Factors affecting germination of tree seeds from dry tropical forests in northern Thailand.

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ABSTRACT

101 species of tree and liana were planted, of which 78 germinated. At least 50% germination occured in 28 species. Dormancy for up to 37 weeks was common and is more predominant among species found in Thai seasonal forests than in Malaysian tropical rain-forest. Dormancy may be linked with season of seed dispersal, tending to be longer for those dispersed at the end of the rainy and during the cold season, and shorter for those dispersed during the hot and beginning of the rainy season. This is not true for all species though.

The effect of different stages of ripeness and various pre-planting treatments were tested, including cleaning, scarification, fire and storage until the end of the dry season. Three species tested with removal of pulpy flesh, varied in their germination response , but for three other species with aril coated seeds, removal of the aril did not improve germination . Seeds of three species planted with and without unopened, normally dehiscent seed cases germinated poorly and were probably immature. Of two species with winged seeds, there was no significant improvement in germination after removal of the wings. Of species treated with scarification, three responded negatively, three positively and 19 gave no significant response. Further research using a more quantitative method of scarification is recommended. Of species treated with fire, germination rate in all cases was either zero or much reduced in comparison with the control. Only two out of 13 species tested germinated better after dry storage until the end of the dry season. Ripeness was a critical factor influencing germination rates, but must be determined separately for each species.

It was concluded that more detailed research is needed, including a study of germination in the forest, in order to improve overall germination rates and to understand the mechanisms by which dormancy prevents germination.

INTRODUCTION

Deforestation in Thailand is progressing at an alarming rate. In Chiang Mai Province alone, the deforested area has doubled between 1975-1985 to over 600,000 ha. Much of this area has been abandoned, but is failing to regenerate naturally due to factors such as lack of seed sources, invasion by grasses and annual burning.

The Royal Forest Department is currently implementing a reforestation programme which aims to restore forest to 40 % of the country. Efforts to replant denuded watersheds entail planting pine where there used to be species-rich natural forests. While plantations of fast growing species are necessary to provide fuel and timber to take the pressure off remaining natural forest, they are not appropriate for national parks and protected areas, where native forest should be restored for watershed protection, provision of forest products, wildlife conservation, preservation of biodiversity, tourism and as a place of retreat for the aesthetic and spiritual enrichment of the lives of an increasingly urban population.

In places which are not regenerating naturally and in areas where rapid reforestation is desirable, active planting programmes of indigenous species will be needed. Such large scale reforestation will require native forest trees to be cultivated for the first time as a nursery crop. This will require knowledge of the conditions required for optimum germination of a wide range of evergreen and deciduous species.

In this project various pre-planting seed treatments were tested and the role of dormancy in preventing germination was studied.

A second aim was to collect material on seed and seedling phenology, ecology and morphology for a handbook, to be written in Thai, on reforestation with native species. The book will contain practical information on the identification, selection and production of trees for planting.

METHODS

SEED COLLECTION

Seed collection was carried out on Doi Suthep at elevations ranging form 600 - 1,600 m. The forest types included Deciduous Dipterocarp-Oak Association, Mixed Deciduous-Evergreen, Primary Evergreen Forest and Secondary growth along roadsides and in disturbed areas (nomenclature according to Maxwell 1988).

As the main fruiting period is in the rainy season, June - October, seed collecting trips during this time were made twice a month, except in June, when no collecting took place due to lack of staff (see Figure 6). In the dry season, fruiting is less prolific and trips were made about once a month.

Seeds were collected from whatever trees were discovered to be fruiting at the time. Whenever possible, they were collected directly from the tree, as this reduced the risk of decay and animal damage, although it did increase the risk of collecting immature seeds. When collected from the ground, the quality was inspected closely for apparent viability. Ideally, at least 300 seeds were collected, to allow varied treatments and adequate replication, but in practice the total amount varied according to availability.

Identification was made in the field by J.F.Maxwell, creator of Chiang Mai University Herbarium. Fruits were placed in named plastic bags for transport. Seeds were treated and planted within two days of collection (except for "storage" treated seeds) being kept in the meantime in open trays or bags in the laboratory.

TREATMENTS

For all species, some seeds were planted as controls. These were usually cleaned , as described, though in some cases the lack of cleaning was a "treatment" itself. These trials constituted a pilot study to screen a wide range of species for a marked response to simple pre-planting treatments. So although as many seeds as possible were planted for each treatment, the trials were not replicated at this stage.

1. Cleaning

Cleaning of the fleshy part of indehiscent fruit is recommended by some authors (e.g. De Vogel 1979) as a means of enhancing germination rates. Other advantages of cleaning many-seeded fleshy fruits include ensuring space for individual seedling germination and facilitating the calculation of germination rates. Cleaning large single-seeded fruit (e.g. *Diospyros glandulosa*) allows more seeds to be planted per unit area. Thus, most fleshy fruit were cleaned as a standard procedure. However, the process of cleaning is often messy and laborious and may not confer any real advantage on the seed (Ng 1980). Thus, some fleshy fruit, both single seeded (e.g. *Gmelina arborea*) and many-seeded (e.g. *Adinandra integerrima*), were also planted whole, in order to establish whether or not the cleaning process be justified.

In some cases (e.g. *Garcinia xanthochymus*, *Irvingia malayana*) some cleaned seeds were dried out at room temperature before planting and others were planted "wet", direct from the pulp.

Seeds of dehiscent species were either gathered as previously dispersed seed or were gathered just before dispersal, when removal of the seed from the case should be easy. In cases where removal was difficult (as with many *Castanopsis* species) this probably indicated that the seed was immature.

2. Scarification

A possible cause of delayed or low germination is a hard seed coat which is impermeable to water or gases, mechanically restrains the embryo or prevents the release of inhibitors (Garwood 1986). This is thought to be especially prevalent in the Leguminosae family and in seeds which pass through the guts of animals and birds during dispersal. Thus scarification of the seed coat would be expected to increase germination rates and reduce dormancy.

Tough-coated seeds and those dispersed by animals or birds were subjected to scarification. Any soft flesh was removed and the seed allowed to dry off at room temperature. They were then rubbed between two pieces of fine-grained sandpaper or in a rough surfaced clay pot to slightly damage the seed coat.

3. Fire

Seeds were placed in a metal box, about the size of a waste-paper bin, on a bed of earth. A 5 cm layer of shredded paper was placed on top and set on fire, simulating the effect of burning leaf litter, but burning at a more constant and controlled temperature. Temperature was measured using thermosensitive pigments applied to thin slivers of brass, which were placed among the seeds. These indicated temperatures of 150 - 280 degrees centigrade, well below the mean ground level temperature of around 400 degrees centigrade, recorded by Stott (1986) in experimental litter burns.

This treatment was specifically applied to members of the Fagaceae family (as suggested by Sukwong et al. 1975) and species from the fire-prone deciduous and mixed deciduous forests.

4. Storage

Seeds were desiccated by drying in the sun. They were then placed in an air tight plastic box on silica gel, simulating the effect of lying on the forest floor throughout the dry season. These were planted out at the end of the dry season in May. This treatment was designed to test for an inbuilt dormancy which may prevent the seed from germinating while conditions are too dry for seedling establishment.

5. Ripeness

Though not strictly a "treatment", some trials involved planting seeds of differing ripeness, to determine the point of maturity. Seeds treated in this way included *Helicia niligirica*, *Pterocarpus macrocarpus*, *Quercus semiserrata*, *Randia sootepensis* and *Terminalia chebula*.

SEED PLANTING

The number of treatments that each species was tested with varied from one to eleven, depending on the number of seeds available, the response of each species to various tests and the germination rate of the control (e.g. if initial rate was 100%, as for Mucuna macrocarpa, then no further testing was carried out.)

Seeds were planted in a shade house which gave protection from strong sunlight, though little from heavy rain. They were placed in soil-filled, labelled plastic trays;- larger seeds in open trays and smaller ones in trays partitioned into 72 modules. The partitioned trays enabled all germinated seeds to be marked individually, so that a running weekly total of germinated seeds, including those that had germinated and died, could be kept. In the open trays, dead seedlings were marked with a small stick. All trays were watered as necessary to keep them permanently moist.

Particularly small seeds were germinated in petri dishes on pieces of damp filter paper. Euodia meliifolia and Lasianthus kurzii were planted in both petri dishes and in soil to assess the effect of the petri dish on germination.

Once germination in a tray appeared to have ceased, the seedlings were carefully removed and planted out in black plastic bags. Those seeds remaining in the tray continued to be monitored for further germination until all seeds had rotted. Seedlings produced during these trials were donated to the Dhammanaat Foundation's reforestation project near Chomthong.

Seed trays were inspected once a week for germinating seeds. "Germination" was defined as the visible emergence of the radicle through the seed coat. Swelling and splitting were not recorded as germination. Each week the percentage germination was recorded and notes were made concerning the size and appearance of the seedlings at the various stages of development. Seedlings were also sketched and photographed.

RESULTS AND DISCUSSION

OVERALL RESULTS

101 species of tree and liana were planted between September 1990 and March 1992 (one and a half years). Of these, at least one seed of each of 78 species germinated and at least 50% germination was achieved in 28 species. The distribution of best germination rates achieved for each species is shown in Figure 1. 23 species completely failed to germinate and there was a generally negative correlation between number of species and highest germination rate achieved.

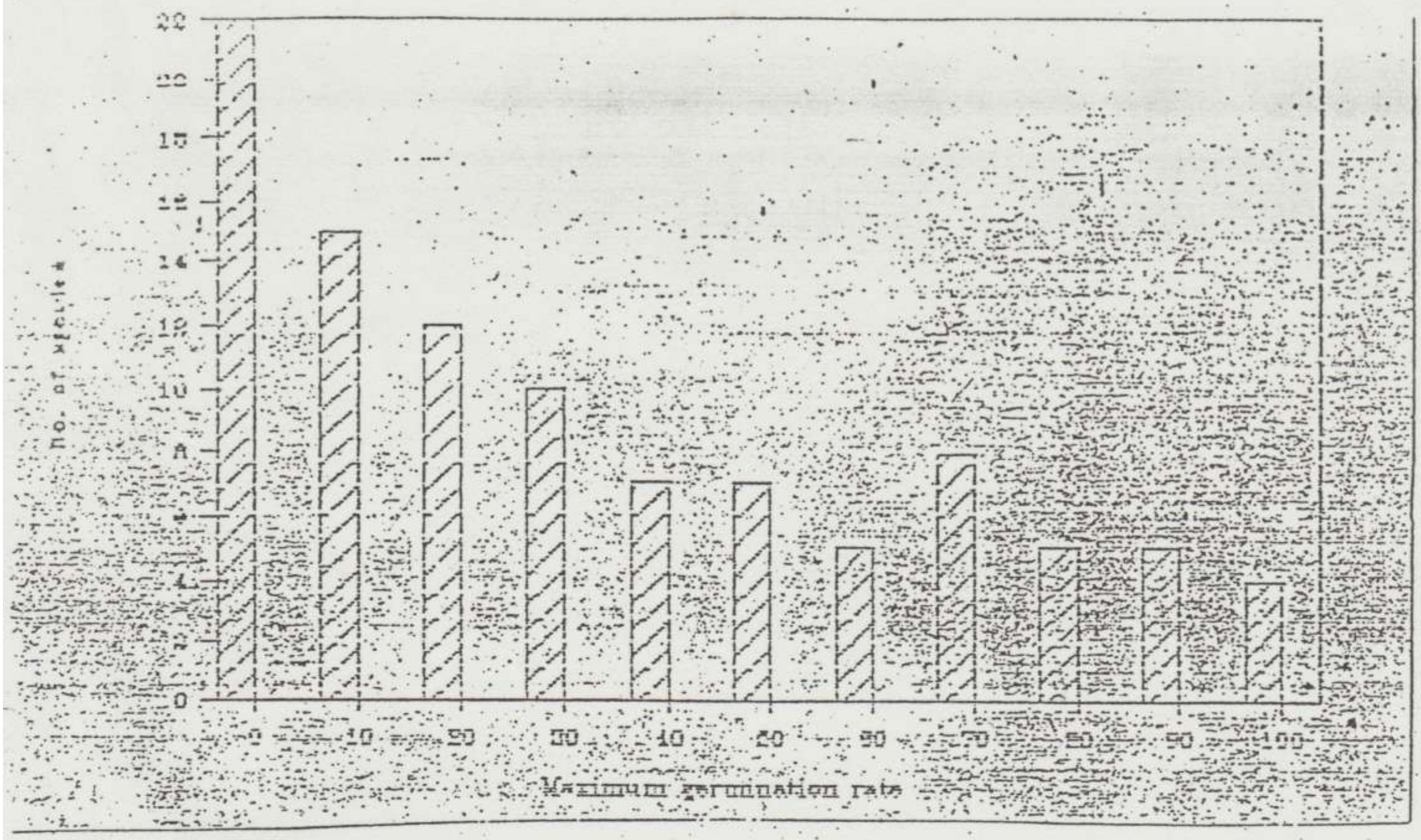


Figure 1. Distribution of maximum germination rates achieved.

DORMANCY AND SEASONALITY OF GERMINATION.

An understanding of seed dormancy is important both for forest management and for nursery production of seedlings. For forest management, knowledge of soil seed bank dormancy enables one to estimate the reservoir of viable seeds likely to be present after destruction of the mother trees by logging or slash and burn agriculture. In a tree nursery it is important to know the length of dormancy of the species planted in order to predict output, create production schedules and organise nursery space.

There are various ways of describing seed dormancy. Perhaps the simplest and most specific is the method adopted by Ng, which is to calculate the time from planting until the first seed germinates (i.e. period of complete dormancy, N weeks), followed by the time between germination of the first and last seed of the cohort (i.e. the period of differential dormancy, P weeks). Thus, for each species, maximum dormancy time for viable seeds under specified conditions would be N + P. For the nurseryman, a predictable period of complete dormancy, followed by a short period of differential dormancy would be ideal germination behaviour. See Appendix for N and P for each planting trial.

One way of classifying seed dormancy using this method is to divide species into those exhibiting "rapid" or "delayed" germination. These categories, which are purely arbitrary, have been defined by Ng as follows: "rapid" germination is when N + P is less than or equal to 12 weeks, while "delayed" is when N is more than or equal to 12 weeks. Using this method, some species would fall into neither category.

The number of species in these trials which fell into the rapid *germination category*, can be determined from Figure 2, which shows the range of total dormancy times (N + P) for all species which germinated and for which the length of dormancy data is available. When the same species was tested several times and dormancy varied between treatments, the dormancy of the control treatment which gave the best germination rate was selected. Results from controls only were used in order to make the data comparable with Ng's.

On this basis, 23 species, or 33% of all species tested, displayed rapid germination. This is in contrast to Ng's data (see Figure 3), which showed 71% of species tested germinating rapidly. This shows a distinct difference between the germination ecology of a Malaysian tropical rain-forest and a Thai dry tropical forest. In the former, where conditions are moist and suitable for germination all the year round, germination is predominantly rapid (71% completing germination in 12 weeks or less). In the latter, which has a 4-6 month dry season, unsuitable for germination, lengthy dormancy is far more common (67% starting germination or continuing to germinate beyond 12 weeks after planting).

However, a closer comparison of our results with Ng's shows that it may not be possible to make any classification of the germination behaviour of individual species by simply observing them under "normal" nursery conditions (i.e. shaded, sheltered, continuously moist). Table 1, below, shows a comparison of results for species planted by both Ng and ourselves.

Table 1.

	Ng (Malaysia)			Hardwick & Elliott (Thailand)				
			Germination class		Control		Scarified	
Species	% germ	P (wks)	Ng	H & E	% germ	P (wks)	% germ	P (wks)
Irvingia malayana	100%	5-8	rap.	del.	70%	26-29	85%	26-31
Leea indica	11%	3-9	rap.	-	8%	7-31	77%	3-26
Eleaocarpus floribundus	14%	25-36	del.	rap.	11%	4-6	-	-
Schima wallichii	96%	1-4	rap.	rap.	63%	3	-	-

Explanations of the different results could include:

- genetic differences between trees found in Malaysia and Thailand
- climatic differences (e.g. temperature, day length, humidity) initiating a different germination response

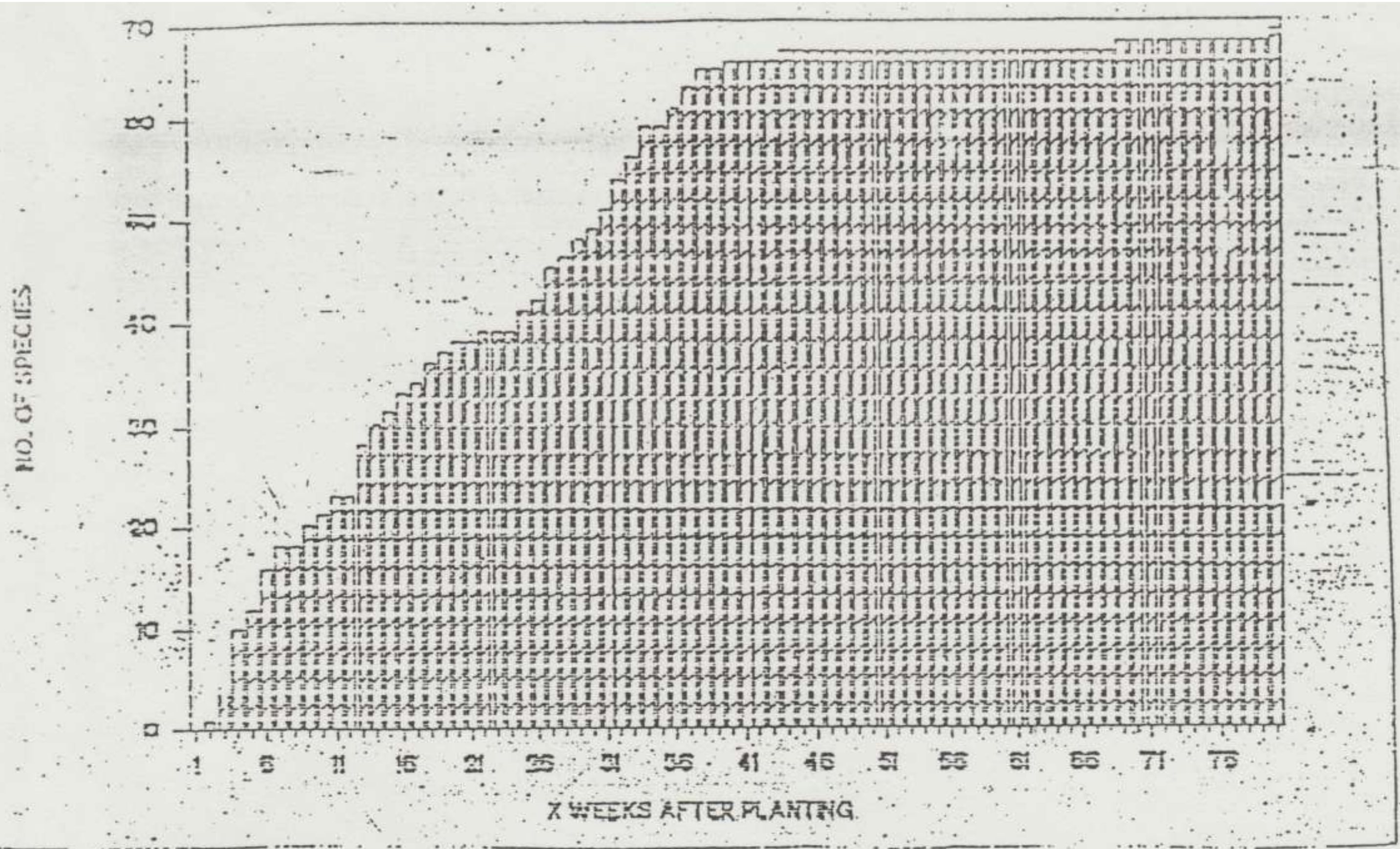


Figure 2. Number of species which have completed germination by X weeks after planting (results of these trials, controls only).

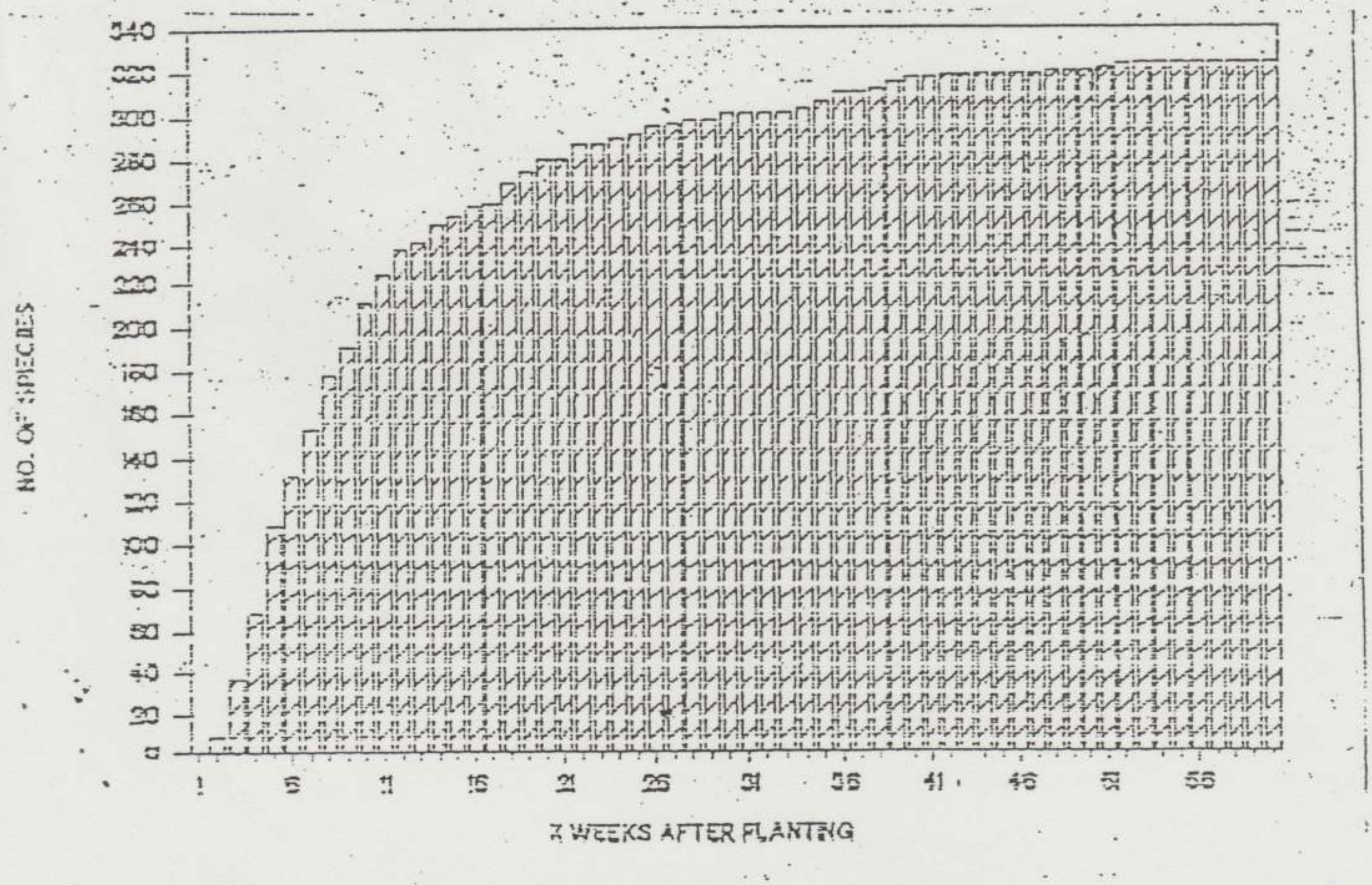


Figure 3. Number of species which have completed germination by X weeks after planting (Ng's results).

Although these results may not be sufficient to permit generalisations to be made about the germination behaviour of individual species, they do highlight a broad difference between the germination ecology of Thai and Malaysian forests. Ng's parabolic distribution of total dormancy periods is in contrast to the more linear distribution of our results and shows that dormancy periods tend to be much shorter for Malaysian species than for Thai species.

The question remains whether, given appropriate background information, it is possible to predict the germination behaviour of individual species. Do definable germination syndromes exist? Ng holds that as the range of germination behaviour forms a continuum, with no natural lines of division, species cannot be subdivided into categories of germination behaviour, except by arbitrary divisions, such as the "rapid" and "delayed" classification. This may be true for species found in a tropical rainforest, but in a Panamanian seasonal tropical forest, Nancy Garwood managed to divide germination behaviour into 3 categories based on season of seed dispersal and length of mean dormancy. Although the system is based on a two-season year (wet and dry), rather than Thailand's three-season year (wet, hot and cold) it is relevant because it is based on the premise that in a climate with a marked dry season, dormancy enables seeds dispersed at any time of the year to germinate under optimum conditions in the wet season. Garwood identified three major germination syndromes:

- Rapid-rainy group: seeds dispersed in the rainy season, having a short dormant period and germinating in the same rainy season they are dispersed in.
- Delayed-rainy group: seeds dispersed in the rainy season, having a long dormant period and germinating in the following rainy season.
- Intermediate dry group: seeds dispersed in the dry season, having an intermediate length of dormancy and germinating in the following rainy season.

Our results similarly show a link between season of seed dipsersal and length of complete dormancy, N (see Figure 4). Seeds dispersed towards the end of the rainy season (September-November) and throughout the cold season (November-January) often showed pronounced dormancy. Those dispersed from the beginning of the hot season in February, until mid-wet season in August tended to germinate much more quickly. However, the average figures for each month mask wide variation between species, which would make it impossible to predict dormancy based on season of dipsersal alone.

Although the results of these trials indicate that dormancy may be strongly influenced by the seasons, the period of peak germination (i.e. the month when most species first started germinating) fell not at the beginning of the rainy season, but during the hottest, driest month - March, with another peak at the end of the rainy season in October (see Figure 5). To see these figures in perspective, they should be compared with the frequency of seed planting throughout the year (see Figure 6). The October germination peak is largely a rapid germination response to the large number of seeds planted in September (see Figure 7). Many of the seeds germinating in March, though, did so after a prolonged period of dormancy (see Figure 8).

It is possible that under nursery conditions, where water is not a limiting factor, other environmental conditions may control dormancy. Factors which may have caused the breaking of dormancy in March for many of the species tested could include:

- increased soil temperatures
- increased day length or light intensity
- extremes of wet followed by rapid drying

An alternative explantion is that seeds contain some form of time lapse mechanism which ensures dormancy for a set length of time (e.g. seed immaturity).

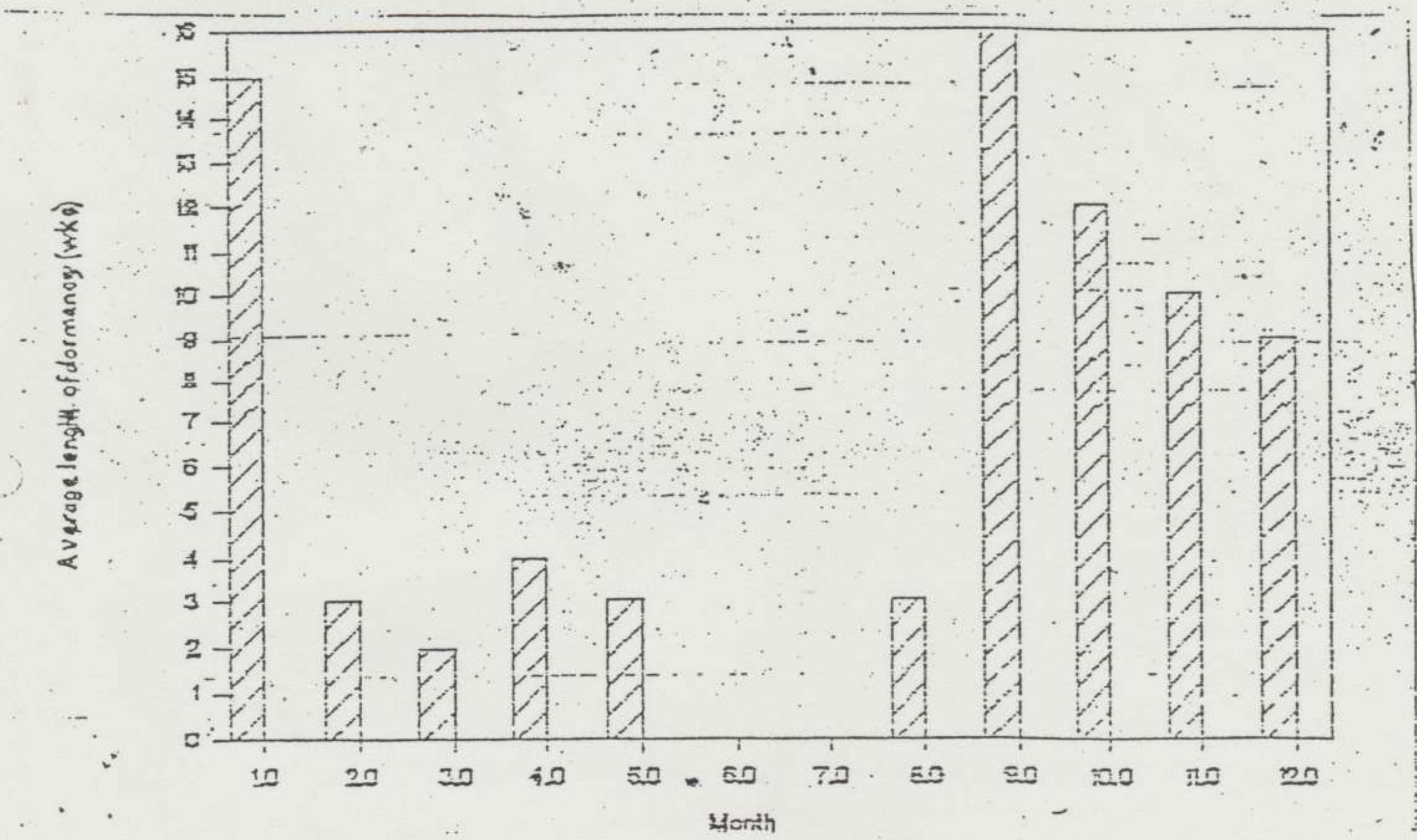


Figure 4. Average length of complete dormancy (N), i.e. time from planting until germination of first seed, of species collected and planted in each month. Where one species was planted more than once, the data from the trial which gave the best germination rate was taken.

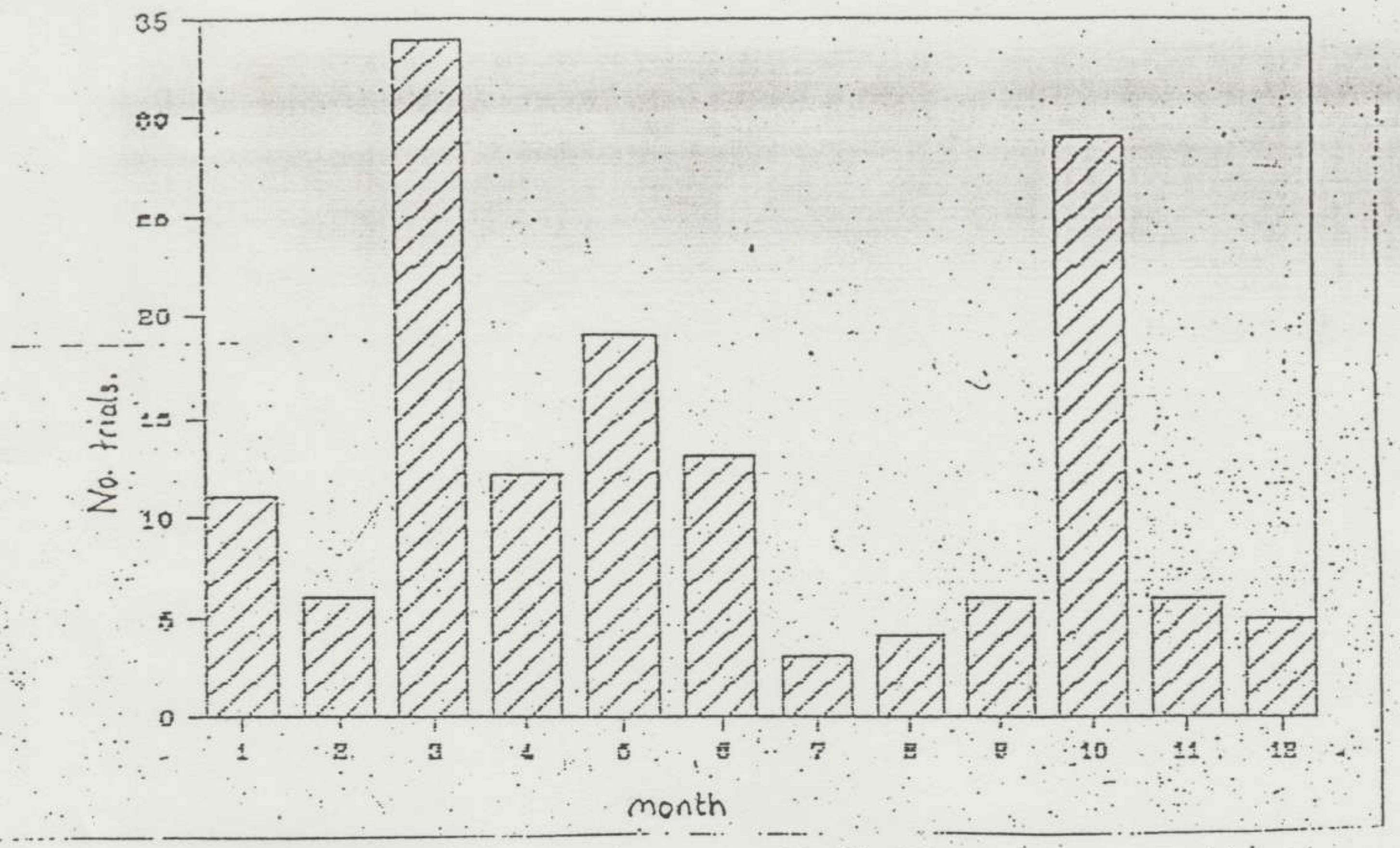


Figure 5. Number of trials which started germinating in each month. The number of trials per species varies randomly from one to about 10.

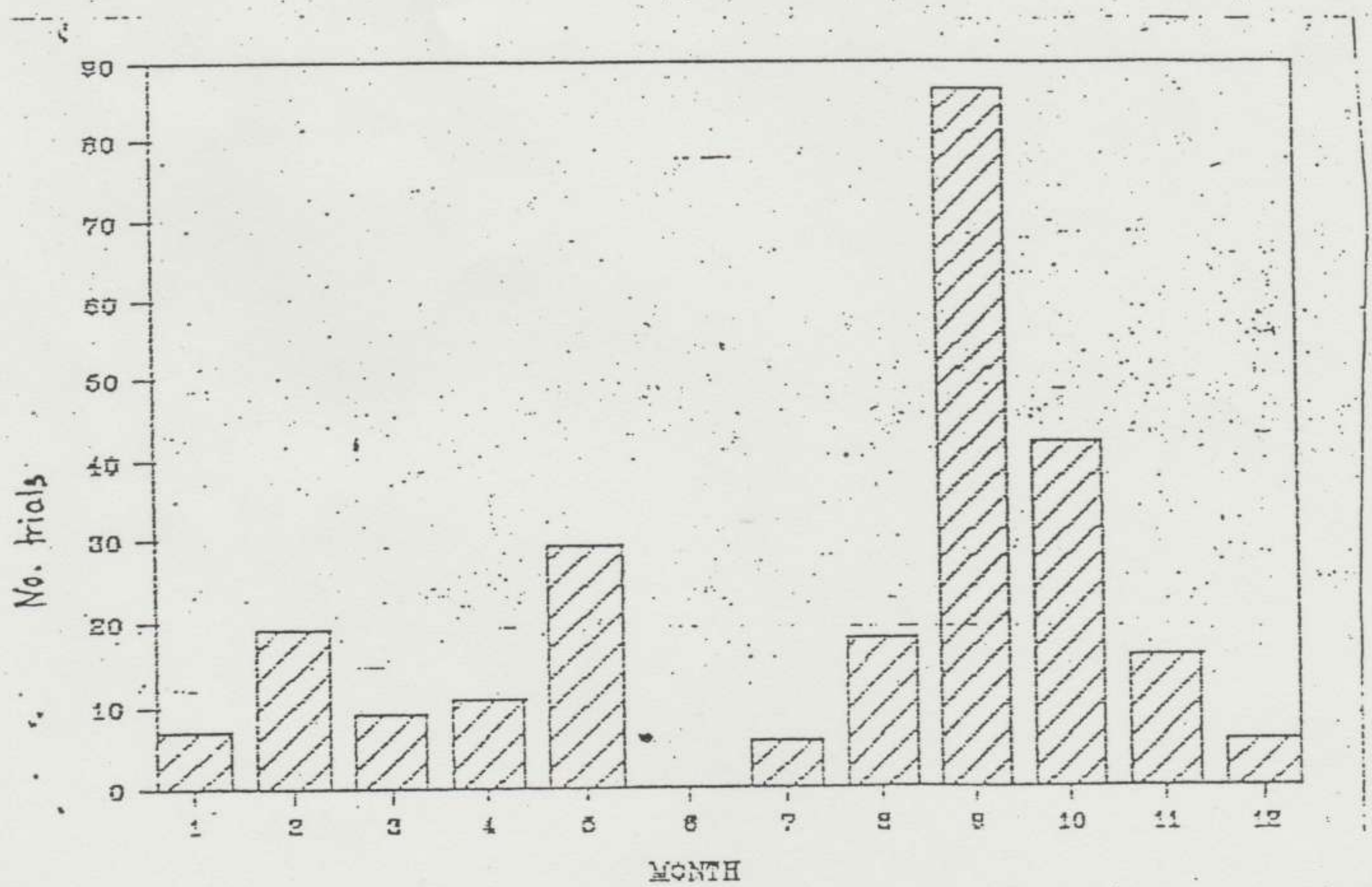


Figure 6. Number of trials planted each month.

October

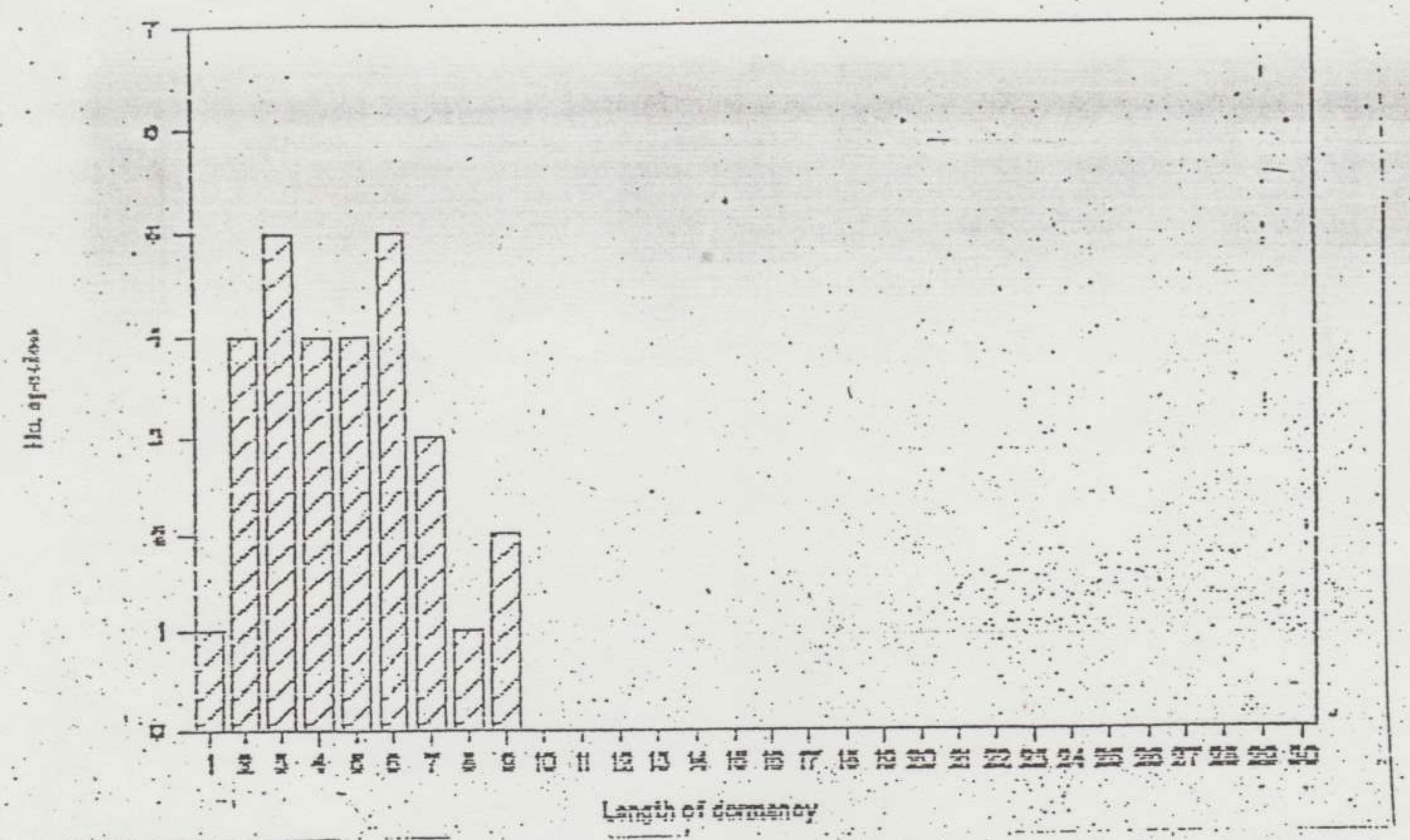


Figure 7. Distribution of length of dormancy of species collected and planted in October (for each species, data from the trial which gave the best germination rate is taken, not including storage trials).

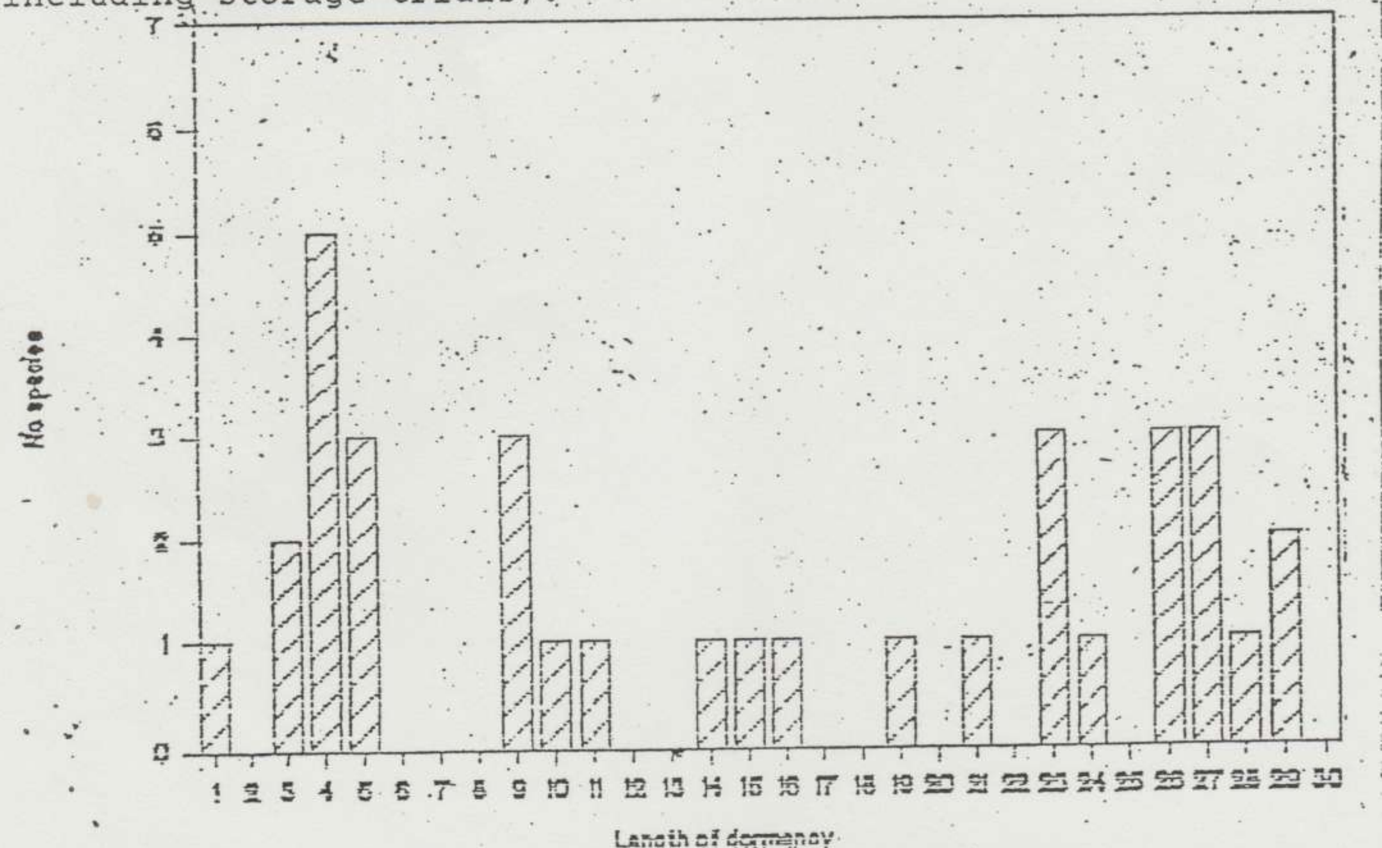


Figure 8. Distribution of length of dormancy of species collected and planted in March (for each species, data from the trial which gave the best germination rate is taken, not including storage trials).

RESULTS OF PRE-PLANTING TREATMENTS

Statistical analysis of the results for each species is inappropriate for this type of study due to the lack of repetition of treatments. As an arbitary measure of effect, for species of which at least 50 seeds were planted, a difference of 20 % may be regarded as "significant" and for those of which less than 50 seeds were planted, a difference of 30 % may be regarded as significant.

1. Cleaning and seed handling

i) Extraction of seed from pulpy fruit.

The seeds of three species were planted within the pulpy fruit tissue. *Adinandra integerrima* is a multi-seeded berry, *Antidesma bunius* and *Gmelina arborea* are drupes.

Table 2.

Species	Treatment	% Germination* (no. planted)	Germ. period (no. wks after planting)	
Adinandra integerrima	Seeds scarif. (petri)	78% (200)	Sep-Nov	(3-10)
	Whole fruit (soil)	c.80% (50)	c.Feb - March 91?	
Antidesma bunius	Seeds scarif. (soil)	23% (100)	Oct-Apr	(7-32)
	Whole fruit (soil)	56% (100)	Mar-Apr	(28-32)
Gmelina arborea	Cleaned seeds (soil)	36% (36)	Apr	(4)
	Whole fruit (soil)	14% (36)	May	(7-9)

* Where multi-seeded fruit were planted the "% germination" refers to the percentage of fruits bearing at least one seedling. "No. planted", the figure in brackets, refers to either seeds or fruit, depending on the unit as stated under "treatment".

Adinandra fruits contain about 30-40 seeds within a sticky pulp. They are very time consuming to extract. When the whole fruit was planted directly into the soil, seeds of at least 80% of the fruits germinated, forming dense clumps of seedlings. The survival rate of these seedlings (though not measured exactly) was much better than that of extracted scarified seeds, germinated in a petri dish and transplanted into soil. Planting whole fruits thus produced healthier seedlings and was less labour intensive than planting extracted scarified seeds in a petri dish.

For Gmelina arborea (a fleshy drupe), of 36 seeds planted for each treatment, only 14% left within the fruit germinated, compared with 36% of those extracted and cleaned. So for this relatively large seeded drupe (fruit 2 x 2.5 cm) extraction appeared to be justified, as well as reducing the space occupied by each seed.

However, for the smaller seeded drupe, Antidesma bunius (fruit 1 x 0.8 cm), 56 % of seeds planted within the fruit germinated, as compared with 23 % of seeds removed and scarified. Germination of in-fruit seeds started after 28 weeks and was completed within a week as opposed to the scarified seeds which germinated between the 7th and 19th weeks. The former pattern of germination would be prefered by the nurseryman, who aims to produce seedlings of a standard age and size at a predicted time.

ii) Removal of aril.

The aril is a thin, fleshy, skin-like layer covering the seed, often found within a dehiscent capsule. It was noted by Ng (1980) that the seeds of Celastrus monospermoides may be protected by an aril which has antidessicant, antiseptic properties. It could be that the arils of other species are valuable in this way, especially if the seed undergoes long dormancy.

Celastrus paniculatus, found on Doi Suthep, has a thin, translucent, orange coloured aril. When month-old seeds of Celastrus were planted in petri-dishes (half scarified, half left with aril intact) all the seeds were attacked by ants and failed to germinate. However, it was interesting to note that the scarified seeds were heavily infected with fungus, while those with arils were quite unaffected. When fresh seeds were planted in the soil with aril intact, germination was low at 13% and dormancy was 29 weeks.

Of two other species with aril coated seeds, (Mangietia garrettii and Unknown Species "F"), germination and dormancy were not significantly affected by removal of the aril. Germination of "F" was 100% both with and without the aril and germination of Manglietia garrettii was 18% with and 12% without.

So, the aril may give some protection to the seed and, for the species examined in these trials, there was no advantage to be gained from its removal. However, its presence does not necessarily insure high germination rates.

iii) Extraction of seeds from unopened, normally dehiscent seed cases.

For naturally dehiscent species, the presence of a closed seed-case implies that the seeds are immature and not ready for dispersal. However, seeds normally ripen on the tree over a period of days or weeks and when a batch of seeds are collected at one time, some seeds will usually be within closed seed cases. In these cases it woul(be useful to know whether it is better to plant with the seed case on, forcibly remove the seed case or store until the seed is naturally shed and then plant it. Another problem is to identify the species, such as Albizia chinensis, which are not naturally dehiscent and whose mature seeds are dispersed within the seed case.

Results for forcibly extracted and non-extracted seeds were as follows:

Table 3.

Species	Germination rates (%) (Number planted) Extracted seeds	Seeds in case
Macaranga denticulata	22% (72)	0% (72)
Ostodes paniculata	26% (19)	15% (19)
Scheichera trijuga	4% (100)	1% (100)

Although germination of all species was improved by forcible seed case removal, overall rates were still low. This could well be because the seeds were still immature. It was noted that upon storage for 1 week, the seed cases of Macaranga, Ostodes and Mallotus broke open naturally. The next step in the investigation would be to store the unopened seed cases until the seeds have been shed and then compare their germination rates with those of seeds forcibly removed.

Eleaocarpus floribundus is an unusual species which gives a false impression of being dehiscent. The fruit is in the form of a fleshy drupe, but on the forest floor the flesh rapidly rots or is removed by frugivores, exposing a three sutured stone which appears to be dehiscent. This capsule-like stone though, does not naturally dehise and is very hard to remove manually. When 36 seeds were planted with and without the case, 11% of those with seed-case intact germinated as opposed to only 3% of those whose case was removed. The tedious process of removing the case is therefore not justified.

iv) Removal of wings.

Ng holds that removal of wings saves space in the seed tray but does not promote germination. Their presence or absence may be irrelevant for species, such as many of those of the Dipterocarpaceae family, whose long wings prodrude above the soil when planted. For smaller winged species though, such as Terminalia mucronata, the wings are buried in the soil along with the seed and may affect germination in some way. Terminalia seeds are up to about 3 cm long, with oval wings spanning the seed. When 36 seeds were planted with wings removed, germination was 36 % as compared with 19 % for seeds planted with wings intact. While these results are not significantly different, the experiment would be worth repeating to see whether the hairy wings absorb water and promote rotting of the seed.

v) Drying out of moist, cleaned seeds.

It has been proposed by some authors (e.g. Burrows 1989) that certain species which have a high seed water content at the time of shedding or which are surrounded by moist fleshy fruit tissue, must remain moist throughout the period of dormancy if they are to remain viable. Three species were used to test this hypothesis:

Table 4.

Species	Drying Treatment	% Germination (* = no. planted)		Germ. period (wks)	
		Dried	Wet	Dried	Wet
Garcinia xanthochymus	Sun-dried for 2 hours	54% (*50)	100% (*10)	16-34	14-17
Irvingia malayana	Air-dried for 2 weeks	Not yet available			
Lasianthus kurzii	Air-dried for 5 hours (planted in petri dish)	46% (*50)	20% (*50)	5-19	7-8

When Garcinia seeds were planted whilst still moist after removal from the fruit, they not only all germinated, but did so over a short period (one month) in March. This is obviously ideal "behaviour" for nursery production. Allowing the seeds to dry out for as little as 2 hours reduced overall germination rate to 54% and caused germination to be spread out over a period of 5 months. A possible explantion for this phenomenon, which would be worth further investigation, is that while remaining moist, Garcinia seeds experience enforced dormancy until some environmental trigger (probably related to climate) causes germination. However, if the seeds are allowed to dry out a prolonged "induced dormancy" (see Burrows 1989) is imposed. This means that seeds which were able to germinate when first released from the parent aquire some form of block. It would be interesting to test these "blocked" seeds for continued viability.

Whatever the causes of dormancy, though, these results indicate that Garcinia seeds should be planted immediately after removal from the fruit and should not be allowed to dry out.

Results from the trials on Lasianthus indicate that the opposite treatment would achieve best results when seeds are planted in a petri dish i.e. that seeds should be allowed to dry out before planting. Two observations help to explain the differences in germination and dormancy. Firstly, initial germination appeared to be stimulated by allowing the seeds to dry out. By the eighth week, 38% of dried seeds had germinated, while only 20% of the continuously moist seeds had. Secondly, whilst some of the dried seeds continued to germinate between the eighth and nineteenth weeks, further germination of the moist seeds over this period was prevented by infection of the petri dish with mould. It is possible that if planted in the soil, mould would not be a problem and the results might be more similar for wet and dry seeds.

2. Scarification

Table 5. Species responding positively to scarification:

Species	Fruit type & Disperser	Percent germination		Dormancy (N wks)		Germ. per. (P wks)	
		Cont*	Scar*	Cont	Scar	Cont	Scar
Garcinia xanthochymus	drupe animal	54% (50)	84% (50)	16	6	18	28
Leea indica	berry bird	8% (100)	77% (100)	7	3	31	26
Spondias axillaris	drupe animal	3% (72)	44% (36)	7	4	continuing	

* First number is the percentage of seeds planted which germinated. Second number, in brackets, is the total number of seeds planted. For further explantion of "Dormancy" and "Germination period" see previous section on Dormancy.

Table 6. Species responding negatively to scarification:

Species	Fruit type & Disperser	Percent germination		Dormancy period(wks)		Germination period(wks)	
		Cont*	Scar*	Cont	Scar	Cont	Scar
Antidesma bunius	drupe bird	56(100)	23(100)	28	7	5	26
Manglietia garrettii	aryl bird?	12 (50)	2 (50)	24	26	2	0
		18 (50)	4 (50)	23	26	2	0
Tetrastigma obovatum	animal/ bird	44(100)	16(100)	5	5	2	30

* See Table 5.

Table 7. Species showing no significant response to scarification:

Species	Fruit type & Disperser	Percent germination		Dormancy period		Germination period	
		Cont*	Scar*	Cont	Scar	Cont	Scar
Alangium salvifolium	drupe bird/animal	50 (36)	39 (36)	4	4	23	23
Albizia chinensis	Legume gravity	25 (72)	38 (72)	3	1	15	23
Cassia fistula	Legume gravity	26 (50)	18 (50)	–	8	12	–
Colona flagrocarpa	winged wind	8 (50)	30 (20)	4	1	5	0
Diospyros glandulosa	drupe bird/animal	73(100)	63(100)	4	4	27	28
Elaeocarpus stipularis	drupe animal	11 (44)	20 (20)	27	27	10	0
Eurya acuminata	dry berry other	3(100)	3(100)	3	3	1	1
Garcinia speciosa	drupe animal	84 (37)	63 (30)	23	23	46	40
Irvingia malayana	drupe animal	70 (20)	85 (20)	26	26	3	5
Kydia calycina	winged wind	21(100)	19(100)	4	1	0	4
Michelia champaca	aryl bird?	24 (72)	15 (72)	2	2	18	18
Mucuna macrocarpa	Legume gravity	80 (5)	100 (5)	3	3	4	34
Phoebe lanceolata	drupe? bird	16 (32)	3 (38)	–	13	–	0
Protium serratum	drupe? bird	10 (50)	2 (20)	29	26	3	0
Randia parviflora	animal	35 (20)	5 (19)	37	37	0	0
Randia sp.	animal	20(100)	14(100)	11	9	5	8

Solanum macrodon	berry bird	10(100)	16(100)	1	2	13	6
Turpinia pomifera	drupe animal	10 (50)	4 (50)	6	5	30	25
Vitex heterophylla	other	1(100)	5(100)	-	27	-	3

* See Table 5.

It was predicted that germination of seeds dispersed by animals and birds and Leguminose seeds would be increased by scarification of the seed coat and that average dormancy would be reduced.

Of the Leguminose species tested, Albizia, Mucuna and Cassia, none showed that scarification had any significant effect on germination rates or dormancy, although Mucuna germinated very well without any treatment. The next step in attempting to improve germination of Albizia and Cassia would be to establish whether scarification was simply too gentle to have any effect (in which case more vigorous sandpapering or a different technique such as boiling water or acid treatment may be effective) or whether another unknown factor (such as light or temperature) is overruling the effect of scarification. Other studies have shown that seed maturity of Legumes is an important factor controlling seed coat permeability and should be taken into consideration in scarification trials (Amata-archachai and Hellum, unpublished results). Thus results were inconclusive for Albizia and Cassia, but showed that scarification is unnecessary for Mucuna.

Contrary to expectations, of the 18 animal and bird dispersed species, germination rates were substantially increased for only 3 species (Garcinia xanthochymus, Leea indica and Spondias axillaris) and were decreased for 3 species (Antidesma bunius, Manglietia garettii and Tetrastigma obovatum). In the cases where scarification increased germination, the period of dormancy until the first germination (D) was consistently shortened. However, for most species where germination was reduced or not affected, dormancy was similarly unaffected. Thus it would seem correct to suppose that for the 3 positively reacting species, scarification did increase the permeability of the seed-coat.

These results show that either passage through the gut of animal is unnecessary for seed germination of most species or that the technique of rubbing with sandpaper does not accurately mimic this process. Further tests, using real animals or different methods of scarification would be needed to establish which of the above is correct.

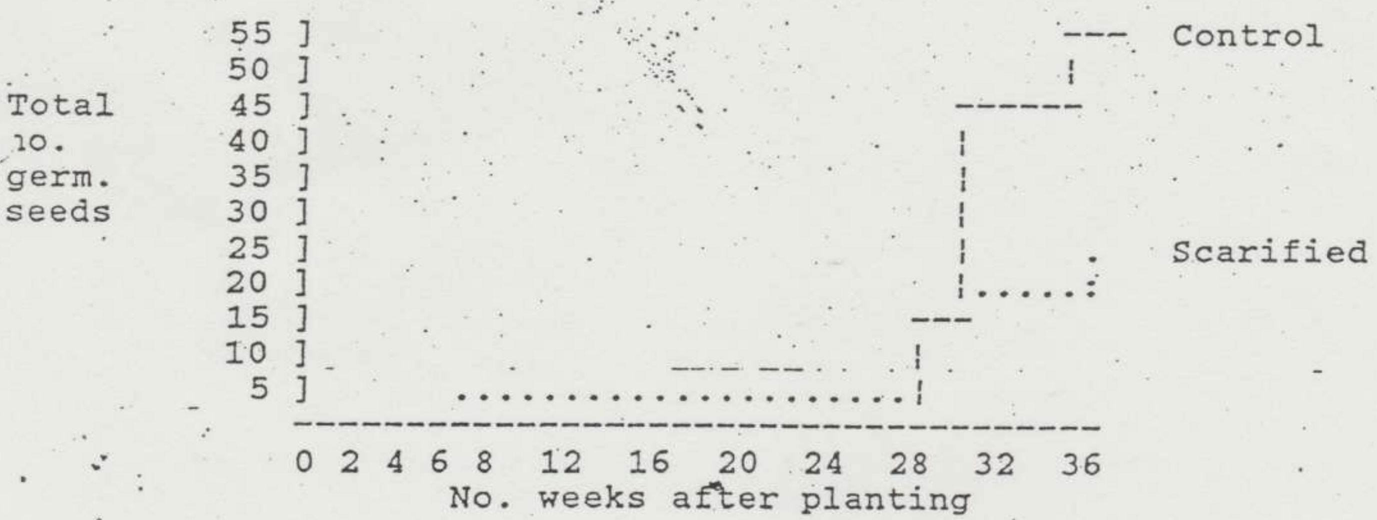
It is interesting to note that while germination of Garcinia xanthochymus was promoted by scarification, that of Garcinia speciosa was slightly reduced (though not significantly according to accepted percentage differences). However, dormancy of G. speciosa was unaffected (remaining at 23 weeks), so scarification could have been too gentle to have any effect on seed-coat permeability and the slightly lower germination rates may reflect natural variation in viablility. It is therefore probably worthwhile to persue scarification trials on the genus Garcinia.

Two wind dispersed species (Colona flagrocarpa and Kydia calycina) were subjected to scarification. As expected, neither were significantly affected, but the results for Colona (slightly increased germination and shorter dormancy) indicate that if the experiment was repeated with a larger sample, scarification may significantly promote germination.

For those species where scarification increased germination rates and shortened the period of initial dormancy, the period of differential dormancy was variable. This suggests that scarification was increasing the permeability of the seed coat in some seeds and not in others. Similarly, scarification of Antidesma seeds prompted a small germination response in the seventh week after planting, while most of the seeds in the trial underwent the same 28 week dormancy as those in the control or failed to germinate altogether. (See Table 1).

These results indicate that scarification with sandpaper does not have a uniform affect on all seeds and could therefore never lead to predictable germination rates and periods of dormancy. So although rubbing with sandpaper is a simple and rapid method of scarification, alternative methods such as acid and hot water treatments may give more consistent and repeatable results.

Fig. 10 Germination of Antidesma bunius



3. Fire

Fire did not promote germination in any of the species tested. Of the 16 species tested, 4 completely failed to germinate, either as a control or after subjection to fire, so the effect of fire could only be judged for 12 species. 7 of these 12 species failed to germinate at all when subjected to fire.

These species included the following (percentage germination of the control shown in brackets):

Antidesma bunius (56%), Castanopsis armata (14%), Castanopsis diversifolia (3%), Cleidon spiciflorum (47%), Colona flagrocarpa (4%), Dipterocarpus obtusifolius (13%), Lithocarpus elegans (1%).

Germination of the other 5 species was reduced or unaffected by fire, but not entirely prevented:

Celastrus paniculatus (cont.13%, fire 4%), Eleaocarpus floribundus (cont.11%, fire 8%), Ostodes paniculata (cont.26%, fire 16%), Randia sootepensis (cont 51%, fire 3%), Schleichera trijuga (cont. 4%, fire 1%)

So for the species tested in these trials, fire cannot be recommended as a pre-planting treatment, even though fire temperatures were lower than those recorded in experimental forest litter burns by Stott (1986).

4. Storage.

Germination of the following species was reduced by storage:

Table 8.

(a) = control i.e. freshly collected seeds
(b) = seeds stored until the end of the dry season

Species	Planting date	% Germination (no. planted)	Germ. period (no. wks after planting)
Albizia chinensis	a) 06/02/91	25% (72)	Feb-Jun (3-18)
	b) 26/05/91	3% (35)	Jun (2)
Antidesma bunius	a) 12/09/90	56% (100)	Mar-Apr (28-33)
	b) 17/05/91	0% (36)	
Cassia fistula	a) 09/11/90	26% (50)	? -May
	b) 03/05/91	1% (36)	May - - (2)
Celastrus paniculatus	a) 04/09/90	13% (100)	Mar-May (29-37)
	b) 17/05/91	0% (100)	
Macaranga kurzii	a) 14/09/90	6% (100)	Oct-Mar (3-28)
	b) 26/05/91	0% (36)	
Phoebe lanceolata	a) 16/09/90	16% (32)	? -Apr
	b) 17/05/91	3% (36)	Jul (10)
Protium	a) 19/09/90	10% (50)	Apr (29-32)

serratum	b) 26/05/91	0% (36)		
Solanum macrodon	a) 09/10/90 b) 26/05/91	10% (100) 0% (36)	Oct-Jan	(1-14)
Terminalia mucronata	a) 04/09/90 27/03/91 b) 17/05/91	0% (50) 36% (36) 0% (36)	 Apr	 (2-5)
Turpinia pomifera	a) 14/09/90 b) 17/05/91	10% (50) 0% (36)	Oct-May	(6-36)
Vitex heterophylla	a) 18/09/90 b) 17/05/91	1% (100) 0% (36)	?	?

Germination of the following species was increased by storage:

Table 9.

(a) = control i.e. freshly collected seeds
(b) = seeds stored until the end of the dry season

Species	Planting date	% Germination (no. planted)	Germ. period (no. wks after planting)	
Schleichera trijuga	a) 04/09/90 b) 03/05/91	4% (100) 19% (36)	Sep-May May	(4-39) (2)
Ormosia sumatrana	a) 12/09/90 b) 03/05/91	9% (100) 28% (36)	Nov-May Jun-Feb	(12-80) (5-43)

The control seeds of Antidesma, Celastrus and Protium underwent long dormancy in moist soil which delayed germination until the hot season, but when stored under dry conditions until the end of the hot season, the seeds failed to germinate.

Most of the other species which responded negatively to the treatment had control seeds which germinated fairly rapidly after planting and finished germinating before the stored seeds were planted. Such species included Albizia, Cassia, Macaranga, Solanum and Terminalia. It may then be possible to predict that species which begin to germinate rapidly (e.g.in under a month) when planted in moist soil, will not benefit from being stored in dry contitions until the dry season.

As only two species (Schleichera trijuga and Ormosia sumatrana) responded positively in these trials it is not possible to draw conclusions from these results about the type of seeds likely to benefit from storage. Also, the data may be incomplete at this point, as species undergoing extremely long dormancy may yet germinate (e.g. germination of Ormosia is almost certainly incomplete at the time of writing). However, two common characteristics of the Schleichera and Ormosia were that they had hard coated seeds and length of dormancy under control conditions was extremely variable among seeds (i.e. total germination period was long).

5. Ripeness

Table 10.

Species	Colour or month of collection	% Germination	% Dormancy
Garcinia cowa	Green Orange	NYA	NYA
Helicia niligirica	Green Brown	44% (9) 18% (17)	8-33 5-33
Irvingia malayana	Yellow Brown	Not Yet Available	
Mallotus philippensis	Feb. March	Not Yet Available	
Michelia champaca	Control Rotted	25% (72) 14% (72)	2-27 3-20
Quercus semiserrata	Green/brown Green Brown	82% (50) 10% (50) 4% (50)	5-16 6-9 ?
Randia sootepensis	Black (Nov) Green (Nov) Black (Jan)	40% (10) 0% (15) 51% (72)	7 9-17
Spondias axillaris	Green? Rotted	3% (72) 6% (36)	6 9
Styrax benzoides	Brown Green	15% (20) 65% (20)	19-26 11-30
Terminalia chebula	Brown Green	17% (6) 67% (6)	18 15-19

- The optimum stage of ripeness or maturity is unique to each species and it is not possible to lay down general rules about it. For example Helicia niligirica, Styrax benzoides and Terminalia chebula appear to germinate best when the seeds are taken from green fruit, while Randia sootepensis only germinates when seeds are taken from black, rotten-looking fruit.

The poor success with germination of the Fagaceae family may be because they are highly sensitive to seed maturity and condition. Germination rates of species in this family (Lithocarpus and Castanopsis) were extremely low or 0, except for Quercus semiserrata which when collected at optimum maturity germinated at 82%.

Mallotus was collected at the beginning and end of the tree's fruiting period. At the beginning many seed capsules were unopended and the seeds appeared moist inside. Towards the end the seed capsules were freely dehiscing and the seeds appeared much drier. Final results for this species are not yet available, but to date none of the earlier batch has germinated, as opposed to 14% of the control and 26% of the scarified seeds in the later batch.

In no case did dormancy have any significant effect on initial dormancy, although the effect on germination period (differential dormancy) was varied and probably resulted from other completely unrelated factors.

CONCLUSIONS

It was found that complete dormancy for anything up to 37 weeks can be expected in species found in Doi Suthep National Park, especially those species collected between September and January. The time of germination is almost certainly linked with the seasons, but the relative importance of various environmental factors (moisture, temperature, light etc) in breaking dormancy is unclear. More detailed research, including a study of germination under natural forest conditions, is needed.

The response of species to various pre-planting treatments was extremely varied and few generalisations can be made at this point, except concerning fire. In no case was fire a successful treatment and in most cases it was detrimental to germination. Of the cleaning treatments, the only consistent result was that it is unnecessary to remove the aril, when present. Responses to ripeness trials and storage were highly variable and trials should continue in order to discover the requirements of each species.

The majority of species showed no significant response to scarification and it is suggested that a more quantifiable method is needed. It may be that scarification was not thorough enough to have an effect on many species.

The generally low germination rates show that much research still needs to be done, if a wide range of native species are to be successfully germinated under nursery conditions for reforestation.

REFERENCES

Burrows, C.J. (1989) Patterns of delayed germination in seeds. (New Zealand Natural Sciences 16:13-19.)

De Vogel, E.F. (1979). Seedlings of Dicotyledons. (Published by Centre for Agricultural Publishing and Documentation, Wageningen)

Garwood, N.C. (1983). Seed Germination in a Seasonal Tropical Forsest in Panama: A Community Study. (Ecological Monographs. 53(2), 1983, pp.159-181.)

Maxwell, J.F. (1988). The Vegetation of Doi Suthep-Pui National Park, Chiang Mai Province, Thailand. (The Tiger Paper, October - December 1988, pp. 6-14)

Ng, F.S.P. (1980) Germination Ecology of Malaysian Woody Plants. (The Malaysian Forester Vol. 43, No. 4 October, 1980.)

Stott, P. (1988). The forest as phoenix: towards a biogeography of fire in mainland south east Asia. (The Geographical Journal 154(3):337-350.

Raich, J.W. & Gong Wooi Khoon (1990). Effects of canopy openings on tree seed germination in a Malaysian dipterocarp forest. (Journal of Tropical Ecology, 6:203-216).

Sukwong, S., Dhamanitayakul, P. & Pongumphai, S. (1975). Phenology and seasonal growth of dry dipterocarp forest tree species. (The Kasetsart Journal 9(2): 105-114.