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Provenance Seed Stands and Provenance Conservation Stands

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Provenance Seed Stands and Provenance Conservation Stands

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CONTENTS

1. INTRODUCTION

One of the objects of the Seed Centre's current Working Programme is to make available seed of provenances afready identified as of high potential for planting on one or more site types, in quantities adequate for the establishment of seed stands and *ex situ* conservation stands. "Semi-bulk" quantities of seed of several tropical pine species are now available for these purposes, while seed of *Tectona* and *Gmelina* will be available later.

This Technical Note describes recommended methods for the establishment and management of PROVENANCE SEED STANDS and PROVENANCE CONSERVATION STANDS. Some countries may already have codified their own procedures of management for seed stands; for others it is thought that the dissemination of "recommended procedures" may be of assistance. It should also help to standardise methods of management from country to country, just as the recommended procedures for the earlier international provenance trials facilitated a common approach to their layout, establishment and maintenance. Local conditions vary widely, however and a flexible approach will always be needed to adapt general prescriptions to the specific problems of each individual site.

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2. DEFINITIONS

Provenance Seed Stand (PSS)

The traditional Seed Production Area (SPA) or Seed Stand, as described by e.g. Matthews (1964), Squillace (1920), Barner (1915), Keiding (1975) and Mittak (1919), is defined as "A plus stand that is generally upgraded and opened by removal of undesirable trees and then cultured for early and abundant production of seed" (Snyder 1912). The characteristics of the traditional SPA, which may be in either indigenous forest or plantations, are: -

(a) It is o1d enough to provide reasonable assurance that it is well adapted to the site and will continue to show rapid, healthy growth and good form.

(b) It is judged to be phenotypically superior to the other stands of similar age and growing in similar conditions, with which it is compared. to be bearing, or about to bear, substantial

(c) It is old enough to be bearing, or about to bear, substantial seed crops.

(d) Its phenotypic quality and the seeding capacity of the residual trees are further improved by the removal of the inferior trees in the crop.

(e) Prior to selection it has not usually been managed for the primary purpose of seed production.

The category of "Selected Stands in OECD's Scheme for the Control of Forest Reproductive Material moving in International Trade is similar - "A stand of trees superior to the accepted mean for the prevailing conditions . .. . . and which may be treated for the production of seed", although in this case the cultural treatment is optional rather than mandatory. The "Registered Seed Areas" or "Selected Stands" used for *Cupressus lusitanica* in Kenya (Dyson 1969) include a mandatory thinning or thinnings to improve stand quality and so conform to Snyder's above quoted definition.

Most authors stress the importance of providing some degree of isolation of seed production areas from foreign pollen of inferior stands or of hybridising species. Complete isolation is impossible for most species, and a maximum contamination of 20% of foreign pollen has been accepted for *Pinus sylvestris* in Finland (Koski 1982). The percentage contamination may be reduced not only by increasing the distance betwreen the SPA and undesirable sources of foreign pollen: e.g. by clearfelling the undesirable sources, or by interposing a physical barrier such as planting isolation strips of eucalypts around SPAs of pine, but also by increasing the amount of pollen produced inside the SPA. For this reason a minimum size of 3-5 ha is commonly prescribed (Andersson 7963, Koski 1982), and seed should not be harvested on the trees near the border.

The amount of genetic gain expected from the use of seed from SPAs, compared with seed from average plantations, is estimated to be modest because the intensity of selection is rather low. The heavy thinning practised in SPAs selects one seed tree out of about ten originally planted. To this must be added the improvement over the average of the other stands of comparable age and growing conditions which results from the initial selection of the SPA. In Kenya cypress this selection factor was about 1 in 20, so that the final selection factor for individual seed trees in the SPA, compared with the average trees in all plantations of the same age-group,was 1 in 200 (Dyson 1969). This is still low in comparison with the factor used for selection of plus trees which, in extensive plantations, is commonly 1 in 10,000 to 1 in 100,000 of the trees planted. There is little evidence on the size of genetic gain actually derived from using SPAs, but estimates include from + 6% for diameter in *Pinus radiata* in New Zealand (Shelbourne 1969) to + 25% in Kenya cypress (Dyson 1969), + 25% for stem straightness in *P. radiata* (Shelbourne 1969) and + 6% for volume in P. sylvestris in Finland (0skarsson 1971). About half of the estimated gain comes from the selection of the SPA and half from its subsequent upgrading.

The Provenance Seed Stand differs from the traditional Seed Production Area or Seed Stand in several ways:

Its primary purpose - seed production - is already known before planting. This has the big advantage that the stand can be sited to provide an appropriate combination of good access, isolation from undesirable foreign pollen and conditions for future heavy seed production. Management can also be directed from the start towards the objective of seed production e.g. through early thinning and perhaps application of fertilisers.

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ii) 0n the other hand there is inevitably an interval of time between the establishment of the stand by planting and the production of substantial quantities of seed. The PSS therefore lacks the big advantage of the traditional SPA, the early availability of seed having a modest improvement in genetic quality over seeds from commercial plantations.

iii) While the judgement of the superiority of an SPA as a whole and of the individual seed trees within it is based on the phenotype (genetic superiority may be tested later through progeny tests), the superior adaptability of a given provenance used in a PSS should be judged from the results of comparative provenance trials carried out on sites similar to that of the PSS. For *Pinus caribaea* and *P. oocarpa* the best sources of information are the international trials organised by the CFI 0xford and for *Tectona grandis* and *Gmelina arborea* those organised by the DANIDA Forest Seed Centre.

The adaptability of certain provenances to particular sites or, in some eases, to a wide range of sites, which has been demonstrated by the international provenance trials, is a strong reason for establishing larger areas of seed stands of the successful provenances as soon as possible. Most of the semi-bulk collections are from 100-200 well-spaced seed trees per provenance, which should provide a sufficiently broad genetic base for future selection and breeding without serious risk of inbreeding. At the same time the selection of those seed trees from among the dominant and co-dominant trees, of average or better than average phenotypic quality, should ensure that a high proportion of the most desirable alleles are passed on to the next generation of trees in the PSS.

Inasmuch as a PSS is planted with seed production as its explicit object of management, it resembles a seedling seed orchard, but the intensity of selection of the individual parent trees is much lower. In the case of a seedling seed orchard the mother plus trees from which seed is collected to establish the orchard are, in extensive plantations, normally selected at a rate of 1 in 10,000 to 1 in 100,000 of the trees planted; each mother tree is registered, mapped and preserved; and the parentage of each individual offspring which forms a component of the orchard can usually be identified. In the case of a PSS the selection of the parent trees which provided the seed is much less intensive. A common rule is to collect from not worse than dominant, and co-dominant trees of average quality, spaced, if possible, at least 100 m apart,; within that category selection is close to random, although constrained by the fact that some trees may bear no or very light seed crops. Seed from individual parents is bulked, therefore parentage of offspring in the PSS is unknown.

As a PSS reaches seed-bearing age, the differences between it and a traditional SPA become less. But the seed yield in the PSS should be higher, from its having been established and managed throughout for the purpose of seed production. The provenance of the parent trees will be known precisely, which is not, always the case with an SPA, and its to local site conditions will have been demonstrated through provenance trials.

PSS is equivalent to the I'Provenance Resource SLand" used *Pinus caribaea* var. *hondurensis*. Nikles and Newton (1980) defined this as "a forest plantation of known provenance and broad genetic base whose boundaries are marked in the field and recorded on official maps, and which may be used for plus tree selection, seed collection, provenance conservation etc.". The aim in Queensland is to preserve the best trees in these stands for future breeding and to produce a good timber stand.

In summary the Provenance Seed Stand may be defined as : A stand of known provenance, preferably already tested and found superior in provenance trials and of broad genetic base, which is (1) planted for the primary purpose of seed production, (2) isolated to reduce pollination from outside sources and (3) upgraded and opened by removal of undesirable trees and cultured for early and abundant seed production.

Provenance Conservation Stand (PCS)

Provenance Conservation Stands may be established either *in situ* or *ex situ*. Wherever control of land by conservation authorities is firmly exercised e.g. in well managed National Parks, *in situ* conservation is an official method of conserving provenances. It has the advantage of conserving a complete ecosystem, not just the constituent species or provenances, and it maintains genotypes and gene frequencies, not just genes, adapted to the local environment. In many areas in the tropics, however, increased land pressure and forest clearing has rendered it difficult or impossible to conserve valuable provenances within their natural distribution. In these circumstances collection of semi-bulk quantities of seed of threatened Provenances and their planting as *ex situ* seed stands and conservation stands, at places where conservation and management can be assured, can play a vital role in conserving genetic resources of immense value to many countries. It is the *ex situ* planted Provenance Conservation Stand with which this note is concerned.

Any successful tree-planting operation conserves genetic resources but subsequent management can have a considerable effect on the width of the conserved gene pool. Take an extreme case of a PSS planted from equal quantities of seed gathered from 20 parents, of which two were consistently superior to the other 18; if the stand was reduced to a final crop of seed trees equivalent to one in ten of the number of trees planted, the result could be a reduction to half-sib families of only two parents. This could lead to inbreeding depression or increased susceptibility to disease.

While management of a PSS will concentrate on favouring the trees most suitable for current ideas of forest production (growth rate, stem form, wood quality etc), management of a PCS attempts to conserve as much genetic diversity as possible, including 'inferior' trees, as an insurance against unpredictable risks and changed needs in the future. It is neither possible nor desirable to conserve every genotype. Even the most stringent conservation regime could not avoid gene frequencies changing according to natural selective forces - the *evolutionary conservation* of Guldager (1975). Some genotypes will die because they cannot withstand local conditions of for example drought, insect attack and competition. The loss can be accepted in planted conservation stands, just as it must occur from time to time in untouched natural stands.

One sensible precaution is not to concentrate the entire gene-pool in one large PSS or PCS. If it is split between two or more sites, the chance of losing the entire gene-pool in a single disaster, e.g. fire, is much reduced.

Better still if there is some variation betueen the environmental conditions of the different sites; evolutionary conservation should then select a slightly different gene-pool on each of the sites and the total available gene-pool within a country would be broadened. It is possible to argue that a series of scattered PSSs, each managed to favour trees judged superior for current commercial objectives, may still conserve sufficient overall variation within the system. While Seed Stand management is likely to lead to a loss of **within-stand** genetic diversity, **between-stand** and hence total genetic diversity could be maintained if there were sufficient, number of PSSs scattered over a diversity of site types. This could lead eventually to the array of separate breeding populations advocated by Namkoong, Barnes and Burley (1980).

Although this argument may be correct in theory, there are some important reasons why a system of PSSs alone cannot yet be relied on to conserve a desirable level of genetic diversity.

1. Knowledge of gene linkages and genotype/environment interactions in tropical trees is still far from eomplete. It is therefore not yet possible to determine the most appropriate number of PSSs and the best pattern for their distribution over di-fferent site types, in order to conserve genetic diversity.

2. Even if the most suitable pattern of distribution of PSSs were knoun, current seed supplies are inadequate to plant the many PSSs on many site types urhich tuould probably be Reeded.

3. In the case of some critically endangered provenances, it may be difficult or impossible to obtain further seed from the natural range.

There is therefore a strong case, at least in the early stages of developing provenance genetic resources, for the establishment of a proportion of Provenance Conservation Stands managed to conserve a high degree of withinstand genetic diversity.

Most tropical countries, in the early stages of developing a tree improvement program, wil1 be more interested in building up their own supplies of improved seed from local Provenance Seed Stands than in conserving genetic diversity. There is, however, no reason why the Provenance Conservation Stands should not contribute some superior genetic material towards the improvement of future generations. Within the stands, provision can be made to retain a restricted number of plus trees for inclusion in the breeding program, while managing the rest of the crop to maintain maximum genetic diversity. The method for doing this is deseribed later.

In summary, the Provenance Conservation Stand may be defined as: A stand of known provenance, preferably already tested and found superior in provenanee trials and of broad genetic base, which is (1) planted for the primary purpose of maintaining a high degree of genetie diversity within the stand, (2) isolated to reduce pollination from outside sources and (3) managed, by means of systematic thinnings, to conserve a high proportion of the original genetic diversity in the seeds or clonal material produced by the stand.

3. ESTABLISHMENT

The management of each PSS and PCS will, in most respects, be identical. The same semi-bulk seed will be used for both types of stand, nursery and planting techniques should be of the same high standard for both and the same considerations as to isolation and maintenance apply. The one major difference is the method of thinning, which in one type of stand is designed to select and favour the trees of superior groruth and form and in the other is designed to maintain genetic diversity. Unless otherwise stated, the techniques recommended below apply equally to both.

Nursery

1) The prime objective of the nursery/planting/tending procedures should be the establishment of a uniform, fully-stocked, and vigorous stand. In consequence it is recommended that the very best practices be adopted to ensure maximum survival and adequate growth, under the close supervision of experienced technical staff.

2) For pines direct sowing of seed into pots or polythene tubes is recommended subject to local experience. If for some reason this method is not, feasible, sowing should be carried out in sand trays, followed by careful transplanting at the cotyledon stage into pots or tubes.
For teak raised for planting as stumps, care should be taken to give the plant adequate space in the nursery. Gmelina may be raised either in pots or as stumps, according to local practice.

3) Tropical mycorrhizae are an essential requirement for healthy growth of tropical pines. It is assumed that previous trial plots will have established mycorrhizal infection and it is recommended that soil containing mycorrhizal material be mixed with the potting soil mixture.

4) Watering, shading, weeding, root pruning, fertilizing, hardening off, and other procedures should follow the best local proven techniques. In the case of tropical pines, general guidance on nursery techniques is available in Technical Note No.4, available from the Seed Centre.

5) One important difference from common operational nursery practice is in respect of culling. Nursery plants should be rejected if dead or dying but not because of delayed germination or slower than average grouth. In some species nursery growth is closely correlated with seed size but neither is correlated with subsequent growth in the field. In a PCS the objective is to conserve maximum genetic diversity, while in a PSS the objective is to thin on the basis of performance in the field. In both cases, therefore, the practice of grading nursery stock and planting only the larger size classes must be avoided.

6) Every pot or tube should be individually colour coded by paint marks before leaving the nursery to prevent any possibility of confusion between provenances, or between provenances and routine planting stock of the same species, during handling and transit.

Total area of Provenance Seed Stands

The following table gives estimates of seed production which may be expected in good seed years from Provenance Seed Stands when they reach maturity. They are rough average estimates for the species and it is likely that seed production will vary considerably from provenance to provenance and from site to site. They provide some guidance as to the total area of seed stands which would be required to provide seed for a stated annual planting area of the provenance in question. For example, if it were planned to plant 1800 ha per year of a given provenance of *P. caribaea var hondurensis* the area of productive Provenance Seed Stands needed would be 6 ha.

	Seed production per ha of seed stand in good seed years kq	Clean seeds/ fruit per kg	Plant %	Plantable plants per ha of seed stand	Area of plantations established in one year from 1 ha of seed stand (+ ha
P. caribaea var hondurenses	15	60,000	45	405,ooo	100
P. oocarpa	7.5	58,000	48	209,000	155
P. keslya	15	50,0u0	42	115,000	233
P. merkusii (Thailand)	7,5	lo,000	42	95,000	70
P. patula	15	125 ,0oo	36	575,OOO	500
Gmelina arborea	300	I ,600	50	240,000	178
Tectona grandis	200	2,000	10	40,000	30

(+ Assuming a total of 1350 plants per ha (spacing 3 x 3 m = 1111 plus approx. 20% for blank-filling).

In practice the total area of Provenance Seed Stands, especially of the most ”popular” provenances, is likely to be limited, at least initially, by the amount of seed available.

Total Area of Provenance Conservation Stands

As a rough guide, it is suggested that each country should aim to plant Provenance Conservation Stands of total area equal to one fifth the area of the Provenance Seed Stands of the same provenance.

Layout of individual stands

1) For both PSS and PCS an area of 5-10 ha is recommended for a single stand.
   Smaller than 5 ha is unlikely to provide a large enough pollen cloud to reduce foreign contamination of pollen to acceptable limits. At a final stocking of 150 stems/ha a 5 ha stand will contain 750 seed trees which should be sufficient to maintain an acceptable degree of genetic diversity into the next generation. A larger area than 10 ha in a single stand would be acceptable, but it is considered preferable to split the gene-pool between several sites in order to reduce the risk of total loss from natural catastrophe and also to conserve a wider range of genetic diversity related to the diversity of the sites. Thus a total of l0 ha PSS or

PCS would be better split between three sites of 10 ha each than in a single block of 10 ha. The additional cost of protecting the stands on three different sites rather than one must be accepted in the interests of risk reduction and of conserving a wider gene pool.

2) The recommended plot shape is approximately square (say 300 x 330 m for 10 ha or 220 x 230 m for 5 ha). Should circumstances dictate, a rectangular or other modification is acceptable, but the shortest diameter should not be less than 150 m to avoid too early emigration of the pollen cloud from the stand (Koski 1982).

3) It is recommended that the best possible isolation of these stands be sought in order to minimize hybridization between them and existing or projected plots, trials, or regular plantations of the same or crossable species. In this connection prevailing wind direction at pollen shed may have to be taken into account, by making the isolation strip wider on the windward than the leeward side. The recommended minimum isolation is 330 m. Where a PSS or PCS of more than one provenance is planted on the same site, they should be at least 330 m apart.

4) Isolation strips may conveniently be planted with trees of another genus. These provide a non-hybridising physical barrier against foreign pollen, can be managed as an integral part of the PSS or PCS and are often more effective than an unplanted strip. In some cases it may be possible to alternate provenance stands of different genera, e.g. a stand of teak could separate two provenances of pine while constituting a PSS or PCS in its own right. Another convenient method is to plant the stands in the middle of operational plantations of another species; planting of the two species may be done simultaneously or the PSS/PCS may be planted after clearfelling a sufficient area within an existing plantation.

5) Local conditions will determine the required demarcation of the plots to prevent accidental damage. Where brousing animals occur, it may be necessary to fence the area.

6) The recommended spacing is 3 m x 3 m to allow for possible mechanical cultivation and later thinning.

Siting of stands

1) One or more sites should be chosen which are representative of considerable areas of a given combination of climate and soil which are available for planting. First choice should be given to the site-type which is typical of that on which the provenance has already demonstrated its good potential, both for vegetative grourth and for seed production, in earlier provenance trials.

2) Additional sites should differ from the first chosen site in one or more respects e.g. in being significantly drier or cooler. The differences should not be so great that the provenance is unlikely to grow well or to produce good seed crops. It may be desirable to have a larger stand on the "first choice" site e.g. 10 ha there and only 5 ha each on the additional sites.

3) All sites should be at least of moderate quality. Adequate soil survey should be carried out before the final selection and abnormally poor sites (e.g. waterlogged or shallow and de-

graded) must be avoided.

4) In some cases, if the provenance grows well and produces a high yield of wood, but only a low yield of seed, on the main planting sites, it may be advisable to plant the Seed or Conservation Stands on sites specially chosen because the local climate is favourable to seed production. For some of the pines, there is an increasing amount of information on the factors which affect seed production. For example, optimum conditions for seed production in *Pinus caribaea* var *hondurensis* appear to be a combination of a marked dry season with mean annual temperature of about 24.5°C, mean daily temperature in coldest month about 21°C and mean daily temperature in hottest month about 27°C (Delwaulle 1982, Gibson et. al. 1983). For *P. patula* at latitude 19°S in Zimbabwe, in contrast, seed production is best about 16oo m altutude, equivalent to temperatures of less than l6°C (mean anual), 11.5°C (mean of coldest month) and 18°C (mean of hottest month).

   In case of a strong genotype-environment interaction, it is possible that the superior phenotypes, selected as seed trees in a PSS which is sited in a climate especially favourable to seed production, would not be equally superior in the different conditions of the main planting area. There is little evidence available on this problem and, in the absence of more precise knowledge, the risk in moving the location of seed stands should be accepted as preferable to the risk of getting inadequate seed because of siting the stands where the climate inhibits flowering or seed ripening.

   Location of seed stands on sites exceptionally favourable to seed production can, therefore, often be justified, particularly in the case of a good wood-producing provenance which is a shy seeder both in its natural range and in the main plantation areas where it has been introduced. Any action which increases production of a valuable but rare seed resource is beneficial. But the planting of large areas of exotics in climates where they never produce any seed, even though the seed can be obtained from elsewhere, should be a matter for concern.

   If a provenance, which naturally produces good crops of seed, produces none at maturity when planted in a very different environment, it may be a symptom that it is not wel1 adapted, and it should be taken as a warning that something might go wrong later on.

5) Access to the proposed sites should be adequate for the purposes of establishment, protection, management and future seed collection.

6) Security of tenure is obviously of prime importance in the selection of sites. Legal ownership should clearly rest with the managing authority, e.g. by siting the stands in government forest reserves.

Planting

1) Site preparation by complete cultivation is the preferred procedure, especially in climates of low rainfall and long dry season. In consequence, stands should be put on gentle slopes, to minimise erosion.

2) Special supervision should be given to lifting and transport of tubes/stumps, e.g. thorough wetting before leaving the nursery, so that planting shock is minimized.

3) Polypots or tubes should be removed at the time of planting.

4) If necessary, filling of blanks should preferably be completed within 2 - 3 months after the initial planting, if the rainfall regime permits.

5) Local conditions will dictate the pioneer species, grasses, climbers, etc. which will appear after planting, and likewise the methods appropriate for their removal. In many cases hand weeding will be the usual technique. Where complete site preparation has been possible, machine cultivation between the rows would be a satisfactory method, but care must be taken not to damage the plants by the machines. Complete removal of weeds is strongly recommended as a precaution against fire damage during the early years. Weeding should be continued periodically until canopy closure. Cover crops may be planted if there is consistent evidence of their beneficial effects under local conditions.

6) Where the local experience indicates that fertilizers are advisable to assist establishment and early growth, they should be applied in accordance with successful local techniques. Apart from major elements, micronutrients such as boron may need to be applied in certain areas.

Protection and Maintenance

1) On certain sites it is essential to take adequate measures to protect Provenance Seed Stands and Provenance Conservation Stands from fire. It is recommended that appropriate fire lines be cleared round the stands and their isolation strips, especially in grassland areas and monsoonal climates with a marked dry season. For some species after a certain age, controlled burning may be both possible and desirable within the stand, for example in Queensland controlled burning is prescribed for *Pinus caribaea* after 10 years (Nikles undated); but this technique requires great skill.

2) Protective measures against pests and diseases may need to be carried out as required e.g. by spraying against defoliators or by early removal of thinnings to prevent insects breeding in them.

3) If fencing is used, it should be regularly maintained to keep out domestic stock and wild life.

4) For tropical pines whole crop pruning to 2 m for access is the minimum desirable. Subsequent pruning should be confined to periodic removal of dead or moribund branches, leaving the maximum volume of live green crowun for seed production. Selective high pruning of the best trees, as carried out in some commercial plantations, should not be

done in either PSSs or PCSs. Pruning of the main crop may be conveniently carried out immediately after a thinning.

No pruning of teak or *Gmelina* is normally necessary, but singling of basal forks from teak stumps may be necessary on some plants during the first year at the same time as weeding operations.

5) Weeding ceases at the time of canopy closure, but occasional climber cutting may be required thereafter.

4. THINNING

The thinning methods to be used in Provenance Seed Stands and Provenance Conservation Stands will differ radically, because the objective of the first is to select and favour the superior phenotypes while the objective of the latter is to conserve a high degree of genetic diversity.

Provenance Seed Stands

Experience in the thinning of Provenance Seed Stands of tropical species is lacking, and guidance can only be given in general terms. Recommendations for thinning schedules should therefore be modified freely in the light of loca1 experience with particular provenances on particular sites.

The aim will be to develop large crowns on the seed trees for maximum seed production per tree. This can best be done by isolating the crown of each seed tree from its neighbours. Excessively large gaps between trees are undesirable because they would reduce the amount of po1len reaching the female flowers from neighbouring trees and so increase the risk of selfing. A useful rule of thumb is that the distance between seed trees should be approximately half the average height of the dominants and co-dominants (Rudolf et al. 1974). To achieve this, thinning schedules can be expected to be considerably heavier than any used in commercial plantations for wood production.

Thinning should be based on dominant height, and will thus be carried out at an earlier age on good sites than on poor ones. On the drier tropical sites it is usually advisable to defer the first thinning until at least two years after canopy closure, in order to ensure the complete suppression of weed (especially grass) growth before opening up the crop. For tropical pines an initial 50% thinning at dominant height of 8 m is recommended. In the wetter tropics, weed growth usually persists under pines and eucalypts throughout the life of the crop, even in unthinned plantations at 2 x 2 m spacing, in these conditions it may be preferable to carry out the first thinning earlier, to cut the unpalatable weeds and graze the remaining ground cover in the plantations. On steep slopes maintenance of some ground cover may be necessary to prevent erosion. Three subsequent thinnings should aim to maintain a spacing/dominant height ratio of about 50% (immediately after thinning) and to reduce stocking to around 140 seed trees per hectare (average spacing 8.5 m) when dominant height is 17 m. For most species growing on average sites (except *P. merkusii* because of its grass stage), this "final crop" of seed trees should be reached at an age of 12- 15 years.

In *Gmelina*, growth rates and crown diameters are likely to be greater than in the pines. A final stocking of 80-100 seed trees per ha is likely to be appropriate and one additional thinning may be required. In *Tectona*, final stocking is likely to be similar to that of *Gmelina*, but will be reached at a considerably later age, perhaps 25-30 years. In marking thinnings, trees to be retained and favoured by the removal of "dangerous neighbours" should be those considered superior in growth rate, stem form, branch angle and freedom from pests and diseases.

At a later stage checks may be needed on seeding capacity and on wood quality from borings (freedom from spiral grain; density not less than average). Some guidance on criteria for selection is contained in appendix 1 which covers selection of Plus Trees, but the degree of superiority of future seed trees over their neighbours will, of course, be much less because they form a higher proportion of the total population (about 1 in 8 or 1 in 10, compared with 1 in 110 for the plus trees in the Conservation Stands).

Line and plot methods of marking thinnings to achieve any given density of stocking, while favouring the the better trees, are described in Appendix 2. Early selection is a skilled operation and assumes a reasonably close correlation between juvenile and mature superiority. The line and plot methods assume that skilled staff are available to select the better trees, while allowing for less experienced staff to mark early thinnings among the poorer trees.

Provenance Conservation Stands

For conservation stands timing of the first thinning and the periodicity of subsequent thinnings should be similar to those of the seed stands. But the method of thinning, predominantely systematic instead of selective, and the intensity of thinning will differ. In the seed stands the very heavy thinning schedule is designed to concentrate seed production on the large crowns of a relatively few superior seed trees. In conservation stands management should ensure a satisfactory seed production per hectare but there is no need to achieve a very highproduction per tree. In fact the more seed trees retained the better, as long as each tree has sufficient crown development to contribute significantly to the seed harvest; the amount of genetic diversity passed on tot he next generation will then be greater than when there are few, widely spaced trees. Final stocking in conservation stands should therefore be approximate to that of commercial stands. For the tropical pines, this can be achieved by omitting the last two thinnings prescribed above for the seed stands this would leave approximately 280 stems/ha in the final crop, as opposed to the 140 of the seed stands.

The simplest way of achieving a systematic thinning without any selective bias is to remove the whole of alternate rows in one direction at the first (50%) thinning and the whole of alternate rows at right angles at the second (50%) thinning. Appendix 3 illustrates this method.

Although a fully systematic thinning method would be the most effective in conserving genetic diversity, its strict application might result in the loss of superior phenotype which could be of great value to a future breeding program. For this reason it is accepted that up to a maximum of ten trees per hectare of exceptionally good vigour and form may be selected and marked before the first thinning and retained in the conservation stands, as exceptions to the rule about systemati thinning. Guidance as to the criteria for assessing candidate plus trees is contained in appendix 1 and diagrams to show how the preservation of these trees can be combined with systematic thinning in the rest of the stand appear in appendix 3. It must be emphasised that only exceptional trees should be marked for retention in this way: the degree of phenotypic superiority should be very much higher than in the final crop seed trees of the seed stands. The retained trees will provide vegetative material, to the breeding programme. They will also provide a source of seed which should combine improved genetic qualities from the female parent with a high degree of genetic diversity from the male parent.

For teak and *Gmelina* a lower final stocking is expected in the conservation stands. A third thinning, removing every second tree in every second diagonal row of the remaining crop, is recommended for these species, as shown in appendix 3. A fourth thinning to about 140 stems/ha may be needed in very wide-crowned hardwoods including *Gmelina*.

Effect of thinnings on understorey

The heavy thinnings in both the seed and the conservation stands may result in an increase in the growth of understorey vegetation. Some increase is to be expected and may even be beneficial if it reduces erosion on the forest floor. If the regrowh appears excessive after any thinning, it may be desirable to postpone the next thinning by a year or two. Ground vegetation increases the cost of cone collection. Apart from manipulation of the canopy, it may be controlled by mechanical slashing or, in the ease of fire-resistant species, by judicious timing of controlled burning shortly before the seed-collection season.

5. RECORDS

It is essential to keep a full record of the history of both the Provenance Seed Stands and the Provenance Conservation Stands, including details of establishment and management methods and observation on growth and health, flowering and seeding phenology etc. An example of a suitable format for recording history developed by J. Granhof, is shown in appendix 4.

6. REFERENCES

Andersson, A. 1963

Seed stands and seed orchards in the tree breeding of conifers. Proc. World Consultation on Forest Genetics and Tree Improvement, Paper 8/1.

Barner, H. 1975

Identification of sources for procurement of forest reproductive material. Report on FA0/DANIDA training course on Forest Seed Collection and Handling, Vol.II pp. 42-64. FAO, Rome.

Barnes, R.D. and Mullin, L.J. 1974

Flowering phenology and productivity in clonal seed orchards of *Pinus patula*, *P. elliottii*, *P. taeda* and *P. kesiya* in Rhodesia. For.Res.Paper No.3 Salisbury.

Barnes, R.D. and Gibson, G.L. 1984

Experimental design, management and selection traits in provenanee trials of tropical pines. Paper for meeting of IUFR0 working parties on provenance and genetic improvement strategies in tropical forest trees, Mutare, Zimbabwe.

Delwaulle, J.C. 1982

Seed production of *Pinus caribaea*. Forest Genetic Resources Information No. 11, p.55 FAO, Rome.

Dyson, W.G. 1969

Improvement of stem form and branching characteristics in Kenya cypresses. 2nd World Consultation on Forest Tree Breeding, Papet 3/5.

FAO 1977

Recommended prescriptions for the establishment and long-term management of *ex-situ* conservation/selection stands. Annexes 7/1 and 7/2.

Report of the Fourth Session of the FAO Panel of Experts on Forest Gene Resourees. FAO, Rome.

Figueroa, 1979

Manual para la eleccion de rodales selectos con fines de la recoleccion de semillas forestales. BANSEF0R, Guatemala Doc. de Trabjajo Projecto 6/GUA/01-T.

Gibson, G.L. 1982

Genotype - Environment Interaction in *Pinus caribeae.* Interim report on Research Scheme Nos. R3251 and R 3644. Commonwealth Forestry Institute, 0xford.

Gibson, G.L., Barnes, -R.D. and Berrington, J. 1983

Flowering and its interaction with environment in provenance trials of *Pinus caribaea.* Commonwealth Forestry Rev. 62(4), 251-263.

Guldager, P. 1975

Ex-situ conservation in the tropics. The methodology of conservation of forest genetic resources. FAO FO:MISC/75/8.

Jones, N. and Burley, J. 1973

Seed certification, provenance nomenclature and genetic history in forestry. Silvae Genetica 22, Heft 3, pp. 53-58

Keiding, H. 1975

Seed stands. Report on FAO/DANIDA training course on Forest Seed Collection and Handling, Vo1.2 pp. 192-211. FA0, Rome.

Kellison, R.C. 1969

Upgrading genetic quality. B. Seed production areas. Lecture notes, FAO/North Carolina State Forest Tree Improvement Training Centre, Raleigh USA, pp. 75-78.

Koski, Veikko , 1982
Quantified standards for regional clonal seed orchards. Forest Genetics Resources Information. FAO No. 11.
Lang-Brovn, J.R. 1965
Spacing in softwood plantations in Western Uganda. Commonw. For. Rev. No.119.
Mattheus, J.D. 1964
Seed production and seed certification. Unasylva Vol. 18, Nos.2-3, pp, 104-108, FAO, Rome.
Mittak, W.L. 1978
Manual 2 para la recoleccion de semillas forestales. INAF0R-BANSEF0R-FA0/TCP. Instituto Nacional Forestal, Guatemala.
Namkoong, G., Barnes, R.D. and Burley, J. 1980
A philosophy of breeding strategy for tropical forest trees. Trop.For. Paper No.15, Commonw.For.Inst., Oxford.
Nikles, D.G. undated
Provenance Resource Stands (PRSS) of Honduras Caribbean pine in Queensland. Dep. of Forestry, Brisbane (mimeo).
Nikles, D.G. and Newton, R.S. 1980
Inventory and use of "provenance resource stands" of *Pinus caribaea* var. *hondurensis* in Queensland. Paper for IUFRO joint symposium and workshop, Brazil.
OECD, 1974
OECD Scheme for the control of forest reproductive material moving in international trade. OECD, Paris.
Oskarsson, 0. 1971
Selection differential and the estimate of genetic gain in plus stand. Folia Forestalia 104 Helsinki. English summary.
Rudolf, P.0., Dorman, K.W., Hitt, R.G. and Plummer, A.P. 1974
Production of genetically improved seed. Chapter 3 in Seeds of Woody Plants in the United states. USDA, Forest service, Agric. Handbook No.450.
Shelbourne, C.J.A. 1969
Predicted genetic.improvement from different breeding methods. Second World Consultation on Forest Tree Breeding, Vol. 2 pp 1023-1029.
Shepherd, K.R. and Slee, M.U. 1969
Tree breeding programmes and silvicultural practice in Australian man-made forests. Paper 9/9 for Second World Consultation on Forest Tree Breeding.
Snyder, E.B. 1972
Glossary for Forest Tree Improvement Workers. USDA, Forest Service
Squillace, A.E. 1970
Development and action programmes for forest tree improvement. Unasylva 24, Nos. 97-98, p.65.

Appendix 1

SELECTION OF PLUS TREES

In order to improve the genetic characteristics and hence the economic value of future, generations, it is necessary to use only the best trees for seed production and for incorporation into tree breeding population where they will cross with other superior trees. Great care is, therefore, needed in making the selection of plus trees in stands.

In the first instance the individual trees are chosen for their phenotypic superiority. This results from the interaction between genotype and environment and it is not possible to determine what proportion of the apparent superiority is heritable and what is due to an exceptionally favourable microsite. Progeny testing of plus trees is necessary to determine whether they are genotipically as well as phenotypically superior. A tree which has had its genetic superiority proved by progeny tests is commonly known as an elite tree.

Plus trees are often selected in two stages. In commercial plantations the initial selection may be made by local staff comparing a superior tree with the average of the plantation. The candidate plus trees so selected are then reassessed by research staff using more rigorous standards of comparison with toehr plus trees. In Provenance Conservation Stands of limited area, it may be easier for the selection to be completed in a single operation; even then it may happen that the initial search reveals rather more candidate trees than the maxiumum of 10/ha desired and that a second, more careful, assessment is needed to eliminate the less good candidates.

Traits to be assessed

Candidate plus trees may be superior in one or more traits. An ideal tree would be superior in all traits of economic vålue, but such trees are exceptional. The traits assessed in selecting trees can vary from a few obvious ones, suh as diameter, height and stem straightness, to a greater number of traits. In recent assessments of provenance trials of tropical pines, well over twenty traits have been assessed, grouped as follows (Barnes and Gibson 1984, Gibson 1982):-

A. Stem traits

1. Height.
2. Diameter at breast height (also at 6 m if taper needs to be assessed).
3. Bark thickness at breast height.
4. Forking. Frequency and level.
5. Straightness.
6. Circularity.
7. Verticality (i.e. absence of stem lean in straight trees).

B. Branch traits

1. Branch diameter.
2. Branch angle.

3. Branch number and distribution (frequency of branch mean number of branches per whorl).
4. Branch order (average length of first order branch stem to second order branching).
5. Branch malformations (ramicorns and basket whorls).

C. Crown traits
1. Crown depth (tip to base of living crown).
2. Crown width and symmetry.
3. Incidence of needleless shoots.

D. Reproductive traits
1. Time of initial flowering.
2. Size of production of flowers and seed.
3. Periodicity of flowering.

E. Wood traits (from cores or discs)
1. Basic density.
2. Fibre dimensions (cross-section and length).

F. 0leoresin
1. Yield.
2. Terpene composition.
3. Rosin.

G. Pests, diseases and disorders
l. Evidence of resistance/susceptibitity to diseases.
2. Evidence of resistance/susceptibitity to insect pests.
3. Evidence of resistance/susceptibility to drought, fire, animals etc.

The choice of traits for assessment depends very much on the species, the age of the crop and the proposed end use. Some traits, such as reproductive and wood traits, may not be susceptible to proper assessment until the trees have reached a certain minimum age. Some traits are applicable only to certain species, e.g. oleo-resin production in pines. In some species specific pests or defects may be so important as to be worth separate assessment, e.g. beeholeborer damage or excessive buttreesing in teak. It is therefore impossible to prescribe a single list of traits to be assessed in all circumstances. There are however, certain traits which are included in nearly all assessments of plus trees for timber production; these are (1) Volume production, estimated through measurement of breast-height, diameter and height. (2) Stemform, with emphasis on straightness, circularity and absence of forking. (3) Branching habit (diameter and angle).

Measurement v. subjective scoring of traits

Many traits can be measured, but only a few can be measured quickly and cheaply. Breast-height diameter is one trait which can be easily measured and which contributes greatly to tree value through its effect on stem volume. Height is also an important contributor to stem volume, but less easy to measure. Both DBH and height should be measured and recorded for all candidate plus trees. Other traits are more difficult to measure. For example, average branch basal diameter is a branch whorl near the base of the living crown can be measured and expressed as a percentage of main stem diameter at the same point. But this would involve climbing of all but the youngest trees and, if comparisons with neighbouring trees were to be made, they would also have to be climbed.

A simpler and quicker method in this case is to make subjective, ocular comparisons between the candidate tree and some of its neighours and to estimate its superiority by a scoring system; the higher the points scored, the greater the superiority of the candidate plus tree over its neighbours. The maximum number of points obtainable per trait varies according to trait and local experience, but one simple system is to use a scoring scale of 0-5 for every trait. Score 1 should be equal to the average of the neighbour trees, score 0 indicates that the candidate is inferior to that average, while scores 2-5 indicate increasing degrees of superiority.

The choice of the neighbour trees, with which the candidate plus tree is compared, is important. In accordance with a practice now used in many tree breeding programs, these should be the 5 largest dominants growing within a radius of about 25 m from the candidate tree. Since these check trees are growing close to the candidate, they are likely to have experienced approximately the same growing conditions. Since they are the largest neighbouring dominants, they should provide a rigorous standard of comparison.

Where measurements are available, as for DBH and height, they can be compared with the average of the corresponding measurements on the check trees and incorporated in the scoring system as follows:-

	Score
Candidate is less than average of check trees	**0**
Candidate approx. equal to the average of check trees	**1**
Candidate is 5-10% greater than the average of check trees	**2**
Candidate is 10-15% greater than the average of check trees	**3**
Candidate is 15-20% greater than the average of check trees	**4**
Candidate is > 20% greater than the average of check trees	**5**

Economic weighting

The advantage of using a standard scoring system of 0-5 for all traits is its simplicity in the field. Where it is felt that some traits are economically more important than others, e.g. stem volume and its components may be considered more important than branch or crown characteristics, it is easy to weight the scores appropriately, and this can be done in the office. In the example which follows differential weighting has been applied.

Example of candidate plus tree scoring

Most tree improvement programs will need to develop their own systems of plus tree selection, appropriate to their loca1 provenances, conditions and needs. The example which follows is a simple system which may be of use during the early stages of management of Provenance Seed Stands and Provenance Conservation Stands pending the development of better adapted local systems.

Trait	Range of possible scores	Maximum score	Economic weight	Maximum score after weighting
Stem diameter	0-5	5	x 4	20
Stem height	0-5	5	x 2	10
Total components stem volume				30
Stem straightness	0-5	5	x 4	20
Stem circularity (including freedom from swellings, buttresses etc.)	0-5	5	x 1	5
Total components stem form				25
Branch diameter	0-5	5	x 2	10
Branch angle	0-5	5	x 2	10
Total branching components				20
Crown depth	0-5	5	x 1	5
Crown width	0-5	5	x 1	5
Total crown components				10
Freedom from pests and diseases	0-5	5	x 3	15
Total				100

Notes:

(1) It is assumed that trees are too young for reproductive capacity or wood quality to be assessed. This would be the case in selecting candidate plus trees before first systematic Thinning in Provenance Conservation Stands. These traits would need to be assessed at a later age.

(2) For each trait score 1 is equal to the average of 5 neighbouring check trees, score 0 is inferior to it. Score 0 in more than two traits disqualifies the candidate tree from further consideration.

(3) In the case of stem diameter and stem height, scoring is based on measurements, as described before in the section "Measurement v. subjective scoring of traits". All other traits are scored on the basis of ocular and subjective comparisons with the average of the check trees.

(4) Maximum score of 5 is given in all cases to the best condition. Branch diameter score 5 refers to the smallest, possible branch-size in relation to stem. Branch angle score 5 refers to the best possible angle of 90° or smaller angles receiving lower scores. For crown components, the deepest possible and the narrowest possible crowns, in relation to stem size, receive score 5.

(5) Freedom from pests and diseases can only be judged in comparison with the check trees and, if necessary, with other neighbouring trees. If the stand as a whole is free from pests and diseases, there is no point in trying to score this trait and it should be omitted.

(6) In comparing a number of candidate plus trees within the same stand, preference should be given to those with the highest total (weighted) scores.

Marking of Plus Trees

Once plus trees have been selected they should be clearly marked as an insurance against accidental felling and to identify them easily for collection of genetic material. A double white paint ring should be used to mark candidate plus trees. When the initial selection has been confirmed by tree improvement staff and a tree is accepted as a Plus tree, a third ring of white paint should be added.

Appendix 2

PLOT METHODS OF TREE SELECTION AND THINNING

Introduction

The methods described below are appropriate for crops, particularly coniferous crops, which are being grown for production of sawlogs on a medium to long rotation and which need periodic thinning and pruning to promote rapid diameter growth and the production of clear knot-free wood. In fuelwood and pulpwood crops, which are normally grown on short, rotations without thinning, these methods have no place. For a fuller description of the methods, see Lang-Brown (1965), on which the present account is based.

The object is to provide methods for the early selection of the best trees in a plantation to be favoured in subsequent operations and for the selection of the poorer trees for thinning, which can be simply and safely applied by sub-professional staff after only a short period of training in the method. The use of small or medium-sized plots enables the prescribed numbers of stems per ha to be selected, while maintaining a uniform distribution and avoiding the creation of large gaps in the plantation.

In the early stages, small plots are used based on the number of original planting spots and the method depends on accurate spacing between and within row. This method is sometimes known as the Sudan Selection Method. After several thinnings have removed a substantial proportion of the crop, it becomes difficult to detect the original rows of trees; at that stage it is advisable to switch to area plots for the marking of the later thinnings.

Plots based on planting rows

The Sudan method based on planting rows should be applied before the first thinning. In a fast-growing conifer such as *Pinus patula* or *P. caribaea* planted on an average site and intensively managed, this would be at an age of 5-7 years and after whole-crop pruning to improve access.

The operator will be accompanied by one, two or three men each carrying a can of paint, distemper or other colouring matter and a brush with which to paint rings on select trees. On level ground, free of stumps, logs and undergrowth, a good operator can keep three paint men employed. The operator will find it convenient to carry a light stick with which to point out select trees to the paint men.

Small rectangular or square plots containing from 6 to 25 original planting spots are used. The full number of planting spots in the plot corresponds to the number of trees per ha originally planted, and the number of trees in the plot corresponding to a lower stocking to be selected as candidate seed trees, or for removal in thinning, can be calculated by simple proportion.

For example, if initial spacing is 2.5 x 2.5 m (1600/ha) and a plot of 16 planting spots is used, the number of trees marked in each plot is exactly one-hundredth of the number marked per ha. If the prescription is to select 200 superior stems per ha as candidate plus trees and 600 inferior stems per ha for thinning, then it will be necessary to paint-mark 2 stems in each plot and blaze the bark of 6 stems in each plot for thinning. Similarly, if it is desired to select as candidate plus trees 139 stems per ha in a plantation planted at 3 x 3 m (1111/ha) ; using a plot of 4 x 4 rows or 16 trees, the number to be selected per plot will be

$$\frac{16 \times 139}{1111} = 2$$

The attached table indicates the stocking (stems/ha) which corresponds to whole numbers of trees in a plot, for a few common plot sizes and initial espacements.

It is important to note that the plot size is based on the number of original planting spots, including blanks as well as surviving trees. The ideal size of plot wi1l depend on local conditions. Steep topography and underthinned crops or those with dense weed growth will reduce optimum plot size.

The use of the nearest whole number of trees in a plot introduces an element of inaccuracy but, as thinning prescriptions often allow for a range of stocking after thinning and so some latitude to the marker, this is not serious. If necessary, it can be overcome by marking different numbers of trees in alternate plots, e.g. by reference to the table it can be seen that, for a 16 tree plot in a 3 x 3 m plantation, a prescription to mark 380 stems/ha for thinning could be fulfilled by marking 5 and 6 trees in alternate plots.

Selection of trees for retention follows the usual criteria. No tree should be selected which has serious defects of form, injury or disease (e.g. crooked or leaning stem, double leaders, dead top, canker, excessively coarse or ascending branches, bark damage).0therwise preference should be given to the most vigorous trees, based primarily on diameter growth and secondarily on height growth.

In commercial plantations for wood production the marking of select trees is and aid to future management because:

(1) 0nly the select trees will be high-pruned. Selective high pruning ensures that the benefits of pruning are concentrated on the best stems wich will remain in the final crop or the later thinnings and that money is not wasted on pruning stems which will soon be removed in the early thinnings.

(2) Thinning, in addition to removal of obviously diseased, deformed, damaged or suppressed trees, should also be directed towards freeing the select, high-pruned trees from competition from nearby large unselect trees not high-pruned and for that reason temporarily more vigorous. Removal of the ”dangerous neighbour” should be one of the primary objectives in thinning. For this reason, though selection of superior trees for retention and marking of the first thinning may be carried out in the same operation, it is essential in each plot to mark the select trees first and decide which trees to thin afterwards.

In Provenance Seed Stands the ”dangerous neighbour” is less important than in commercial stands, since no high pruning is to be done on the trees selected as candidate seed trees. Nevertheless this Sudan method still has a useful role, since it, allows for the marking of some thinnings to be done by relatively unskilled field staff, provided that the initial selection of the best trees is performed by an experienced forester.

In the early thinnings, unselect trees should all be removed before any of the select trees. These thinnings may be marked by relatively inexperienced field staff and, even if some mistakes occur, the retention of the select trees as candidate seed trees will ensure high quality in the final seed stand. It is known that a certain proportion of trees may change their ranking during the course of a rotation (the best tree in the crop at 5 years may not always be the best at age 35), but it is thought that these effects are small in comparison with the advantages of the Sudan method in simplifying management by field staff. Only in the case of serious mechanical injury or disease appearing after the initial selection should a select tree be thinned in preference to an unselect one.

Espacement checks

Before carrying out the initial selection, it is advisable to check whether the actual horizontal planting espacement corresponds to the nominal espacement. Small discrepancies do not matter, but larger consistent differences, which may occur in steep topography if spacing was measured up and down the slope instead of horizontally, must be adjusted. The Sudan method depends for its success on the use of a reasonably accurate estimate of the true planting density in stems per (horizontal) ha.

Later thinnings

For later thinnings, it becomes difficult to base plots on planting rows, because so many of the trees have already been removed. It is then convenient to lay out a continuous series of square plots 20 x 20 m (l/25 ha) and mark the appropriate number of stems for thinning in each plot. If, for example, in a final thinning the prescription is to leave 150 trees per ha, then

$\frac{150}{25} =$ 6 trees in each plot should be retained and the remainder marked

for trimming. In steep topography adjustments will need to be made for slope, since the plots need to be 20 x 20 m in horizontal distance.

Table

Number of trees per plot and corresponding numbers per ha for initial espacements of 2 x 2 m, 2.5 x 2.5 m and 3 x 3 m.

Initial spacing			**2 x 2 m**	**2.5 x 2.5 m**	**3 x 3 m**
Initial stocking			**2500/ha**	**1600/ha**	**1111/ha**
Plot size (No. og planting spots)			**Corresponding stems/ha**	**Corresponding stems/ha**	**Corresponding stems/ha**
25	**20**	**16**			
25	20	16	2,500	1,600	1,111
	18		2,250	1,440	1,000
		14	2,187	1,400	972
20	16		2,000	1,280	889
		12	1,875	1,200	833
	14		1,750	1,120	778
		10	1,562	1,000	694
15	12		1,500	960	667
	10	8	1,250	800	556
10	8		1,000	640	444
		6	938	600	417
8			800	512	356
		5	781	500	347
	6		750	480	333
	5	4	625	400	278
6			600	384	267
5	4		500	320	222
		3	469	300	208
4			400	256	178
	3		375	240	167
		2	313	200	139
3			300	192	133
	2		250	160	111
2			200	128	89
		1	156	100	69
	1		125	80	56
1			100	64	44

Appendix I

GUIDELINES FOR A SYSTEMATIC THINNING REGIME [/1]

In Provenance Conservation Stands the thinning regime should be designed to maintain the diversity of the original gene pool of the *ex situ* stand throughout the life of the crop. To ensure a reduction in stocking without subjective bias requires the adopted regime to be systematic in nature. The simplest method of doing this is to remove whole rows of trees or a proportion of rows at intervals according to a predetermined pattern.

The regime suggested below is based on a simple spacing/dominant height ratio (after thinning) of 50 % whereby 50 % of the crop is removed at each of two thinnings. Two thinnings are expected to be sufficient for pines and the narrower crowned hardwoods such as eucalypts. For wide-crowned hardwoods a further thinning to remove 25 % of the crop is likely to be required and possibly a fourth thinning to remove one third of the residual. In crops planted at 3 x 3 m, the succession of stockings in stems/ha will be 1111 (when planted), 556, 278 (and possibly 208, 139). An explanatory diagram of the strictly systematic thinning method is attached.

In situations where the host country wishes to make early selection of superior phenotypes for an immediate local breeding programme, it will be necessary to make provision for some flexibility in the regime to cater for the retention of these trees where they occur in rows scheduled for removal. The easiest method is to treat them in isolation with their eight most immediate and surrounding neighbours, removing these competitors as follows:

Before Thinning			First Thinning			Second Thinning		
1	2	3	1	-	3	-	-	-
4	P	5	-	P	-	-	P	-
6	7	8	6	-	8	-	-	-

Remove trees no. 2, 4, 5 and 7 in the first thinning and no. 1, 3, 6 and 8 in the second thinning. Inevitably, this will affect the symmetry of the prescribed pattern of thinning in the immediate area, but this will only occur at the most at 10 locations per hectare and eventually the spatial maldistribution wil1 be reduced when the crop is older and thinning operations have ceased. In this connection it is recommended that plus trees should not be chosen within a radial distance of 12 metres of each other. Diagrams are attached showing how to combine thinning to free plus trees with systematic thinning in the remainder of the stand.

/1 Based on guidelines for management of conservation stands established under FA0/UNEP project No. ll08-75-05.

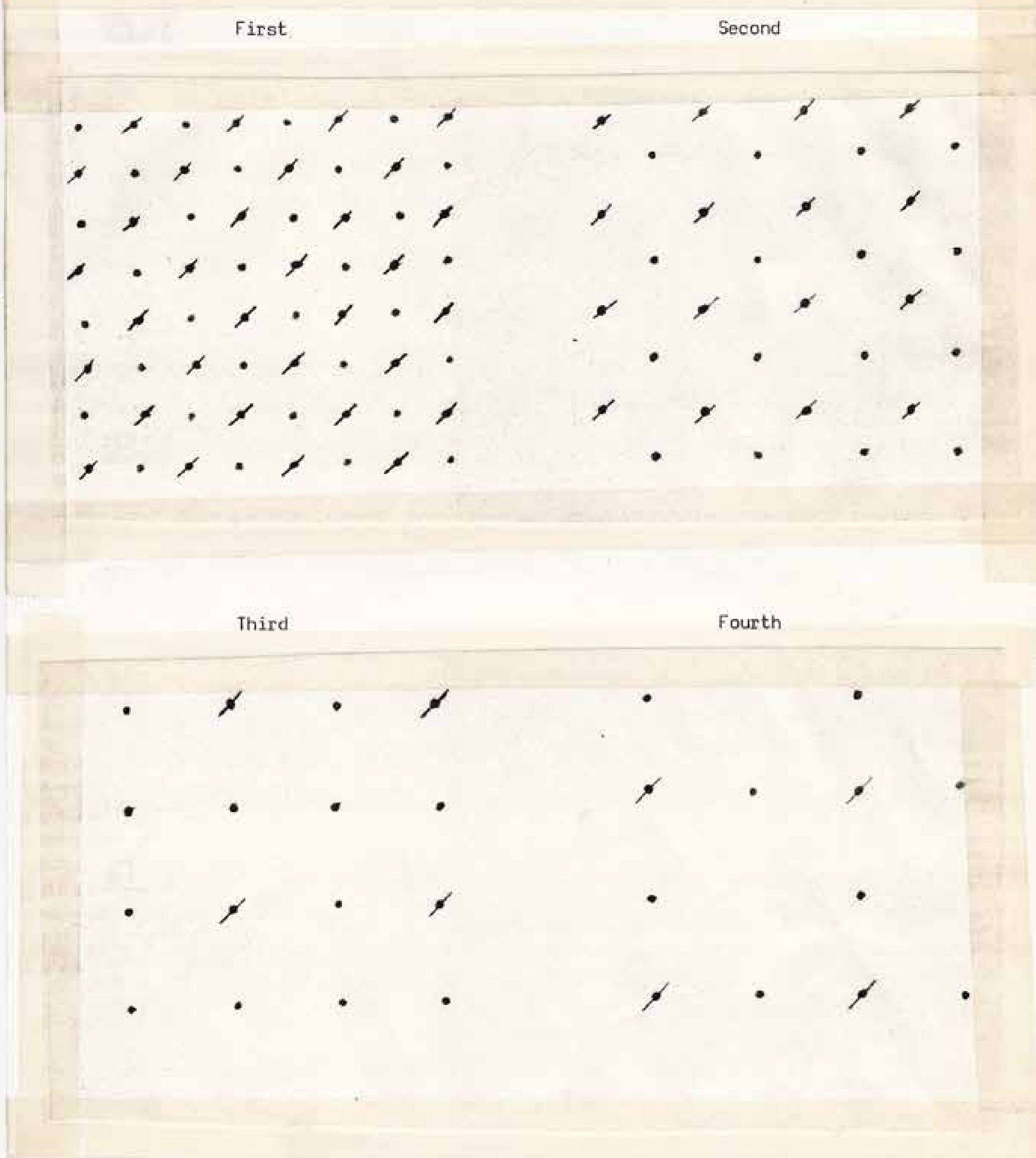
THINNING REGIME

Dominant height (metres)	**Thin to N**	**Mean square apaeing (metres)**	**Method**
(when planted)	1,111	3	-
8	556	4.2	Remove alternate diagonal rous retaining plus trees (PT§) uhere appropriate and removing 4 of the immediate I neighbours of each PT.
12	278		Remove alternate vertical ro\us; retain plus trees and remove remaining 4 of the I neighbours of each PT.
16	208		Remove every second tree in every seeond remaining diagonal rour; retain PTs..
18	139	8.5	Remove remaining trees in each of the previously partially thinned alternate diagonal rous; retain PTs.

N.B. 0n the occasion of each thinning, old stumps must be checked in order to identify rows and trees for removal clearly-marked, preferably by spot marking or slashing each tree in advance of the thinning operation.

DIAGRAM SHOWING SEQUENCE OF SYSTEMATIC THINNINGS

(with no plus trees)



PROVENANCE CONSERVATION STAND

First Thinning

P = plus tree

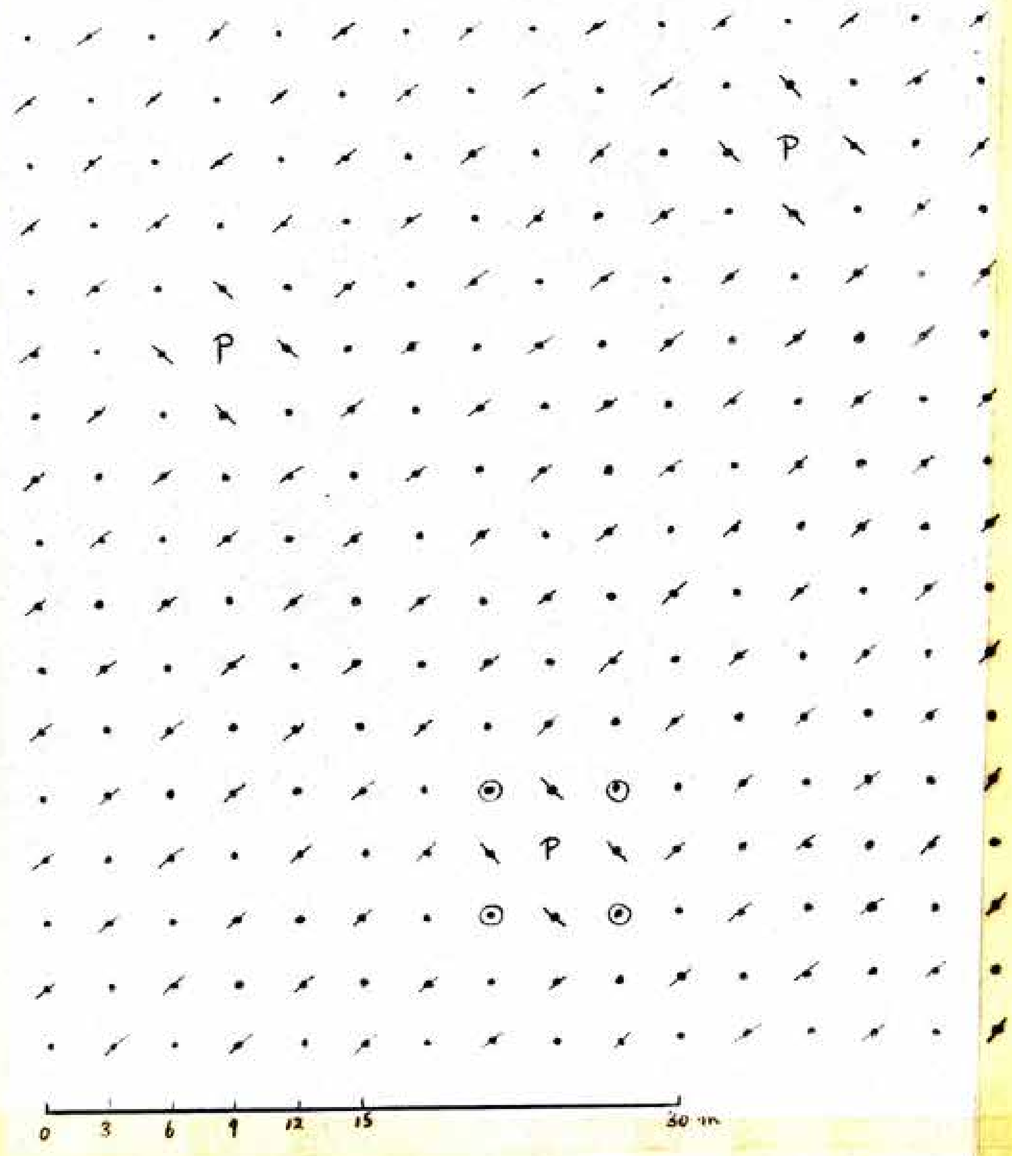
. = other trees (unthinned)

╲ = tree thinned to free plus tree

╱ = tree thinned in systematic thinning of alternate diagonals

⊙ = unthinned tree retained temporarily close to plus tree, although occurring in a thinned diagonal

Stocking after thinning = 560 stems/ha (cf. 556 stems/ha if no plus trees and strictly systematic thinning).



PROVENANCE CONSERVATION STAND

Second Thinning

P = plus tree

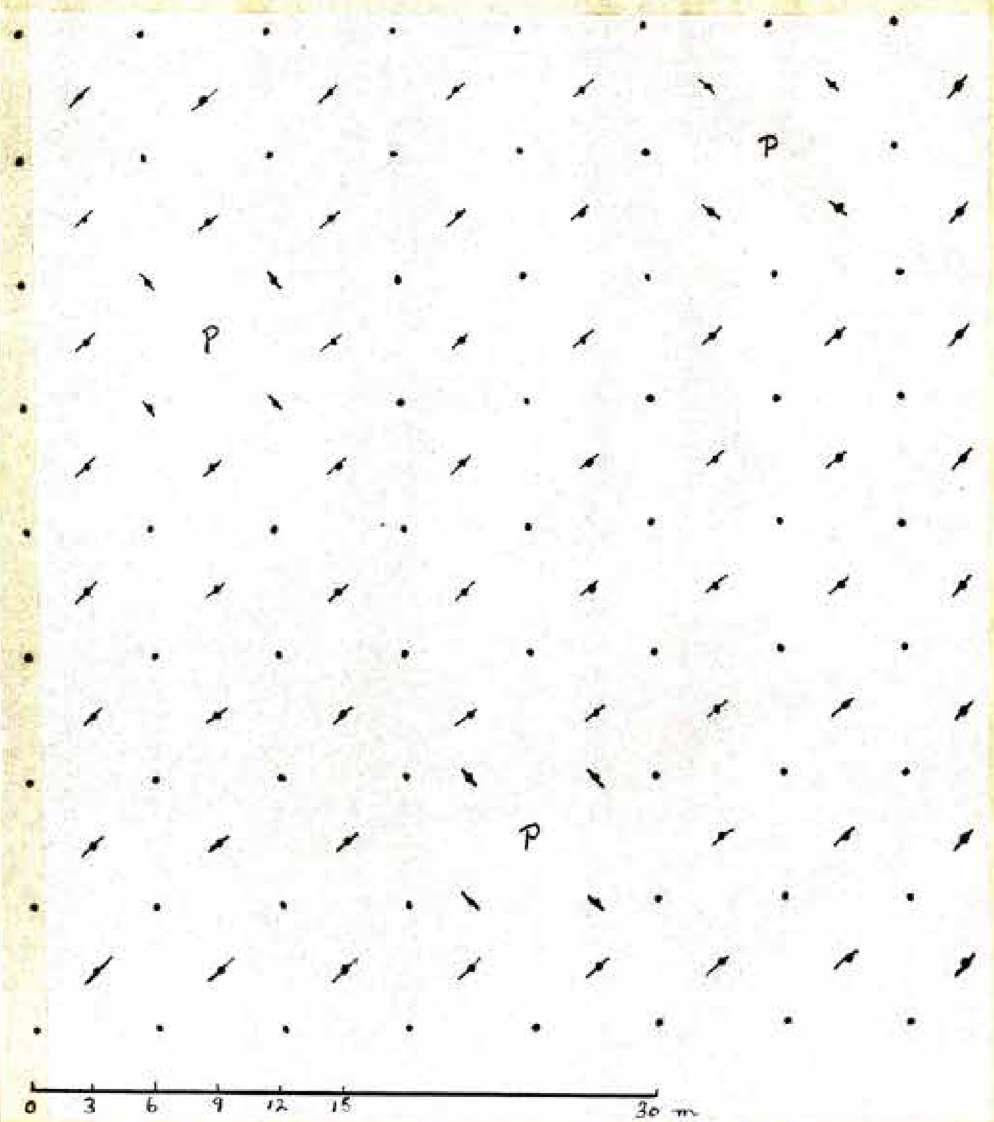
. = other trees (unthinned)

↘ = tree thinned to free plus tree

↗ = tree thinned in systematic thinning of alternate rows

Stocking after thinning = 260 stems/ha (cf. 278 stems /ha if no plus trees and strictly systematic thinning).

Two thinnings are expected to be sufficient for e.g. pines and eucalypts.



PROVENANCE CONSERVATION STAND

Third Thinning

P = plus tree

. = other trees (unthinned)

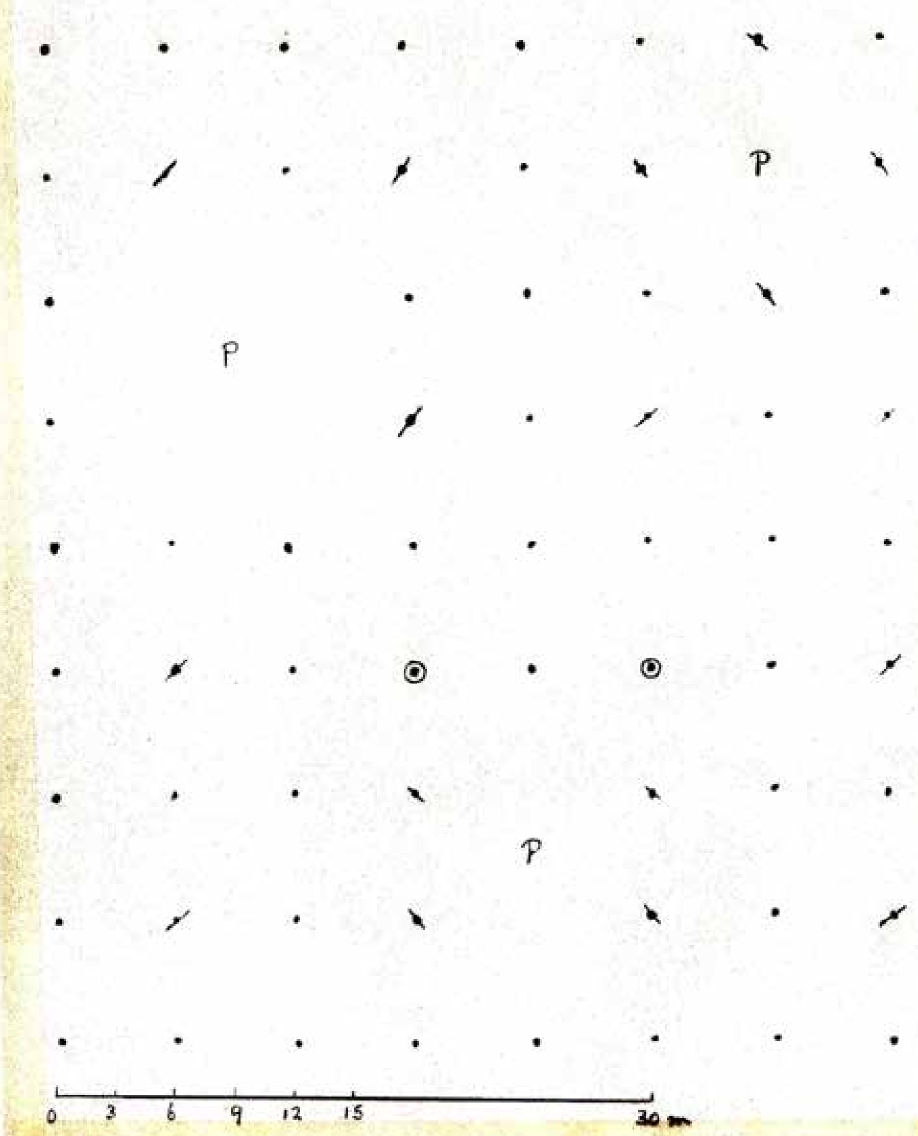
╲ = tree thinned to free plus tree

╱ = tree thinned in systematic thinning of alternate trees in alternate diagonals

⊙ = unthinned tree retained to avoid excessive gap near plus tree, although due to be thinned as part of systematic thinning

Stocking after thinning = 187 stems/ha (cf. 208 stems/ha if no plus trees and strictly systematic thinning)

Three or four thinnings are required for e.g. teak and Gmelina.



PROVENANCE CONSERVATION STAND

Fourth Thinning

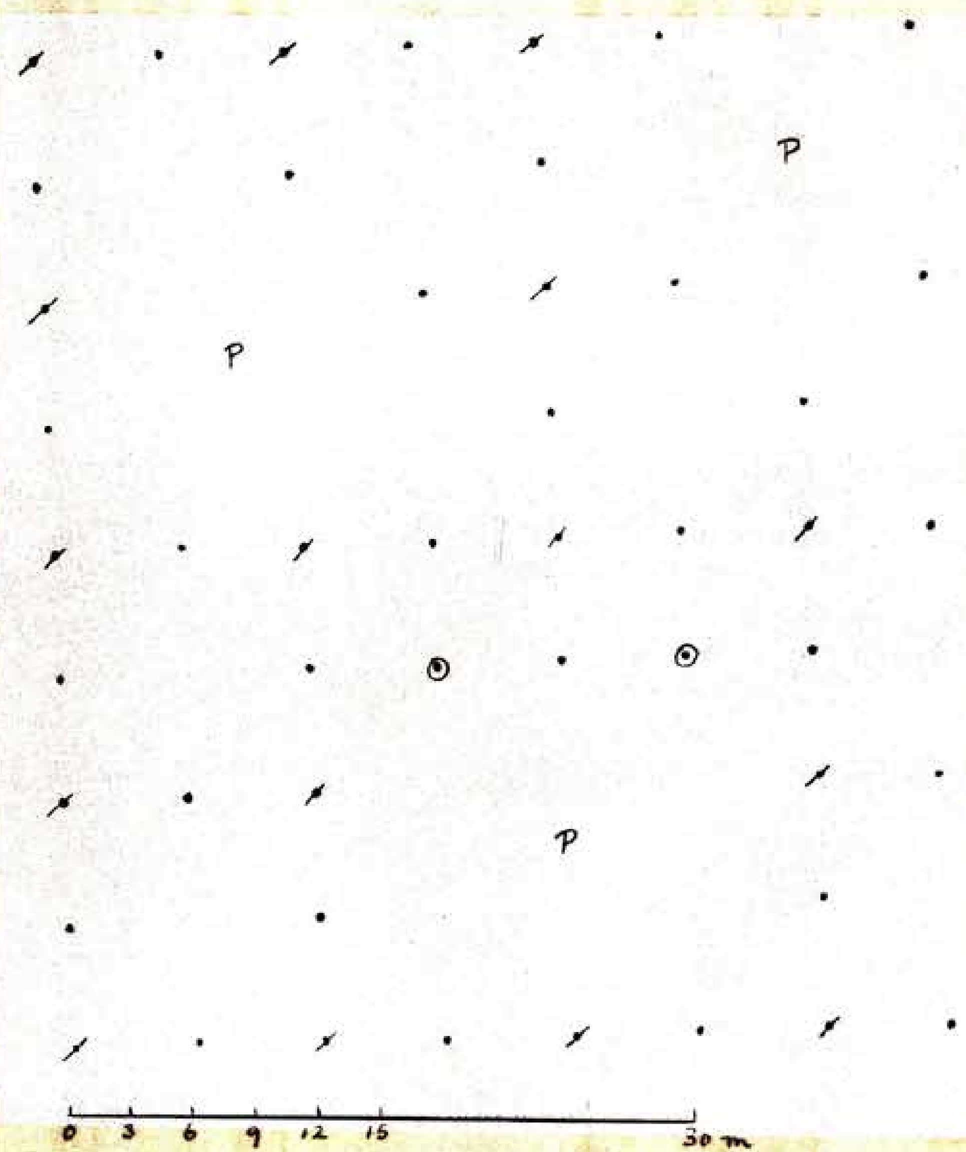
P = plus tree

. = other trees (unthinned)

/ = tree thinned in systematic thinning to complete removal of alternate diagonals

⊙ = unthinned tree retained to avoid excessive gap near plus tree, although due to be thinned as part of systematic thinning of alternate diagonals

Stocking after thinning 135 stems/ha (cf. 139 stems/ha if no plus trees and strictly systematic thinning).



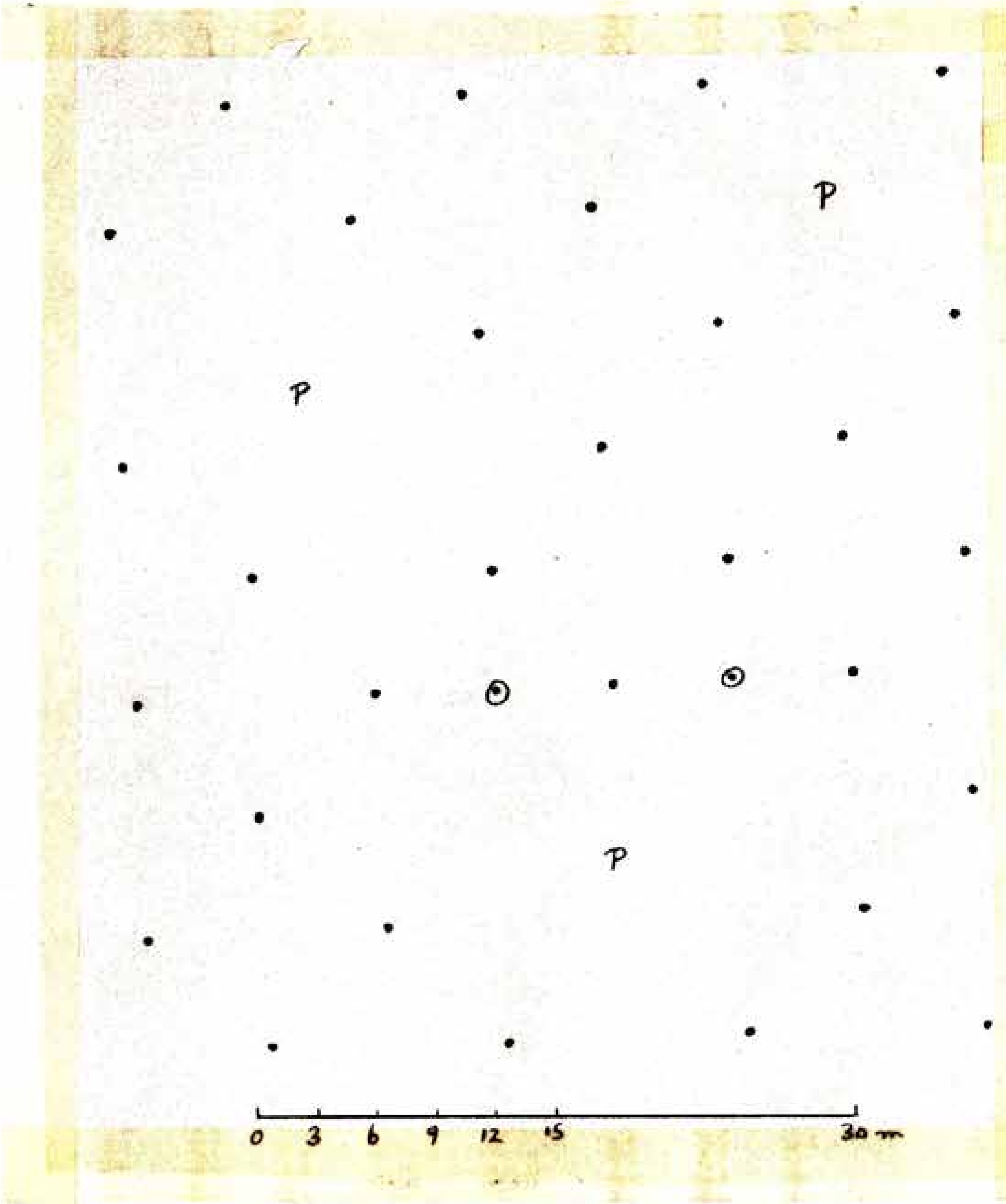
PROVENANCE CONSERVATION STAND

After Fourth Thinning

P = plus tree

. = other trees

⊙ = tree retained to avoid excessive gap near plus tree, although due to be thinned under systematic thinning regime.



Appendix 4

A
(front)

Provenance seed & gene conservation stand registration data

REGISTRATION

Seed reg.no., local .... DFSC ....
Stand reg.no., local .... DFSC ....
Purpose, conservation stand ...., seed stand ....
Species .... Provenance ....
(ref. seed collection data)

LOCALITY

Latitude .... Country ....
Longitude .... State/Province ....
Elevation (m) .... Region and forest admin. unit ....
Map reference ....
Detailed location (ref. sketchmap) ....
.... Block size (ha) ......

SITE

Topography ....Aspect ....
Soil type ....S-depth ....
Monthly rainfall distrib. (mm) J F M A M J J A S O N D
Temperature ^{o}C, mean ann. .... mean hottest month ....
Nearest weather station ....

ESTABLISHMENT

Land clearing method ....
Site preparation ....
....
Planting date(s) .... weather condition ....
" method .... spacing (m) ....
Supervisor .... Total n. of plants ....
Survival ....%/date........; ....%/date.......; ....%/date.........
Replacement ....plants; ....plants; ....plants.
Stocking after 3 years ....
Isolation species .... distance (m) to nearest contaminator ....
Fencing .... demarcation ....
Miscellaneous (e.g. fertilizer applied) ....
....
....

A

(back)

Sketchmap

ref. stand reg. no. ....

Provenance seed- & gene conservation stand registration data

MAINTENANCE

Year by year note details of actions: cultivation (mechanical/hand), weeding (mech./hand), fertilizer fertilizer application (type, dose), fireprotection, etc.	
Year	Activity

MANAGEMENT

Year by year note details of actions: pruning (stem/ha. p-height), thinning scheme (method, intensity) etc.	
Year	Activity

ref. stand reg. no. ....

Provenance seed & gene conservation stand registration data

FLOWERING AND SEED PRODUCTION

Year by year note details of: first noted appearance of flowers (female and male, (synchronisation of flowers, first cone setting producing viable seed, time for 25% production, 50% production and full production, annual production hereafter, controlled pollination, artificial flower induction etc.	
Year	Observation

DAMAGE

Year by year note details (extent, severety and treatment) of any damage caused by: climate (drought/flood), fire, cattle, pests (insects/fungi), diseases, man.	
Year	Observation