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Propagating framework trees to restore seasonally dry tropical forest in northern Thailand

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Abstract. In northern Thailand, a growing interest in restoring forests for wildlife conservation and environmental protection is increasing demand for high quality planting stock of a wide range of native forest tree species. Since most native tree species have never been grown in nurseries, their production is hindered by a lack of knowledge of basic propagation methods. Basic data on germination and performance of ten indigenous 'framework' tree species, *Castanopsis acuminatissima, Dalbergia rimosa, Diospyros glandulosa, Eugenia albiflora, Ficus glaberrima* var. *glaberrima, Lithocarpus craibianus, Melia toosendan, Prunus cerasoides, Quercus semiserrata* and *Spondias axillaris* were collected during the production process. Different species produce seeds at different times of the year and they have different growth rates, yet saplings must attain a plantable size by the optimum planting time i.e. the start of the wet season. Germination percentages ranged from 38 to 89%, and the time in the nursery to reach a plantable size ranged from 119 days for *Prunus cerasoides*, when it had reached a mean height of 48.6 cm (SD 7.9), to 609 days for *Lithocarpus craibianus*, when it had reached mean height of 40.5 cm (SD 10.6). This paper discusses the scheduling of production for these candidate framework species.

Introduction

Deforestation is one of the most serious environmental problems throughout the tropics, causing rural poverty, watershed degradation and loss of biodiversity. In Thailand, tree-planting projects, using mixtures of several native forest tree species have become a popular method to restore forest to degraded areas (Chatwiroon 1997). The success of such projects depends largely on the selection of suitable tree species and on the size and the quality of the trees planted. In the past, most tree nurseries in Thailand grew few, mostly commercially valuable species such as teak, pine and eucalyptus, usually for the establishment of monoculture plantations. Now, to satisfy a growing interest in restoring forests for conservation and environmental protection, there is an urgent need to raise high quality saplings of a much wider range of native forest trees.

One effective approach to forest restoration is the 'Framework Species Method' (Goosem and Tucker 1995; Lamb et al. 1997; Tucker and Murphy 1997) developed in Queensland, Australia. The method depends on tree planting to provide a 'framework' for re-establishing biodiversity. Framework tree species are relatively fast growing with dense spreading canopies which, when planted in degraded areas, 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. Framework species need to be easy to propagate in nurseries. Healthy, vigorous saplings, 40–60 cm tall (30 cm for fast-growing species) are planted out 1.6–1.8 m apart at the beginning of the wet season. Weeds are controlled and fertiliser is sometimes applied. After 3 wet seasons, canopy closure occurs and no further management input is required. Seven years after planting 20 to 30 framework tree species in degraded grassland sites in Queensland, the regenerating forests had developed closed canopies up to 8.7 m tall and had been naturally colonised by up to 49 additional tree species (Tucker and Murphy 1997).

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 of the year; the seeds vary in their dormancy and seedlings grow at different rates (Blakesley et al. 2000). Furthermore, they must all reach a plantable size by the optimum planting time, which in northern Thailand is at the beginning of the monsoon (i.e. May–June). This allows maximum time for establishment before the onset of the dry season in November. The vast majority of northern Thailand's indigenous forest tree species have not previously been propagated in nurseries. Lack of information about how to grow them has limited their use in reforestation programmes.

Therefore, the Forest Restoration Research Unit (FORRU) at Chiang Mai University initiated a research programme to determine optimum propagation methods for a range of potential framework tree species (Elliott et al. 1998). Seedlings are grown from seed in a nursery to supply trees for the establishment of experimental plots to test the applicability of the framework species method for restoring forest to degraded sites in northern Thailand's conservation areas. Ten candidate framework species (*Melia toosendan* Sieb. & Zucc., *Castanopsis acuminatissima* (Bl.) A. DC., *Lithocarpus craibianus* Barn., *Ficus glaberrima* Bl. *var. glaberrima, Prunus cerasoides* D. Don, *Dalbergia rimosa* Roxb. var *rimosa, Quercus semiserrata* Roxb., *Eugenia albiflora* Duth. ex Kurz, *Spondias axillaris* Roxb. and *Diospyros glandulosa* Lace) known to be dispersed at different times throughout the year were selected for this study. The primary objective was then to determine production times in the nursery and to relate these to the time of seed collection, pricking out and dispatch. The investigation was designed to formulate production schedules for tree species most likely to act as framework species and to identify research priorities for individual species.

Study area description

Trees were propagated in a nursery at 1 000 m asl, near the park headquarters of Doi

Table 1. Climate of the study area. Data are from the nearest meteorological station (about 10 km away), at a similar elevation to the study sites – Huay Kog-Ma Watershed Research Station, near Phuping Palace in northern Thailand at 1,350 m asl (1966–1983).

Season	Months	Total no. of rainy days	Average monthly rainfall (mm)	Mean monthly temperature (°C)
Early Dry (ED)	Nov.–Jan.	12	50.9	17.3
Late Dry (LD)	Feb.–Apr.	9	32.6	21.6
Early Wet (EW)	May.–Jul.	58	283.6	20.9
Late Wet (LW)	Aug.–Oct.	60	331.2	19.8

Suthep-Pui National Park, north-west of Chiang Mai. The experimental plots were in a degraded watershed (18° 52′ North, latitude and 98° 51′ East, longitude), 1,207–1,310 m asl, providing very harsh conditions. Although not strictly part of this paper, the plots are described to indicate the environment which propagated trees must be able to withstand. Originally the plots would have been covered in evergreen forest, which was cleared between 1960–70. Subsequently the area was cultivated for vegetables and further degraded by frequent fires. Although a few scattered mature trees remain, the area is now dominated by weedy herbaceous vegetation such as *Pteridium aquilinum* (L.) Kuhn (Dennstaedtiaceae), *Bidens pilosa* L. var. *minor* (Bl.) Sherf, *Ageratum conyzoides* L., *Eupatorium odoratum* L. and *E. adenophorum* Spreng. (all Compositae), *Commelina diffusa* Burm. F. (Commelinaceae), and *Imperata cylindrica* (L.) P. Beauv. var. *major* (Nees) C.E. Hubb. ex Hubb. & Vaugh. and *Thysanolaena latifolia* (Roxb. ex Horn.) Honda (both Gramineae). Consequently, planted trees must be able to survive intense heat and drought conditions, particularly in the late dry season (see Table 1) and compete with rank, weedy vegetation.

Northern Thailand has a monsoonal climate with pronounced dry and wet seasons. Average annual precipitation recorded at weather stations within the national park at similar altitudes ranges from 1 670 to 2 094 mm. For the purposes of this paper the year was divided into the 4 major seasons (Table 1).

Methods

Ten potential framework species were chosen to include species whose seeds were dispersed in different seasons (Table 2). These species were collected and immediately sown in baskets in a medium of forest soil and coconut husk mixed in the ratio 1:1. For most species, 1 500 seeds were sown. Exceptions were *Prunus cerasoides* (1 200), *Quercus semiserrata* (280) and *Diospyros glandulosa* (600). Once the first pair of leaves had fully expanded, all seedlings were pricked out and transplanted into black plastic bags, 2.5 inches in diameter by 9 inches in depth (6.5 × 23 cm), filled with a potting medium of forest soil, peanut husk and coconut husk, mixed in the ratio of 2:1:1. Seedlings were shaded inside the nursery under a plastic roof (approximately 20% full sunlight) for about 2 weeks. During this time nitrogen fertiliser (45-0-0) was applied every 2 days. Approximately 20 g of fertiliser was

Table 2. Nursery production characteristics for selected framework species.

Species	Family	Germination (%)	Time to germination of 1st seed (days after sowing)	Pricking out (days after sowing)	Time in the nursery to reach plantable size (days)
Early Dry dispersal					
Melia toosendan Sieb. & Zucc.	Meliaceae	50	24	43	138
Castanopsis acuminatissima (Bl.) A. DC.	Fagaceae	45	13	90	568
Lithocarpus craibianus Barn.	Fagaceae	38	112	224	609
Late Dry dispersal					
Ficus glaberrima Bl. var. glaberrima	Moraceae	72	32	131	494
Early Wet dispersal					
Prunus cerasoides D. Don	Rosaceae	65	11	33	119
Dalbergia rimosa Roxb. var. *rimosa*	Leguminosae (Papilionoideae)	39	5	26	376
Quercus semiserrata Roxb.	Fagaceae	55	8	47	276
Eugenia albiflora Duth. ex Kurz	Myrtaceae	62	20	130	379
Late Wet dispersal					
Spondias axillaris Roxb.	Anacardiaceae	52	17	49	276
Diospyros glandulosa Lace	Ebenaceae	89	20	45	188

Table 3. Height and root collar measurements for selected framework species when ready for planting.

Species	Time after pricking out (days)	Mean height (cm) (SD)	Mean root collar diameter (mm) (SD)
Early Dry dispersal			
Melia toosendan Sieb. & Zucc.	95	65.6 (10.6)	3.5 (0.7)
Castanopsis acuminatissima (Bl.) A. DC.	478	46.1 (12.8)	4.3 (0.9)
Lithocarpus craibianus Barn.	385	40.5 (10.6)	3.5 (0.8)
Late Dry dispersal			
Ficus glaberrima Bl. var. *glaberrima*	363	37.4 (10.0)	4.4 (1.2)
Early Wet dispersal			
Prunus cerasoides D. Don	86	48.6 (7.9)	2.7 (0.3)
Dalbergia rimosa Roxb. var. *rimosa*	350	55.2 (17.5)	5.5 (1.3)
Quercus semiserrata Roxb.	229	44.0 (11.0)	4.5 (1.0)
Eugenia albiflora Duth. ex Kurz	249	48.2 (12.8)	4.1 (1.0)
Late Wet dispersal			
Spondias axillaris Roxb.	227	56.9 (14.4)	6.6 (1.3)
Diospyros glandulosa Lace	143	41.6 (14.0)	3.7 (0.4)

mixed with 10 l of water and applied to the seedlings by a watering can. After two weeks, the seedlings were placed outside, under black shade netting (slan, approximately 50% of full sunlight). Following assessment of percentage germination, more than 100 seedlings of each species were pricked out, the exact number dependent on the requirements for planting out. From these, 15 seedlings per species, randomly selected (avoiding edge rows), were regularly monitored for height and root collar diameter. Measurements were repeated every 45 days. Ten granules of Osmocote slow-release fertiliser (15-15-15) were applied every three months and weeds, pests and diseases controlled, as required for each species. Monitoring ceased when the saplings were ready for planting out i.e. when they had grown at least 40–60 cm tall (30 cm for the fastest-growing species) and appeared healthy and vigorous. Saplings were hardened off in full sunlight and dispatched for planting in June each year. Only saplings considered good quality were planted out.

Results

The species were divided into four categories, based on the season of seed dispersal (as defined in Table 1). All ten species had germination percentages in excess of 35%, which is acceptable for framework species (Table 2). Two species, *Melia toosendan* and *Prunus cerasoides* performed very well in the nursery, producing plants suitable for planting in less than 140 days (Table 2). Both germinated quickly, with germination percentages of 50 and 65 respectively. They grew rapidly after pricking out. *Melia toosendan* reached a mean height of 65.6 cm (SD 10.6) and a mean root collar diameter of 3.5 mm (SD 0.7), 95 days after pricking out, at the beginning of the planting season (Table 3). *Prunus cerasoides* also grew rapidly, reaching a mean height of 48.6 cm (SD 7.9) and a mean root collar diameter of 2.7

mm (SD 0.3) in the early part of the subsequent dry season, just 86 days after pricking out, and some 8 months ahead of the scheduled planting date (Table 3).

Spondias axillaris and *Diospyros glandulosa*, which were dispersed in the late wet season, also performed relatively well in the nursery, producing plants suitable for planting in 276 and 188 days respectively (Table 2). Both germinated quickly, with germination percentages of 52 and 89 respectively. Their growth rates after pricking out were moderate. By planting time, at the start of the following wet season, *Spondias axillaris* had grown to a mean height of 56.9 cm (SD 14.4), with a mean root collar diameter of 6.6 mm (SD 1.3) (Table 3). *Diospyros glandulosa* had grown to a mean height of 41.6 cm (SD 14.0), with a mean root collar diameter of 3.7 mm (SD 0.4) (Table 3).

Three other species, each dispersed in the early wet season, also performed relatively well in the nursery, producing plants suitable for planting at the start of the following wet season. *Dalbergia rimosa* and *Quercus semiserrata* both germinated quickly, with germination percentages of 39 and 55 respectively, whilst 62% of *Eugenia albiflora* seeds germinated more slowly (Table 2). Their growth rates after pricking out were slow. By planting time, *Dalbergia rimosa* had grown to a mean height of 55.2 cm (SD 17.5), with a mean root collar diameter of 5.5 mm (SD 1.3). *Quercus semiserrata* had grown to a mean height of 44.0 cm (SD 11.0), with a mean root collar diameter of 4.5 mm (SD 1.0). *Eugenia albiflora* had grown to a mean height of 48.2 cm (SD 12.8), with a mean root collar diameter of 4.1 mm (SD 1.0) (Table 3). *Ficus glaberrima* var. *glaberrima* germinated over a much longer period; so despite its seeds being sown at the start of the early dry season, seedlings were not pricked out until mid-way through the early wet season. After pricking out, saplings grew steadily. By planting time, they had grown to a mean height of 37.4 cm (SD 10.0), with a mean root collar diameter of 4.4 mm (SD 1.2) (Table 3).

In contrast to most of the species described above, *Castanopsis acuminatissima* and *Lithocarpus craibianus* were sown in the early dry season, but did not grow into saplings large enough for planting by the following planting season. At that time, the mean height of *Castanopsis acuminatissima* saplings was only 12.4 cm (SD 3.5), whilst *Lithocarpus craibianus* had grown to a mean height of less than 13.3 cm (SD 4.6) (measurement taken mid way through the wet season). Consequently these species remained in the nursery for more than 550 days. Prior to planting at the start of the subsequent wet season, *Castanopsis acuminatissima* had grown to a mean height of 46.1 cm (SD 12.8), with a mean root collar diameter of 4.3 mm (SD 0.9) and *Lithocarpus craibianus* had grown to a mean height of 40.5 cm (SD 10.6), with a mean root collar diameter of 3.5 mm (SD 0.8) (Table 3).

Discussion

Production of framework tree species for forest restoration projects requires simple techniques, easily acquired by local communities, the handling of relatively small numbers of many different tree species and the maintenance of genetic diversity.

Such methods are clearly different from those used for mass-production of commercial trees for plantations. Many of the conventional techniques developed for commercial species are inappropriate for small-scale 'forest conservation' nurseries and cannot be directly transferred to such operations.

In the seasonally dry climate of northern Thailand, container-grown saplings are planted out at one time of the year, May-June, once the monsoonal rains have become reliable. This allows maximum time for sapling establishment, particularly the development of an expansive root system, essential to enable planted trees to survive the hot, dry conditions which prevail from February to April. Almost no rain falls at that time of the year and daytime temperatures often exceed 35 °C. The nursery manager must produce a crop of saplings of many different tree species, all of which must have grown large enough for planting by the same time of year. This process is complicated by seasonal variation in seed dispersal, germination and growth rates amongst the species, as illustrated by the ten species selected for this paper.

Two species grew rapidly in the nursery, producing plants suitable for dispatch in less than 140 days, *Melia toosendan* and *Prunus cerasoides*. The former had a short germination period, coupled with a rapid growth rate in containers. Consequently it is ideal for nursery production because, following seed collection in the early dry season, the trees are ready for hardening and dispatch at the start of the wet season. In contrast, *Prunus cerasoides* was dispersed in the early wet season, which gave insufficient time to grow saplings to a plantable size by the early wet season planting. However, seeds germinated quickly, and the plants reached a suitable height for planting in the early part of the subsequent dry season, some 8 months ahead of the scheduled planting date. Storing plantable saplings in the nursery for 8 months is costly in terms of labour and space. Therefore, it would be highly desirable to store *Prunus cerasoides* seed for up to 6 months prior to sowing. Saplings grown from stored seeds sown in January-February should be ready for planting by June.

At the other extreme are three species that are more problematic for nursery production. Fruit of *Castanopsis acuminatissima* and *Lithocarpus craibianus* ripens in the early dry season, which should allow sufficient time to grow saplings to a plantable size by the following wet season. However, germination of *Lithocarpus craibianus* is slow under nursery conditions and growth of its saplings, and those of *Castanopsis acuminatissima* is also quite slow. The saplings are not ready for planting at the start of the first wet season after seed collection. They must be held in the nursery for more than 18 months. Although collected early in the year, *Ficus glaberrima* also germinated slowly, and so remained in the nursery for approximately 16 months. The most likely means of increasing the efficiency of production of these species would be to investigate a combination of seed storage and increased use of fertiliser to accelerate sapling growth in containers.

The other five species in this study all performed relatively well in the nursery, with growth rates resulting in plants that were ready for dispatch within 12 months, at the start of the following wet season.

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References

Blakesley D., Anusarnsunthorn V., Kerby J., Navakitbumrung P., Kuarak C., Zangkum S. et al. 2000. Nursery technology and tree species selection for restoring forest biodiversity in northern Thailand. In: Elliott S., Kerby J., Blakesley D., Hardwick K., Woods K. and Anusarnsunthorn V. (eds), Forest Restoration for Wildlife Conservation. Chiang Mai University, pp. 207–222.

Chatwiroon P. 1997. Forest situation and some responses in Thailand. Paper presented at the workshop 'From Reforestation to Rehabilitation'. Kuranda, Queensland, Australia.

Forest Restoration Research Unit 1998. Forests for the Future: Growing and Planting Native Trees for Restoring Forest Ecosystems. In: Elliott S., Anusarnsunthorn V. and Blakesley D. (eds), pp 60.

Goosem S. and Tucker N. 1995. Repairing the Rainforest. Cassowary Publications, Cairns, Australia.

Lamb D., Parrotta J., Keenan R. and Tucker N. 1997. Rejoining habitat fragments: restoring degraded forest lands. In: Laurance W.F. and Bierregaard R.O. (eds), Tropical Forest Remnants: Ecology, Management and Conservation of Fragmented Communities. University of Chicago Press, pp. 366–385.

Tucker N. and Murphy T. 1997. The effects of ecological rehabilitation on vegetation recruitment: some observations from the Wet Tropics of North Queensland. Forest Ecol. Manage. 99: 133–152.