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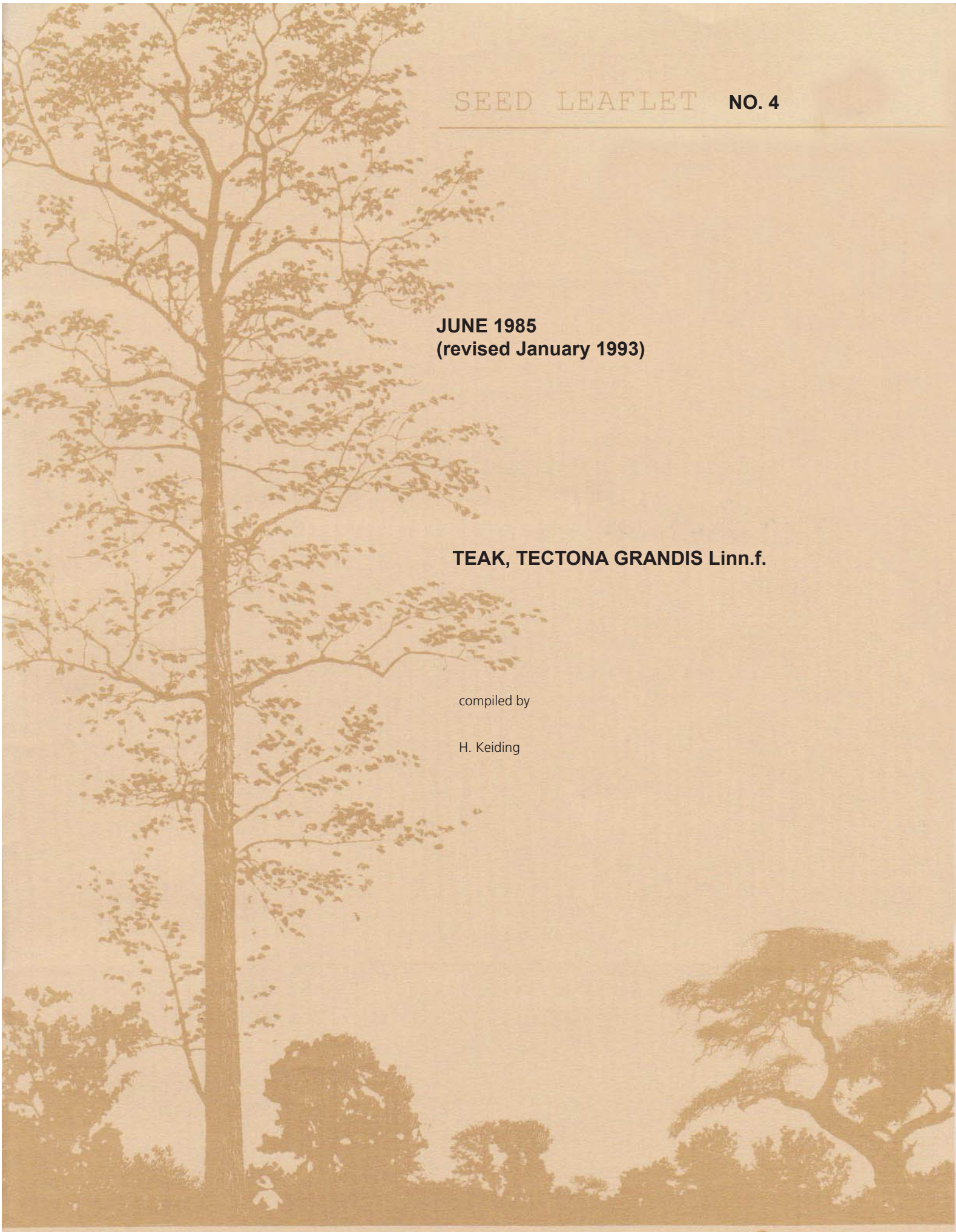

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(revised January 1993)

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H. Keiding

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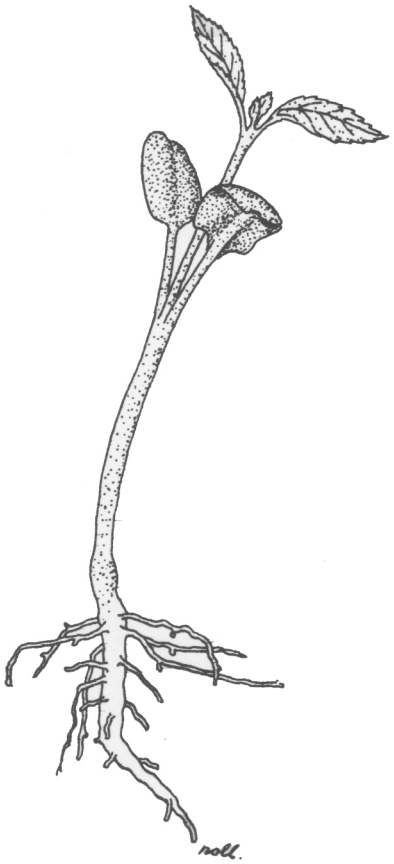

1. INTRODUCTION

Sources of Information

The information for this leaflet has been sought and compiled mainly from sources available at the Danida Forest Seed Centre (see 10. References) supplied with personal experience and from consultations with specialists on the subject.

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2. NOMENCLATURE

Botanical name:	Tectona grandis, Linn.f.
Synonyms:	None
Family:	Verbenaceae
Common names:	India: Sagun (Hind.); Tegu, tegina (Kan.); Thekku (Tamil); Burma: Lyiu; Thailand: Mai Sak; Indonesia: Djati; Mali: Fati; France: Teck

3. THE TREE

Size and growth habit

A large deciduous tree which, under favourable conditions, may reach a height of 30-40 m. In dry habitats growth becomes more stunted and branching more widespread and bushy. On good sites clear boles of 15-20 m or more can usually be obtained, as lower branches are shaded out in competition. Fluting and buttresses are often found at the base of older trees.

Bark: thick, grey or light greyish brown, fibrous with shallow longitudinal fissures, peeling off in long, thin, narrow flakes on older trees (Troup, 1921)

Leaves: large, i.e. 25-50 cm in length and 15-35 cm in width, elliptic or obovate, upperside rough, green to dark green, underside dense stellate with grey sometimes whitish to tawny tomentum (matt wooly hairs). Leaf position opposite.

In its natural habitat teak occurs in mixed, deciduous forests in a number of different forest types, normally constituting a small percentage of the total number of individuals, but occasionally in almost pure stands.

Natural distribution

Within S.E. Asia, the Indian sub-continent, Burma, Thailand and the western part of Laos. It is naturalized in the eastern part of Java. Northern limit is latitude 25°N (Burma) and southern limit 9°N in India. Teak's longitudinal limits are 70°-100°E. Within these limits the occurrence is discontinuous, the teak forests being separated by mountain ranges, plains, farmland and other types of forest.

Variation and improvement

Growth and growth habits show great variation according to site conditions and are mainly demonstrated at the population/provenance level. Although attempts (Bor, 1939) have been made to identify and describe varieties, only one (the Teli variety from India) seems to be recognized. In provenance trials, variation has been observed in morphological characters such as leaf size and colour, bark type, branch size and branching habit, flowering and fruits. It is usually possible to distinguish between Central Indian, Thai, Indonesian and certain of the African (landrace) origins in such trials, but only in very broad terms, as individual tree variation is considerable and sometimes overshadows the between-provenance variation.

Thus there is a good basis for improvement by provenance/individual tree selection, which has led to improvement and breeding work being carried out in many countries.

Seed is now available from registered sources, selected seed stands and from clonal seed orchards. Although seed from improved sources is gaining in importance, the quantities still cover only a relatively small percentage of the total consumption.

Importance for forest plantations

Teak is widely planted in the monsoonal climate of S.E. Asia, in West Africa, to some extent in Central America, East Africa and Oceania, plus, on a smaller scale, in numerous other places with a seasonal tropical climate.

Teak's importance as a forest-plantation species is clearly demonstrated, although its adaptability to different sites has been a little overrated.

Main Uses

Teak is one of the most versatile timber trees, being used for both heavy and light construction work, housebuilding, carpentry, furniture, wood carvings etc.

4. REPRODUCTIVE BIOLOGY

Flowers

The flowers are small (6-8 mm in diam.) whitish and bisexual. i.e. complete with stamens and pistil. They appear in large panicles containing up to a few thousand flower buds which open only a few at a time during the flowering period of 2-4 weeks.

Figure 1: Young inflorescence, partly developed (1).
Single flower enlarged (2).
Drawings by Finn Stubsgaard

The corolla is undivided at the lower half which forms a tube to which 6 or 7 stamens are fixed. It contains a small amount of nectar. The pistil is composed of an ovary with 4 ovules and a style with a forked stigma (Bryndum & Hedegart, 1969). The pollinating agents are different insects (Hedegart, 1973).

Age of trees at first flowering

This varies considerably depending on site, climate, silvicultural management and genetic background.

In climates where teak has a fast juvenile growth, e.g. high forest zone of West Africa, flowering and seeding may occur 2 years after planting. Other factors are involved as explained below.

In teak's natural habitat, e.g. India and Thailand, flowering may start 6-8 years from planting, sometimes even later.

The size or height of the trees generally seems to have greater influence on initiation of flowering under plantation conditions than age. However, on marginal sites flowering may also be initiated early on smaller trees as a reaction to adverse conditions. In drier areas of India, the so-called "teakpole areas", there is an abundant seed production.

Teak shows great individual variation in both initiation and amount of flowering and seed production. It has been proved to be a strongly hereditary character. The early flowering experienced in "landraces" of West Africa and Trinidad is most probably due to a persistent collection of seed from early flowering trees and prolific seeders.

Main season for flowering

This is the rainy season starting about a month after the first rains. In the monsoonal climates it generally means June-July. In areas south of the equator, for example in Papua New Guinea flowering takes place in February-March, and in Indonesia in January.

Periodicity of flowering

Teak usually flowers every year, but with varying abundance. Damage to flowers and seed has become more widespread with the extension of plantations, at least in some regions, and may influence seed production.

Pests and diseases harmful to flowers

In Thailand, flowering and fruit-setting of teak is greatly disturbed by defoliator insects, especially in plantations, seed production areas and seed orchards (Kaosa-ard, 1985, pers. communication). The larvae of *Pagyda salvaris* (Pyralidae) has been observed causing serious damage to the flower buds, preventing their development into fruits (Hedegart, 1975). Other insects (not yet identified) damage the developing fruits by making holes in them and thus reduce their germination capacity.

Season of seed maturity

The fruit attains its full size in approximately 50 days, but is not really mature until 120 days after fertilization. A sign of maturity is that fruits can be shaken from the tree or better still have fallen to the ground by themselves (Hedegart, 1973).

The fruit and seed

The fruit is a hard, irregularly rounded drupe (dry type stone fruit) containing 4 seed chambers, which are surrounded from inside by the following layers: 1) a stony endocarp, 2) a thick, felty, brown mesocarp and 3) a thin papery exocarp, formed from the persistant calyx. When fruits are collected from the ground, the latter will often have fallen off or have been burnt in ground fires.

The seeds are oval in shape and measure about 6 mm in length and 4 mm in width. Only rarely have all 4 seed chambers fully developed seeds, the normal number being 1-2. Seeds may be extracted by force by cracking the hard

endocarp, but this has only been done on an experimental scale so far.

Thus the unit for handling is actually a fruit which, for practical and conventional reasons, is termed "seed" if nothing else is specified.

The teak fruit varies in size from 5-20 mm in cross section, the most common size being between 11 and 17 mm.

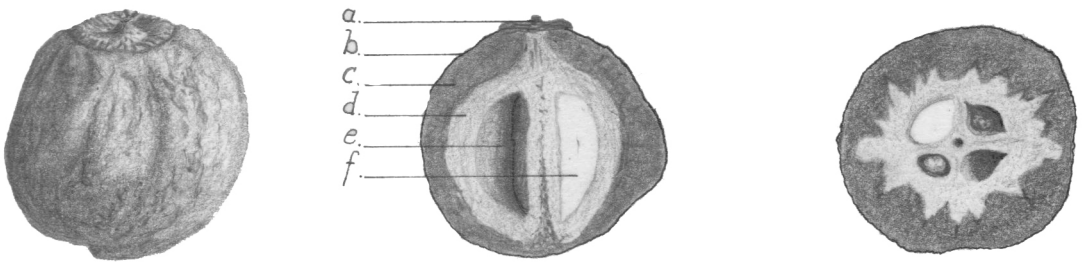

Figure 2: Teak fruit shown with lengthwise (I) and crosswise (II) sections.
a: fruit scar, b: exocarp (not seen in picture), c: mesocarp,
d: endocarp with seed chamber (e), f: seed.
Drawings by Finn Stubsgaard

Germination

The seeds normally germinate on the ground (epigeal) by sending radicles through cracks of the hard endocarp. The cotelydons emerge a little later from the same cracks and consist of two small (about 1 cm long) ellipt and fairly thick seed leaves, which usually are covered with hairs that become red on touching. The normal leaves, in opposite arrangement, come out one to two weeks later. See frontispiece.

The germination generally starts 10-12 days after sowing, but may be spread over varying lengths of time. See later. However, and again speaking in general terms, the majority of seedlings will have appeared within 40 days.

Dormancy

This is an important characteristic of teak seed which causes a number of problems. Dormancy appears as a delay in germination, a delay which varies from a few weeks to a year or even years.

The most immediate effect of dormancy is uneven germination. As teak plants are very sensitive to shade, later germinating plants will invariably be suppressed by the earlier germinated ones when the seeds are sown in the traditional way by broadcast.

In anyone seedlot coming from the same source there is an individual seed variation in speed of germination resulting in a successive germination over a period of up to 5-6 weeks, sometimes longer. In some instances where variation is greater, some seed may not germinate until the following year.

There are even cases of germination from the same seedlot taking place over 3 years.

However, the variation in dormancy is often much greater between seedlots from different sources than between individual seeds. This has been demonstrated most clearly in connection with provenance trials.

Attempts have been made to find correlation between the climate of the seed source and degree of dormancy in the seeds. Although seed from drier regions of teak's natural distribution seems to have a higher degree of dormancy, the correlation between annual rainfall and dormancy has not really been proven. Other factors play a part and according to Gupta *et al.* (1975) the most important ones seem to be (1) lack of soil fertility at the seed source site, i.e. nutrient deficiency and (2) presence of water-soluble germination inhibitors in the felty mesocarp.

Delay in germination may also be due to insufficient "after-ripening", a phenomenon which sometimes is classified as a kind of dormancy that may be broken solely by proper storage and time. It has been experienced that teak seed stored for a year or more often increases its germination percentage (Teak Improvement Centre 1974).

Dormancy may also, to some extent, be responsible for the low utilisation of the germination potential commonly experienced. When the viability or germination potential for a large number of provenances was estimated by cutting and tetrazolium tests, it was found by subsequent sowing in the nurseries that the germination percentage usually was much lower than indicated by the viability tests (Keiding & Knudsen, 1974).

Recent research seems to indicate that the main reason for dormancy in teak is mechanical resistance caused by the hard endocarp. The presence of inhibitors may be a contributory factor. Not all seeds absorb enough water to initiate germination, either because of difference in osmotic potential or because some seeds have more room to imbibe (Jœker &Vej rd, 1992).

The great difference between potential and realised germination is due to a number of factors. This is reflected by the many different methods of pretreatments. See p.12.

The complex nature of dormancy, and how to "break" it, is thus one of the major problems when dealing with teak seed in the nursery.

5. SEED/FRUIT COLLECTION

Choice of stand

Where possible, phenotypically good stands in plantations between the age of 15-45 years should be chosen as collection units. Conditions for seed production may be improved by proper thinnings which means giving the individual seed tree adequate spacing for crown development, and at the same time removing the least desirable phenotypes. The conditions for seed collection and control/protection of the stand will be improved by such treatments as clearing the forest floor and demarcating the area.

Collection in natural stands of mixed teak forests will rarely be feasible for practical forestry, while it may be important for research purposes (provenance testing) and for conservation. Some caution should be exercised when collecting from prolific seeders. Wolf and wayside trees, trees growing on marginal sites, and certain domesticated strains may all be prolific seed producers, but the genetic qualities are often less desirable. This is connected with teak's mode of flowering in which inflorescences are formed in the terminal buds. After flowering and the death of the inflorescence a fork takes over the terminal growth. Thus the first inflorescence will interrupt the 'persistance of the leader or axis' and thereby reduce the length of the bole. The earlier this happens in the life of the tree, the greater is the chance of a reduced quality of tree.

The possibilities for selection of stands for seed collection vary tremendously from teak's natural habitat (India, Thailand) to countries in which teak is introduced from one or a few sources (West Africa).

In order to provide the increasing areas of plantation with enough seed greater efforts will have to be made in organising seed supply. This implies, concurrently with the growing recognition of using the right seed sources, an intensified screening of available material with subsequent selection of seed production areas. In connection with choice of stand it will, in the initial phases, mean a certain restriction on collection areas and the introduction of some measures of control. The selection and improvement of seed sources may gradually be refined with the application of improvement programs and certification systems.

Forecast of seed crop

A reasonable estimate of seed crop has to be based on local experience, i.e. previous collections related to area and number of trees. Age of trees, environmental conditions and silvicultural treatment influence the average production of seed. Climatic fluctuations and insect/pest damage have an influence on the deviation from the average crop.

If no prior knowledge is available, some average figures from different situations may assist the forecast. In this respect reference is made to Barner & Olesen (1984), in which a more detailed account of seed crop assessment is given.

India

Seed production areas (S.P.A.), Andra Pradesh, mature trees 20 years, average annual yield: 4 kg/tree (range: 2-7 kg)

S.P.A., Topslip, Tamil Nadu, age of trees 43 years, average annual yield: 2.9 kg/tree.

Thailand

Plantations/S.P.A. stands > 20 years: 10-50 kg/ha
Seed orchards, 18 years: 7-10 kg/tree or with 50 trees per ha = 350-500 kg/ha

Source of information: Kaosa-ard (1985) who points out the apparent decline in seed yield from plantations and S.P.A.'s the last 20 years.

Nigeria

S.P.A. mature trees: 2-2.5 kg/tree/yr

Seed orchard, 8 years, 1973: 1.67 kg/tree/yr
1974: 4.14 kg/tree/yr

Indonesia

Plantations, graded seed: 25-33 kg/ha/yr

Except for the Indonesian figures, which are of older date and refer to seed graded according to size (> 14 mm) and the Thai seed orchard figures, there seems to be a fairly general agreement about 2-4 kg / tree /year for mature trees. Fluctuation in annual crops is illustrated in the figures from the clonal seed orchard in Gambari, Nigeria.

As seed is usually available every year, the forecast will mainly be of interest in respect of possible deviations. The immediate impression of abundance or sparsity of flowering may give indications of possible deviations from the average crop, provided insect or other damage to the flowers do not interfere.

Number of fruits/seeds per kg.

The following figures were derived from the provenance collections for international provenance testing 1971-73, and cover unsorted seed from 56 sources throughout the natural range of teak plus a few landraces.

Number of fruits	**per kg**	**per litre**
lowest:	1070	
highest:	3467	
mean:	2065	510

As each fruit may contain up to 4 seeds, but rarely have more than 1-2 fully developed ones, the number of seeds should be somewhat higher than the number of fruits. Usually only one seed per fruit manages to develop into a plant and therefore in practice, number of fruits and seed are considered the same.

Collection method

Teak seeds or fruits are nearly always picked from the ground. Only equipment required is a bag or tin. Where seeds from individual trees are required, the fruits may be shaken to the ground by climbing and shaking branches in the trees. To ease collection plastic sheets may be spread on the ground. In seed orchards, beating and shaking is the most efficient method. (Kaosa-ard, 1985).

The efficiency of collection depends on the ground conditions. If undergrowth or grass is present, it may be difficult to recognize the seed. Therefore, the ground in seed-production areas is usually cleared and sometimes burned.

Collected seed is transferred to a seed store, which may be of different construction, see p.12.

Timing of collection within season

The seeds/fruits fall in a period of about 3-4 months within the dry season. Seeds with the highest germination capacity and with the least damage to the seed are found at the end of the season (Eidmann 1934; Hedegart, 1975).

The potential of germination for healthy seeds picked at different times within the season is more or less the same but the first fallen seeds need more after-ripening and a longer period of drying than the later collected ones in order to give the same result in germination (Eidmann, 1934). The maturity, or readiness for germination, depends apparently on the length of time the fruits/seeds remain on the trees and is not improved by lying on the forest floor for 2-3 months during which time they are exposed to varying conditions.

Therefore, if seeds are collected only once from a certain area, say at the latter part of the seed-fall, it will not be possible to distinguish between earlier and later fallen seeds. To obtain the highest degree of utilization, seed should be collected at least in two rounds and the first collected batch given more intensive drying and more storage time before being sown.

6. SEED PROCESSING

Cleaning methods

The only cleaning needed is the removal of the thin papery exocarp (calyx) and possibly twigs, leaves and damaged seeds. The removal of the calyx, where it still remains around the seed, is easily done by rubbing or pounding the seeds and by subsequent winnowing from bamboo trays, separating the crushed calyx from the seeds. Damaged seeds refer to insect-damaged seeds, which in some cases may constitute a fairly large proportion. They are usually recognized by holes in the soft mesocarp.

Occasionally the soft felty mesocarp is removed from the fruits in order to improve germination. The weathering and thereby softening of the hard endocarp becomes more direct and at the same time possible germination inhibitors may have been taken away. Although some improvement in germination has been achieved, the effect of the treatment is varying. Mechanical potato peelers have been tried with promising results but only on a small scale (Hedegart, 1975) .

Drying

Before storage seed should be air dried until constant weight is obtained. Methods for actual measurements of moisture content of the seed are still lacking as the 'seed' in terms of handling is a fruit consisting of layers of different constitution. Very different lengths of time, from 3-4 days up to a month, have been stated (India) as necessary for sufficient drying. Again this is no doubt connected with local climatic conditions and timing of collection within season. Proper drying becomes increasingly important when longer storage is intended.

The seeds are usually dried in the sun.

Grading according to size

The practice of sorting the seeds according to size has been developed and applied in Indonesia since the early 1930' s. Eidmann (1934) particularly investigated the influence of seed size on germination and early growth of the seedlings. He found that bigger seeds, i.e. >14 mm, germinated faster or had better germination energy than smaller seeds and that the growth the first year therefore was better. As a consequence, seeds smaller than 14 mm in cross section were not used, which partly explains the relatively low figures for seed production per ha in Indonesia (see page 8) as these seeds make up about 40%.

The method of grading the seed in size classes was not described, but **if** the procedure is considered justified, it would be possible to use mechanical separators constructed for agriculture, furnished with suitable sieves. The greatest advantage in separating the seeds according to size would be the development of the young plants in the sowing beds. Bigger seeds will generally germinate faster and more evenly and thereby produce more equally sized plants. The lack of uniformity in seed beds of teak makes it

necessary to outplant, i.e. pull stumps, in two consecutive years and it very often results in a reduced utilization of seed and seedlings.

Smaller seeds, which in Indonesia means less than 14 mm in cross section, still have a germination potential more or less equal to the bigger ones, but they require longer after-ripening before they can be utilized (Eidmann, 1934). Thus, if grading of seed was combined with different storing/after-ripening procedures and sowing of different size classes in separate beds, a better utilization of the seed could be obtained (Verapong, 1980).

However, because of the variation in average seed size from different sources it will be very difficult to state the exact limits within which seed should be treated differently.

Grading may, if properly applied and combined with selective handling of different size classes, increase utilization of the seed considerably, but it does not solve all the problems. Therefore, pretreatments and sowing techniques have to be considered too. See p.12.

7. SEED STORAGE AND PRETREATMENT

The purpose of storage may be summarized as follows:

1. Compensation for uneven seed crops by reserving seed for years with low seed production. Particularly relevant for specified seed sources.
2. Promotion of germination capacity due to after-ripening.
3. Accumulation of samples for research and conservation.

Storage

Teak seed stores well and may keep its germination capacity for several years provided certain conditions are fulfilled, such as:

(1) Low moisture content before storage,

(2) Protection against fluctuations in temperature and humidity.

In this respect teak seeds are similar to many other tree species.

The special features about teak seeds influencing storage are their bulkiness, dependence on collection time within season and after-ripening, and dormancy phenomena.

Another factor determining the establishment of more or less elaborate storage facilities is the length of storage most commonly required. In practical forestry the major part of the seed is still used within one year after collection. This trend may change with increasing demand for seed and more requests for specified sources (origins).

The technical requirements for storage all aim at maintaining, or in some instances improving, the germination capacity of the seed.

Different storage treatments of teak seed may be summarized as follows:

a) No treatment, i.e. seed is piled in a convenient place near a nursery preferably in a shed or in a store room but not necessarily dried before 'storage'.

   Germination percentage may be maintained up to 6 months after which time it may drop to 50% or less the longer it is kept (Eidmann, 1934). Seed should be sown within 3-4 months from collection to be on the safe side.

   There is little scope for improving utilization in connection with storage.

b) Drying in the sun until constant weight and storing in airtight containers (tins, glass jars, double plastic' bags). Storage at dry, shaded and relatively cool place. Moisture content usually not measured but is probably about 12%.

   Germination capacity may be maintained up to two years (Vichien *et al.*, 1974). Some improvements can be achieved due to after-ripening effect. This accounts especially for seed collected early in the season and (perhaps) for the smaller seed sizes. Requirements: Special store rooms or buildings.

c) Storage at low, constant temperature, 0°-4°C, after drying to constant weight, i.e. cold storage. Packing material does not seem to matter very much although plastic bags proved to be better than cotton bags after 3 years' storage (Vichien *et al.*, 1974).

   Germination capacity may be maintained for 7 years or more. Cutting and Tetrazolium tests at the Danida Forest Seed Centre carried out for the same 23 provenances in 1973 and in 1980, respectively, showed on an average no decline in numbers of fruits with full seeds (cutting test) or with fully stained seeds (tetrazolium test). Individual provenances may vary and very few lose viability completely while many show an increase.

   Requirements: Specially constructed store rooms with careful and adequate insulation, refrigerators and stable energy provision.

Because of the bulkiness of teak seed and the high cost of installing and maintaining cold storage, the option described under b) will probably be the most widely applied method.

Seed pests and diseases

According to Mathur (1960) the following insect may damage stored seed:

Lasiodernus servicorne (Ausbiidae), but without doing serious harm. Usually no particular protective measures are taken against insect damage.

If stored seed is not properly protected, rodents may cause considerable damage.

Pretreatments

Because of the special characteristics of the teak fruits, in which the seeds are surrounded by a hard stony endocarp and a soft felty mesocarp, they require special treatment before sowing. To this should be added the after-ripening and dormancy phenomena. Due to the considerable variation in these characteristics both between seed lots from different sources and within seed lots from the same source, a number of different pretreatments have been applied/described (Murthy, 1973b). None of these are applicable for all types of teak seed, in fact different seed sources require different pre-treatments (Pattanath, 1980).

The problem is to decide on one pretreatment method amongst the dozen or more different ones tried and described (Murthy, 1973b) when the knowledge of the seed on hand in respect to its physiological state and dormancy usually is limited. It is characteristic for most methods that they have been developed locally, based on experience with seed from more or less the same sources over a number of years. Comparative and more systematic investigations with a range of origins from dry to wet climates are still lacking. This shortage of research will be increasingly felt the more teak is planted and seed transferred.

Although pretreatments may vary in length and intensity they all aim at softening the hard endocarp, removing or reducing the effect of the soft mesocarp and shortening the dormancy period. The goal is fast and even germination of as many seeds as possible. The treatments often have some elements in common and may be grouped as follows:

1. **Soaking in water**

   Seeds are soaked in stagnant or running water for 24-72 hrs. They may be kept in gunny bags or handled freely in basins or pits. 24-48 hrs are most commonly used. Sowing is performed immediately after soaking is completed.

2. **Soaking in water with alternate drying**

   Several variants of this method are in use, but the most common practice is 24 hours' soaking alternating with 24 hours' drying, the process being repeated for 2 weeks. The length of soaking or drying may be changed as well as the whole treatment period. No comparative trials exist to prove which is the best.

3. **Treatment with hot water and other media**

Hot water treatment is performed in two ways:

3.1 The seeds are soaked in water for 48 hours. The water is heated until boiling after which the seeds remain in the cooling water for another 24 hours.

3.2 The seeds are immersed in containers with boiling water for 15 minutes after which time the water is drained away. Hereafter the seeds are broadcast in germination beds for subsequent pricking out in polythene pots (Nigeria).

4. Pretreatment and pregermination combined

4.1 -Pit method: seeds are arranged in layers alternating with layers of straw or soil and green leaves which are watered for seven days. Germinating seeds are pricked out in prepared beds.

Variants of the pit method are developed for teak seed from dry regions. Depending on the length of the pretreatment period the method may be termed:

4.2 -"Weathering": Seeds may be placed in shallow concrete pits or on bamboo troughs (3.5 x 1.4 x 0.45 m) after collection and exposed to sun and rain from April to October. Germinating seeds during that period are pricked out, while the rest are packed in gunny bags in November and stored until next sowing season, i.e. in May the following year.

4.3 -The method described for Nigeria (3.2) also combines pretreatment with pricking out of germinated seeds into polythene pots.

5. Mechanical treatments with or without combination of soaking/ drying

5.1 -Scorching of seed in a light running fire.

5.2 -White-ant treatment. Seeds are placed near anthills with the purpose of letting the termites eat the mesocarp. Not a completely reliable method as it may not be possible to ensure uniform treatment.

5.3 -Kiln treatment (heating) for 7 days at 27°C and 70% humidity. Scope limited.

5.4 -Removal of the mesocarp may be carried out with grating machines. In Thailand a mechanical potato peeler has been used. In some instances germination was improved but on a large scale the method is hardly feasible.

The mechanical treatments are usually supplementary to the soaking/ drying ones in order to make the latter more effective.

A general prescription for the use of pretreatment methods is difficult to make for a number of reasons: some are related to the characteristics of the teak fruits; others to the scope of seed handling (research or plantations); and yet others again to different aspects of seed handling, e. g. drying, grading, storage.

Therefore, realising that precise information on the seed at hand in all these respects will usually not be available or, if it is, the combined effect of them may not be possible to foresee, one has to be content with a method that

generally has appeared to improve germination and which is practicable in the circumstances.

Such methods are to be found among the 'soaking' and 'soaking/drying' treatments, i.e. methods 1 and 2 previously described.

The best safeguard for obtaining a high utilization of seed would probably be:
Soaking treatment combined with pregermination and successive pricking out.

In this way the unevenness in speed of germination (germination energy) could be both reduced and circumvented.

8. TESTING OF SEED

Moisture content (M.C.)
The M.C. may be determined by the oven method in which a certain quantity of seed is dried and weighed. The problem with teak is that the actual seeds are enclosed by a hard and a soft seed coat and that the M.C. estimate, strictly speaking, refers to the fruit. For practical purposes the M.C. for seeds and fruit may be considered the same.

The most reliable estimate is, according to Madsen (1976), drying of the fruits at 103°C for 18 hours and comparison of weights before and after drying. Crushing of fruits is not recommended as this gives too low an estimate. Apparently dry seed stored for more than one year had an M.C. of 12%.

The method described above is the ISTA standard method prescribed for many kinds of seed.

There are so far no data available for M.C. requirements at different lengths of storage and relative humidities.

Viability percentage
Viability tests indicate the potential germination capacity of a seed lot. Provided this potential is properly utilized by applying the right pretreatment and sowing techniques, they also indicate the germination percentage.

For teak, however, there seems to be a fairly wide gap between number of viable seeds estimated by cutting and Tetrazolium tests and the actual germination obtained in the nursery.

Apparently the methods of preparing and treating teak seed for sowing have not generally been adequate for the full utilization of the germination capacity. There are several reasons for that, some of which have been dis-

cussed in previous sections, but the fact remains that the difference between viability tests and actual germination results shows the need for further studies of the germination mechanism and further development of methods to improve the germination.

1. Cutting test
The hard endocarp may be opened with a pair of pliers making it possible to examine all 4 chambers for seeds.

Only fully developed, healthy seeds, whitish in colour and filling the chamber are counted. If there are more than one good seed per fruit, only one is included in the calculation of viability percentage, which is the number of fruits with 1-4 viable seeds as a percentage of all fruits examined. The reason for following this procedure is that normally only one seedling per fruit emerges or develops.

The cutting test of 54 provenance samples from the international provenance trials gave percentages of sound (viable) seeds varying from 44 to 100% with an average of 78%. The actual germination percentages obtained at different locations were, although varying from place to place, generally much lower the first year after sowing and not always consistent with the figures of the cutting test. According to the Teak Improvement Centre (1974) the reliability of cutting tests may depend on pretreatment. No doubt other factors are involved as for instance dormancy.

2. X-ray radiography
In order to reduce the time and labour involved in opening the fruits mechanically the method of X-ray radiography may play a practical role. X-ray radiographs are photographic reproductions on special films of fruits after exposure to X-rays. The technique and procedure is described by Kamra (1973). With some experience in handling the apparatus and developing the films it is possible to distinguish between fully developed seeds, damaged or poorly developed seeds, and empty seed chambers.

Further advantages from using X-ray radiographs are (1) that more fruits can be examined simultaneously (approx. 60 fruits per film); (2) that the fruits are not damaged and may be sown afterwards; and (3) that records of the investigations can be stored on films and re-examined (Kamra 1973). However, only the morphological development of the seeds is recorded while the physiological soundness and the rate of dormancy still have to be evaluated. Until this has been achieved, we will find differences between the germination potential estimated by the above methods and the actual germination percentages.

The estimate of percentage teak fruits with fully developed seed by the X-ray method with results from 5 provenances from different rainfall origins (Kamra 1973) compares well with the average figures from the cutting test mentioned above, i.e. 69% for the X-ray method and 78% for the cutting test.

3. Tetrazolium test

Due to the difficulty of extracting or exposing the seeds from a teak fruit very few results of Tetrazolium tests are available or have been reported. No standard rules for judging the staining have been made by ISTA up to now (see ISTA 1976). Of the few records available reference should be made to a comprehensive test of the provenance samples for the international provenance trials in 1973 and again in 1980 at the Danida Forest Seed Centre:

The procedure was as follows:

A sample of fruits from each provenance was examined for full seeds until 25 fruits with 1-4 full seeds were obtained. The investigation for fully developed seeds was made by cutting slices of the fruit until the seed chambers were visible. For this purpose a small circular saw was mounted so that the individual fruits held in position by a pair of tongs could be cut into thin slices in the same manner as a sausage is in a butcher's shop.

The fruits to be tested were immersed in a 2% tetrazolium solution for 24 hours after which the recording of fully stained, partially stained and unstained seed was made.

The results may be summarized and explained as follows:

Table 1.

Year tested	Age of seed years	No. of provenance samples	Cutting test mean %	Range of cutting test %	Fully stained seeds mean % 1	Fully stained seeds mean % 2	Range-Type 1	Range-Type 2
1973	1-2	54	78	44-100	71	56	32-100	2-100
		23	76	56-100	73	55	29-92	18-85
1980	8-9	23	75	56-92	74	55	0-100	0-92

1. In row 2, a separate calculation is made for 23 provenances out of the 54. In row 3 (1980) a new test series was made for the same 23 provenances as in row 2.
2. Fruits containing 1-4 fully developed seeds are counted as one 'seed' .
3. Fully stained seeds, type 1: indicate proportion of fully stained seeds to number of well developed seeds tested.
4. Fully stained seeds, type 2: indicate proportion of fully stained seeds to the total number of fruits in the sample (with and without full seeds). These proportions are the most realistic estimates of the actual germination capacity, and they are calculated on basis of the percentage of fully developed seeds in the cutting test. Example: cutting test gives 76% full seeds. Of these again 73% are fully stained. In relation to total number of fruits with and without seeds, the proportion of fully stained seeds is 73% of the 76% which is 55%.

From the table it may be noted that both the cutting test and the tetrazolium test figures are almost identical for the same 23 provenances tested both in 1973 and in 1980. The seed, which has been stored under constant low temperature (+ 5°C), has apparently lost nothing in viability in the course of the 7 years.

Germination tests

Depending on the conditions under which the germination tests are carried out, i. e. routine testing in the field or experimental investigations in the laboratory, the following methods may be applied:

a) Field testing (quoted from TIC, 1974)

Fill a tray of appropriate dimensions, giving suitable space for say 100 fruits, with a 10 cm deep layer of sand. The sand may be ordinary river sand which has been sterilized by heating on a pan over a fire.

Place the fruits with the hilum, i.e. the flat or concave side of the fruit, downwards, and with the top level with the surface of the soil. Irrigation water should always be sterilized by boiling,

e.g. in used kerosene tins. Apply water so that the sand is moist all the way down. Place the tray under a frame covered with a transparent sheet of plastic.

Keep the sand moist all the time, but do not apply more than 6 mm of water in anyone day. On cloudless days ventilate at midday by elevating the frame some 5-l0cm. Observation and recording may be carried out at appropriate intervals, usually every 7th day, or more often if we are dealing with fast germinating fruits. The point is to use intervals of the same length.

At each date of observation the total number of fruits that have germinated is recorded. The number of new germinants in the period between assessments is obtained by subtracting the previous total from the present. This procedure makes it possible to register the germination percentage in different periods and thereby the germination rate.

It is advisable to record the germination on special forms (see TIC 1974).

b) Research

Experimental investigations will often have to be conducted under laboratory conditions and outside the tropical climate.

In these circumstances one of the most important factors is a constant temperature around 30-35°C as well as the maintenance of a moist germination medium. Light seems also required as well as some kind of pretreatment of the seed. Thus it is necessary to have access to stable electric power for running of thermostates and artificial light.

Standard prescriptions for germination of teak seed are given by Gupta *et al.*, India, 1975, and by ISTA, 1976. They are almost identical, differing only slightly in pretreatment of seed and in length of observation.

The Indian rules are stated below with the ISTA rules in brackets.

Germination medium:	sand
Temperature:	30°C
Light:	required for 8 hours per day
Observation starts:	14th day
Observation ends:	30th (28th) day

Pretreatment of seed:

1. Soak in water for 24 hours, wash and dry, or
2. Soak in Sach's nutrient for 4 hours and drying before sowing, or
3. (Repeated soaking and drying for 12 days).

In India enamel trays, 45 x 30 x 6 cm, are used as containers. Light is supplied with fluorescent bulbs for 8 hours a day. Other containers and sources of light may serve the purpose equally well. See Robbins, 1984.

9. NURSERY PRACTICE

This subject will be covered by Seed Leaflet, No. 4A.

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