3.408	**0.009**
Within Groups	1057686	58	18235.96		
Total	1368465	63			

* = The mean difference is significant at the 0.05 level

Table 15. Mean relative growth rate of basal diameter (%/year) of ***S. arboreum*** with 6 treatments

Sarcosperma arboreum					
Treatments	N	Mean	SD	Std. Error	LSD Test
BN	19	**30.76**	48.93	11.22	**b**
MN	20	**64.21***	34.61	7.74	**a**
SN	8	**88.88***	17.88	6.32	**a**
BP	20	**33.03**	44.35	9.91	**b**
MP	20	**61.41***	33.12	7.4	**a**
SP	18	**74.3***	41.8	9.85	**a**
Total	**105**	**55.29**	**43.33**	**4.22**	

	Sum of squares	DF	Mean Square	F	Sig.
Between group	39221.49	5	7844.298	4.976	**0.000**
Within Groups	156052.8	99	1576.29		
Total	195274.2	104			

* = The mean difference is significant at the 0.05 level

Table 16. Mean relative growth rate of height (%/year) of ***S. arboreum*** with 6 treatments

Sarcosperma arboreum					
Treatments	N	Mean	SD	Std. Error	LSD Test
BN	19	**-11.67**	60.32	13.83	**c**
MN	20	**44.48**	58.75	13.13	**b**
SN	8	**76.4**	18.84	6.66	**ab**
BP	20	**53.57**	66.73	14.92	**b**
MP	20	**99.73***	45.16	10.09	**a**
SP	18	**120.73***	47.17	11.11	**a**
Total	**105**	**62.07**	**69.17**	**6.75**	

	Sum of squares	DF	Mean Square	F	Sig.
Between group	201920.1	5	40582.019	13.629	**0.00**
Within Groups	294788.4	99	2977.66		
Total	497698.5	104			

* = The mean difference is significant at the 0.05 level

Table 17. Mean relative growth rate of canopy (%/year) of ***S. arboreum*** with 6 treatments

Sarcosperma arboreum					
Treatments	N	Mean	SD	Std. Error	LSD Test
BN	19	**119.94**	50.4	11.56	**c**
MN	20	**149.75**	57.57	12.87	**c**
SN	8	**146.94**	56.25	19.89	**c**
BP	20	**370.24**	377.2	84.34	**b**
MP	20	**533.66***	417.89	93.44	**a**
SP	18	**194.18**	74.69	17.6	**c**
Total	**105**	**266.88**	**290.54**	**28.35**	

	Sum of squares	DF	Mean Square	F	Sig.
Between group	2531993	5	506398.5	8.025	**0.000**
Within Groups	6247199	99	63103.025		
Total	8779192	104			

* = The mean difference is significant at the 0.05 level

Table 18. Mean relative growth rate of basal diameter (%/year) of ***P. neriifolius*** with 6 treatments

Podocarpus neriifolius					
Treatments	N	Mean	SD	Std. Error	LSD Test
BN	6	**22.95**	25.47	10.39	**b**
MN	13	**17.44**	24.44	6.78	**b**
SN	8	**54.59***	30.95	10.94	**a**
BP	11	**3.94**	24.03	7.24	**b**
MP	19	**5.15**	16.22	3.72	**b**
SP	17	**21.04**	19.52	4.73	**b**
Total	**74**	**17.56**	**26.18**	**3.04**	

	Sum of squares	DF	Mean Square	F	Sig.
Between group	16319.118	5	3263.824	6.579	**0.000**
Within Groups	33736.946	68	496.132		
Total	50056.064	73			

* = The mean difference is significant at the 0.05 level

Table 19. Mean relative growth rate of height (%/year) of ***P. neriifolius*** with 6 treatments

Podocarpus neriifolius					
Treatments	N	Mean	SD	Std. Error	LSD Test
BN	6	**19.55**	29.14	11.89	**b**
MN	13	**21.32**	42.23	11.71	**b**
SN	8	**108.22***	73.98	26.15	**a**
BP	11	**32.81**	23.61	7.11	**b**
MP	19	**47.94**	41.17	9.44	**b**
SP	17	**78***	35.71	8.66	**a**
Total	**74**	**52.13**	**49.67**	**5.77**	

	Sum of squares	DF	Mean Square	F	Sig.
Between group	59700.762	5	11940.152	6.74	**0.00**
Within Groups	120463.2	68	1771.518		
Total	180164	73			

* = The mean difference is significant at the 0.05 level

Table 20. Mean relative growth rate of canopy (%/year) of ***P. neriifolius*** with 6 treatments

Podocarpus neriifolius					
Treatments	N	Mean	SD	Std. Error	LSD Test
BN	6	**15.58**	28.27	11.54	**b**
MN	13	**30.74**	28.63	7.94	**b**
SN	8	**140.21***	65.61	23.19	**a**
BP	11	**44.63**	47.22	14.23	**b**
MP	19	**62.42**	64.56	14.81	**b**
SP	17	**154.91***	44.44	10.77	**a**
Total	**74**	**80.07**	**71.51**	**8.31**	

	Sum of squares	DF	Mean Square	F	Sig.
Between group	200489.8	5	40097.958	15.769	**0.000**
Within Groups	172908.3	68	2542.77		
Total	373398.1	73			

* = The mean difference is significant at the 0.05 level

Table 21. Mean mortality rate of specie across all treatments

SPECIES	N	Mean	SD	Std. Error	LSD Test
E. albiflora	6	**22.83**	14.24	5.81	**c**
P. neriifolius	6	**48.6**	21.02	8.58	**ab**
S. arboreum	6	**27.07**	19.67	8.03	**bc**
C. tribuloides	6	**55.55***	20.52	8.37	**a**
Total	**24**	**38.52**	**22.72**	**4.63**	

	Sum of squares	DF	Mean Square	F	Sig.
Between groups	4613.438	3	1537.813	4.232	**0.018**
Within Groups	7267.29	20	363.365		
Total	11880.728	23			

* = The mean difference is significant at the 0.05 level

Table 22. Mean mortality rate of treatment across all species

Treatments	N	Mean	SD	Std. Error	LSD Test
BN	4	**49.99**	27	13.5	**ab**
MN	4	**43.74**	22.18	11.09	**ab**
SN	4	**59.37***	23.65	11.82	**a**
BP	4	**30.2**	23.66	11.83	**ab**
MP	4	**23.95**	7.11	3.55	**b**
SP	4	**23.95**	10.95	5.47	**b**
Total	**24**	**38.52**	**22.73**	**4.63**	

	Sum of squares	DF	Mean Square	F	Sig.
Between groups	4348.854	5	869.771	2.078	**0.116**
Within Groups	7534.757	18	418.598		
Total	11883.611	23			

* = The mean difference is significant at the 0.05 level

Table 23. Mean relative height growth rate of specie across all treatments

SPECIES	N	Mean	SD	Std. Error	LSD Test
E. albiflora	6	**97.61***	63.82	26.05	**a**
P. neriifolius	6	**51.3**	35.25	14.39	**ab**
C. tribuloides	6	**13.47**	69.13	28.22	**b**
S. arboreum	6	**63.87**	46.61	19.03	**ab**
Total	**24**	**56.56**	**60.1**	**12.26**	

	Sum of squares	DF	Mean Square	F	Sig.
Between groups	21740.019	3	7246.673	2.362	**0.102**
Within Groups	61348.185	20	3067.409		
Total	83088.204	23			

* = The mean difference is significant at the 0.05 level

Table 24. Mean relative height growth rate of treatment across all species

Treatments	N	Mean	SD	Std. Error	LSD Test
BN	4	**-4.98**	29.78	14.89	**b**
MN	4	**7.82**	56.65	28.32	**b**
SN	4	**81.38****	73.88	36.94	**a**
BP	4	**54.85**	21.26	10.63	**ab**
MP	4	**81.74****	26.87	13.43	**a**
SP	4	**118.59****	44.11	22.05	**a**
Total	**24**	**56.56**	**60.1**	**12.26**	

	Sum of squares	DF	Mean Square	F	Sig.
Between groups	45058.706	5	9011.741	4.265	**0.010**
Within Groups	38029.498	18	2112.75		
Total	83088.204	23			

** = The mean difference is significant at the 0.01 level

Table 25. Mean relative basal diameter growth rate of specie across all treatments

SPECIES	N	Mean	SD	Std. Error	LSD Test
E. albiflora	6	**53.5****	20.57	8.4	**a**
P. neriifolius	6	**20.85**	18.36	7.49	**b**
C. tribuloides	6	**15.81**	22.47	9.17	**b**
S. arboreum	6	**58.76****	22.94	9.36	**a**
Total	**24**	**37.23**	**27.73**	**5.66**	

	Sum of squares	DF	Mean Square	F	Sig.
Between groups	8732.903	3	2910.968	6.497	**0.003**
Within Groups	8961.639	20	448.082		
Total	17694.542	23			

** = The mean difference is significant at the 0.01 level

Table 26. Mean relative basal diameter growth rate of treatment across all species

Treatments	N	Mean	SD	Std. Error	LSD Test
BN	4	**25.56**	7.52	3.76	**ab**
MN	4	**28.28**	41.21	20.6	**ab**
SN	4	**62.52***	31.49	15.74	**a**
BP	4	**19.55**	13.84	6.92	**b**
MP	4	**40.57**	25.55	12.77	**ab**
SP	4	**46.91**	24.66	12.33	**ab**
Total	**24**	**37.23**	**27.73**	**5.66**	

	Sum of squares	DF	Mean Square	F	Sig.
Between groups	5093.197	5	1018.639	1.455	**0.253**
Within Groups	12601.344	18	700.075		
Total	17694.542	23			

* = The mean difference is significant at the 0.05 level

Table 27. Mean relative canopy growth rate of specie across all treatments

SPECIES	N	Mean	SD	Std. Error	LSD Test
E. albiflora	6	**131.01**	39.06	15.94	**b**
P. neriifolius	6	**74.74**	58.66	23.94	**b**
C. tribuloides	6	**41.66**	82.3	33.59	**b**
S. arboreum	6	**252.45****	164.67	67.22	**a**
Total	**24**	**124.97**	**123.14**	**25.13**	

	Sum of squares	DF	Mean Square	F	Sig.
Between groups	154496.8	3	51498.921	5.301	**0.007**
Within Groups	194293.4	20	9714.671		
Total	348790.2	23			

** = The mean difference is significant at the 0.01 level

Table 28. Mean relative canopy growth rate of treatment across all species

Treatments	N	Mean	SD	Std. Error	LSD Test
BN	4	**53.84**	52.47	26.23	**ns**
MN	4	**65.24**	91.37	45.68	**ns**
SN	4	**102.5**	90.92	45.46	**ns**
BP	4	**179.4**	137.65	68.82	**ns**
MP	4	**193.4**	227.89	113.94	**ns**
SP	4	**155.4**	49.12	24.56	**ns**
Total	**24**	**124.97**	**123.14**	**25.13**	

	Sum of squares	DF	Mean Square	F	Sig.
Between groups	70788.732	5	14157.746	0.917	**0.492**
Within Groups	278001.4	18	15444.525		
Total	348790.2	23			

ns = The mean difference is non significant

Table 29. Mean height of specie across all treatments

SPECIES	N	Mean	SD	Std. Error	LSD Test
E. albiflora	6	**44.85***	8.78	3.58	**a**
P. neriifolius	6	**28.36**	11.63	4.75	**b**
C. tribuloides	6	**26.11**	12.31	5.02	**b**
S. arboreum	6	**38.67**	9.57	3.9	**ab**
Total	**24**	**34.49**	**12.63**	**2.58**	

	Sum of squares	DF	Mean Square	F	Sig.
Between groups	1395.578	3	465.193	4.083	**0.021**
Within Groups	2278.955	20	113.948		
Total	3674.533	23			

* = The mean difference is significant at the 0.05 level

Table 30. Mean height of treatment across all species

Treatments	N	Mean	SD	Std. Error	LSD Test
BN	4	**47.18***	7.71	3.85	**a**
MN	4	**34.06**	13.62	6.81	**ab**
SN	4	**25.87**	12.55	6.27	**b**
BP	4	**43.9***	9.83	4.91	**a**
MP	4	**32.52**	7.36	3.68	**ab**
SP	4	**23.47**	8.5	4.25	**b**
Total	**24**	**34.49**	**12.63**	**2.58**	

	Sum of squares	DF	Mean Square	F	Sig.
Between groups	1796.815	5	359.363	3.445	**0.023**
Within Groups	1877.719	18	104.318		
Total	3674.533	23			

* = The mean difference is significant at the 0.05 level

Table 31. Mortality of seedlings size class all species across all treatments

SIZE	N	Mean	SD	Std. Error	LSD Test
BIG	8	**40.1**	25.77	9.11	**ns**
MEDIUM	8	**33.85**	18.55	6.56	**ns**
SMALL	8	**41.66**	25.48	9.01	**ns**
Total	**24**	**38.53**	**22.73**	**4.63**	

	Sum of squares	DF	Mean Square	F	Sig.
Between groups	273.438	2	136.719	0.247	**0.783**
Within Groups	11610.174	21	552.865		
Total	11883.611	23			

ns = The mean difference is non significant at the 0.05 level

Table 32. Mean relative height growth rate of all species across all treatments

SIZE	N	Mean	SD	Std. Error	LSD Test
BIG	8	**24.93**	39.96	14.13	**b**
MEDIUM	8	**44.78**	56.97	20.14	**b**
SMALL	8	**99.98***	59.74	21.12	**a**
Total	**24**	**56.56**	**60.1**	**12.26**	

	Sum of squares	DF	Mean Square	F	Sig.
Between groups	24197.985	2	12098.992	4.314	**0.027**
Within Groups	58890.219	21	2804.296		
Total	83088.204	23			

* = The mean difference is significant at the 0.05 level

Table 33. Mean relative canopy growth rate of all species across all treatments

SIZE	N	Mean	SD	Std. Error	LSD Test
BIG	8	**116.63**	117.49	41.54	**ns**
MEDIUM	8	**129.3**	174.71	61.77	**ns**
SMALL	8	**128.96**	73.31	25.92	**ns**
Total	**24**	**124.97**	**123.14**	**25.13**	

	Sum of squares	DF	Mean Square	F	Sig.
Between groups	834.383	2	417.191	0.025	**0.975**
Within Groups	347955.8	21	16569.323		
Total	348790.2	23			

ns = The mean difference is non significant at the 0.05 level

Table 34. Mean relative basal diameter growth rate of all species across all treatm

SIZE	N	Mean	SD	Std. Error	LSD Test
BIG	8	**22.55**	10.8	3.81	**b**
MEDIUM	8	**34.42**	32.42	11.46	**ab**
SMALL	8	**54.71***	27.48	9.71	**a**
Total	**24**	**37.23**	**27.73**	**5.66**	

	Sum of squares	DF	Mean Square	F	Sig.
Between groups	4231.591	2	2115.795	3.3	**0.050**
Within Groups	13462.951	21	641.093		
Total	17694.542	23			

* = The mean difference is significant at the 0.05 level

Table 35. Mortality of seedlings with pruning treatments

TREATMENT	N	Mean	SD	Std. Error	T-Test
NO PRUNING	12	**51.03****	23.03	6.65	**a**
PRUNING	12	**26.03**	14.44	4.17	**b**

	T-Test					
TREATMENT	Mean	SD	Std. Err	t	df	Sig. (2-tailed)
NO PRUNING PRUNING	25	14.32	4.13	6.047	11	**0.000**

** = The mean difference is significant at the 0.01 level

Table 36. Relative height growth rate of seedlings with pruning treatı

TREATMENT	N	Mean	SD	Std. Error	T-Test
NO PRUNING	12	**28.07**	64.71	18.68	**b**
PRUNING	12	**85.06****	39.93	11.52	**a**

	T-Test					
TREATMENT	Mean	SD	Std. Err	t	df	Sig. (2-tailed)
NO PRUNING PRUNING	-56.99	47.72	13.77	-4.137	11	**0.002**

** = The mean difference is significant at the 0.01 level

Table 37. Relative canopy growth rate of seedlings with pruning treat

TREATMENT	N	Mean	SD	Std. Error	T-Test
NO PRUNING	12	**73.88**	75.86	21.89	**b**
PRUNING	12	**176.06****	142.33	41.08	**a**

	T-Test					
TREATMENT	Mean	SD	Std. Err	t	df	Sig. (2-tailed)
NO PRUNING PRUNING	-102.18	115.85	33.44	-3.055	11	**0.011**

* = The mean difference is significant at the 0.05 level

Table 38. Relative basal diameter growth rate of seedlings with pruni

TREATMENT	N	Mean	SD	Std. Error	T-Test
NO PRUNING	12	**38.78**	32.51	9.38	**ns**
PRUNING	12	**35.68**	23.35	6.74	**ns**

	T-Test					
TREATMENT	Mean	SD	Std. Err	t	df	Sig. (2-tailed)
NO PRUNING PRUNING	3.1	24.53	7.08	0.439	11	**0.669**

ns = The mean difference is non significant at the 0.05 level

APPENDIX IV

Correlation analysis

Table 1. Correlations between distance from the parent tree with mortality rate

Sarcosperma arboreum			
		Distance	***S. arboreum***
Pearson	Distance	1.000	**-0.792**
Correlation	Mortality	**-0.792**	1.000
Sig.	Distance	0.000	**0.111**
(2-tail)	Mortality	**0.111**	0.000
N	Distance	**5**	**5**
	Mortality	**5**	**5**

Table 2. Correlations between distance from the parent tree with mortality rate

Podocarpus neriifolius			
		Distance	***P. neriifolius***
Pearson	Distance	1.000	**- 0.925**
Correlation	Mortality	**-0.925**	1.000
Sig.	Distance	0.000	**0.024**
(2-tail)	Mortality	**0.024***	0.000
N	Distance	**5**	**5**
	Mortality	**5**	**5**

* = Correlation is significant at the 0.05 level (2 tailed)

Table 3. Correlations between distance from the parent tree with mortality rate

Eugenia albiflora			
		Distance	***E. albiflora***
Pearson	Distance	1.000	**-0.170**
Correlation	Mortality	**-0.170**	1.000
Sig.	Distance	0.000	**0.785**
(2-tail)	Mortality	**0.785**	0.000
N	Distance	**5**	**5**
	Mortality	**5**	**5**

Table 4. Correlations between distance from the parent tree with mortality rate

Castanpsis tribuloides			
		Distance	***C. tribuloides***
Pearson	Distance	1.000	**-0.903**
Correlation	Mortality	**-0.903**	1.000
Sig.	Distance	0.000	**0.036**
(2-tail)	Mortality	**0.036***	0.000
N	Distance	**5**	**5**
	Mortality	**5**	**5**

* = Correlation is significant at the 0.05 level (2 tailed)

Table 5. Correlations between distance from the parent tree with the relative height growth rate (%/year) of

Sarcosperma arboreum			
	Mean	SD	N
RGR height	**13.45**	**15.39**	**55**
Distance	**8.38**	**5.62**	**55**

Correlation			
		RGR height	Distance
Pearson	RGR of height	1.000	**-0.147**
Correlation	Distance	**-0.147**	1.000
Sig.	RGR of height	0.000	**0.284**
(2-tail)	Distance	**0.284**	0.000
Sum of	RGR of height	**12798.77**	-686.780
Squares	Distance	**-686.72**	1707.480
Covariance	RGR of height	**237.01**	-12.718
	Distance	**-12.718**	31.620
N	RGR of height	**55**	**55**
	Distance	**55**	**55**

Table 6. Correlations between distance from the parent tree with the relative height growth rate (%/year) of

Podocarpus neriifolius			
	Mean	SD	N
RGR height	**22.32**	**27.02**	**81**
Distance	**7.22**	**5.96**	**81**

Correlation			
		RGR height	Distance
Pearson	RGR of height	1.000	**-0.067**
Correlation	Distance	**-0.067**	1.000

Sig.	RGR of height	0.000	**0.554**
(2-tail)	Distance	**0.554**	0.000
Sum of	RGR of height	**2848.43**	-860.250
Squares	Distance	**-860.25**	58427.380
Covariance	RGR of height	**35.6**	-10.750
	Distance	**-10.75**	730.340
N	RGR of height	**81**	**81**
	Distance	**81**	**81**

Table 7. Correlations between distance from the parent tree with the relative height growth rate (%/year) of

Eugenia albiflora			
	Mean	SD	N
RGR height	**10.81**	**7.72**	**54**
Distance	**8.67**	**5.11**	**54**

Correlation			
		RGR height	Distance
Pearson	RGR of height	1.000	**0.129**
Correlation	Distance	**0.129**	1.000
Sig.	RGR of height	0.000	**0.354**
(2-tail)	Distance	**0.354**	0.000
Sum of	RGR of height	**1388.91**	269.450
Squares	Distance	**269.45**	3161.550
Covariance	RGR of height	**26.2**	5.080
	Distance	**5.08**	59.650
N	RGR of height	**54**	**54**
	Distance	**54**	**54**

Table 8. Correlations between distance from the parent tree with the relative height growth rate (%/year) of

Castanopsis tribuloides			
	Mean	SD	N
RGR height	**23.85**	**20.44**	**71**
Distance	**5.53**	**3.35**	**71**

Correlation			
		RGR height	Distance
Pearson	RGR of height	1.000	**0.105**
Correlation	Distance	**0.105**	1.000
Sig.	RGR of height	0.000	**0.384**
(2-tail)	Distance	**0.384**	0.000
Sum of	RGR of height	**786.48**	503.260
Squares	Distance	**503.26**	29268.830
Covariance	RGR of height	**11.23**	7.190
	Distance	**7.19**	418.120
N	RGR of height	**71**	**71**
	Distance	**71**	**71**

Table 9. Correlations between canopy cover with mortality rate in the forest of

Sarcosperma arboreum			
	Mean	SD	N
Canopy cover	**80.00**	**15.81**	**5**
Mortality	**17.36**	**7.94**	**5**

Correlation			
		Canopy cover	Mortality
Pearson	Canopy cover	1.000	**-0.002**
Correlation	Mortality	**-0.002**	1.000
Sig.	Canopy cover	0.000	**0.997**
(2-tail)	Mortality	**0.997**	0.000
Sum of	Canopy cover	**1000.00**	-1.000
Squares	Mortality	**-1.000**	252.210
Covariance	Canopy cover	**250**	-0.250
	Mortality	**-0.25**	63.050
N	Canopy cover	**5**	**5**
	Mortality	**5**	**5**

Table 10. Correlations between canopy cover with mortality rate in the forest of

Podocarpus neriifolius			
	Mean	SD	N
Canopy cover	**80.00**	**15.81**	**5**
Mortality	**32.68**	**38.89**	**5**

Correlation			
		Canopy cover	Mortality
Pearson	Canopy cover	1.000	**0.786**
Correlation	Mortality	**0.786**	1.000
Sig.	Canopy cover	0.000	**0.115**

(2-tail)	Mortality	**0.115**	0.000
Sum of	Canopy cover	**1000.00**	1933.000
Squares	Mortality	**1933.000**	6051.860
Covariance	Canopy cover	**250**	483.250
	Mortality	**483.25**	1512.960
N	Canopy cover	**5**	**5**
	Mortality	**5**	**5**

Table 11. Correlations between canopy cover with mortality rate in the forest of

Castanopsis tribuloides			
	Mean	SD	N
Canopy cover	**80.00**	**15.81**	**5**
Mortality	**11.94**	**8.2**	**5**

Correlation			
		Canopy cover	Mortality
Pearson	Canopy cover	1.000	**0.976****
Correlation	Mortality	**0.976****	1.000
Sig.	Canopy cover	0.000	**0.005**
(2-tail)	Mortality	**0.005**	0.000
Sum of	Canopy cover	**1000.00**	507.000
Squares	Mortality	**507.000**	269.990
Covariance	Canopy cover	**250**	126.750
	Mortality	**126.75**	67.490
N	Canopy cover	**5**	**5**
	Mortality	**5**	**5**

** = Correlation is significant at the 0.01 level (2-tailed)

Table 12. Correlations between canopy cover with mortality rate in the forest of

Eugenia albiflora			
	Mean	SD	N
Canopy cover	**80.00**	**15.81**	**5**
Mortality	**9.78**	**5.81**	**5**

Correlation			
		Canopy cover	Mortality
Pearson	Canopy cover	1.000	**0.892***
Correlation	Mortality	**0.892***	1.000
Sig.	Canopy cover	0.000	**0.042**
(2-tail)	Mortality	**0.042**	0.000
Sum of	Canopy cover	**1000.00**	328.000
Squares	Mortality	**328.000**	252.210
Covariance	Canopy cover	**250**	82.000
	Mortality	**82**	33.790
N	Canopy cover	**5**	**5**
	Mortality	**5**	**5**

* = Correlation is significant at the 0.05 level (2-tailed)

Table 13. Correlations between canopy cover with relative height growth rate of

Sarcosperma arboreum			
	Mean	SD	N
RGR height	**13.34**	**15.52**	**54**
Canopy cover	**78.11**	**5.41**	**54**

Correlation			
		RGR height	Canopy cover
Pearson	RGR of height	1.000	**-0.137**
Correlation	Canopy cover	**-0.137**	1.000
Sig.	RGR of height	0.000	**0.323**
(2-tail)	Canopy cover	**0.323**	0.000
Sum of	RGR of height	**12766.49**	-610.528
Squares	Canopy cover	**-610.528**	1555.813
Covariance	RGR of height	**240.877**	-11.519
	Canopy cover	**-11.519**	29.355
N	RGR of height	**54**	**54**
	Canopy cover	**54**	**54**

Table 14. Correlations between canopy cover with relative height growth rate of

Podocarpus neriifolius			
	Mean	SD	N
RGR height	**22.2**	**27.52**	**78**
Canopy cover	**79.55**	**4.31**	**78**

Correlation			
		RGR height	Canopy cover
Pearson	RGR of height	1.000	**0.004**
Correlation	Canopy cover	**0.004**	1.000
Sig.	RGR of height	0.000	**0.973**

(2-tail)	Canopy cover	**0.973**	0.000
Sum of Squares	RGR of height	**1434.84**	36.220
	Canopy cover	**36.22**	58335.260
Covariance	RGR of height	**18.63**	0.470
	Canopy cover	**0.47**	757.601
N	RGR of height	**78**	**78**
	Canopy cover	**78**	**78**

Table 15. Correlations between canopy cover with relative height growth rate of

Eugenia albiflora			
	Mean	SD	N
RGR height	**10.81**	**7.72**	**54**
Canopy cover	**78.47**	**4.78**	**54**

Correlation			
		RGR height	Canopy cover
Pearson Correlation	RGR of height	1.000	**-0.138**
	Canopy cover	**-0.138**	1.000
Sig. (2-tail)	RGR of height	0.000	**0.319**
	Canopy cover	**0.319**	0.000
Sum of Squares	RGR of height	**1259.37**	-275.950
	Canopy cover	**-275.95**	3161.559
Covariance	RGR of height	**23.762**	-5.207
	Canopy cover	**-5.207**	59.652
N	RGR of height	**54**	**54**
	Canopy cover	**54**	**54**

Table 16. Correlations between canopy cover with relative height growth rate of

Castanopsis tribuloides			
	Mean	SD	N
RGR height	**23.85**	**20.44**	**71**
Canopy cover	**75.66**	**8.3**	**71**

Correlation			
		RGR height	Canopy cover
Pearson	RGR of height	1.000	**-0.126**
Correlation	Canopy cover	**-0.126**	1.000
Sig.	RGR of height	0.000	**0.295**
(2-tail)	Canopy cover	**0.295**	0.000
Sum of	RGR of height	**4823.083**	-1496.175
Squares	Canopy cover	**-1496.175**	29268.837
Covariance	RGR of height	**68.901**	-21.374
	Canopy cover	**-21.374**	418.126
N	RGR of height	**71**	**71**
	Canopy cover	**71**	**71**

Table 17. Correlations between soil moisture with mortality rate of

Sarcosperma arboreum			
	Mean	SD	N
Soil moisture	**3.00**	**5.62**	**6**
Mortality	**6.46**	**1.21**	**6**

Correlation			
		Soil moisture	Mortality
Pearson	Soil moisture	1.000	**0.719**
Correlation	Mortality	**0.719**	1.000
Sig.	Soil moisture	0.000	**0.108**
(2-tail)	Mortality	**0.108**	0.000
Sum of	Soil moisture	**158.00**	24.600
Squares	Mortality	**24.600**	7.413
Covariance	Soil moisture	**31.6**	4.920
	Mortality	**4.92**	1.483
N	Soil moisture	**6**	**6**
	Mortality	**6**	**6**

Table 18. Correlations between soil moisture with mortality rate of

Podocarpus neriifolius			
	Mean	SD	N
Soil moisture	**6.05**	**2.26**	**6**
Mortality	**7.5**	**7.17**	**6**

Correlation			
		Soil moisture	Mortality
Pearson	Soil moisture	1.000	**0.921****
Correlation	Mortality	**0.921****	1.000
Sig.	Soil moisture	0.000	**0.009**

(2-tail)	Mortality	**0.009**	0.000
Sum of Squares	Soil moisture	**25.55**	74.750
	Mortality	**74.750**	257.500
Covariance	Soil moisture	**5.111**	14.950
	Mortality	**14.95**	51.500
N	Soil moisture	**6**	**6**
	Mortality	**6**	**6**

** = Correlation is significant at the 0.01 level (2-tailed)

Table 19. Correlations between soil moisture with mortality rate of

Eugenia albiflora			
	Mean	SD	N
Soil moisture	**6.71**	**1.78**	**6**
Mortality	**3.83**	**5.34**	**6**

Correlation			
		Soil moisture	Mortality
Pearson Correlation	Soil moisture	1.000	**0.816***
	Mortality	**0.816***	1.000
Sig. (2-tail)	Soil moisture	0.000	**0.047**
	Mortality	**0.047**	0.000
Sum of Squares	Soil moisture	**15.90**	38.910
	Mortality	**38.910**	142.830
Covariance	Soil moisture	**3.182**	7.783
	Mortality	**7.783**	28.567
N	Soil moisture	**6**	**6**
	Mortality	**6**	**6**

* = Correlation is significant at the 0.05 level (2-tailed)

Table 20. Correlations between soil moisture with mortality rate of

Castanopsis tribuloides			
	Mean	SD	N
Soil moisture	**4.83**	**3.65**	**6**
Mortality	**6.2**	**1.71**	**6**

Correlation			
		Soil moisture	Mortality
Pearson	Soil moisture	1.000	**0.935****
Correlation	Mortality	**0.935****	1.000
Sig.	Soil moisture	0.000	**0.006**
(2-tail)	Mortality	**0.006**	0.000
Sum of	Soil moisture	**66.83**	29.300
Squares	Mortality	**29.300**	14.680
Covariance	Soil moisture	**13.367**	5.860
	Mortality	**5.86**	2.936
N	Soil moisture	**6**	**6**
	Mortality	**6**	**6**

** = Correlation is significant at the 0.01 level (2-tailed)

Table 21. Correlations between ground flora cover with RGR for height of

Sarcosperma arboreum			
	Mean	SD	N
RGR height	**23.09**	**14.75**	**46**
Weed cover	**13.3**	**14.26**	**46**

Correlation			
		RGR height	Weed cover
Pearson	RGR of height	1.000	**0.088**
Correlation	Weed cover	**0.088**	1.000
Sig.	RGR of height	0.000	**0.563**
(2-tail)	Weed cover	**0.563**	0.000
Sum of	RGR of height	**9799.532**	829.142
Squares	Weed cover	**829.142**	9160.119
Covariance	RGR of height	**217.767**	18.425
	Weed cover	**18.425**	203.558
N	RGR of height	**46**	**46**
	Weed cover	**46**	**46**

Table 22. Correlations between ground flora cover with RGR for height of

Podocarpus neriifolius			
	Mean	SD	N
RGR height	**16.53**	**10.94**	**75**
Weed cover	**22.54**	**27.99**	**75**

Correlation			
		RGR height	Weed cover
Pearson	RGR of height	1.000	**0.074**
Correlation	Weed cover	**0.074**	1.000
Sig.	RGR of height	0.000	**0.527**

(2-tail)	Weed cover	**0.527**	0.000
Sum of Squares	RGR of height	**8867.005**	1682.506
	Weed cover	**1682.506**	57993.436
Covariance	RGR of height	**119.824**	22.737
	Weed cover	**22.737**	783.695
N	RGR of height	**75**	**75**
	Weed cover	**75**	**75**

Table 23. Correlations between ground flora cover with RGR for height of

Eugenia albiflora			
	Mean	SD	N
RGR height	**19.15**	**9.86**	**53**
Weed cover	**10.87**	**7.78**	**53**

Correlation			
		RGR height	Weed cover
Pearson Correlation	RGR of height	1.000	**0.042**
	Weed cover	**0.042**	1.000
Sig. (2-tail)	RGR of height	0.000	**0.767**
	Weed cover	**0.767**	0.000
Sum of Squares	RGR of height	**5061.792**	166.242
	Weed cover	**166.242**	3151.613
Covariance	RGR of height	**97.342**	3.197
	Weed cover	**3.197**	60.608
N	RGR of height	**53**	**53**
	Weed cover	**53**	**53**

Table 24. Correlations between ground flora cover with RGR for height of

Castanopsis tribuloides			
	Mean	SD	N
RGR height	**25.36**	**16.37**	**71**
Weed cover	**23.85**	**20.44**	**71**

Correlation			
		RGR height	Weed cover
Pearson	RGR of height	1.000	**0.128**
Correlation	Weed cover	**0.128**	1.000
Sig.	RGR of height	0.000	**0.288**
(2-tail)	Weed cover	**0.288**	0.000
Sum of	RGR of height	**18777.406**	2998.789
Squares	Weed cover	**2998.789**	29268.837
Covariance	RGR of height	**268.249**	42.840
	Weed cover	**42.84**	418.126
N	RGR of height	**71**	**71**
	Weed cover	**71**	**71**

Table 25. Correlations between ground flora cover with soil moisture

Sarcosperma arboreum			
	Mean	SD	N
Soil moisture	**7.13**	**1.56**	**6**
Weed cover	**20.23**	**3.07**	**6**

Correlation			
		Soil moisture	Weed cover
Pearson	Soil moisture	1.000	**0.895***
Correlation	Weed cover	**0.895***	1.000
Sig.	Soil moisture	0.000	**0.016**
(2-tail)	Weed cover	**0.016**	0.000
N	Soil moisture	**6**	**6**
	Weed cover	**6**	**6**

* = Correlation is significant at the 0.05 level (2-tailed)

Table 26. Correlations between ground flora cover with soil moisture

Castanopsis tribuloides			
	Mean	SD	N
Soil moisture	**6.28**	**1.68**	**6**
Weed cover	**24.3**	**5.71**	**6**

Correlation			
		Soil moisture	Weed cover
Pearson	Soil moisture	1.000	**0.927****
Correlation	Weed cover	**0.927****	1.000
Sig.	Soil moisture	0.000	**0.008**
(2-tail)	Weed cover	**0.008**	0.000
N	Soil moisture	**6**	**6**
	Weed cover	**6**	**6**

** = Correlation is significant at the 0.01 level (2-tailed)

Table 27. Correlations between ground flora cover with soil moisture

Podocarpus neriifolius			
	Mean	SD	N
Soil moisture	**6.06**	**2.32**	**6**
Weed cover	**15.21**	**4.88**	**6**

Correlation			
		Soil moisture	Weed cover
Pearson	Soil moisture	1.000	**0.870***
Correlation	Weed cover	**0.870***	1.000
Sig.	Soil moisture	0.000	**0.024**
(2-tail)	Weed cover	**0.024**	0.000
N	Soil moisture	**6**	**6**
	Weed cover	**6**	**6**

* = Correlation is significant at the 0.05 level (2-tailed)

Table 28. Correlations between ground flora cover with soil moisture

Eugenia albiflora			
	Mean	SD	N
Soil moisture	**6.75**	**1.81**	**6**
Weed cover	**16.3**	**4.38**	**6**

Correlation			
		Soil moisture	Weed cover
Pearson	Soil moisture	1.000	**0.864***
Correlation	Weed cover	**0.864***	1.000
Sig.	Soil moisture	0.000	**0.026**
(2-tail)	Weed cover	**0.026**	0.000
N	Soil moisture	**6**	**6**
	Weed cover	**6**	**6**

* = Correlation is significant at the 0.05 level (2-tailed)

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