FORESTS *for* THE FUTURE:

Growing and Planting Native Trees for Restoring Forest Ecosystems

BY

THE FOREST RESTORATION RESEARCH UNIT

The British Council

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Seed dispersing pigeons feast on Hovenia dulcis fruits

It is impossible to ascribe this book to a single author or even a small group. The information contained within it has been contributed by all the many people who have participated in the FORRU project, including...

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Forru staff, volunteers and villagers after tree planting on Doi Suthep, 1995.

FORESTS FOR THE FUTURE:

GROWING AND PLANTING NATIVE TREES FOR RESTORING FOREST ECOSYSTEMS

"..some day Man may want to rebuild what has been squandered
and from remnants of original habitat
he can..draw genetic stock
and learn how ecological pieces have adjusted
to create a harmonious system."

George B. Schaller

FOREST RESTORATION RESEARCH UNIT

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DRAWINGS BY SURAT PLUKAM

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CONTENTS

A young boy learns how to grow trees at FORRU's community tree nursery at Ban Mae Sa Mai

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The Head and staff of Doi Suthep Pui National Park Headquarters have played an essential role in the project. We are especially grateful to Mr. Prawat Wohandee, Head of the National Park, Mr. Amporn Panmongkol, Deputy Head and Mr. Prasert Saentaam. The University of Bath, Horticulture Research International and The Natural History Museum, London supported the participation of David Blakesley and Nancy C. Garwood respectively. We also thank the staff and volunteers, especially Nigel Tucker and Tania Murphy, at Lake Eacham Regional Nursery in Queensland, where FORRU staff received valuable training. Training of FORRU staff was also provided by the ASEAN-Canada Forest Tree Seed Centre. Last but not least, we thank the Biology Department, Science Faculty, Chiang Mai University for institutional support of FORRU and especially for providing herbarium and botanical database facilities.

The text of this book was originally compiled in English by Stephen Elliott and David Blakesley and translated into Thai by Sudarat Zangkum, Kunagorn Boonsai and Vilaiwan Anusarnsunthorn. The cover picture and drawings are mostly by Surat Plukam and photographs by Stephen Elliott, Puttipong Navakitbumrung and Cherdsak Kuarak. Helpful comments on the text were provided by J. F. Maxwell and M.R. Smansnid Svasti who also designed FORRU's logo.

All opinions expressed in this book are those of the editors and not necessarily those of the sponsors or reviewers. The editors would like to take this opportunity to thank anyone, not already mentioned above, who has contributed towards the FORRU project and the production of this book.

MESSAGE FROM THE DIRECTOR OF THE BRITISH COUNCIL, THAILAND

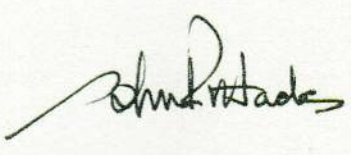
Dr. John Richards
Director
The British Council, Thailand

The British Council

Tropical forests cover only 7% of Earth's land surface, yet they are home to more than half of the world's plant and animal species. The forests are also important in many other respects; in Thailand, forest products provide many peoples' livelihoods; they provide the oxygen we breath and the water we drink. Yet these forests are being destroyed faster than any other ecosystem. Thailand still retains significant natural tropical forests, but much of what once existed has already gone. In 1990 remaining forest cover in Thailand was only 17% of its original area and less than one third of this was primary forest in its original state. Once this unique environment is lost, it is difficult to re-establish it and therefore it is vitally important that adequate areas of forest are conserved.

The work of the Forest Restoration Research Unit (FORRU) of Chiang Mai University and Doi Suthep-Pui National Park of the Royal Thai Forest Department are making a most important contribution to the rehabilitation of damaged forest areas within the remaining natural forests of Northern Thailand. Their work has generated much interest and support from amongst scientists of other countries, including the United Kingdom. The British Council has been pleased to have supported the unit in various ways, especially in enabling Dr. Nancy Garwood, Dr. David Blakesley and their teams at the Natural History Museum, London and the University of Bath respectively to contribute to the work of FORRU since it began in 1994.

The purpose of this book is to provide a simple, accessible and practical guide to forest restoration so that others may apply the findings of the FORRU project. The full success of the practical work of the Chiang Mai team and their international collaborators will be demonstrated if others are able to apply procedures and knowledge generated by the project in other areas of Thailand's remaining tropical forest. I am delighted that the British Council had been able to contribute to its publication and the dissemination of the practical advice it contains.



MESSAGE FROM RICHE MONDE (BANGKOK) LTD.

Prof. Tasman Smith
Executive Chairman
Riche Monde (Bangkok) Ltd.

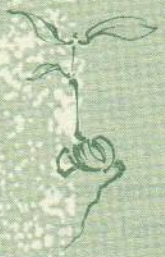
Riche Monde
Bangkok

A healthy economy depends on a healthy environment. Without clean air and water, the food and beverage industry could not survive. Forests play a major role in maintaining environmental quality by regulating the climate and preserving watersheds. Yet, despite a national ban on commercial logging, Thailand's forests continue to disappear at an alarming rate. As a company whose profitability depends on a healthy environment, Riche Monde (Bangkok) Ltd. recognizes the importance of not only preserving what remains of Thailand's once extensive forests, but also acting positively to restore forests which have been degraded or destroyed. Therefore, the company established a fund for environmental education and conservation in 1993 to provide scholarships for Thai students to study environmental management and to support research projects that would help preserve and enhance Thailand's natural resources.

One of the projects supported by the fund was the establishment of the Forest Restoration Research Unit (FORRU) on Doi Suthep. After nearly four years of work, the unit is now producing valuable information to enable the planting of native tree species to restore natural forest ecosystems in northern Thailand. Through workshops and other educational activities, the unit has provided information to enable more people to become involved in tree planting activities and has helped to improve the efficiency of existing reforestation projects. Through publication of this book, the practical approach towards reforestation which has been developed by FORRU will now be accessible to a much wider audience. This book provides an excellent starting point for people who want to become actively involved in restoring this nation's forests, but feel that they lack the technical knowledge needed. Riche Monde (Bangkok) Ltd. is proud to have had the opportunity to sponsor the establishment of FORRU and we hope that other private sector companies will share our viewpoint by investing in the long term viability of Thailand's environment.

Tasman Smith

PART 1



INTRODUCTION

The Forest Restoration Research Unit

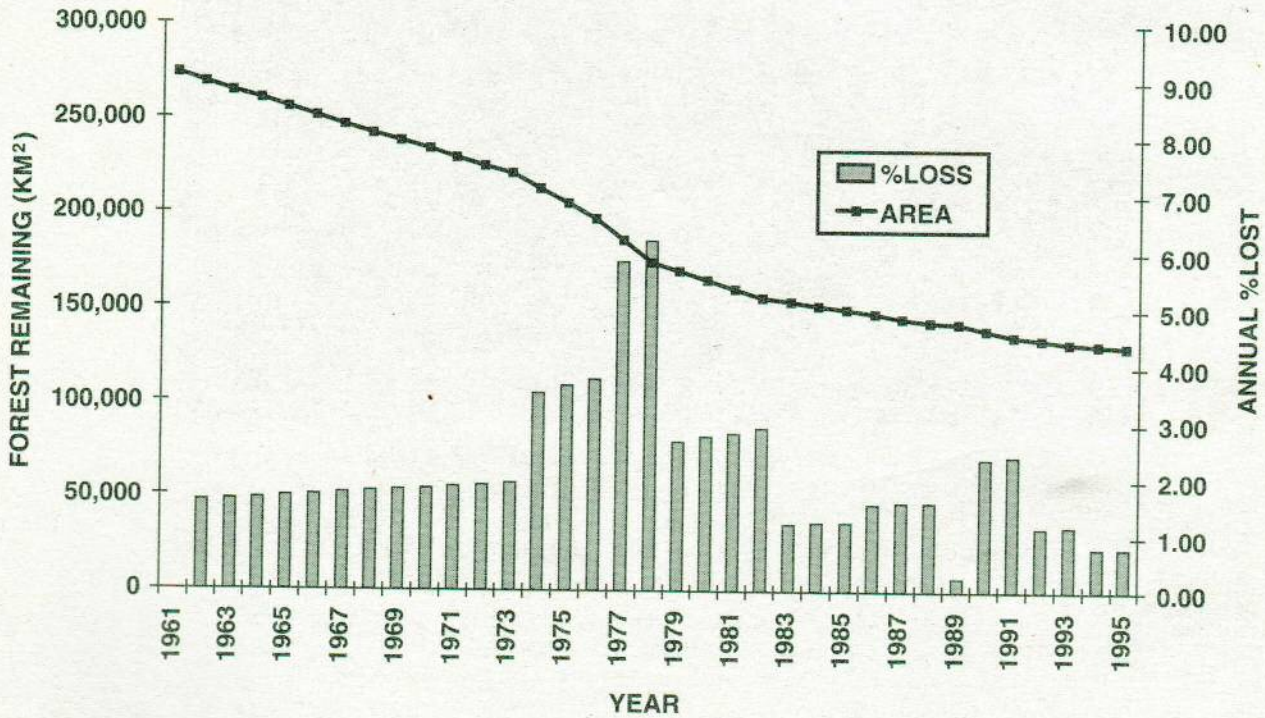
With a founding grant from Riche Monde (Bangkok) Ltd. FORRU opened on November 21st 1994. From left to right Kuhn Amporn Panmongkol (former Doi Suthep-Pui Park chief), Prof. Chote Teetranon (CMU President), Prof. Tasman Smith (Riche Monde Bangkok Ltd. CEO), Prof. Kittichai Watananikorn (Science Faculty Dean), Mr. Mark Graham (Liaison for Riche Monde Bangkok Ltd.) and Kuhn Nonglak Thanaraks (Riche Monde Bangkok Ltd. Official).

INTRODUCTION

Deforestation is one of the most important environmental problems in Thailand today, causing loss of wildlife habitat, erosion of watersheds and worsening rural poverty. Protecting what remains of Thailand's forests is essential for the environmental stability of the country; but protection alone is clearly not enough. Since establishment of the first protected areas in the 1960's, Thailand's forest cover has been reduced from 53% (Bhumibamon, 1986) to about 22.8% or 111,010 km^2 (FAO, 1997). Unofficial estimates, however, put Thailand's forest cover at below 20% (Leungaramsri & Rajesh, 1992).

A ban on commercial logging since 1989, has helped to slow the destruction, but the deforestation rate still exceeds 1,000 km^2 per year (according to Royal Forest Department statistics), due to illegal logging, agricultural expansion, and development projects. Following the logging ban, many former timber concession areas were designated national parks or wildlife sanctuaries. Conservation areas now cover about 13% of the country, but large parts of many of them are deforested. Protective measures can, at best, only slow deforestation. If the trend of forest loss is to be reversed, better protection must be complemented by restoration.

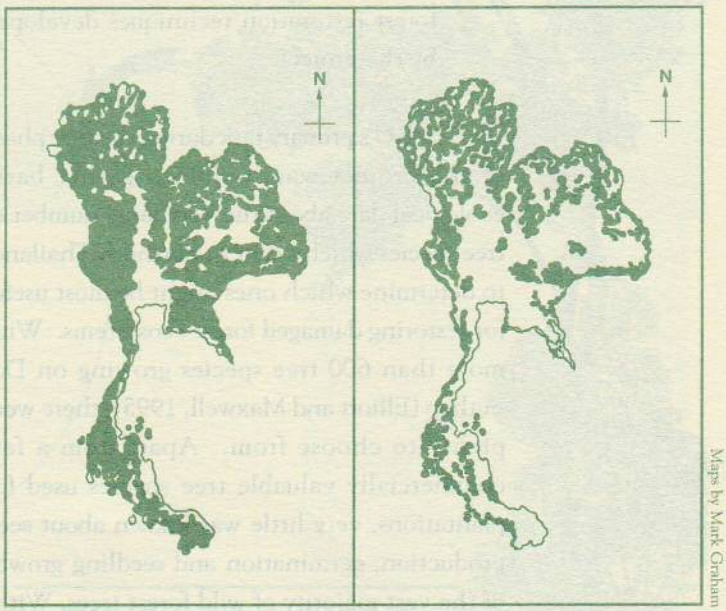
The government, non-governmental organizations and local communities all recognize the need to reforest degraded areas. Tree planting events, organized by state agencies, companies, villagers, students etc. are very



Thailand's forest area has declined to about 111,000 km^2 (bold line). The rate of loss (vertical bars) peaked in the late 1970's, reached a minimum in 1989, when commercial logging was first banned, but then increased and is now about 0.8% annually (RFD statistics).

popular. Since 1993, various projects to celebrate the Golden Jubilee of His Majesty King Bhumibol Adulyadej have encouraged even more people to become involved in restoring forests. Even private sector companies have provided generous donations to support tree planting.

However, although people participate enthusiastically in tree planting events, the results are often disappointing. Restoring complex natural forest ecosystems requires a completely different approach to that of conventional plantation forestry with pines or eucalypts. Forest ecosystems contain a very wide diversity of tree species, many of which have never been studied in detail. Seedlings grown for tree planting projects are often of low quality or they belong to species unsuitable for the site being planted. Methods of growing and planting native forest tree seedlings need to be improved and appropriate methods to care for seedlings in the first few years after planting (e.g. fertilizer application, weeding etc.) need to be developed. Based on research carried out by the Forest Restoration Research Unit since 1994, this book provides some preliminary advice on how to grow and plant selected tree species, considered to be especially useful in accelerating the natural regeneration of forest ecosystems. We hope that it will encourage more organizations to become involved in restoring Thailand's degraded forest areas and improve the efficiency of ongoing projects.



Maps by Mark Graham

Thailand's forest cover in 1950 was approximately 60%.

Thailand's forest cover today is less than 20%.

The Forest Restoration Research Unit (FORRU)

FORRU was established in 1994 to address some of the technical problems of re-establishing natural forest ecosystems on degraded sites within conservation areas (Elliott et al., 1995). It is a joint initiative between Chiang Mai University (CMU) and Doi Suthep-Pui National Park (under the Royal Thai Forest Department (RFD)) which adjoins the university campus. The unit is situated near the Headquarters of Doi Suthep-Pui National Park (18°50' N, 98° 50' E) at about 1,000 m elevation and has a permanent research staff of 5. It consists of a large nursery, an office and a computer room. The project has also recently established a community tree seedling nursery and field trials at Ban Mae Sa Mai, an Hmong hill tribe village in the north of the national park.

The aim of the project is to determine the most effective methods to complement and accelerate natural forest regeneration on deforested sites within conservation areas to increase biodiversity and protect watersheds. Specific objectives include:

i) development of tools for studying the restoration of natural forest ecosystems, such as a seedling identification handbook, seedling herbarium and databases of seed, fruit and seedling morphology;
ii) understanding of the ecological processes

of natural forest regeneration to determine ways in which these processes might be accelerated;

iii) identification of tree species suitable for planting to complement natural seedling establishment;

iv) development of appropriate methods to propagate such tree species and test their performance after planting out and

v) training of interested groups in the new forest restoration techniques developed by the project.

FORRU's primary task during the first phase of the project was simply to gather basic ecological data about the very large number of tree species which occur in northern Thailand, to determine which ones might be most useful for restoring damaged forest ecosystems. With more than 600 tree species growing on Doi Suthep (Elliott and Maxwell, 1995), there were plenty to choose from. Apart from a few commercially valuable tree species used for plantations, very little was known about seed production, germination and seedling growth of the vast majority of wild forest trees. Without such information, it was impossible to make sensible choices as to which tree species to use in forest restoration projects, so FORRU collected the seeds of as many species as possible and developed criteria to assess their potential to restore damaged forest ecosystems (Elliott et al., 1997a). Initially research concentrated on upper watershed areas.

When can seeds be collected ?

Most nurseries propagate tree seedlings from seed, so it is important to know when ripe seeds are available. To provide such information, FORRU staff walk along forest trails near the unit once every three weeks and observe 339 marked trees of 94 native forest tree species with binoculars, recording when and how many fruits are produced. The data collected are fed into a computer to produce graphs, which can be used by nursery managers to help plan seed collection programs (*see* opposite page).

Data on the characteristics of fruits and seeds (e.g. colour, size, shape, weight etc.) are entered into a computer database which can be used to help identify species and provide clues as to their seed dispersal mechanisms (Pakkad, 1997). Different fruit or seed types vary in their potential to be naturally dispersed into deforested areas and some are more likely to attract wildlife into planted sites than others, so it is important that fruit and seed characteristics are considered among the criteria used to select trees for forest restoration projects.

Seed Germination

With so many tree species to choose from, it makes sense to select those for forest restoration projects which are easy to grow, so germination trials at FORRU were designed to find out which species germinate easily without the complication of pre-treating the seeds in some way. These trials are providing data on the length of seed dormancy and germination rates, so that nursery managers can estimate how many seeds to sow and how long they might have to wait to produce a required number of seedlings.

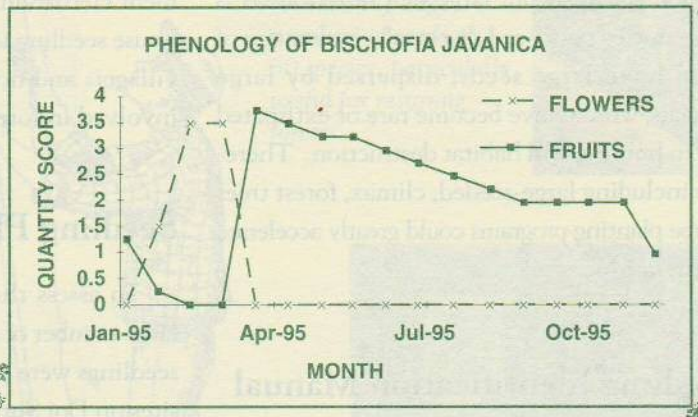
Seeds are collected from any trees observed in fruit, along with data about the parent trees (e.g. location, habitat, girth, height, bark characteristics etc.). Dried specimens of the trees' fruits and leaves are prepared and stored at the CMU Biology Department Herbarium, so that the parent tree species can be identified. These specimens comprise a valuable reference collection which workers on tree planting projects can consult to confirm identification of tree species being planted.

In the first phase of the project, simple experiments were carried out to compare seed germination in partial shade (similar to that in deforested gaps) and deep shade (similar to that beneath a forest canopy) to eliminate species which are strongly shade dependent, since they

PHENOLOGY

Scientific study of the seasonal cycles of living things.

At FORRU we study the phenology of flowering and fruiting of mature forest trees. The quantities of flowers and fruits observed on more than 300 trees are recorded at three week intervals. Data are processed with a computer to generate a graph of each species' phenological profile.



This phenological profile of Bischofia javanica shows that fruits mature from March until November. They should only be collected when falling from the canopy in December to February.

FORRU staff teach school children how to grow tree seedlings at the Hmong village of Mae Sa Mai.

would be of no use for planting in sunny deforested sites. The results of these experiments are showing that many so called primary or climax forest tree species can germinate and grow well in the low shade conditions characteristic of deforested sites. The absence of such species from large deforested areas is often due to poor seed dispersal, since many of them have large seeds, dispersed by large animals, which have become rare or extirpated due to hunting and habitat destruction. Therefore including large-seeded, climax, forest trees in tree planting programs could greatly accelerate regeneration.

Seedling Identification Manual

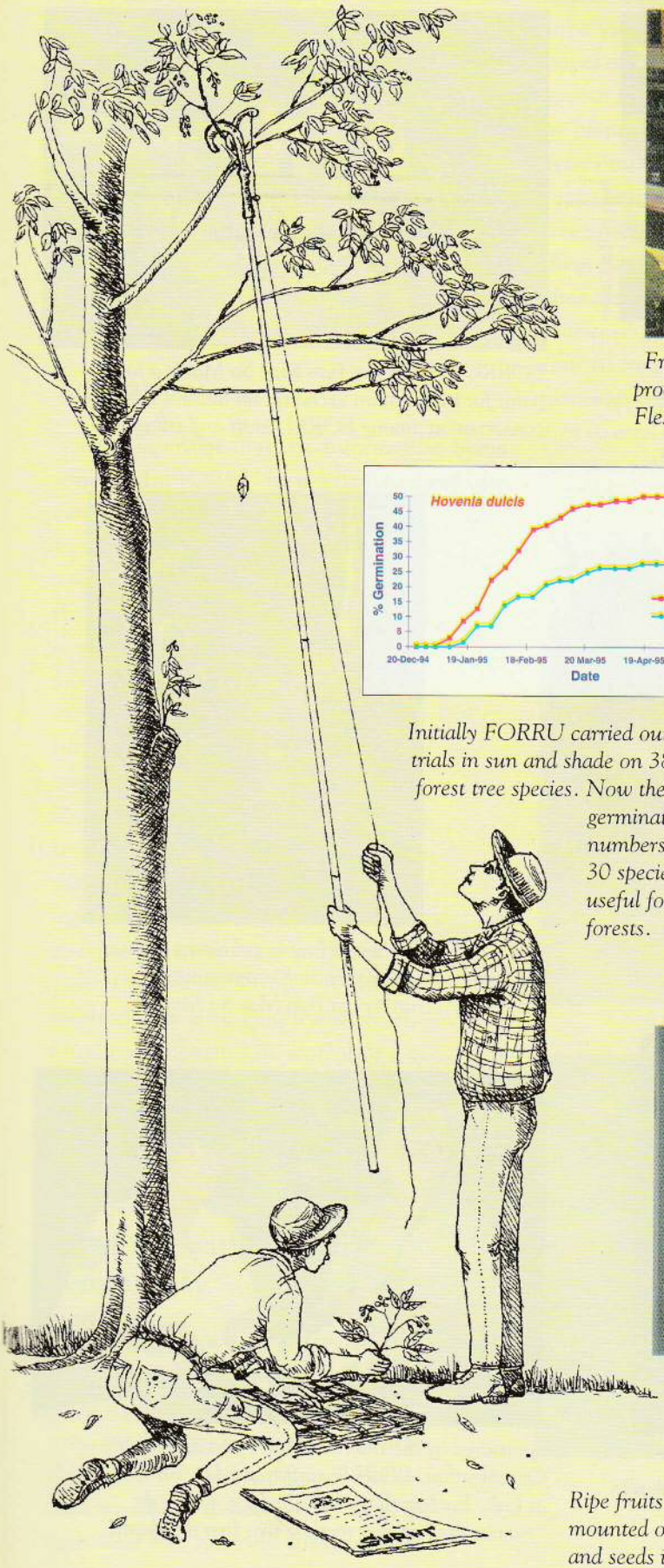
Whether you are surveying deforested sites for naturally established seedlings, selecting seedlings from a nursery or digging them up from the forest, you will need to know how to identify them. Conventional plant identification books use flower or fruit characteristics to determine species. Tree seedlings are too young to bear any flowers or fruits, so a specialized text is needed to help tree planters identify seedlings.

In order to provide material for such a text, seedlings of known age are harvested from the germination experiments at different stages of development. They are photographed, drawn, described and prepared as dried herbarium specimens, stored at CMU's Biology Department Herbarium. The aim is to produce an easy to use seedling identification book for foresters, villagers and non-governmental organizations involved in forest restoration projects.

Seedling Planting Trials

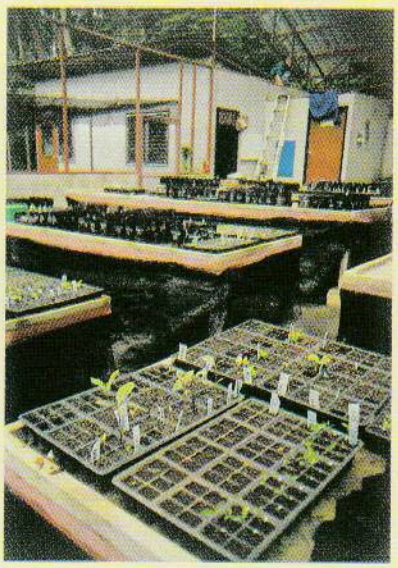
To assess the relative performance of the large number of species germinated at FORRU, seedlings were planted randomly in deforested sites on Doi Suthep amongst weedy vegetation and their survival and growth rates monitored. These trials revealed enormous variability among species in their ability to survive in the harsh conditions of deforested sites and intense competition from weeds. Subsequently species selection criteria were refined (Elliott et al., 1997a) and a preliminary list produced of so-called "framework" species which, on the basis of previous results, were judged to have the greatest potential to accelerate forest regeneration (*see* Part 2). Research was begun to

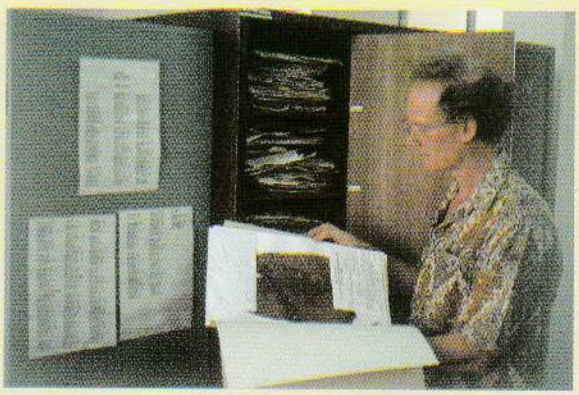
COLLECTING SEEDS - THE FUTURE FOREST ?



Fruits collected from Doi Suthep-Pui National Park are processed at FORRU's nursery before the seeds are sown. Fleshy fruit parts are removed to prevent fungal infection.

Initially FORRU carried out germination trials in sun and shade on 380 native forest tree species. Now the unit is germinating large numbers of seeds of 30 species, particularly useful for restoring forests.





Dried reference specimens are kept in the Herbarium of Chiang Mai University's Biology Department.

Ripe fruits are collected from tall trees using a cutter mounted on a long pole. A specimen of the fruit and seeds is collected to identify the species.

WORKING WITH PEOPLE

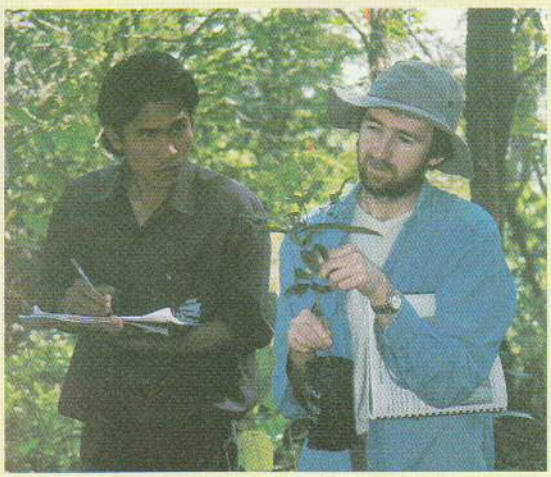
Photo by Mark Graham

FORRU is a collaborative initiative between Doi Suthep-Pui National Park and CMU's Biology Department. Former park chief, Kuhn Amporn Panmongkol, discusses nursery blueprints with Dr. Stephen Elliott and Dr. Vilaiwan Anusarnsunthorn (Sept. 9th 1994).

FORRU's nursery at Ban Mae Sa Mai is a focal point for information exchange on natural resources conservation among FORRU staff and villagers.

Education is a vital activity at FORRU. Here school children learn about framework tree species, during one of the unit's workshops.

A young Hmong girl learns potting techniques at the community tree nursery at Ban Mae Sa Mai.



International training - with support from the British Council, U.K. experts, such as David Blakesley provide continual advice to FORRU staff.

Sponsored by the International Tropical Timber Organization, FORRU staff trained in 1997 at Lake Eacham Regional Nursery, where the "framework" species method was first developed.

improve seedling propagation methods in the nursery, to ensure that seedlings planted out were as healthy and vigorous as possible (Zangkum, 1998). Small experimental plots were established to test different methods of weed control and fertilizer application. Many of the trees planted are now thriving and the advice on growing and planting seedlings, in Parts 3 & 4 of this book, is mostly based on the experience gained during these experiments.

Education

It is essential that the information being generated at FORRU is passed on to those who can use it to improve tree planting programs. In addition to hosting many visits from a wide range of different organizations throughout the year, FORRU organizes workshops to share information generated by the project. FORRU is expanding its educational activities with the recent appointment of a full-time education officer from Voluntary Service Overseas, U.K. Ms. Janice Kerby is training FORRU staff to produce educational materials and improve workshops. Furthermore the project has produced several publications (listed on pages 59-60). If you are interested in arranging a visit to the unit, participating in workshops or obtaining copies of publications, please contact FORRU at the address given inside the back cover of this book.

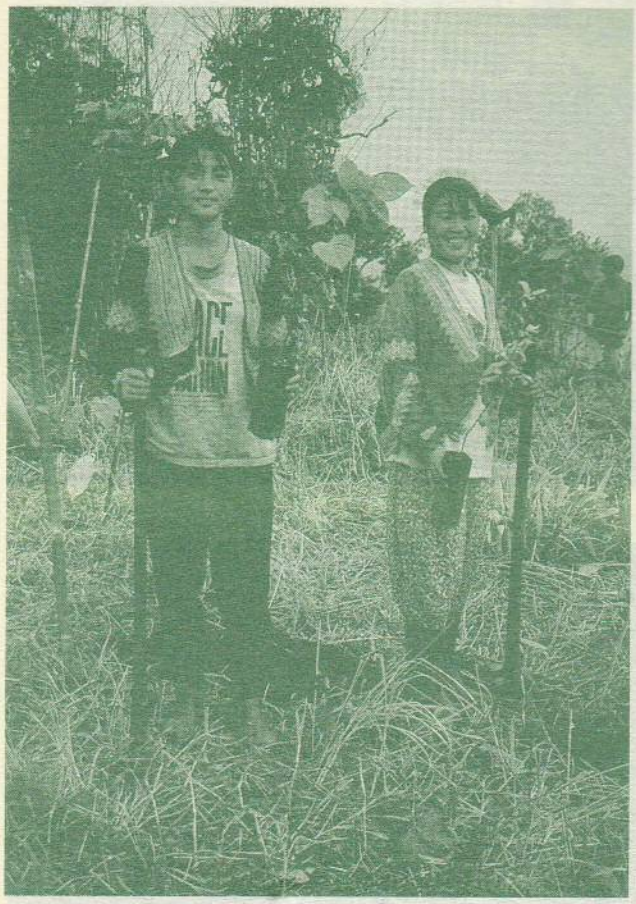
Working with a local community

FORRU is not a social development project. Its aim is not to persuade individuals or communities to plant trees, but to provide technical advice to those who decide for themselves that they would like to become involved in restoring the nation's disappearing forests. One such community is the Hmong hill tribe village of Mae Sa Mai on the northern slopes of Doi Suthep-Pui. The villagers wanted to join the King's Golden Jubilee celebrations by planting native forest trees on abandoned agricultural land above their village. At first they obtained seedlings of a limited number of tree species from local nurseries and planted them directly into weedy vegetation with no after-care. The results were disappointing. Doi Suthep-Pui National Park HQ asked FORRU staff to help the villagers improve their tree planting program and, since FORRU needed an area to establish experimental plots, a partnership was formed.

Hmong villagers plant tree seedlings produced at FORRU's community nursery in their village of Mae Sa Mai to celebrate the Queen's birthday, August 1997.

The villagers were dissatisfied with the limited species choice and poor quality of seedlings obtained from local tree nurseries, so FORRU provided funds for them to build their own nursery near the village and trained and employed two villagers to run it. The Ban Mae Sa Mai community tree nursery has now more than doubled the seedling production capacity of FORRU, enabling the project to plant much larger experimental plots and it has reduced transportation costs, since it is much nearer to the planting site than FORRU's research nursery. It also provides an opportunity to test the feasibility of new techniques developed by FORRU, within a local community.

A rather unexpected outcome of establishing the village nursery was that it became a meeting place for the village's conservationists, who formed their own association, the "Mae Sa Mai Resources Conservation Volunteer Group". The group organized the cutting of fire breaks and manned fire lookouts to protect the planted areas. Regular meetings between the group and FORRU staff occur at the new village nursery, during which FORRU staff provide technical advice about species selection, nursery methods, planting and management of planted sites. The villagers provide local information on the usefulness of the various species and their relative attractiveness to wildlife. Having seen the results of FORRU's initial experimental plots, using the framework species method, the villagers agreed to test the method in larger plots in 1998, using seedlings mostly grown in their own nursery. Sponsored by the Biodiversity Research and Training Program, the 1998 plots are testing the performance of 29 potential framework species, as well as assessing the effects of various weeding, mulching and fertilizer treatments.



In June 1998, villagers from Ban Mae Sa Mai joined with school children from Chiang Mai, RFD staff, the YMCA and FORRU staff to plant seedlings to establish experimental plots, sponsored by the Biodiversity Research and Training Program.

PART 2

SELECTED TREE SPECIES FOR RESTORING FOREST ECOSYSTEMS

Framework tree species like this Bischofia javanica sapling (about 18 months after planting) can accelerate forest regeneration by attracting birds and shading out weeds.

Selected Tree Species for Restoring Forest Ecosystems

In this part, details are presented of ten of the most promising tree species for forest restoration projects, based on the results of FORRU so far. There are no universal rules for restoring forests. Each site has its own particular conditions and each species its own requirements. With current incomplete ecological information about Thailand's trees, forest restoration is more of an art than a science. There is no substitute for detailed local knowledge. It should also be remembered that the work of FORRU is still ongoing. Therefore, these recommendations are preliminary and may change as the long-term results of planting trials become available. For the most up-to-date advice, please contact FORRU.

Section 1 - The "framework species" method

Attempting to replant all tree species that originally comprised a forest ecosystem before its destruction is not only impractical, but also unnecessary. Nature has great powers of regeneration, so all that is needed is to restore the essential basic elements of the forest and then let nature complete the task. The objective of tree planting should be to accelerate natural forest regeneration by increasing tree density and species diversity and by encouraging the dispersal of seeds of non-planted tree species into planted sites. This means conserving any existing seedling community and adding carefully selected species to it; specifically those that will grow rapidly, shade out weeds and attract seed-dispersing wildlife.

The framework species method of forest restoration (Goosem and Tucker, 1995; Lamb et al. 1997) was first developed in the late 1980's in Queensland, Australia, where planting just 20-30 carefully selected "framework" tree species resulted in rapidly regenerating forests, accumulating up to 80 tree species, within 6-10 years (*see* page 29). The method relies on selecting tree species that are i) fast-growing with dense spreading crowns that rapidly shade out competing weeds and ii) attractive to seed-dispersing wildlife, especially birds and bats. In addition, framework species must be easy to propagate in nurseries. High quality seedlings of 20-30 framework tree species, 50-60 cm tall (30 cm for the fastest-growing species) are planted 1.6-1.8 m apart at the beginning of the rainy season. Weeds are vigorously controlled and fertilizer is sometimes added, but after 2-3 rainy seasons, the canopy closes, the forest becomes self-sustaining and no further maintenance is required. Once the "framework" of a forest has been re-established, the other components of the ecosystem can return naturally.

After a training course which covered the framework species method in Queensland, Australia in 1997, FORRU staff reviewed data they had already collected on more than 350 tree species, indigenous to northern Thailand, searching for those with the potential to act as framework species. Below are ten suggestions.

They are not the only species that should be planted, but they do have a track record of good performance after planting out in deforested sites. We encourage tree planters to experiment with as many native species as is practical, bearing in mind the framework criteria outlined above. Currently FORRU is concentrating on upper watershed areas, so the species described below are mostly suitable for planting on sites above 1,000 m elevation. Thai names of tree species mentioned in this part are listed in the fold-out table at the end of this book.

Section 2 - Three major groups of framework species

There are three main groups of framework species, which should always form a major component of tree planting projects to restore natural ecosystems in northern Thailand. One or several species from each group should be planted. Figs should constitute about 20% of trees planted, Fagaceae and Leguminosae each about 10-15% and the rest other species.

Figs, *Ficus* spp. (Moraceae)

With at least 33 fig tree species indigenous to northern Thailand, they are a prominent feature of evergreen forests in the region. They are excellent framework species, since many species produce edible figs within a year or two after planting. Enclosed within the figs are hundreds of minute flowers which, after pollination by specialized fig wasps, develop into tiny fruits. Birds, attracted to feed in planted fig trees, bring with them the seeds of other forest trees, which are deposited when they defaecate, thus adding species to the tree seedling community of regenerating forest. Figs contain a laxative which encourages this process. Some figs begin life as epiphytes growing on the trunk or branches of large forest trees, but many can survive well when planted in the ground. It is important to choose fig species which adopt a fairly upright habit at the young seedling stage. Some figs tend to trail or scramble when grown in containers and these are not the most useful for shading out weeds. Some fig species (*e.g. Ficus hispida* L. f. var. *hispida)* are common colonizers of deforested areas. If many individuals of such species are already present, select different species for planting. About 20% of seedlings planted should be fig species.

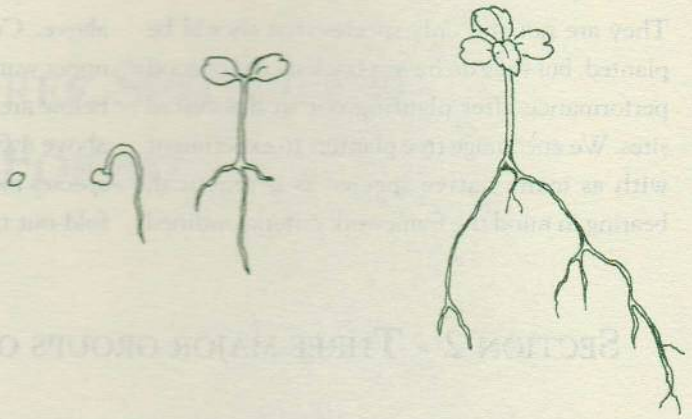
Figs and foliage of Ficus subulata

Example - *Ficus subulata* Bl. var. *subulata*

Habit: a small evergreen tree, branching densely from near the base. It starts to produce figs from 2 years of age. Figs are present for many months, at any time of year.

Uses: the figs are edible.

Habitat: disturbed areas in evergreen and mixed evergreen-deciduous forests from 800 to 1,600 m elevation.



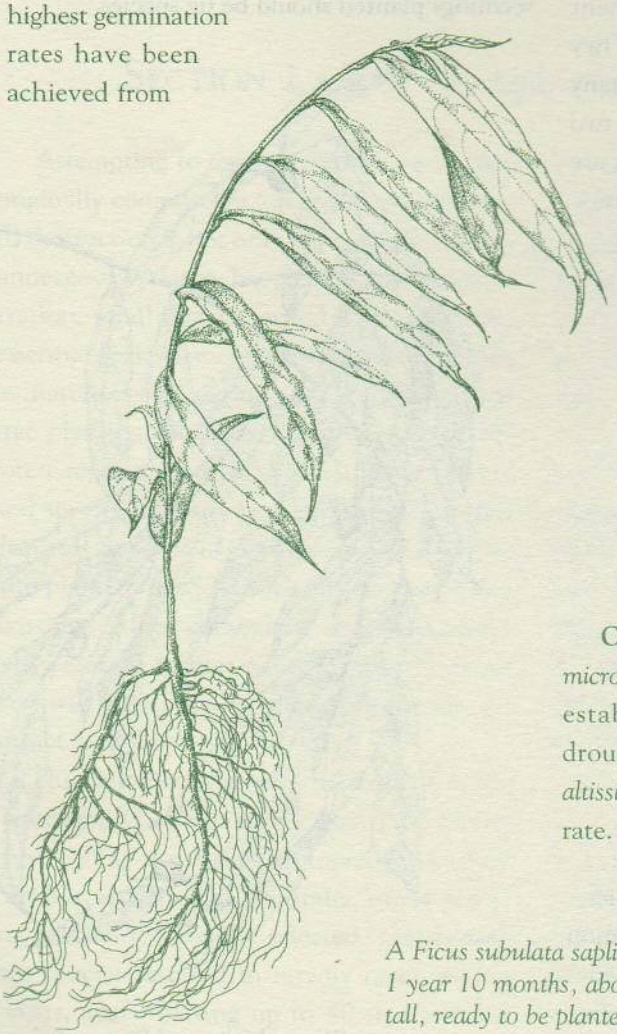
Very young seedlings of Ficus subulata

Seed collection: collect seeds only from ripe figs, when they are orange to red. Although figs can be seen at almost any time of the year, highest germination rates have been achieved from those collected in January. Scoop out seeds from the centre of the fig. Each fig contains many fruits and seeds.

Germination: sow seeds thinly in a germination tray in light shade. Most seeds should germinate 20-60 days after sowing. Germination rates of up to 70% can be expected.

Seedlings: once seedlings have grown to about 4-6 cm tall (2-3 months after germination), prick them out of the germination tray and transfer them into containers. Apply slow release fertilizer (e.g. Osmocote) as instructed on the packet. Since the species has a slightly trailing habit, staking is advised. Grow in the nursery until 50-60 cm tall (1-2 years) before planting.

Other related species worth trying: *Ficus microcarpa* L. f. var. *microcarpa* forma *microcarpa* establishes well in deforested sites and is drought tolerant (*see* page 30). Also *Ficus altissima* Bl., a forest giant, has a high growth rate.



A Ficus subulata sapling aged 1 year 10 months, about 50 cm. tall, ready to be planted

Legumes (Leguminosae)

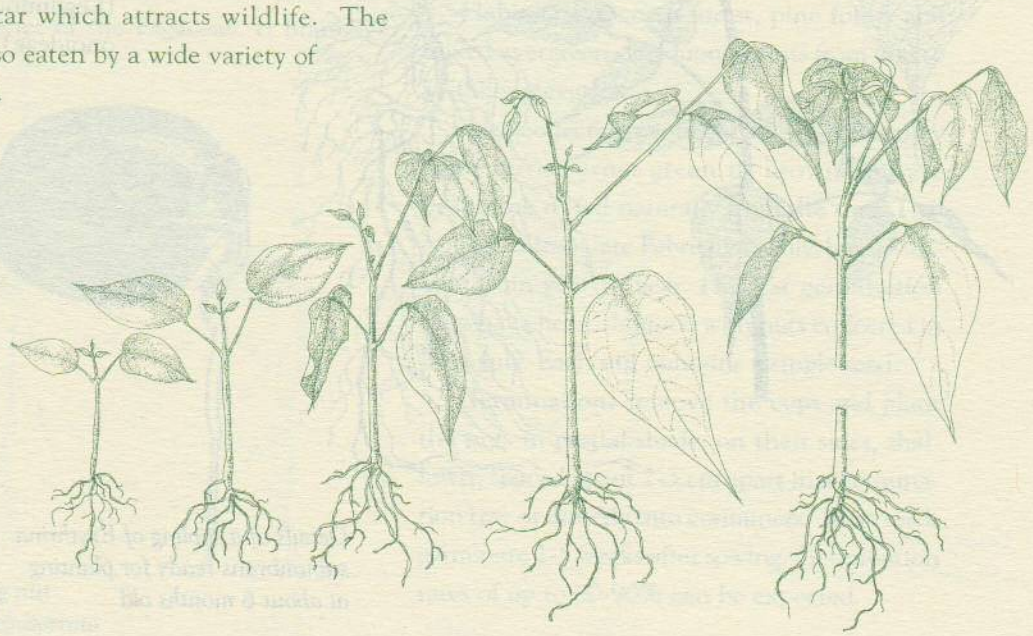
Many of the 61 tree species of the family Leguminosae indigenous to northern Thailand are exceptionally useful for forest restoration projects. Many have nodules on the roots, within which live bacteria capable of using nitrogen from air to make proteins. This means that leguminous trees often have high growth rates on degraded sites, even where soils are low in nutrients. Several species (e.g. *Albizia odoratissima* (L. f.) Bth., *Albizia chinensis* (Osb.) Merr. (both Leguminosae, Mimosoideae) commonly colonize deforested sites naturally. If many individuals of such species are already present, select different legume species for planting.

Foliage and pods of Erythrina subumbrans

Example - *Erythrina subumbrans* (Hassk.) Merr. (Leguminosae, Papilionoideae)

Habit: an exceptionally fast-growing, deciduous tree, branching near the base with spreading crown. The stem is thorny which may protect seedlings from herbivores. The attractive red flowers produce copious quantities of nectar which attracts wildlife. The seeds are also eaten by a wide variety of bird species.

Young seedling stages of Erythrina subumbrans



Habitat: evergreen forest and mixed evergreen-deciduous forest from 350 to 1,700 m elevation, especially along stream valleys at lower elevations.

Seed collection: pods can appear on the trees from January until May. Collect seeds when the pods are brown and beginning to split open. If the pods look ripe but are not yet splitting open, cut them from the tree and leave them in a dry place until they dry out and split naturally.

Germination: sow seeds shallowly and thinly in a germination tray in partial shade. The germination rate is often low (30-40 %), so sow at least 3-4 times more seeds than the required number of seedlings. Germination is very rapid. Most seeds germinate 7-14 days after sowing.

Seedlings: this species is the fastest growing of all those investigated by FORRU so far, so prick out seedlings and transfer them into containers immediately after germination. Seedlings germinated from seed collected early in the fruiting season (January to February) can be ready for planting out (i.e. at about 30 cm tall) at the beginning of the rainy season in June. Seedlings from seed collected late in the fruiting season (April to May) must be kept in the nursery until June of the following year. As they grow very fast, pruning of shoots and roots is often necessary to prevent seedlings from outgrowing their containers. Do not apply fertilizer.

Other related species worth trying: *Erythrina stricta* Roxb. (Leguminosae, Papilionoideae).

Details of a sapling of Erythrina subumbrans ready for planting at about 6 months old

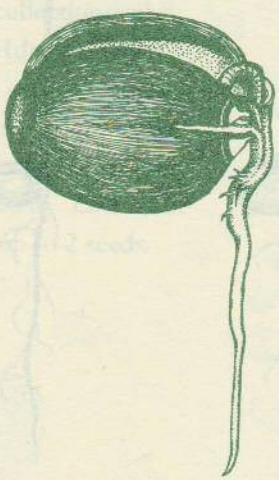
Oaks and Chestnuts (Fagaceae)

This family includes some of the commonest tree species in evergreen forests in northern Thailand, where at least 31 species are known to occur. The family includes many species useful for forest restoration, although some tend to be rather slow growing. They attract seed-dispersing wildlife into planted sites by their nutritious nuts and they cast dense shade, which inhibits weed growth. The nuts of several species are edible by humans. Therefore, they are popular species for including in the creation of community forests.

Foliage and fruits of Quercus semiserrata

Example - *Quercus semiserrata* Roxb.

Habit: a large evergreen tree, with a straight bole and dense crown. It is one of the faster growing species of the Fagaceae. It branches near the base, often within a year after planting and produces a dense spreading crown.



A germinating nut of Quercus semiserrata

Uses: the wood is used for general construction and for agricultural tools.

Habitat: evergreen forest, pine forest and mixed evergreen-deciduous forests from 800 to 1,700 m elevation.

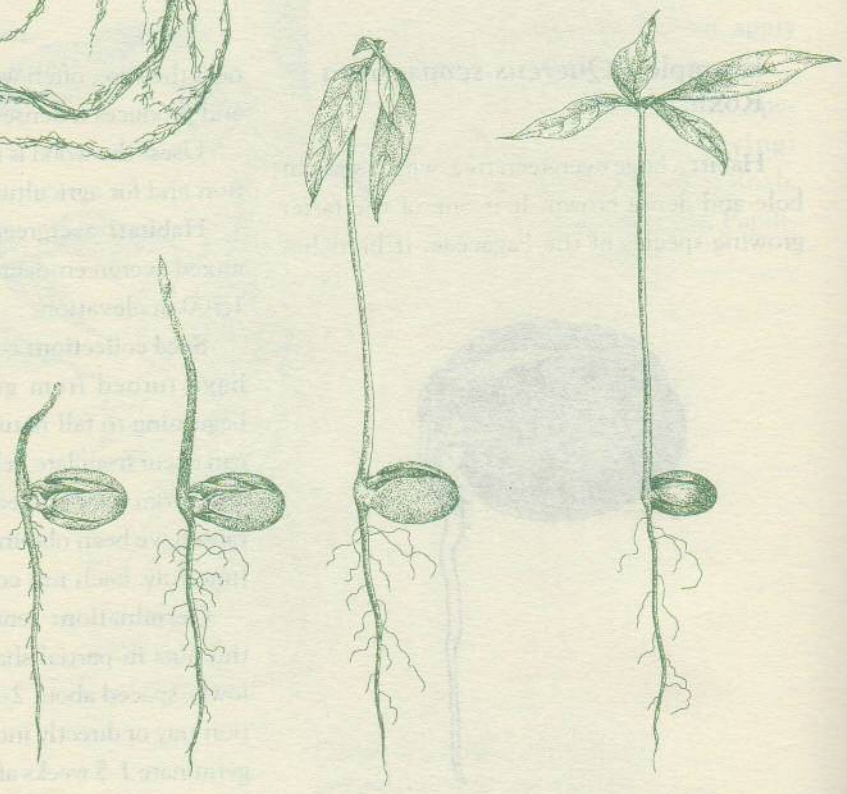
Seed collection: collect nuts only after they have turned from green to brown and are beginning to fall naturally from the tree. This can occur from late February to July, but is variable from year to year. Highest germination rates have been obtained with nuts collected in June-July. Each nut contains a single seed.

Germination: remove the cups and plant the nuts in partial shade, on their sides, shallowly, spaced about 2-3 cm apart in a germination tray or directly into containers. Most seeds germinate 1-5 weeks after sowing. Germination rates of up to 60-90% can be expected.

A *Quercus semiserrata* sapling ready for planting

Seedlings: this species has a fast-growing tap root which is easily damaged during transplantation, so transfer seedlings germinated in trays into containers as soon as the shoot appears and before the tap root becomes too long. Apply slow release fertilizer (e.g. Osmocote) as instructed on the packet. Seedlings are usually large enough for planting out (50-60 cm tall) by the beginning of the rainy season of the year following seed collection (i.e. aged 11-16 months).

Other related species worth trying: *Lithocarpus elegans* (Bl.) Hatus. ex Soep., *Lithocarpus fenestratus* (Roxb.) Rehd. and *Castanopsis calathiformis* (Skan) Rehd. & Wils.



Young seedling stages of Quercus semiserrata

3 days 5 days 11 days 18 days

SECTION 3 - OTHER INDIVIDUAL FRAMEWORK SPECIES

Bischofia javanica Bl. (Euphorbiaceae)

Habit: a large (up to 30 m tall), climax, evergreen or deciduous tree, often changing its leaves in February-March, with a very dense crown. Its small fleshy fruits (drupes) are exceptionally attractive to a great variety of birds and mammals, including pigeons, bulbuls, barbets, leafbirds, squirrels and wild pigs.

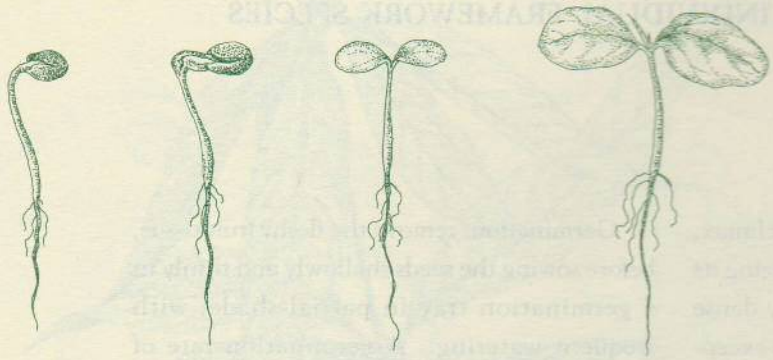
Uses: the wood of this species is used for general construction, furniture, carvings, agricultural tools and charcoal. It is an excellent shade tree for growing coffee in agroforestry systems and it is sometimes planted as a timber plantation species in other countries. The very young shoots can be eaten as a vegetable.

Habitat: bamboo-deciduous forest, evergreen forest and mixed evergreen-deciduous forest, especially near streams from 525 to 1,250 m above sea level.

Seed collection: collect fruits (drupes) when they are soft and dark brown to bluish-black, usually from December until February. Each fruit contains up to 2 seeds.

Germination: remove the fleshy fruit tissue, before sowing the seeds shallowly and thinly in a germination tray in partial shade, with frequent watering. A germination rate of

A sapling of Bischofia javanica, ready for planting at about 18 months old



1 day 3 days 8 days 17 days

Young seedlings of Bischofia javanica

about 75% can be expected. Most seeds germinate within 20-40 days after sowing.

Seedlings: prick out seedlings from the germination tray when they are about 5 cm tall (usually about 30 days after germination) and transfer them into containers. The young seedlings need plenty of water. They are fairly slow growing, requiring about 18 months in the nursery before they are tall enough (50-60 cm) for planting out. Growth can be accelerated by applying a slow release fertilizer (e.g. Osmocote) as directed on the packet.

Further information: Sunarno et al. (1995).

Other related species worth trying: *Glochidion kerrii* Craib (Euphorbiaceae).

Foliage and fruits of Bischofia javanica

Gmelina arborea Roxb. (Verbenaceae)

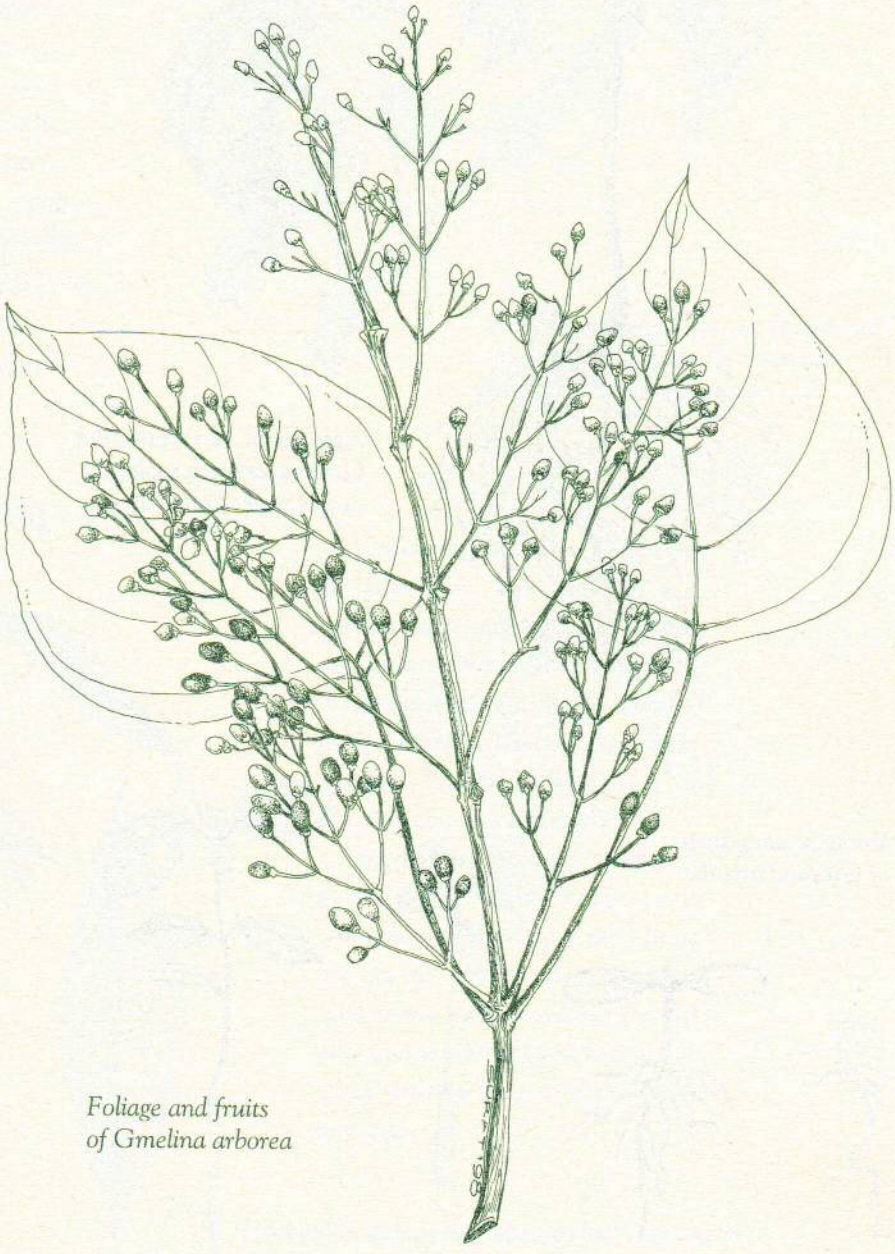
Habit: a common, fast growing, medium sized (up to 30 m tall), deciduous tree, with dense crown, producing fleshy fruits (drupes), 3-4 years after planting. Fruits are avidly eaten by deer and cattle.

Uses: this species is widely used as a plantation tree for pulp and paper production outside Thailand. The wood is used for floors, ceilings and furniture, carvings, boats and tools. A yellow dye can be extracted from the fruits and wood ash. A tea, made from the unripe fruits, is used to treat stomach ailments.

Habitat: found in practically all forest types, especially in disturbed areas, 350-1,500 m elevation. Widely planted.

Seed collection: collect fruits when they are yellow-green to yellow, usually from March to June and sow the seeds immediately. Each fruit contains up to 3-4 seeds.

Germination: remove the fruit pulp by hand and by washing. Sow the seeds shallowly in a germination tray, in partial shade, with the



Foliage and fruits of Gmelina arborea

pointed end of the seed downwards, spaced 2-5 cm apart. Most seeds germinate within 12-35 days. Germination rates of 80% or more can be expected.

Seedlings: prick out seedlings from the germination trays after the first pair of leaves have expanded, 4-12 days after germination and pot them into containers. Seedlings must be kept in the nursery until the rainy season of the following year (i.e. 13-16 months). Prune the seedlings and reduce fertilizer use to prevent seedlings outgrowing their containers. Seedlings can be planted when about 30 cm or more tall.

Aged about 12 months, this Gmelina arborea sapling is nearly ready for planting.

Young seedling stages of Gmelina arborea

Helicia nilagirica Bedd. (Proteaceae)

Habit: a common, evergreen tree, with spreading crown. It produces fruits fed upon by mammals.

Habitat: mixed, evergreen and pine forests, especially along the forest edge, road sides and other disturbed areas, 675-1,800 m elevation.

Seed collection: collect fruits when they are green, dark brown or black outside and when the surface of the seeds is purple. July is the optimum seed collecting month. Each fruit contains a single seed. Fallen fruits can sometimes be found in great abundance. Seeds which are beginning to germinate (even if they have been nibbled by animals) or even young seedlings can be collected from around fruiting trees and grown successfully in nurseries.

Rodents and monkeys can be attracted into planted plots by the nutritious fruits of Helicia nilagirica.

Germination: after removing the fruit flesh, sow the seeds in a germination tray, spaced about 5 cm apart or directly into individual containers, in light shade. Germination occurs 18-120 days after sowing. Germination rates of 60-70% can be expected.

Seedlings: transfer seedlings germinated from trays into containers when they are about 5-7 cm tall. Seedlings grown from seed sown in July should be tall enough for planting out (i.e. about 50-60 cm) by June of the following year.

Distinctive, light green, serrated leaf blades with yellowish veins make the seedlings and saplings of Helicia nilagirica easy to spot on the forest floor.

Hovenia dulcis Thunb. (Rhamnaceae)

Foliage and fruits of Hovenia dulcis.

Habit: a rare, exceptionally fast-growing, deciduous tree, up to 20-30 m tall, with a dense, spreading crown. The fruits (capsules) are very attractive to birds (pigeons and bulbuls) and rodents and it rapidly resprouts after fire damage.

Uses: the fruit stalks are used in a traditional treatment of hangovers.

Habitat: evergreen forest, especially near streams, from 1,000 to 1,300 m elevation.

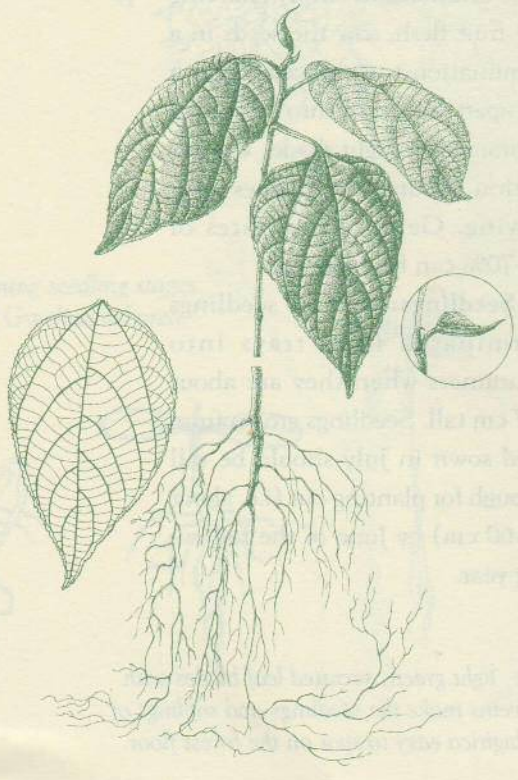
Seed collection: collect fruits when they are brown or black and beginning to dry out, usually in November to January. Cut ripe fruits from the trees, because they are rapidly consumed by animals as soon as they fall to the ground. Each fruit contains up to 3 seeds.

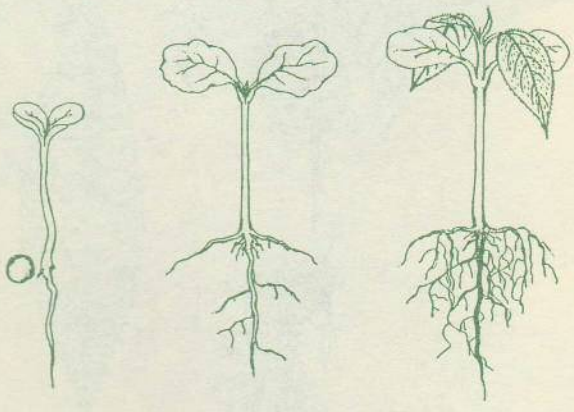
Germination: remove the fruit pulp and immediately sow seeds shallowly in a germination tray in partial shade. The germination rate is often about 50% or lower, so sow at least double the number of seeds, than the required number of seedlings. Time to germination is very variable, but most seeds germinate 20-80 days after sowing.

Seedlings: prick out seedlings from germination trays, once they have developed 4-5 leaves (not including the seed leaves) i.e. about 20 days after germination, and transfer them into containers. Seedlings grow very rapidly in full sunlight, but might require some shade in the first few weeks. Seedlings germinating in January to April should be ready for planting out (i.e. 50-60 cm tall) at the beginning of the rainy season of the following year i.e. after about 14-18 months. If seedlings begin to outgrow their containers, prune them and stop applying fertilizer. This species can grow up to 8 m in the first three years of life (see page 30).

Further information: see Kopachon et al. (1996).

A sapling of Hovenia dulcis about 6 months old





3 days 6 days 14 days

Young seedling stages of Hovenia dulcis

Melia toosendan Sieb. & Zucc. (Meliaceae)

Habit: a common, fast-growing, deciduous tree, capable of rapid regeneration after damage. Fruiting can occur on saplings as young as 2-3 years old.

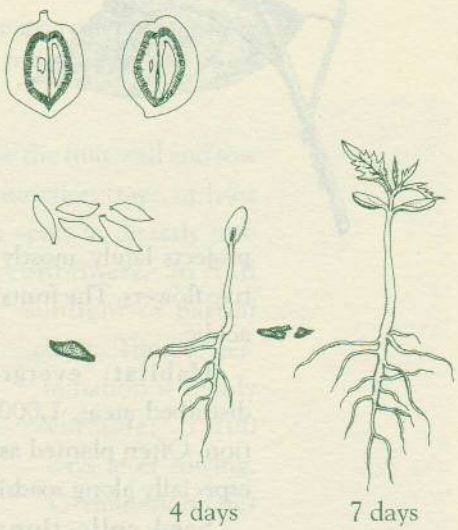
Habitat: evergreen forest and mixed evergreen-deciduous forest, 550-1,450 m elevation.

Seed collection: collect fruits (drupes) when they are yellow and fairly soft, usually in November-April. Each drupe usually contains 4-5 seeds imbedded in a woody endocarp (pyrene).

Germination: remove the fruit tissue and break open the inner woody endocarp to remove the small, shiny, black seeds. Sow them shallowly in a germination tray in partial shade. Most seeds germinate 14-50 days after sowing. Germination rates of 60% or more can be expected.

Seedlings: prick out seedlings from the germination trays when they are about 10 cm tall, with 1-3 leaves (not including the seed leaves), usually 10-14 days after germination and transfer them into containers. Seedlings germinated in November-December can be ready for planting (i.e. about 30 cm tall) the following rainy season, if provided with fertilizer, frequently watered and grown in full sunlight. Seedlings germinated later must be kept in the nursery for about 18 months and prevented from outgrowing their containers by not applying fertilizer. Pruning usually kills this species.

Melia toosendan foliage and fruits



Seeds, fruit (longitudinal section) and young seedlings of Melia toosendan

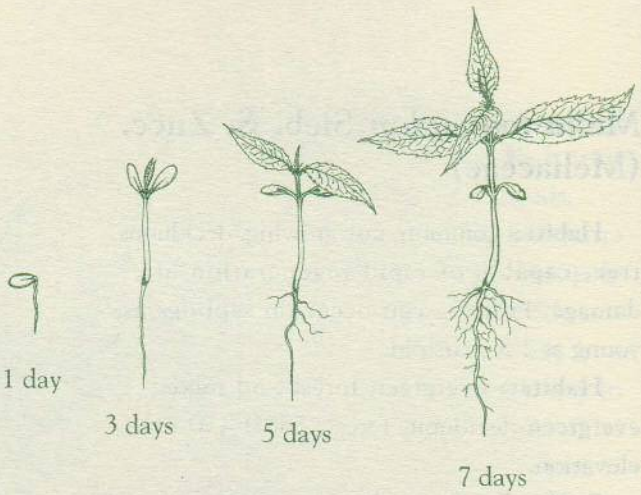
A Melia toosendan seedling ready for planting

Other related species worth trying: *Trichilla connaroides* (Wight & Arn.) Bentv. (Meliaceae) is highly drought tolerant and grows rapidly in deforested sites.

Prunus cerasoides D. Don (Rosaceae)

Habit: a medium-sized, fast-growing, deciduous tree with conspicuous pinkish-purple flower petals and small red fruits which attract birds.

Uses: this species has become particularly popular for tree planting projects lately, mostly because of its attractive flowers. The fruits are edible but rather acidic.



Young seedlings of Prunus cerasoides

Foliage and fruits of Prunus cerasoides

Habitat: evergreen forest and disturbed areas, 1,000-2,000 m elevation. Often planted as an ornamental, especially along roadsides.

Seed collection: collect fruits (drupes) when they are red and fairly soft, usually in March-April. Each drupe contains a single seed.

Germination: remove the fruit flesh and sow the seeds shallowly in a germination tray in partial shade. Most seeds germinate 10-60 days after sowing. Germination rates of 70% or more can be expected.

Seedlings: prick out seedlings from the germination trays when they are about 5-7 cm tall, with 4-5 leaves (not including the seed leaves), usually 7-10 days after germination, and transfer them into containers. Despite the high growth rate of this species, seedlings germinated in March-April will not be tall enough (i.e. about 30 cm) for planting by the beginning of the rainy season of the same year. They must be kept in the nursery until the rainy season of the following year (i.e. 13-14 months). Prevent them from becoming too large for their containers by pruning and by not applying fertilizer unless the seedlings show signs of nutrient deficiency.

A sapling of Prunus cerasoides ready for planting, about 13 months old

Sapindus rarak DC. (Sapindaceae)

Habit: an uncommon, medium-sized, deciduous, fast growing, resilient, canopy tree, reaching a height of 10-25 m.

Uses: soapy substances, extracted from the fruit, are used to make soaps and shampoos. Its wood is used for general construction, furniture, boards and combs.

Habitat: evergreen forest and mixed evergreen-deciduous forest, often in disturbed areas, 625-1,620 m elevation.

Seed collection: collect fruits (drupes) when they are wrinkled, yellow-brown to brown and beginning to dry out. Ripe fruits can be collected from August to January, but it is recommended that fruits are collected in August, if available. Each fruit contains a single, black, seed.

Shampoo can be made from the fruits of Sapindus rarak.

Germination: remove the fruit wall and sow seeds in germination trays, at least 5 cm apart or directly into containers, in full sunlight or partial shade. Time to germination is highly variable; 7-100 days after sowing. Germination rates of 80% or higher can be expected.

Young seedling stages of Sapindus rarak

6 days 10 days 18 days 24 days 36 days

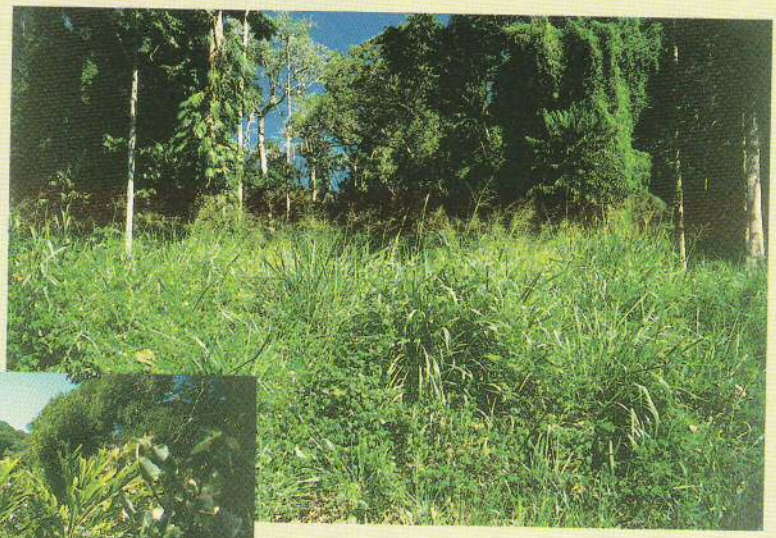
A sapling of Sapindus rarak, aged about 10 months, ready for planting

Seedlings: prick out seedlings from germination trays after the first pair of leaves has fully expanded (i.e. when about 5 cm tall and aged about 14 days) and transfer them into containers. Due to high variability in the time to germination of this species, pricking out has to be done about once per month for several months until all viable seeds have germinated. Seedling growth is rather slow at first, but can be accelerated by application of fertilizer. Seedlings germinated in August can be ready for planting (i.e. 50-60 cm tall) by June of the following year.

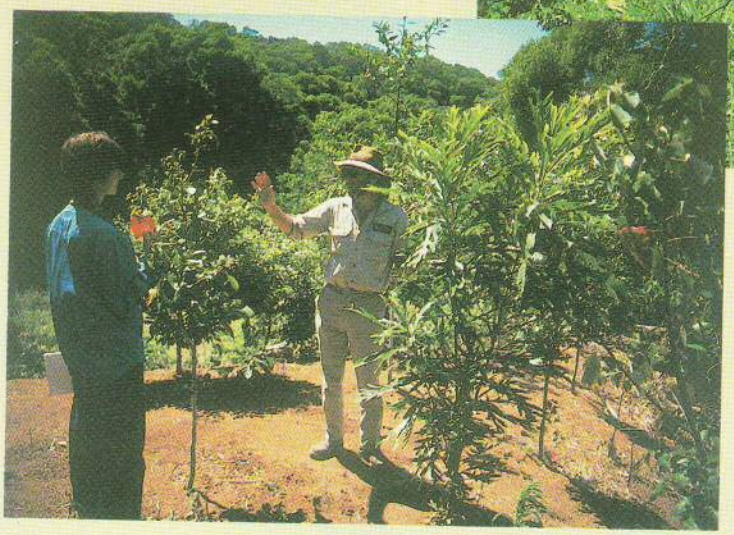
Other Species Worth Experimenting With

Species	Family
Cinnamomum iners Reinw. ex Bl.	Lauraceae
Diospyros glandulosa Lace	Ebenaceae
Eugenia albiflora Duth. ex Kurz	Myrtaceae
Eurya acuminata DC. var. *wallichiana* Dyer	Theaceae
Garcinia mckeaniana Craib	Guttiferea
Horsfieldia amygdalina (Wall.) Warb. var. *amygdalina*	Myristicaceae
Horsfieldia thorelii Lec.	Myristicaceae
Manglietia garrettii Craib	Magnoliaceae
Phoebe lanceolata (Nees) Nees	Lauraceae
Rhus rhetsoides Craib	Anacardiaceae
Schima wallichii (DC.) Korth.	Theaceae
Turpinia pomifera (Roxb.) Wall. ex DC.	Staphyleaceae
Xanthophyllum flavescens Roxb.	Polygalaceae

The Framework Species Method of Forest Restoration in Queensland, Australia



Degraded grasslands dominate much of the Atherton Tableland in northern Queensland. They are sprayed with a non-residual herbicide and planted with 50-60 cm tall seedlings of 20-30 framework tree species.

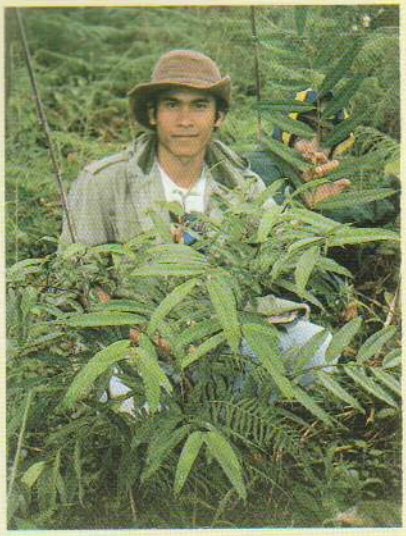


One year after planting, the saplings are already attracting wildlife into this planted plot. Close spacing (1.6-1.8 m) allows the canopy to close within 2-3 years and shade out weeds.

Nigel Tucker, Head of Lake Eacham Regional Nursery, where the framework species method was developed, shakes hands with FORRU's Puttipong Navakitbumrung, after planting a seedling during a training course in Queensland in 1997.

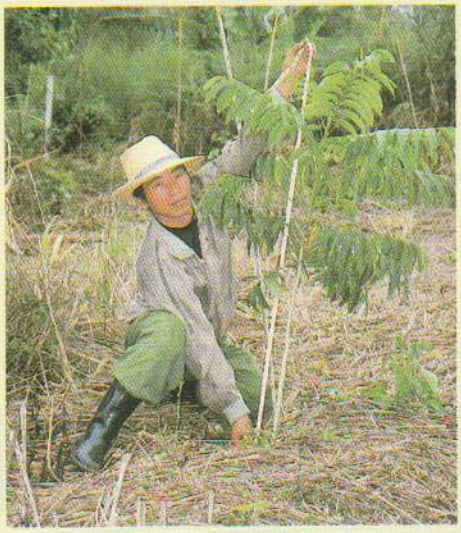
After 6-8 years a new forest is created. Seedlings of an additional 49 tree species, originating from seed brought in by birds and bats, have colonized this plot (Tucker & Murphy, 1997).

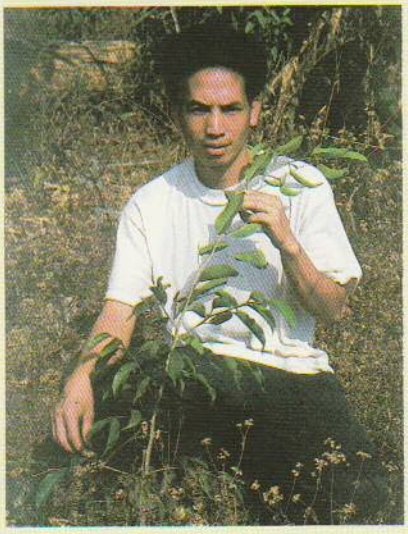
Framework Tree Species for Northern Thailand ?



(left) Gmelina arborea, already producing a dense crown, 5 months after planting.

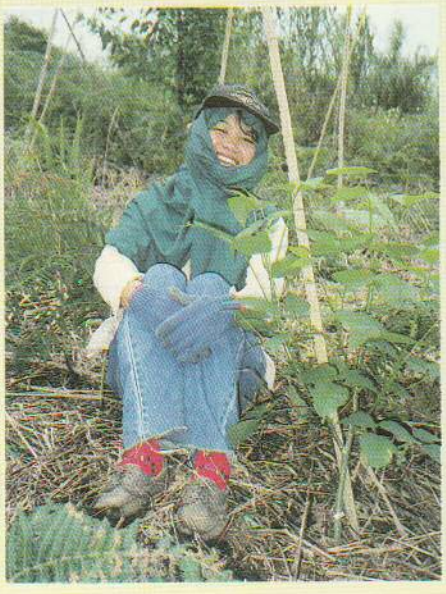
(right) This Ficus subulata sapling (5 months after planting) already has figs which will attract seed-dispersing birds into the planted plot.





(left) This Sapindus rarak sapling is 1.5 m tall, after one rainy season's growth.

(right) Ficus microcarpa (8 months after planting) remains green throughout the dry season.



(left) Erythrina subumbrans (5 months after planting) is one of the fastest-growing species tested by FORRU so far.

(right) This Hovenia dulcis tree is only 3 years old, but is nearly 8 m tall.

PART 3

GROWING YOUR OWN TREES

Section 1 - Establishing a tree nursery
Section 2 - Seed collection
Section 3 - Growing seedlings in containers
Section 4 - Production scheduling

A reliable water supply is essential when selecting a site for a tree nursery.

GROWING YOUR OWN TREES

"Give fools their gold and knaves their power,
Let fortunes bubbles rise and fall;
Who sows a field, or trains a flower,
Or plants a tree is more than all."
John Greenleaf Whittier (1807-92), U.S. poet. "A Song of Harvest"

When any group of people get together and start a tree nursery, a lot more happens than just the production of tree seedlings. The sense of community is strengthened, social relationships develop and participants learn as much about each other as they do about trees and forest. Very few people who get involved in growing and planting trees fail to have a rewarding experience. Here, answers are suggested to some of the common questions asked by groups wishing to establish small nurseries to grow forest trees (i.e. villagers, school children, NGO's etc.). Although the techniques presented are those which have been successfully used in FORRU's nurseries in northern Thailand, they can probably be applied anywhere in the country.

Why should a community grow its own tree seedlings, rather than obtain them from local nurseries ?

1. the community can select the species grown;
2. the community can control the quality and quantity of seedlings;
3. the community will take pride in the seedlings they produce and will therefore take good care of them;
4. a tree nursery can become a focal point for educational and social activities, which encourages greater community involvement in tree growing and planting activities;
5. community tree nurseries can be established close to planting sites, so transportation costs and damage to the seedlings during transportation are both minimized and
6. the community can control production costs.

Loading up seedlings ready for planting at the beginning of the rainy season - the successful conclusion to any community tree nursery project.

SECTION 1 - ESTABLISHING A TREE NURSERY

Where should a nursery be built ?

1. on a flat or slightly sloping site which has good drainage;
2. in a sheltered, partially shaded site (note that you can provide artificial shade, which will be discussed later);
3. near a permanent water supply and
4. near a road.

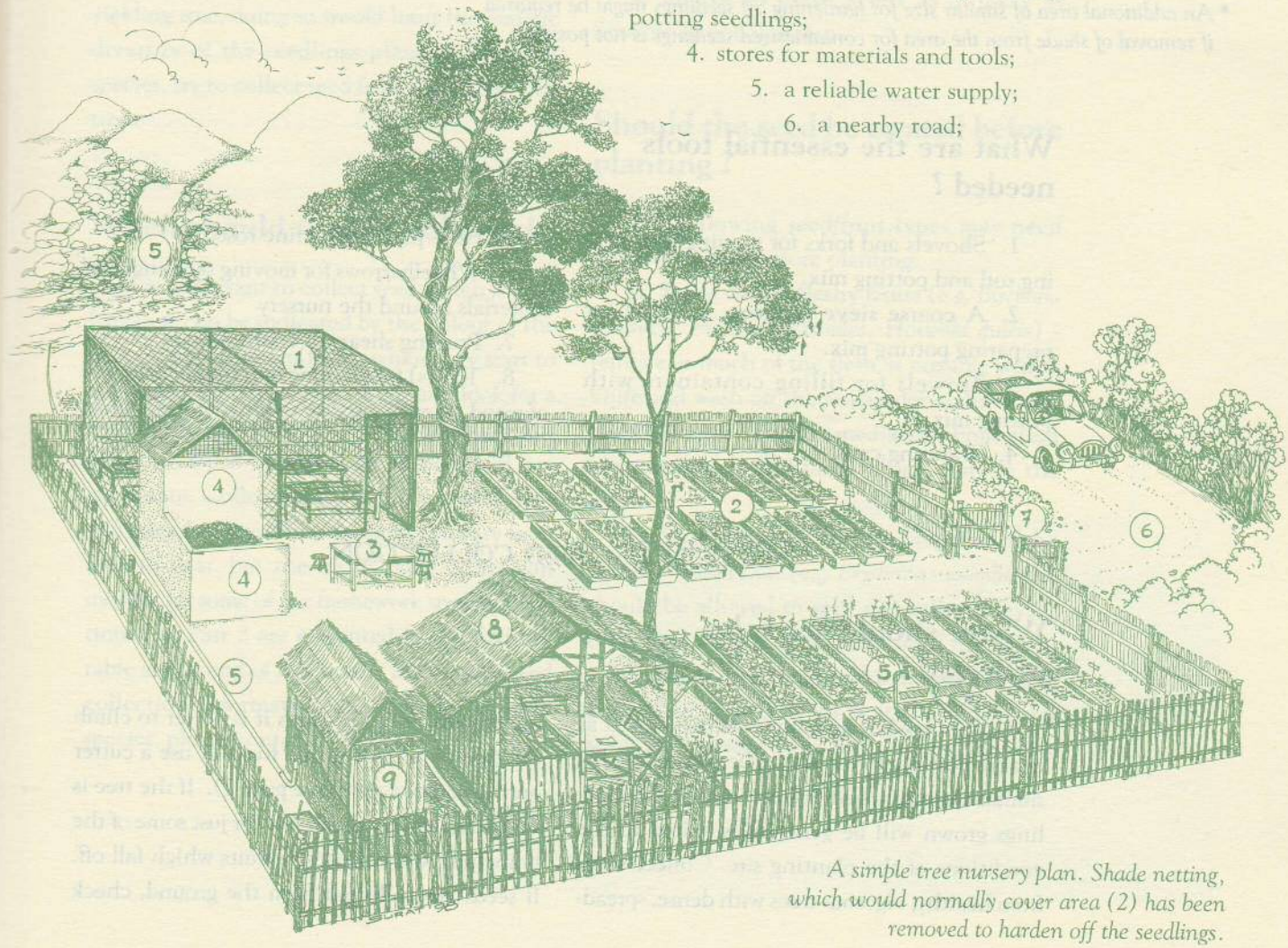
How many trees will need to be grown ?

The number of tree seedlings needed will depend on the area of the site to be planted. Plan for about 500 tree seedlings per rai (1 ha = 6.25 rai). You should also consider that, with success, you may wish to increase the number of trees grown in the future, so choose a nursery site which will allow expansion.

What are the essential design features of a tree nursery ?

As shown below, a nursery should include most of the following features:

1. a shaded area, protected from seed predators by wire mesh, with benches for seed germination trays;
2. an area with removable shade where seedlings can grow in containers until ready for planting (the nursery plan below shows shade removed);
3. a shaded work area for sowing seed and potting seedlings;
4. stores for materials and tools;
5. a reliable water supply;
6. a nearby road;



A simple tree nursery plan. Shade netting, which would normally cover area (2) has been removed to harden off the seedlings.

7. a fence to protect the seedlings from animals
8. a shelter for discussions with visitors and
9. a toilet.

There is no rigid design requirement, but the nursery plan on the previous page is a good example of a small-scale tree nursery design.

How much space will be needed ?

The table below relates the size of the area to be planted per year to the size of the nursery required. For example if the area to be planted per year is 20 rai, 10,000 seedlings will be needed, requiring a nursery of about 185 m^2.

Area to be planted (rai/yr)	Number of seedlings needed	Seed germination area (m^2)	Area for containerized seedlings* (m^2)	Materials & tools storage, shelter, toilet etc. (m^2)	Total area required (m^2)
1	500	1	7.5	15	23.5
2	1,000	2	15	15	32
4	2,000	4	30	15	49
20	10,000	20	150	15	185
40	20,000	40	300	15	355

** An additional area of similar size for hardening off seedlings might be required if removal of shade from the area for containerized seedlings is not possible.*

What are the essential tools needed ?

1. Shovels and forks for moving and mixing soil and potting mix.
2. A coarse sieve (approx. 1.5 cm) for preparing potting mix.
3. Trowels for filling containers with potting mix.
4. Watering cans.
5. Hose pipe with a fine rose.
6. Wheelbarrows for moving seedlings and materials around the nursery.
7. Pruning shears or coarse knives.
8. Tool(s) for pricking out; simple flat piece of wood, or even a spoon to lift young seedlings.

SECTION 2 - SEED COLLECTION

Where should seeds be collected ?

Collect seeds from patches of good forest as near as possible to the site to be planted and of similar elevation, bedrock etc. so that the seedlings grown will be genetically suited to the conditions of the planting site. Collect seeds from healthy, vigorous trees with dense, spreading crowns. In most cases it is better to climb the tree to cut down ripe fruits or use a cutter on the end of a pole (see page 7). If the tree is small enough, try shaking it (or just some of the branches) and collect the fruits which fall off. If seeds are collected from the ground, check

whether they are infected by fungi or infested with insects.

It is important to correctly identify the tree species from which seeds are collected. As yet there is no comprehensive book describing the trees of Thailand. Local names are often unreliable. If you are unsure of the species, collect a small branch with leaves and fruits and dry it in a plant press (sheets of newspaper pressed flat between two pieces of board). Seek expert advice to have the specimen identified. The Herbarium at the Biology Department of Chiang Mai University can help with the identification of specimens.

Can seeds be collected from a single tree ?

No. Although sufficient seed may be collected rapidly and easily from just one high-yielding tree, doing so would limit the genetic diversity of the seedlings planted. For each species, try to collect seed from more than one tree.

When should seed be collected ?

It is important to collect seed which is ripe. Ripeness can be indicated by the colour of the fruit or, for dehiscent fruits, when they start to split open. Cut open some seeds and look for a well developed embryo. Seeds which are not fully developed or which are too old will not germinate. Collecting them is a waste of time and nursery space. Fruiting times can vary from year to year, but the most likely collection months for some of the framework species mentioned in Part 2 are presented in the fold-out table at the end of this book. If you need seed collection information about these or other species, please contact FORRU.

How much seed should be collected ?

The number of seeds collected depends on the number of seedlings required and on the capacity of the seeds to germinate and grow into healthy seedlings. FORRU has some data on this, but it will vary from tree to tree. By keeping accurate records, you will learn from experience the likely germination rates for different species.

What precautions should be taken when collecting seeds ?

1. do not leave seeds in the sun where they may dry out and consequently die;
2. do not leave seeds in a damp place or exposed to rain where they may rot or germinate prematurely;
3. do try to plant seeds as quickly as possible after collection.

Should the seed be treated before planting ?

The following seed/fruit types may need some treatment before planting:

1. Seeds within fleshy fruits (e.g. *Bischofia javanica*, *Prunus cerasoides*, *Hovenia dulcis*) - remove as much of the flesh as possible with a knife and wash off the remainder under water, then plant the seed immediately. Fruit flesh attracts insects and fungi which damage the seed.

2. Seed pods, such as those of species of the family Leguminosae (e.g. *Erythrina subumbrans*), should be allowed to split naturally by laying them out in a sunny, dry place until they open.

3. Seeds contained within a tough pyrene (woody inner layer of the fruit) - when several seeds are present (e.g. *Melia toosendan*), the

woody structure should be gently broken open in a vice and the seeds removed. If there is only one seed inside, the woody layer can be gently cracked in a vice or sliced open with a knife and the seed left inside. This will allow water to enter the seed and trigger germination.

4. Seeds with toughened seed coats - rub small seeds with sand paper (e.g. *Eurya acuminata*) to make the seed coat more permeable to water. With larger seeds, chip away a small part of the seed coat with a knife. Do not cut too deeply to avoid damaging the embryo.

Can the processed seed be stored ?

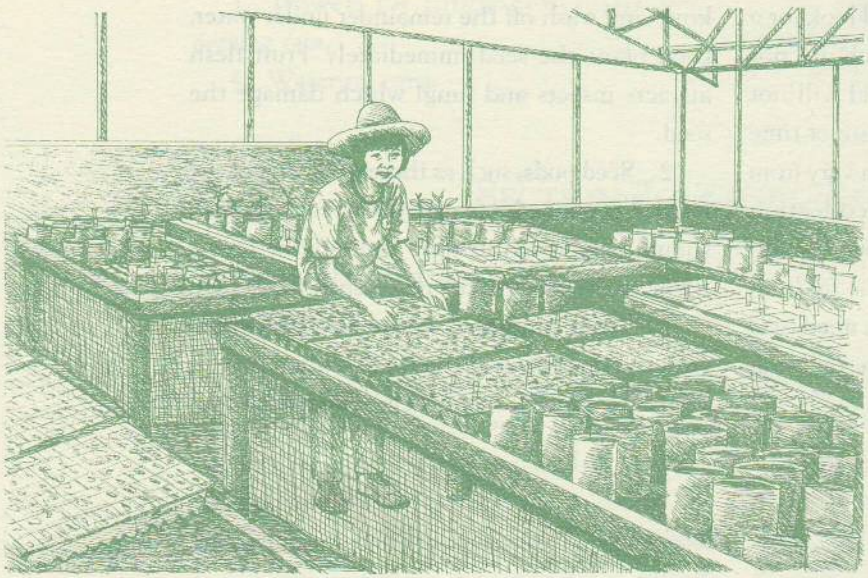
It is recommended that seed is planted as soon as possible after collection and treatments (if needed) have been applied. The length of time seeds remain viable varies among species and is not known for most native tree species. Only dried seed can be stored successfully, but many seeds die if dried. Therefore, if seeds need to be stored for a short time, dry them and keep them in a pest-proof container in a cool, dry place. Bottles, tins, wooden boxes or sacks are preferable to plastic containers.

SECTION 3 - GROWING SEEDLINGS IN CONTAINERS

At FORRU, tree seeds are germinated *en masse* in plastic trays containing a germination mix. After germination, young seedlings are pricked-out into individual containers of potting mix and grown on in an initially shaded area. The seedlings are exposed to full sunlight to 'harden' them prior to planting in the field.

How should seeds be germinated ?

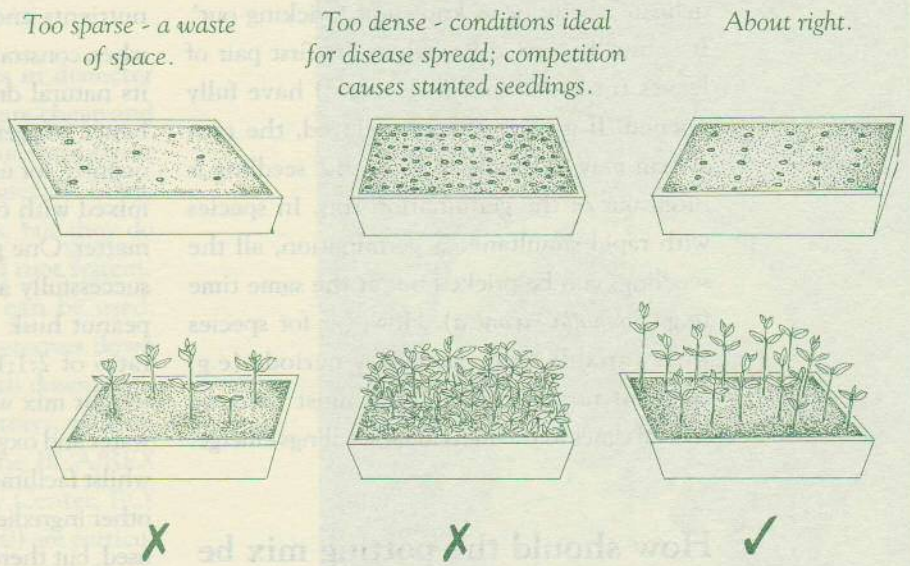
Sow most seeds in germination trays, about 6-10 cm deep with plenty of drainage holes, filled with a mixture of two thirds forest soil with one third coconut husk. A mix of 50% forest soil with 50% coarse sand is more suitable for very tiny seeds, especially those susceptible to damping off, but whatever germination mix is used, it must have good aeration and drainage. Do not add fertilizer to the germination mix. Place seeds just below the surface; a general rule is twice their diameter below the surface. If the seeds are sown too close together, they may be particularly vulnerable to disease. Sowing thinly will not affect germination, but may be uneconomic. Water the trays lightly, immediately after sowing the seeds and daily thereafter, with a watering can or spray bottle, to avoid disturbing the surface of the germination mix. Place trays in the shade.



Seed germination usually takes place in trays on benches.

Larger seeds with high germination rates (e.g. *Helicia nilagirica and Quercus semiserrata)* can be sown directly into individual containers, filled with potting mix.

Sowing density



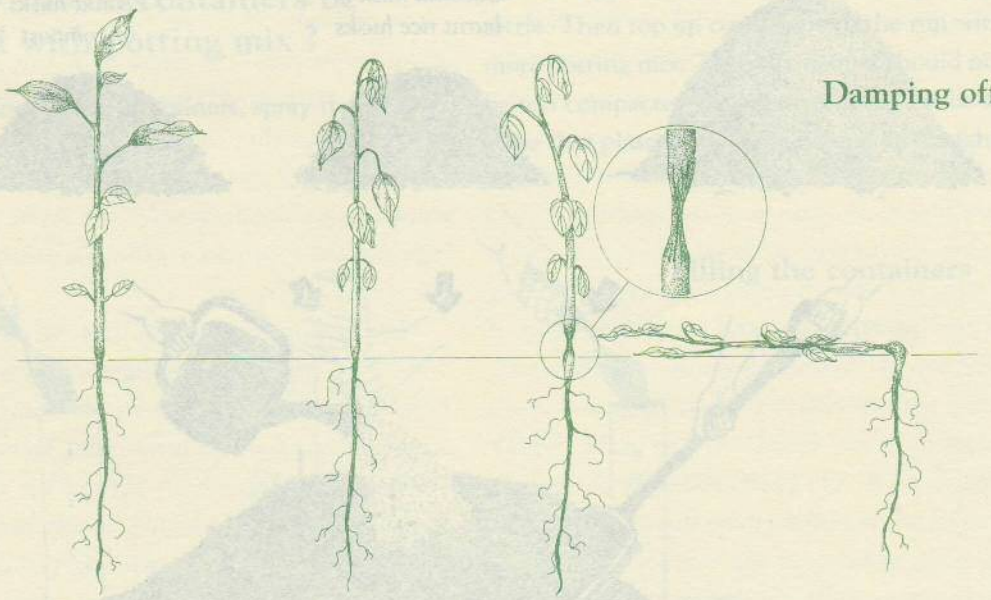
Are there any diseases which might occur at this stage?

The seedlings must be carefully monitored for signs of disease, because they are particularly susceptible to 'damping off' - a term which covers several fungal diseases which make the seedlings look like they have been pinched at the base of the stem. Other symptoms include drying of the young leaves. Once a seedling becomes infected, immediately remove it to prevent spread of the disease to neighboring seedlings. Sowing the seeds too densely, leading to poor air movement and high humidity around the seedlings, creates ideal conditions for the spread of the disease. If damping off becomes a serious problem, the seedlings can be sprayed with a fungicide such as Captan.

When should seedlings be transferred into larger containers ?

Seedlings germinated in trays must be transferred individually into larger containers, filled

Damping off



This seedling has just been infected with one of many fungi which cause damping off.

The leaves start to wilt.

The stem appears "pinched" and brown near the base.

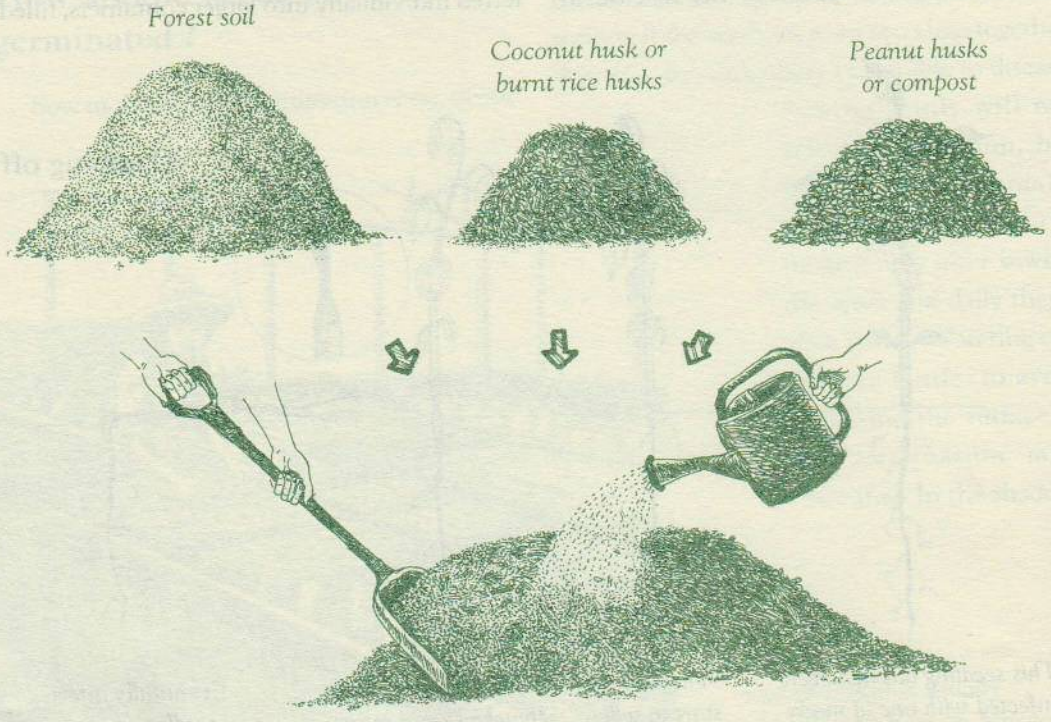
Eventually infected seedlings collapse and die.

with potting mix for further growth. This delicate operation is known as 'pricking out'. It is usually carried out when the first pair of leaves (or sometimes the second) have fully opened. If pricking out is delayed, the root system may be damaged when the seedling is lifted out of the germination tray. In species with rapid simultaneous germination, all the seedlings can be pricked out at the same time (e.g. *Bischofia javanica*). However for species with variable seed dormancy periods (e.g. *Sapindus rarak*), pricking out must be done several times as the individual seedlings emerge.

How should the potting mix be prepared ?

The function of potting mix is to support vigorous growth of seedlings in containers. It must support a healthy root system, by supplying oxygen, nutrients and water and provide support for root anchorage. Forest soil is a very good growing medium, as can be appreciated from the lush growth of the forest. It contains nutrients and beneficial microorganisms, but when constrained within an artificial container, its natural drainage capacity is restricted and hence oxygen availability is reduced. Consequently, for use in a nursery, forest soil must be mixed with other ingredients, rich in organic matter. One potting mix which has been used successfully at FORRU consists of forest soil, peanut husk and coconut husk mixed in the ratio of 2:1:1. This makes a crumbly, lightweight mix which can supply the nutritional, water and oxygen requirements of the seedlings, whilst facilitating good root development. Any other ingredients with similar properties can be used, but there must be a reliable and abundant supply available locally at low cost. Making compost from leaf litter, household waste etc. can reduce the need to buy organic materials from the market, but it is also labour intensive. Burnt rice husks are a cheap alternative to coconut or peanut husks.

Making the potting mix



Mix thoroughly together and moisten before filling containers

What kind of containers should be used ?

Black plastic bags 2½ inches in diameter by 9 inches in depth (8 x 25 cm) are cheap and effective and have been used successfully at FORRU with a wide range of species. Some nurseries use shorter plastic bags, but they do not allow development of a good root system.

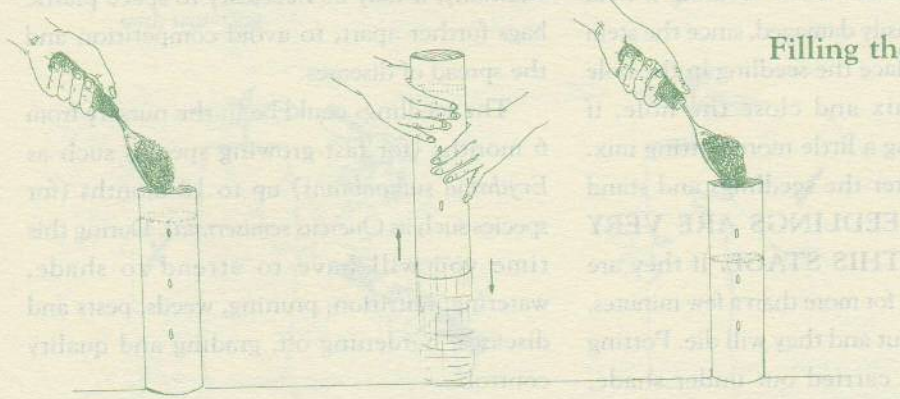
Alternatively root trainers can be used. They are rigid plastic pots with grooves down the sides which direct root growth downwards and prevent root spiraling. REX trays, made in Thailand and available from the JICA/REX project (Mahasarakham Nursery Center, P.O. Box 81, Muang, Khon Kaen 40000) are particularly recommended. They consist of blocks of 24, very tough, moulded, black, plastic pots with vertical grooves and large holes in the bottom, allowing air pruning of roots (see below). They take up less nursery space than plastic bags. They can be re-used many times and they are easier to fill and transport than plastic bags. Experiments at FORRU have demonstrated that seedlings grown in REX trays have consistently better root development than those grown in plastic bags (Zangkum, 1998).

Although initially expensive, root training containers like this REX tray, provide a cost-effective method to grow tree seedlings, since they can be re-used many times.

How should containers be filled with potting mix ?

Before filling containers, spray the potting mix with water to moisten it, without saturating it. Then fill the bags by hand, or with a trowel. When the container appears full, bang it on the ground, to allow the potting mix to settle. Then top up containers to the rim with more potting mix. The potting mix should not be too compacted, but neither should it be so loose that plastic bags do not stand up straight.

Filling the containers

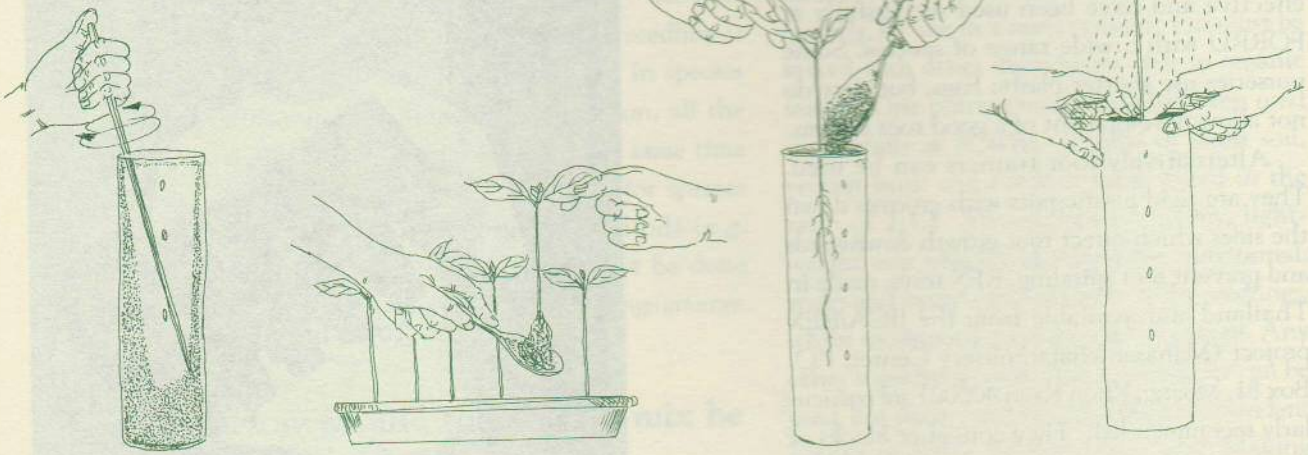


Fill container to the rim with potting mix.

Bang container on the ground to allow the potting mix to settle down.

Add more potting mix to fill the container to the rim.

Potting seedlings



With a stick, make a hole in the potting mix, deep enough to take the roots of the seedling without bending them.

Gently lift out a seedling from the germination tray with a spoon.

Place seedling in container and fill with potting mix.

Firm down the potting mix and water.

How should seedlings be transferred into containers ?

After filling containers with potting mix, moisten the mix. With a stick, make a hole in the mix, deep and wide enough to accept the seedling without bending the roots. Hold a seedling by a leaf, between the forefinger and thumb and gently prize it out of the germination tray with a spoon. If the seedling is held by the stem, it is easily damaged, since the stem is very delicate. Place the seedling in the hole in the potting mix and close the hole, if necessary by adding a little more potting mix. After potting, water the seedlings and stand them in shade. **SEEDLINGS ARE VERY DELICATE AT THIS STAGE.** If they are pricked out and left for more than a few minutes, the roots will dry out and they will die. Potting should always be carried out under shade, preferably at the end of the day.

How should seedlings be cared for in the nursery ?

If using plastic bags, make sure they are placed upright and take care not to squeeze them when handling them. Initially, plastic bags can be placed 'pot-thick', i.e. they all touch each other without being squashed together. Once the seedlings have grown substantially, it may be necessary to space plastic bags further apart, to avoid competition and the spread of diseases.

The seedlings could be in the nursery from 6 months (for fast-growing species such as *Erythrina subumbrans*) up to 18 months (for species such as *Quercus semiserrata*). During this time you will have to attend to shade, watering, nutrition, pruning, weeds, pests and diseases, hardening off, grading and quality control.

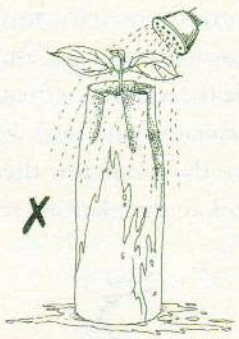
When should seedlings be shaded and by how much ?

If seedlings are placed in direct sunlight just after pricking out, they will die. To protect them from high temperatures and full sunlight, place them under black shade netting (slan) which reduces sunlight by about 50%. Seedlings are usually grown under such shade until they are ready for hardening off before planting out. Shade netting can be hung 0.5-2.5 m above the seedlings. More than about 50% shade will produce weak, tall seedlings which are highly susceptible to disease.

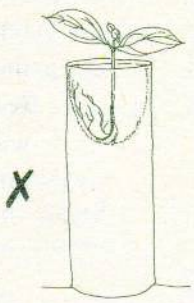
How much water will the seedlings require ?

Watering is one of the most important tasks in the nursery. Not much water is held in a container of potting mix, so seedlings can rapidly dry out. During the first 4 weeks after pricking out, water seedlings twice per day; thereafter once per day late in the afternoon, using a watering can or hose pipe with fine rose (*see* page 31). The potting mix should be soaked to the bottom of the container. The best judge of how much water to give is you. If the potting mix is still wet when you come to water the seedlings, it may not be necessary to water that day. Too much water can be as bad as too little, as it inhibits root growth and encourages diseases. Mosses or liverworts on the surface of the potting mix indicate that the seedlings are being given too much water.

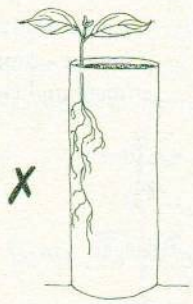
Take care when potting



Plastic bag not filled to the top. Top of bag collapses interfering with watering.

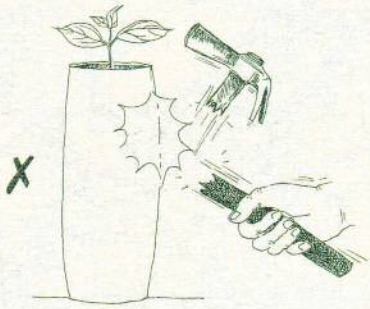


Hole not deep enough, forcing roots to curl.

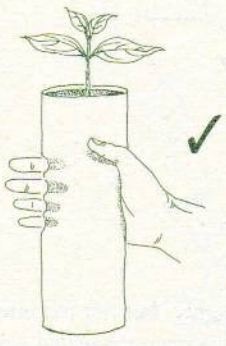


Seedling not in the centre. Root development one-sided.

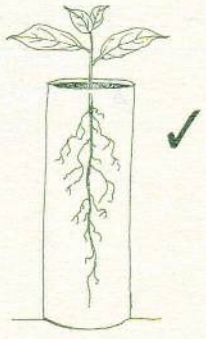
Potting mix too loose.



Potting mix compacted and hard, inhibiting root development.



The potting mix should be firm enough to leave a hand imprint when squeezed gently.



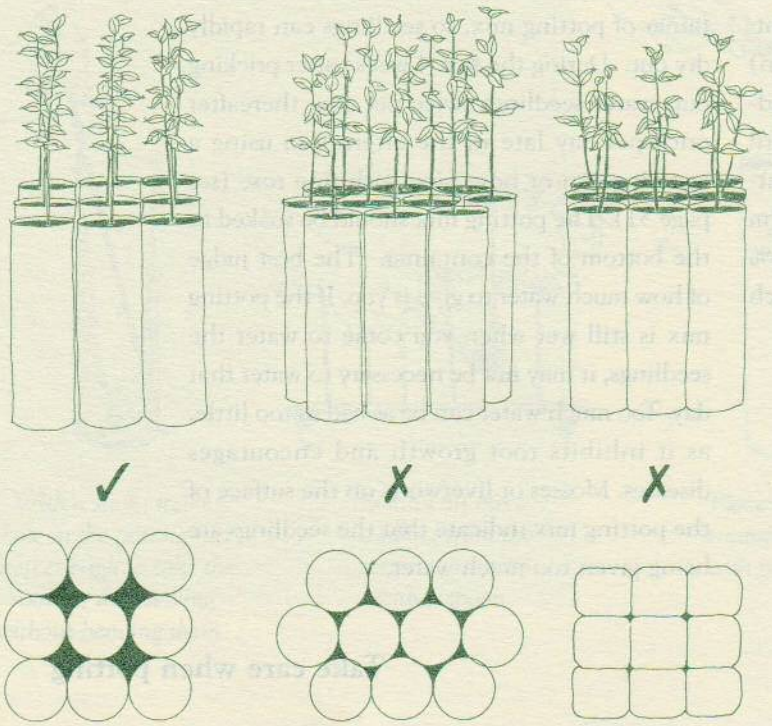
A perfectly potted seedling.

Standing down

Initially stand seedlings "pot thick" - container rims just touching.

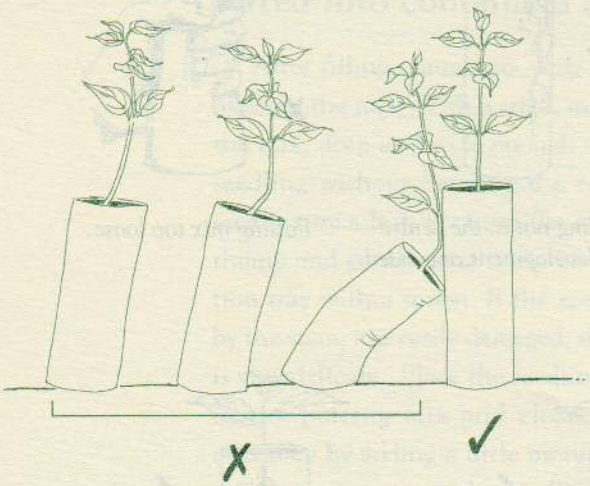
Wrong - not enough space between containers.

Wrong - containers squashed together.



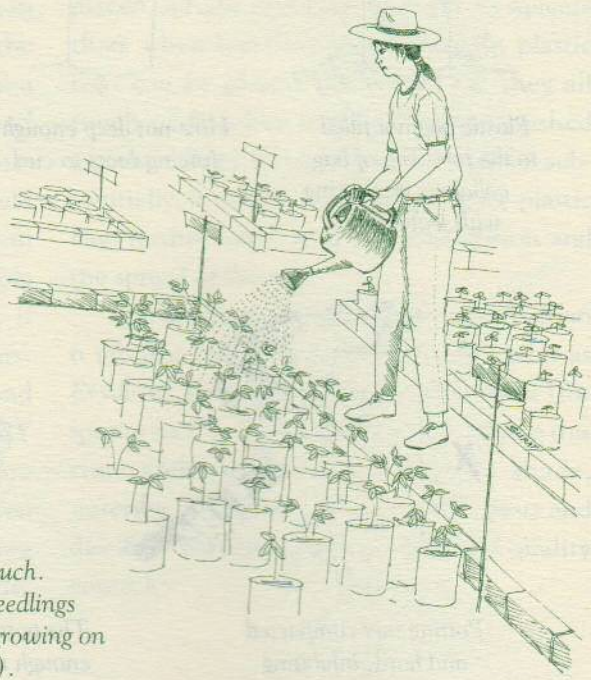
These containers are tilted causing deformed stems.

Correct - container straight and vertical.



Is it necessary to give fertilizer to the seedlings ?

The decision to use fertilizers will depend on the growth rate required, or the appearance of the seedlings. In some cases it may be necessary to accelerate growth by adding fertilizer, so that seedlings will be tall enough for planting out at the beginning of the rainy season. Also weak, slow-growing seedlings with yellow leaves usually need fertilizer. If this is the case, add about 10 granules (approximately 0.3 g) of slow-release Osmocote fertilizer NPK 15:15:15 to the surface of the potting mix in each container every 3 months. Although slow-release fertilizers like Osmocote, are more expensive than ordinary fertilizers, they are used in very small quantities and labour costs are reduced because they are applied very infrequently. Do not give fertilizer to rapidly growing species, especially those able to fix nitrogen from the air (e.g. *Erythrina subumbrans*). Fertilizer will make them outgrow their containers before the planting season.

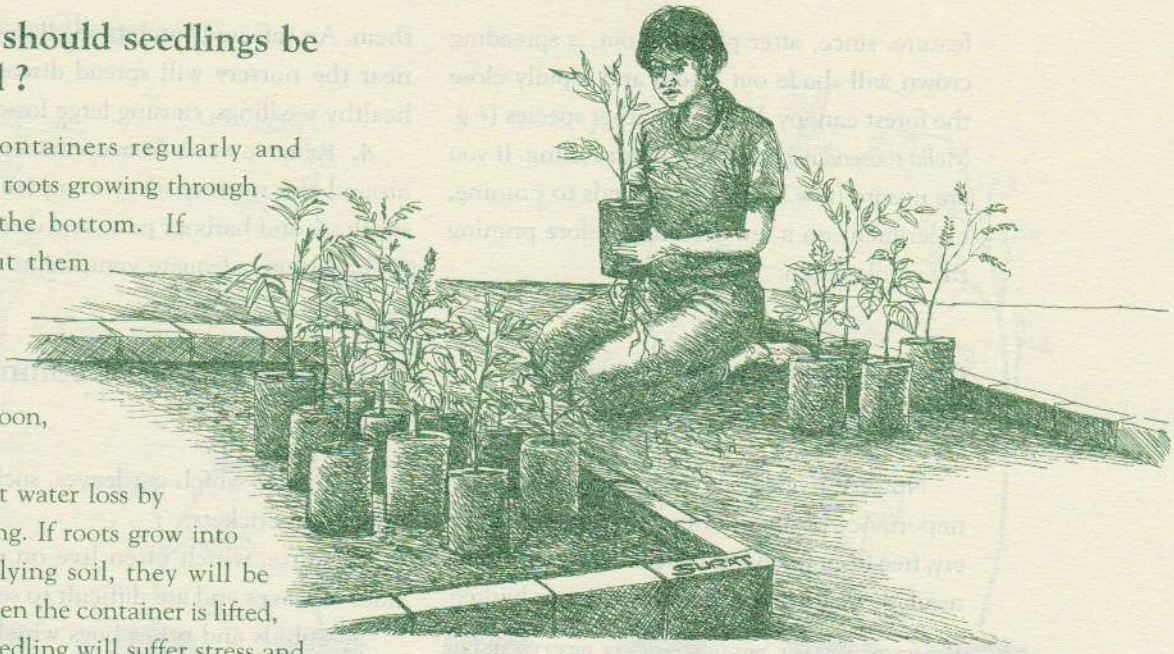


Water thoroughly, but not too much. Keep your eyes open for wilted seedlings (not enough water) and mosses growing on the potting mix (too much water).

When should seedlings be pruned ?

Lift containers regularly and check for roots growing through holes in the bottom. If found, cut them back with secateurs, in the late afternoon, to reduce subsequent water loss by the seedling. If roots grow into the underlying soil, they will be broken when the container is lifted, and the seedling will suffer stress and possibly die. An alternative is to keep seedling containers off the ground on raised wire grids. Roots growing out of the bottom of the containers will die if exposed to air for a long time.

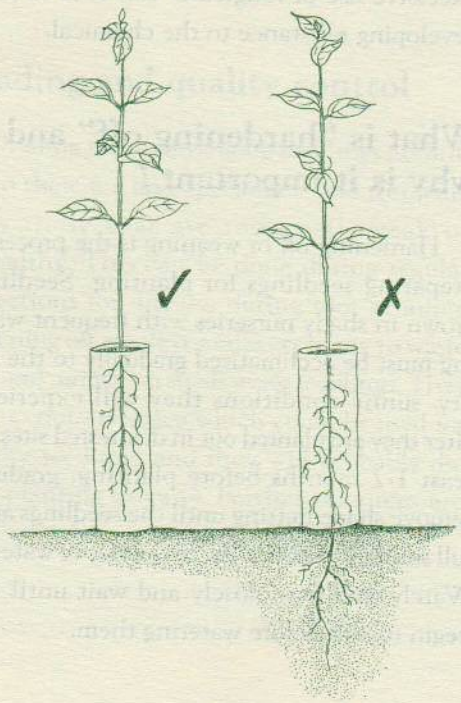
It is not normally necessary to prune seedling shoots. However, some species need to be kept for a long period in the nursery to wait for the planting season and they become too tall for their containers. At the time of planting, seedlings should usually be 50-60 cm tall (2-3 times taller than the depth of the container). If they begin to lean over, prune them, starting at the top and working down, until they stand up by themselves. In some species (e.g. *Erythrina subumbrans* and *Prunus cerasoides*) pruning encourages branching, a desirable



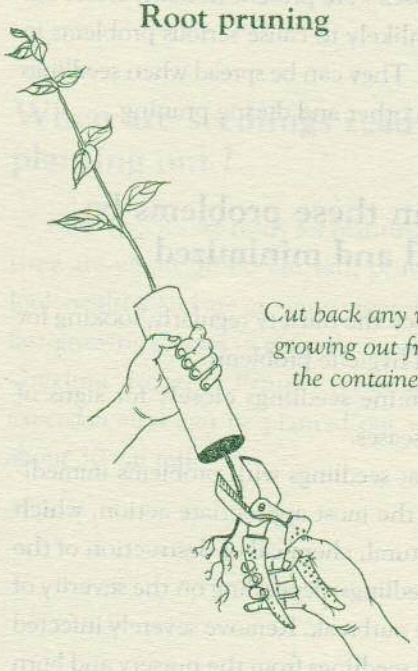
Regular nursery operations like root pruning provide an opportunity to remove weak or malformed seedlings.

Good - roots are all inside the container.

Bad - roots have grown into the soil beneath the container.



Root pruning



Cut back any roots growing out from the container.

feature, since, after planting out, a spreading crown will shade out weeds and rapidly close the forest canopy. However, other species (e.g. *Melia toosendan*) often die after pruning. If you are unsure how a species responds to pruning, experiment on a few seedlings before pruning the whole batch.

Control of weeds, pests and diseases in the nursery

Nursery hygiene is very important. The importance of maintaining a clean, tidy nursery, free from weeds and checking the seedlings regularly for disease connot be over emphasized.

REMEMBER THAT PREVENTION IS BETTER THAN CURE.

What are the causes of disease ?

1. **Fungi** - although most are beneficial, some cause root rots and damping off. Fungal spores are spread in air, water and in the soil. Fungal hyphae are filaments which grow through soil and dead plant tissue
2. **Bacteria** - most are harmless, but some may cause blight, cankers and wilts. They are also spread in air, water and in the soil
3. **Viruses** - are present in many trees, but most are unlikely to cause serious problems in the nursery. They can be spread when seedlings touch each other and during pruning.

How can these problems be detected and minimized ?

1. Check the nursery regularly, looking for health and hygiene problems.
2. Examine seedlings closely for signs of pests or diseases.
3. Treat seedlings with problems immediately with the most appropriate action, which will be cultural, chemical or destruction of the affected seedlings, depending on the severity of the disease outbreak. Remove severely infected or infested seedlings from the nursery and burn them. An infected batch of seedlings left in or near the nursery will spread diseases to the healthy seedlings, causing large losses.
4. Remove weeds from containers and from around the nursery; they compete with the seedlings and harbour pests and diseases.
5. Ensure adequate ventilation.

What are the most common pests ?

1. insects which eat leaves, such as caterpillars and crickets;
2. mites, which often live on the undersides of leaves and are difficult to see;
3. aphids and other bugs which suck sap from leaves and stems and transmit diseases and
4. weevils and other pests which live in the soil.

With frequent inspections, many of these animals can be removed by hand without the need to use pesticides or to discard seedlings.

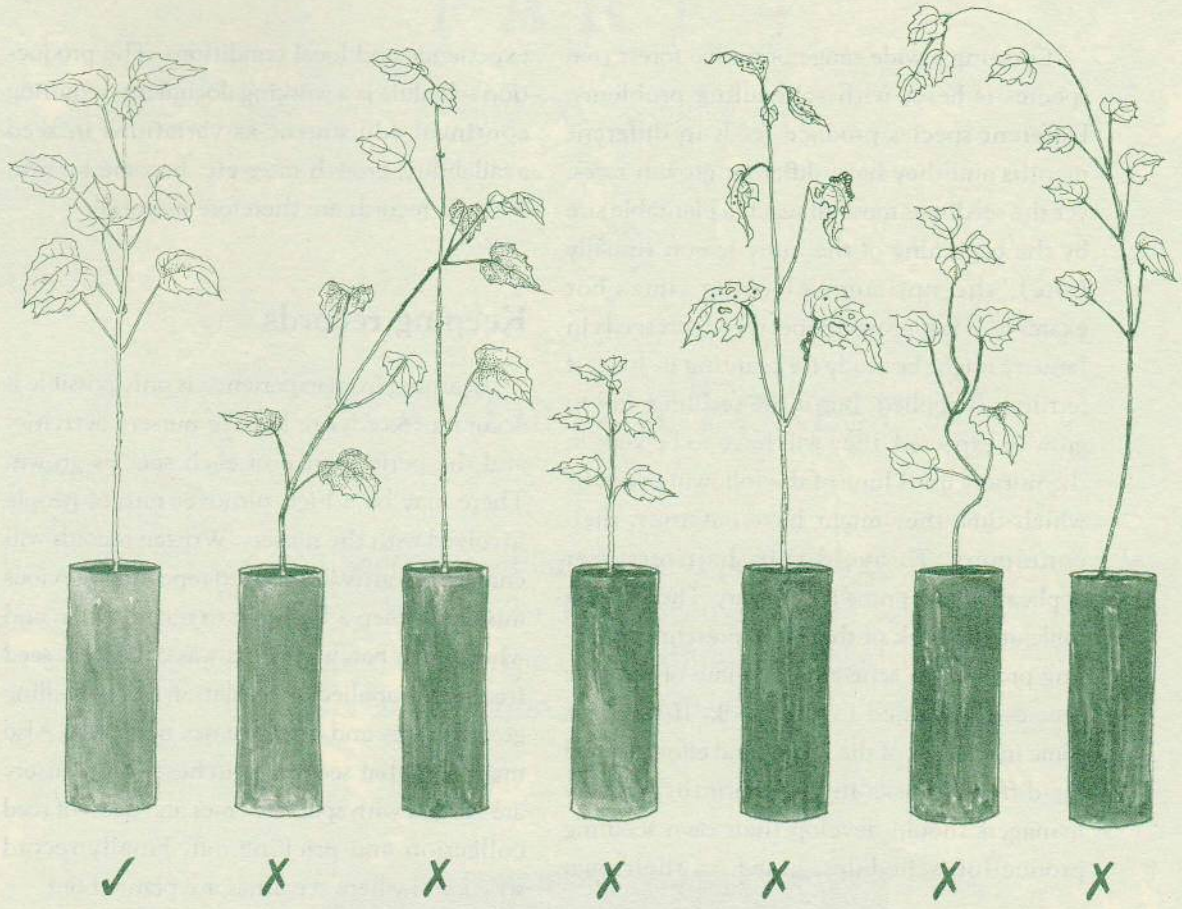
Why not just spray routinely for both pests and disease ?

This is one option, but chemicals are expensive and hazardous. Residues could be harmful to both workers and beneficial organisms. Excessive use of fungicides can lead to fungi developing resistance to the chemical.

What is "hardening off" and why is it important ?

Hardening-off or weaning is the process of preparing seedlings for planting. Seedlings, grown in shady nurseries with frequent watering must be acclimatized gradually to the hot, dry, sunny conditions they will experience after they are planted out in deforested sites. At least 1-2 months before planting, gradually remove shade netting until the seedlings are in full sunlight. Reduce the frequency of watering. Watch seedlings closely and wait until they begin to wilt before watering them.

Grading seedlings



A perfect healthy seedling.

Discard - stem is distorted.

Discard - leaves dropping.

Discard - poor growth.

Discard - wilting and other signs of disease.

Discard - deformed.

Discard - weak unbalanced shoot.

Grading and quality control

Grading means arranging seedlings according to their size and appearance and throwing away those that are too small, weak or unhealthy. This can be done during regular inspections for disease, during root pruning, hardening off etc. It is a false economy to waste time and money on small weak seedlings. They take up nursery space which could be used for healthy seedlings and they will probably die after planting anyway. Further resources are then wasted on unnecessary replanting.

When are seedlings ready for planting out ?

Most species are ready for planting out when they are about 50-60 cm tall, provided they look healthy and are growing vigorously. Some fast-growing species (e.g. *Erythrina subumbrans*, *Gmelina arborea*, *Prunus cerasoides*, *Melia toosendan* etc.) can be planted out when only about 30 cm tall.

Section 4: Production scheduling

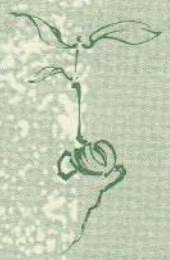
Growing a wide range of native forest tree species is beset with scheduling problems. Different species produce seeds in different months and they have different growth rates, yet the seedlings must all reach a plantable size by the beginning of the rainy season (usually June), the optimum planting time. For example, a fast growing species which seeds in January might be ready for planting in June, if fertilizer is applied. But if the seedlings fail to grow as expected, they will have to be kept in the nursery until June of the following year, by which time they might have outgrown their containers. To avoid this, halt fertilizer application and prune if necessary. The fold-out table at the back of this book presents a seedling production schedule for some of the tree species mentioned in this book. It provides some indication of the labour and effort needed for different tasks in each month. Nursery managers should develop their own seedling production schedules, based on their own experience and local conditions. The production schedule is a working document, requiring continual adjustment as variations in seed availability, growth rates etc. become known. Written records are therefore essential.

Keeping records

Learning from experience is only possible if accurate records are kept of nursery activities and the performance of each species grown. There may be a high turnover rate of people involved with the nursery. Written records will enable new arrivals to avoid repeating previous mistakes. Keep a log book to record when and where each batch of seeds was collected, seed treatments applied, germination rates, seedling growth rates and any diseases observed. Also make sure that seedling batches in the nursery are labeled with species names and dates of seed collection and pricking out. Finally record when and where seedlings are planted out.

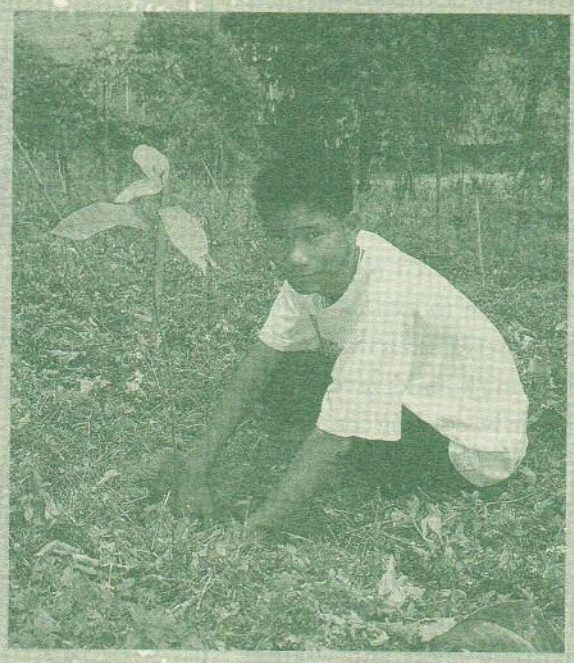
Careful scheduling and record keeping are essential to produce seedlings of 20-30 framework species needed to restore diverse forest ecosystems.

PART 4



PLANTING A FOREST

Section 1 - Planning and preparation
Section 2 - The planting event
Section 3 - Caring for seedlings after planting
Section 4 - Monitoring



It is important to involve children in tree planting projects, since they will benefit most from the mature forest.

PLANTING A FOREST

"He who plants a tree plants a hope."
Lucy Larcom (1826-93), U.S. poet, "Plant a Tree"

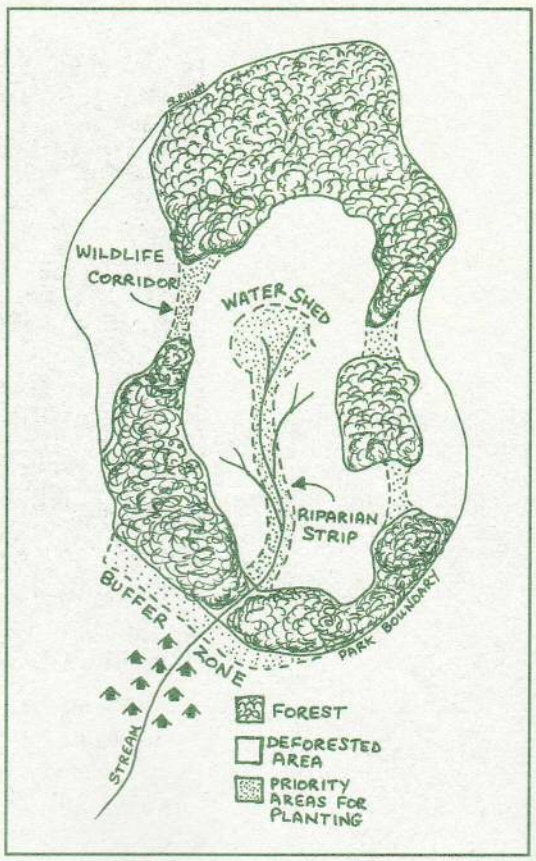
Planting is undoubtedly the most satisfying part of forest restoration. However do not forget the time, effort and expense which has been put into producing the seedlings. Carelessness during planting, which damages or kills the seedlings, can render 1-2 years of nursery work useless. Also planting is only one of many steps to restoring a forest. Unless tree planting is followed up with weeding, fertilizer application and especially fire control for several years afterwards, it may amount to nothing.

SECTION 1 - PLANNING AND PREPARATION

Where to plant ?

With such large areas of deforested land and the high costs of replanting, it makes sense to first plant trees on sites which will provide the maximum ecological benefits. In a largely deforested landscape, remaining forest is usually fragmented into small, separated patches. Migration of wildlife between the forest patches is prevented and small isolated populations become highly vulnerable to extirpation. In areas where wildlife conservation is the primary objective, tree planting should reverse the effects of fragmentation by creating corridors of forest to reconnect the forest patches. Planting along stream sides is also useful to prevent stream bank erosion and siltation and to create moist refuges for wildlife during the dry season. Tree planting in buffer zones protects the borders of national parks and wildlife sanctuaries from outside influences.

In most cases, however, the choice of planting site will be a joint decision made by local communities, landowners and Forest Department officials. Ecological considerations are often overridden by social and legal constraints and



Where possible, plant for maximum ecological benefit.

by practical considerations such as steepness and accessibility. Start discussions with interested parties about suitable planting sites at least a year before seedlings will be ready for planting and make sure that written permission has been obtained from landowners and the relevant authorities.

When to plant ?

Plant at the beginning of the rainy season, once the rains have become regular and reliable. In northern Thailand this is usually late May to June. This gives seedlings maximum time to develop a good root system before the first dry season. Most mortality of seedlings occurs during or shortly after the first dry season after planting.

Preparing to plant

About six months before the planting date, check the nursery for seedlings likely to be ready for planting. If there are not enough for the area to be planted, obtain extra seedlings from local nurseries. If they are in small plastic bags, repot them into 2 1/2 x 9" bags and add slow release fertilizer. This will improve their chances of being vigourous and healthy by the planting date

About two months before planting, place all seedlings to be planted in one part of the nursery, and begin the hardening off process (see Part 3).

Tree planting is very popular and it is usually easy to find large numbers of volunteers to help. However, start contacting volunteers well in advance and ask experienced planters to act as team leaders. Use a planting rate of about 15 trees per person per hour to help estimate the number of people required.

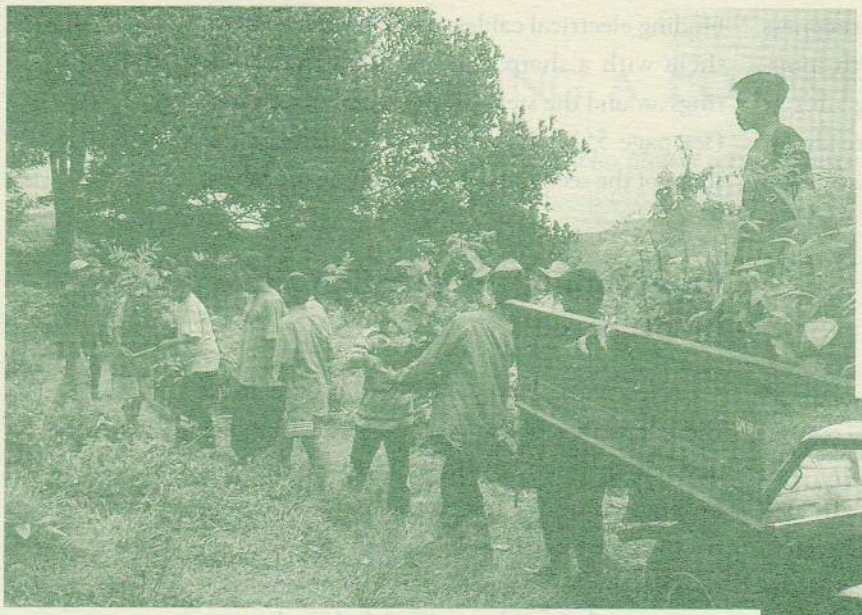
Select a sample of seedlings for monitoring after planting and label them, whilst they are still in the nursery. Use metal bands used for binding electrical cables, scratch numbers onto them with a sharp nail and form them into rings around the stems of the sampled seedlings (*see* page 55). Take care not to damage the stems of the seedlings when attaching the labels.

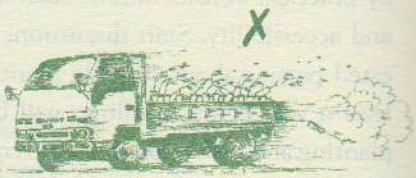
How should the planting site be prepared ?

A few weeks before the planting date, mark the boundaries of the planting site with poles and put up a sign board, displaying the area to be planted and a telephone number where people interested in helping with tree planting or objecting to it can contact the organizers.

Survey the site about a week before planting. Look for naturally established tree seedlings. Cut the weeds around them so that they are clearly visible and mark them with a bamboo stake or coloured tape. Tell everyone involved in site preparation and planting to avoid trampling or cutting the seedlings. Natural seedlings should be encouraged as much as possible by weeding, mulching and fertilizer application. Planting should add to natural regeneration, not replace it. Naturally established tree seedlings reduce the number of planted seedlings needed and they will always grow faster than those planted.

Clear the site of weeds, using hand tools. Slash the weeds and dig out the roots. Lay the cut vegetation evenly across the soil surface as a mulch. This will help to inhibit regrowth of weeds. Use of a non-residual herbicide (e.g. glyphosate) will clear the site of weeds more effectively than hand tools. It is also cheaper and requires less labour, but people must be trained to use herbicides safely and unless a great deal of care is exercised during spraying, herbicide will also kill naturally established seedlings. Contact FORRU for further information. Do not use fire to clear sites for forest restoration, as it burns naturally established seedlings. It also stimulates subsequent weed growth, kills beneficial soil organisms and removes the possibility of using slashed weeds as mulch.





Protect seedlings from wind damage during transportation by covering them with shade netting.

Take care when loading or unloading seedlings. Pack them firmly into baskets, so that they will not move during transportation.

SECTION 2 - THE PLANTING EVENT

How should seedlings be transported to the planting site ?

Reduce stress to seedlings during transportation by watering them, after loading them onto a vehicle. If using plastic bags, keep them upright; do not stack them on top of each other or squash them together so that they loose their shape. REX trays (*see* page 39) have the advantage of stability and cannot be squashed together during transportation. They are also easier to carry. During the journey to the planting site, keep seedlings shaded and protected from wind damage. Divide the planting site into subsites of about 2 rai and unload one batch of about 1,000 seedlings at each subsite.

How should planters be organized ?

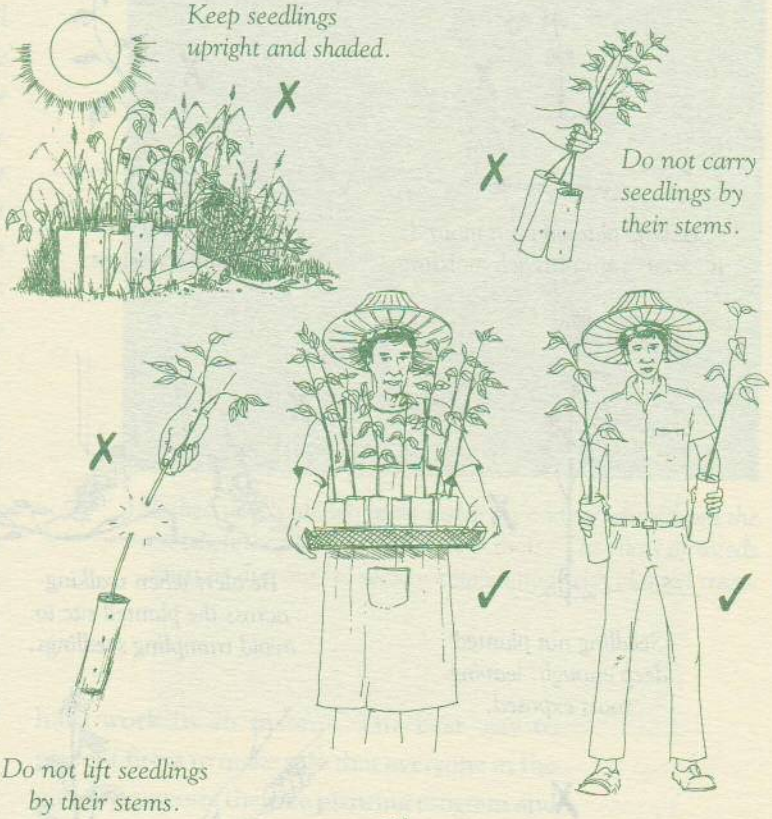
Divide planters into teams of about 12, each with a team leader. Hold a meeting of team leaders shortly before the planting day. Make sure they can recognize the species being planted and know the planting methods to be used. Team leaders are responsible for directing which seedlings are planted where, ensuring correct spacing and that species are evenly distributed across the site. Define a subsite for each team to plant. Demonstrate how to plant a tree and display boards with diagrams explaining the planting methods, (*see* page 51) so that people who have never planted trees know what to do.

Tree planting is also a social and educational event. Organizers should welcome planters as they arrive and explain the project to anyone wanting further information. Food should be provided. Social events after planting provide an opportunity to build support for further tree planting activities.

How should seedlings be planted ?

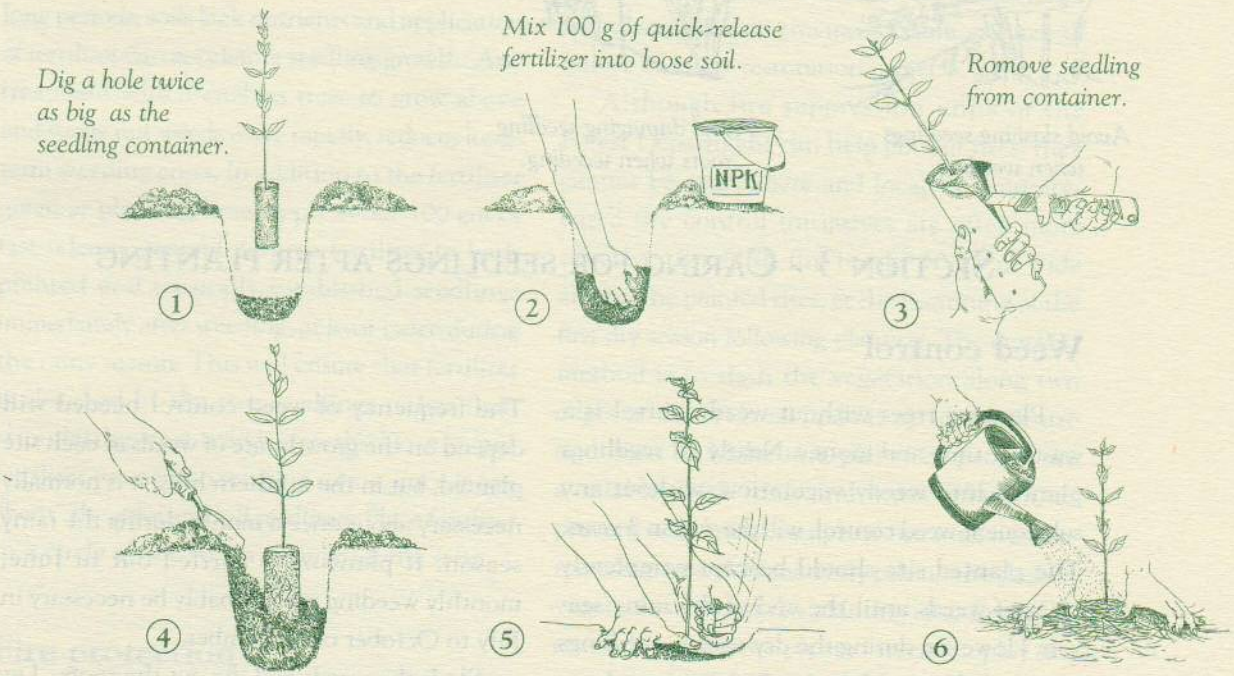
Plant the seedlings randomly 1.5-1.8 m apart (500-700 seedlings per rai). This close spacing will result in rapid canopy closure and shading out of weeds. Mark the positions where seedlings are to be planted with bamboo poles. Dig holes about twice as big as the seedling containers and mix about 100 gm of quick release fertilizer into loose soil at the bottom of each hole. If using plastic bags, remove each seedling by cutting along one side. With REX trays, gently lift out each seedling. Place each seedling in a hole, fill in with loose soil and firm down the soil around the seedling. Form a saucer around the stem to save water and place a thick layer of cut weeds or straw around each

At the planting site



The correct ways to carry seedlings in the field.

How to plant a tree

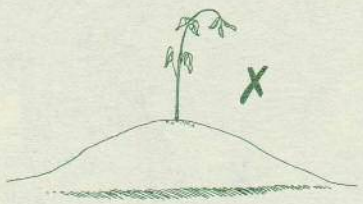


Place seedling in hole and fill in with soil.

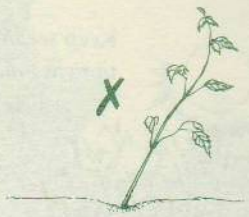
Firm soil around the seedling and make a shallow depression to collect water.

Place mulch (cut vegetation) around the seedling and water it or plant when raining.

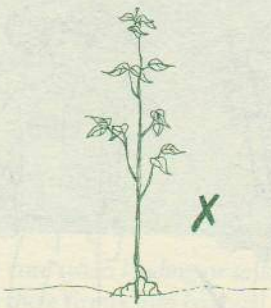
Prevent damage to planted seedlings



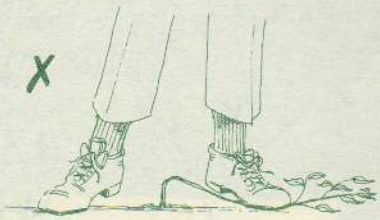
Seedling planted on a mound; it's roots cannot reach moisture.



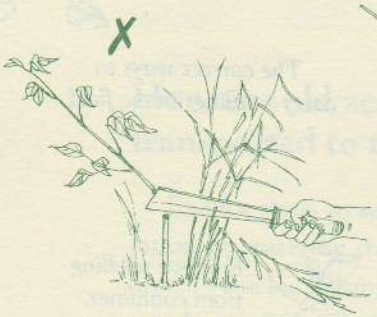
Seedling not planted upright.



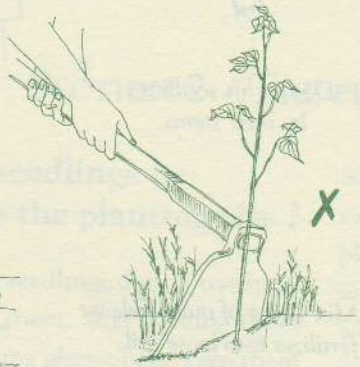
Seedling not planted deep enough, leaving roots exposed.



Be alert when walking across the planted site to avoid trampling seedlings.



Avoid slashing seedlings when weeding.



Avoid damaging seedling roots when weeding.

seedling to form a mulch. If there is a source of water nearby, water each seedling. If not, plant when rain is likely. Do not leave plastic bags to litter the site. Collect them for proper disposal. Collect and re-use REX trays. One team of 12 people will probably be able to plant about 1,000-1,500 trees per day, about 1.5-3 rai depending on the spacing between seedlings.

After the planting is over

A day or two after planting, walk around the planting site and check on the seedlings. Pick up discarded plastic bags or other litter and make the first measurements of seedlings which have been labeled for monitoring.

SECTION 3 - CARING FOR SEEDLINGS AFTER PLANTING

Weed control

Planting trees without weed control is a waste of time and money. Nearly all seedlings planted into weedy vegetation, without any subsequent weed control, will die within 3 years. The planted site should be kept completely clear of weeds until the end of the rainy season. However, during the dry season, seedlings surrounded by weeds have a higher survival rate than those fully exposed to the sunny, hot and dry conditions prevalent at that time of year. The frequency of weed control needed will depend on the growth rate of weeds at each site planted, but in the northern hills, it is normally necessary about once a month during the rainy season. If planting is carried out in June, monthly weeding will probably be necessary in July to October or November.

Slash the weeds and dig out the roots. Lay the slashed vegetation around the stems of planted seedlings. It will form a mulch which

will suppress subsequent weed growth near the seedlings. Weeds with vigourous roots, especially large clumps of grasses should be stacked in piles with roots uppermost. Otherwise they rapidly re-root and continue to grow. Allow weeds to grow up a little at the end of the rainy season and resume weeding once the rainy season re-commences the following May or June. For manual weeding with hand tools, use a weeding rate of 20 - 40 m^2 per person per hour (depending on weed types and density) to calculate labour requirements.

Although a non-residual herbicide (e.g. glyphosate) is far more effective and cheaper than hand weeding, it can only be applied during dry, windless days which are very rare during the monsoon. It is very difficult to avoid herbicide drift killing many of the planted seedlings, especially when the seedlings are small in the first rainy season after planting. Therefore herbicide use should only be considered if manual labour is unavailable or too expensive. Contact FORRU for further advice.

Slashed weeds absorb more nutrients and moisture from the soil when they re-grow from their roots. The roots of weeds must be dug out, to reduce competition with planted trees.

Fertilizer

On sites which have been cultivated for long periods, soils lack nutrients and application of fertilizer can accelerate seedling growth. Any treatment which enables trees to grow above and shade out weeds more rapidly, reduces long-term weeding costs. In addition to the fertilizer given at planting time, apply about 100 gm of fast-release, general purpose fertilizer to both planted and naturally established seedlings immediately after weeding, at least twice during the rainy season. This will ensure that fertilizer is absorbed by the tree seedlings rather than stimulating new weed growth. Do not put fertilizer too near to seedling stems, since it can "burn" the stem and kill seedlings. Place fertilizer in a circle about 30 cm away from the stem.

Fire protection

Fire is an annual hazard during the dry season and can completely wipe out years of hard work in an instant. The best way to prevent fire is to make sure that everyone in the vicinity supports the tree planting program and understands the need not to start fires anywhere near the planted sites. However, no matter how much effort is put into raising awareness of fire prevention amongst the local community, fire will always remain the most common cause of failure of forest restoration projects.

Although fire suppression units of the Forest Department can help put out fires, they cannot be everywhere and local, community-based fire control initiatives are often more effective. Establish fire breaks 10-15 m wide around the planted sites, at the beginning of the first dry season following planting. The quickest method is to slash the vegetation along two edges of the firebreak, pile it up in the centre and burn it. Make sure plenty of people are available, with tools and water sprayers, to prevent accidental escape of fire into the surrounding area. Alternatively pile up the slashed vegetation around the planting sites for use as a mulch around the planted trees. Employ fire watchers to alert local people when fires are spotted so that they can help put out the fires. Place oil drums full of water and fire fighting

Does tree planting really work ?
You can only find out by monitoring.

tools at strategic places around the planted site. Green tree branches make excellent fire beaters. If a permanent stream runs nearby, above the planting site, it might be possible to run water pipes into the planted sites. This can greatly increase the efficiency of fire fighting activities. For further information and to obtain fire fighting tools, please contact the nearest Forest Department fire-fighting unit.

Maintenance planting

Monitoring (see Section 4 below) will provide information on the numbers of seedlings surviving in the first 1-2 years after planting. Even with the best nursery and planting methods, it is unlikely that all seedlings will survive. Replace dead seedlings at the beginning of the rainy season 1 year after the initial planting and repeat after 2 years if necessary.

Section 4 - Monitoring

Why is monitoring necessary ?

The purpose of monitoring is to find out if tree planting actually achieves the desired effects. For conservation projects, this means finding out whether or not planted seedlings survive and grow well and whether tree planting accelerates the regeneration of non-planted tree species and other wildlife. Monitoring can help to identify problems with species selection and methods of planting and caring for seedlings. It stimulates further experiments to continuously improve tree planting activities.

What are control plots and why are they important ?

Control plots are not planted with seedlings but are as similar as possible to planted sites in all other ways e.g. altitude, slope, aspect, previous land use etc. Planted plots are compared with the controls to determine if planting results in a richer, denser forest than natural regeneration. If not, further time and money need not be wasted on nursery and tree planting activities. Instead resources can be directed towards protecting natural regeneration from fire and perhaps encouraging it by weeding and applying fertilizer.

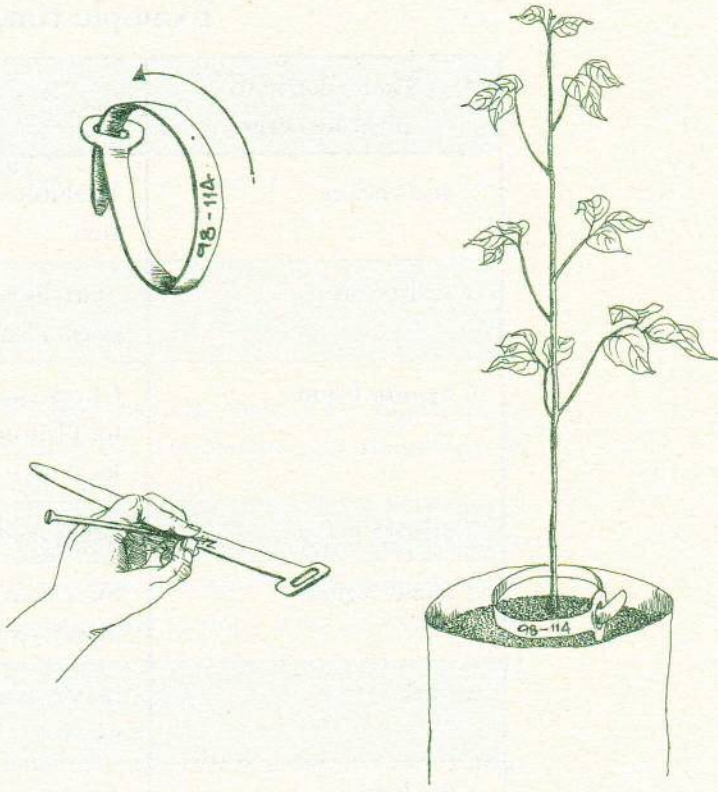
What is the simplest way to carry out monitoring ?

One of the simplest ways to assess the effects of tree planting is to take plenty of photographs of both planted plots and the controls, from the same points every few months. Photographs are easier to understand than statistics of survival and growth rates. They convey immediately the

overall outcome of tree planting. However, if you want to know which species grow well and which are failures, measurements must be made.

How should seedlings be sampled for monitoring ?

When large numbers of seedlings are planted, it is impossible to measure them all. The minimum requirements for adequate monitoring is a sample of at least 20 of each species planted. The larger the sample, the better. Select seedlings to include in the sample randomly; label them in the nursery before transportation to the planting site and plant them out randomly, but make sure you can find them again easily. Place a coloured bamboo pole by each seedling to be monitored; rewrite the identification number from the seedling label onto the bamboo pole with a weather proof marker pen and draw a sketch map to help you find the sample seedlings in the future.



Labeling a seedling for monitoring.

What measurements should be made and when ?

Rapid monitoring can involve simple counts of surviving vs. dead seedlings. More detailed monitoring can include measurements of seedling height and/or root collar diameter (for calculation of growth rate) and health. A simple health score is usually sufficient e.g. 3=perfect health, 2=some leaves damaged or diseased, 1=nearly dead and 0=dead. Monitoring is most conveniently carried out in pairs, with one person taking the measurements and the other recording the information on a prepared data sheet (*see* page 54) . One pair can collect data on up to 400 seedlings per day. Monitoring should take place at least twice per year in the first 2-3 years after planting (at the end of the rainy season and at the end of the dry season) and annually after that. Simple computer spreadsheet programs can be used to calculate average survival and growth rates and measures of variability.

How should other aspects of forest restoration be monitored ?

To monitor the return of biodiversity, survey both planted and control sites for naturally establishing tree seedlings, using transects or permanent subplots. Identify and label the seedlings found and monitor their survival and growth once per year. Surveys of wildlife can also be done. Birds are perhaps the easiest group to work with and they are important dispersers of seeds. For a rapid bird survey technique see MacKinnon (1981).

For further details of monitoring data sheets and computer analysis of results, please contact FORRU.

Example timetable for planting

Time relative to planting event	Action
2 years before	Establish nursery; start seed collection and seedling production.
1 year before	Start discussions with local communities and authorities to select planting sites.
6 months before	Check nursery for numbers of seedlings likely to be ready for planting; obtain more seedlings, if needed, from other local nurseries.
2 months before	Begin hardening off seedlings.
1 month before	Start contacting volunteer planters; label seedlings to be monitored; mark planting site boundaries.
1 week before	Survey planting site; mark natural seedlings; clear site of weeds.
1 day before	Transport seedlings to planting site; brief planting team leaders
PLANTING EVENT - JUNE	
1 week after	Take first measurements of seedlings to be monitored.
During first rainy season after planting	Monthly weeding; fertilizer application in August and October.
End of first rainy season.	Monitoring
Beginning of first dry season after planting	Cut fire breaks and organize fire patrols.
End of dry season	Monitoring; prepare for maintenance planting.
1 year after	Maintenance planting

GLOSSARY OF TECHNICAL TERMS

Barbets: a group of seed-dispersing birds.

Biodiversity: the variety of living things considered collectively e.g. species diversity, genetic diversity, ecological diversity etc.

Bulbuls: a large group of seed-dispersing birds.

Capsule: a type of dry dehiscent fruit.

Climax forest: undisturbed forest at maximum development in terms of structure and species composition.

Community forest: a forest managed collectively by local people.

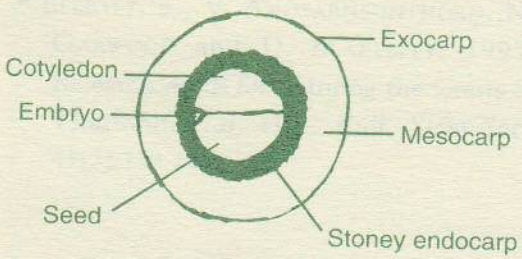
Damping off: a term which covers a range of fungal diseases which attack the stems of seedlings.

Deciduous: leaves dropping in the dry season.

Dehiscent: splitting open.

Dormancy: seed dormancy is the inactive condition of seeds between dispersal and germination.

Drupe: a type of fruit with a tough stoney or woody inner layer surrounding the seed(s).



Fruit (drupe) and seed parts of Prunus cerasoides.

Ecology: scientific study of the factors determining the distribution and abundance of plants and animals

Ecosystem: any area or space within which living organisms and the non-living environment interact to bring about an exchange of materials between the living and non-living parts of the system.

Embryo: rudimentary shoot and root within the seed.

Epiphyte: a plant which grows on, but does not penetrate, another plant.

Evergreen: retaining green leaves all year round.

Extirpation: the disappearance of a species from a local area.

Extinction: the complete disappearance of a species globally.

Fire break: a strip of land usually 10-15 m wide cleared of vegetation, to prevent the spread of wild fires.

Forest restoration: any activity aimed at re-establishing the forest ecosystem that was originally present on a deforested site before deforestation occurred. One particular kind of reforestation.

Framework species: tree species which, when planted as seedlings help accelerate natural forest regeneration. They are i) fast-growing with dense spreading crowns which rapidly shade out competing weeds and ii) attractive to seed-dispersing wildlife, especially birds and bats.

ha (Hectare): an area of 10,000 m^2.

Habit: the growth form of a plant e.g. as a tree, shrub, herb etc.

Hardening off: the process of gradually acclimatizing seedlings in the nursery to the conditions they will be subject to after planting out.

Herbarium: a collection of dried plant specimens.

Morphology: scientific study of the form and structure of plants and animals.

Nut: a type of fruit with a hard fruit wall.

Pod: a type of fruit, like a bean.

Pricking out: lifting seedlings from germination trays and potting them into individual containers.

Primary forest: undisturbed forest at maximum development in terms of structure and species composition.

Pyrene: the stoney or woody, inner layer of a drupe and the seed(s) contained within it.

Rai: an area of 1,600 m^2.

Root trainers: containers with vertical grooves to direct root growth downwards and prevent root spiraling.

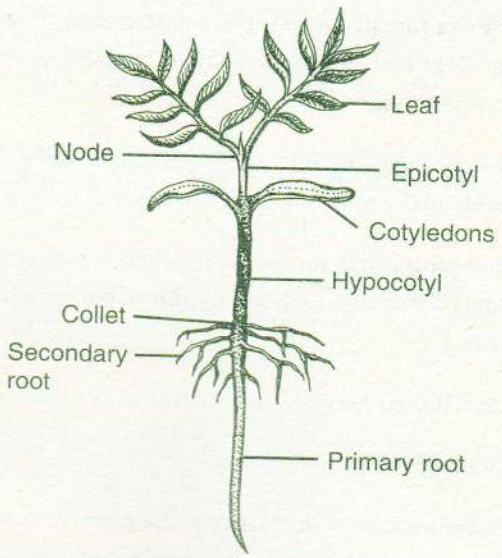
Rose: the head of a watering can or hose pipe with tiny holes, used to convert a stream of water into a fine spray.

Reforestation: planting trees to re-establish tree cover of any kind; includes plantation forestry, agroforestry and forest restoration.

Sapling: an immature tree; the developmental phase from production of the first adult leaves until flowering.

Seedling: the developmental phase of a plant from germination until the production of the first leaves similar in shape to those of the adult plant.

Seed predator: any animal which eats and/or destroys seeds without dispersing them.



Seedling parts of Sapindus rarak

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- What other information would you like to see included in a 2nd edition of this book and how would you like it to be presented ?
- If you have any comments at all about this book, we would like to hear from you. Information about how to contact FORRU is provided on inside the back cover.

How to Contact FORRU

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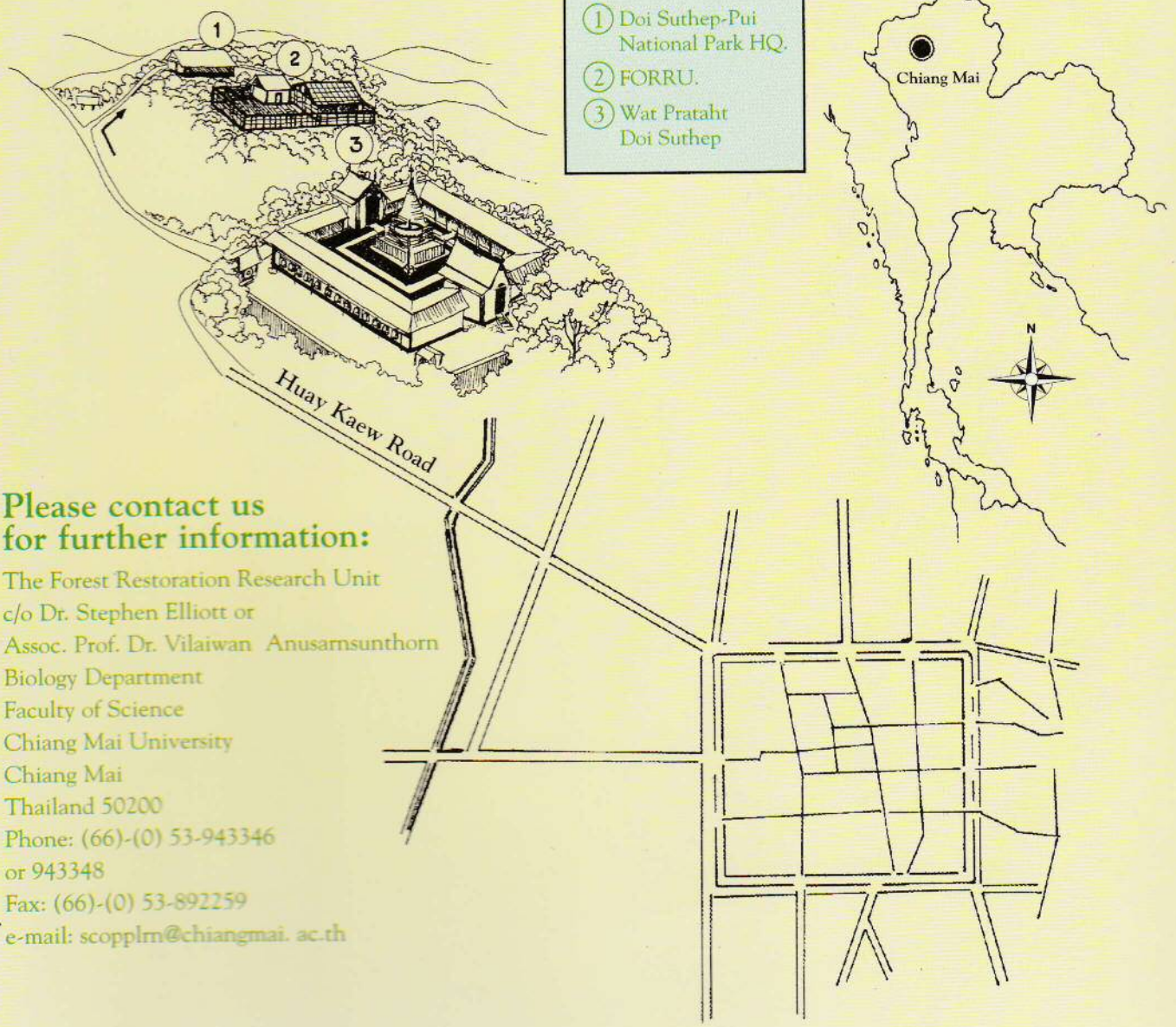

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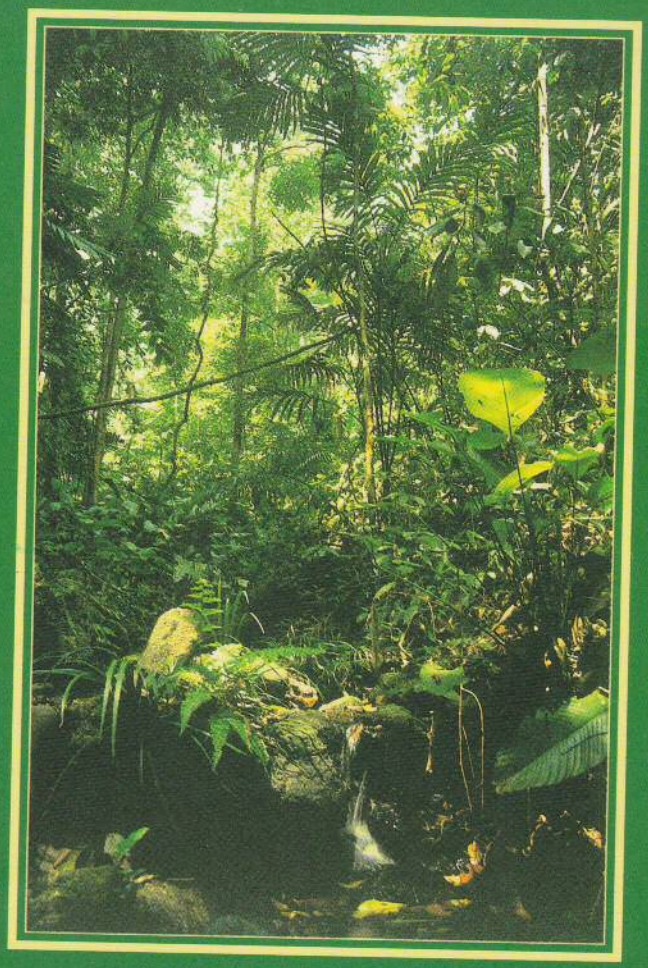

All over Thailand people who are concerned about the rapid destruction of the Kingdom's once magnificent forest are banding together to plant trees. Gone are the days when plantations of pines and eucalypts were considered the only viable form of reforestation. Nowadays, with ecological awareness on the increase, there is growing interest in watershed protection and conservation of wildlife and re-establishing more natural forests to meet these needs. Unfortunately the recent surge in public enthusiasm for planting native forest trees, has not been supported with sound technical advice. Seedlings planted are often of poor quality, or are of inappropriate species and care for them after planting is often insufficient. This book, based on the work of the Forest Restoration Research Unit (a joint initiative between Chiang Mai University and Doi Suthep-Pui National Park) since 1994, offers a basic introduction to growing and planting native trees to restore natural forest ecosystems. It provides practical advice on which tree species to plant; how to grow them in a nursery and how to organize a tree planting event. If you are already involved in reforestation activities or if you are thinking of starting a new tree planting group, this book will be of interest to you.