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Research towards the restoration of northern Thailand's degraded forests

Stephen Elliott[a], Vilaiwan Anusarnsunthorn[a], Siriporn Kopachon[a], J. F. Maxwell[a], David Blakesley[b] and Nancy C. Garwood[c]

[a]*Forest Restoration Research Unit, Department of Biology, Faculty of Science, Chiang Mai University, Thailand 50200*
[b]*University of Bath, School of Biology and Biochemistry, Bath BA2 7AY, U.K.*
[c]*Department of Botany, The Natural History Museum, Cromwell Road, SW7 5BD, London, U.K.*

Abstract

Throughout northern Thailand, large areas of land within national parks and wildlife sanctuaries are deforested or degraded and require reforestation. Within such protected areas, where the primary objectives are conservation of biodiversity and watershed protection, reforestation should aim to recreate the original forest ecosystems. Recently, many community groups have organized tree plant events to restore forests to about 8,000 sq km degraded land, to mark the golden jubilee of His Majesty King Bhumibol Adulyadej. However, such tree planting projects are often constrained by lack of knowledge of the habitat requirements of the several hundred native tree species being used. Knowledge of how to germinate the seeds and raise healthy seedlings is also limited and there is no identification manual for tree seedlings.

The Forest Restoration Research Unit (FORRU), a joint initiative between the Royal Forest Department and Chiang Mai University, with sponsorship from Riche Monde (Bangkok) Ltd., was established in November 1994 to determine the most effective methods to complement and accelerate natural forest regeneration in deforested areas, to increase biodiversity and protect watersheds. Its objectives are: 1) to develop 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; 2) to determine how the ecological processes of natural forest regeneration might be accelerated; 3) to identify which tree species are suitable for planting to complement natural seedling establishment; 4) to develop appropriate methods to propagate such tree species and carry out experimental planting trials and 5) to teach interested groups about appropriate forest restoration techniques.

Current research at FORRU includes a study of the fruiting phenology of 94 tree species to provide information on the seasonal availability of seeds for planting. Fruit and seed characteristics are entered into a computer database to enable correlation between seed characteristics and germination success. More than 200 tree species have been tested for germination in partial and deep shade, to determine which might be suitable for planting in the hot, partially shaded conditions found in deforested gaps. One of the major tasks of FORRU is to photograph, draw and describe seedlings at all stages of development to compile a seedling identification guide. Seedling planting trials are being carried out to determine the performance of a wide range of native forest tree species under various conditions. Some preliminary results on phenology, seed germination and seedling performance in a deforested gap are presented. Initial results indicate that several primary forest tree species can grow well in gaps and that planting them would not only increase the biodiversity of regenerating forest, but also accelerate forest succession.

Keywords: Seasonal tropical forest; Monsoon forest; Reforestation; Forest restoration; Phenology; Seed germination; Seedling establishment and propagation

1. Introduction

Like many rapidly developing tropical countries, Thailand has experienced extensive deforestation. The official estimate of current forest cover is 134,910 km^2 or 26% of the country (Rao, 1994), down from 53% in 1961 (Bhumibamon, 1986). However, these figures do not distinguish between plantations and natural forests and unofficial estimates put Thailand's natural forest cover at less than 20% (Leungaramsri & Rajesh, 1992). Between 1981 and 1990 the annual deforestation rate was 3.3% - the highest rate in SE. Asia (Rao, 1994). In 1989 the government banned commercial logging, in response to floods, blamed on deforestation, which devastated parts of southern Thailand. However, since then forest destruction has continued, although probably at a reduced rate.

Of particular concern has been the deforestation of the mountainous northern region. Not only are the northern forests a significant repository of the region's biodiversity, but they are also the country's most important water catchments, supplying water for the rapid agricultural, industrial and urban development in and around Bangkok and central Thailand. Furthermore, they provide a range of forest products and ecological services to rural communities. However, in the single northern province of Chiang Mai, satellite images revealed that the deforested area more than doubled in just ten years from 3,235 km^2 in 1975 to 6,513 km^2 in 1985 (GRID, 1988).

Following the logging ban, the National Forest Policy, which stipulates that 40% of the country should be under forest cover, was adjusted. The target for production forest was reduced from 25% to 15% of the country's area whilst that for conservation forests was increased from 15% to 25%. This policy was implemented by designating many former logging concessions as national parks or wildlife sanctuaries. Such areas now cover about 72,020 km^2 (13% of the country, or more than half of the total forest area (Boontawee et al., 1995)). Consequently large parts of many national parks and wildlife sanctuaries were already degraded or deforested before they acquired protected status. If such areas are to fulfill their functions of conserving biodiversity and protecting watersheds, they must be reforested.

Until recently, most reforestation projects in Thailand involved establishing single-species plantations, mostly pines and eucalypts, even within protected areas. Such plantations are of little value for wildlife conservation and watershed protection but, because the expertise and technology to establish them already existed and was easily imported, they proved to be the quickest method of re-establishing tree cover. However, attitudes towards reforestation within protected areas have recently changed considerably. Now senior Royal Forest Department officials are actively promoting "enrichment planting", using a wide range of native tree species and a random planting pattern, as the main reforestation method within protected areas (Chatwiroon, personal communication, 1996).

In 1993 a nation-wide project, involving the government, NGO's and the private sector, was launched to replant 8,273 sq km of deforested land, as part of celebrations marking His Majesty King Bhumibol Adulyadej's Golden Jubilee, at an estimated cost of about US$ 600 million. By the end of 1996 a total of 1,237 km^2 will have been completed within degraded reserved forest areas and 700 sq km outside reserved forests. So far, nearly 700 million seedlings have been grown for the project, which has attracted US$ 3.6 million in donations (up to May 1996, data provided by the Royal Thai Forest Department). The project stipulates use of a wide range of native forest tree species and that restored forests are to be preserved for conservation. Almost overnight the emphasis changed from plantation forestry to recreating complex forest ecosystems with their great diversity of tree species. People from all walks of life are helping to plant trees and many companies are sponsoring the work with large donations. However, implementing such an abrupt change in policy has been considerably constrained by lack of knowledge of how to grow and plant seedlings of the wide range of native tree species needed. Such basic knowledge as the seasonal availability of seed, optimal seed storage and germination conditions and habitat requirements of all but the most commercially valuable species is almost non-existent. Of great concern is the lack of any text enabling seedling identification, since failure to recognize seedling species often results in them being planted on unsuitable sites. The Flora of Thailand describes some adult trees, but not their seedlings and it is less than 25% complete (Santisuk et al., 1991).

2. The Forest Restoration Research Unit (FORRU)

FORRU was established in November 1994 to tackle some of the technical problems involved in re-establishing natural forest ecosystems on degraded sites within national parks and wildlife sanctuaries in northern Thailand (Elliott et al., 1995). It is a joint initiative between Chiang Mai University (CMU) and the Headquarters of Doi Suthep-Pui National Park (under the Royal Thai Forest Department (RFD)), which adjoins the university campus. The project was made possible through the generous sponsorship of a private sector company, Riche Monde (Bangkok) Ltd., which has agreed to fund FORRU for the first six years of operation, as part of its long-term environmental support program. FORRU has a full-time staff of four who carry out a research program on tree seed germination and seedling morphology and performance. Research advisers from Bath University, U.K. and the Natural History Museum, U.K. have played a significant role in helping to design the research program and several student volunteers from Britain have also contributed to the project.

FORRU is situated at the Headquarters of Doi Suthep-Pui National Park, northern Thailand (18^{o} 50' N, 98^{o} 50' E) at about 1,000 m elevation in a transitional zone between mixed evergreen-deciduous forest and evergreen forest (for a description of the forest types of Doi Suthep-Pui National Park see Maxwell, 1988). The park has a very high diversity of vascular plants (Elliott, Maxwell & Beaver, 1989) and was recently listed as a "centre of plant diversity" (Elliott and Maxwell, 1995). Six hundred and twenty six species of tree or treelet have been recorded within the national park, of which about 400 grow in the habitats and elevation range around the research unit (Chiang Mai University Herbarium Database, 1996). The area experiences a monsoonal climate, with a marked dry season from December to April, when monthly rainfall is usually less than 50 mm, followed by a rainy season which peaks in August. Annual rainfall is usually about 1,000 at the base of the mountain and about 2,000 mm near the summit (1,685 m elevation). There is a cool season from November to February, during which mean daily temperatures are 20.2-24.2^{o}C, after which temperatures rise sharply, peaking at about 30^{o}C in April. Facilities at the unit include a seed germination laboratory with benches under a transparent roof; a seedling growth area under shade netting where seedling morphology is studied and seedlings are grown on and an office for data analysis, drawing and photography.

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

1. 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.
2. Study of the ecological processes of natural forest regeneration to determine ways in which these processes might be accelerated.
3. Identification of tree species suitable for planting to complement natural seedling establishment.
4. Development of appropriate methods to propagate such tree species and the carrying out of experimental planting trials.
5. Training of interested groups in appropriate forest restoration techniques.

Current research activities include a study of the phenology of adult trees; compiling a database of fruit and seed morphology; seed germination experiments; photographing, drawing and writing descriptions of seedlings to compile a seedling identification handbook and seedling planting trials in deforested sites.

3. Fruit and Seed Phenology and Morphology

Phenological studies are carried out primarily to determine the seasonal availability of seeds of a wide range of tree species, but in addition, flowering, leaf flushing and leaf fall are also recorded. Along existing trails 339 trees of 94 species are observed with binoculars every three weeks and scored for the presence of flowers, fruits and foliage. A linear scale of 0-4 is used: 4 representing maximum intensity of reproductive activity or canopy cover and 3, 2, and 1 representing 75%, 50% and 25% of the maximum intensity or canopy cover respectively (method adapted from Koelmeyer, 1959).

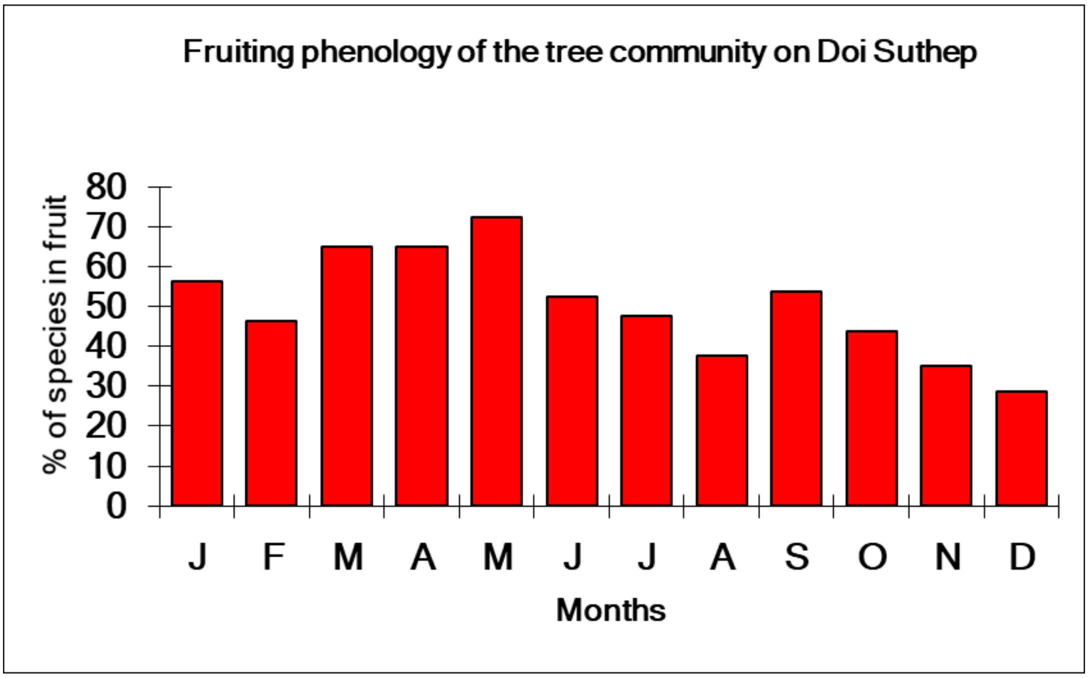
A summary of the first year's data is presented in Table 1 (not all species are represented, since some failed to flower or fruit in the first year). Such a table is useful in helping to plan seed collection programs for nurseries where seedlings are being raised for forest restoration projects. At the tree community level, fruiting peaked at the beginning of the rainy season in May (Fig. 1), suggesting a tendency for tree species to disperse and germinate their seeds when soil moisture availability is at a maximum. However, even in the poorest fruiting month (December), 29% of species bore fruit and more than 50% of species were fruiting in 6 months of the year.

Table 1.
Seasonal availability of tree seeds: xxxxx = fruits observed, PPP = fruiting peak

Species	**Family**	**n**	**Months in which fruits were observed**											
			J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Acrocarpus fraxinifolius Wight ex Arn.	Leguminosae (Caesalpinioideae)	4	xxxxx	xxxxx	xxxxx	PPP	PPP							
Acronychia pedunculata (L.) Miq.	Rutaceae	7							xxxxx		xxxxx	xxxxx	PPP	xxxxx
Adinandra integerrima T. And. ex Miq.	Theaceae	5	xxxxx	xxxxx	xxxxx	xxxxx	PPP	xxxxx	xxxxx	xxxxx				
Alstonia scholaris (L.) R. Br. var. scholaris	Apocynaceae	3	xxxxx	xxxxx	PPP	xxxxx	xxxxx						xxxxx	
Anneslea fragrans Wall.	Theaceae	1	PPP											
Antidesma bunius (L.) Spreng.	Euphorbiaceae	3				xxxxx	xxxxx	xxxxx	xxxxx	PPP	xxxxx			
Aphanamixis polystachya (Wall.) R.Parker	Meliaceae	9	PPP	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx		xxxxx	xxxxx	xxxxx	xxxxx
Archidendron clypearia (Jack) Niels.	Leguminosae (Mimosoideae)	4			xxxxx	PPP	xxxxx	xxxxx						
Artocarpus lanceolata Trec.	Moraceae	2			xxxxx		PPP	xxxxx						
Baccaurea ramiflora Lour.	Euphorbiaceae	8			xxxxx	PPP	xxxxx							xxxxx
Bischofia javanica Bl.	Euphorbiaceae	4	xxxxx		xxxxx	xxxxx	xxxxx		PPP	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx
Bombax ceiba L.	Bombacaceae	1												PPP
Bridelia pubescens Kurz	Euphorbiaceae	8	xxxxx						xxxxx		xxxxx	PPP	xxxxx	xxxxx
Callicarpa arborea Roxb. var. arborea	Verbenaceae	1				xxxxx		PPP						
Castanopsis acuminatissima (Bl.) A. DC.	Fagaceae	7	xxxxx	xxxxx	PPP	xxxxx	xxxxx							
Castanopsis diversifolia King ex Hk. f.	Fagaceae	3			xxxxx	xxxxx	PPP		xxxxx	xxxxx	xxxxx	xxxxx		
Castanopsis tribuloides (Sm.) A. DC.	Fagaceae	8	xxxxx		PPP	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	
Cleidion spiciflorum (Burm. f.) Merr.	Euphorbiaceae	8		PPP	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx		
Colona floribunda (Kurz) Craib	Tiliaceae	3	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx				xxxxx		PPP	xxxxx
Cryptocarya aff. ferrea Bl.	Lauraceae	8	xxxxx		xxxxx		PPP	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	
Dalbergia fusca Pierre	Leguminosae (Papilionoideae)	5	PPP	xxxxx	xxxxx	xxxxx	xxxxx							
Debregeasia longifolia (Burm. f.) Wedd.	Urticaceae	1											PPP	
Dillenia parviflora Griff. var. kerrii (Craib) Hoogl.	Dilleniaceae	5	xxxxx	xxxxx	PPP	xxxxx	xxxxx	xxxxx						
Diospyros glandulosa Lace	Ebenaceae	4			xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	PPP	
Dipterocarpus costatus Gaertn. f.	Dipterocarpaceae	3	xxxxx	xxxxx	PPP	xxxxx	xxxxx							
Dipterocarpus tuberculatus Roxb. var. tuberculatus	Dipterocarpaceae	12	xxxxx	xxxxx	PPP	xxxxx	xxxxx	xxxxx						
Duabanga grandiflora (Roxb. ex DC.) Walp.	Sonneratiaceae	7	xxxxx	xxxxx	xxxxx	PPP	xxxxx				xxxxx	xxxxx		
Dysoxylum procerum Wall. ex Hiern	Meliaceae	1	PPP	xxxxx	xxxxx						xxxxx	xxxxx	xxxxx	xxxxx
Elaeocarpus floribundus Bl.	Elaeocarpaceae	2	PPP	PPP	PPP	PPP	PPP	xxxxx						
Elaeocarpus prunifolius Wall. ex C. Muell.	Elaeocarpaceae	1		xxxxx	xxxxx	xxxxx	PPP							
Eriobotrya bengalensis (Roxb.) Hk. f. forma bengalensis	Rosaceae	1		PPP										
Eugenia albiflora Duth. ex Kurz	Myrtaceae	8	xxxxx	xxxxx	xxxxx	xxxxx	PPP							
Euodia meliifolia (Hance) Bth.	Rutaceae	1	xxxxx								PPP	PPP	PPP	PPP
Eurya acumminata DC. var. wallichiana Dyer	Theaceae	3	PPP	xxxxx	xxxxx	xxxxx								
Eurya nitida Korth. var. siamensis (Craib) H. Keng	Theaceae	5									xxxxx	PPP		

Table 1. cont.														
Species	**Family**	**n**	**Months in which fruits were observed**											
			J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Ficus altissima Bl.	Moraceae	5	xxxxx	xxxxx	PPP	xxxxx	xxxxx	xxxxx			xxxxx	xxxxx		
Ficus fistulosa Reinw. ex Bl. var. fistulosa	Moraceae	1				xxxxx	xxxxx	PPP	PPP	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx
Ficus microcarpa L. f. var. microcarpa forma microcarpa	Moraceae	1	PPP											
Ficus subulata Bl. var. subulata	Moraceae	2					xxxxx	PPP	xxxxx	xxxxx	xxxxx		xxxxx	xxxxx
Garcinia mckeaniana Craib	Guttiferae	7			PPP	xxxxx	xxxxx							
Garcinia speciosa Wall.	Guttiferae	9	xxxxx	xxxxx	xxxxx	xxxxx	PPP							
Garcinia xanthochymus Hk. f. ex T. And.	Guttiferae	9	xxxxx	xxxxx	xxxxx	xxxxx	PPP	PPP	xxxxx	xxxxx	xxxxx			
Hovenia dulcis Thunb.	Rhamnaceae	2		xxxxx	xxxxx		xxxxx	xxxxx			PPP	xxxxx		
Knema conferta (King) Warb.	Myristicaceae	1					PPP	PPP	PPP					
Kydia calycina Roxb.	Malvaceae	2	PPP	xxxxx	xxxxx	xxxxx	xxxxx						xxxxx	xxxxx
Macaranga denticulata (Bl.) M.-A.	Euphorbiaceae	4					xxxxx	xxxxx	PPP	xxxxx	xxxxx	xxxxx		
Macaranga kurzii (O.K.) Pax & Hoffm.	Euphorbiaceae	9			xxxxx		xxxxx	xxxxx	xxxxx	PPP	xxxxx	xxxxx		
Mallotus philippensis (Lmk.) M.-A. var. philippensis	Euphorbiaceae	4	xxxxx	xxxxx	xxxxx						xxxxx	xxxxx	PPP	xxxxx
Markhamia stipulata (Wall.) Seem. ex Sch. var. kerrii Sprague	Bignoniaceae	5	xxxxx	xxxxx	xxxxx	xxxxx	PPP	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx
Melia toosendan Sieb. & Zucc.	Meliaceae	1	xxxxx		PPP	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx
Metadina trichotoma (Zoll. & Mor.) Bakh. f.	Rubiaceae	5	PPP	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx		xxxxx			
Michelia champaca L.	Magnoliaceae	3			xxxxx		xxxxx	PPP	xxxxx	xxxxx				
Micromelum hirsutum Oliv.	Rutaceae	2	xxxxx	xxxxx	PPP	xxxxx	xxxxx	xxxxx						
Morus macroura Miq.	Moraceae	4		xxxxx	PPP	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx			
Nyssa javanica (Bl.) Wang.	Nyssaceae	1				PPP	PPP	PPP	PPP	xxxxx	xxxxx			
Ostodes paniculata Bl.	Euphorbiaceae	2					PPP							
Paramichelia baillonii (Pierre) Hu	Magnoliaceae	7	xxxxx		xxxxx	xxxxx	xxxxx	PPP	xxxxx	xxxxx	xxxxx			
Phoebe cathia (D. Don) Kosterm.	Lauraceae	1				PPP	PPP							
Phoebe lanceolata (Nees) Nees	Lauraceae	1						PPP	PPP	PPP				
Phyllanthus emblica L.	Euphorbiaceae	1	PPP			xxxxx					xxxxx			PPP
Phyllanthus kerrii A.S.	Euphorbiaceae	5	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx			xxxxx	PPP	xxxxx	xxxxx
Phyllanthus roseus (Craib & Hutch.) Beille	Euphorbiaceae	4	xxxxx	xxxxx	xxxxx	xxxxx	PPP	xxxxx						
Picrasma javanica Bl.	Simaroubaceae	1				xxxxx	PPP	PPP	PPP	PPP	xxxxx	xxxxx	xxxxx	
Polyalthia simiarum (Ham. ex Hk. f. & Th.) Bth. ex Hk. f. & Th.	Annonaceae	1							PPP					
Prunus arborea (Bl.) Kalk. var. montana (Hk. f.) Kalk.	Rosaceae	1	PPP		xxxxx		xxxxx		xxxxx		xxxxx	xxxxx	xxxxx	xxxxx
Sapindus rarak DC.	Sapindaceae	2	PPP		xxxxx	xxxxx	xxxxx				xxxxx	xxxxx	xxxxx	xxxxx
Sapium baccatum Roxb.	Euphorbiaceae	7	xxxxx	xxxxx	xxxxx	xxxxx	PPP	xxxxx	xxxxx	xxxxx				
Sarcosperma arboreum Bth.	Sapotaceae	7		xxxxx	PPP	PPP	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx		
Schima wallichii (DC.) Korth.	Theaceae	9	PPP	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx				xxxxx	xxxxx
Semecarpus cochinchinensis Engl.	Anacardiaceae	8	xxxxx	xxxxx	PPP	xxxxx	xxxxx	xxxxx	xxxxx		xxxxx	xxxxx		
Shorea roxburghii G. Don	Dipterocarpaceae	1					PPP							
Styrax benzoides Craib	Styracaceae	3			xxxxx					PPP	xxxxx	xxxxx		
Talauma hodgsonii Hk. f. & Thoms.	Magnoliaceae	8				xxxxx						PPP		
Tarennoidea wallichii (Hk. f.) Tirv. & Sastre	Rubiaceae	2	PPP						xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx
Terminalia chebula Retz. var. chebula	Combretaceae	1						xxxxx	PPP	xxxxx	xxxxx	xxxxx	xxxxx	
Terminalia mucronata Craib & Hutch.	Combretaceae	2	xxxxx			xxxxx			xxxxx	xxxxx	xxxxx	xxxxx	PPP	xxxxx
Trema orientalis (L.) Bl.	Ulmaceae	2	xxxxx	xxxxx	PPP	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx		
Turpinia pomifera (Roxb.) Wall. ex DC.	Staphyleaceae	8	xxxxx	xxxxx	xxxxx	xxxxx	PPP	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	
Wendlandia paniculata (Roxb.) DC. ssp. scabra (Kurz) Cowan	Rubiaceae	3	xxxxx	xxxxx	xxxxx	xxxxx	PPP	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx
Xanthophyllum flavescens Roxb.	Polygalaceae	3						PPP						

Figure 1. Fruiting phenology of 81 species of the tree community in Doi Suthep-Pui National Park.



If trees along the phenology trails are observed in fruit, seeds are collected for germination trials. In addition, a target list of tree species fruiting each month is generated, using the Chiang Mai University Herbarium Database. Extra trips are then made to collect the seeds of fruiting species not present on the phenology trails. A dried voucher specimen is made of every tree from which seeds are collected and data on location, habitat, girth, height, bark characteristics etc. are also collected. Voucher specimens are stored at CMU Biology Department Herbarium. Fruit and seed characteristics (colour, type, dimensions, wet and dry mass etc.) are also recorded and are being entered into a database that will act as an identification aid as well as provide the means to reveal relationships between seed/fruit morphology and germination success rate or phenology. Morphological data on about 100 species have been entered into the database so far.

4. Seed Germination

Seed germination experiments currently aim to identify which tree species germinate easily without any special treatments and to give some indication of the % germination that could be expected, so that nursery managers can estimate how many seeds to sow to produce a target number of seedlings. Furthermore, the germination experiments are providing information on length of seed dormancy, so that nursery managers know how long they may have to wait before seedlings are produced. Some experiments are also being carried out to test seeds collected from fruits at different stages of maturity. In the first three year phase of the project, the aim is to test all 400 tree or treelet species known to grow in the vicinity of the research unit with a simple experiment to compare germination in partial shade (shade level similar to a deforested gap) and deep shade (shade level similar to that beneath a forest canopy). Future experiments will be carried out on those species which fail to germinate in phase one, to test treatments to break seed dormancy and assess the potential for vegetative propagation.

Seeds are usually removed from fruits and planted in modular plastic trays under two shade treatments: partial shade (about 40% of full sunlight, similar to conditions in partially regenerating gaps) and deep shade (less than 1% full sunlight, similar to conditions under an evergreen forest canopy). For the partial shade treatment, seed trays are placed on top of concrete benches, under a transparent plastic roof; for the deep shade treatment, trays are placed underneath the benches, screened around the sides with black plastic shade netting. For each of the two shade treatments, 72 seeds are divided into three replicate batches of 24, which are randomly assigned to different benches and watered daily. Each replicate consists of 24 adjacent modules (3.5 x 3 x 7cm) in one seed tray containing forest soil.

Of those species for which germination trials have been completed so far, 50% achieved a germination rate of 50% or more in one or both shade treatments (Table 2). Twenty five per cent germinated significantly better in partial shade, whilst none germinated significantly better in deep shade (paired t-test, $p \leq 0.05$). The remainder showed no significant difference in germination between treatments. Of those species which germinated significantly better in partial shade, 21 (84%) are characteristic of mature primary forest, indicating that, although they may be tolerant of deep shade, they are not dependent on it for germination and might be able to germinate adequately in low shade in gaps. Direct sowing of seeds or transplantation of seedlings of such species into deforested areas will be tested as a possible method to accelerate succession and increase the diversity of regenerating forest, especially for those species with large seeds, which may be limited in gaps by inadequate seed dispersal.

5. Seedling Identification Manual

One of the major aims of the germination experiments is to produce seedlings from identified parent trees for illustration and description for an identification manual of the forest tree seedlings of northern Thailand. Seedlings of known age are harvested from the germination experiments at different stages of development. They are photographed, drawn (example shown in Fig. 2) and prepared as dried herbarium specimens stored at CMU Biology Department Herbarium. Seedling specimens are stored in the same folders as the voucher specimens of the parent trees from which they originated. Detailed written descriptions are also prepared. The aim is to produce a seedling identification guide which foresters, villagers and non-governmental organizations involved in rural development and conservation can use to recognize seedlings already present in deforested sites and to select suitable seedling species for planting.

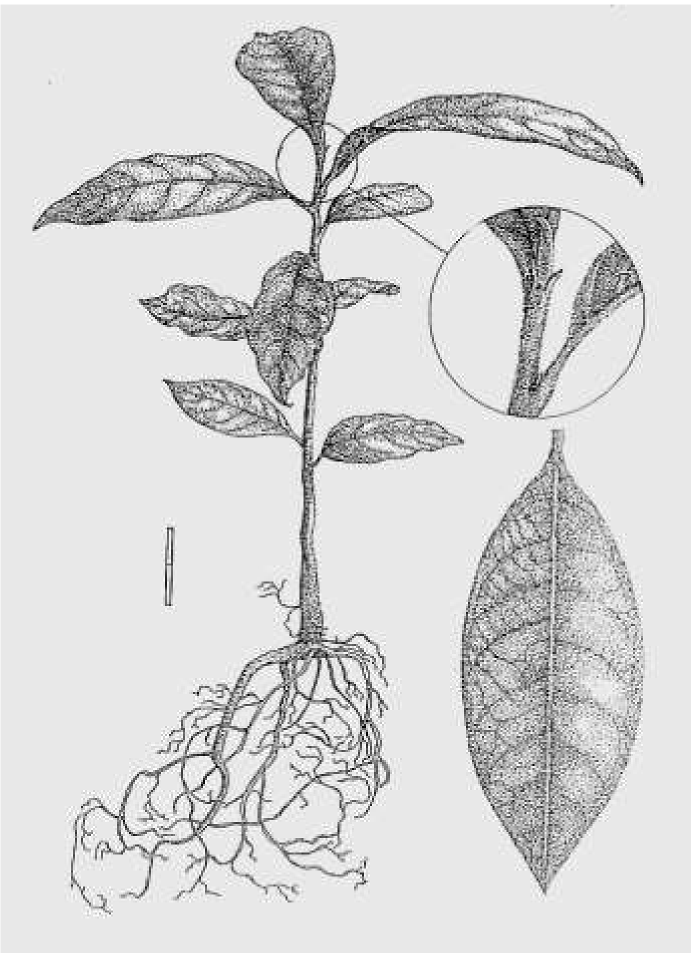


Figure 3. One example of the pen and ink drawings being prepared for the seedling identification manual: *Schima wallichii* (DC.) Korth. (Theaceae), aged 389 days, the scale bar is 2 cms. Artist, Mr. Surat Plukam.

Table 2

Results of seed germination trials in partial and deep shade

S. NUMBER	SPECIES	FAMILY	Habitat*	Dormancy (days)		% Germination				Leafing*
				Partial Shade	Deep Shade	Partial Shade	Deep Shade	t	Sig	
s080b1	Acer laurinum Hassk.	Aceraceae	PE	15	15-169	2.8	9.7	-1.39	ns	E
s031b1	Acrocarpus fraxinifolius Wight ex Arn.	Leguminosae (Caesalpinioideae)	PE	26-145	-	6.9	0.0	1.39	ns	D
s002b1	Acronychia pedunculata (L.) Miq.	Rutaceae	PED	59	-	1.4	0.0	1.00	ns	E
s118b1	Adenanthera pavonina L. var. microsperma (Teijsm. & Binn.) Niels.	Leguminosae (Mimosoideae)	PD	9-72	9-114	43.1	36.1	1.89	ns	D
s034b1	Albizia odoratissima (L. f.) Bth.	Leguminosae (Mimosoideae)	PED	7-70	7-62	52.8	59.7	-0.50	ns	D
s111b1	Anacolosa ilicoides Mast.	Olacaeae	PE	7-98	7-35	90.3	80.6	1.07	ns	E
s108b1	Anneslea fragrans Wall.	Theaaceae	PED	12-26	19-40	5.6	11.1	-1.51	ns	DE
s113b1	Aporusa villosa (Lindl.) Baill.	Euphorbiaceae	PED	25	32	4.2	1.4	0.55	ns	D
s112b1	Archidendron clypearia (Jack) Niels. ssp. clypearia var. clypearia	Leguminosae (Mimosoideae)	SED	7-98	7-35	52.8	45.8	1.89	ns	E
s129b1	Artocarpus gomezianus Wall. ex Trec.	Moraceae	PED	21-63	21-63	100.0	93.1	1.00	ns	D
s083b1	Artocarpus lanceolata Trec.	Moraceae	PE	15-50	15-36	84.7	72.2	1.00	ns	E
s048b1	Betula alnoides B.-H.	Betulaceae	SE	-	48	0.0	1.4	-1.00	ns	DE
s004b2	Bischofia javanica Bl.	Euphorbiaceae	PED	19-75	19-40	75.0	80.6	-0.61	ns	DE
s047b1	Bridelia pubescens Kurz	Euphorbiaceae	PED	71-99	-	6.9	0.0	5.00	0.1	D
s044b2	Buchanania latifolia Roxb.	Anacardiaceae	PD	12-34	20-34	61.1	16.7	6.05	0.1	D
s061b1	Canthium glabrum Bl.	Rubiaceae	PE	45-115	66-108	23.6	6.9	3.46	0.1	E
s121b1	Careya arborea Roxb.	Lecythidaceae	PD	11-88	18-39	93.1	88.9	0.87	ns	D
s053b1	Colona floribunda (Kurz) Craib	Tiliaceae	PD	37-101	80-185	4.2	8.3	-0.87	ns	D
s098b1	Craibiodendron stellatum (Pierre) W.W. Sm.	Ericaceae	PD	23	23-30	2.8	2.8	0.00	ns	DE
s074b1	Cryptocarya aff. ferrea Bl.	Lauraceae	PE	26-54	26-75	23.6	20.8	0.55	ns	E
s026b2	Dalbergia fusca Pierre	Leguminosae (Papilionoideae)	SD	22	22-57	44.4	25.0	5.29	0.1	D
s075b1	Debregeasia longifolia (Burm. f.) Wedd.	Urticaceae	SED	15-29	15-36	100.0	100.0	-	-	E
s102b1	Dillenia parviflora Griff. var. kerrii (Craib) Hoogl.	Dilleniaceae	PD	28-154	-	38.9	0.0	10.58	0	D
s049b1	Diospyros ehretioides Wall. ex G. Don	Ebenaceae	PD	41-119	126	37.5	1.4	4.67	0	D
s012b1	Diospyros glandulosa Lace	Ebenaceae	PED	27-244	22-244	77.8	48.6	2.42	ns	E
s109b1	Duabanga grandiflora (Roxb. ex DC.) Walp.	Sonneratiaceae	PED	17-59	17-31	86.1	94.4	-2.00	ns	E
s067b1	Engelhardia spicata Lechen. ex Bl. var. spicata	Juglandaceae	SED	27-41	27-55	29.2	27.8	0.14	ns	D
s006b1	Euodia meliifolia (Hance) Bth.	Rutaceae	PED	15-253	15-31	5.6	2.8	0.76	ns	D
s086b1	Eurya acuminata DC. var. wallichiana Dyer	Theaceae	PE	25-151	53-130	69.4	18.1	4.33	0.1	E
s054b1	Eurya nitida Korth. var. siamensis (Craib) H. Keng	Theaceae	SE	94	115	72.2	56.9	1.98	ns	E
s072b1	Ficus altissima Bl.	Moraceae	PD	13-118	20-97	97.2	72.2	6.00	0.1	E
s022b1	Ficus capillipes Gagnep	Moraceae	PE	31-227	59-227	87.5	76.4	1.14	ns	DE
s029b1	Ficus microcarpa L. f. var. microcarpa forma microcarpa	Moraceae	PD	28-84	28-84	100.0	80.6	1.61	ns	E
s039b1	Ficus subulata Bl. var. subulata	Moraceae	SED	33-208	33-124	69.4	33.3	2.14	ns	E
s120b1	Garcinia cowa Roxb.	Guttiferae	PD	39-67	46-67	72.2	83.3	-0.72	ns	D
s128b1	Garcinia mckeaniana Craib	Guttiferae	PE	38-87	38-87	77.8	65.3	1.96	ns	E
s003b1	Garcinia xanthochymus Hk. f. ex T. And.	Guttiferae	PE	85-176	99-183	87.5	81.9	0.57	ns	E
s090b1	Gardenia obtusifolia Roxb. ex Kurz	Rubiaceae	PD	30-135	30-100	52.8	18.1	5.74	0.1	D
s158b1	Garuga floribunda Decne.	Burseraceae	PD	23-79	-	32.0	3.0	2.39	ns	D
s091b1	Gluta usitata (Wall.) Hou	Anacardiaceae	PD	16-51	23-58	80.6	69.4	2.22	ns	D
s078b1	Gmelina arborea Roxb.	Verbenaceae	PED	18-32	18-137	83.3	18.1	11.75	0	D

Table 2 cont.

Results of seed germination trials in partial and deep shade

S. NUMBER	SPECIES	FAMILY	Habitat*	Dormancy (days)		% Germination				Leafing*
				Partial Shade	Deep Shade	Partial Shade	Deep Shade	t	Sig	
s078b1	Gmelina arborea Roxb.	Verbenaceae	PED	18-32	18-137	83.3	18.1	11.75	0	D
s016b1	Gordonia dalglieshiana Craib	Theaceae	PE	25-67	32-67	18.1	6.9	4.00	0.1	E
s104b1	Helicia nilagirica Bedd.	Proteaceae	SE	89-96	68-110	2.8	12.5	-3.50	0.1	E
s077b1	Hiptage benghalensis (L.) Kurz ssp. candicans (Hk. f.) Siri.	Malpighiaceae	PD	11-32	11-32	30.6	31.9	-0.12	ns	D
s119b1	Horsfieldia amygdalina (Wall.) Warb. var. amygdalina	Myristicaceae	PED	32-72	32-83	63.9	79.2	-3.05	0.1	E
s018b1	Hovenia dulcis Thunb.	Rhamnaceae	PE	17-115	24-115	50.0	27.8	1.68	ns	D
s020b1	Litsea salicifolia Nees ex Roxb.	Lauraceae	PE	59-136	66-136	8.3	12.5	-1.73	ns	E
s100b1	Macropanax concinnus Miq.	Araliaceae	PE	30-79	30-51	25.0	23.6	0.15	ns	E
s055b1	Mallotus philippensis (Lmk.) M.-A. var. philippensis	Euphorbiaceae	SED	28	-	1.4	0.0	1.00	ns	E
s134b1	Mammea siamensis (Miq.) T. And.	Guttiferae	SD	13-62	13-62	87.5	88.9	-0.16	ns	E
s070b1	Markhamia stipulata (Wall.) Seem. ex Sch. var. stipulata	Bignoniaceae	SED	5-20	5-27	55.6	43.1	5.20	0.1	D
s005b1	Melia toosendan Sieb. & Zucc.	Meliaceae	PED	115-234	-	11.1	0.0	3.02	0.1	D
s095b1	Memecylon plebejum Kurz	Melastomataceae	PED	16-44	16-44	23.6	9.7	3.78	0.1	E
s162b1	Mesua ferrea L.	Guttiferae	PD	12-68	19-105	45.8	22.2	4.71	0.1	E
s132b1	Michelia champaca L.	Manoliaceae	PE	31-52	59	15.3	1.4	1.89	ns	DE
s089b1	Micromelum hirsutum Oliv.	Rutaceae	SE	11-46	11-18	87.5	91.7	-0.58	ns	E
s153b1	Mischocarpus pentapetalus Radlk.	Sapindaceae	PED	40-47	40-61	4.2	9.7	-1.11	ns	E
s032b2	Mitragyna hirsuta Hav.	Rubiaceae	SED	35-217	105-133	72.2	8.3	4.67	0.1	D
s081b1	Morus macroura Miq.	Moraceae	PED	15-29	22-50	100.0	76.4	2.79	ns	D
s073b1	Oroxylum indicum (L.) Vent.	Bignoniaceae	SD	12-40	12	97.2	93.1	0.87	ns	D
s007b1	Paramichelia baillonii (Pierre) Hu	Magnoliaceae	PE	26-68	12-124	63.9	27.8	5.20	0.1	D
s036b1	Phyllanthus emblica L.	Euphorbiaceae	SED	35-119	76-126	40.3	16.7	2.43	ns	D
s069b1	Planchonella aff. annamensis Pierre ex Dub.	Sapotaceae	PE	31-101	31-94	25.0	30.6	-1.11	ns	E
s025b1	Prunus arborea (Bl.) Kalk. var. montana (Hk. f.) Kalk.	Rosaceae	PED	43-169	91-106	18.1	2.8	5.50	0.1	E
s071b1	Prunus cerasoides D.Don	Rosaceae	SE	27-125	41-139	58.3	13.9	5.75	0.1	D
s062b2	Quercus semiserrata Roxb.	Fagaceae	PE	38-87	38-94	91.7	87.5	0.43	ns	E
s159b1	Sandoricum koetjape (Burm. f.) Merr.	Meliaceae	PE	18-60	18-46	48.6	36.1	5.20	0.1	E
s013b1	Sapindus rarak DC.	Sapindaceae	PE	18-136	24-100	61.1	52.8	3.46	0.1	D
s015b1	Sapium baccatum Roxb.	Euphorbiaceae	PED	32-144	53-67	25.0	11.1	1.28	ns	E
s106b1	Sarcosperma arboreum Bth.	Sapotaceae	PED	46-74	60-116	18.1	44.4	-1.90	ns	E
s023b7	Schima wallichii (DC.) Korth.	Theaceae	SED	12	12	54.2	31.9	2.87	ns	E
s066b1	Spondias axillaris Roxb.	Anacardiaceae	PE	11-32	11-67	43.0	36.0	0.59	ns	D
s139b1	Sterculia angustifolia Roxb.	Sterculiaceae	PD	-	14	0.0	1.0	-1.00	ns	D
s057b1	Stereospermum colais (B.-H. ex Dillw.) Mabb.	Bignoniaceae	SD	15-38	15-71	45.8	68.1	-2.29	ns	D
s117b1	Streblus asper Lour.	Moraceae	SD	9-65	9-93	43.1	25.0	1.36	ns	E
s079b1	Strychnos nux-vomica L.	Loganaceae	PD	32-137	39-81	69.4	38.9	8.31	0	D
s058b1	Symplocos sumunita B.-H. ex D. Don	Symplocaceae	PE	61-138	61-131	91.7	72.2	5.29	0.1	E
s063b1	Terminalia alata Hey. ex Roth	Combretaceae	PD	11-46	17	12.5	13.9	-0.28	ns	D
s050b1	Terminalia mucronata Craib & Hutch.	Combretaceae	PD	28-55	35-91	13.9	6.9	1.89	ns	D
s115b1	Toona microcarpa (C. DC.) Harms	Meliaceae	PED	11-39	11-32	22.2	31.9	-0.71	ns	D
s017b1	Turpinia nepalensis (Roxb.) Wall. ex Wight & Arn.	Staphyleaceae	PE	31-73	59-115	20.8	9.7	1.51	ns	DE
s021b1	Turpinia pomifera (Roxb.) Wall.	Staphyleaceae	PE	24-143	24-143	81.9	5.6	9.88	0	E
s082b1	Vernonia volkameriifolia DC. var volkameriifolia	Compositae	SE	8-29	8-15	31.9	25.0	1.15	ns	E
s051b1	Vitex quinata (Lour.) Will.	Verbenaceae	PED	35-98	-	23.6	0.0	3.21	0.1	DE
s146b1	Xanthophyllum flavescens Roxb.	Polygalaceae	PED	25-95	25-116	66.7	50.0	1.24	ns	E
s065b1	Xylia xylocarpa (Roxb.) Taub. var. kerrii (Craib & Hutch.) Niels.	Leguminosae (Mimosoideae)	PD	3-32	3-39	76.4	76.4	0.00	ns	D

*P=primary, S=secondary, E=evergreen, D=deciduous

6. Seedling Planting Trials

The first pilot seedling planting trial of the FORRU research program was established in September 1995 near Mahidol Waterfall in Doi Suthep-Pui National Park (18° 50.08' N, 98° 54.71' E) at 1,110 m elevation with a south to south westerly aspect and slopes ranging from 5-35°. The site had been cleared for agriculture by Hmong tribal people living at the nearby Chang Khien Village and then degraded further by fire and cattle grazing. It consists of a seasonal stream gully with an abandoned litchi plantation (*Litchi chinensis* Sonn. (Sapindaceae)) on one side and a steep slope, which had been burnt and dominated by the grass *Thysanolaena latifolia* (Roxb. ex Horn.) Honda on the other. The ground flora in the abandoned litchi plantation was mostly dominated by grasses (*Imperata cyclindrica* (L.) P. Beauv. var. *major, Microstegium vagans* (Nees ex Steud.) A. Camus, *Saccharum arundinaceum* Retz.) mixed with *Eupatorium odoratum* L. (Compositae). FORRU staff, Hmong villagers, student volunteers and Forest Department officers planted about 400 seedlings randomly over the site in holes measuring approximately 30x30x30 cm. Approximately 3-5 g of Osmocote slow release fertilizer was added to each hole before each seedling was planted. Seedlings were monitored two weeks after planting and at the end of each season (end of the cool dry season in February 1996 and end of the hot, dry season in May 1996). Monitoring, which will continue, involves measuring the height and basal diameter of each surviving seedling and scoring them for general health on a scale of 0 (dead) to 3 (no damaged leaves). Although seedlings of 29 tree species were planted, only twelve had sample sizes large enough to permit meaningful analysis over the period September 1995 to May 1996 (Table 3). Mortality rates ranged from 12 to 63% and were highly variable between species. There were also very large differences in relative growth rates (based on height increment) between species (3 - 73 %/y). It is important to note that several species characteristic of primary forests performed as well as or better than those known to occur naturally in regenerating gaps.

Table 3.
Performance of seedlings in planting trials, Sept 95-May 96

Species	Family	Leafing*	Habitat**	n	% Mortality	Relative Growth Rate %/y
Castanopsis tribuloides (Sm.) A. DC.	Fagaceae	E	PED	19	53	73
Cinnamomum iners Reinw. ex Bl.	Lauraceae	E	PE	23	22	55
Eugenia tetragona Wight	Myrtaceae	E	SE	30	36	42
Gordonia dalglieshiana Craib	Theaceae	E	PE	41	63	61
*Helicia n*ilagirica Bedd.	Proteaceae	E	SE	8	12	10
Lithocarpus elegans (Bl.) Hatus. ex Soep.	Fagaceae	E	PED	7	28	48
Melia toosendan Sieb. & Zucc.	Meliaceae	D	PED	8	12	40
Phoebe lanceolata (Nees) Nees	Lauraceae	E	SED	60	38	45
Sapindus rarak DC.	Sapindaceae	D	PE	10	40	22
Semecarpus cochinchinensis Engl.	Anacardiaceae	E	SED	28	25	49
Stereospermum colais (B.-H. ex Dillw.) Mabb.	Bignoniaceae	D	SD	6	35	3
Styrax benzoides Craib	Styracaceae	E	SED	8	25	50

* E=evergreen, D=deciduous
** P=primary, S=secondary, E=evergreen forest, D=deciduous forest

7. Education

It is essential that the information being generated at FORRU is disseminated to those who can effectively use it to improve tree planting programs. During the first three year phase of the project FORRU has concentrated on data accumulation, with educational activities confined to day visits by schools, NGO's, government officials etc. However, the first residential workshop at FORRU, aimed at village leaders, NGO's and government officials, will take place in November 1996. The workshop will demonstrate the methods developed at FORRU and provide feedback as to how best to present the information currently being generated by the unit to those who wish to make use of it. Since the seedling identification handbook will take a long time to produce, FORRU is compiling individual species accounts, as information on each species is completed (see Kopachon et al., 1996). In the second three-year phase of the project (starting June 1997) a full time educational officer will be employed to prepare education materials and organize further workshops.

8. Conclusions

FORRU has only just begun to tackle the enormous research needs to improve forest restoration projects in northern Thailand. However, in the short time that it has been open, the unit has developed useful methods for studying a large number of native forest tree species. One of the most important objectives of the unit is to identify which species are suitable for planting in deforested gaps to accelerate re-establishment of canopy cover, increase biodiversity of regenerating forest and hasten the succession towards primary forest. From the seed germination trials, we have been able to identify primary forest species which germinate readily in partial shade with no special treatments and which are not commonly found establishing naturally in deforested gaps. One explanation for the absence of such species in gaps is lack of seed dispersal; a limiting factor easily overcome by planting seedlings. They would be easy to propagate from seed in low-tech village-scale nurseries for tree planting projects and planting them would add diversity to the regenerating forest as well as shortening the successional sequence. From the information available to date, FORRU has identified the following species for testing in future seedling planting trials to determine their tolerance of gap conditions:-

1. In evergreen forest areas above 1,000 m elevation: *Anacolosa ilicoides* Mast. (Olacaceae), *Artocarpus lanceolata* Trec. (Moraceae), *Eurya acuminata* DC. var. *wallichiana* Dyer (Theaceae), *Ficus capillipes* Gagnep. (Moraceae), *Garcinia mckeaniana* Craib (Guttiferae), *Garcinia xanthochymus* Hk. ex T. And.(Guttiferae), *Hiptage benghalensis* (L.) Kurz ssp. *candicans* (Hk. f.) Siri. (Malpighiaceae), *Hovenia dulcis* Thunb. (Rhamnaceae), *Paramichelia baillonii* (Pierre) Hu (Magnoliaceae), *Quercus semiserrata* Roxb. (Fagaceae), *Sandoricum koetjape* (Burm. f.) Merr. (Meliaceae), *Sapindus rarak* DC. (Sapindaceae), *Spondias axillaris* Roxb. (Anacardiaceae), *Symplocos sumunita* B.-H. ex D. Don (Symplocaceae) and *Turpinia pomifera* (Roxb.) Wall. (Staphyleaceae).
2. In deciduous forest areas below 1,000 m elevation: *Adenanthera pavonina* L. var. *microsperma* (Teijsm. & Binn.) Niels. (Leguminosae, Mimosoideae), *Buchanania lanzan* Spreng. (Anacardiaceae), *Careya arborea* Roxb. (Lecythidaceae), *Ficus altissima* Bl. (Moraceae), *Ficus microcarpa* L. f. (Moraceae), *Garcinia cowa* Roxb. (Guttiferae), *Gardenia obtusifolia* Roxb. ex Kurz (Rubiaceae), *Garuga floribunda* Decne. (Burseraceae), *Gluta usitata* (Wall.) Hou (Anacardiaceae), *Mesua ferrea* L. (Guttiferae), *Strychnos nux-vomica* L. (Loganaceae) and *Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) Niels. (Leguminosae, Mimosoideae).
3. In either habitat: *Artocarpus gomezianus* Wall. ex Trec. (Moraceae), *Duabanga grandiflora* (Roxb. ex DC.) Walp. (Sonneratiaceae), *Gmelina arborea* Roxb. (Verbenaceae), *Horsfieldia amygdalina* (Wall.) Warb. var. *amygdalina* (Myristicaceae), *Morus macroura* Miq. (Moraceae) and *Xanthophyllum flavescens* Roxb. (Polygalaceae).

Establishment of seedlings in gaps could be achieved by various methods including i) direct sowing of seeds into gaps, ii) germinating seeds in nurseries and transplanting the seedlings produced into gaps, iii) transplanting seedlings from forests directly into gaps and iv) nurturing seedlings collected from forests in nurseries before transplanting them into gaps. Collection of seedlings from the forest often damages the roots, which may reduce seedling performance even after care in a nursery (Hardwick, personal communication, 1996). Consequetly, FORRU will compare the effectiveness of these various options. Preliminary results from the current pilot seedling planting trial (Table 3) indicate that the following primary forest species might perform well in deforested sites: *Cinnamomum iners* Reinw. ex Bl. (Lauraceae), *Lithocarpus elegans* (Bl.) Hatus. ex Soep. (Fagaceae) and *Melia toosendan* Sieb. & Zucc. (Meliaceae). The latter is particularly resilient and resprouts vigorously after cutting or burning. FORRU is carrying out more extensive planting trials to test these species under a range of different conditions.

The first phase of the FORRU project has concentrated on collecting descriptive information on a wide range of tree species. Future work will tend to concentrate on those species identified in phase one as being particularly suitable for accelerating natural regeneration by planting seedlings in deforested areas. Research will focus on improving propagation techniques for mass production of vigorous, healthy seedlings and future planting experiments will investigate the effectiveness of various simple planting treatments (artificial shade, mulching, fertilizers etc.) on seedling performance. In addition, alternatives to planting seedlings, such as encouraging birds and mammals to act as natural seed dispersers, improving the growth rate of naturally established seedlings etc., will be explored.

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