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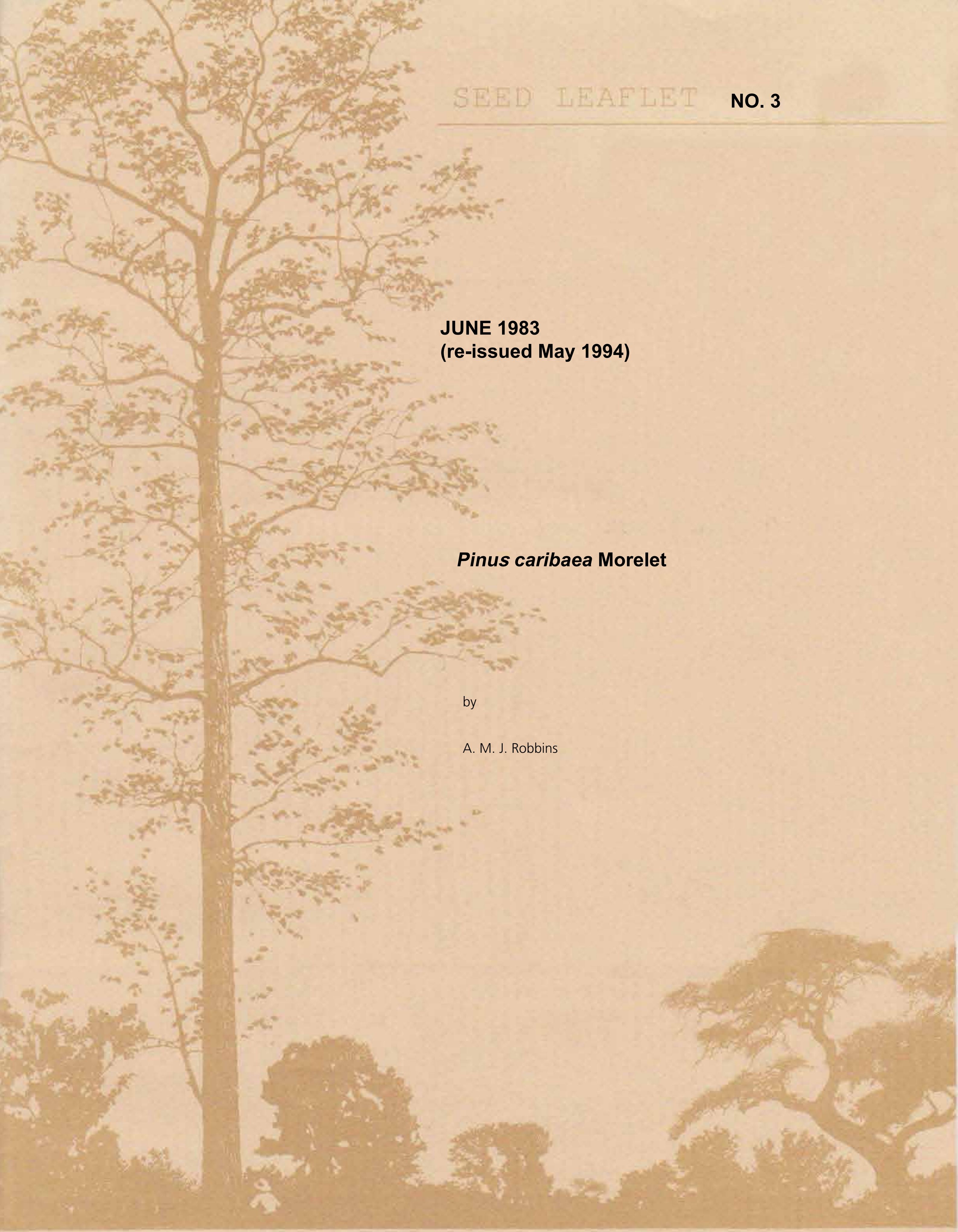

SEED LEAFLET **NO. 3**

JUNE 1983
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Pinus caribaea Morelet

by

A. M. J. Robbins

DANIDA FOREST SEED CENTRE

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1. INTRODUCTION

Sources of Information

Information in this leaflet, if unsupported by references, is derived from observations and data recorded in internal documents over the period 1975 1982 of the Banco de Semillas, Escuela Nacional de Ciencias Forestales, Siguatepeque, Honduras.

If not otherwise stated, information given refers to *Pinus caribaea var. hondurensis.*

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2. NOMENCLATURE

Botanical name:	*Pinus caribaea* Morelet Synonyms: *Pinus bahamensis Griseb., P. hondurensis Seneclauze, P. hondurensis Loock, P. recurvata Rowlee.* Before 1950, the name *P. caribaea* was used to de scribe also *P. elliottii var. elliottii* and *P. elliottii var. densa* in the southern U.S.A. (Little and Dorman, 1954; Lamb, 1973).
Family:	Pinaceae
Common names:	In Latin America the tree is variously referred to as Pino de la costa, Pino costanero, Pino colorado, Pino *caribaea*, Ocote blanco, and Pino macho (Lamb, 1973). The timber is referred to as Carib bean pine or Caribbean pitch pine.

3. THE TREE

Size and Growth Habit

P. caribaea is a typical pine, with fascicles of 3-4 needles, reaching a maximum of 45 m in height and 1.35 m in diameter on good sites in Belize (Lamb, 1973). The insular varieties are generally smaller in size than that of the mainland. The tree is found naturally forming uneven-aged pure forest, often as a mosaic of even-aged stands, with some broadleaved species such as Quercus. The stands are defined ecologically as a fire climax, since they owe their existence to periodic fires which suppress the majority of competition from broadleaved species (Taylor, 1963).

The form of the tree is variable. Branching is generally moderate to light when growing in stands, with the live crown forming 1/4 -2/3 of the bole height. Open-grown trees have large, deep crowns and frequently coarse branching.

Some trees show sinuosity of stem, spiral grain, and acute-angled branching, characteristics which are highly heritable. As opposed to *P. oocarpa*, the young trees do not coppice.

Natural Distribution

P. caribaea is found in Central America (Nicaragua, Honduras, El Salvador, Belize, Guatemala), Mexico, and also in Cuba and the Bahamas group of islands (Lückhoff, 1964; Critchfield and Little, 1966; Lamb, 1973; Styles, 1980), covering a range in altitude from sea level up to 800 m. The upper limit is probably controlled by the effect of temperature on seed formation, thus limiting natural regeneration. On the mainland, the distribution is discontinuous, the species being found in valleys and on plains, and often clearcut for agriculture. The remaining stands have been heavily exploited for timber, and as a result the forest is poorly stocked. Overfrequent fires also help to maintain a low stocking. Many provenances are in danger of extinction.

On the mainland, the species is generally found on acidic latosols and lithosols and the more fertile valley soils. In the Bahamas, the species is found on nearly pure coral soils that are highly alkaline (Lückhoff, 1964). The climate is very variable within the natural distribution. Honduran provenance climates range from 700 mm mean annual rainfall with 6 -7 months dry season, to over 3000 mm mean annual rainfall and 2-3 months dry season. Temperature is less variable, ranging between mean annual values of 22°C to 27°C. Lückhoff (1964) and Lamb (1973) give detailed accounts of the natural distribution and site variation of *P. caribaea*, and Greaves (1978) gives climatic details for individual collection sites throughout the natural range. Details of distribution within Honduras are given in Robbins and Hughes (1983) and Styles and Hughes (1983).

Variation and Improvement

P. caribaea was first described as a species by Morelet based on botanical specimens from the Island of Pines, Cuba. For a time it was confused with P. elliottii Enqelm. of the SE U.S.A., until Little and Dorman (1954) showed the two to be clearly defined species. Barrett and Golfari (1962) and LUckhoff (1964) investigated the variation of the species throughout its natural range, and came to the conclusion that it should be divided into three intraspecific groups, which are described by Barrett and Golfari as: (i) *P. caribaea* var. *caribaea* found in Cuba and the nearby Isle of Pines (now Island of Young People); (ii) *P. caribaea* var. *bahamensis* (Griseb.) Barr. et Golf., found on many of the Bahamas group of islands, and (iii) *P. caribaea* var. *hondurensis* (Senecl.) Barr. et Golf., found on the mainland of Central America and Mexico, including the Honduran island of Guanaja. Botanical differences between the varieties are described by Lückhoff (1964), Lamb (1973) and Styles (1980).

Hybridisation has been tentatively identified between *P. caribaea* and *P. oocarpa* where the two species overlap in their natural distribution (Styles, Stead and Rolph, 1982), and artificial hybrids have been produced in Honduras and Australia.

The varieties and provenances of *P. caribaea* have been studied in detail as part of the Central American Pine Provenances Research Project, based at the Commonwealth Forestry Institute, Oxford, England (Kemp, 1973; Greaves, 1981). Results of the international provenance trials are available from many countries (see Burley and Nikles, 1973; Nikles, Burley and Barnes, 1978) and are summarised up to 1978 by Greaves (1980) and Gibson (1982).

Vigour generally increases in the sequence *P. caribaea* var. *caribaea*, *P. caribaea* var. *bahamensis*, *P. caribaea* var. hondurensis whereas stem and crown form improve in the reverse order. *P. caribaea* var. hondurensis on the mainland can be divided into two main groups: those from the humid, lowland coastal plains, and those from the higher, drier inland locations. The inland provenances are more inclined to produce needleless shoots and die back when planted on humid, lowland equatorial sites. Coastal provenances are more windfirm. Those from the coastal plains of Honduras and Nicaragua tend to produce long foxtails under some conditions, and in general produce vigorous well-formed trees, except for the Slilma Sia/Rio Coco provenances which are unusual in having a large number of stem defects. The Potosi provenance in N. Honduras produced trees of poor form (sinuous stems and coarse branching). The island provenance of Guanaja is of medium growth rate with a distinctive multinodal form in many stems.

Genotype-environment interaction studies have been carried out for *P. caribaea* provenances (Barnes, Gibson and Bardey, 1980; Gibson 1982). Results indicate that quantitative traits (height, diameter) tend to be under less strict genetic control than qualitative traits. No provenance is outstanding in production over all sites, although some produced outstanding individuals in certain localities. The Guanaja island provenance is a high volume producer, has highest wood density, the thickest bark, and the most stable branching habit. Conelet production is under strong genetic control, inland provenances producing more conelets than coastal. In general, a large proportion of the total variation occurs between trees within provenances, rather than between provenances, and it is concluded that it is likely to be advantageous to include more than one provenance in any commercial or breeding population.

Biochemical studies of oleoresin and isoenzymes are being carried out to facilitate understanding of the genetic variation (e.g. Matheson and Bell, 1980).

Provenance regions for *P. caribaea* have been tentatively identified within the Republic of Honduras by Robbins and Hughes (1983).

Seed stands are being established in the natural forests in Honduras following the guidelines of Hughes and Robbins (1982) and also in Guatemala (W.L. Mittak Schubertstrasse 5, D-8087 Turkenfeld, Germany, pers. comm.). They are planned also for Nicaragua and Belize. In exotic plantations, seed stands have been established in Fiji (Bell, 1979, 1980), in Brazil (Bertolani and Nicolielo, 1978), Jamaica, and many other countries (Gavidia, 1978). Most of the plantations originate from the Mountain Pine Ridge provenance of Belize, or from Poptun, Guatemala.

Breeding programmes are advanced in many countries (Gavidia, 1978), notably in Australia where the improved Queensland Byfield provenance of Mountain Pine Ridge origin is available and is becoming extensively planted in other countries.

Importance for Plantation and Uses

P. caribaea is now well-proved as an excellent species for the afforestation of lowland and some medium altitude sites in the tropics. The large amount of genetic data available on the species, combined with increasing seed supplies from both natural and derived provenances, are factors which have contributed to its widespread use.

The total area of *P. caribaea* plantations at the end of 1970 was 32,000 ha, of which 82 % was var. *hondurensis* (Lamb, 1973). The total rose to 280,000 ha by the middle of 1977, increasing at a rate of 56,000 ha/yr. The planting programme during the 1980's was expected to reach 90,000 ha/yr, equivalent to an annual seed demand of 11,000 kg or more (Nikles, 1979).

The principal countries using *P. caribaea* are Brazil, Zaire, Fiji, Australia, Jamaica, Tanzania, South Africa, Malaysia and Surinam (Gavidia, 1978).

The timber of *P. caribaea* is very good for general construction purposes, and is also used for pulp, chipboard and plywood manufacture. The resin obtained from the sapwood is used for producing turpentine, rosin and associated products, but yield is not as good as *P. oocarpa*. In indigenous forests the tree is used for firewood, and there are local industries for the manufacture of poles and posts.

4. REPRODUCTIVE BIOLOGY

Flowering and Seed/Fruit Development (See figure 1)

Trees are monoecious, with a tendency towards unisexuality in some individuals. The numerous male strobili are sessile, in whorled, short, crowded clusters near the ends of twigs, and mostly in the lower part of the crown. In position they are equivalent to needle bundles. Each strobilus is 20-32 mm long, 5 mm broad, with 12 -18 ovate, scarious margined, reddish brown bracts at the base. Female strobili are found mostly in the upper part of the crown, appearing near the apex of elongating twigs but becoming lateral, with generally 2-4 strobili in a whorl, and from 1-3 whorls formed in a year. Trees that have predominantly male strobili show a distinct foliage pattern, with gaps in the needle growth where the strobili have dehisced (Lamb, 1973).

In the species' natural range, the female strobili are probably initiated from September to October, about 2-3 months before pollination. Receptive strobili, or conelets, are found from November to February in Honduras, and December to March in Belize (Lamb, 1973). Flowering tends to be later with increasing altitude and latitude. In southern hemisphere plantations, in Australia (Queensland) *P. caribaea var. caribaea* flowers from June to July, *var. hondurensis* from March to June, and *var. bahamensis* from April to June (Slee and Nikles, 1968). In Brazil (Agudos region), *P. caribaea var. hondurensis* pollination occurs from May to June (Bertolani and Nicolielo, 1978). In Fiji, flowering occurs from mid-March to late August with a peak period from June to July (Bell, 1979). Out of season flowering appears to be quite common in natural stands and plantations.

After pollination, the conelet, which is about 10 -12 mm long, increases in size to 15 -20 mm in length and 10 mm in width, changing colour from pink, through light green, to brown. At the same time the peduncle elongates slightly to 10 -15 mm and bends backwards, this process being completed by about 1-2 months after pollination. The conelet then remains unchanged for up to 12 months, until fertilisation of the egg cells occurs. The conelet then enlarges to full size within a period of three months, and then matures rapidly, becoming fully mature 18-21 months after pollination. In natural stands in Honduras and Nicaragua, the cones are mature from May to July; in Belize, from June to August; and in the Bahamas in August. In southern hemisphere plantations the period is from January to February in Australia (Queensland) (Slee and Nikles, 1968). In Brazil (Agudos region), *P. caribaea var. hondurensis* matures in March, and *var. caribaea* from January to February. In Fiji, cones are ready for picking from late January to early March (Bell, 1979).

In natural stands, the period when cones are mature coincides with the beginning of the rains, as it does in most other countries. Despite generally rainy conditions, cone opening and seed dissemination is very rapid, occurring within a month of maturity, or less. However, variation between trees and stands prolongs the period of cone maturity within anyone area to 2 -3 months. In general, cones tend to mature during the same period, despite variation in flowering times (Lamb, 1973), but in natural stands in Honduras, trees are found that are consistently early or late maturers.

Conelet abortion can be quite high, due to incomplete pollination, competition between conelets and vegetative growth, and/or insect attack. Further significant abortion appears to occur after fertilisation.

Seed production in exotic plantations is often poor (Lamb, 1973) due either to cool temperatures preventing the formation of flowers, or to humid conditions during the flowering period preventing the pollen from reaching the female strobili. Thus seed production areas or seed orchards outside the natural range must be located in sufficiently tropical areas, with a distinct dry winter season.

Inland provenances of *P. caribaea var. hondurensis* tend to flower (*ex-situ*) at an earlier age than coastal provenances (Greaves, 1980) and also produce more conelets (Barnes, Gibson and Bardey, 1980).

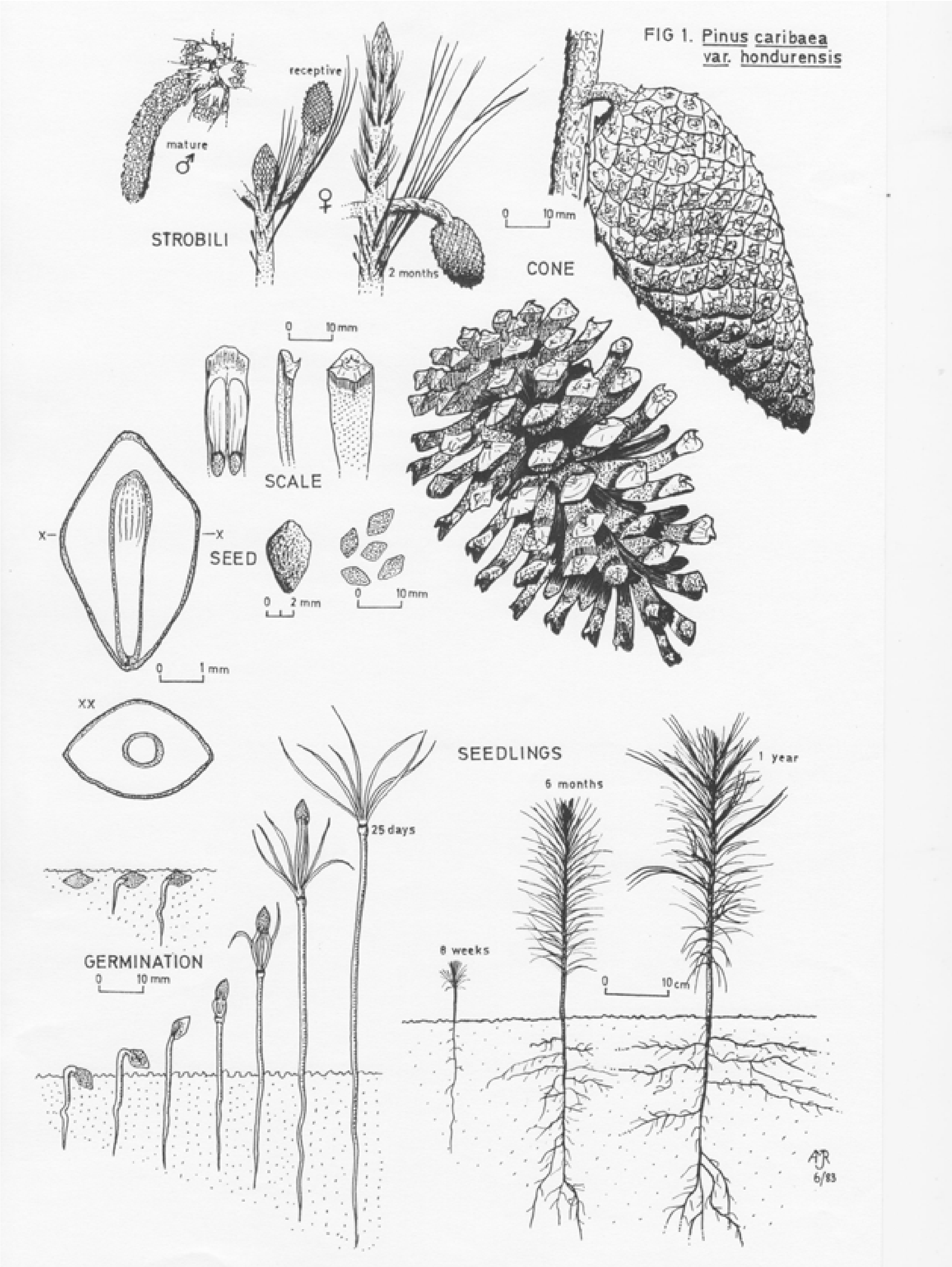
A worldwide survey of flowering and seed production of *P. caribaea var. hondurensis* has been carried out by Gallegos (1980).

Cone and Seed Characteristics (see Figure 1)

The mature cones are symmetrical, generally from 5 -10 cm long, conical in shape when closed, more than twice as long as broad, being from 25 to 35 mm in diameter. The cone is usually early deciduous, falling soon after maturity, but can in some areas be persistent for a year or more. There is some variation between trees in cone shape, though much more in cone size. The cone scales bend backwards to form a barrel shaped open cone. The scales are thin, flexible, flat, and dark chocolate brown on the inner surfaces. The apophysis has a transverse ridge, tan coloured and shining, with a small umbo that is slightly raised, grey, ending in a prickle that is less than 1 mm long but variable in size (Lamb, 1973). The number of cone scales varies from 150 to 190 of which about 70 % are fertile (i.e. capable of producing seed). Seeds are borne in pairs on the top of the cone scales, in shape narrowly ovoid, about twice as long as broad, pointed at both ends, and 3 angled. Length averages less than 6 mm, width 3 mm (Lamb, 1973). Lückhoff (1964) gives a table of comparative seed sizes and weights for *P. caribaea* from different localities. The *var. bahamensis* seeds are smaller than other sources. Seed size of *var. hondurensis* may increase with altitude. Seeds of *var. hondurensis* from Belize appear to have a much thicker testa than other provenances (Lückhoff, 1964).

The colour of the seed, with the outer covering of the testa intact (i.e. before processing) varies from black, mottled grey, to light brown. Processing removes a varying amount of this coating to reveal a buff coloured inner layer. Seed that is extracted before maturing completely tends to be lighter in colour.

A wing is loosely attached (articulate) to the seed in the varieties hondurensis and bahamensis, but is persistent (adnate) in variety *caribaea*, and cannot be removed during processing without damage to the seed. *P. caribaea* from Belize tends to have wings that are more difficult to remove than the other mainland provenances. The wings are 10 -20 mm long, and are proportional in length to the seed.



A.M.J. Robbins, june 1983

General morphology of the seed is similar to most pines, with an embryo lying longitudinally within female gametophytic tissue (commonly, but incorrectly, referred to as the endosperm).

Seed Dispersal and Germination (See figure 1)

Seed is dislodged and dispersed from the open cone by the wind. Most of the seed will fall within 25 m of the seed trees, some reaching 100 m, but hurricane force winds may increase the range considerably.

The seed generally fall in the wet season, and germination follows rapidly afterwards. Germination is epigeal: the radicle first emerges from the seed to form the primary tap root, after which the hypocotyl elongates forming an arc above the soil, finally bringing the cotyledons above ground usually with the seed coat attached.

Cotyledon number varies from 4-8 with a mean of 6-7, which are followed by primary or juvenile foliage, and then the secondary or adult foliage. There are distinct differences in seedling characteristics between varieties (Lückhoff, 1964). Seedlings of *P. caribaea var. caribaea* and *var. bahamensis* are characterised by their bright green colour, very early formation of secondary needles (after 2-3 months) which are long and coarse, and growth is slow and bushy. Primary needles have usually disappeared after six months. In contrast, *Pinus caribaea var. hondurensis* from the mainland has seedlings with a much more rapid growth, tall and slender in form, the secondary needles are produced only after nine months, and primary needles remain persistent for one year or more.

P. caribaea var. hondurensis seedlings from Honduras are similar to *P. oocarpa* from the same country, but tend to have a longer hypocotyl without the pink colouration of *P. oocarpa*, and also longer and lighter green cotyledons.

Seed and Cone Pests and Diseases

In natural stands damage occurs to cones from cone borers (*Dioryctria sp.*) both at conelet stage and in the second year. In Belize on the Mountain Pine Ridge, the species *D. sysstiatiodes* Dyar and *D. majorella* Dyar have been identified (Lamb, 1973). Hedlin *et al.* (1980) record *D. erythropasa* Dyar as the principal species throughout Mexico and Central America.

Parrots and macaws destroy the cone in some localities whilst feeding on the seeds, particularly in the mainland coastal populations of *P. caribaea*. The pine cone rust, *Cronartium conigenum* (Pat.) Hedge & Hunt, can cause serious damage in natural stands. The cones are infected during the first year of development; as a result they swell up to 120 mm or more in diameter, finally becoming covered in bright yellow-orange aecidiospores in the third year after infection (Gibson, 1979). Serious losses of *P. caribaea* seed due to the fungus have been reported in Belize (Etheridge, 1968). The fungus requires *Quercus sp.* as an alternate host, the eradication of which would be the most effective control, but prohibitively expensive to do in most cases.

After collection, the cones are easily susceptible to infestation by fungal moulds if improperly stored. Normally the fungi attack only dead or brown tissues, and not the green parts of the cone. During cone drying and extraction, the fungal spores become mixed with the seed and lodge in the seed coat and may cause problems during the germination of the seed. Several genera have been identified by the Commonwealth Mycological Institute, U.K. on seed lots from Honduras and include *Aspergillus, Penicillium, Rhizopus, Syncephalastrum, Trichoderma, Fusarium, Curvularia,* and *Mucor*, which are either saprophytic or facultative and do not normally attack the seed or seedling. However, some lots have shown infestation by pathogenic fungi, of which the potentially most dangerous is *Botrydiplodia theobromae* (Robbins and Ochoa, 1980). This fungus appears to be prevalent in seed from high rainfall areas near to hardwoods where coffee, bananas, etc. are grown, and may be the cause of occasional serious seedling loss both in Honduran nurseries and in other countries. Fungicidal treatment of the seed will prevent such losses.

5. SEED AND FRUIT PRODUCTION AND COLLECTION

Choice and Management of Trees and Stands

Trees suitable for collection in natural stands are from 12-15 years and older, sufficiently stocked to ensure adequate pollination. Isolated trees should not be collected from, because of the increased likelihood of self-pollination and consequent large number of empty seeds. In plantations, female cones are produced when trees are 3-4 years old, but do not generally produce viable seed, probably due to inadequate pollination (Lamb, 1973). Generally, seed collection should be restricted to good seed years, since in poor years the proportion of insect damaged and empty seed tends to be much higher.

Ideal spacing for trees in a seed production area derived from plantations is probably similar to that indicated by Florence and McWilliams (1954) for *P. elliottii*, i.e. about 180 stems/ha at age 20. In Fiji, plantations are thinned to the best 200 stems/ha in two stages at 5 and 7 years (Bell, 1980). In Brazil, thinning favours the best 300 stems /ha (Bertolani and Nicolielo, 1977). Seed stands derived from natural forest (mean age 15 -20 years) in Honduras are thinned to between 1/3 and 1/2 the average height of the seed trees, equivalent to 150 -225 stems/ha (Hughes and Robbins, 1982).

In selecting seed trees, particular care should be taken to favour those of good form, avoiding sinuous stems, coarse and acute angled branching, and poor pruning, which are highly heritable characters. Such characteristics are best identified when the trees have had time to develop them after 10-15 years, so selection of final trees in a seed stand should be left until that age. Fertilizers may assist in increasing cone and seed yield. The elements and concentrations must be applied according to the soil fertility. Date of application may be critical, especially if the fertilizer should be applied just before reproductive cell initiation. See Puritch, 1977, for general aspects.

Cone Yields

Yield of cones per tree varies considerably, and the ability to produce cones is under strict genetic control. Unfortunately, the best phenotypes are generally poor cone producers. In natural unmanaged stands in Honduras, typical seed trees used for bulk collections (20-40 years old) produce 500-2000 cones/tree. The majority of trees produce much less than this, both in natural stands and plantations, due to close spacing, but properly managed seed stands should produce within the range given per tree, equivalent to at least 15 kg of seed/ha.

Abundance of the seed crop varies from year to year, but no fixed periodicity of crops has been demonstrated.

Crop Estimation

The cone crop may be estimated once the cones have reached full size, and are still green (i.e. approximately 2-3 months before the cones become mature). The best method is to make a subjective estimate of the crop per tree (poor, regular, good) using good quality 7 x 50 binoculars, as described in Dobbs *et al.* (1976). Care should be taken when estimation occurs during the rains to exclude counting old cones that have reclosed. Distinguishing between old grey cones and new green cones can be difficult, and noting position will help distinguish the two types.

The yield of seed from cones may be estimated using a cone cutter or machete (see Dobbs *et al.*, 1976). The ratio of the number of cut seeds per surface to full seeds per cone is from 1:12 to 1:18. Average counts for natural stands are 1-5 cut seeds, representing 14-80 full seed per cone. Yields from coastal provenances of *P. caribaea var. hondurensis* tend to be much lower than inland provenances.

Maturity Indices

Care must be taken to avoid collecting immature cones, which is particularly likely to happen at the beginning of the collection season. Time of maturing varies between and within trees in anyone stand, and if collection is made too early, a large proportion of immature cones may be collected. These will either not open or produce weak seed. It is generally best to lose some of the crop by delaying collection ensuring that all cones are mature. Careful note should be taken of variation in maturing dates between stands, and collections should be organised to suit.

Estimation of maturity is best done using several indices, since none is sufficiently reliable by itself. Cones should generally be more than half brown in colour, and when cut in two, the cone axis should be dark brown. If the apex of the cone is pressed with the thumb, it should feel firm, the scales easily cracking open, coloured light brown on the interior surfaces. The seed coat must be darkening in colour, and the gametophytic tissue and embryo should be firm and white, nearly or completely filling their respective cavities.

Specific gravity appears to be a useful criterion, as it is with other pine species. Studies by Hughes (1981) indicate that a cone with a density (=SG) of 1.14 grams/cm^3 or more is unlikely to open properly during processing and is too immature for collection. As a guide, if over 3/4 of a cone sample floats in water (SG=l), then collection can start from the area that the sample represents. This relation should be checked for each provenance and country.

Collection Methods

The most convenient method for climbing trees is by using climbing spurs, safety belt or saddle, and appropriate ropes as described and illustrated in Robbins *et al.* (1980) and Yeatman and Nieman (1978). Damage to the sapwood by spurs is normally not significant. If the trees are to be climbed repeatedly, and it appears that damage will be unacceptable, then lower bole ascent may be accomplished using sectioned aluminium ladders, or tree bicycle, pruning the trees where necessary.

The cones, in 1 or 2 whorls of 1-4 cones, have a short peduncle which is generally weak but may be quite resistant. Care must be taken not to break the rather fragile branchlets whilst dislodging the cones, as this would seriously reduce cone crops for three or more years in the future. The best type of cutter is the bell type, developed in Honduras and used in other Central Americal countries (Robbins *et al.*, 1980; Robbins, 1982), fixed to the end of a light weight aluminium pole (about 5 m long). The cutter is designed to be used pushing outwards towards the branch tip, whilst the collector is within the tree crown. Cones on trees in grafted seed orchards would be best collected from a mobile platform outside the tree, cutting individual cones with secateurs.

Climbing in natural stands is generally done at the beginning of the rains, and inclement weather can seriously hinder collection so allowance must be made for this in planning. Climbers should be able to climb about 3-5 trees per day (average crop). If seed tree yield averages 75 litres of cones/tree, yield per climber/day will be about 225 -375 litres of cones. The actual rate of collection will depend on crop, and size and distribution of seed trees.

Cone Storage

Cones that have just been picked have a high moisture content (40-55 % fresh weight basis), and the green tissues will continue to respire for over a week after collection, producing water and heat. The cones should therefore be left in sacks for as short a time as possible, preferably not more than 1 -2 days, in the shade and properly ventilated (see Dobbs *et al.*). If the cones cannot be transported to the processing area within this period, the sacks must be emptied and the cones stored in bulk in the shade, either on a clean floor and frequently turned, or in a wooden bin with a raised slatted floor, as described in Robbins *et al.* (1980). Care must be taken, by keeping the cones as cool and dry as possible, to avoid fungal growth, which generally occurs on brown tissues rather than green.

Once cones have become brown and are still moist, the scales can start to open giving the seed inside ideal conditions for germination (moisture, warmth, oxygen) if they are not kept cool and allowed to dry. In such a case, pregermination of the seed may occur, reducing viability and vigour of the seed lot. This can be detected during collection and processing by a cutting test.

6. SEED PROCESSING

Precuring

Cones of *P. caribaea* require precuring before drying to open. This is best done by spreading them on stackable trays with wire mesh bottoms (capacity 50-100 litres of cones), under shade, and leaving until the cone has turned completely brown. This will take from 5-10 days depending on ambient conditions during which the moisture contents (MC) of the cones will decrease from 40-55 % to around 15-25 %.

If cones are not precured but are placed in high heat or sun while partially green, any postmaturing of the seed will not be accomplished, resulting in loss of vigour, and a condition known as case hardening will occur, where the outer green tissues dry so quickly that loss of internal moisture is restricted and the cone will only partially open or not at all. A satisfactory method of maturing very green cones (SG more than 1.2) is not known.

Cone Drying and Seed Extraction

Properly mature *P. caribaea* cones open relatively easily, despite the fact that maturation occurs during the rains. Sun drying is generally adequate, provided the climate is not too humid. In some countries, it may be necessary to transport cones to a drier area so that drying is more rapid. The ideal method of sun drying is to use the same trays used for precuring, spreading them out individually, and covering at night or during rain.

The method of drying on tarpaulins can be used, provided care is taken in keeping the rain out. In this case, if trays are not available, precuring is best done in wooden bins (as previously described), located at the processing site. Sunny weather conditions (27°C mean ambient temp., 70 % mean day-time relative humidity (R) will allow cones to open in 2-3 days.
If space or climate do not permit sundrying, cones may be dried in a laboratory forced draught oven (small lots), or in larger kilns such as the ESNACIFOR type described by Robbins (1985). A regime of 40-45°C and 20-30% RH for up to 24 hours should be sufficient. In lowland tropical areas with high ambient temperature and RH, it may not be possible to reach low kiln RH, and drying will take longer. Care must be taken not to apply high heat to cones when the seed still has a high MC % or the drying air has a high RH, and temperatures in excess of 40°C should only be used at the end of the drying period. Temperatures up to 50°C have been used apparently without reduction of seed viability or vigour (M. Duran, Olanchito, Honduras, pers. comm.), but are generally not recommended. Air circulation within the kiln must be adequate.

During opening, the volume of a cone increases by a factor of 2-3 and loading of trays should take this into account. Once open, the cones release the seed easily, and if the tarpaulin method is used, frequent raking is sufficient to dislodge most of the seed. If trays are used, then the cones must be put through a tumbler, a suitable size holding 50 litres of open cones, and tumbled for about two minutes.

Extraction efficiency is affected by several factors. The presence of cone borers will prevent scales from opening completely. Overdrying will cause apical scales to bend backwards onto basal scales, trapping basal seeds if these have not already fallen out. Leaving the cones overnight or moistening will allow the cones to reclose a little, remedying the situation. Immature cones are characterised by opening from the apex first, being prevented from complete opening by the basal scales which do not open. This is because the cone matures from the apex towards the base, although normal opening is from base to apex, or uniformly.

Dewinging

After extraction, the wings must be removed from the seed. *P. caribaea var. caribaea* has adnate or persistent wings which are difficult to remove without damaging the seed (Lückhoff, 1964), and should be gently broken off by rubbing the seed together. The other varieties may be dewinged in small quantities by being placed in a linen bag and lightly rubbed together by manipulating the outside of the bag. For larger quantities, the best method is to wet the seed and then tumble together. Suitable tumblers may be made from drums, turned by hand or motor, or a cement mixer. In Honduras, best results are obtained by tumbling about 75 litres of seed with wings, firstly dry for 15 minutes then adding water by sprinkling and tumbling for a further 45 minutes. About 1 litre of water should be added for each 50 litres of seed with wings.

Cleaning

The mixture resulting from drying, extraction, and dewinging contains seed, wings, cone-scale and needle parts, small stones, and a large amount of dust. The seed may be separated by firstly screening (sieving) either by hand or with a machine. Suitable screens have a round aperture. Typical sizes for Honduran *P. caribaea* are No. 12 (4.76 mm diam.) which allows seed to pass but retains bigger material, and No.6 (2.38 mm diam.) which will retain seed. If round aperture screens are unavailable for hand processing, then wire mesh sieves (square apertures) can be tried.

The screened seed should then be winnowed, so as to remove wing parts and other material the same size as the seed, and also empty seed. This may be done using a domestic fan, or by machine in combination with screening. Cleaning machines are available commercially that are suitable for the annual processing of at least 200 kg of seed and upwards. Almost all empty seed can be removed by careful adjustment of the airflow (an empty seed weighs about 1/2 -1/3 the weight of a full seed).

If care is not taken during collection and storage, some seed lots may have a high percent of dead seed (immature or pregerminated). These will have a similar weight to viable seed, and are difficult to remove. Simak (1981) describes a method of separation which depends on the differential adsorption and evaporation of moisture from dead and viable seed which accentuates weight differences, thus enabling separation by flotation or on a gravity table. This may work for *P. caribaea*.

After cleaning, the seed is dried in the sun on a sheet, about two seeds thick, and raked frequently. The seed will lose about 1-1.5 % MC (fresh weight basis) per hour. For small quantities, a forced draught laboratory oven may be used with a temperature of 40-45°C. If ambient conditions are not suitable for reaching an MC which is low enough, the seed should be taken to a drier geographical area, or a dehumidification chamber should be used.

Seed Yield

Bulk collections from natural stands of *P. caribaea var. hondurensis* vary considerably in yield. Inland provenances yield from 250 g of pure processed seed per 100 litres of closed cones, up to 625 g/100 litres. Coastal provenances tend to be lower, from 125-250 g/100 litres. A large amount of immature cones or insufficient precuring is generally the cause of very poor yields, though in some cases this may be due to poor pollination, as can occur in the coastal provenances, and in exotic plantations. Bertolani and Nicolielo (1977) state a yield of 500 g/30 kg of cones (approx. 80 litres) from plantations in Brazil. In Jamaica, yield from *P. caribaea var. hondurensis* plantations from the central region is approximately 300 g/100 litres (Harold Brown, Forest Department, Kingston, Jamaica, pers. comm.), but plantations in the Blue Mountain region yield little seed, probably due to the humid climate during pollination.

The seed potential (as defined by Bramlett, 1964) of *P. caribaea var. hondurensis* is 100-140, and the above mentioned yields represent a seed efficiency for bulk lots (i . e. total number of filled seed/seed potential x 100) from 6-30 % or 7-35 full seeds per cone. It is likely that efficiency could be increased up to 50 % by improving pollination.

7. SEED STORAGE AND PRETREATMENT

P. caribaea seed is classed as orthodox, and therefore the optimum conditions for routine storage are 6-8 % seed MC (fresh weight basis) and 3-4°C ambient air temperature. The MC % should be maintained by storing in either rigid containers with a hermetic seal lid for small quantities, or in polythene bags of at least 100 microns (4/1000") thickness, sealed by twisting the mouth and crimping with soft iron or copper wire.

Under the above conditions, the seed can be stored for at least five years and probably up to 10 without significant deterioration in viability. If a cold store is not available, and seed MC can be kept at the recommended level, then seed will store for up to a year (average ambient temperature 22°C). Seed that is stored unsealed will reach an equilibrium MC with the atmosphere of around 12 % or higher, and may be liable to attack from fungi and insects, and therefore needs to be treated with chemicals. Orthocide and Dieldrin have been used for this purpose in Honduras, added to the seed lot as powder. Where possible, the use of chemicals should be avoided, since they may, in themselves, reduce viability. Storage life at ambient temperature will be about 4-6 months. Seed that has not been dried should be stored in canvas or cotton bags, to avoid sweating and overheating resulting from respiration.

No pretreatment of the seed prior to sowing is normally necessary, since no form of dormancy is known.

8. SEED TESTING

Sampling

Sampling methods are standard. Medium to large lots are best sampled using a seed trier. If seed cleaning is inefficient, and a large proportion of empty or dead immature seed remain in the seed lot, then difficulty may be experienced in obtaining representative seed samples (Gordon and Wakeman, 1978).

Purity and Pure Seed Weight

Purity and pure seed weight are assessed using normal ISTA procedures (ISTA, 1976, 1981) and applying the appropriate definitions for pure seed and impurities. Purity, using standard cleaning methods, should average 97 % (range 94-99 %).

Pure seed weight varies according to variety and provenance. Lückhoff (1964) gives the following values (nearest 1000): *P. caribaea var. bahamensis* 85,000 -76,000; *var. caribaea* 62,000; *var. hondurensis* 52,000 (Mountain Pine Ridge), 65,000 -80,000 (Stann Creek); and *var. hondurensis* seed lots from Honduras average 59,000 (range 51,000 -77,000). Lamb (1973) gives the following figures: *var. bahamensis* from Gr. Bahama 81.000; *var. caribaea* from Cuba 59. 000; *var. hondurensis* from coastal plain 71.000; *var. hondurensis* from Mountain Pine Ridge 52.000; and *var. hondurensis* from Honduras 72.000.

Moisture Content Determination

Moisture content determination is conveniently done by drying a sample (two replicates of 5 g each) to constant weight in an oven at 105°C. ISTA recommended the use of toluene distillation on account of the volatile oils present in the seed, but the method is beyond the means of most seed programmes, and has been withdrawn as a prescribed test. An electronic grain moisture meter gives sufficiently accurate results for determining how much drying is required prior to storage, but the meter must be calibrated by the user.

Germination Tests

The standard ISTA regime of 30°C/light/8 hours -20°C/dark/16 hours appears to be suitable for *P. caribaea*, but equally good germination results have been obtained at ambient conditions of temperature and light in Honduras (average temp. 21°C, range 19°-23°C).

The moisture content of the air should be around 95 % RH. The substrate can be filter paper, towelling (e.g. "Kimpak"), or sterilised, sieved sand. The last two are preferred, as the seedlings can develop upright, and classification is easier, and any fungal growth (which may be severe) is restricted. A convenient system for maintaining moisture and retaining the substrate is to place each replicate of 100 seeds within a transparent plastic box with lid (a size of 11 x 17 x 6 cm high is suitable). The boxes may be placed on a bench out of direct sunlight and allowed to follow ambient temperature and light, or placed in an incubator.

Seeds begin to germinate after 2-3 days, and germination is normally complete after 21 days. Counts may be made every 7 days, or every 3-4 days if germination vigour is to be compared between lots. Germination percentage averages 74 % with a range of 66-93 %. Standard ISTA definitions can be applied for the classification of seedlings and remaining ungerminated seeds (see also next section). Common abnormal seedlings are those with unpigmented cotyledons, twin embryos, emergence of cotyledon first, and those attacked by fungus that has developed from the seed coat.

In any one seed lot, the earliest germinating seed tend to produce the biggest seedlings (Venator, 1973). Seedling size may be positively correlated to seed size as with some other conifers.

Rapid Tests of Viability

The cutting test is useful for quick estimates of viability during collection and processing. Seeds should be soaked for 24 hours to facilitate sectioning. Viable seed are full, with fresh white tissue. Immature seed are distinguished by partial filling of the embryo and gametophytic tissue cavities. Seed that has started to germinate (due to improper storage) can be identified by a yellowing of the embryo (although a light yellow colour is sometimes normal), which may even become green. If the gametophytic tissue has a slightly glazed appearance, somewhat grey or yellowish, this will indicate a weak or dead seed. Completely dead seed will often be black, due to fungal attack.

The tetrazolium test can be used successfully. To ensure complete penetration, the seeds should be soaked in water for 24 hours, and then sliced open along the broad face of the testa, parallel, and to one side of the embryo. The cut seeds should then be placed in the salt, in the dark, for a period of 4 hours at 35°C to achieve sufficient penetration. Suitable estimates of viability can be made on examination of the embryo alone, which is eased out of the gametophytic tissue using a seeker. Viable seeds, class A, are those that are totally stained, irrespective of density of staining. Class B may show small areas of unstained tissue in the cotyledons or hypocotyl. Non-viable seeds, class C, show the radicle tip, or large areas of the hypocotyl or cotyledons unstained. Class D is totally unstained.

Radiographic tests of viability can be used for *P. caribaea*. Preliminary work in Honduras indicates that the following conditions produce a good radiograph: paper: Kodak X-Omat, cassette: thin envelope homemade from polythene/carbon paper, kV: 10, mAs: 180, ffd: 90 cm. This technique would be excellent for studying maturity of the seed, following Simak's (1980) classification of development classes.

9. REGENERATION PRACTICES

Nursery Propagation

Nursery practice for *Pinus caribaea* follows closely the general practice for tropical pines summarized in Danida Forest Seed Centre Technical Note No. 4 (Napier & Willan 1983). Experience with *P. caribaea* has been described by Voorhoeve and van Weelderen (1971) for Surinam, Paul (1972) for Malaysia, Bharathie (1973) for Sri Lanka, Ekwebelam (1974) for Nigeria, and Lamb (1973) in general.

P. caribaea var. *hondurensis* is one of the faster tropical pines in the nursery. Growth rates vary with climate, soil and nursery management but in the low altitude tropics with good nursery techniques a height of 30 cm should be attainable in about 6 months. The optimum size at planting recommended for container-grown stock in Honduras (Napier, 1982) is 15-25 cm high, root collar diameter of at least 2-5 mm and root/shoot ratio (dry weight) of 0.8-1.0. For bare-rooted stock, regularly root-pruned, recommended size is 20-30 cm high, root collar diameter 3-6 mm and root/shoot ratio of at least 0.25 -0.30. *Var. bahamensis* and *var. caribaea* are slower in the nursery than *var. hondurensis*.

Container-grown stock is normally used in the tropics but bare-rooted stock has been used with considerable success in Queensland.

Direct Sowing

This method has been tried in several countries within the natural distribution of *P. caribaea var. hondurensis*. Trials in the Mosquitia region of Nicaragua, using the same coating as suggested by Derr and Mann (1976), failed due to the toxicity of the chemicals. However, further trials without seed treatment were successful, since there appeared to be little loss to predators.

Recommended rates of sowing were 150 g of viable seed per ha, broadcast, or, so as to economise on seed, sown in spots at 6 seeds/spot and 1200 spots/ha (Wolffsohn, 1974). Application of triple superphosphate was essential to allow release of seedlings from the surrounding vegetation.

In Honduras, the toxicity of Derr and Mann's formulation has also been confirmed, but treatment at lower concentrations appear to be satisfactory. The mixture currently used for 1 kg of seed is 60 g Arasan, 20 g Endrin 50 %, 5 ml latex, and 100 ml water. No aluminium powder was used. In general, sowing in spots at 10 seeds/spot appears reasonably successful, and broadcast sowing may be better in the Mosquitia area (Troensegaard, 1981).

Any attempt at direct sowing should be preceded by careful testing of the chemicals and method of sowing.

Natural Regeneration

This method is the most important for natural forests and has been studied in detail in Nicaragua by Wolffsohn (1974). An adequate amount of seed trees must be left (10/ha or higher) and the site prepared by prescribed burning. In general, regeneration of *P. caribaea* in Central America is abundant, especially in the Mosquitia coastal plains.

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