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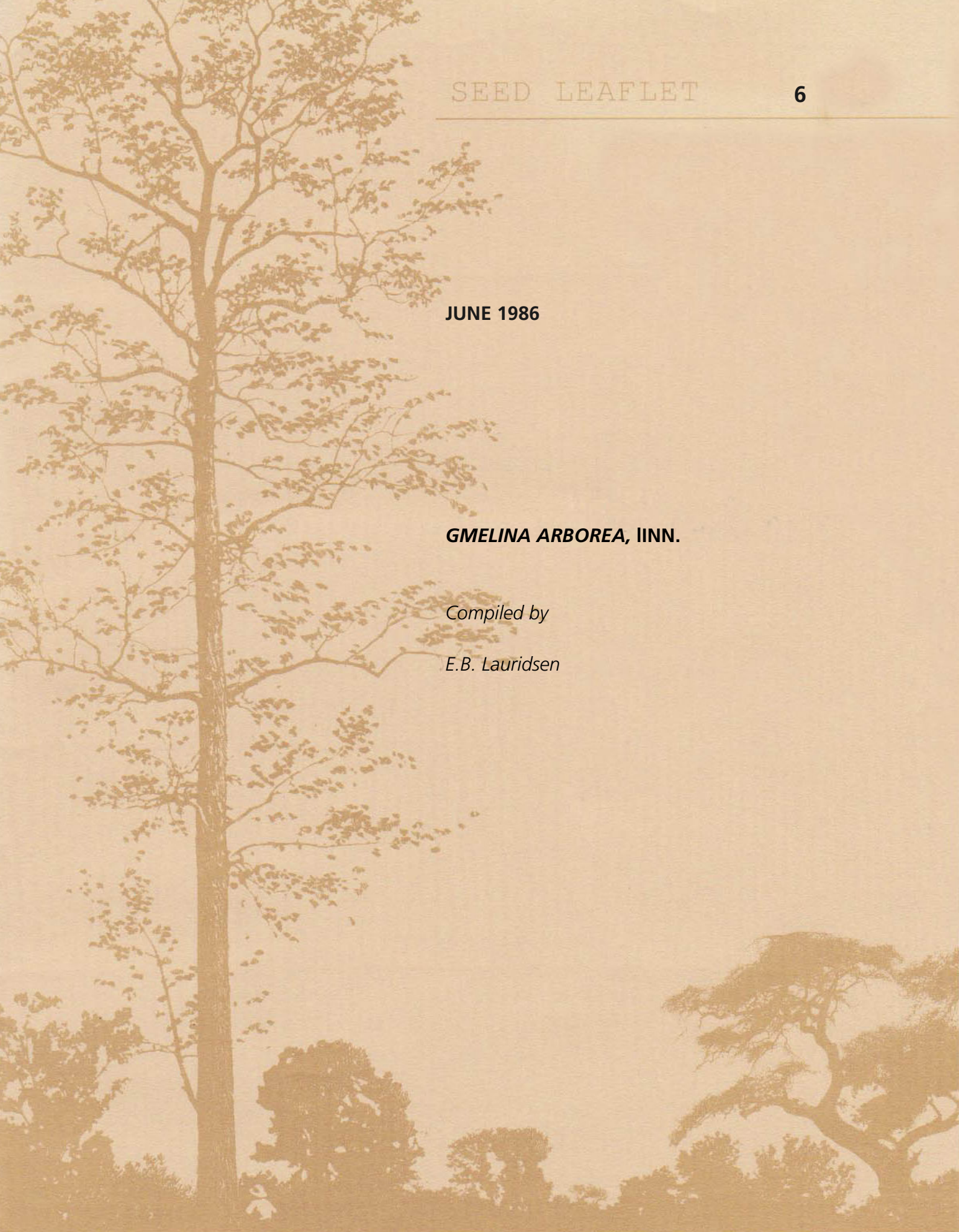

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Compiled by

E.B. Lauridsen

DANIDA FOREST SEED CENTRE

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1. NOMENCLATURE

Botanical name: *Gmelina arborea*, Linn.
The genus includes 8 species of which
Gmelina arborea and
G. molluccana may develop into trees.

Family: Verbenaceae

Common name: India: Gamari, Gumadi
Bangladesh: Gamar
Burma: Yemane

2. DISTRIBUTION

Lamb (1968): "The species extends from the lower Himalayan course of the river Chenab (West Pakistan) south east and south through India, Nepal, Sikkim, Assam, East Pakistan, Ceylon, through Burma to Thailand, Laos, Cambodia, Vietnam and the southern provinces of China (Yunnan and Kwangsi Chuang). (*Gmelina arborea* is found in Malaysia, Indonesia and the Philippines, but it is uncertain if its occurrence is natural there).

The tree is usually very scattered in occurrence becoming frequent only in moist localities in Burma and Chittagong. In drier regions such as the Punjab it is rare. It is most frequent in the mixed deciduous forests of Burma associated with teak (*Tectona grandis*), *Terminalia tomentosa* and various species of Bamboo. It is occasionally found in evergreen forests, it is not unknown in Sal (*Shorea robusta*) forests and extends into comparatively dry regions of Central India. In the Western Himalayas it ascends the outer hills and valleys to 4000 feet, where it may occasionally be seen in stunted form even in somewhat dry situations, (Troup 1921)." *Gmelina arborea* occurs in the natural forests at rates varying from less than one tree to up to 1000 trees per square kilometre.

From the beginning of this century *Gmelina arborea* has been introduced into many countries, and large plantations are found in South East Asia, West Africa and South America.

3. VARIATION

Two varieties or forms have been distinguished from the holotype:

- *G.a. glaucescens*, Hook. in sub-tropical Himalaya, Assam of North-East India, in Burma and Tenasserim (now Thailand). Distinguished by a glaucous underside of the mature leaves. Probably only the form of Gmelina arborea from moist places (Hooker 1885).

- *G.a. canescens*, Haines. in Bihar, Vest Bengal and Orissa of India. This variety or form has dense, simple hairs on the underside of the leaves.

No information has been reported on the genetic structure of naturally occurring populations of *Gmelina arborea*.

Substantial differences have been found between provenances in respect of growth, stemform (Lauridsen, Wellendorf and Keiding 1986) and wood density which varied with rainfall, latitude and longitude (Voessner 1980). Sixteen provenances differed in respect of fruit-stone, seed, and of leaf-size and petiole length for seedlings, with no geografic trend. (Arimah 1979).

Akachuku,1984, found important phenotypic variation among trees in respect of wood density and fibrelength. He estimated that a good part of the variation was genetic variation.

Rita Tang Ing Eng & Ong Seng Heng, 1982, found sufficient variation in wood density to warrant breeding for this character.

Local races, socalled "landraces" , may have evolved especially in Vest Africa. Provenances from Nigeria and Ivory Coast exhibit thus a much finer stemform than other provenances in an international provenance trial series.

4. REPRODUCTIVE BIOLOGY

The flower

The flowers are arranged in large, terminal panicles. The inflorescence branches several times with variation from tree to tree. Inflorescences on potted plants were found to branch only once (Okoro 1978). Bolstad and Bawa, 1982, report the number of inflorescences per tree - on 6-year old trees - to vary from 30 to 350.

The flower is large, up to 25 mm long, perfect, with an irregular 5-lobed tubular corolla, slender at the base and ventricose upwards, colour dull chestnut with yellow lip and throat, tomentose. The flowers are arranged in large terminal panicled cymes. The flower has four stamens, the style is slender, the ovary 4-celled, 4-ovuled (Hooker 1885). The flower hangs down when open, showing two small upper lips, two medium sized side lips and a relatively large lower lip, which curves upwards. The stamens are brightly yellow. Sometimes the two-celled anthers on the lower pair of stamens are level with and in contact with the stigma, sometimes the style is much shorter than both pairs of stamens, hence no contact between stigma and anthers (Okara 1978) sometimes the length of the style is intermediate to the length of the two sets of anthers.

Age of first flowering

Gmelina arborea starts flowering and fruiting at the age of three (Lamb 1968), and cuttings from adult trees may start to flower already in the nursery (Okara 1978).

Seasonal variation in flowering and fruiting

Flowering and fruiting are normally abundant every year for a stand as a whole, but is irregular for single trees.

In Asia in the natural distribution area flowering start s generally during the dry season when trees are leafless, i.e. from February onwards. Fruits mature from April onwards, and both continue well into July. In the Philippines fruits are collected from May to September.

In the Amazonian basin flowering extends over a 9-month period. Fruit-ripening start s in November and the peak fruit-fall occurs in January-February (Woessner 1979).

(The rest of this section an seasonal variation in flowering and fruiting refers largely to Okoro,1978, for Nigerian conditions).

Individual trees started flowering between August and November, with a

variation for single trees from year to year of not more than one month.

Flowering started as trees started to lose their leaves.

In one region with the highest rainfall - of four studied - same trees showed, over a 3-year period, each year two definite peaks of flowering - in terms of number of inflorescences - and some trees showed two peaks in one of the years only.

When there were two peaks, the first occurred in October and the second in March. Also, the flowering season was for some trees prolonged, sometimes running into the next flowering season, for others it ended consistently in June.

Peak-size varied from year to year, the first peak in a year was always the larger.

Flowering appeared - within a range of 4 degrees - to start earliest in locations at lower latitudes and latest at higher latitudes. Rainfall did not appear to influence the onset of flowering.

The peak or peaks of fruit production occurred about one month after the peak in flower production. The trees would then have lost the leaves.

Lifespan of inflorescences

Inflorescences with flower buds, developing flowers and open flowers would last from around 6-10 months an standing trees, and around 2-4 months on potted plants. All stages from buds to mature fruits would thus be present on an inflorescence during the major part of this period (Okoro 1978).

Flower, fruit and seed development

The inflorescence develops gradually during the flowering season. The older flowers are thus found at the base of the inflorescence.

The tiny sessile, white flower bud develops into a flower with all structures in around 12 days. The flower will open during the night, remain open for one day and then the corolla will generally drop off the following day. Same may remain an for up to two days (Okoro 1978).

Mature fruits would develop around 1½ month after the appearance of the white flower buds (Okoro, 1978). Bolstad & Bawa, 1982, report mature sized fruits 38 days after pollination.

The mature fruits may fall from the trees while still green. Woessner, 1979, found that the fallen fruits would turn yellow within a week's time. After about two weeks from falling the colour would have turned into brown and after about 3 weeks from falling many fruits would have become black. He found a relationship between fruit colour and seed maturity. Green fruits

would to same extent contain immature seed, which matured during the period where the fruits turned yellow. With change of colour into brown and black an increasing fraction of seed would obviously deteriorate. Figure 1 shows this development visualized by changes in seed germination capacity.

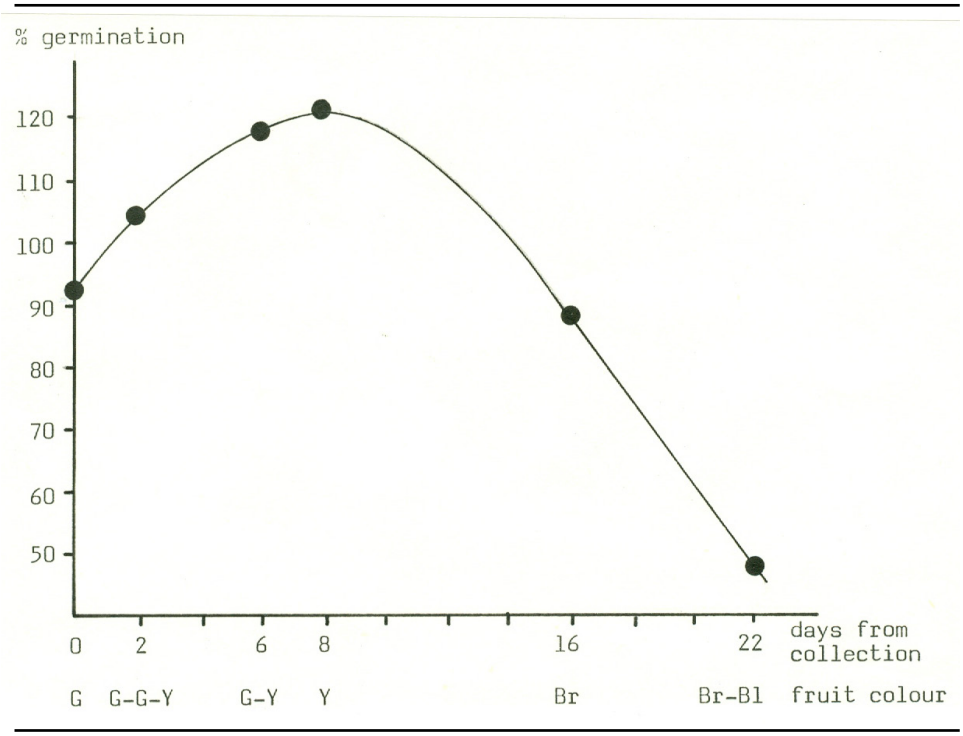

Figure 1: Relation of fruit colour and seed maturity to germination
(G = green, Y = yellow, Br = brown, Bl = Black

Pollination

Okoro,1978, found only few insects visiting the flowers, but was an the other hand doubtful as to the possibility of wind-pollinatian. Bolstad & Bawa, 1982, found the individual flower to excretenectar and to be adapted to pollination by medium-sized to large bees. Bees of the families *Anthophorida* and *Xylocopidae* were found visiting flowers during the part of the day when the stigma was receptive.

Pollen appears on the anthers during the farenaan following the night of opening of the flower, and would form a white ridge on the edge of the anthers (Okoro 1978).

Bolstad & Bawa,1982, found the stigma to be receptive from sunrise to 1300 hours of the day fallowing the night of the opening of the flower.

Okoro, 1978, found the style of pollinated flowers to fall off one day after the abscission of the flower, and the colour of the ovary to change from initially white, over purple to finally green.

Only a few fruits an each inflorescence developed ultimately into maturity (Okoro 1978).

Bolstad & Bawa, 1982, report less than 3 % of flowers on unbogged inflorescences developed into mature fruits obviously following open pollination by bees. Following cross-pollination by hand they found 58 % of the flowers pollinated to develop into mature fruits. Self-pollinated flowers aborted within a period of 15 days during which they had attained a size around half that of mature fruits from cross- or open-pollinated flowers. Ovaries from emasculated and isolated flowers aborted after 3 days without sign af development, i.e. no apomixis.

Bolstad & Bawa,1982, conclude that *Gmelina arborea* is self-incompatible or self-sterile. On the other hand, solitary and apparently isolated trees in natural forests, of India for example, have been found to fruit heavily (Lauridsen 1978). Self-fertilization may be a factor in these cases.

Diseases of flower, fruit and seed

In Asia *Chunrocerus niveosparsas*, Hemiptera, feeds on the sap of flowers and buds, and in Africa *Dysdercus supertitiosus*, Hemiptera, feeds on the sap of fruits (Greaves 1981).

Various sucking, defoliating or sceletonizing insects - apart from those killing trees – may also destroy buds, flowers or fruits in the course of their activity.

There are no reports an diseases attacking apart from the odd fungus that may damage germinating seed. (One root-disease, *Sclerotium rolfsii*, found in Sierra Leone, Gambia and Nigeria can be seed borne. Greaves, 1981).

Fallen fruits are devoured by game and cattle and may be destroyed in the chewing and digestion process. Seed may be destroyed by rodents or by ants and other insects entering through the stony endocarp where the pointed end has been broken off, see below.

The fruit and stone

The fruit is a succulent ovoid or oblong drupe, 20-35 mm in length, with a shiny, leathery pericarp and a sweetish, pulpy mesocarp.

The stony endocarp (the stone), from 10-25 mm in length, is smooth surfaced, undivided, with one round and one pointed end, and with 4 valve-like structures, see figure 2. The painted end of the stone is more fragile than the rest of the endocarp.

The stones vary considerably in size from provenance to provenance, within provenances, and within trees. The size of fruits from one particular tree may also vary considerably from year to year. Lauridsen,1978, reports thus for 39 provenances from mainly natural forests a range in the number of stones per kilogramme of 660 - 2820 with mean of 1580. Bowen, 1980, reports for 16 provenances of mainly plantation origin a range of 990 - 3000 stones per kilogramme with a mean of 1606.

The stone normally contains 4 seed chambers - rarely 5 - with dividing walls of a soft and porous structure. One or more of the chambers contain a seed, or sometimes a rudimentarily developed seed-structure, see figure 2. Figure 3 shows the average number of seed chambers filled with seed as found by Woessner, 1979.

Bowen, 1980, found seed size to increase with stone size, e. g. 6.5-9.3 mm seed length and 15.8-16.6 mm stone length, respectively. The number of seed chambers per stone varied from 2.7 to 3.6, and the number of sound seed per stone from 1. 3 to 2.7, with no obvious correllation bewteen the last two characteristics, or for any of them to stone size.

Germination

The germination of Gmelina seed is epigeous with the radicle emerging first and the cotyledons issuing shortly after. Depending on the position of the first germinating seed, the stone may be left in the ground or be pushed up (Troup 1921), and the conditions for possible remaining seed to germinate may thus be more or less favourable.

Seed in freshly collected and well treated fruits germinate readily and generally at high levels. Troup, 1921, states 90 %, Woessner, 1979, reports 122 % in the nursery and 187 % potentially (all seedlings per 100 stones). Gupta and Pattanath, 1976, report 187 % in the laboratory.

However, the germination is much depending upon conditions in the germination bed. Assuming optimal conditions, both temperature and light seem to affect germination. Gupta and Pattanath, 1976, found the maximum germination at a constant 30° C, whereas alternating day-night temperatures at 30°<-->20 °C resulted in zero germination, see figure 4.

Smith, 1978, found the optimal temperature regime between a constant 31°C and a constant 36°C. Constant temperatures below the optimal, i.e. 26°C, 21°C and 16°C, caused significant reduction in germination until near-zero and zero was reached at 21°C and 16°C respectively, see figure 5.

A day<-->night regime of 26°<-->16°C gave as high a germination as found for the constant temperature of 3°C. However, the length of the germination period was doubled.

After 30 days - when germination of the seed lots, kept at constant non-optimal temperatures, had ceased - the seeds were transferred to the near-optimal constant 31°C. All lots then continued or started germination, which reached essentially the same level as that of seed kept all the time at the near-optimal 31°C. It appeared further that the germination period was reduced for the lots kept initially at constant 16°C or 21°C, and that it was doubled for the lot kept at constant 26°C, all as compared to the lot kept at the near-optimal 31°C.

Figure 2: Appearance and structure of stones of *Gmelina arborea*.

a-f: Variation in size and shape of stones from one seedlot. Scale 1:1.
a: Complete stone.
b-f: Stones with the tender, pointed end torn off.
g-k: Cross section of stones.
h: Stone with dry fruit pulp (mesocarp).
i: Central cavity (5) with porous walls, exposed when pointed end is removed.
g: Note contour of valve.
k-l: Valves have fallen off during imbibition or germination thus exposing seed.
1: Seed.
2: Seed chamber with no seed or rudiment of seed.
3: Dry pulp
4: Stony endocarp.
5: Central cavity.

Smith compares this last result of reduced germination period with results obtained for seed kept in "imbibed storage". He assumes that during the period (30 days) where the seeds were kept imbibed at 16°C and 21°C some of the damage accumulated during dry storage was repaired. He further expects an increased growth rate for seedlings from these seeds, which would mean that a pretreatment of Gmelina seed for about a month at between 16°C and 21°C would be feasible.

The results show too that seeds of *Gmelina arborea* are not inertly dormant, but are capable of responding quickly to favourable germination conditions.

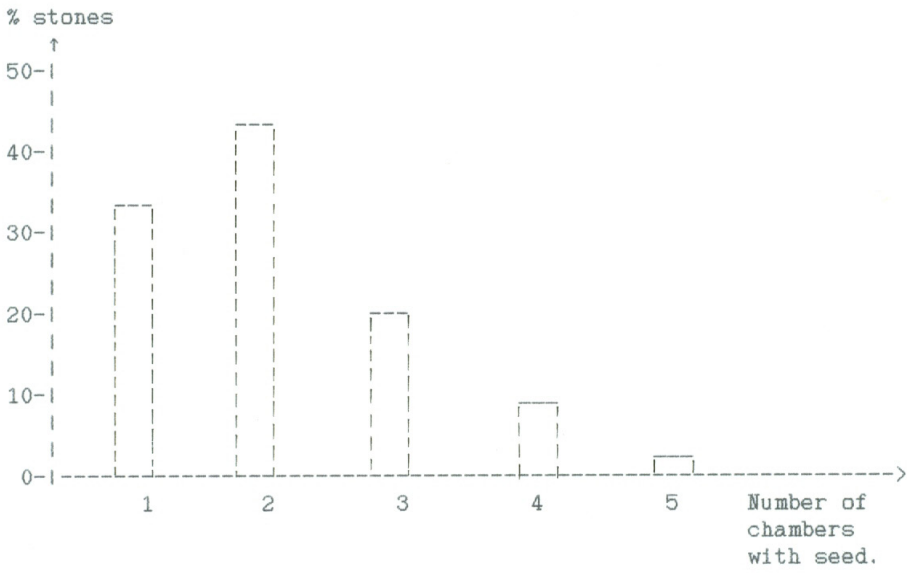

Figure 3: The frequency of stones with one or more seed chambers filled with seed.

Gupta *et al.* 1975, found Gmelina seed to have no specific light requirements, i.e. to germinate equally well in darkness and in full light.

Aminuddin & Ng, 1982, on the other hand concluded that the germination of Gmelina seed is influenced by light. They sowed seed in full sunlight, under partial shade (roofing of palm leaves) and in deep shade under a forest canopy. Their result is summarized in figure 6. Germination varied from around 80 % in full light, over 11-42 % in partial shade, to NIL under the forest canopy. The seeds exposed to the latter two treatments for 2,4 and 6 month were after completion of these treatments transferred to full light where germination then continued and started, respectively. The seed in partial shade appeared to lose germination potential with increasing time under shade, whereas the seed buried in the soil under forest canopy for up to 6 month retained their germination potential in full.

Gmelina arborea - occurring naturally in dense moist to semi-evergreen forests, amongst others - may be conceived as a pioneer species and a comparison to the behaviour of other pioneer species in tropical humid forests would be relevant. Vasques-Yanes studied the seed of two such species and summarizes his results as follows: "The tropical forest pioneer trees *Cecropia obtusifolia* and *Piper auritum* germinate and become established in large light gaps of the forest canopy in the rain forest of south-eastern Mexico. Germination of the seeds of both species is under photo control and is triggered when the red: far-red (R: FR) ratio of the incident light increases due to a reduction of the green canopy density. Exposure to simulated light canopies retarded and reduced germination. The light environment inside the forest inhibits germination totally . Experiments with alternate R and FR light treatments indicate the need for long periods of exposure to R light for germination, and demonstrate a strong reversibility of the R light stimulation by FR light in both species. This property of the seeds may be related to the detection of light gap size and its differentiation from the normal sunflecks of the forest".

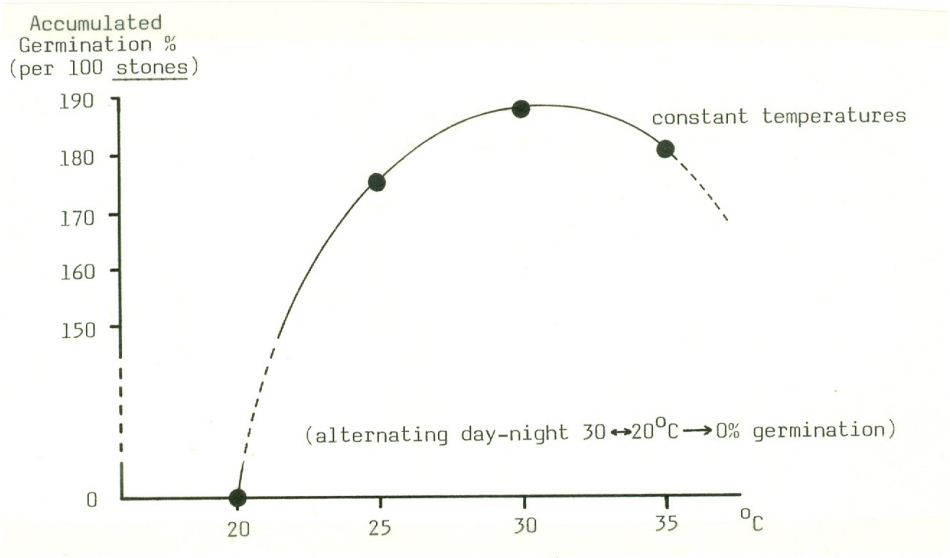

Figure 4: Temperature and germination (Gupta & Pattanath).

The results of Aminuddin & Ng for *Gmelina arborea* agree with this result.

Seed of two provenances were sown in light and darkness. For both there was a significant increase in germination under light, see figure 7.

Gmelina arborea occurs amongst others - for example in Central India - in mixed deciduous forests with a much lighter canopy than in the moister forest types. The seed of *Gmelina arborea* from these light forests may react differently to light.

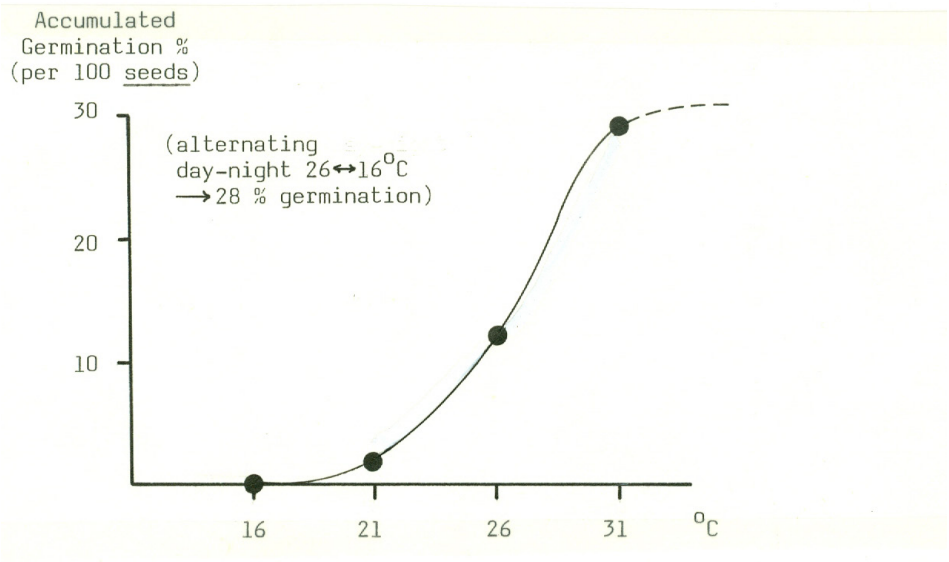

Figure 5: Temperature and germination (Smith)

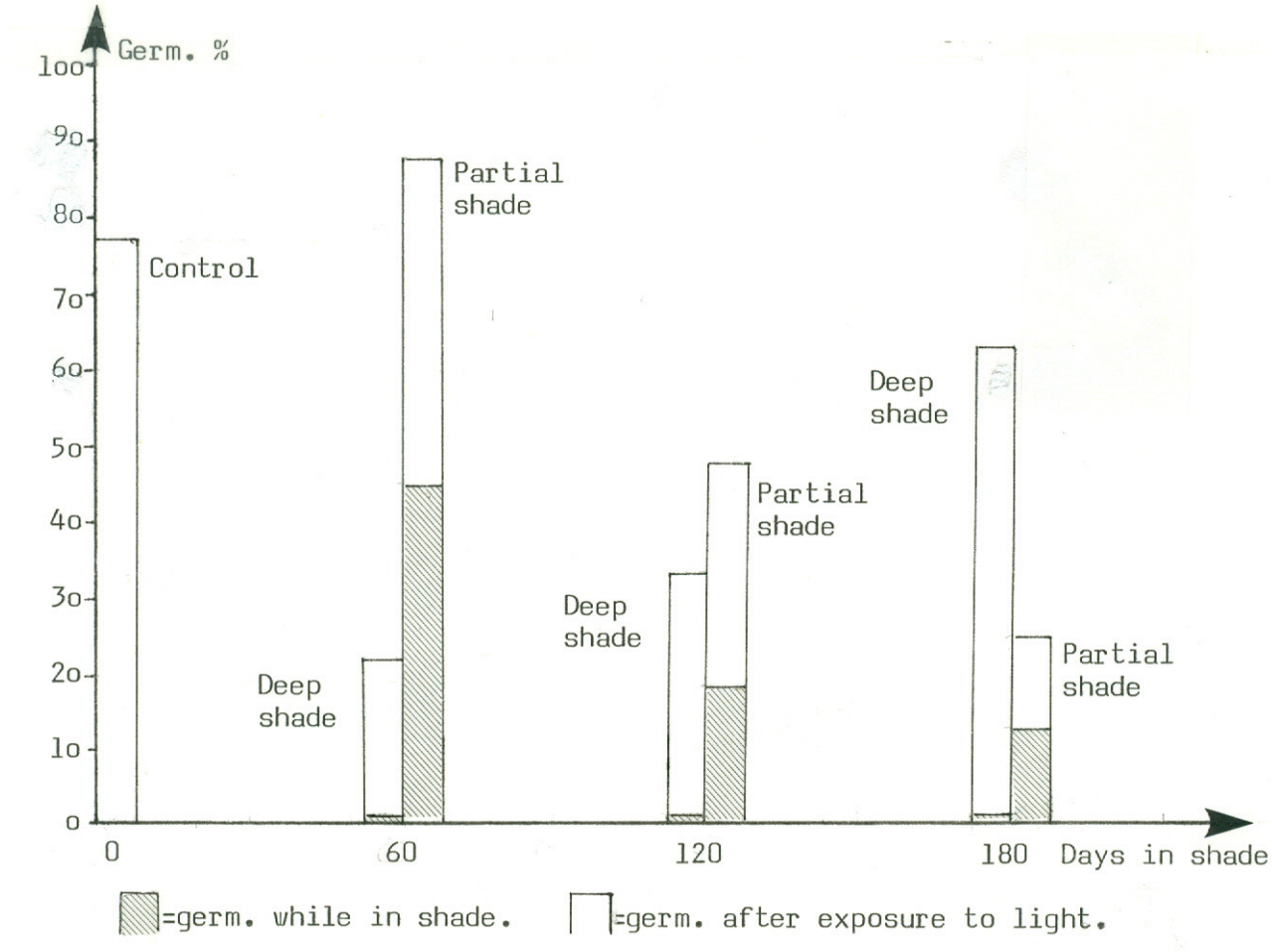

Figure 6: Light and germination (Aminudding & Ng).

Dormancy

The influence of temperature on dormancy in seed of *Gmelina arborea* was mentioned above. Further, the fact that Aminuddin & Ng found a high germination for seed buried for up to 6 months in the soil under deep shade from forest canopy, and that seed when placed in full light started germination immediately, confirms that dormancy is not inert in Gmelina seed.

5. Fruit/Stone Production

The fruit production of 50 mature trees in a natural forest in south India was studied over 2 years. Table 1 shows the variation among trees in fruit set.

In connection with seed collections for international provenance trials on average of 230 grammes clean, dry stones were collected per tree, varying from 30 to 2500 grammmes per tree. These amounts were collected generally over one month, and may comprise only a limited part of the total production.

Woessner, 1979, reports from the Amazone area that adequate seed yields are obtained from plantations of five years of age or alder. These plantations are thinned to 440-650 stems per hectare before collection started.

Sim & Jones, 1984, state that out of 1800 hectares planted up till 1980 only two stands, 5 and 6 years old and making a total of 29 hectares, produced fruits.

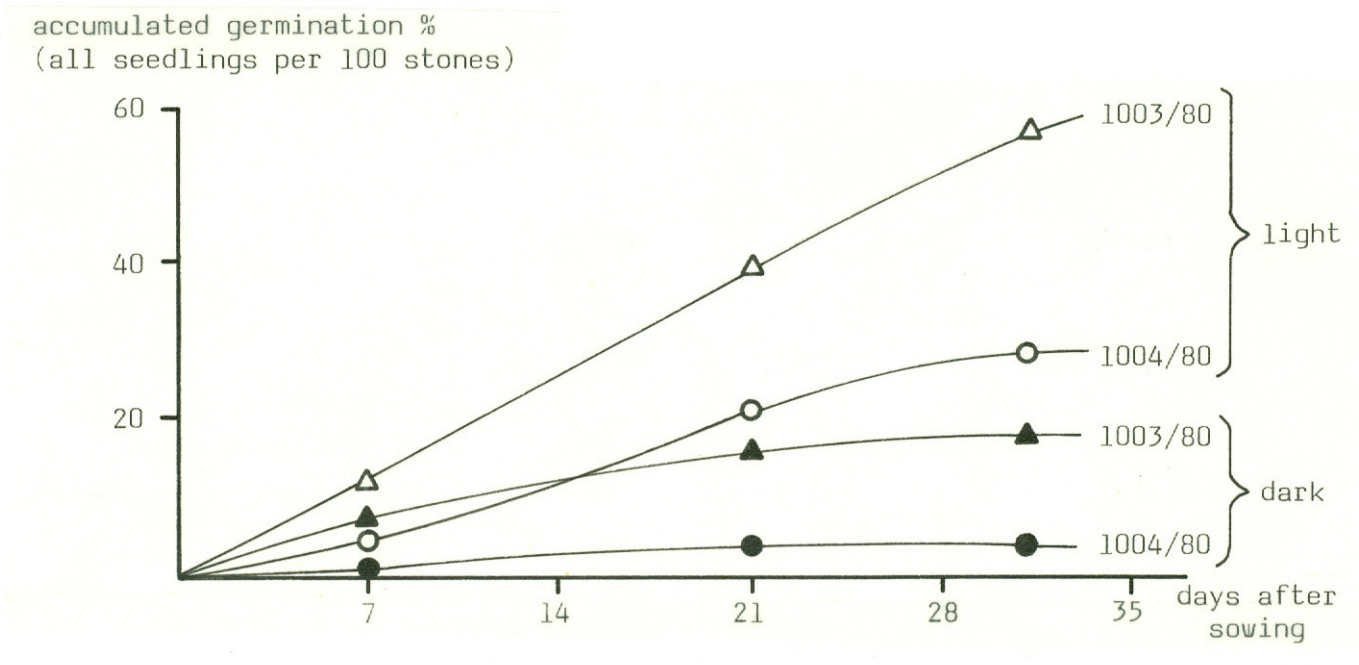

Figure 7. Light and germination (DANIDA Forest Seed Centre).

Egenti *et al.* 1980, report from Nigeria that 25 hectares of seed stands yield on an average 800 kg cleaned stones per year, i.e. 32 kg/ha/y.

Bowen, 1980, refers to Nigerian conditions where 12 16-year-old trees of 50-60cm DBH produced 1.7 kg stones each, with a range of 0.3 to 4.1 kg per tree. This would in a seed stand with trees spaced at say 10 by 10 meter correspond to around 170 kg stones per hectare.

Table 1. Yearly variation in stone production among single trees in a natural population of *Gmelina arborea*.

Group of trees	Proportion of trees in group (%)	1976 gr. stones per tree	1977 gr. stones per tree
A	58	360	780
B	26	470	NIL
C	6	NIL	625
C	10	NIL	NIL

Bowen et al., 1982, report from Malaysia a yield of 664 gr stones per tree collected over 4 month from a 14-year-old stand which had been thinned to 100 trees per hectare 7 month in advance of the collection. This corresponds to 66 kg stones per hectare, and an estimated 75% of the total production in the stand.

6. FRUIT COLLECTION

In plantations

The collection of fruits in plantations poses few problems only. Fruits are generally collected from the ground, partly because it is much cheaper, partly because removal of mature fruits directly from the tree would damage the remainder of the inflorescences. Especially in areas with extended fruit development, the loss would be prohibitive (Bowan *et al.* 1982).

Bowen et al. ,1982, states that in Malaysia seed stands have to be visited frequently, i.e. at 2 days' interval, or twice weekly, in order to collect the fruits at the right stage of maturity. Also, a high quality of site maintenance, i. e. weed cleaning, is necessary to facilitate seed collection. In order to obtain a reasonable proportion (around 75%) of the yield it was necessary to continue collection over a total of 4 months.

Woessner, 1979, reports that in Jari in the Amazone ripe fruits may be found for at least 9 months of the year. Sizeable amounts of fruits fall to the ground beginning in November, but the maximum fruit production falls in January-February, and will last for 3-6 weeks.

Woessner further states that in plantations with 440-650 stems per hectare one man can easily collect 50 kg fruits, or around 3 kilos of dry stones per man-day.

In natural stands

In natural forests collection is difficult to organize, supervise and carry out because of the scattered occurrence of Gmelina trees there. If there is, for example, 1 tree per 2 hectares, the collection of 50 kilogrammes of dry stones will require an area of around 250 hectares and 34 man-hours every second day during one month's time. This corresponds to around 500 man-hours, or 1¼ man-days per kilogramme of stone. This can of course vary very much depending on fruit set, the density of the forest and of the ground vegetation.

The influence of fruit colour on seed germination as discussed on page 7 shows that only green, green-yellow or yellow stones should be collected if the fruits are to be stored or transported before depulping in order to ensure the highest possible seed quality and to minimize handling costs.

If depulping of the fruits and drying of the stones are to be done within around 24 hours then yellow-brown fruits may be included in the collection, as they apparently still give a reasonable germination.

Fruits that have started to turn black should in any case be discarded.

In order to maintain a high level of seed quality through the subsequent transport and handling, fruits should during collection be graded according to colour in three groups: Those mainly green, those mainly yellow and those mainly brown, see below under "depulping".

Game and cattle devour Gmelina fruits and may give heavy competition to seed collectors (Bowen 1980). The resulting product: clean stones, are often found to a large extent scattered in the forest and elsewhere. It is often claimed that fruits which have passed through animals give good germination. It would however, in general, not be advisable to collect stones cleaned in such a process, because any control the collector may otherwise have over origin of seed, number of mother-trees, seed maturity or decay, is lost.

For successful collection programmes to result in quality seed of well documented origin, the acquisition and skilful use of the knowledge as mentioned above is very essential. This includes the observation of flowering and fruiting period at the concerned localities as these periods can vary much from year to year and from place to place as seen above.

A close and qualified supervision during the actual collection is further a must.

7. TRANSPORT, PROCESSING AND HANDLING OF FRUITS/STONES

Transport

Transport of unpulped fruits should be in open weave, cloth or net sacks, not in polyethylene or plastic bags.

In order to avoid fermentation, fruits should be brought to the cleaning area within 24 hours. This is especially important for fully ripe - i.e. fully yellow and brown - fruits, whereas green or partly yellow fruits probably can withstand longer time before processing.

The bags should not be exposed to direct sunlight (Bowen 1980).

As much care as possible should be taken to avoid damage to the skin of the fruits, since fermentation is more likely to start among damaged fruits.

Depulping

The effect of keeping fruits with pulp is evident from figure 1. The figure is based on the results of keeping fruits for zero-22 days in a 12 cm thick layer (Woessner 1979). Germination increased initially from 93 % (green fruits) to 122 % (yellow), whereafter it decreased at a steady rate to 48%. The potential germination was stated to be close to 160 %. Within the first week, where after-ripening occurred and caused a steady increase in germination, there was apparently at the same time a loss of nearly 40 %, maybe due to the start of some fermentation processes. Losses may of course also occur due to the epigeous type of germination, and it is not clear from Woessners paper which of the factors have been effective.

Even if the stones are to be sown immediately upon depulping, small remains of pulp appear to reduce germination slightly, i.e. up to 10 % for ripe fruits (Woessner 1979).

As soon as possible after collection - within 24 hours (Woessner 1979, Bowen 1980) - processing and depulping should be started.

The fruits which are not fully ripe, i.e. the mainly green fruits, are arranged in the shade in a layer not more than 15 cm deep for after-ripening until they turn yellow or mainly yellow. This may last for up to a week.

The fruits are washed thoroughly with water one or several times a day in order to remove extracts and thus to prevent fermentation during after-ripening (see also Iwegbulam below).

Depulping of ready fruits is done either manually for small lots or by machine for large seed lots.

Iwegbulam,1983 found fermentation in a running stream of water to facilitate depulping, to be less time consuming than other depulping methods and to give excellent germination.

Depulping by hand is done by threshing, mashing or tumbling the fruits until the pulp is loose. The pointed end of the stony endocarp may be torn off in this process, but this should not be harmful to the seed (Woessner 1979).

At the Jari Company in Brasil a modified coffee-depulper is used for machine depulping. The machine is effective, but does not remove all the pulp from the stones. Fifty kilogrammes of fruits per minute can be depulped by this machine

Sim & Wong, 1985, describe a coffee-depulping machine, modified for *Gmelina arborea*. The pulp is rubbed off by a toothed rotating drum working against a plate. Around 150 kilos of fruits can be depulped in a day.

Cleaning of stones

Stones left in bags for just 2 days, not fully cleaned of pulp and in moist condition, can experience a drop in germination of around 20 %, and if left for one week the temperature in the sacks may reach temperatures up to 45°C and germination may drop to near zero (Woessner 1979). Complete cleaning and drying are thus essential within one day of depulping.

In Jari the final cleaning is done either manually by rubbing and washing the stones or at the same time as the stones are dried (see below).

In Malaysia the stones are spread on a wire-mesh tray and rinsed with water to remove juice and traces of pulp. Finally after drying, the stones are polished on a spinning metal plate in an unmodified coffee-dehusking machine to remove any further pulp. The process also removes the pointed end of the stone (Sim & Wong 1985).

Drying

The level of seed moisture to be attained would depend upon the length of time the stones are to be kept before sowing.

- If sowing is soon after cleaning, air-drying would be sufficient.
- if longer period of transport or storage is to follow, the seed moisture must be brought down to below 10%, and this may not be possible with ordinary air-drying, incl. drying in the sun (Bowen 1980) .

Woessner,1979, describes a method of simultaneous cleaning and drying. The still moist stones are poured into a baffled, perforated steel cylinder,

which can hold 480 kg stones. The drum is slowly rotating in a room with an air-temperature of 35-55ºC, which is maintained by the excess heat from a power generator. A moisture content of 8-10% can be reached in about 20 hours. The movement of the stones over the perforated walls scours the outside of the stones clean, and in addition the pointed end of the stones is ground away exposing the interior to drying (and later to rapid imbibition).

Bowen, 1980, describes a simple system where stones are dried in a polythene tent erected over a wooden frame, and with an air vent at the top. The stones are arranged an stackable wire-mesh trays, and air heated by the sun is circulated around the stones by a fan placed inside the tent. The nuts have to be turned frequently to ensure even drying. The temperature in the tent may reach 60°C or more. These temperatures are fatal to the seed, hence frequent supervision is required. The length of drying time is not given, but probably 2 days may be necessary to reduce moisture to below 10 %.

Stones may also be dried, first in the sun (length of time is not stated) and then in a perforated, baffled and rotating drum through which 50°C warm air from a heater is forced. A seed moisture content of 6-10 % can be achieved in 4 hours. In this process cleaning of pulp remains can be done simultaneously. (Bowen 1980).

Sim & Vang, 1985, found drying for 2 days in 40ºC-60ºC warm air to reduce seed moisture to 5-8 %, with full retention of germination.

For very long storage drying at high temperatures may reduce storability of the seed. At Kew Gardens in England drying for gene conservation purposes is done at 15ºC and at a relative humidity of 15 %. Seeds are kept for up to 3 weeks in these conditions.

Stone grading

Bowen, 1980, states that larger stones generally contain larger seeds and produce more vigorous seedlings than smaller stones. Thus, if there are plenty of stones, then he recommends to grade stones by removing around 10 % of the smallest stones from the bulk.

Woessner,1979, showed on the other hand that germination of the smallest 8 % of a bulk did not differ essentially from the next 65 % of the bulk. Only by removing the 73 % smaller-sized stones was a significant increase in germination achieved. Seed grading was done to facilitate sowing by machine.

Protection

Rodents may cause severe losses in stored stones. Such losses are prevented best by storing in metal containers or in tightly closed buildings.

Woessner found the application of fungicides to Gmelina stones to be too expensive compared to a slight gain obtained in germination.

At the DANIDA Forest Seed Centre it was found that neither the fungicides applied to stones received in Denmark for international provenance trials, nor some generally recommended chemicals applied at the time of seed testing were able to control growth of fungi, where such growth was recorded during the course of testing for germination in the laboratory.

Finally, no insects were found in any of 44 seedlots - representing 37 different localities received in Denmark for the above mentioned provenance scheme.

8. SEED TESTING

Pretreatment

Stones which have been under transport or in storage for longer periods may need some pretreatment to activate possible dry seeds before a proper test of viability and germination can be made, or before seeds can be utilized for sowing. Freshly collected and treated, fully ripe seeds may not require any pretreatment.

Smith,1978, reported on the possible positive effect of preconditioning Gmelina seeds - which had been stored for one year at 3°C - at 16-21°C for 30 days, and on a possible negative effect of conditioning at 26°C, see page 11. The report does not show if a shorter preconditioning period than 30 days would be appropriate.

Until more information is available, non-fresh seed should be pretreated (imbibed) in the dark, in moist sand (field capacity) and at a temperature held as near as possible to 26ºC for 30 days.

Dissection or cutting test

If stones are received by a seed station or by a nursery without proper documentation of viability and germination, a quick examination should be carried out before further handling is done.

If a small circular, electric saw is available, a cross-cut of each stone of a proper sample of the bulk received is made. The thin layer of the cut-surface which has been in touch with the saw-teeth is cut off with a sharp knife, and the seeds are examined to see if they are fully developed, of a white colour, of a fresh and firm appearance, and are not ill smelling.

It is possible also to make a cross-cut of stones with the help of a strong

pair of wire-cutters or secateurs (Bowen 1980).

Bowen, 1980, recommends to crack open stones and extract seeds by inserting a round 3 mm thick nail into the hole (which is normally found) at the pointed end of the stone. This method is faster and results in less damage to the seeds than cracking by a vice.

The cutting test is insufficient to give a full picture of seed quality, especially if the seeds are not freshly collected or optimally treated. Table 2 shows the results of different test methods done on 3 seed-lots which had been stored 1 year.

In order to enable the comparison of test results it is essential that recording is done so it is clear what is meant. State for example: "% stones containing only 1 sound seed", or "% stones containing 4 sound seeds", or "% stones containing 1 or more sound seeds" or "Number of seeds per 100 stones" etc. Which of the various options to present would depend upon the purpose of the reporting. Generally the presentation of both the last two options are most useful.

Viability testing

Testing with Tetrazolium chloride may give ambiguous results. When no or few seeds only were fully stained, i.e. fully viable, the comparative germination in the laboratory or in the field was invariably zero or poor. However, when there were many fully stained seeds, the comparative germination was erratic, see table 2 where there was no correspondance between the Tetrazolium test and germination.

Seed to be viability tested are first pretreated as above described, if they are not newly collected.

The Tetrazolium test may then be done by cross-cutting the stones with a finely toothed small, circular and electrically powered saw holding the stone with a pair of forceps or tongs. A thin layer of cells on the cut-surface of the seed is then removed by a sharp knife. The cut-surfaces of the stones/seeds are then immersed in a 1 % aquatic solution of Tetrazolium chloride (or bromide) for 24 hours at 30°C. A longer time of immersion may be needed, up to 48 hours - probably if the seeds have been stored for long time. The seeds (cut-surfaces) are then examined for staining.

Table 2. Comparative results of test methods on 3 provenances of *Gmelina arborea*.

Seed source	Cutting	Tetrazolium	Lab. germ.	Field germ.
	% stones with min. 1 sound seed	% stones with min. 1 fully stained seed	All seedlings per 100 stones (51-58 days)	% stones giving min. 1. seedling (50 days) *
A	100	60	10	1
B	100	72	8	1
C	100	68	96	35

*) Data from Director, Proj. FAC-ARFF, Min. Eaux-Ror.-Chasses-Peches et Tourism, Rep. Centrafricaine.

Probably better, the seeds may be extracted from the stones after pretreatment as described above and then immersed in the Tetrazolium solution. In this way the staining of all essential structures can be examined, see ISTA, 1985.

As for the cutting test recording must show the basis for percentage calculations.

Germination testing

If the stones are not freshly or recently collected, then a pretreatment as above described is carried out.

As light appears to influence the germination of seed of *Gmelina arborea*, germination should be done in full light in a room either with sufficiently large window-openings or equipped with lamps of "daylight-quality".

As the unit of handling in the nursery is the stone, this should also be the unit for standard testing.

Testing should be under a temperature as near a constant 30-31°C as possible.

The sowing medium may be sand screened through a wire-mesh with holes of 0.05 mm diameter. The sand should be sterilized at 140°C, and the sand may be reused 5-6 times, whereafter toxic substances may have built-up (Bowen 1980).

The germination trays should be sufficiently large, e.g. 25 by 25 by 6 cm to contain 50 stones spaced conveniently for a proper study of seedlings.

The sand should be moist to field capacity and kept at that level by replacing water. The most convenient method is to put the sand into the tray, wet the sand thoroughly and let free water drain off, sow the seed, put on the lid - or if no lid, then put the tray into a plastic bag, which is closed lightly - and then weigh the whole unit. If the sand is showing signs of drying out, water is added until the original weight of the unit has been reached (Bowen 1980).

The stones are sown in a vertical position with the pointed end downwards. The advantage of this has not been verified for *Gmelina arborea*, but for *Tectona grandis*, a species with a germination similar to that of *Gmelina arborea* stone orientation has proved to have a significant influence on germination. This may be due to a higher probability of the stone not being pushed up by the first emerging seedling if oriented correctly.

The assessment, recording, and presentation of results must be done so it is clear what the results mean. In the international provenance scheme on *Gmelina arborea* germination of a seedlot stored for about 3 months could vary between 7 nurseries for example, from 12 to 92 %, with mean 56 %. Part of the difference would likely be due to differences in nursery skill and nursery conditions. Some would however, be due to differences in assessment, recording and reporting procedures. It is impossible to see what would have been the actual cause(s).

Holmes, 1951, provided the following guidelines for period of assessment:
- Days from sowing to first germination: 9-13.
- Days from sowing to peak germination period: 17-20.
- Days after first germination when no more germination occurs: 47-89.

Gupta *et al.* 1975, gave the following testing rules for *Gmelina arborea*:
- Days from sowing to first count: 12. (Around 33% of seeds have germinated in general until this day. If on this day no, or few seedlings only, have emerged, the seedlot shauld be categorized as a poor seedlot, and be discarded).
- Final count: 28 days (probably from sowing).

Experience at the DANIDA Forest Seed Centre with many different seed sources shows that germination may start 6-7 days after sowing.

It is recommended to start observations already within a week from sowing. If little has happened 12 days after sowing under optimal conditions, the seed lot should be discarded. The length of the total observation period should be varied according to the results of viability testing with Tetrazolium. That is, the period should be shortened or extended depending upon, respectively, how close to or far from the viability level the germination has reached.

When germination starts, recording should be done every day to ensure that dead seedlings do not disappear before they can be recorded.

Seedling normality should be assessed. A typical normal seedling has been described by Troup, 1921, as follows:

Hypocotyl: Circular or obscurely quadrangular; 7-18 mm long; white, turning green; finely pubescent.

Epicotyl: More or less quadrangular near the nodes; green; finely pubescent.

Cotyledons: The petiole is 2-5 mm long; channelled or flattened above; finely pubescent.
The lamina is 13-18 mm long and 8-10 mm wide; somewhat fleshy; elliptical-ovate; entire; yellow, turning green; finely pubescent. The midrib is deeply impressed on upper surface, and the lateral veins are less distinct.

Primary roots: Smooth; circular and tapering with a moderate number of lateral roots.

Primary leaves: Simple and opposite.
The petiole is 8-40 mm long; channeled above; green; glabrous or finely tomentose.
The lamina is 4-8 cm long by 3-8 cm wide, broadly ovate, acute-acuminate; widely dentate-sinuated. The base is cor date-cuneate, or obtuse; glands near the petiole; green above, glaucous belaw; glabrous, or lower surface glabrescent or finely pubescent with capitate hairs on the principal veins; 3-5 pairs of lateral veins, incl. 2 prominent basal lateral veins.

Recording and presentation of results may be done in several ways:
- Number of seedlings per 100 stones.
- Number of stones - each producing minimum 1 seedling - per 100 stones.

The first expression is useful if stumps are to be produced, or where transplanting of seedlings is feasible in the case of seed scarcity. The latter expression is useful for sowing in pots or directly in the field, where seedlings in excess of 1 are thinned out. Both results should as far as possible be presented.

9. STORAGE

Woessner, 1979, found for well dried stones - i.e. 6-10 % moisture content - in cold storage - 5°C, and 20-25 % R.H. - moderate lasses of germination of 5 % per year over a 2-year period. He found that storage in burlap bags were as satisfactory as storage in expensive sealed drums for up to 2 years of storage. This is valid probably only where humidity can be controlled at the low level shown above.

Bowen, 1980, recommends that seed mixture should be between 6 and 10%, storage temperature 3-5°C and storage should be done in air-tight metal drums.

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