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Pousujja, Reungchai; Granhof, Jens; Willan, R.L.; Graudal, Lars

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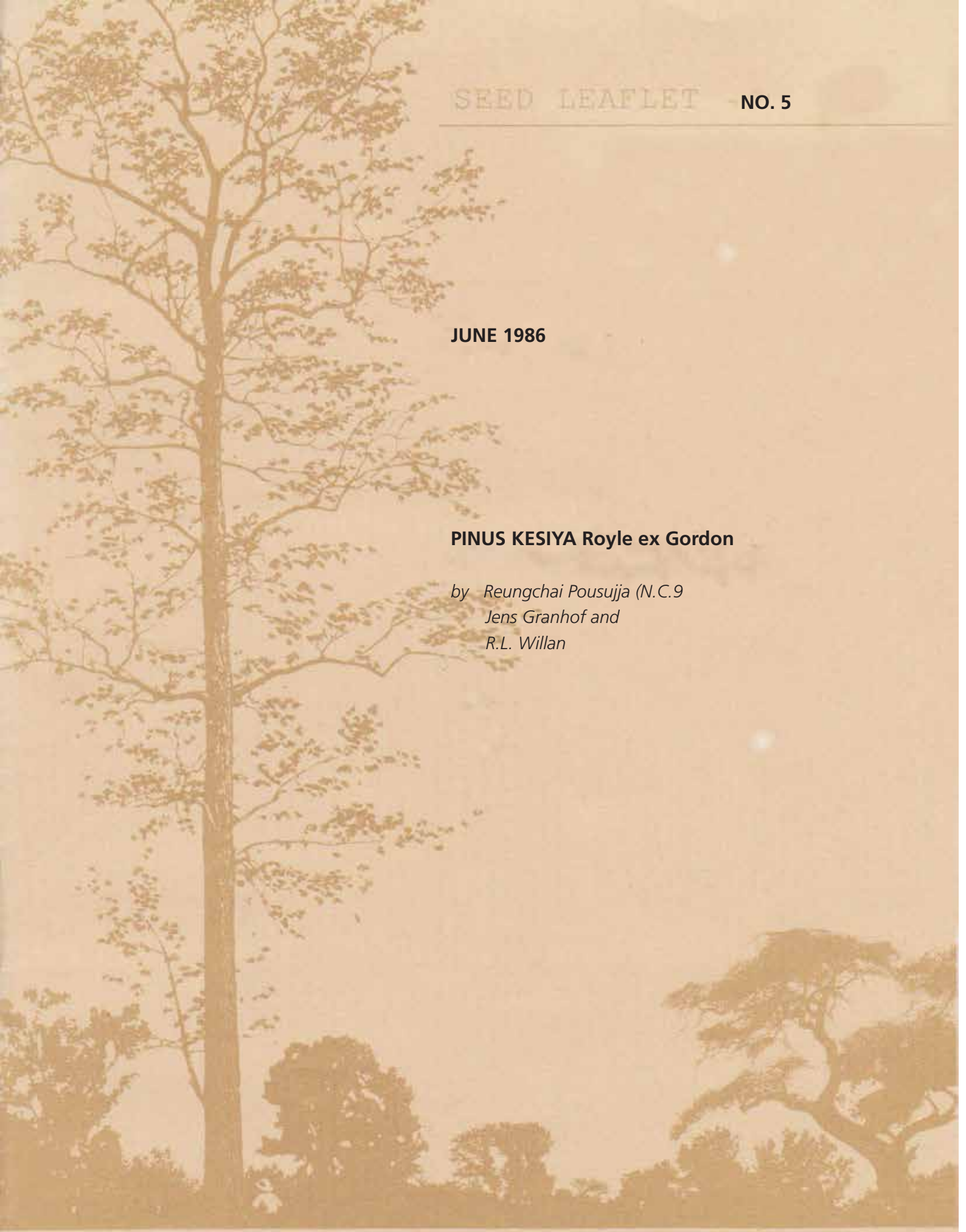

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PINUS KESIYA Royle ex Gordon

by Reungchai Pousujja (N.C.9
Jens Granhof and
R.L. Willan

DANIDA FOREST SEED CENTRE

Titel
Pinus kesiya Royle ex Gordon

Authors
Reungchai Pousujja[1] (N.C.), J. Granhof[2] and R.L. Willan[2]

1: Senior Research Coordinator, Pine Improvement Programme, Silvicultural Research Sub-division, Royal forest Department, Bangkok.
2: Consultant, Danida Forest Seed Centre, Denmark

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1. INTRODUCTION

Sources of Information

A recent and very comprehensive summary of information on *Pinus kesiya* is contained in Tropical Paper No. 9 of the Unit of Tropical Silviculture - *Pinus kesiya* (Armitage and Burley 1980). The present note draws heavily on that reference, especially on chapters 2 (Taxonomy and Nomenclature), 3 (Distribution and Ecology) and 6 (Silviculture, Growth and Yield).

Other recent and important references to *P. Kesiya* include those by Seward (1980) for Zimbabwe and Wisopakan and Granhof (1983) for Thailand.

2. NOMENCLATURE

Botanical name: *Pinus kesiya* Royle ex Gordon

Synonyms: *P. kesiya*. Hook.f., *P. insularis* Endl., P. *kasya* Parl. in DC, *P. khasyana* Griff., *P. yunnanensis* Franch., *P. Khasia* Engelm., *P. langbianensis* A. Chev.

The nomenclature of this species has recently been clarified (Styles & Burley 1972, Styles 1980). The authors' main conclusions are that

(1) In terms of the International Code of Botanical Nomenclature, the valid name for the species is *Pinus kesiya* Royle ex Gordon, not *P. khasya* as was commonly used in the past.

(2) The occurrences, previously accorded specific status by some authors in the Philippines (*P. insularis*), Vietnam & Laos (*P. langbianensis*) and China (*P. yunnanensis*) are no more than racial variants within a single species. The name *P. kesiya* is applicable to them as well as to the ocurrences in India, Burma, Thailand and Tibet which were previously known as *P. khasya*.

Family: Pinaceae.

Common names: The common name of *P. kesiya* varies from country to country: Tinyu (Burma), Dingsa, Uchal or Far (India), Maihing or Khoua (Laos), Thongbala, Langbian pine (Vietnam), Son sarmbai or Son pluagbang (Thailand), Benguet pine (Philippines) and Yunnan pine (China).

3. THE TREE

Size and Growth Habit

P. kesiya is a three-needled pine. Fascicles of 2 or 4 needles occur very rarely. In Thailand flushing takes place twice a year, during the cool dry season (November-December) and again in May-June.

In natural stands *P. kesiya* generally grows into a large tree, attaining heights between 25 and 45 m when mature. Growth data summarized by Armitage and Burley 1980 indicate considerable variation according to site conditions and past history. For example, the best stands in the Philippines, at over 1800 m elevation in the Boboc area of Benguet Province, reached 30-40 m, whereas the isolated Zambales stands at lower elevation in western Luzon rarely reach more than 23 m (Jacalne and Lizardo 1958, Turnbull 1972). In the better stands of Burma trees may reach 10-45 m in height, while in the Khasi Hills of Assam trees over 20 m are rare (Hundley 1951, Bor 1942). Diameters are commonly 40-50 cm, but good unlogged stands may average 80-95 cm and occasional individuals have been recorded up to l50 cm. On good sites in Vietnam the species may live more than 150 years (Nguyen Kha L966).

P. kesiya grows mainly in sub-tropical or temperate lower montane and montane conditions. It often occurs in pure stands with grass understorey, but may be associated uith *Pinus merkusii, Quercus spp.*, *Castanopsis* spp., dry dipterocarps and ericacious genera. It readily colonises sites degraded by fire or shifting cultivation and on such sites forms a mosaic of groups or stands of trees. Trees within each stand are approximately the same age, while adjacent stands may differ widely in age.

Height growth is rapid for the first 20 years, then slows down (Nguyen Kha 1966). As a result, crowns are pyramidal or ovoid at first, becoming rounded or umbrella-shaped with age. Crooked stems and basal sweep are common in many stands (Cooling 1967). In open conditions branching becomes heavy and results in severe nodal swelling.

Natural Distribution

P. kesiya has a wide but discontinuous distribution in south-east Asia, between latitudes l2º and 30º N and between longitudes 90º and 122º E. It occurs in India, Burma, China (Yunnan, Szechwan and Tibet), Thailand, Laos, Vietnam and Philippines (Critchfield and Little 1966, Mirov 1967, Armitage and Burley 1980). The extreme altitudinal range is from 100 to 1000 m, but optimum development is usually betveen 1000 and 1800 m. Details of the main occurrences in each country are given by Turnbull, Armitage and Burley (1980).

Rainfall is usually between 1000 and 2000 mm, with a distinct dry season of 2-4 months, but in certain parts of India and Burma the rainfall is much more. Mean annual temperature varies from about 15º C at the higher elevations to about 25º at the lowest.

Typical soils are free-draining acid podzols, sandy soils, and red or yellow clays or clay-loams. In Vietnam *P. kesiya* tolerates soils which are more acid and less base rich than those on which *P. merkusii* will grow (Nguyen Kha 1966). The precise pattern of *P. kesiya* distribution is greatly influenced by the incidence of fire. In general, fire favours pine at the expense of broadleaved species, but excessively severe fires may destroy pine generation and lead to the formation of grass savanna.

Variation and Improvement

The distribution of *P. kesiya* comprises a number of large separate complexes interspersed with smaller isolated occurrences.

Major complexes are (Critchfield and Little 1966):

(a) The Assam, Tibet and West Burma populations of the Khasi, Naga and Chin Hills (1000 - 2900 m) and the valleys of the Rongto Chu and Zayul Chu Rivers of Tibet (l200 - 2400 m).

(b) The populations of East Burma (Shan and Karenni States) and North-West Thailand (Chiang Mai and Mae Hong Son provinces) (760-1800 m).

(c) The south China (Yunnan) populations including those previously known as P. yunnanensis

(d) The South Vietnam population of the Annam Cordillera mountain chain, viz. the Longbian and Haut Donnai Plateau (1300-2100 m).

(e) The insular (N. Luzon) population of the Philippines, viz. the Central Cordillera (750-2450 m) and the Zambales mountains (450 - 1400 m).

Between these major populations occur smaller isolated populations. Those in North Burma may provide links beteen the Assam/West Burma populations and the extensive Yunnan populations. There are also good indication that the populations of Yunnan are in contact with the East Burma/Shan states/North-west Thailand populations. Further east, in central Thailand and in Laos, the possibility exists that the small scattered populations are truly isolated and genetically differentiated.

Finally the island provenances in Luzon in the Philippines are separated from the easternmost continental-populations of Vietnam by 1100 km of sea.

The discontinuous distribution of *P. kesiya* and the wide variation in altitude and rainfall which occur within that distribution suggest the likelihood of considerable genetic variation. Comparative provenance trials, local or internationally coordinated, in many countries have demonstrated that such genetic variation does in fact exist within and between provenances, in respect of stem form, branching, crown, flowering, terpene chemistry, wood properties, growth rate and resistance to pests. Earlier trial results have been summarized by Burley and Armitage (1980) and more recent ones in Barnes and Gibson (1984). The latter reference contains a general summary of provenance trial results worldswide (Gibson and Barnes 1984) and results for several individual countries, viz. Australia, Northern Territory (Tozer and Robertson 1984), India (Das and Stephen 1984), Kenya (Chagala 1984), Madagascar (Mondeil 1984), Swaziland (Morris 1984), Tanzania (Madoffe *et al.* 1984), Thailand (Granhof 1984 a) and Zimbabwe (Mullin *et al.* 1984). Results from Zambia are available in Mikkola (l982) and from Philippines in Schroeder (1985). Existing trials do not contain comparisons of the full range of this species. There would therefore seem to be a need for a more comprehensive study representing a wider range, as well as including a number of the improved landraces which have developed through selection in some countries where *P. kesiya* has been an important plantation species for some length of time, e.g. Zambia and Madagascar. Collection of provenance seed lots for a new series of international trials is now being arranged through cooperative efforts of national forest services, Commonwealth Forestry Institute and The DANIDA Forest Seed Centre.

Efforts in breeding *P. kesiya* have been directed mainly towards the improvement of stem straightness and branching habit, since crooked stems and coarse branching are defects particularly associated with this species. Seed stands have been established in natural populations in Thailand and Philippines and in plantations in Zambia, Malawi, Madagascar and Brazil. Seed orchards exist in these same countries, also in

Zimbabwe, South Africa and Papua New Guinea; in most countries Vietnam and Philippine provenances, with Zambian and Madagascan land races predominate in the orchards (Nikles 1979, Guldager *et al.* 1980). New seed stands have been selected recently in the Dalat area of Vietnam.

Importance for Plantation and Uses

The biggest plantation areas of *P. kesiya* are in Madagascar and Zambia. Mikkola (1982), reported 26,000 ha planted in the copperbelt of Zambia by October of that year, while Mondeil (1984) reported over 75,000 ha of plantations of this species in the Madagascar highlands. Vietnam has over 5,000 ha planted in Lam Dong Province, as well as smaller areas elsewhere (Granhof (1984 b). Species and provenance trials and pilot plantations exist in many countries in Africa, Asia and Latin America. *P. kesiya* has proved adaptable to a variety of sites within an altitudinal range of 700 - 1800 m, with a summer rainfall of a minimum of 700 mm (preferably 1000 - 2000 mm) and a distinct dry season. At higher altitudes and lower temperatures it grows less well than *P. patula* or *P. elliottii*, while in the lowland tropics it is inferior to *P. caribaea*.

Its biggest defects, which have so far prevented its being planted more extensively, are the tendency, especially in certain provenances, to coarse branching, forking and crooked stems, all of which increase the proportion of undesirable reaction wood within the bole. Where reaction wood is not a problem, *P. kesiya* is a general-purpose wood of moderate strength which has been found suitable for use as light and heavy structural timber, boat building, flooring, furniture, cabinet work, joinery, turnery, pencils, plywood, agricultural tools, poles, boxes, pulpwood and partical board (Worrall & Burley 1980). It also produces high quality oleo-resin, though resin yield is lower than that of the other S.E. Asian pine, *P. merkusii*.

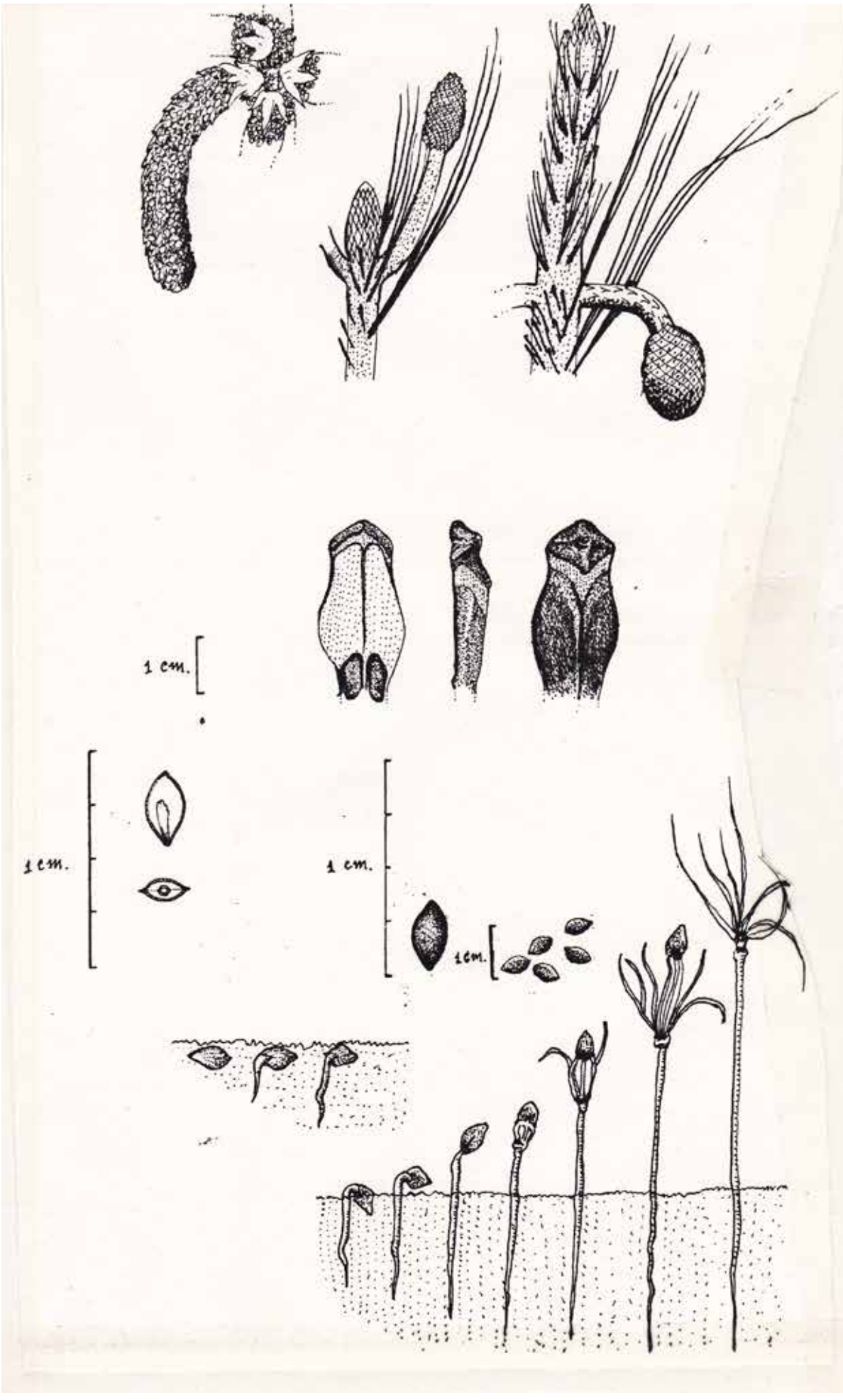
4. REPRODUCTIVE BIOLOGY

Flowerinq and Fruit/Seed Development

P. kesiya is monoecious. Male strobili are produced in place of needle fascicles and occur in clusters several centimetres back from the ends of the shoots. Each strobili is cylindrical to oblong, bright yellow or light brown, about 5 mm in diameter by 15 mm long. Female strobili are produced in place of lateral shoots and appear singly or in pairs or threes near the ends of branches, usually in the upper half or third of the tree. They are 5 - 10 mm long and up to 8 mm in diameter when receptive, greenish purpte, borne on a long peduncle which later attaches the mature cone firmly to the branch (Armitage and Wood 1980, Styles 1980).

In natura stands flowering and cone production take place annually from age 10-20 onwards. In exotic plantations in Africa, in contrast, flowering starts from age 3-7 years. There is often a period of 3-5 years between first, flowering and first production of substantial quantities of viable seeds. In the humid lowland tropics without a dry season, e.g. Malaya and Java, *P. kesiya* is incapable of flowering and setting seed normally.

In the natural stands in S.E. Asia, male and female flowers appear in the cool, dry season from December to March (Armitage and Wood 1980). Studies in northern Thailand showed that young male flowers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became visible in early November and that pollen was shed from the end of November to the end of Febuary (Kingmuanqkau 1974, Pousujja and Kingmuangkau 1983). The period of pollen shed for individual trees varied from 2-3 weeks up to 2 months. The period of pollen shed may vary slightly from year to year; individual trees in the Thailand study started and finished pollen shed two weeks earlier in 1972 than in 1971. Female flower buds on the same trees appeared from mid December to early Febuary and the receptive period in January or Febuary lasted seven days.

Cone development takes 23-25 months from pollination to maturity in Thailand (Pousujja and Kingmuangkau 7983). The conelet remains small (less than 2 cm in length) for the first year, until fertilization takes place. Thereafter cone elongation is rapid over the next six months and maximum length of 6-7 cm is reached about 18 months after pollination. Further maturation of seeds takes place after the cones have reached their full size and cone harvesting can be carried out in Thailand from December to Febuary. Cones are ready for collection when the colour over about 50 % of the surface has changed from green to brown. At this stage the "endosperm" has obtained a firm consistency and is of a grey colour (Granhof 1975). In Philippines, Veracion and Padolina (1971) found that best germination was obtained from seeds harvested in November to January when specific gravity of cones had fallen to 0.88.

In the southern hemisphere, where *P. kesiya* has been planted successfully as an exotic, flowering and cone ripening also take place in the cool dry season, which in this case occurs from June to August. In Zimbabwe Barnes and Mullin (1974) found that male and female flowering lasted about five weeks, with a peak from late July to mid August, while ripe cones are normally collected from the third week in June to the third week in July (Seward 1980). In Zambia cones turn brown in July but green cones have been collected successfully in May-June to supply seed needed for sowing in July (Guldager 1974, cited in Armitage and Wood l980).

Observations in Thailand indicated that over 50 % of female flowers fail to develop conelets which survive the first year. On the other hand, cones which reach the stage of rapid elongation from 12-18 months usually survive to set viable seeds (Pousujja and Kingmuangkau 1983).

Cone and Seed Characteristics

Mature cones vary considerably in size. In Zimbabwe cones from 12 different clones varied in length from 5.5 - 10.5 cm and in diameter from 3.5 - 4.5 cm (Barnes and Mullin 1974). Cones are glossy brown, pendulous, often strongly reflexed, strongly persistent, ovoid to ovoid-conical in shape; subsessile or borne on a short peduncle 0.5 - 1.0 cm long; either solitary, in pairs, or sometimes in whorls of three. Cone scales are thickened towards the apex; apophysis pyramidal, convex; umbo beaked or flattened, more rarely depressed, with a short blunt deciduous mucro (Styles 1980).

The seeds are winged and borne in pairs on the upper surface at the base of the ovule-bearing cone scales. Average dimensions of Indian seeds were: seed 5.1 mm long, wing 12.7-17.8 mm long by 5.1-7.5 mm wide. Comparable figures from Vietnamese seeds were: seed 5.3 mm long by 3.9 mm wide, wing 20 mm long by 4 mm wide (Troup 1921 and Nguyen Kha 1966, cited by Armitage and Wood 1980).

Seed Dispersal and Germination

Seed dispersal is by wind. Cones open and seed is shed during the dry season, Febuary - March in S.E. Asia. The cones are persistent and may remain on the branches for several years after seed shed. In the mountains of the Philippines frequent up-draughts during the dry season can transport the winged seeds upwards and across the valley slopes for considerable distances (Cooling 1967).

Germination is epigeal. Cotyledon number is most commonly 7, but may range from 5 to 9. For the first 5-12 months young seedlings have only simple primary leaves, with finely serrate margins; thereafter the secondary foliage of needle fascicles is developed. Seedling survival is favoured by open conditions and bare, weed-free soil, which result from landslides, abandoned cultivation or previous fires. Absence of fire for at least five years is necessary if seedlings are to become established (Armitage and Wood 1980).

Seed and Cone Pests and Diseases

Little information is available on the pests and diseases of *P. kesiya* cones and seeds. Two species of moth, *Dioryctria abietella* and *D. sylvestrella* can cause severe cone losses by laying eggs on young cones; the larvae burrow into the tissues and destroy cones and seeds. The same species may also destroy whole reproductive shoots before the flowers can be formed (Bradley 1969, Chaklom 1975). In Baguio, Philippines, Lapis (1982) found that *Dioryctria abietella* larvae attacked young cones of *P. kesiya*, preventing seed formation.

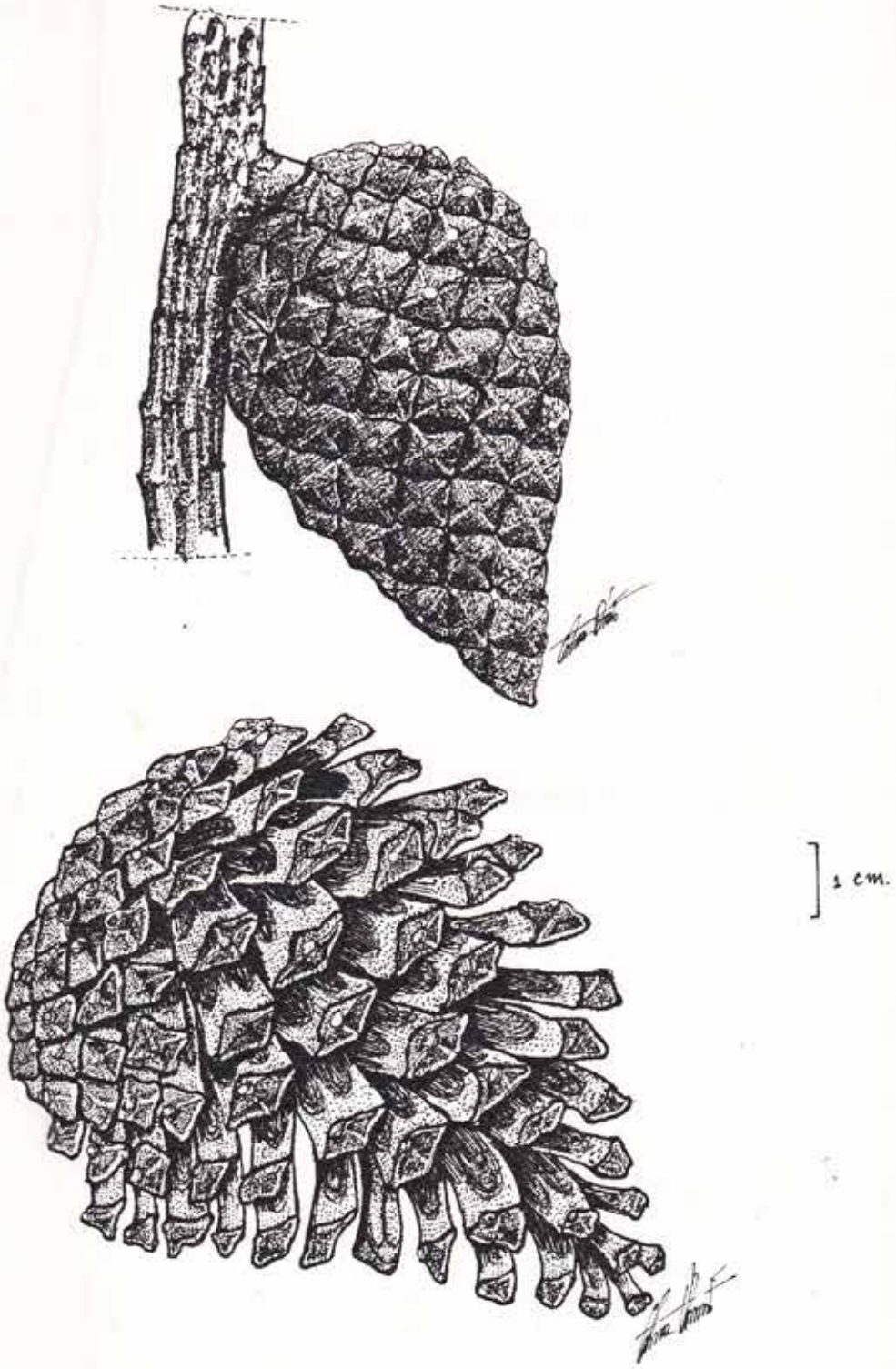
Fungal moulds may affect germination of seeds, especially if cones or seeds are improperly stored.

5. SEED AND FRUIT PRODUCTION AND COLLECTION

Choice and Management of Trees and Stands

Wherever possible, seed should be collected from stands which are better than average in both form and vigour. Seed should not be collected from isolated trees because of the risk of selfing. Natural stands should be at least 15 years old. In younger stands it is difficult to judge the true form and vigour of the tree and seed crops may sti11 be light at that age. In managed plantations substantial seed crops are borne at an earlier age than in natural stands, but it is still advisable to defer collection until at least age 10 in order that the stand can develop characteristics which are likely to be maintained for the remainder of the rotation.

Within an unimproved stand, it is desirable to restrict collection to ”seed trees”, which are phenotypically superior to the rest of the stand. In the case of *P. kesiya*, stem form is most important; trees showing basal sweep, sinuous or forked stems and heavy or high-angled branching should be avoided. In this way phenotypic superiority can be ensured in the mother trees, although there is no control over the quality of the trees providing the pollen. In order to maintain variability within a bulk seed collection, it is desirable to collect from a minimum of 25-50 mother trees per stand, separated from each other by a distance not less than seed fall (FA0 1969). When large quantities of seed are needed from stands of limited area, collectors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may be forced to relax the above recommendations, but, such relaxation should be regarded as only a temporary expedient.

Within a stand selected for seed production, early action should be taken to remove the poorest phenotypes; this will improve the phenotypic quality of the male, as well as the female, parents; at the same time the greater crown room increases the seed crop on each of the remaining trees. More than one thinning may be needed. *P. kesiya*, like other pines, is a strong light demander and responds well to early thinning. In seed production areas selected in mature natural stands in Thailand, thinning is designed to leave the best 75-100 phenotypes per ha (Chuntanaparb 1975). In younger planted stands, a thinning regime has been proposed which would reduce stocking, after four thinnings, to about 140 stems per ha at dominant height 17 m, equivalent to an age of around 12-15 years on average sites (Willan 1984). Heavy thinning in seed production areas is standard practice in Madagascar, Malawi and Zambia (Guldager *et al.* 1980). Wide final spacing is also necessary in seed orchards; a final stocking of 120 trees/ha was prescribed for the earliest seedling seed orchard in Thailand (Chuntanaparb 1975), while in Zimbabwe a clonal seed orchard was reduced to 100 grafts per ha at age 11 (Barnes and Mullin 1974).

Within its natural range and in similar climates elserwhere, mature *P. kesiya* bears abundant seed crop annua1ly. Little research has therefore been done on treatments to increase flowering and seed setting, but Shelbourne (1963) obtained no response from fertilization, girdling or root pruning.

Noble (1981) compared germination of seeds collected from 45-50 year old trees in the Philippines, tapped for resin (a) on one face for 1 year 4 months (b) on two faces for 2 years 10 months, with untapped controls. There were no significant differences.

Cone Yields

There appears to be a big variation in the number of mature cones harvestable per tree. In Thailand studies were made over several years of cone production in 8 different natural seed sources, based on a minimum of 25 trees per source (Wisopakan and Granhof 1983). The number of cones per tree varied from 80 to 175 (average 130) and the weight of cones per tree from 2.9 kg to 7.4 kg (average 5.3 kg). In a planted seed stand of Vietnam origin in Zambia (Guldager 1974, cited in Armitage and Wood 1980) found that cone production averaged only 20 per tree at 10-11 years, but isolated or edge trees of the same age produced 100 cones per tree. A clonal seed orchard in Zimbabwe, planted at wide initial spacing and reduced to 156 grafts per ha at 7 years, produced an average of 103 cones per graft at 8 years (Barnes and Mullin 1974). See also appendix 1 on page 25.

Turnbull (1972) noted that, within particular localities in the Philippines, heavier cone crops occur at higher elevations than at the lower ones. *P. kesiya* is adapted to a strongly seasonal climate with a distinct, dry season. If it is planted in the humid lowland tropics with rainfall throughout the year, e.g. in Malaysia and Java, cone yields are negligeable.

Crop Estimation

Where seed collection is carried out annually in a given stand, some indication of next year's crop may be obtained by observing one year old conelets while collecting the current crop of mature cones. But this needs to be confirmed shortly before collection is due.

In Thailand normal practice is to survey potential collection stands about three weeks before expected picking time to assess the size and maturity of the crop (Wisopakan and Granhof 1981). A pair of 7 x 50 binoculars is a useful aid and crops may be classified subjectively in three classes of "poor", "average" and "good", as described for other species of conifer (e.g. Dobbs *et al.* 1976, Robbins 1983 a). Care should be taken to distinguish between the current crop and any persistent cones left from previous years.

If necessary, the yield of seeds from cones may be estimated by cutting longitudinal sections of a sample of cones, using a cone cutter or machete (Dobbs *et al.* 1976, Robbins 1983 a). The ratio of full seeds per cone to full seeds exposed on a cut surface in *P. kesiya* has not been reported in the literature and may vary according to provenance. For other tropical pines, *P. caribaea* and *P. oocarpa/tegunumanii,* a ratio of from 10:1 to 20:1 applies (Robbins 1983 a, 1983 b)

Maturity Indices

The simplest method of estimating cone maturity is by colour changes, which are usually accompanied by hardening of the cone scales. In Thailand recommended practice is to collect *P. kesiya* cones when an average of 50 % of the surface has changed colour from green to brown (Granhof 1975).

Maturity may be confirmed by cutting test. The gametophytic tissue ("endosperm") in pines passes through a "milky" and then a "dough" stage; at maturity it should be firm and the embryo well developed.

Specific gravity has been successfully used to estimate cone maturity in a number of temperate pines. Cones (and seeds) lose moisture as they mature, therefore mature cones have a lower specific gravity than immature cones. Flotation tests in water or in various oils can be effective in diffentiating between mature cones which float and immature ones which sink. This test does not appear to be commonly used in *P. kesiya*. In another tropical pine, *P. caribaea*, it was found that, if ¾ of a cone sample floats in water (SG = 1.0) collection can start in the area sampled; any cone with SG of over 1.14 is too immature to be worth collecting (Hughes 1981, cited in Robbins 1983 a).

Deliberate collection of unripe cones may give acceptable results and is sometimes dictated by local conditions e.g. the need to fit in with annual sowing dates in the nursery. Particular care must be taken during the processing of immature cones. Guldager 1974, cited in Armitage and Wood 1980, found that green cones could be successfully collected in Zambia.

Collection Methods

A major problem in collecting in natural stands is access. *P. kesiya* is often found on high ridges, only to be reached by foot with some hours' walking from roadside. Thus the climbing method should avoid the use of heavy equipment. Use of iron climbing spurs fitted to leather boots, with safety belt and supporting line of terylene, helmet of glass-fibre and heavy leather gloves is the technique presently in use in Thailand (Wisopakan and Granhof 1983). The total weight of this equipment is 3 kg making it particularly suitable for use in inaccessible stands in roadless country.

When the collector reaches the crown, he uses two canvas bags attached to his belt and a specially designated collection hook. This is sharpened on both sides and can be used either for pulling or pushing off the cones, whilst the collector is within the crown thus avoiding the breakage of twigs with new conelets,

which would seriously reduce cone crops for the next 2-3 years. The hooks are mounted on light iron pipes, which can be extended to a length of about 3 m.

In stands of medium-size trees a climber can in a day collect from 6 trees with an average of 25-30 kg of cones.

Plantations and seed stands are usually more accessible than natural stands, but in steep terrain they may also be unsuitable for mechanized collecting methods. In plantations in montainous regions of Zimbabwe ladders 3 m in length and 15 kg in weight, extendable to 5 m, are used in conjunction with safety belts and long-handled collecting hooks (Seward 1980). In seed stands in Thailand vertical steel pipe ladders are used, secured to the bole by nylon straps. By attaching a number of different sections one above another, a height of 18 m can be reached (Wisopakan and Granhof 1983). The use of ladders avoids the damage to bark and sapwood which would result from climbing the same trees every year by means of spurs.

Seed orchards are normally planted on gentle topography. In these conditions and if the orchards are large in size, a mobile collecting platform may be an efficient method of collection. In Thailand the Afron 450 skylift is used. The picking platform can be raised to 5 m and the picker himself can control the operation (Wisopakan and Granhof l983).

Cone Storage in the Forest

When collections take place over a long period, storage of cones in the forest may become necessary. Bulk quantities of fresh cones, if stored at high temperature and humidity, are very susceptible to deterioration through the action of moulds and other fungi and through overheating due to a high rate of respiration. Well ventilated shelter is needed against rain and direct sunlight, and cones stored in gunny bags must be well spaced on racks. No detrimental effects have, however, been experienced from this method of careful storage in Thailand (Wisopakan and Granhof 1983). Loose-weave hessian sacks or nylon-mesh laundry bags (Yeatman and Nieman l978) allow good air circulation through the side of the container and are well suited to this purpose. Large open-mesh baskets are ideal for promoting free air circulation in cones and may be constucted from locally available materials, whether metal, willows, bamboo or rattan.

6. SEED PROCESSING

Precuring

In Thailand cones are precured by storing them for 7-14 days in gunny bags under a covered shed, with good aeration (Wisopakan and Granhof 7983). This allows after-ripening of the seeds and avoids the "case-hardening" which may occur if freshly collected cones are immediately sun-dried. The case-hardening condition can result from the outer green tissues drying too quickly, before the inner tissues can lose moisture; the cone scales then fail to open properly.

Cone Drying and Seed Extraction

Seed collection is normally carried out in the dry season, when conditions are very suitable for sun drying of the cones. In Thailand the cones are dried in full sun during the period December to March. They are spread on trays 1 x 1 m square, with 10 cm high wooden sides, a bottom of 1 cm- wire mesh and a cover of polythene sheeting (Bryndum 1975, Wisopakan and Granhof 1983). After the cones open, the seeds fall through the wire netting into a canvas suspended under the trays, from which they are collected. In the case of small samples which must be kept separate, e.g. for provenance trials, smaller trials, smaller trays are used, from which the seeds fall through a metal funnel into a bag attached to the outlet. The trays are mounted on wooden scaffold at a convenient height.

Extraction takes place in the cold season in Thailand, hence it is important to use polythene sheeting over the seeds to trap the sun's heat and raise cone temperature. Without the covers, cone drying is slower and less complete; in one experiment, the amount of seed extracted in 7 days under polythene was almost double that extracted without polythene. A further aid to fuller extraction is to incorporate frequent manual cone stirring in the trays or to tumble the dry cones in a rotating drum covered by 1 cm wire mesh. The standard practice now is to leave the cones five days in the trays under polythene and then tumble them for several minutes in the drum. Extracted seeds should be removed frequently from the canvas under the trays, to prevent overheating.

Wire-mesh trays have also been used successfully in Zambia, Zimbabwe, Philippines and (for other tropical pine species) Honduras. If wire-mesh trays are not available, cones may be spread on tarpaulins or corrugated iron sheetinq (Robbins 1984 a, Cooling 1967). In all cases, arrangements must be made for immediate covering of exposed cones in the event of rain.

Cooling (1967) found that the increased heat developed in corrugated iron sheeting in full sun gave much quicker opening of cones than grass mats in the same conditions.

Sun drying is the normal method for seed extraction of *P. kesiya*. Cones can be opened more quickly by immersing them in boiling water for 5 - 15 seconds, as done experimentalty in Philippines (Penafiel *et al.* 1975), but the method is impracticable for bulk quantities.

P. kesiya cones can also be dried in a kiln. In the convection kiln used in Zimbabwe it was found that the maximum safe temperature was 45ºC. This was the same as for *P. elliottii* and *P. taeda* but considerably lower than the 60ºC maximum safe temperature for *P. patula* (Seward 1980). Cones open in 8 hours in this kiln. Detailed specifications and diagrams for a low cost drying kiln used successfully for *P. caribaea* and *P. oocarpa* in Honduras, which would be suitable for *P. kesiya*, are available in Robbins (1985).

Dewinging

After extraction the wings must be removed from the seed in order to make seed processing and nursery sowing easier.

For small quantities of seed, e.g. seed samples of plus trees for progeny testing, dewinging may be done by hand by putting the seeds into a small cloth bag, and lightly rubbing them together with the fingers in the bag.

In Thailand, removal of wings from pine seed is done mechanically in a vertical cylinder dewinger "Damas" holding 0.1-5 m^3 or 150 litres. Dewinging is done by rotating a conical snail which rubs the seeds against each other as well as against the wall of the cylinder and then presses the seed through the narrow cylinder outlet. Rotation of the snail can be adjusted to different speeds. The machine can handle 11 kg of seeds with wings per hour, with no damage observed to the seed (Wisopakan and Granhof 1983).

Other types of mechanical dewinger have been used successfully for pine seeds and would probably work well with *P. kesiya*. Drums or cement mixers are commonly used, rotated manually or by motor. Water is sometimes added to reduce mechanical damage. Thus, in Honduras, seeds with wings are first tumbled for 15 minutes, water is then sprinkled on the seeds at a rate of about one litre of water for 50 litres of seed, and tumbling is continued for a further 45 minutes. This method works well with the two tropical pines, *P. oocarpa* and *P. caribaea* var. *hondurensis* (Robbins 1983 a, 1983 b).

Cleaning

The mixture resulting from extraction and dewinging contains seeds, wings, fragments of cone scales, needles and other matter. Seeds need to be separated from other matter and, as far as possible, full seeds from empty seeds.

In Thailand and Philippines hand winnowing by means of flat baskets or bamboo trays as used for winnowing rice, is an effective cleaning method (Cooling 1967, Bryndum 1975, Wisopakan and Granhof 1983). It avoids the use of expensive, imported equipment. In Thailand the initial winnowing is followed by a second winnowing of the discarded fraction. This results not only in the removal of extraneous matter but in an improvement in the percentage of full seeds in the retained fraction. Cutting tests showed that the original full seed percentage of 82 % was raised to 98 % in the improved fraction, while the discarded fraction (about 10 % of the total volume) contained only 18 % full seed or about 2 %, of the total full seed in the seed lot. One operator takes about 8 minutes to winnow 1 kg.

An artificial air-flow may be provided by simple mechanical equipment. In Zimbabwe a home-made cleaner was constructed by fitting a tapered aluminium sleeve with internal baffles onto a constant speed domestic fan (Seward 1980). The narrow end of the sleeve projected over a compartmented receptacle, full seeds fell into the nearest compartment, while the lighter impurities and empty seeds were blown into the further compartments.

Winnowing or blowing may be preceded by a sieving or screening operation to separate material which differs appreciably from the seed in size. Sieving may be manual or mechanical. In Honduras suitable mesh sizes for *P. caribaea* and *P. oocarpa*, which have seed sizes comparable to *P. kesiya* are No. 12 (4.76 mm diameter) which allows seed to pass but retains bigger material and No. 6 (2.38 mm diameter) which retains seed but not smaller fragments (Robbins l983 a, 1983 b).

Seed moisture content must be tested between processing and storage. If extraction is done in the dry season by sun-drying and dewinging is done dry, seeds normally have a moisture content less than 8 % (fresh weight) and are suitable for storage. If moist dewinging has been done, it may be necessary to redry the seeds. In the dry season this can be done easily by spreading the seeds on a sheet in the sun, about two seeds thick, and raking frequently (Robbins 1983 a, l983 b). If sun-drying is not possibler, an electric drying oven with forced draft ventilation may be used (Wisopakan and Granhof l983, Robbins 1983 a, 1983 b). In Honduras a temperature of 40-45° C has been found suitable for seeds of *P. caribaea* and *P. oocarpa*; a similar temperature may be suitable for *P. kesiya* but this needs to be confirmed by trials.

Seed Yield

In Thailand the average yield of seeds per cone from mature natural stands in 8 different localities, based on collections over several years, was 68 seeds (range 54 to 79) of which 80 % or 54 seeds per cone (range 43 to 67) were full seeds (Wisopakan and Granhof 1983). The equivalent weight figures for total seeds were an average of 30 g per kg of cones and a range from 24 to 35 g per kg of cones. Average weight of seed produced per tree was 158 g (range 76 to 250 g). More recent data from single-tree collections made in 1985 are shown in appendix 1.

In planted stands or seed orchards in several countries in southern Africa, the number of seeds per cone varied from 20 to 50 (Armitage and Wood l980). In Zimbabwe seed orchards 5-8 years old an average of 68 % of the seeds were found to be full (Barnes and Mullin 1974). In Zambia Geary and Pattinson (1956, cited in Armitage and Wood 1980) estimated the seed production of a Luzon (Philippines) provenance to vary between 118 and 129 potentially fertile ovules per cone and that about 50 % of this number might be expected to produce full and viable seeds.

7. SEED STORAGE AND TREATMENT

P. kesiya seed is classified as orthodox. Fresh seed from natural stands displays high germinability and retains viability reasonably well for 6 - 12 months without any special storage arrangements (Armitage and Wood 1980).

Loss of viability in orthodox seeds is largely governed by the rate of respiration. For storage over several years. Therefore, any measures which reduce the rate of respiration without otherwise damaging the seed are likely to be effeetive in extending longevity. These measures include lowering of moisture content, lowering of temperature and exclusion of oxygen.

At the seed section of the Pine Improvement Project in Chiang Mai, Thailand routine storage practice is to dry the seed to less than 8 % moisture content (fresh weight basis), pack in two sealed polythene bags (thickness 5 mil or 125 microns), label both inside and outside the bag and store in a cool room at + 4-5ºC (Wisopakan and Granhof 1983). Different sizes of polythene bag are used, varying from 100 g to 2 kg capacity, in accordance with expected needs, allowing retrieval of any desired quantity from the store without opening the packets and exposing the seed. The storage rooms are cooled by a Sabroe/Atlas air-cooled condensing unit for two rooms, with one evaporator and independent controls for each room. The rooms incorporate 20 cm insulation in the roof and 10 cm in the walls. From research on different factors affecting seed longevity it was found that, over the 4 year period of the trial, there was no advantage in storing *P. kesiya* seed at sub-zero temperatures, compared with the standard + 4 or 5º C, and that the species stored well for 2 years either at low temperature (+ 4 - 5ºC) in unsealed containers or in sealed containers at higher temperatures.

Dormancy has not been observed in *P. kesiya* and no special treatment is needed to initiate germination. Research in Philippines has shown that, when used for quarantine purposes, fumigation with hydrogen cyanide, applied at a dosage of 1.7 kg per 0.1^3 m of container space for 4 hours at 10ºC, had a detrimental effect on germination of *P. kesiya* seeds after 6 months' storage, but that halving this dosage rate caused no deterioration in germination after the same period (Lasmarias and Baja-Lapis 1977).

8. SEED TESTING

Sampling

Standard sampling methods should be used to ensure that the samples tested are, as far as possible, representative of each seed lot.

In Thailand, when a seed lot has been extracted and cleaned, it is thoroughly mixed before drawing samples by "Boerner" sampler for testing. This device consists of a cylinder with a funnel at the top. Opening of a valve at the bottom of the funnel releases the seed which flows down the funnel and strikes a cone which is directly under the centre of the opening. Around the base of the cone are 30 outlets. When the seed falls, it is separated into 30 individual streams, merging again into 2 streams emptying into 2 pans. By repeating this procedure several times, each time using the amount emptied into one of the pans only, the sample size is gradually reduced by repeated halving, while being thoroughly mixed all the time (Wisopakan and Granhof 1983).

Purity and Pure Seed Weight

Purity and pure seed weight are assessed using normal ISTA procedures (ISTA 1985) and applying the appropriate definitions for pure seed and impurities. In Thailand it was found that, purity % of seed extracted and cleaned by the methods described earlier averaged 96 % (range 93 to 99 %). Seed orchard seed collected in Zimbabwe over 4 years averaged 98.6 % purity (Seward 1980).

Figures for seed weight are available from several countries. It is not always clear whether these figures are for seeds/kg of pure seed or seeds/kg of seed "as received" but, if an average purity of over 95 % can be assumed, both figures are of similar magnitude.

In Thailand figures are available from 2l different provenances spread over 2½ degrees of latitude and 4 degrees of longitude and at altitudes from 450 to 1300 m (Wisopakan and Granhof l983):

	Average	**Range**
Number per kg	51,000	45,000 - 57,000
Weight of 1000 seeds (g)	19.6	22.2 - 17.5

Seed weights for other countries in continental Asia, cited by Armitage and Wood 1980 (India, Burma and Vietnam) are similar to Thailand, but for Laos a figure of only 40,000 is cited. More recent figures from Vietnam are 62,000/kg for the main occurrence on the Langbian plateau (Dalat area) and 83,000/kg for the Hoang Su Phi provenance in N.W. Vietnam near the Chinese border (Granhof 1984 b). Seed orchard seed collected in Zimbabwe over four years averaged 49,000 seeds per kg of pure seed (Seward 1980).

Numbers of seed per kg in the insular provenances of Philippines appear to be considerably higher than the Thailand provenances. Turnbull (1972) reported the following:

Seeds per kg

Provenance	Average	Range
Central Cordillera (< 1500 m)	63,000	50,100 - 67,800
- - (> 1500 m)	72,200	69,000 - 75,600
Carabello Mountains (500-1100 m)	74,500	71,000 - 76,300
Zambales Mountains (580-1110 m)	62,800	59,800 - 75,800

Bryndum (1975) found that the average weight of seeds released from the cones at the beginning of the drying period was higher than those released later e.g. a 1000 seed weight of 17.8 g for seed released during the first day decreased to 15.2 g for seed released on the seventh day. This related to a decrease in the percentage of full seeds, from 84 % on the first day to 65 % on the seventh day.

Moisture Content

P. kesiya is suitable for the standard method of testing moisture content prescribed by ISTA, i.e. weighing of two replicate samples of about 5 g each, drying in an oven at a constant temperature of l03° C ± 2° C for 17± 1 hours, cooling in a desiccator fot 30-45 minutes and then reweighing in an atmosphere 70% relative humidity. Loss of weight is then expressed as a percentage of the fresh weight of the samples to give the moisture content of the seeds, viz.:

$$\text{Moisture Content \% : } \frac{\text{Weight before dryinq less weiqht after drying x 100}}{\text{Weight before drying}}$$

More rapid but slightly less precise measurements of moisture content can be made by an electric moisture meter. In the Pine Improvement Project in Thailand an automatic moisture tester "Super Beha" has been used successfully. The device is based on the measurement of the dialectric constant at a very high radio frequency, to ensure a fine accuracy of measurement. The daily checking of the calibration against a quantity of glass beads of a known dialectric constant ensures a uniform and accurate determination of the moisture content in homogeneous seed. A feature of the "Super Beha" is the inclusion of ample insulation between the condenser plates and the samples under test. Satisfactory results have been obtained in measuring moisture contents up to 29 % (Wisopakan and Granhof 19Bl).

Germination Tests

The most recent publication from ISTA (1985) prescribes suitable conditions for germination testing of *P. kesiya*. These conditions are: seeds placed on top of paper substrate, exposed to alternating temperatures and light conditions (8 hours 30° C with light/16 hours 20° C without light); first germination count 7 days after sowing, final count after 21 days. Relative humidity should be maintained at 90-95 % around the seeds. Germination tests should be performed on the "pure seed" fraction of the seed sample.

In the Pine Improvement Project in Thailand, the "Jacobsen" apparatus (Copenhagen tank) has been used successfully for germination testing of *P. kesiya* (Wisopakan and Granhof 1983). The apparatus provides standardized germination conditions with automatic control of afternating temperatures in the waterbath

into which the ends of the filter-paper substrate dip. A total of 400 seeds are used, divided into replicates of 25 or 50 seeds each, placed on the filter-paper and covered by a bell jar. Overhead artificial illumination of 750-1250 lux is supplied by fluorescent light.

An alternative method of testing *P. kesiya*, which is also used for routine sowing for nursery plant production, is to use moist blotting paper 55 x 22 cm (Sirikul 1975). The paper is folded with 9 furrows, each of which is l.5 to 2 cm deep, leaving about half of the paper unfolded. Seed is sown in the furrows, except for the middle one, at 35 seeds per furrow or 280 per pack. To suck the water into the pack, a wick is placed in the middle furrow. After sowing, the paper is folded up, the unfolded part wrapped round it and secured with rubber bands, and seed registration number, experiment number and sowing date are marked on the pack with waterproof colour.

The seed packs are placed on a germination tray, with wick ends dipping into a water bath but without the packs being soaked by direct contact with the water. The trays are finally stocked indoors on shelves. This method works well but gives germination estimates about 4 % lower than those obtained from the Jacobsen apparatus (Wisopakan and Granhof 1983). It occupies much less space than the Jacobsen method. The use of plastic boxes with tight-fitting lids, to retain the moisture in the substrate, as described by Robbins (1984 b), would be suitable for *P. kesiya*.

Germination starts within 5-7 days of sowing. Germination of fresh seed is commonly between 70 and 90 %. Evidence from Thailand suggests that a major factor affecting germination is the percentage of empty seeds; the average viability of 7 provenances in one test was 75.4 %, compared with 80.5 % full seeds (Bryndum 1975). In Zimbabwe seed orchard seed collected over 4 years averaged 92.8 % germination (Seward l980). Penafiel and Noble (1978) found that seeds collected from the northern crown exposure of trees in the Philippines had significantly higher germination than seeds collected from eastern, southern or western exposures (95 % compared with 79-86 %). They also germinated more quickly.

Rapid Tests of Viability

Cuttinq test. The simplest viability testing method is visual inspection of seeds which have been cut open with a knife or scalpel; the seed should be soaked for 24 hours to facilitate sectioning. Seeds with milky, unfirm, mouldy, decayed, shrivelled or rancid-smelling embryo and aborted seeds that have no embryo can be judged as non-viable without much difficulty (Bonner 1974). Full seeds with fresh white tissues and a well-developed embryo are likely to be viable. It is not always possible to distinguish moribund, recently dead or recently injured seeds which still appear the same as sound ones. The cutting test is particularly useful for quick estimates of viability during collection and processing.

The tetrazolium test prescribed by ISTA has been used successfully in Zimbabwe (Seward 1980)). The treatment is:

(1) Soak seeds 18 hours in distilled water
(2) Section seeds lengthwise, parallel and to one side of the embryo
(3) place cut sections in 1% solution of tetrazolium and incubate for 3 hours at 30° C in the dark
(4) Examination of embryos to assess the degree of staining.

In Thailand tetrazolium is used in conjunction urith the Foss Electric "Vitascope 11100" machine. This uses a vacuum at a temperature of 45° C and the absorption process is therefore greatly accelerated; seed staining is usually complete within half an hour (Wisopakan and Granhof 1980, and Knudsen 1982).

The test depends on the ability of the enzymes in living tissue to reduce the colourless tetrazolium salt to the red chemical formazan. Fully stained embryos can safely be assumed to be capable of germination and unstained embryos to be dead. Problems arise in the intermediate cases where embryos are partially stained. In such cases the seed analyst needs considerable experience in order to interpret the degree of staining in terms of germination capacity.

Radiographic tests of viability have been used successfully for a number of pine species. The X-ray method permits the detection of empty seeds, mechanical damage and abnormally developed internal-seed structures, measurement of the thickness of the seedcoat and, when combined writh a contrast agent, assessment of seed viability. The development of soft X-ray equipment has greatly simplified the operation and a processed X-ray print may be obtained in a few minutes (Belcher 1973).

The X-ray method is a useful one and is likely to play an increasing role in seed testing. Earlier models of X-ray machines were expensive, but recent models, particularly from Japan, are much cheaper, Improvements in photographic films and paper have speeded up the process and simplified the interpretation. Besides, there are now, possibilities of using non-toxic water, instead of toxic chemicals as a contrast agent for testing seed viability (Simak 1982).

Kamra (1984) compared estimates of germinability by the X-ray contrast method with actual germination in a Jacobsen apparatus, using *P. kesiya* and *P. merkusii*. In 5 samples of *P. kesiya* having germination per cent from 94 to 99 %, all the estimates by X-ray were within one percentage point of the germination on Jacobsen apparatus. In a single sample which had nil germination on Jacobsen apparatus, the estimate by X-ray was 3 %. The investigation has shown that, with experienced analysts, the X-ray contrast method can give accurate estimates of germinability in *P. kesiya*. The method used was: 16 hours soaking in water, superficial drying by filter paper, 1 hour's soaking in 40 % aqueous solution of sodium iodide in the dark, washing in running water for 1-5 minutes, drying in an oven at 70º C for 90 minutes, X-ray photography. Details of photography were: KV 14, mA 5, focus-film distance 50 cm, exposure time 10 seconds, film Agfa-Gevaert "Structurix D 7", developed in Structurix Developer G-127, fixed in Universal Fixative G-321.

9. REGENERATION PRACTICES

Nursery Propagation

Nursery practice for *P. kesiya* follows closely the qeneral practice for tropical pines summarized by Napier and Willan (1983). General nursery experience with *P. kesiya* is described comprehensively by Armitage and Wood (1980), while *P. kesiya* practice in specific countries has been reported by Calvert (1970) for Zambia, Granhof (1974), Sirikul (1975) and Lloyd, Havmøller and Granhof (1980) for Thailand.

Nursery stock is normaly raised in individual containers, often polythene tubes, and takes 4.5 to 8 months to reach a suitable size for outplanting. The period varies according to the planting size considered best for local conditions, the standard of nursery technique including fertilization, and the elevation and hence temperature of the nursery. Plants grow considerably faster near sea level in the tropics than in highland areas. Height of plants at planting time is usually within the range 15-25 cm, but plants as small as 10 cm and up to 30 cm or more have been planted successfully.

Direct Sowing

This method, which usually incorporates the pelleting of the seeds with insecticide and rodent/bird repellent, has been used on a considerable scale for pines in the southern USA (Derr and Mann 1976). Armitage and Wood (1980) cite several instances of direct sowing of *P. kesiya*, in the Philippines and in the Khasi Hills of India. In the Mountain Province of the Philippines 75 % germination and 70 % survival were achieved after one year (Penafiel *et al.* 1975), but at Bukidnon in the same country germination was only 4-2 %, due largely to rodent damage which accounted for 90 % of the seed (Dalmacio and Barangan 1976). DDT, at a strength of 100 g in 100 ml of water, with a sticker and applied at 25 ml per 100 g of seed, proved ineffective; survival was only 5 % compared with 3.4 % for the control. Later trials of rodent repellents against two common species of rat in the Philippines proved much more effective (Dalmacio 1977). Both Thiram (7.5 and 3.73 %) and aldrin (2.0 and 1.0 %) reduced consumption of *P. kesiya* seeds by almost 100 % after 3 days without inhibiting total germination, and both still reduced consumption significantly when applied at lower concentrations (1.9 and 0.5 % respectively).

Direct sowing requires much greater quantities of seed than use of nursery plants. Even if seed is available in large quantities and at low cost, afforestation by planting is usually preferred, because it is far more reliable and produces higher initial growth rates and far greater uniformity in both stocking and growth.

Natural Regeneration

Natural regeneration of *P. kesiya* is common in the natural range of the species and has been reported in exotic plantations under suitable conditions e.g. in Zimbabwe (Barrett and Mullin 1968) and South Africa (Poynton 1977). The species readily colonises land disturbed by logging or burning, especially if the mineral soil is exposed.

Seed dispersal in the natural montane habitat of *P. kesiya* is very effective, especially if seed trees are situated on or near the ridge tops (Cooling 7967). Armitage and Wood (1980) quote several authors who recommend that between 10 and 20 seed trees per ha should be retained in Philippine pine forests after felling, in order to promote natural regeneration. These need not be uniformly scattered but may be grouped in four or five groups per ha, each group with about four trees.

Agencies observed to be destructive of seeds or natural regeneration include rodents, insects, domestic stock, shifting cultivation and suppression by woody regrowth, grass and weeds (Armitage and Wood 1980). Fire is an important factor and may cause death or severe damage and dieback to seedlings and saplings up to four years old or more. Bhumibhamon *et al.* (1980) found that germination of *P. kesiya* seeds was inhibited, and germinative energy reduced, by aqueous extracts from dried and powdered parts of *Imperata* grass, so phylotoxicity may be a problem on *Imperata* sites in addition to competion for light, water and nutrients.

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1985 Seed Production in P. kesiya

Natural Stands in Thailand

Collections in l985 were made from single trees, dominant and in quality with emphasis on stem-straightness, forking, branch thickness but with due consideration to cone bearing. The distance between seed trees was 100 m. Cones and seedlots were kept separate from the time of collection through extraction to storage.

The following data summarize cone and seed production and provide a picture of extraction efficiency. In l985 collection of maximum amount of cones per tree was attempted.

Collections in 1985 may have been forced in time and started before sufficient cone-maturity had been achieved. This appears from the correlation between collection period, colour of cones and g seed per cone (col. 15); this underlines the importance of proper time for collection. Cones should be green/brown to brown or all brown at the time of collection.

Generally the output of seed was less in 1985 than during 1975-1980. When extraction is maximised (as in sample counts) the number of seeds per cone appears fairly stable, on an average around 63 seeds per cone or 1.56 g seed per cone.

The special purpose of collection for provenance testing provided for almost twice the number of cones per tree than during normal collections.

Interesting is the relation $\frac{\text{g seed per cone by count}}{\text{g seed per cone by average}} = \frac{1.56}{0.80} = \text{c. } 2$

indicating that with normal extraction procedures apparently only about 50 % of the seeds are extracted.

Seed Collection from Single Trees of Pinus kesiya - Natural Stands in Thailand - 1975-80 and 1985

Seed Source	Collection period	Condition of cones at collection	Collection Data				Cone Production		
			No. of trees collected	Kg. cones collected	No of cones collected	Kg seed extracted	No. cones/tree	Kg. cones/tree	Av. cone weight gr
Year(s)							1975-80 / 85	1975-80 / 85	1985 / 75-80
Doi Inthanon	16-24/1/85	green/brown - brown	33	324	9993	7.092	82 / 303	2.9 / 9.8	32 / 36
Doi Suthep	14-16/1/85	green-green/brown	29	262	6824	5.036	145 / 235	5.6 / 9.0	38 / 39
Phu Kradung	28-31/1/85	g/brown-brown, start opening	26	249	4518	4.301	- / 174	- / 9.6	55 / -
Nam Now	1/2-3/2/85	brown and opening	38	249	6580	6.863	- / 173	- / 6.6	38 / -
Nong Krating	12-13/1/85	green- green/brown	33	246	8103	4.620	148 / 245	6.6 / 7.5	30 / 45
Average			32	266	7203	5.582	125 / 226	5.0 / 8.5	39 / 40
Col: 1	2	3	4	5	6	7	8	9	10 11

Seed Source	Collection period	Seed Production								
		kg cones per kg seed	gr seed per kg cone	gr seed per cone by sample count	gr seed per cone by average C.7 : C.6	Seeds/cone by sample count	Seeds per gr.	Seeds/cone by seed weight	gr. seed per tree	Efficiency of extraction %
Year(s)		75-80 / 85	75-80 / 85	75-80 / 85	85	85				
Doi Inthanon	16-24/1/85	39 / 46	26 / 22	1.0 / 1.43	- 0.71	62	53	38	195	50
Doi Suthep	14-16/1/85	37 / 52	27 / 19	1.38 / -	- 0.74	-	52	38	136	
Phu Kradung	28-31/1/85	- / 58	- / 17	- / 1.51	- 0.95	67	53	50	165	63
Nam Now	1/2-3/2/85	- / 36	- / 28	- / 1.74	- 1.04	61	50	52	180	60
Nong Krating	12-13/1/85	28 / 53	36 / 19	1.72 / -	- 0.57	-	46	26	144	
Average		35 / 49	30 / 21	1.36 / 1.56	- 0.80	63	51	41	165	57
Col: 1	2	12	13	14	15	16	17	18	19	20