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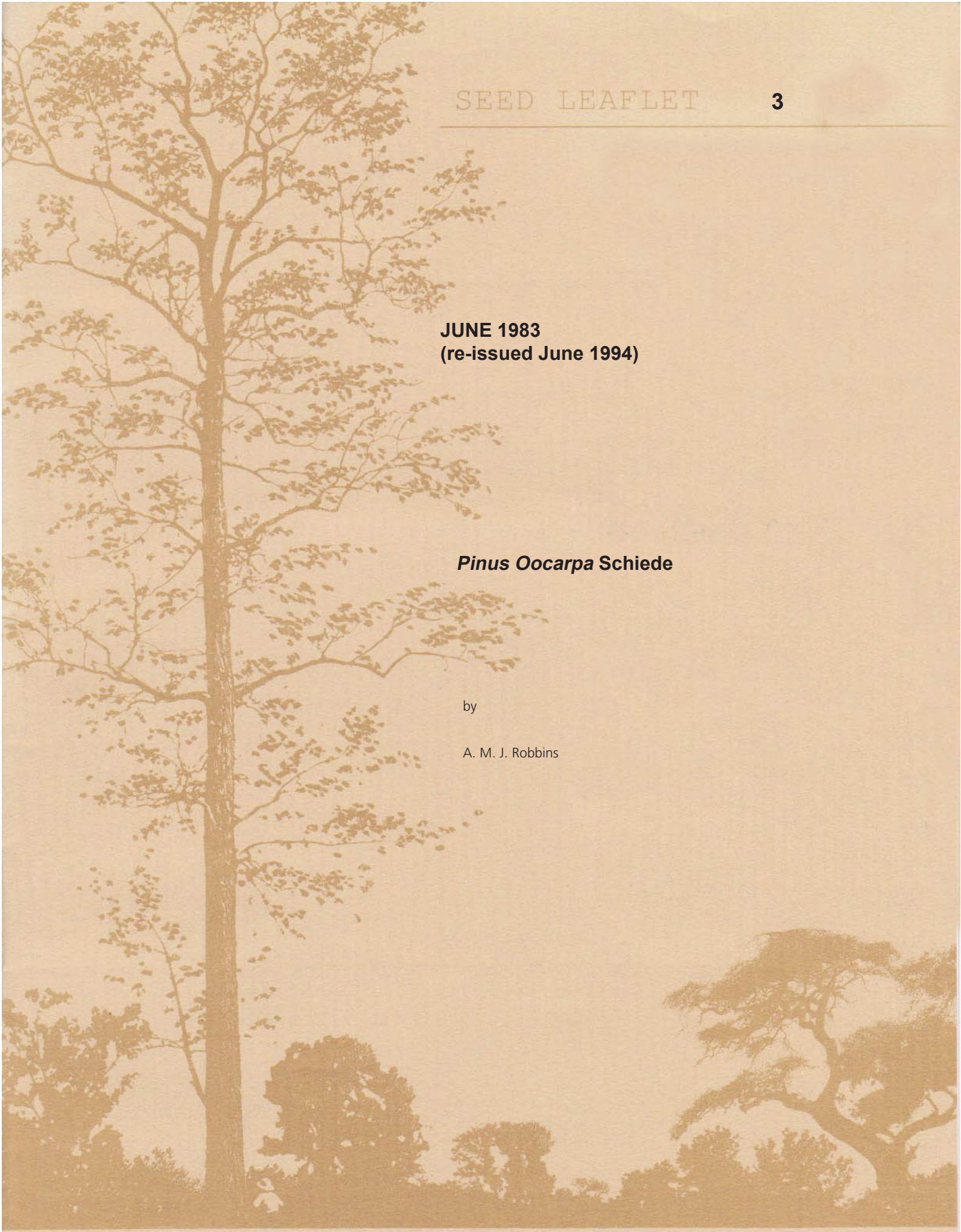

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Pinus Oocarpa Schiede

by

A. M. J. Robbins

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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.

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2. NOMENCLATURE

Botanical name:	*Pinus oocarpa* Schiede
Synonyms:	*Pinus oocarpoides* Lindley
Family:	*Pinaceae*
Common names:	In Central America the tree is referred to as Pino ocote or Pino colorado. The term "ocote" refers specifically to the resinous heartwood used for fire lighters. The timber is often described along with *Pinus caribaea* Morelet as Caribbean Pitch Pine.

3. THE TREE

Size and Growth Habit

P. oocarpa is a typical pine, with fascicles of 4 -5 needles, reaching a maximum height of around 45 m and a d.b.h. of 1 m on good sites. Generally the tree is much smaller in its native habitat, reaching a he of 20-30 m. 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 spp.* The stands are defined ecologically as a fire subclimax, since they owe their existence to periodic fires which suppress the majority of competition from broadleaved species (Denevan, 1961).

Form is generally good, with a straight bole and a moderate to light branching habit when growing in stands, with the crown forming ¼ to ⅓ of the

bole height. Open-grown trees have large, deep crowns and fairly coarse branching.

Some trees have acute angled branching, and there is a tendency towards aerial forking of the main stem, both characteristics probably being highly heritable. Young trees will coppice at the base or higher up after injury from grazing or fires.

Natural Distribution

P. oocarpa is found from Mexico south to Nicaragua (Critchfield & Little, 1966), with a typical altitudinal range in Central America from 700 m up to 1600 m, but it occurs in some areas up to 2000 m. Both lower and upper limits may be determined by the effect of temperature on reproductive processes, thus limiting natural regeneration. In general the distribution is fairly continuous, being broken up, particularly on the better soils, by clear cutting for agriculture. The better formed stands have been heavily exploited for timber, and as a result the forest is often poorly stocked. Frequent fires also result in low stocking.

The species is generally found on the poorer acidic lithosols and also on deeper, more fertile, soils formed from metamorphic rocks.

The climate varies considerably within the natural range. Mean annual rainfall ranges from 700 to 1800 mm with a dry season lasting from 5 to 7 months. Mean annual temperature varies from 22°C down to 16.5°C at the highest elevations. Greaves (1979) gives climatic details for collection sites throughout the natural range. Details of distribution within Honduras are given in Robbins &Hughes (1983).

Variation and Improvement

The typical tree type as described here is *P. oocarpa subsp. oocarpa*, found from Mexico south to Nicaragua. *P. oocarpa subsp. microphylla* Shaw has a limited range in N. Mexico. *P. oocarpa subsp. trifoliata* Mart. is found in the drier parts of Mexico and perhaps Central America (Styles, 1980). *P. oocarpa var. ochoterenai* as described for Mexico is conspecific with the closely related *P. patula* Schiede and Deppe (Styles 1976). Reported occurrences of this variety in Guatemala, Honduras and Belize are probably *P. patula subsp. tecunumanii* Schwerdtfeger (Styles 1985), as are certain Nicaraguan stands previously identified as typical *P. oocarpa* (Barnes and Styles, 1982; Styles and Hughes, 1983; Styles 1985). Hybridisation has been tentatively identified between *P. oocarpa* and *P. caribaea* where the two species overlap in their natural distribution (Styles, Stead and Rolph, 1982), and artificial hybrids have been produced in Honduras and Australia. Hybrids may occur naturally with *P. patula* subsp. *tecunumanii* and *P. maximinoi* Moore.

The provenances of *P. oocarpa* have been studied in detail as part of the Central American Pine Provenance Research Project based at the Commonwealth Forestry Institute, Oxford, England (Kemp, 1973; Greaves, 1981). Results of the international provenance trials are available from many individual countries (see Burley and Nikles, 1973; Nikles, Burley and Barnes,

1978; Greaves, 1982a, 1982b) and are summarised up to 1978 by Greaves (1980). The best provenances appear to be those from the southern part of the range in Nicaragua and in Belize. However, some of these occurrences may, in fact, be P. *patula subsp. tecunumanii* (Barnes and Styles, 1982; Styles 1985). The general vigour and form quality of the other provenances tend to decline with increasing latitude, being best in Honduras and poorest in Mexico.

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

Seed stands have been established in natural forest in Honduras (Hughes and Robbins, 1982) and in exotic plantations, particularly in South America. Breeding programmes are underway in many countries (see Gavidia, 1978; Greaves 1982a, 1982b).

Importance for Plantations and Uses

P. oocarpa is proving to be an excellent species for afforestation on medium altitude sites in the tropics. The increasing amount of genetic data available on the species, and the expanding seed supplies are facilitating its use. The total area planted around the world in 1977 was estimated at 23,377 ha (Gavidia, 1978). The area was in 1982 probably four times this amount, increasing by about 20,000 ha/year.

The timber of *P. oocarpa* is excellent for construction purposes, and the first quality timber is used for pine furniture and panelling. The timber is also used for pulp, chipboard, and plywood manufacture.

The resin obtained from the sapwood is of good quality for produc turpentine, rosin, and associated products. In indigenous forests, the tree is widely used for firewood, and there are local industries for manufacturing poles and posts.

4. REPRODUCTIVE BIOLOGY

Flowering and Seed/Fruit Development

Trees are monoecious, with a tendency towards unisexuality in some individuals. The male strobili are numerous, sessile, and found in whorled, short and crowded clusters near the ends of twigs in the lower part of the crown. Individual closed male strobili are 20-30 mm long, and 5-7 mm broad. The female strobili are found mostly in the upper of the crown, appearing near the apex of elongating twigs, but becoming lateral in a whorl of typically 2 -4, with gene 1 or rarely 2 whorls per year.

In the species' natural range in Honduras, the female strobili are probably initiated from August to October, becoming visible as buds about a month before pollination, which then occurs typically during November -January in Honduras, and during January-February in Mexico (Patino, 1973). Flowering

tends to be later with increasing altitude and latitude. In Brazilian plantations, (Agudos region, Sao Paolo), pollination occurs during June-July, due to reversed seasons in the southern hemisphere (Bertolani and Nicolielo, 1978).

After pollination, the female strobilus or conelet, which is about 10-12 mm long, increases in size to about 15-20 mm, changing colour from pink, through light green, to brown. At the same time the peduncle elongates to 25-40 mm and bends backwards. This process is completed within about two months after pollination, after which the conelet remains unchanged for up to 12 months until fertilisation of the egg cell occurs. The conelet then suddenly increases to final size during a period of three months (approximately March-May in Honduras). Maturation of the cone takes a further six months, the main period of cone maturity and seed dissemination occurring in Honduras during the dry season from February to May, 25-29 months after pollination.

Development periods shorter than the above have been noted in natural stands (Mirov, 1962; Robbins, 1982b), and the conelet can start to increase to full size only six months or less after pollination, reducing the period to maturity by eight months. This may be because a resting stage of the pollen tube is circumvented, perhaps due to more favourable climatic conditions. If this type of development is found to be fairly common, it may explain the extended seed dissemination period that has been reported by many workers (e.g. Hudson *et al.*, 1981; Wolffsohn, 1982) in natural stands in Honduras. Bertolani and Nicolielo (1978) state that in plantations of *P. oocarpa* in Brazil, mature seed can be found throughout the year, and cones of different stages of maturation can be found on the same tree. Peak production in these plantations occurs during June-August (24-26 months after pollination).

Conelet abortion after pollination can be high, up to 80 % (Houkal, 1980). This may be due to incomplete pollination, to competition between conelets and vegetative growth, or to insect attack. Further significant abortion occurs after fertilisation. Adequate pollination depends on suitable weather conditions at flowering time (dry, sunny), and will be a critical factor for seed production outside the species' natural range.

Cone and Seed Characteristics

The mature cones are very variable in shape and size. The typical cone is broadly ovoid or egg-shaped (as the specific name suggests), about 70-80 mm long and 50-55 mm wide. However, shapes ranging from almost spherical to narrowly ovate with lengths from 40 to 150 mm are found, the variation being principally between trees within a stand. Variation within an individual is very limited. Older trees appear to have smaller cones. The cones are persistent, remaining on the tree for several years, and are borne on long peduncles (as compared with those of *P. caribaea* which are short or sessile).

The number of cone scales on a mature cone varies from 120 to 160, of which about half are fertile (i.e. capable of producing seeds). Seeds are

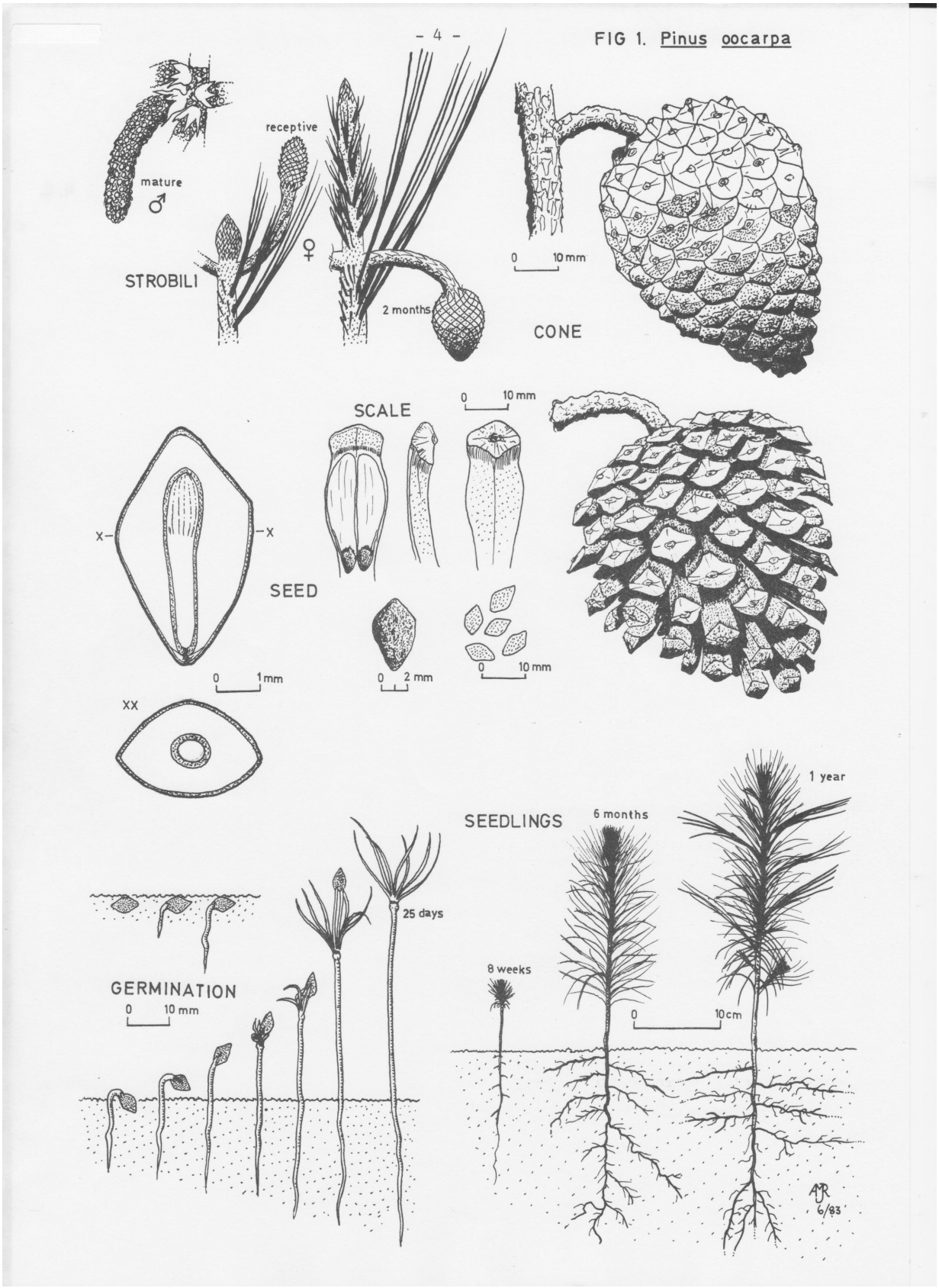

Figure 1: Details of Pinus oocarpa

borne in pairs on top of the cone scale, in shape narrowly ovoid, about twice as long as broad, pointed at both ends, averaging about 6 mm long and 3 mm wide. The colour of the seed, with the outer coating of the testa intact (i.e. before processing) varies from black, grey, to 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. General morphology of the seed is similar to most pines, with an embryo lying longitudinally within female gametophytic tissue (commonly referred to as the endosperm).

Seed Dispersal and Germination

Seed is dislodged and dispersed from the open cone by wind. If there is insufficient wind, the seed may remain in the cone for several weeks before being released. It appears that the flexing process of the cone scales due to diurnal variation of temperature and relative humidity of the air greatly assists in unsticking the seed from the cone.

Wolffsohn (1982) states that in natural stands 90 % or more of the regeneration is found within 25 m of the seed trees. The normal limit is around 100 m, but hurricane force winds may increase the range considerably.

The seed generally falls during the dry season, and may spend some time on the ground before conditions are suitable for germination, during which it is liable to heavy attack from predators (Wolffsohn, 1982).

Germination is epigeal (see Figure 1). The radicle first emerges to form a primary root. The hypocotyl then elongates, forming an arc above the soil and finally bringing the cotyledons above ground, usually with the seed coat attached. There are from 4 to 7 cotyledons, normally 5-6, which are followed by juvenile and finally adult foliage, which is generally formed only after 9 months.

In comparison with *P. caribaea var. hondurensis* from Honduras, *P. oocarpa* seedlings from the same country tend to have a shorter, reddish hypocotyl, and shorter, darker green cotyledons.

Seed and Cone Pests and Diseases

In natural stands considerable damage occurs to cones from cone borers (*Dioryctria sp.*), both at the young stage and when in the second year. *Dioryctria erythropasa* has been identified by Becker (1973) in cones collected in Honduras. *Megaselis scalaris* has been identified attacking seed in Honduras (J.V. Mankins, pers. comm.). Parrots can extensively destroy the cones in limited areas whilst on the seeds. The cone rust *Cronartium conigenum* infests conelets, causing them to swell to a mass up to 120 mm in diameter, which become covered in bright orange aecidiospores in the third year after infection. In some areas the fungus may significantly reduce seed yields (Gibson, 1979; Shieber, 1967; Wolffsohn, 1982). The fungus requires Quercus as an alternative host, the eradication of which would be the most effective control, but prohibitively expensive to do in most cases (Gibson, 1979).

5. SEED AND FRUIT PRODUCTION AND COLLECTION

Choice and Management of Trees and Stands

Trees suitable for seed collection in natural stands are aged 12 to 15 years and older and sufficiently stocked to ensure pollination. Seed from isolated trees should not be collected, because of the increased likelihood of self pollination and consequent large numbers of empty seeds. Ideal spacing for trees in a seed production area derived from plantations is probably similar to that indicated by Florence and McWilliam (1954) for *P. el1iottii*, i.e. about 180 stems/ha at age 20. In Honduras, seed stands derived from natural stands are thinned to a spacing between 1/3-1/2 the average height of the seed trees (equivalent to 150-225 stems/ha) (Hughes and Robbins, 1982). In Brazil, plantations are thinned to favour the best 300 trees/ha (Bertolani and Nicolielo, 1977).

Cone Yields

Yield of cones per tree varies considerably, and the ability to produce cones is under strong genetic control. In natural, unmanaged stands, typical seed trees used for collection (20-40 years old) produce 200-400 cones per tree. There are approximately 600-800 cones per 100 litres, so volume production per tree is around 30-50 litres. Properly managed seed stands should produce this amount per tree, equivalent to a yield of 5-10 kg of seed/ha (Hughes and Robbins, 1982). No periodicity of crops has been demonstrated yet, although abundance of the crop varies from year to year, and from stand to stand.

Crop Estimation

The cone crop may be estimated once the cones have reached full size, and are still green (i.e. approximately six months before the cones become mature). The best method is to make a subjective estimate of the cone crop per tree (poor, regular, good) using good quality 7 x 50 binoculars, as described in Dobbs *et al.* (1976).

The yield of seeds from the cones may be estimated using a cone cutter or machete (see Dobbs *et al.*, 1976). The relation between the number of cut seeds per surface and full seeds per cone is approximately 1:10 for small cones, 1:20 for cones. Average counts for natural stands are 1-3 cut seeds, representing 10-40 full seed per cone.

The best maturity index of the cone crop is cone colour, and cones should be collected when totally brown. Because the period from cone maturation to cone opening in individual trees is quite long (1-2 months), and there is considerable variation in maturing times between stands, collection operations can be extended over several months, and it is not normally necessary, nor advisable, to collect green cones. If green cones have to be collected, they should have a greasy appearance and a dark green/brown colour, i.e. tending to yellow/brown.

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). Damage to the sapwood by spurs is not normally 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 whorls of 1-4, have a very tough peduncle, and care must be taken not to break off the branchlets whilst cutting the cones, which would seriously reduce cone crops for four or more years in the future. The best type of cutter is the bell type, developed in Honduras and used in other Central American countries (Robbins *et al.*, 1980; Robbins, 1982a), fixed to the end of a light weight aluminium pole (about 5 m long). The cutter is designed to be used by 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 done during the dry season, so few problems are encountered from inclement weather. Climbers should be able to climb about 4-5 trees per day. If seed tree yield is around 30-50 litres of cones, the yield per climber per day will be about 250 litres.

Cone Storage

Brown cones have a fairly low moisture content (15-20 % fresh weight basis), and can be stored in sacks without danger of seed deterioration and fungal growth, provided the sacks are kept cool and well ventilated.

A convenient size of sack for storage and transport holds around 100 litres of closed cones, equivalent to a weight of approximately 36 kg fresh cones. Climbers may prefer to transport cones from the forest to the storage area in partially filled sacks to facilitate carrying.

6. SEED PROCESSING

Cone Drying and Seed Extraction

The cones of *P. oocarpa*, if collected when mature, do not require precuring before drying. About 1-2 weeks after being picked the moisture content of the cones will be around 15-18 %. Prolonged storage (1-2 months) under cool conditions or confined in sacks will allow the cones to dry down to 12 % without opening, which will then impede subsequent attempts to open the cone, particularly the basal scales, making seed extraction less efficient. Therefore it is best to dry and open the cones as soon as possible after collection.

In natural stands, since collection is done during the dry season, the simplest method of drying is by using the sun. This may be done by placing the cones on trays with wire gauze bottoms, or using tarpaulins. The cones should be covered at night to avoid dew formation and reabsorption of moisture. Sunny weather conditions (25°C mean ambient temperature, 60 % mean daytime RH) will open the cones in about 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 in Robbins (1985). A temperature of 50-55°C for up to 24 hours should be sufficient, depending on the initial temperature and relative humidity of the ambient air. A regime of 50°C for 8 hours, followed by 6 hours using stored heat overnight at an average of 45°C (average kiln RH 30-35 %) has successfully opened cone lots in the ESNACIFOR kiln. Temperatures up to 55°C do not appear to reduce seed germination percent or vigour, and may even improve it (Zendejas Elizondo *et al.*, 1971). Air circulation within the kiln must be adequate.

The discarded cones make excellent fuel to fire the kiln burner. Typical drying regimes in the ESNACIFOR kiln required only 400-500 litres of open cones to dry 3200 litres of closed cones. Flues will need to be cleaned frequently owing to the large amount of smoke produced.

During the opening of the cone, there is an increase in volume by 1.5-2.0 times, so loading of trays or tarpaulins should take this expansion into account. The seed is extracted from the cone by shaking. This may be done manually, knocking one cone against another, or by tumbling the cones for 2 minutes, a suitable size of tumbler holding 50 litres of open cones. If sun drying with a tarpaulin is used, most of the seed can be extracted during the drying period by raking the cones, but complete extraction normally requires final tumbling.

Extraction efficiency is affected by many factors. When possible (as with the tarpaulin method), cones should be moved frequently during the drying process. This may increase production by 5-10 % over tumbling at the end of the drying period only. Tumbling should be done as soon as possible after drying so that the cones do not start to close again as they absorb mois-

ture. Overdrying of the cones should be avoided, since apical scales may reflex so far as to touch basal scales, hence impeding seed removal. Cone shape affects the ease with which seed may be extracted; long narrow cones permit wider spacing between scales when open thus facilitating seed removal, whereas cones that are spherical in shape open with narrow spacing. Resin exudation caused by cone borer damage prevents surrounding scales from opening completely.

Should cones be stored for too long, so that opening is incomplete during drying, the cones may be soaked for 24 hours to relieve the condition. Sun and kiln drying temperatures will normally break the resin seal between the scales. However, placing the cones in boiling water for a minute has been claimed to hasten opening and improve seed extraction (M. Duran, Olanchito, Honduras, pers. comm.).

Dewinging

After extraction, the wings must be removed from the seed. For small quantities, this may be done in a linen bag where the seeds are 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, then tumbling for a further 45 minutes. About 1 litre of water should be added for each 50 litres of seeds 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 machine. Suitable screens have round apertures. Typical sizes for Honduran *P. oocarpa* 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 us a domestic fan, or by machine in combination with screening. Cleaning machines are available commercially that are suitable for production of 200 kg/season and upwards. Almost all empty seeds can be removed by careful adjustment of the airflow (an empty seed weighs about 1/2-1/3 the weight of a full seed).

After cleaning, the seed may be dried in the sun on a sheet, about two seeds thick, and raked frequently. The seed will lose about 1.0 -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.

Seed Yield

Bulk collections from natural stands of *P. oocarpa* yield around 160 to 250 g of cleaned seed per 100 litres of cones, depending on provenance and cone selection. Typical cleaning fractions produced during cleaning of seed from 100 litres of cones are as follows: 497 g (63 %) rubbish, 43 g (6 %) empty seed, and 245 g (31 %) full seed (total weight of seed with wings 785 g). The empty seed discarded in this example represented 15 % by **weight** or 35 % of the total **number** of pure seed extracted (Robbins and Ochoa, 1980). Bertolani and Nicolielo (1977) a yield of 120 g of pure seed per 30 kg of cones (approx. 90 litres) from plantations in Brazil.

The seed potential (as defined by Bramlett, 1964) of *P. oocarpa* cones is approximately 140, and the above yields represent a seed efficiency (total number of filled seed/seed potential x 100) of about 11 % (15 full seeds per cone). A seed efficiency for selected cones from one provenance in Honduras has been as high as 25 % (36 full seeds per cone). Houkal (1980) indicates that yield can be greatly improved by careful selection of cones (discarding old and diseased ones), and using correct extraction techniques. In this cone analysis, Houkal found that 25 % of the total full seeds were not extracted by simply knocking the the cones together.

In seed stands established in managed plantations it is expected that seed efficiency can be increased further by ensuring adequate pollination, and perhaps application of fertiliser.

7. Seed Storage and Pretreatment

P. oocarpa 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 airtight lids 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 wire.

Under the above conditions, the seed can be stored for at least five years and probably up to ten without significant deterioration in viability. If a cold store is not available, but the seed moisture content can be kept at the recommended level, then the seed will store for up to one year (average ambient temp. 22°C).

Seed that is stored unsealed will reach an equilibrium moisture content with the atmosphere of around 12 % or higher, and become liable to attack from fungi and insects. Under these conditions the seed may need to be treated with chemicals. Orthocide and Dieldrin have been used for this purpose in Honduras, added to the seed lot as a powder. Whenever 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. It is advisable to store seed that has not been dried, 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 sampled using a seed trier. If seed cleaning is inefficient and a large proportion of empty 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 percent, using standard cleaning methods, should average 98.5 % (range 95-99 %). Pure seed weight averages 58,000 seed/kg (range 57,000-61,000) in Honduras, and 43,600 seed/kg (range 36,000 53,700) in Mexico (Patiflo, 1973).

Moisture Content

Moisture content determination is most conveniently done by drying a sample 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 hrs. -20°C/dark/16 hrs. appears to be suitable for *P. oocarpa*, 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). In a study on the optimum temperature for pines, Perner (1966) found that *P. oocarpa* germinated best at 32°C, rather than at 8, 16, or 24°C.

Relative humidity of the air should be about 95 %. Substrate can be filter paper, towelling (e.g. "Kimpak"), or sterilised, sieved sand. The last two are preferred as the seedlings can develop upright, classification of the seedlings is easier, and any fungal growth 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 cm x 6 cm in height 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 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 percent-

age averages 82 % (range 77-92 I). Standard ISTA definitions can be applied for classification of seedlings and remaining ungerminated seeds. Common abnormal seedlings are those with unpigmented cotyledons, twin embryos, or emergence of cotyledons first.

Rapid Tests of Viability

The cutting test is useful for quick estimates of viability during collection and processing. Seeds should be soaked in water for 24 hours to facilitate sectioning. Viable seeds are full, with fresh white tissues. A slightly glazed appearance, somewhat grey or yellowish, will indicate a dead or weak seed. A certain amount of cavity between the testa, gametophytic tissue, and embryo is allowable.

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 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 seed, 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. oocarpa*. Preliminary work in Honduras indicates that the following conditions produce a good radiograph: Paper: X-Omat, Cassette: home-made from carbon paper, Kv: 10, mAs: 180, ffd: 90 cm.

9. REGENERATION PRACTICES

Nursery Propagation

Nursery practice for *Pinus oocarpa* follows closely the general practice for tropical pines summarized in Danida Forest Seed Centre Technical Note 4, 'Nursery Techniques for Tropical and Subtropical Pines' (Napier & Willan, 1983). Experience with *Pinus oocarpa* has been described by Calvert (1970) for Zambia, Ekwebelam (1974) for Nigeria and Greaves (1982b) in general. *Pinus oocarpa* is slightly slower than *P. caribaea* in the nursery. In Honduras a height of 10-20 cm, root collar diameter of at least 2.0 mm and a root/shoot ratio of 0.9 is recommended for container stock at planting; this should be attained in 5-6 months (Napier, 1982). For bare-rooted stock, regularly rootpruned, the same height is recommended but root-collar diameter should be 3-6 mm and two-thirds of the stem should be lignified (Napier, 1981).

Direct Sowing

This method has been used for *Pinus oocarpa* in Honduras, with varying degrees of success (Troensegaard, 1981). Seed treatment has been based

on that recommended for the southern pines (Derr and Mann, 1976), but at reduced concentrations, since it appears that *Pinus oocarpa* has a thinner testa and is more susceptible to damage from the chemicals. The following mixture appears to be suitable for 1 kg of pure seed: Arazan 60 g, Endrin 50% 20 g, Latex 5 ml, water 100 ml. No aluminium powder was used, and does not appear necessary for separation of the seed, provided they are moved during drying.

The laboratory germination of treated seed is about 10 percentage points less than for untreated seed. It is thought that most damage to the seed has resulted from the organic liquid in which the Endrin is dissolved. It is important that proper tests are carried out with any mixture proposed.

Sowing has been tried broadcast and in cleared spots. The latter appears to give the best results, using 10 seeds per spot, at a rate of 1500 spots/ha.

Natural Regeneration

This method is the most important for natural stands of *Pinus oocarpa* in Central America, but is unlikely to be used extensively for regenerating exotic plantations. The process has been studied in detail for *Pinus oocarpa* in Central America (particularly in Honduras) by Wolffsohn (1982). The method requires the retaining of an adequate number of seed trees (14-20 or more/ha), combined with some form of site preparation, usually prescribed burning. Losses of seed in the tree and on the ground to predators are apparently very heavy. Successful regeneration is considerably more difficult to achieve than with *P. caribaea*.

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