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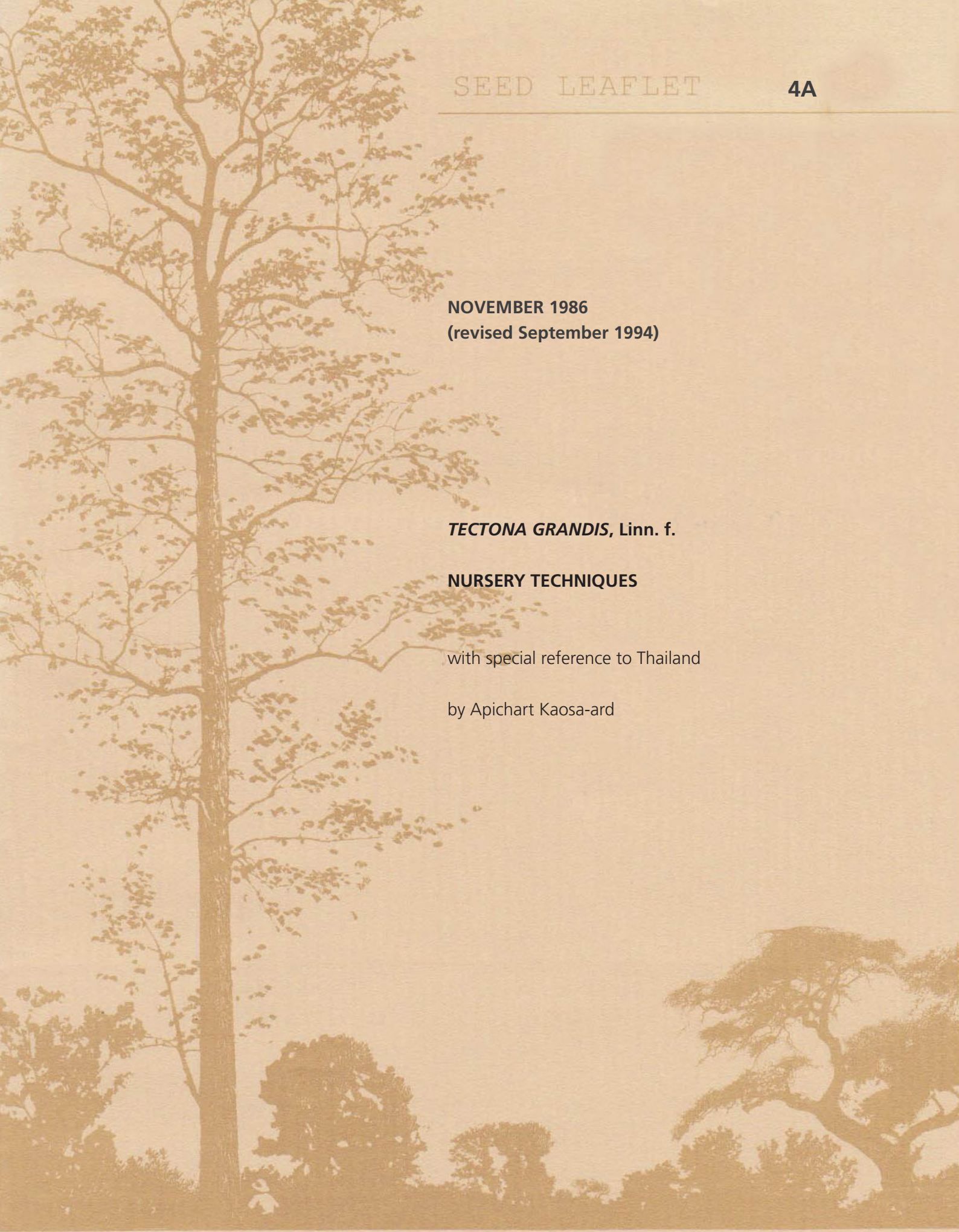

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TECTONA GRANDIS, Linn. f.

NURSERY TECHNIQUES

with special reference to Thailand

by Apichart Kaosa-ard

DANIDA FOREST SEED CENTRE

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FOREWORD

When the material for the Seed Leaflet on teak was compiled, it was decided to publish it in two parts: one concerning the specific information about the reproductive biology, collection and handling of seed (issued June 1985) and the other one about the nursery aspects.

The reasons for this arrangement were partly the bulk of the material and therefore the presentation of it in two entities and partly that Dr. Apichart Kaosa-ard of Thailand had already published an article about nursery techniques in the Thai language. This publication, written with special reference to conditions in Thailand, was thought to be sufficiently general in application that, after translation into English and some editing, it would suit the purpose of a Seed Leaflet as well.

With the kind permission of the Royal Forestry Department of Thailand and of the author of Nursery Techniques we are now pleased to present the second half of the Seed Leaflet on Teak.

Danida Forest Seed Centre

ACKNOWLEDGEMENTS

This paper is supported by the Royal Forest Department of Thailand and the Danida Forest Seed Centre of Denmark. The author would like to thank Mr. H. Keiding and Dr. A. Kaosa-ard for their patience and encouragement.

1. INTRODUCTION

Teak is one of the most well-known timbers in the world. Because of its various favourable characteristics and properties, such as fine grain, beautiful golden colour and durability with respect to weather, insects (termites) and fungi, it is suitable for multiple utilizations.

Teak (*Tectona grandis* Linn. f.) is indigenously confined to the South and Southeast Asian region. Its natural occurrence is limited to a number of countries in the regions, i.e. India, Myanmar, Thailand, Laos and Java in Indonesia. Since the price of teak is relatively high compared with various other kinds of timber and its sources of supply are limited, the species has been introduced and large-scale teak planting programmes have been set up in several countries in the tropics. These countries include Trinidad, Togo, Nigeria, Benin and many more.

In Thailand, teak occurs naturally throughout the northern part of the country covering an area of 170.000 km^2. Due to population pressure, both the stock of teak trees in the forests and the forest areas have been depleted rapidly. The remaining teak forest area is approximately 25,000 km^2 (RFD, 1984). Moreover, Thailand, which was one of the major teak exporting countries, has started to import teak timber from neighbouring countries, e. g. Myanmar and Laos. In 1984 for example, 30,840 m^3 of teak timber was imported to Thailand for processing and for local consumption (RFD, 1984). Therefore teak plantations have been widely established throughout the country particularly in the north where the species is native.

The first teak plantation in Thailand was established, on trial, in 1910 and a number of pilot plantations of this species were established thereafter. The first two large-scale plantations are Mae Huad plantation in Ngao District, Lampang province, and Mae Ta plantation in Long District, Prae province. Since 1960, the teak planting programme has been incorporated in the National Social and Economic Development Plan and has been continuously implemented.

Teak plantation establishment programmes in Thailand are operated by both the government and private organizations, e.g. the Royal Forest Department (RFD), the Forest Industry Organization (FIO) and various provincial timber companies. The total area of teak plantations established by these organisations is approximately 1,655 km^2 (Kaosa-ard, 1985), and the rate of annual planting programme of this species has increased steadily. The rotation of teak plantation is between 30 and 60 years, depending on the site qualities, silvicultural practices and the purpose of utilization.

Since the plantation of teak has attracted both government and private interests immensely, investments in this field have increased rapidly. As a result, new technological knowledge regarding teak nursery and plantation establishment techniques is highly demanded. Although a large volume of scientific results in this field has been recorded, in various journals (Mathur, 1973) and graduate university theses (Anon., 1968), a manual on teak nursery practice and plantation establishment on a commercial scale is not yet available.

2. GENERAL DESCRIPTION

The purpose of this section is to discuss both botanical (phenological) and ecological aspects of the species and to provide background information for seed procurement and nursery operation of teak (see also Keiding, 1985).

2.1 Botanical Aspect

Teak is a deciduous tree species and is phenologically classified, according to Longman and Jenik (1974), as the periodic-growth deciduous type. It has a marked seasonal growth rhythm with alternate leaf shedding (dormancy) and leaf/shoot flushing (active growth) periods. The seasonal pattern of shoot growth development of this species varies from one locality to another depending on the climatic conditions. In Thailand and India, for example, the active shoot growth (leaf/shoot flushing, flowering and fruiting) period of the species is in May-September, whereas in Indonesia it is in November-March. A study on seasonal shoot growth of teak in Thailand, Kaosa-ard (1982b) reported that there are 4 marked stages of shoot growth pattern in this species throughout the year. These stages (Figure la) are:

(1) the spring bud-break period in April-May,
(2) the shoot growth flushing period in May-June,
(3) the growth declination period in July-October,
(4) the leaf shedding and dormancy period in December-March.

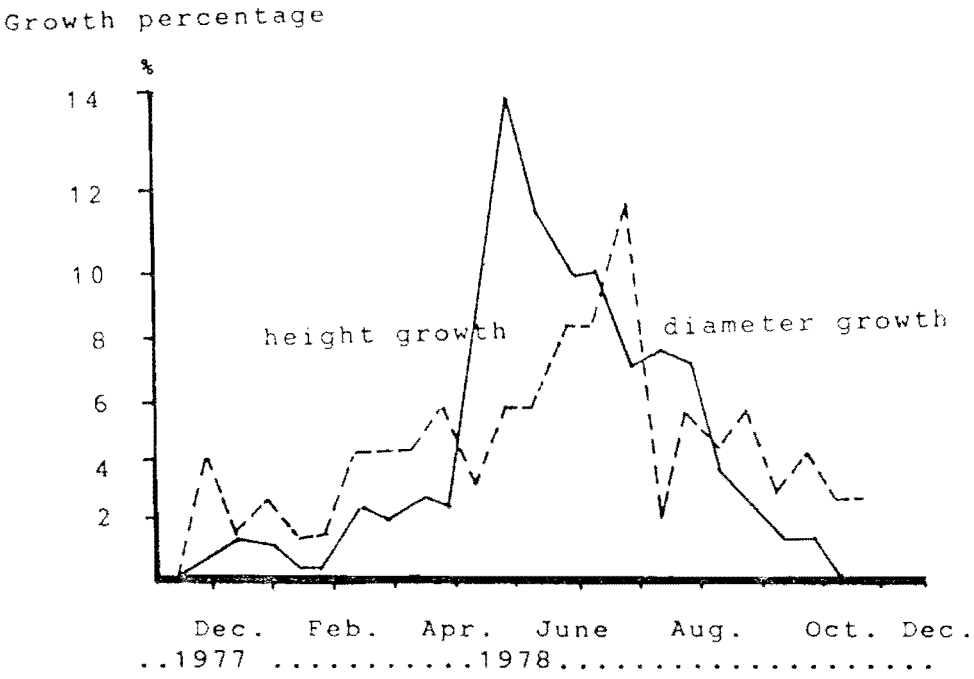
The pattern of temperature and rainfall distribution (Figure lb) shows that the bud-break and shoot growth flushing periods of teak fall within the period of April-May (after the first monsoon storm) when the climate is relatively warm and humid. After the flushing period, the amount of shoot growth of this species decreases rapidly over the rainy season, (June-October) ceases during October-December. The species then starts shedding its leaves during the cool dry season (December-February) and, thereafter, stands without leaf throughout the hot dry season (March-April).

It is thus evident that:

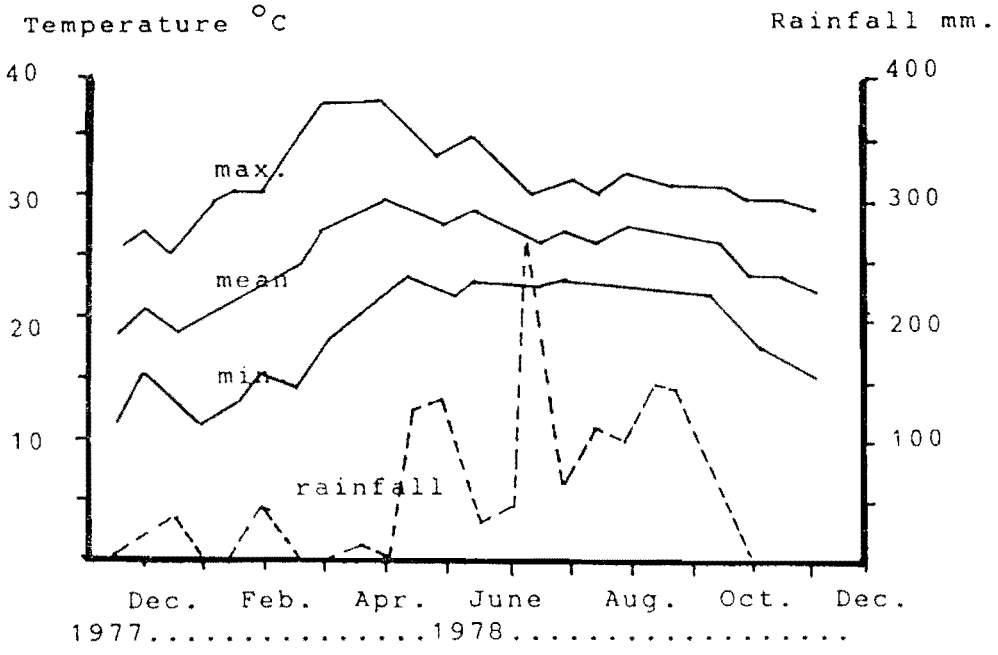
(1) There is only one shoot growth flushing period of the species.
(2) After flushing, the growth potential of its shoot will decrease steadily throughout the rainy season even though moisture during this period is relatively high.
(3) The most favourable period for shoot growth of teak is in April-May (in Thailand), when the climatic condition is relatively warm and humid.

Therefore, the following points should be taken into account in nursery and planting practices:

(1) The plantation should be planted soon after the first monsoon rain, i.e. between April-May, to obtain favourable growth conditions of the species.



a. Amount of growth per 15 days.



b. Climatic conditions at intervals of 15 days.

Figure 1. Seasonal shoot growth of teak in relation to climatic conditions in Lampang, Thailand. Source: Kaosa-ard (1982b).

(2) The seedlings in the nursery should be lifted and prepared into stumps before the growth flushing period in order to obtain a higher growth potential when planted.

The relationship between the lifting time of nursery seedlings, planting time, and subsequent survival and growth potential of the stumps after planting out in the field will be discussed in more detail in Section 7.2.

2.2 Ecological Aspects

Several studies on eco/physiological aspects of the species conducted both under its natural conditions and under controlled environmental conditions showed that there are a number of factors controlling the distribution and the growth of teak (Kaosa-ard, 1981b). These factors include soil, moisture, temperature and light.

2.2.1 Soil. The most suitable soil for teak is the deep and well drained alluvial soil (Kulkarni, 1951; Puri, 1951; Seth and Yadav, 1959), with an optimum range of soil ph between 6.5 and 8.0 (Kulkarni, 1951) and with a relatively high calcium and phosphorus content (Bhatia, 1954; Puri 1951).

2.2.2 Moisture. Although the limits of the annual rainfall in the teak region are from 500 to 5,000 mm, the most favourable range of rainfall for a better growth and timber quality is between 1,200 and 1,600 m (Kermode, 1957; Kaosa-ard, 1977). A study conducted in the phytotron showed that when other factors such as temperature, light and soil nutrients, are optimum, the differences in soil moisture content caused a substantial difference in growth and development of the species (Kaosa-ard, 1977). The study showed that by reducing the moisture content in the soil from 19% to 6% for two months the following parameters of the teak seedlings, i.e. height growth, leaf area production, stump dry weight and total dry weight, decreased to approximately ½, $^1/_5$, $^1/_3$ and $^1/_5$ respectively of the amounts at 19% soil moisture.

2.2.3 Temperature. A series of studies on the effects of temperature on growth and development of teak seedlings (Ko Ko Gyi, 1972; Kanchanaburangura, 1976; Kaosa-ard 1977) showed that the optimum temperature for growth and development of teak seedlings was between 27/22°C to 36/31°C (day/night temperature) with a most favourable temperature of 30/25°C. If the temperature dropped either gradually or abruptly below 18°C, the seedlings would gradually turn yellowish; their leaves would be thicker and eventually they would stop growing (Kaosa-ard, 1977).

2.2.4 Light. Teak is a light-demanding species and the optimum light for growth and development of the species is between 75-100% of full sun light (Bhatnagar, 1966; Nwoboshi, 1972). The day length or photoperiod appears to have less effect on seedling growth and development. Under optimum temperature conditions there is no difference in growth and development of the seedlings grown at different day lengths (8, 12 and 16 hours) (Ko Ko Gyi, 1972; Kanchanaburangura, 1976).

3. REPRODUCTIVE BIOLOGY

Seed is one of the most important inputs for forest nursery production and plantation establishment. In nursery production the seed used must have good viability and germination potential, (1) to facilitate nursery operation, (2) to obtain a large number of seedlings from the seed sown, (3) to obtain uniform seedlings and consequently, (4) to reduce the cost of nursery operation and/or the cost of seedling production. In plantation establishment, the seed used must be genetically good seed to produce timber of higher volume and value in a shorter time, i.e. to increase the profit from the plantation investment.

3.1 Seed Morphology

The term »teak seed« used in the nursery and plantation practice is botanically a »teak fruit«. It is a dry stone-fruit which is called a »drupe«. According to the International Seed Testing Association (ISTA), the »teak seed« is classified as the compound seed structure (ISTA, 1976). Its structure consists of a thin papery outer layer (pericarp), which is normally removed during seed processing, a thick corky middle layer (mesocarp) and a stony inner part (endocarp). Inside the endocarp are four chambers containing 0-4 seeds (normally 1-2 seeds). The characteristics of the teak fruit is illustrated in Figures 2 and 3, and its variation in seed content is shown in Table 1.

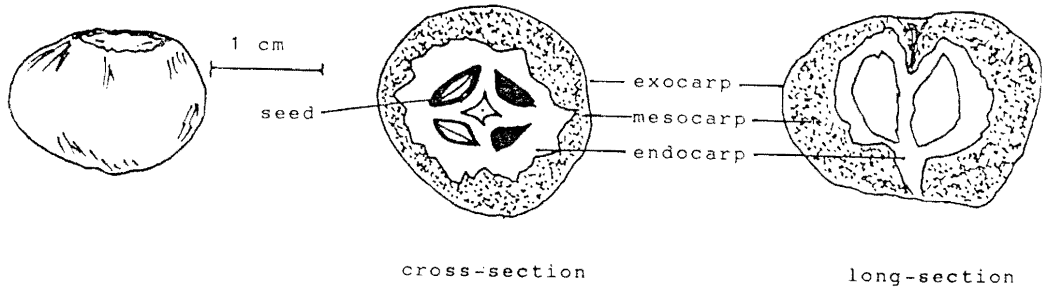


Figure 2. Characteristics of teak fruit (a compound seed structure).

Figure 3. Teak fruit and seeds (1-cm scale)

Table 1: Variation in the number of seeds per fruit by site in Thailand. (Data presenting the percentage value from the cutting test).

Seed Sources	Percentage Fruits with 0-4 seeds					
	0	1	2	3	4	Σ
Mae Hongsorn	25	45	22	7	1	100
Chiang Mai	25	54	22	3	1	100
Lamphun	20	46	24	8	2	100
Lampang 1	20	35	15	4	1	100
Lampang 2	45	44	16	4	2	100
Lampang 3	34	42	15	3	1	100
Lampang 4	33	48	23	5	2	100
Phrae	19	51	4	1	5	100
Average	28	45	21	5	1	100

Sources:Bryndum (1966),
TIC (1980),
Bhumibhamon *et al.* (l980) and
Kaosa-ard & Wisetsiri (1980).

For practical purposes, the term »teak seed« will be used instead of teak fruit throughout this paper and the term »teak fruit« will be used only when a distinction between fruit and seed is necessary.

The size and weight of teak seed depend on several factors, e.g. the seed source and climatic condition. A series of studies on provenance variation of teak suggested that there is a large variation in seed size and weight among the tested provenances (Anon. 1973 and Murthy 1973). The seed diameter varies from 5 mm to 20 mm with an average of 12 mm. The number of seeds per kg is between 1,000 and 3,500 with an average of 2,000 seeds per kg (Anon. 1973 and Murthy, 1973). The variation of size and weight of the seed collected from the same seed source in different years is shown in the following table.

Table 2: Variation in number, weight, and viability of teak seed from the Mae Huad Seed-Production Area in Thailand

	1977/1978	**1978/1979**
seeds per kg	2,206 ± 69 (10)	1,912 ± 26 (30)
seeds per litre	546 ± 15 (10)	481 ± 7 (30)
kg seed/litre	0.27 ± 0.10 (10)	0.26 ± 0.002 (30)
viability %	60.0 ± 1.0 (100 x 12)	54.0 ± 1.2 (100 x 20)

Figures in brackets indicate number of samples
Source: Kaosa-ard (1981a)

3.2 Seed Viability

In general, the term »seed viability« refers to the ability of a seed to germinate under optimum conditions. In estimating seed viability, the conditions of a seed embryo and/or endosperm are observed either by the biochemical test, e.g. the tetrazolium (TZ) test, or by the physical and mechanical tests, e.g. the x-ray and the cutting test. These techniques have been described by Kamra, 1973; ISTA, 1976 and Willan, 1984a.

Generally, most forest tree seeds are mono-embryo seeds, i.e. one seed contains one embryo and the result of the viability test will be expressed in percentage. Since a teak fruit contains 1-4 seeds, an explanation of the test result is quite difficult. According to ISTA (1976), the evaluation of a teak seed germination test is applied as follows:

> »A tree seed giving rise to multiple seedlings as a result of polyembryony shall be counted as a single seed in the gemination test. In the case of compound seed structure, e.g. *Tectona grandis*, the average number of seedlings produced by 100 seed structures shall be determined.«

On the basis of this rule, the average number of viable seed in 100 fruits (compound seed structures) is considered as the percentage of viability of teak seed. As a result, the maximum percentage of viability of teak seed can be as high as 400%. Hedegart (1974) defined "teak seed viability" as:

> »the percentage of fruit containing at least one well developed and sound seed as determined by visual judgement in the cutting test.«

This definition seems to be more practical for teak seed testing and nursery practice and will be used in this paper.

The viability of teak seed is commonly examined by the x-ray and the cutting methods. The x-ray method is widely used in laboratories for research purposes. For practical purposes, the easier and cheaper cutting method is widely used. The cutting test, developed by the Teak Improvement Centre, Lampang, Thailand (TIC), indicated a germination capacity of the seed in nursery as high as 75% (Hedegart, 1974).

The technique of the teak cutting test is as follows:

(1) the seeds are sampled from a seedlot (one litre per sample per sack of 45 kg);
(2) the sampled seeds are soaked in water for 3 days;
(3) the seeds are cut by cross-section;
(4) the endosperm in each seed chamber is observed;
(5) if a white, crispy and fresh endosperm is found in at least one seed chamber, the seed is counted as a viable seed.

The viability of teak seed varies from 40 to 85% (Tables 1 and 3) depending on several factors, such as seed size, seed sources, seed year, the climatic conditions during the flowering and fruit-setting period etc.

A number of studies on the relationship between seed size and viability indicated that seed viability increases with the increase in seed size (Murthy, 1973; Hedegart, 1974; Suangtho, 1980; Bhumibhamon *et al*, 1980; Kaosa-ard, 198la). For example, the average viability of teak seed in diameter classes of 0.9-1.0, 1.0-1.1, 1.1-1.2 cm and larger than 1.2 cm were 41, 53, 62 and 71% respectively (Kaosa-ard, 198la). The source and seed year also affect seed viability of teak seed.

Table 3: Variation in viability of teak seed collected from different forests in Lampang Province, Thailand.

Seed Sources	Viability %
1. Lampang 1 (Chae Hom)	84.3
2. Lampang 2 (Serm Ngam)	81.2
3. Lampang 3 (SPA 1947, Ngao)	79.2
4. Lampang 4 (SPA 1960, Ngao)	78.3
5. Lampang 5 (Mae Phrik)	77.7
6. Lampang 6 (Mae Tha)	72.3
7. Lampang 7 (Sop Prap)	71.2
8. Lampang 8 (Mae Tip, Ngao)	49.8
9. Lampang 8 (Muang)	46.2

Source: Janchai (1982)

3.3 Seed Germination

It is well known that germination of teak seed (under nursery conditions) is relatively low (25-35 %) and sporadic (between 10-90 days and extending over several years after sowing) (Bryndum, 1966; Hedegart, 1974; Keiding and Knudsen, 1974). Such germination behaviour of the seed causes a large variation in both quantity and quality of the seedlings in nursery production.

Several factors affect the germination of teak seed, including moisture, temperature and light.

According to ISTA (1976) the test conditions for teak seed germination are as follows: prior to sowing the seed is treated by alternate soaking and drying 6 times (3 days) and then spaced uniformly on moist sand and exposed to light. The germination temperature is set at 30°C. The first count for seed germination is after 14 days and the final count 28 days after testing.

Moisture: The level of soil moisture is very important in controlling seed germination. A study on the effect of soil moisture regime on germination of teak seed showed that the germination percentage decreased markedly with an increase in the soil moisture level, from 11% to 26.4%. The optimum range of soil moisture for teak seed germination is between 11 (or slightly lower) and 18% (with air humidity of about 70-80%). Above this upper limit (18%), the seed tend to deteriorate and eventually die (Suangtho, 1980).

In nurseries, the germination of teak seed is greatly affected by moisture condition. Bryndum (1968) reports the experience that by adding 6 mm of water on dry days during the rainy season, germination was increased from 20 to 50%.

It is accepted that soaking of the seed for 2-3 days or alternate soaking and drying several times before sowing is the most effective and appropriate pre-sowing treatment for teak seed (Wijesinghe, 1963; Murthy, 1973; Suangtho, 1980).

Temperature: The optimum temperature for teak seed germination is between 27-33°C (Ko Ko Gyi, 1972; Gupta *et al.* 1975; Suangtho, 1980). This is the normal temperature range in tropical countries.

Light: Light is also one of the most important factors controlling the germination of teak seed. Murthy (1973) showed that germination of teak seed decreases sharply (from 27 to 4.5 and 0.2 %) with a decrease in light intensity (from full sunlight to shaded room and dark room). Therefore, shading seed beds during the germination period will decrease the seed germination capacity.

The knowledge on germination behaviour of teak seed in this section can be used as a guideline for pre-sowing treatment and sowing techniques in nursery operation. This topic will be discussed in more detail in Section 7.2.

3.4 Sources of Seed

In general, a plantation establishment programme is divided into 3 stages: (1) species and/or provenance trials, (2) a conventional commercial planting programme and (3) a modern planting programme.

The first stage aims at discovering species and provenances that are suitable for the selected location. During this stage, a number of tree species for similar planting purposes or one tree species from a number of provenances (sources) are planted in the test plantations. Based on the results of the first stage, the promising species or provenances are identified for seed collection for use in a large-scale conventional planting programme. In the last stage, the seed used are from the genetically improved seed sources, e.g. seed production areas and seed orchards. The plantations in such a programme are superior in both volume production and stem/wood qualities than the plantations in the former programme.

The results of test plantations of teak in Thailand clearly demonstrate the importance of provenances or seed sources on growth and form of the plantations. The results presented in Table 4 show that although the planting site (Ngao, Thailand) is quite favourable for teak, the provenances or seed sources have shown a marked effect on growth and development.

Table 4: The effects of seed source (provenance) on growth and development of teak in the 7-year-old plantation in Ngao, Lampang, Thailand.

Seed Source	Height (m)	Diam. (cm)	Stem Straightness	Persistence	Mode of branching	Flowering
Score			0.4	0-6	0-4	0-5
Seed Production Area, Lampang, Thailand	12.6	47.2	3.2	5.3	3.0	4.1
Java, Indonesia	12.1	45.3	3.0	5.2	3.0	4.0
Phayao, Thailand	11.3	42.2	2.8	5.1	2.9	3.9
Tak, Thailand	10.9	41.3	2.7	5.0	2.9	3.9
Chiang Mai, Thailand	10.7	40.7	2.5	5.0	2.8	3.8
Mysore, India	9.0	38.4	2.4	4.8	2.8	3.5
Mysore, India	8.9	38.1	2.4	4.5	2.8	3.3
Maharashta, India	7.9	33.9	2.1	4.2	2.7	3.1

Source: Pinyopusarerk and Keiding (1981).

In Thailand, a map for teak seed zones was delineated (Kaosa-ard, 1983a) on the basis of the climatic condition (ratio between the annual rainfall and the annual mean temperature moisture index). The natural range of the species is subdivided into 4 climatic zones (Figure 4) for seed collection and utilisation.

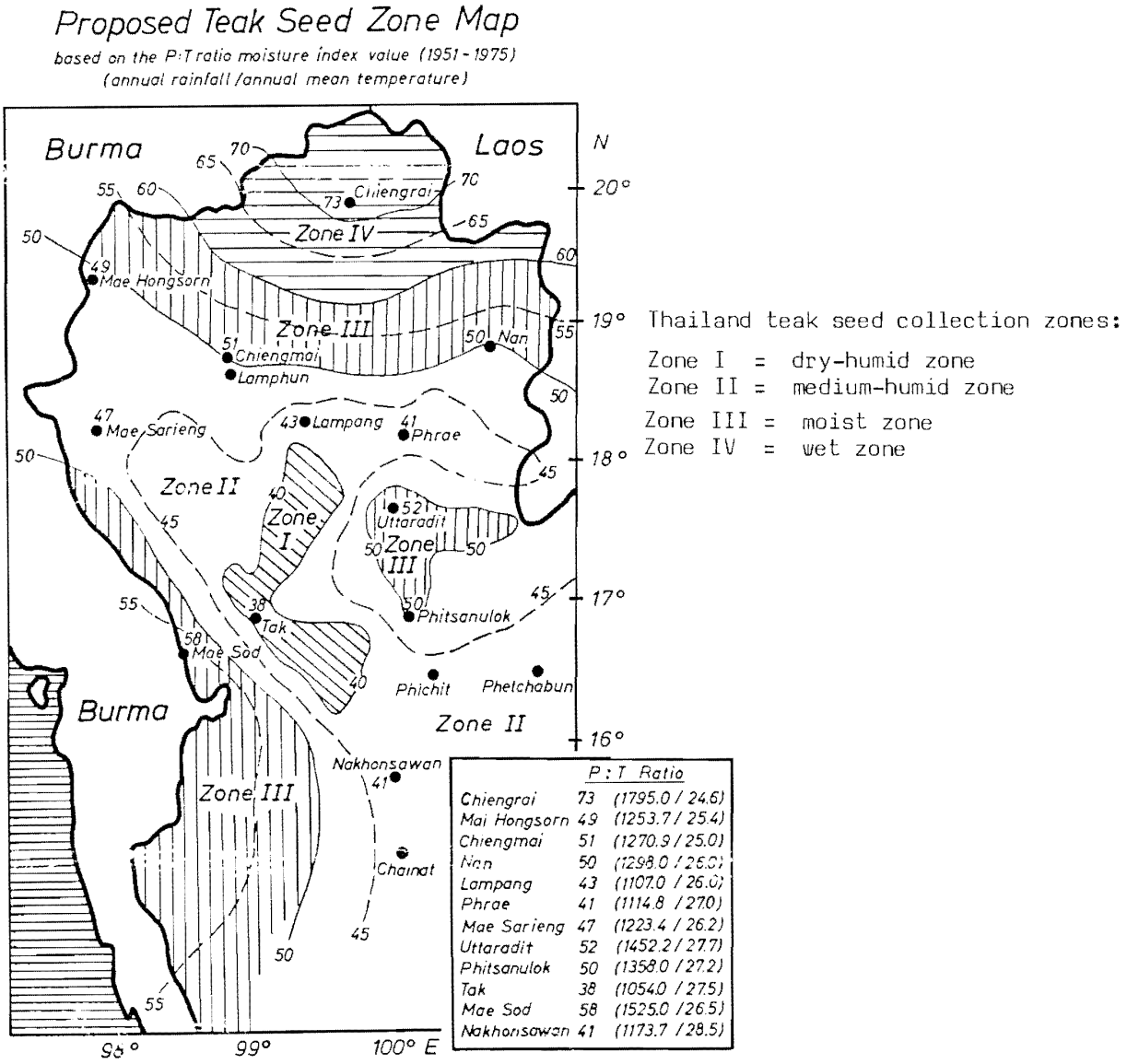


Figure 4: Teak seed zone map - Thailand

4. SEED COLLECTION

In general, teak seed is collected off the ground and the time for seed collection (in Thailand) is between March and April, i.e. after the monsoon storms. Since the demand for teak seed has increased rapidly, collection of seed from standing trees has become more common especially in seed orchards, i.e. to obtain earlier and larger amounts of seed. The disadvantage of this practice is that there is a great risk of obtaining immature seed, which is generally low in germination potential and longevity, especially when long-term storage is required. Techniques used for the judgement of seed maturity and/or fruit ripening of the species are, therefore, necessary.

A series of studies on seed collection times at the TIC indicates that:

(1) it takes about 45 days after pollination for teak seed to develop to full size (Figure 5).

(2) it takes about 70-150 days for a fruit of full size to reach maturity.

(3) the period for teak seed collection is between January and May (Figure 6).

Based on these studies it is recommended that teak seed should not be collected before January.

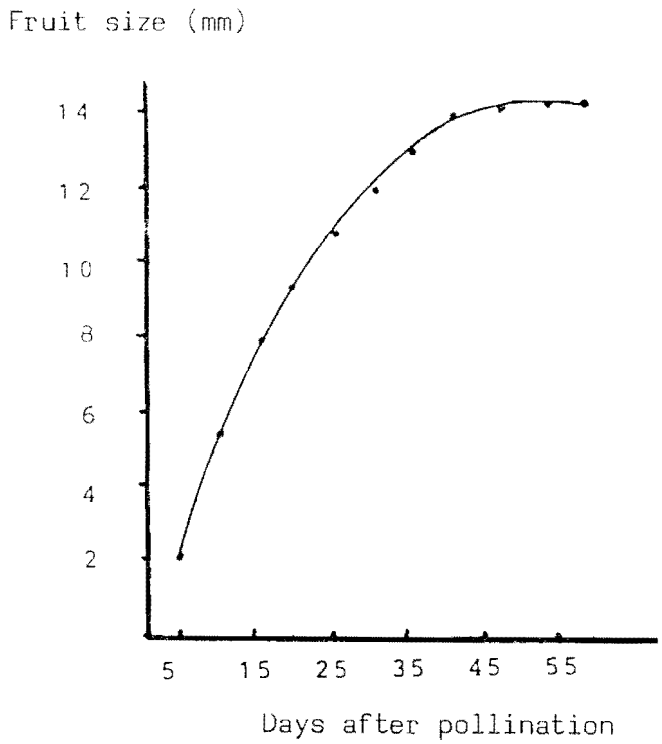


Figure 5. Development of teak seed after pollination (Source: modified from Hedegart 1973)

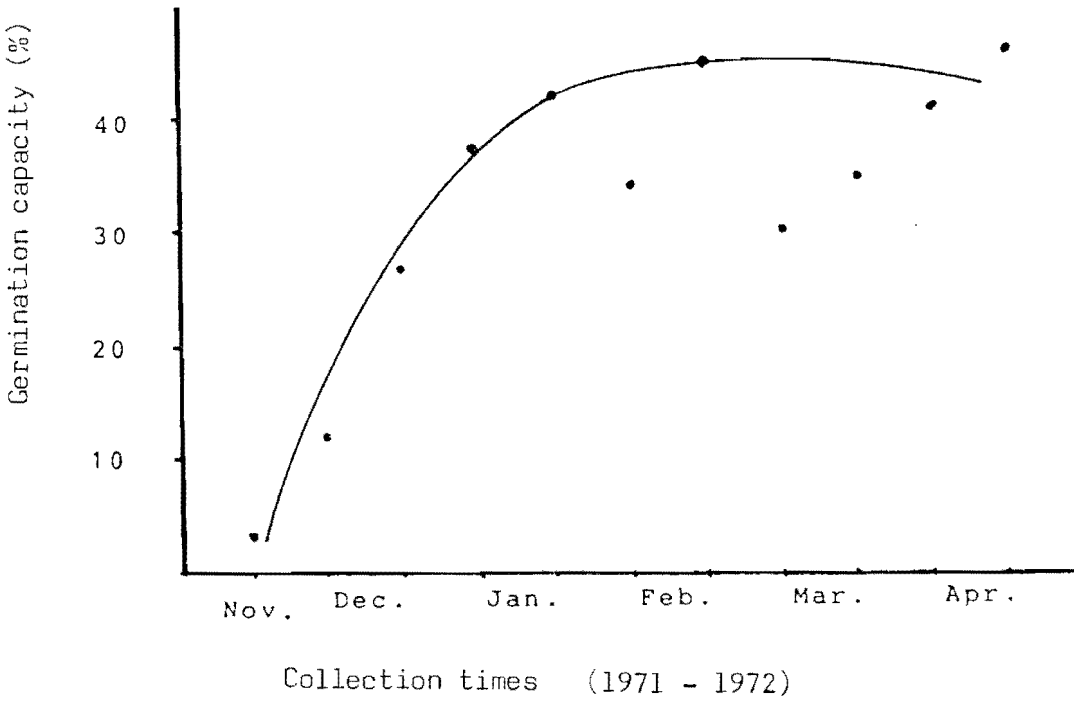


Figure 6. Germination capacities in relation to time of seed collection. (Source: modified from Hedegart 1973)

5. SEED PROCESSING AND STORAGE

After collection, the fruits are sun-dried for 2-3 days and later placed in polyethylene or cotton bags. Then the crispy skin (pericarp) of the fruit is removed by squeezing and/or beating the bag. The skin is then separated from the fruit by blowing and screening.

Due to the shortage of seed for large-scale planting programmes, storage of teak seed is usually short-term (1 to 2 years). In this type of storage the seeds are kept in the sacks (about 45 kg/sacks) and placed in a room protected from termites and rats. The stored seed should be labelled indicating their source, date of collection and other biological records.

For long-term storage (2-5 years), the seed to be stored must be well dried and clean. It is kept in plastic sacks (about 25 kg/sack) and placed in a well insulated seed store. For very long-term storage (longer than 5 years) a cold storage is necessary. Long-term (cold) storage is used only for special purposes such as for progeny and provenance tests, gene bank, conservation etc. A series of studies on long-term storage of teak seed at the TIC gave the following results:

(1) Teak seed cannot be stored safely even for 1 year in a moist condition and without any special protection.

(2) Teak seed can be stored safely for 2-5 years in sealed plastic bags and glass jars and placed in ordinary rooms.

(3) Teak seed can be stored safely for 2-5 years in sealed plastic bags and placed in a cold store at a temperature between -4°C and +4°C.

(4) Teak seed can be stored safely for 2-5 years in cotton bags and kept in a cold store at a temperature between -4°C and +4°C.

However, the result of these studies is confined to a small amount of seed because the capacity of the cold store is limited. Further large-scale seed storage experiments are required. The theoretical background and techniques of seed storage have been described by Harrington (1959), Barner (l975b) and Willan (l984).

The objective of teak seed testing is to identify the quality of seed in relation to seedling production. In general, the qualities to be tested include:

(1) purity,
(2) determination of seed weight and/or volume,
(3) seed viability and/or germination.

The above tests are sufficient for guaranteeing seed quality in nursery production. Further details on the techniques and evaluations can be found in ISTA (1976, 1981) and Willan (1985).

6. TEAK NURSERY

6.1 Types of Teak Nursery

Teak nurseries can be operated as:

(1) temporary nurseries or
(2) permanent nurseries or nursery centres.

A temporary nursery is usually established in a situation where the teak plantations are scattered, e.g. in enrichment planting and social forest planting programmes, or when plantations are distant from one another. The advantages of a temporary nursery are as follows:

(1) It is easy to establish and maintain because of the size.
(2) There are fewer problems on soil fertility, weeds, diseases and insects, because it is usually in operation for only a few years.
(3) The cost of transport of stumps from the nursery to the planting site is reduced because it is normally located near the planting site.
(4) There are no requirements for mechanization and various modern equipment.
(5) The initial investment requirement is relatively low compared with what is needed for a nursery centre. A temporary nursery, however, is not designed to produce and supply stumps for a large scale planting programme and the cost of stumps production is relatively high due to low output.

Figure 7: A small-scale teak nursery (TIC, Thailand)

A permanent nursery or a nursery centre, on the other hand, is suitable for large-scale planting programmes. It also supplies stumps for a large number of small local planting programmes. A nursery centre allows more economic application of modern machines and equipment such as farm tractors, machines for ploughing, disk harrowing, seed bed preparation, drill-sowing, lifting of seedlings, irrigation system, and stump storage facilities. The semi-mechanization or full mechanization system in nursery operation will yield millions of seedlings of uniform size. The unit cost of seedlings produced from the nursery centre is lower than the seedlings from the temporary nursery. However the initial cost of investment for the establishment of a nursery centre is very high and the depreciation of soil fertility over the years requires additional inputs.

Figure 8: A large-scale teak nursery (FIO, Thailand)

6.2 Site Selection

In section 2 (p. 2-4) the influence of the environmental factors controlling the distribution and growth of teak has been discussed in detail. To reiterate, the optimum conditions for teak growth and development are:

1. Alluvial and well drained soil
2. Annual rainfall between 1,200 and 1,600 mm
3. Rainfall distribution about 6 months
4. Soil pH between 6.5 and 8.0
5. Soil with relatively high calcium and phosphorus content
6. Temperature between 27° - 36°C.

Apart from the above conditions, there are a number of factors which need to be taken into account when selecting a site, especially for the nursery centre. These factors are as follows:

1. The nursery should be located where transport and other communication facilities are available.
2. The area must be flat and large enough for a 3-year rotation operation i.e. one year for seedling production, one year for seed-bed preparation and seed-sowing operation and the remaining year for soil fertility recovery.
3. The nursery must be located in an area where water is available throughout the year.
4. The nursery should be located in an area where labour is easily available.

It should be kept in mind that the cost of physical infrastructure of a nursery centre is very high at the beginning, e.g. buildings, road and irrigation system construction. Therefore, alternative sites should be compared and the site for nursery establishment must be carefully selected.

7. NURSERY OPERATION

After a suitable site has been selected, the next steps are land clearing, site preparation, surveying, mapping and planning for land allocation for various activities and functions. These could be areas for nursery beds, offices, residential and other construction work such as roads, offices, garages, store rooms, seed storage buildings, buildings for stump preparation and storage. The details of nursery layout and civil structures have been discussed by Aldhous (1972).

7.1 Land Cultivation and Seed-bed Construction

In teak nursery operation, seedlings will be left in seed beds for at least one year before the stumps are produced.

To prepare seed beds, the nursery area is first ploughed (with a 3-disk-harrow) to break and level the soil. The ploughed area is left to dry for a few days and reploughed twice (with a 7-disk-harrow) in a cross-direction to refine the soil and to remove the debris. After ploughing, the seed beds are then thrown up either by workers or by machine. The teak seed beds are 1.10-1.20 m in width and 50-100 m in length. The length of seed beds depends on the shape and size of the nursery areas. The working space between the seed beds is 30-50 cm.

The total area of the nursery beds depends largely on the efficiency of nursery operation (i.e. the capacity of seedling production per unit area of the seed bed) and the amount of seedlings to be produced. In Thailand, experiences gained at the FIO teak nursery centres and at the TIC indicate that the optimum number of plantable seedlings in nursery beds is about 25-30 seedlings per square metre. That is about 160,000-190,000 seedlings per 1 ha of nursery (the width of seed bed is 1.10 m and the space between seed beds is 50 cm).

7.2 Pre-sowing Seed Treatments

It has been discussed earlier that germination of teak seed is generally poor and sporadic. This usually causes a large variation in size of seedlings and a poor seed utilization efficiency (number of plantable seedlings from 100 seeds sown) in nursery operation. This germination behaviour is greatly affected by the two seed factors, i.e. seed viability and seed dormancy. To improve the germination of teak seed by means of pre-sowing treatments, the following factors should be taken into account.

Seed Viability Screening: In general, there is a large variation in seed viability (45-85%) among seed lots (sources). This causes some problems in nursery operation, e.g. amount of seed requirement and the sowing rate. To overcome these problems, both the dead and the empty seed should be discarded in order to raise the viability of the seed lots (reduces variation). At present, there are no practical techniques such as blowing and floating techniques which will identify or remove both the dead and the empty teak seed. There are indications that seed size and seed viability in a given seed lot are closely related, i.e. larger seeds have higher viability percentage. Therefore, by removal of small-seed fractions which consist of a large portion of aborted and insect damaged seed, the viability percentage of the remaining seed fraction will be largely increased. However, to identify the exact size of low viability seed fractions for removal is quite difficult because the seeds from different seed lots (sources) are usually different in size. For instance,

seeds from dry sources are generally smaller than seeds from moist sources. In practice, the low-viability seed-fraction of a given seed lot can be evaluated by grading and cutting tests. In this technique, a seed sample is taken from each seed lot and graded into 5-6 diameter classes. The seeds from each class are sampled (100 seed/sample) and cut for their viability examination. The results of the cutting test will indicate small-seed fraction(s), which has viability lower than 10%, for removal. To remove the small-seed fraction, the whole seed lot is screened (using the round-opening type screen) by hand or by machines. The techniques of seed screening have been discussed by Turnbull (1975) and Willan (l984).

Seed Dormancy: Under nursery conditions, the germination of teak seed starts 10-15 days after sowing, reaches its peak value in 35-45 days and then decreases steadily to 80-90 days. In general, the germination percentage of the seed (in the first year) is about 35%. The ungerminated (but still viable) seeds will maintain viability and germinate in the following year(s) when conditions are favourable. This germination behaviour is due to dormancy. The real cause of teak seed dormancy is still unknown. However, three main factors have been found to influence seed dormancy: (1) seed structure, (2) seed maturity and (3) seed biochemistry.

The seed structure, i.e. the thick corky mesocarp and stony endocarp, may prevent the entry of both water and gas to the seed to initiate its germination process. It may also restrict an expansion and development of the seed embryos if the conditions are not really favourable.

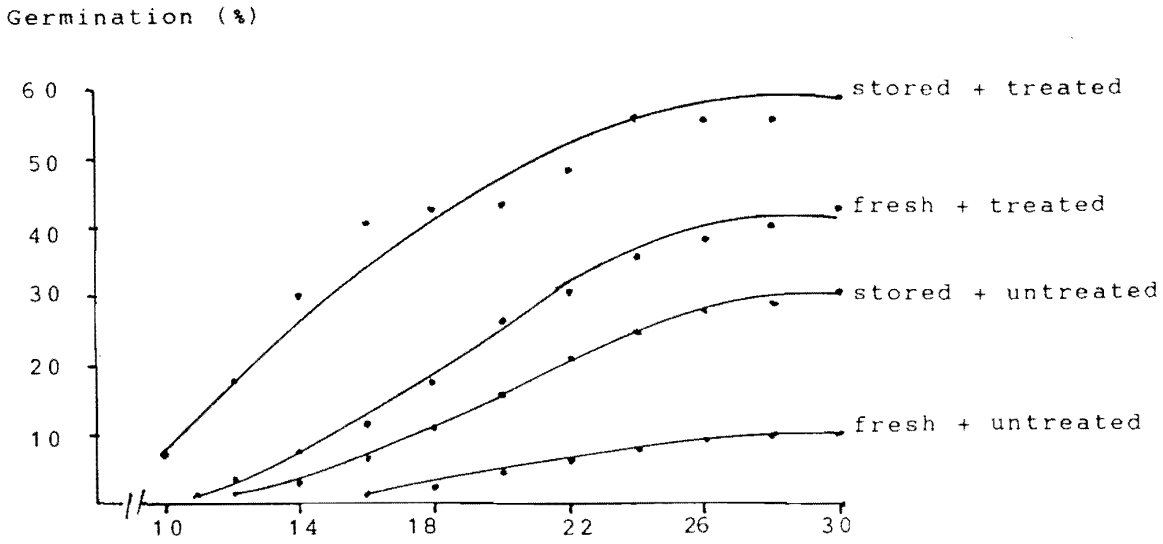
The conditions of seed embryos such as seed maturity (Gartner, 1956; Bryndum and Hedegart, 1969; Joshi and Kelkar, 1971; Hedegart, 1973), post-harvest storage conditions of the seed (Troup, 1921; Kimariyo, 1973; Murthy, 1973; Suangtho, 1980) and genetic constitution (seed source or provenance) (Kermode, 1957; Ko Ko Gyi, 1972; Keiding and Knudsen, 1974) are also found to greatly affect seed dormancy in teak.

The content of water-soluble chemical substance in the mesocarp of teak seed has also been found to be inhibitory to seed germination (Ponoy, 1980; Fairlamb and Davidson, 1976).

To improve germination of teak seed by means of breaking the seed dormancy, these factors and their combinations should be considered.

Several attempts have been made to improve the germination of teak seed by means of pre-sowing treatments (Troup, 1921). These treatments can be grouped as (1) water treatments (e.g. seed soaking, soaking in running water, alternate soaking and drying etc.), (2) chemical treatments (e.g. acid and hormonal treatments etc.), mechanical treatments (e.g. cracking the mesocarp and endocarp, removal of the seed mesocarp etc.), (4) heat treatments (e.g. scorching of the seed with low fire, boiling and dry-heating at different temperatures and for different periods etc.), (5) other treatments (e.g. fermenting, burying in pits etc.) (Suangtho, 1980; Keiding, 1985).

Based on these treatments it has been concluded by Suangtho (1980) that (1) there is no method that particularly affects seed germination; (2) the results of the same or similar pre-sowing seed treatment varied from one study to another; (3) none of the most effective methods have been developed into practical techniques for a large-scale nursery operation. A series of studies on seed germination conducted by Suangtho (1980) showed that treatment of the seed by dry-heating either at 50°C for 1-5 weeks or at 80°C for 48 hours was the most effective method in improving seed germination. (Figure 9). In his studies Suangtho (1980) reported that the treatment increased germination percentages between 2 to 5 times depending on the seed lots (e.g. seed sources, seed years and storage periods after seed collection).



Days after sowing at 33/28°C day/night temperature

stored = 1-year stored seed
treated = 80°C for 48 hours
fresh = unstored seed

Figure 9: Effects of heat treatment on germination of teak seed.

Figure 10: Seedlings in nursery beds (FIO, Thailand). (sowing rate: 1 litre/sq.m).

Figure 11: Profile of seedlings in nursery (showing growth competition)

Based on the results of Suangtho's studies (1980) there is a possibility of developing an appropriate technique for a large scale pre-sowing seed treatment. Fruit or cone drying kilns may be used for this type of seed treatment. The types ard operating techniques of drying kilns have been intensively discussed by Turnbull (1975) and Willan (1984).

7.3 Seed Sowing

Sowing Time: The time for seed sowing affects both seed germination and seedling size. In general, the sowing period of teak seed is between May-June, i.e. at the beginning of the rainy season. However, in a large-scale nursery operation the seed sowing activity should be completed before the first heavy monsoon rain in the middle of April. This is to facilitate machine operation during the dry period but also to take advantage of warm and moist conditions during April-rain, which will allow better seed germination.

Figure 12: Seed sowing by machine (drill sowing), FIO

Sowing Rate (Density): In open nursery production, the rate of seed sowing or sowing density directly affects the cost of nursery operation (e.g. amount of seed requirement, land cultivation and seed-bed preparation, seed sowing and tending of nursery seedlings) and seedling growth. Denser sowing will yield a larger proportion of seedlings of small or under plantable size (< 1.0 cm diam. at ground level) as a result of competition. On the other hand, sparse sowing will produce seedlings of over plantable size (> 2.0 cm).

The optimum rate of seed sowing depends upon many factors, such as

(1) characteristics of seedlings and spacing requirement;
(2) seed viability and germination behaviour;
(3) survival rate after germination; and
(4) sowing techniques.

In general, the optimum sowing rate and the amount of seed requirement can be roughly estimated by using the following modified formula:

$$R = \frac{P}{S \times G \times U}$$

where R = sowing rate (litre/sq.m or kg/sq.m)
P = no. of plantable seedlings per sq.m.
S = no. of seeds per litre or per kg.
G = germination capacity (G %/100)
U = plant percent (U%/100)

(U = number of plantable seedlings per 100 seeds sown).

For example, in estimating the sowing rate of teak seed (R) given the values of P, S, G and U as follows:

P = 30 seedlings/sq.m
S = 500 seeds/litre
G = 35% (0.35)
U = 20% (0.20)

$$R = \frac{30}{500 \times 0.35 \times 0.20} = 0.86 \text{ litre/sq. m}$$

The effects of sowing rate on seedling growth, efficiency of seed utilization are presented in Table 6 demonstrating that:

(1) the efficiency of seed utilisation increases (from 3.9 to 20%) with a decrease in sowing rate (from 3.0 to 0.2 litre/sq.m.);

(2) the requirement of seed bed area increases (from 1.8 to 5.0 sq.m/100 seedlings) with a decrease in sowing rate (from 3.0 to 0.2 litre/sq.m.).

Table 5: Sowing rate of teak seed in relation to seedling production, seed and area requirement of seed beds.

Sowing rate	**100**	**400**	**1,500**	**seeds/sq.m**
	0.2	**0.8**	**3.0**	**litre/sq.m**
spacing	10 x 10	5 x 5	2.5 x 2.5	cm
germination (60 days)	40	45	46	%
total no. seedlings (223 days)	40	118	175	
no. plantable seedlings (223 days	20	46	57	
seed utilization	20	11.5	3.9	%
To raise 100,000 seedlings				
seed requirement (approx.)	1,000	1,800	5,100	litre
(500 seeds/lt.) seed bed area (approx.)	5,000	2,200	1,700	sq.m.

Source: Teak Improvement Centre (Experiment no.2, 1965)

In nursery practice, where the seed from ordinary seed sources are used and sown without any special pre-sowing treatments, the sowing rate of 1 litre/sq.m (about 500 seed/sq.m) appears to be the optimum rate and this rate has been adopted and practised in the RFD and FIO nursery centres in Thailand. When seed from improved seed sources, e.g. seed production areas and seed orchards, is used in connection with a seed pre-sowing treatment, this rate of sowing must be reduced in order to maximize the seed utilization percentage.

Sowing Depth: After sowing, the seed should be covered by some material such as soil, sand, sawdust or rice-husk (1) to protect the seed from being washed away by rain or during watering; (2) to protect the seed from rodents and other animals; (3) to retain soil moisture for the germination process; (4) to protect the germinating seed from exposure to sun light.

The thickness of covering material has direct effect on both seed loss and seed germination. If the seeds are not adequately covered, they can be washed away easily. This is due to their structure which is round, light and corky. On the other hand, if the seeds are too deeply covered especially with soil or sand, their germination capacity will be reduced drastically. A study on the effects of sowing depth on seed germination and seedling production (Kaosa-ard and Wisetsiri 1980) reported that there was a negative relation between the sowing depth (0-4.5 cm) and germination capacity of teak seed (Table 7). That is, the deeper the seed sown the poorer the seed germination. Moreover, the number of seedlings produced (plant percentage) also decreases greatly with an increase in the depth of seed sowing.

Table 6: The effects of sowing depth on germination and seedling production of teak seed.

sowing depth (cm)	**germination (%)**	**number of seedlings from 100 seeds sown**	
		(60 days)	**(1 year)**
0*	51.2	64.2	56.0
1.5	16.2	19.2	16.0
3.0	5.8	6.2	11.0
4.5	0.5	0.5	0.5

* sowing at 0 was done by pressing the seed down until the seed surface was at the surface level of the seed bed.
Source: Kaosa-ard and Wisetsiri (1980)

Although the results in Table 6 show that sowing at the surface level (0 cm) of the seed beds gives the highest germination percentage, it is very risky to practise under nursery conditions because (1) the seeds will be washed away easily and (2) a large amount of the germinating seeds will be uprooted and/or directly exposed to the sun. Therefore, the seeds must be covered with material after sowing. The material used for covering seed beds after sowing should be light and/or porous. Moreover, it should be free from disease and insects and also be non-toxic to the germinating seeds. In Thailand, the most suitable materials used are rice-husks and its ash (charcoal-like). Sawdust is also often used but it should be used with care because it may introduce disease and increase the acidity of the soil.

In nursery operation at the TIC, the seed is broadcasted on seed beds (1 litre/sq.m) and covered with about 2-3 cm of rice-husk. The germination is about 35-45 % and the production totals about 25-45 seedlings/sq.m. In the FIO nursery centre, where a machine is used for seed sowing (drill sowing with average 1 litre/sq.m.), the seed in drills (about 3 cm in depth) is covered lightly with soil by the same machine. The seedling production is about 25-30/sq.m.

8. TENDING OF NURSERY

After sowing, nursery tending begins immediately and continues until seedlings are ready to be lifted for planting. The activities include watering, weeding, top-dressing, pest control and fire protection.

8.1 Watering

In general, watering in teak nurseries does not seem to be very important because most of the activities concerning seed sowing and tending of seedlings are in the rainy period (May-October).

However, in some locations with short dry-spell periods in April-July, i.e. during the seed germination and seedling establishment period, watering is still very essential. During these dry-spell periods, seed beds must be watered to maintain both soil moisture and air humidity. In a large-scale nursery an irrigation system such as overhead sprinklers can be very useful, whereas in a small-scale nursery manual watering such as can-watering is quite adequate. The importance of watering during the dry-spell period after seed sowing has been well documented in the various TIC studies.

8.2 Weeding

As mentioned earlier, teak is a light-demanding species. Therefore, weeding in a nursery is one of the most important activities in teak nursery operation. In general, weeding in a teak nursery will be conducted 4 times, i.e. before sowing; after germination; during growth and development of seedlings; and at the end of the growing season.

The first weeding (before sowing) is usually conducted by spraying herbicides such as alachlor (»Alanix«), paraguate (»Gramoxone«) and glyphosate (»Round-up«) to eliminate existing weeds and the sprouting of e.g. bulbs, rhizomes and roots and to reduce weeds during the period of seed germination.

The second weeding (about 60 days after seed sowing) is conducted to reduce competition during the early establishment of the seedlings. In this second weeding, the weeds are carefully uprooted by hand and removed from the seed beds.

The third weeding is usually done about 60-80 days after the second weeding to speed up growth and development of the established seedlings. During weeding, the top-pruning or top-dressing of the over-dominant seedlings may also be conducted as necessary.

The last weeding is conducted at the end of the growing season (December-January) for fire protection.

In all weeding stages, the spaces between seed beds are also weeded either by spraying of herbicides or by manual weeding.

8.3 Top Dressing of Seedlings

In general there is a large variation in height and diameter growth among seedlings in nursery beds. The causes of this variation are (1) the uneven germination of the seed and (2) the competition for light among seedlings. To reduce this variation by reducing competition among seedlings, the top dressing or top pruning of seedlings in nursery beds is required. In this practice, most of the over dominant and dominant seedlings are top cut by using knives or garden shears to open space for growth and development of the suppressed seedlings. This activity is usually conducted at the same time as the third weeding.

8.4 Pest Control

Diseases: The outbreak of diseases in teak nurseries does not occur frequently. This is because (1) the teak nursery is an open nursery receiving full sun light; (2) the nursery is operated on a rotation basis; and (3) nursery watering will be conducted only during the dry-spell periods. However, if the conditions are favourable for the outbreak of disease, such as too moist and too dense, two kinds of disease, i.e. damping-off and leaf disease (leaf rust and powdery mildew) may occur.

To protect teak nurseries from the outbreak of these diseases: (1) the materials used for covering seed beds should be dry, unfermented and free from disease; (2) the nursery bed area should be well drained especially in the middle of the rainy season; (3) nursery weeding should be done properly; and (4) when the outbreak occurs, fungicides such as »Benlate«, »Cuprox« etc. must be used immediately.

Insects and Other Animals: Insects and other animals can also cause certain problems in teak nurseries. During the seed sowing, seed germinating and seedling establishment periods both seed and seedlings should be protected (e.g. by trapping, poisoning etc.) from rats, rabbits and other kinds of rodents. During the growth and development period of seedlings, there are two types of insects, i.e. the leaf skeletonizer (*Pyrausta machaeralis*) and the leaf defoliator (*Hyblaea puera*), which can do most damage to the seedlings. They are the caterpillars (larvae) of the moths. Attacks of both insects can be controlled either by spraying insecticides such as »Sevin«, »Aldrin« or »Dieldrin« or by spraying commercial bacteria such as Bacillus thuriu-genensis. Termites may also cause a lot of damage to nursery seedlings especially in the dry season. They normally feed on the seedling taproots and the attacked seedlings will eventually die. To control termites, the seedlings are watered (by watering-can) with insecticides such as »Aldrin«, »Dieldrin«, »Chlordane«, »Heptachlor«.

8.5 Fire Protection

Fire protection seems to be very important in teak nurseries especially in the hot dry period (January-April). The danger from fire should not be overlooked because the seedlings shed their leaves. At this time the nursery bed area is full of dry teak leaves, which is a good fuel and a cause of seedling destruction by fire. To protect nursery seedlings from fire, weeding and cleaning of nursery bed areas should be done properly before the dry period. Various measures for fire prevention (fire lines, fire watchers) and fire suppression may also be needed.

9. PREPARATION OF STUMPS

9.1 Lifting and Stumping

Lifting and stumping of teak seedlings from nursery beds is generally conducted during the planting time, i.e. May-June. However, in nurseries where a long-term stump storage is practised, this activity will be conducted in the dry period (February-March).

Lifting of nursery seedlings can be done by hand (digging/pulling) and by machine (a lifter). Hand lifting is commonly practised in teak nurseries especially during the planting period because the soil is wet and about 800-1,000 seedlings can be lifted per man/day. Machine lifting is very practical in a nursery centre where millions of seedlings are to be lifted within a few weeks. This is especially the case when the seedlings are lifted for storage in the dry period. However, the disadvantage of machine lifting is that every seedling (both big end small) in nursery beds will be lifted and a large proportion of small seedlings may have to be discarded.

Figure 13: Stump preparation (TIC) Thailand)

After lifting, the seedlings are transported to a stumping shed. To prepare a stump for planting, the stem part of a seedling is cut off at about 3-5 cm above the root collar, leaving 1-2 pairs of buds for sprouting and developing into a new plant. The lateral roots are all trimmed off close to the taproot.

The main taproot is also cut off if longer than 15 cm. The optimum length of stump is between 15-20 cm and the taproot is the major part of a teak planting stump.

After preparation, stumps may be graded (according to their diameter at the root collar) and bundled by using a rubber band or a bamboo split (50 stumps/ bundle) for storage or for transport to the planting sites. Teak stumps have been classified by the TIC into 3 grades for the purpose of planting and storing. These grades are:

(1) small (but still plantable) stumps (7-9 m diameter at ground level);
(2) optimum size stumps (9-15 m);
(3) big stumps (>15 mm).

The small stumps should be planted out into the field soon after they have been lifted and prepared, whereas the bigger classes can be stored for a longer period before planting out. To grade stumps, the instrument (made of plastic or wooden board) illustrated in figure 14 is used.

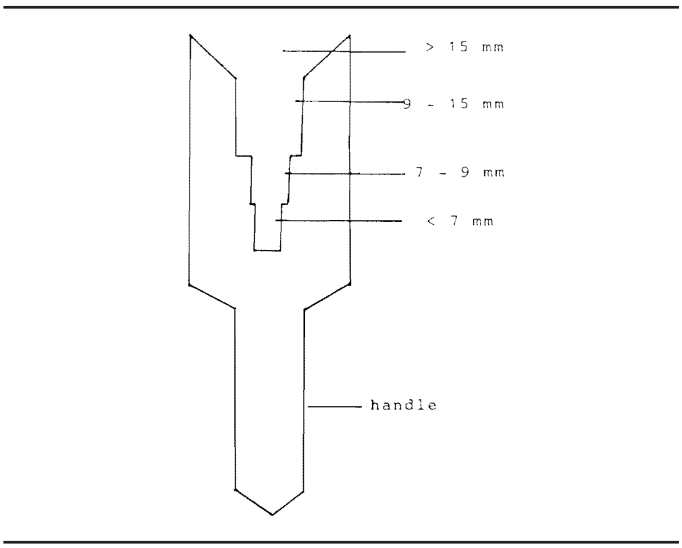


Figure 14: Instrument used for the grading of teak stumps.

9.2 Stump Storage

There are two types of storage of teak stumps before planting out, i.e. short term and long term storage.

9.2.1 Short Term Storage

A short term or temporary storage (1-3 weeks) of teak stumps is commonly practised in teak nursery operation. The purpose of this storage is to protect stumps from drying and rotting or losing their sprouting ability. In this type of storage, the stumps (in bundles) will be kept in the shade and covered with moist sacks. A regular spraying of water may be needed if the weather condition is too dry or too hot.

9.2.2 Long Term Storage

A long term (4-6 months) storage of teak stumps is usually practised in nursery centres. The use of this type of storage is as follows:

(1) To improve the efficiency of nursery operation by shifting some activities such as lifting/stumping of seedlings from the peak (April-June) to the off-peak (January-March) period of nursery operation.

(2) To facilitate planning for distribution of stumps because the amount of available stumps can be checked during lifting/stumping and storage.

(3) Planting of stored stumps can be done at any time when the conditions in each planting site are favourable.

(4) Surplus stumps can be kept for a longer period and used for re-planting.

(5) In terms of survival and growth potential, the stored stumps perform better than freshly lifted/ prepared stumps in poor and dry planting sites. Under good conditions (e.g. steady precipitation and good weeding) there is hardly much difference between stored and routine stumps. Under less favourable conditions (e.g. dry periods, less weeding, late in the planting season) the advantage of stored stumps becomes evident. The further away the conditions are from optimal the greater the advantage of stored stumps.

The long term storage of teak stumps was first initiated by the TIC. A series of studies on stump storage was conducted during a period of 1972-1975 and their results have been reported by Lauridsen (1973), Lauridsen and Kaosa-ard (1973), Kaosa-ard and Lauridsen (1974). The conclusions of these studies are that:

(1) stumps can be stored safely for a period of up to 9 months in an under-ground store (pit store).

(2) to obtain better growth potential in the field, February-March (the dormant period of teak seedlings) is the most favourable period for lifting/stumping of nursery seedlings and storage.

(3) April-May (after the first heavy monsoon rains) is the most favourable period for planting of the stored stumps.

Figure 15: Storing of teak planting stumps (FIO, Thailand)

On the basis of these studies, a practical technique of stump storage was developed by the FIO nursery centre in 1975-1976 and has been adopted since. This storage technique covers 4 major issues, i.e. storage building, storage medium, storage procedure and maintenance of stumps during storage.

9.2.3 Storage Building

A storage building is constructed to cover the underground stores (pit-stores). To avoid flooding during the period of heavy rain, it should be located on a well drained area and trenches should be dug around the building. Inside the building, underground stores are constructed with bricks or concrete to protect against soil moisture. The size of the store varies depending on the amount of stumps to be stored. In general, the optimum size of each underground pit used in the nursery centres is 2 x 5 x 1 m (width, length and depth) with a storage capacity of approximately 45,000 stumps.

9.2.4 Storage Medium

The most suitable medium used for covering and protecting stumps from drying during storage is fine and dry river sand. It is inexpensive and free from diseases and insects, whereas sawdust ferments when moist.

9.2.5 Storage Procedures

The most suitable time for lifting and storage of teak seedlings is in February-March (the dormant period). During this period the seedlings will have a high sprouting and growth potential which can be maintained under suitable storage conditions (Kaosa-ard, 1977).

Lifting/stumping and storage activities must be conducted only during dry conditions (no rain). If the nursery is wet, stumps tend to sprout and deteriorate during storage.

After lifting/stumping, the stumps are tied together into bundles by thick rubber bands. Each bundle contains about 50 stumps.

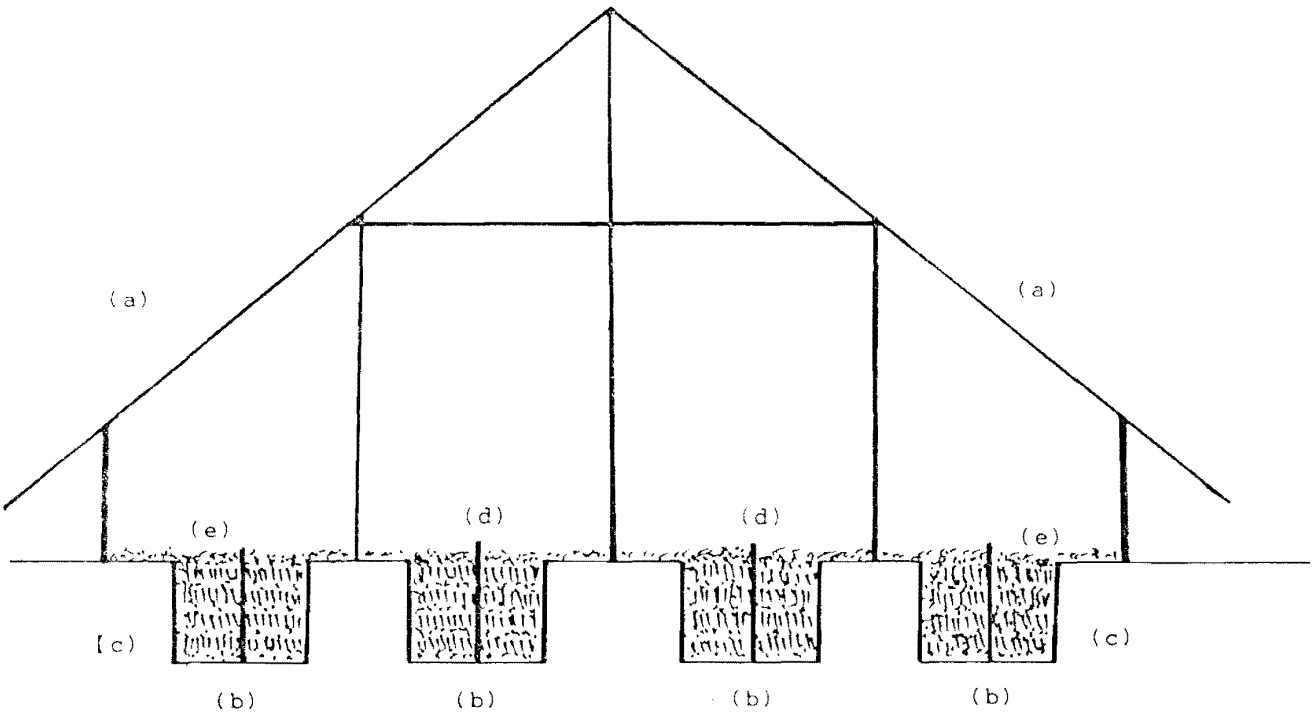
To store stumps, the store is first filled with a layer of sand (about 10 cm thick). The stump bundles are then placed vertically in the store with a spacing of 10 x 10 cm. They are then covered with 10 cm of sand. The second layer of stumps is then placed. This procedure of placing the stumps is repeated until the store is full, leaving about 30 cm at the top to be filled with sand. While the stumps are being layered, two pipes (made of cloth or non-insulated material) are also buried vertically in each store. The purpose is to insert a maximum/minimum type thermometer for measuring the temperature inside the store during storage. The cross section of a storage building is illustrated in Figure 16.

9.2.6 Maintenance of Stumps During Storage

During storage, the temperature inside the stores are observed daily. The temperature should be constant between 25-30°C. If the temperature is higher than 30°C, the stumps should be removed, left for cooling overnight and then placed into the store again. Heating of stumps during storage is caused by many factors and the most important factor is the condition of the seedlings during lifting/stumping. If the temperature inside the store exceeds 50°C, most of the stored stumps will rot.

9.3 Shipment of Stumps

Stumps (freshly lifted or stored stumps) ready for transport to the planting sites should be well protected from drying. They should be kept in sacks labelled with their seed source. For a long trip, the sacks should be filled with moist sawdust.



(a) storage building
(b) underground stores
(c) stored stumps
(d) cloth pipes
(e) fine sand

Figure 16: A cross-section of a stump storage building.

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