ELSEVIER

Forest Ecology and Management 164 (2002) 31–38

Forest Ecology and Management

www.elsevier.com/locate/foreco

Propagating framework tree species to restore seasonally dry tropical forest: implications of seasonal seed dispersal and dormancy

David Blakesley[a,*], Stephen Elliott[b], Cherdsak Kuarak[b], Puttipong Navakitbumrung[b], Sudarat Zangkum[b], Vilaiwan Anusarnsunthorn[b]

[a]*Horticulture Research International, East Malling, West Malling, Kent ME19 6BJ, UK*
[b]*Science Faculty, Biology Department, Forest Restoration Research Unit, Chiang Mai University, Chiang Mai 50200, Thailand*

Received 4 December 2000; received in revised form 10 April 2001; accepted 10 April 2001

Abstract

One effective approach to forest restoration in degraded tropical forestland is the so-called 'framework species method' which involves planting 20–30 indigenous forest tree species to re-establish a basic forest structure that catalyses the recovery of biodiversity. For the seasonally dry tropical forests of Doi Suthep-Pui National Park in northern Thailand, a provisional list of 36 potential framework species was compiled, from 19 different families representing a broad spectrum of the tree flora. This paper examines the seed germination characteristics of these species when grown as a nursery 'crop' for planting to restore degraded sites, focussing on germination phenology and dormancy. It considers how such characteristics affect the first stage of nursery production from seed collection to pricking out seedlings in the nursery. Twenty-nine species had a germination percentage of 60% or greater, which is acceptable for nursery production. The median length of dormancy (MLD) ranged from 7 days in the case of *Erythrina subumbrans* to 219 days for *Lithocarpus garrettianus*. Germination was defined as rapid if the MLD occurred within 3 weeks, and slow if occurring after 12 weeks. Twelve species germinated rapidly and eight germinated slowly, the remainder being intermediate. Seedling emergence ranged over a period of 7 days in the case of *Erythrina stricta* and *E. subumbrans* to 322 days in the case of *L. garrettianus*.

Keywords: Tropical forest restoration; Seed dormancy; Germination; Seedling development; Framework tree species

1. Introduction

Deforestation is a serious environmental problem throughout the tropics causing rural poverty, watershed degradation and loss of biodiversity. Efforts to restore forests are increasing, but such efforts are often limited due to lack of knowledge about how to propagate the majority of indigenous tree species. One effective approach to forest restoration is the 'framework species method' (Goosem and Tucker, 1995; Lamb et al., 1997; Tucker and Murphy, 1997) first developed to restore forest in degraded areas of Queensland's Wet Tropics World Heritage Site in Australia. The method depends on tree planting to restore basic forest structure which then encourages

* Corresponding author. Tel.: +44-1732-84-3833;
fax: +44-1732-84-9067.
E-mail address: david.blakesley@hri.ac.uk (D. Blakesley).

0378-1127/02/$ – see front matter
PII: S0378-1127(01)00609-0

the recovery of biodiversity. Seven years after planting 20–30 framework tree species in degraded grassland sites in Queensland, the regenerating forests developed closed canopies up to 8.7 m tall and was naturally colonised by up to 49 additional tree species (Tucker and Murphy, 1997). Framework tree species are fast growing with dense spreading canopies which rapidly shade out weeds. They also provide resources for wildlife (such as fruit, nectar or perching sites) at an early age. Animals (especially birds and bats) attracted by such resources, disperse the seeds of additional non-planted tree species into the planted sites, thus accelerating the return of biodiversity. Seed of framework species should be easy to collect and germinate in nurseries. A reasonable growth rate is also required in the nursery to ensure efficient use of nursery space and facilities.

Although detailed information exists on the propagation of commercially valuable tree species, very little is known about potential framework tree species, which tend to be non-commercial, indigenous forest tree species with high ecological value but low or unexplored economic value. For the vast majority of the huge diversity of forest tree species in Southeast Asia flowering, fruiting and germination phenology are not known and propagation techniques have not yet been developed. Of the 36 potential framework species reported here, only *Bishofia javanica*, *Duabanga grandiflora*, *Hovenia dulcis* and *Prunus cerasoides* have been studied previously (Datta and Sharma, 1989; Frett, 1989; Kamaluddin and Grace, 1993; Kopachon et al., 1996; Hardwick et al., 1997) and none within the context of producing a 'crop' of framework species.

Producing a wide range of framework tree species is far more complex than mass propagation of a small number of commercial plantation species. Indigenous tree species in Thailand produce seeds at different times throughout the year. However, seeds of tree species in seasonally dry tropical forests in the neotropics tend to germinate at the beginning of the rainy season (Garwood, 1983), providing seedlings with sufficient time to establish a good root system before onset of drought conditions during the following dry season. However, it is not clear how germination phenology and year-round seed dispersal affect the nursery operation. What may be the optimum strategy to enable trees to establish themselves naturally may work against the needs of small-scale tree nursery managers.

A list of 36 potential framework species from 19 different families was drawn up, based on pilot studies in the nursery, preliminary field trials over 3 years and fruiting characteristics. This included pioneers such as *Melia toosendan* and climax species such as *H. dulcis*. Key families include the Moraceae (four species), Meliaceae (two species), Leguminosae (two species) and Fagaceae (six species) (Table 1). The list is necessarily provisional because long-term field trials are needed to determine the age at which the listed tree species first produce wildlife resources and the degree to which they enhance biodiversity recovery. The present paper examines seed germination characteristics of potential framework species when grown as a crop, focussing on dispersal, germination phenology and dormancy. It considers how such characteristics affect the first stage of nursery production, from seed collection to pricking out seedlings in the nursery. It also reviews the suitability of the species as framework species based on the essential criterion of seed germination.

2. Materials and methods

2.1. Study site

Trees were propagated in a nursery at 1000 m elevation near the headquarters of Doi Suthep-Pui National Park, north-west of Chiang Mai, northern Thailand (l8°51′N latitude and 98°54′E longitude). The area experiences a monsoonal climate with pronounced dry and wet seasons. Average annual precipitation recorded at nearby weather stations at similar elevations ranges from 1670 to 2094 mm. The wet season lasts from May to October and the dry season from November to April.

All the seed was collected in natural or slightly disturbed forest ecosystems close to the nursery between elevations of 700–1600 m. This elevation range covers all the major forest types in the park, including the deciduous forest associations of the lowlands (deciduous dipterocarp oak, bamboo deciduous forest and mixed evergreen deciduous forest) and the evergreen forest of the uplands (Maxwell and Elliott, in press).

Table 1
Forest types, altitudinal ranges (northern Thailand) and fruit types of potential framework species

Species	Family	Forest type[a]	Altitude range (m)	Fruit type
Balakata baccata (Roxb.) Ess.	Euphorbiaceae	MED/E	400–500	Drupe
Bischofia javanica Bl.	Euphorbiaceae	BD/MED/E	525–1250	Drupe
Callicarpa arborea Roxb. var. *arborea*	Verbenaceae	DDO/BD/MED	375–1250	Berry
Castanopsis calathiformis (Skan) Rehd. and Wils.	Fagaceae	EP	1050–1500	Nut
Castanopsis tribuloides (Sm.) A. DC.	Fagaceae	MED/E/EP	900–1685	Nut
Cinnamomum iners Reinw. ex Bl.	Lauraceae	MED/E	700–1425	Berry
Debregeasia longifolia (Burm. f.) Wedd.	Urticaceae	MED/EP	525–1685	Achene
Duabanga grandiflora (Roxb. ex DC.) *Walp.*	Sonneratiaceae	MED/E	650–1450	Capsule
Eriobotrya bengalensis (Roxb.) Hk. f. *forma multinervata* Vidal	Rosaceae	E	1000–1650	Drupe
Erythrina stricta Roxb.	Leguminosae	BD/E/EP	400–1680	Pod
Erythrina subumbrans (Hassk.) Merr.	Leguminosae	MED/E	500–1680	Pod
Eugenia albiflora Duth. ex Kurz	Myrtaceae	MED/E/EP	800–1525	Berry
Eurya acuminata DC. var. *wallichiana* Dyer	Theaceae	E	1000–1500	Berry
Ficus altissima Bl.	Moraceae	BD/MED	350–1050	Fig
Ficus racemosa var. *racemosa*	Moraceae	MED	350–500	Fig
Ficus semicordata B.-H. ex J.E. Sm. Var. *semicordata*	Moraceae	BD/E/EP	350–1550	Fig
Ficus subulata Bl. var. *subulata*	Moraceae	MED/E	825–1400	Fig
Gmelina arborea Roxb.	Verbenaceae	BD/MED/E/EP	350–1475	Drupe
Heynea trijuga Roxb. ex Sims	Meliaceae	BD/MED/E/EP	550–1680	Capsule
Hovenia dulcis Thunb.	Rhamnaceae	E	1025–1300	Capsule
Lithocarpus elegans (Bl.) Hatus. ex Soep.	Fagaceae	B/MED/EP	450–1450	Nut
Lithocarpus garrettianus (Craib) A. Camus	Fagaceae	B/MED/E	550–1100	Nut
Manglietia garrettii Craib	Magnoliaceae	E	1050–1600	Aggregate follicle
Markhamia stipulata (Wall.) Seem. ex K. Sch. var. *kerrii* Sprague	Bignoniaceae	BD/MED/E/EP	950–1500	Capsule
Melia toosendan Sieb. and Zucc.	Meliaceae	MED/E	700–1450	Drupe
Michelia baillonii Pierre	Magnoliaceae	MED/E	650–1100	Aggregate follicle
Nyssa javanica	Polygalaceae	MED/E	550–1400	Drupe
Ostodes paniculata Bl.	Euphorbiaceae	E	1000–1350	Capsule
Phoebe lanceolata (Nees) Nees	Lauraceae	MED/E/EP	550–1550	Drupe
Planchonell punctata Flet.	Sapotaceae	DDO/BD/MED/E/EP	350–1525	Berry
Prunus cerasoides D.Don	Rosaceae	MED/E/EP	1050–1685	Drupe
Quercus semiserrata Roxb.	Fagaceae	MED/E/EP	800–1675	Nut
Quercus vestita Rehd. and Wils.	Fagaceae	E/EP	1200–1600	Nut
Rhus rhetsoides Craib	Anacardiaceae	MED/E/EP	650–1550	Drupe
Sapindus rarak DC.	Sapindaceae	MED/E	625–1620	Drupe
Spondias axillaris Roxb.	Anacardiaceae	MED/E/EP	700–1600	Drupe

[a] BD: bamboo and deciduous; DDO: deciduous dipterocarp oak; MED: mixed evergreen and deciduous; E: evergreen; EP: evergreen and pine (*sensu* Maxwell and Elliott, in press).

2.2. Seed germination

Seeds of the 36 potential framework species were collected from single parent trees of each species when fruits were mature and ripe. Fruits were cut from branches or collected from the ground only if they were 'fresh' and undecayed. Following the removal of the fruit pericarp, seeds were sown within 2–3 days of collection into modular plastic trays, on to the surface of a medium of two parts forest soil to one part coconut husk. For each species, 72 seeds were divided into three replicate batches of 24 which were randomly assigned to different benches and watered daily. Each replicate consisted of 24 adjacent compartments (3.5 cm × 3.0 cm × 7.0 cm) in one-seed tray. Seed trays were placed on the top of concrete benches, partially shaded under a transparent plastic roof (approximately 40% full sunlight, similar to the light intensity in partially regenerating gaps). Once the first pair of leaves had fully expanded, seedlings were

Table 2
Seed germination data of potential framework tree species, suitable for forest restoration plantings in northern Thailand

Species	Seed collection month	Mean germination percentage[a] (S.D.)	MLD (days)[b]	Time over which seeds germinated (days)[b]	Germination and synchrony categories[c]
Balakata baccata (Roxb.) Ess.	December	25 (6.3)	67	112	IG/AS
Bischofia javanica Bl.	November	43 (14.6)	85	154	SG/AS
Callicarpa arborea Roxb. var. *arborea*	August	67 (21.7)	86	63	SG/IS
Castanopsis calathiformis (Skan) Rehd. and Wils.	June	61 (19.2)	16	42	RG/IS
Castanopsis tribuloides (Sm.) A. DC.	September	83 (8.3)	31	42	IG/IS
Cinnamomum iners Reinw. ex Bl.	April	75 (8.3)	17	63	RG/IS
Debregeasia longifolia (Burm. f.) Wedd.	March	100 (0)	15	14	RG/S
Duabanga grandiflora (Roxb. ex DC.) *Walp.*	April	86 (2.9)	31	42	IG/IS
Eriobotrya bengalensis (Roxb.) Hk. f. *forma multinervata* Vidal	September	79 (3.6)	16	203	RG/AS
Erythrina stricta Roxb.	May	67 (33.3)	10	7	RG/S
Erythrina subumbrans (Hassk.) Merr.	April	39 (2.4)	7	7	RG/S
Eugenia albiflora Duth. ex Kurz	May	71 (12.5)	24	147	IG/AS
Eurya acuminata DC. var. *wallichiana* Dyer	March	69 (6.4)	60	126	IG/AS
Ficus altissima Bl.	March	97 (2.4)	34	105	IG/AS
Ficus racemosa var. *racemosa*	February	92 (4.2)	27	70	IG/IS
Ficus semicordata B.-H. ex J.E. Sm. var. *semicordata*	March	92 (5.0)	52	41	IG/IS
Ficus subulata Bl. var. *subulata*	January	71 (8.3)	60	175	IG/AS
Gmelina arborea Roxb.	March	83 (18.2)	25	14	IG/S
Heynea trijuga Roxb. ex Sims	November	83 (14.4)	96	203	SG/AS
Hovenia dulcis Thunb.	August	71 (15.0)	97	154	SG/AS
Lithocarpus elegans (Bl.) Hatus. ex Soep.	September	69 (9.6)	143	231	SG/AS
Lithocarpus garrettianus (Craib) A. Camus	September	56 (37.3)	219	322	SG/AS
Manglietia garrettii Craib	October	74 (4.8)	81	140	IG/AS
Markhamia stipulata (Wall.) Seem. ex K. Sch. var. *kerrii* Sprague	March	56 (2.1)	13	15	RG/.S
Melia toosendan Sieb. and Zucc.	April	67 (15.0)	15	70	RG/IS
Michelia baillonii Pierre	June	31 (6.9)	101	63	SG/IS
Nyssa javanica	July	67 (19.1)	39	70	IG/IS
Ostodes paniculata Bl.	November	53 (16.8)	124	203	SG/AS
Phoebe lanceolata (Nees) Nees	April	79 (4.2)	44	56	IG/IS
Planchonella punctata Flet.	June	89 (1.7)	17	35	RG/IS
Prunus cerasoides D.Don	March	74 (4.8)	52	63	IG/IS
Quercus semiserrata Roxb.	June	92 (7.2)	18	35	RG/IS
Quercus vestita Rehd. and Wils.	September	74 (13.4)	14	21	RG/S
Rhus rhetsoides Craib	December	50 (50.0)	24	28	IG/IS
Sapindus rarak DC.	January	83 (8.3)	45	98	IG/AS
Spondias axillaris Roxb.	March	43 (4.8)	11	21	RG/S

[a] Three replicates.
[b] Pooled replicates.
[c] RG: rapid germination; IG: intermediate germination; SG: slow germination; S: synchronous; IS: intermediate synchrony; AS: asynchronous.

pricked out and transplanted into individual containers. Germination was monitored throughout the germination period and was defined as emergence of any part of the shoot. The dates of the first and last seeds to germinate were recorded, and the median length of dormancy (MLD) calculated (pooling individuals of each species from the three replicate batches) from the germination times of all seeds which germinated.

3. Results

Germination percentage, one of the key selection criteria for framework species, ranged from 25 to 100% (Table 2). However, 80% of species had a germination percentage of 60% or greater, which is more acceptable for this type of nursery operation. Only three species had low germination percentages: *Balakata baccata* (25%); *Michelia baillonii* (31%); *Erythrina subumbrans* (39%). However, these species still qualify as potential framework species due to other attributes, such as high growth rate in containers or good field performance (unpublished data).

The MLD ranged from 7 to 219 days. For the purposes of nursery production, germination was defined as rapid if the MLD was 21 days or less, and slow if the MLD was 84 days or more. Twelve species could be classified as having rapid germination: *Castanopsis calathiformis*; *Cinnamomum iners*; *Debregeasia longifolia*; *Eriobotrya bengalensis*; *Erythrina stricta*; *Erythrina subumbrans*; *Markhamia stipulata*; *Melia toosendan*; *Planchonella punctata*; *Quercus semiserrata*; *Quercus vestita*; *Spondias axillaris*. In contrast, *Bischofia javanica*, *Callicarpa arborea*, *Heynea trijuga*, *Hovenia dulcis*, *Lithocarpus elegans*, *Lithocarpus garrettianus*, *Michelia baillonii* and *Ostodes paniculata* were categorised as having slow germination. The remaining 16 species had MLD's of between 3 and 12 weeks and could be regarded as having intermediate germination rates.

Considering the framework species as a whole, most species (28 or 78%) fell into the categories of rapid or intermediate germination. Of the 21 species collected in the late dry and early wet season, only one species, *Michelia baillonii* germinated slowly (Fig. 1). In contrast, of the 15 species collected in the late wet and early dry season, seven species germinated slowly (19% of the total); the remaining eight were intermediate or rapid. This seasonal variation resulted in a peak in nursery germination in the first-half of the year, when the median seeds of 72% of species germinated (Fig. 2). This coincided with the end of the latter part of the dry season and the early part of the wet season.

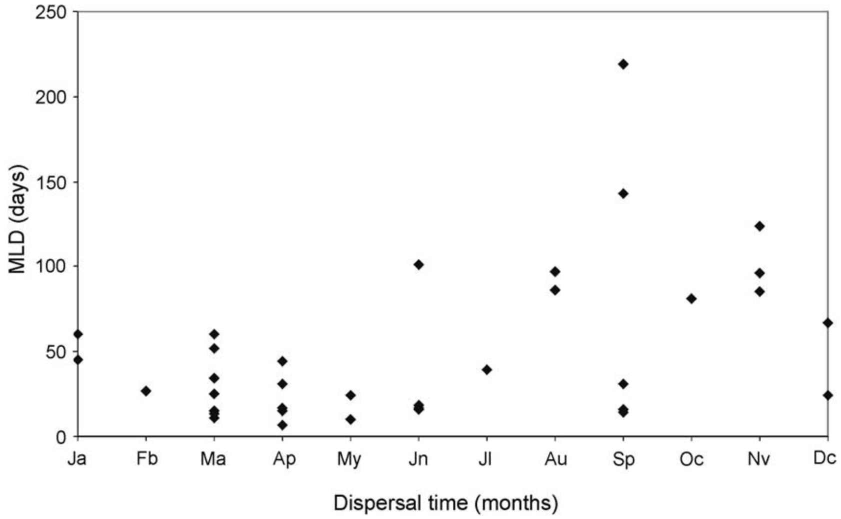

Fig. 1. The relationship between the MLD and the month of seed collection of species collected in Doi Suthep-Pui National Park (700–1600 m asl). Each point represents an individual species.

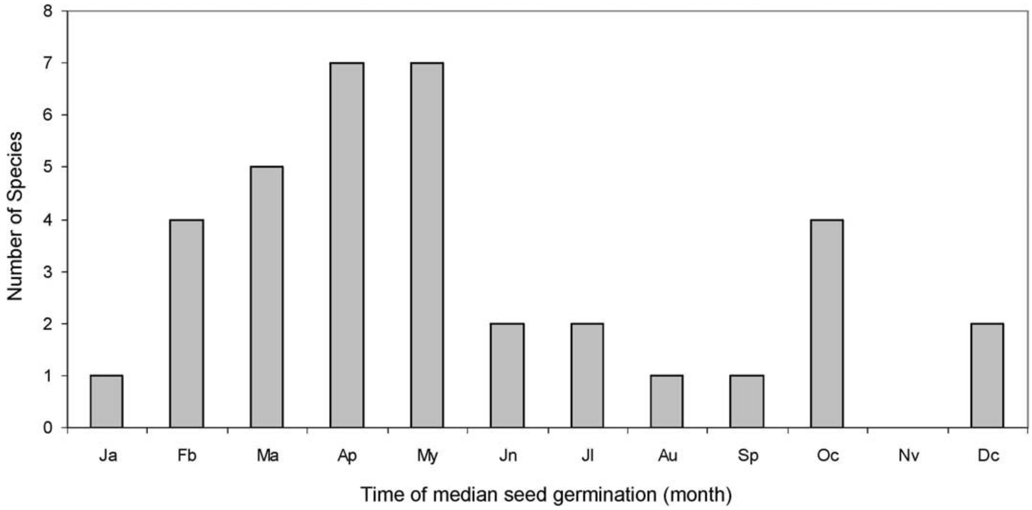

Fig. 2. Number of species located in Doi Suthep-Pui National Park (700–1600 m asl), whose median seed emergence falls in each month.

Seedling emergence ranged over 7 days for both *Erythrina* spp. to 322 days for *L. garrettianus*. For tree production in the nursery, germination was defined as synchronous if all seedlings of a given species emerged within 21 days, and highly asynchronous if this occurred over a period of more than 84 days. Seven species germinated synchronously, six of which also had an MLD of less than 21 days (Table 2): *Debregeasia longifolia*; *Erythrina stricta*; *Erythrina subumbrans*; *Markhamia stipulata*; *Quercus vestita*; *Spondius axillaris*. The other species which germinated synchronously, *Gmelina arborea*, also germinated relatively rapidly, with an MLD of 25 days. Species exhibiting highly asynchronous germination were distributed across intermediate- and slow-germinating species. Of the latter group of species, none germinated synchronously; 63 days was the shortest time of seedling emergence, and the mean emergence time for the eight species was 164 days.

4. Discussion

Few phenological studies have been reported with the framework species described in this paper. The most studied has been *Hovenia dulcis*, with several reports on seed germination (Frett, 1988, 1989; Kopachon et al., 1996) and the successful micropropagation of axillary buds from mature trees (Echeverrigaray et al., 1998). Hardwick et al. (1997) studied germination and emergence of *Prunus cerasoides* collected on Doi Suthep, and also found that it fruited late in the dry season with a high germination percentage. *Bischofia javanica* has previously been propagated from seed, and grown in controlled environments to stimulate different forest canopies (Kamaluddin and Grace, 1993). This study showed that *B. javanica* has a wide acclimation potential to the changing light levels, which may occur in gaps. There is a report of soft rot on seedlings of *Duabanga grandiflora* (Datta and Sharma, 1989). Although there are a number of other publications relating to related taxa within the families reported here, particularly in America and the neotropics, no other relevant work has been published on the potential framework species described in this paper.

Because of the rainfall patterns in a seasonally dry tropical forest, the ideal time to plant out container-grown tree seedlings is at the start of the wet season. It is a considerable challenge to produce a crop of seedlings, of a plantable size, of 36 framework tree species, all to be dispatched at the same time of year when seeds are available at different months throughout the year and they exhibit widely different rates of germination and growth in the nursery. The present study has shown that nursery production of such a 'collection' of native species, about which very little is known, presents considerable logistical problems for the nursery manager, even to get the seedlings to the point of pricking out into containers. The first of these is that to propagate 36 framework species, at least one collection trip would be required in every month of the year and probably more in March, April and September when 18 species (50% of the framework species) are available for collection. Furthermore, these species exhibit considerable variation in dormancy and germination synchrony. It can be clearly seen from the scatter plot of MLD (Fig. 1) that species with seeds dispersed in the late dry/early wet season tend to germinate quickly in the nursery, whereas those with species dispersed towards the end of the wet season and into the dry season, are likely to have a much longer dormancy period. Seven of the framework species appear to be ideal for nursery production, because they are collected at one time of the year in the late dry/early wet season (with the exception of *Quercus vesita*) and germinate rapidly and synchronously. These species, therefore, require minimum time in the germination facility where they are particularly susceptible to pests and diseases. The other species collected at this time (with the exception of *Michelia baillonii*) have intermediate germination, and vary in the synchronicity of germination, and include species such as *Eurya acuminata* and *Ficus subulata* which are highly asynchronous. Another predictable group of species, in terms of nursery planning, are those dispersed in the late wet/early dry season which germinate slowly and also asynchronously.

Whilst it is beyond the scope of this paper to consider the manipulation of growth and development of framework species in containers, it is clear from the above discussion that seedlings will be ready for pricking out throughout the year. Further work is now underway to assess the second stage of nursery production of these species, from pricking out through to weaning and dispatch.

Acknowledgements

FORRU was funded with financial support from Riche Monde (Bangkok) Ltd. and United Distillers PLC. Shell Forestry Limited, the Biodiversity Research and Training Programme and the Science Faculty of Chiang Mai University sponsored the research described in this paper. Other donors have included The Fagus Anstruther Memorial Trust, The Peter Nathan Trust, The Robert Kiln Charitable Trust, The Barbara Everard Trust for Orchid Conservation, Mr. Alan and Mrs. Thelma Kindred, Mr. Nostha Chartikavanij, Mr. R. Butterworth and Mr. James C. Boudreau. The authors thank J.F. Maxwell for identifying the tree species named in this paper. Voucher specimens are stored at the Chiang Mai University Herbarium, Biology Department. The authors are grateful to all research assistants and volunteers who assisted with data collection and processing and care of the plants in the nursery including: Jumpee Bunyadit, Thonglaw Seethong, Tim Rayden, Kevin Woods, Rungtiwa Bunyayod and Janice Kerby. The Head and staff of Doi Suthep-Pui National Park Headquarters provide essential collaboration for FORRU's research. We are especially grateful to the Head of the National Park, Mr. Paiboon Sawetmelanon, Mr. Amporn Panmongkol (Deputy Head) and Mr. Prasert Saentaam.

References

Datta, B., Sharma, G.D., 1989. Report on soft rot of *Duabanga grandiflora* seedling (Roxb. ex DC.) Walp. Curr. Sci. 58, 574–575.

Echeverrigaray, S., Mossi, A.J., Munari, F., 1998. Micropropagation of raisin tree (*Hovenia dulcis* Thunb.) through axillary bud culture. J. Plant Biochem. Biotechnol. 7, 99–101.

Frett, J.J., 1988. Requirements for germination of *Hovenia dulcis* seeds. Hortscience 23, 677.

Frett, J.J., 1989. Germination requirements of *Hovenia dulcis* seeds. Hortscience 24, 152.

Garwood, N.C., 1983. Seed germination in a seasonal tropical forest in Panama: a community study. Ecol. Monogr. 53, 159–181.

Goosem, S.P., Tucker, N.I.J., 1995. Repairing the Rainforest—Theory and Practice of Rainforest Re-establishment in North Queensland's Wet Tropics. Wet Tropics Management Authority, Cairns, pp. 71.

Hardwick, K., Healey, J., Elliott, S., Garwood, N.C., Anusarnsunthorn, V., 1997. Understanding and assisting natural regeneration processes in degraded seasonal evergreen forests in northern Thailand. For. Ecol. Manage. 99, 203–214.

Kamaluddin, M., Grace, J., 1993. Growth and photosynthesis of tropical forest tree seedlings (*Bischofia javanica* Blume) as influenced by a change in light availability. Tree Physiol. 13, 189–201.

Kopachon, S., Suriya, K., Hardwick, K., Pakaad, G., Maxwell, J.F., Anusarnsunthorn, V., Garwood, N.C., Blakesley, D., Elliott, S., 1996. Forest restoration research in northern Thailand. 1.

Fruits, seeds and seedlings of *Hovenia dulcis* Thunb. Nat. Hist. Bull. Siam. Soc. 44, 41–52.

Lamb, D., Parrotta, J., Keenan, R., Tucker, N.I.J., 1997. Rejoining habitat remnants: restoring degraded rainforest lands. In: Laurence, W.F., Bierrgaard Jr., R.O. (Eds.), Tropical Forest Remnants: Ecology, Management and Conservation of Fragmented Communities. University of Chicago Press, Chicago, IL, pp. 366–385.

Maxwell, J.F., Elliott, S., in press. Vegetation and Vascular Flora of Doi Suthep-Pui National Park, Chiang Mai Province, Thailand. The Biodiversity Research and Training Programme, Bangkok.

Tucker, N.I.J., Murphy, T.M., 1997. The effects of ecological rehabilitation on vegetation recruitment: some observation from the Wet Tropics of North Queensland. For. Ecol. Manage. 99, 133–152.