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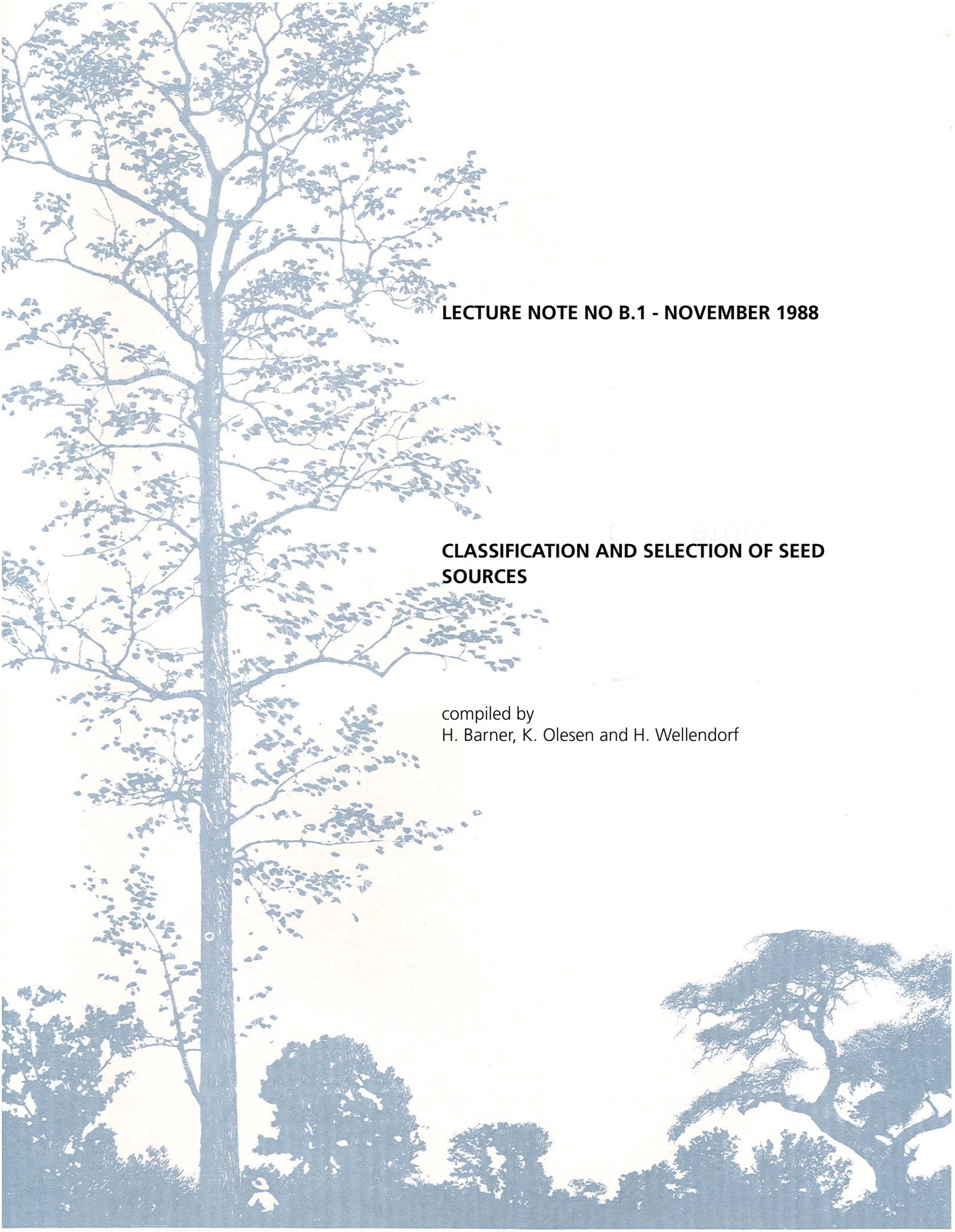

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CLASSIFICATION AND SELECTION OF SEED SOURCES

compiled by
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DANIDA FOREST SEED CENTRE

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1. INTRODUCTION

There is ample evidence in many countries that significant genetic differences exist between seed sources (Willan 1988). The choice of seed source may, therefore, be decisive for the success, mediocrity or failure of future plantings.

To avoid serious mistakes the consumer must know which seed sources are available, what they are selected for and to what extent they will match the planting site and the purpose of the planting programme. To facilitate the choice of seed source for meeting the requirements it will be useful if publications are available on the location of seed sources, the ecological conditions prevailing in the seed source areas and the criteria for selection of the seed sources.

Unfortunately there is some confusion on terminology and classification. This calls for the establishment of internationally recognised definitions and classifications of seed sources, which will be dealt with in this lecture. Other problems in connection with seed transfer and seed documentation will be dealt with in separate lectures.

The following categories of seed sources for collection of commercial quantities of seed will be defined and classified:

1. Seed collection zones
2. Identified stands
3. Selected stands
4. Seed production areas
5. Provenance seed stands
6. Seed orchards

The following criteria for classification and selection of seed sources will be presented:

Collection units and mixing of seed lots.
Development and composition.
Geographic history: location, origin and provenance.
Genetic history: selection, breeding and testing.
Seed documentation.

These criteria for classification of categories of seed sources are outlined in Appendix 1.

An increasing degree of selection and information is found from seed source category 1 to 6. However, this does not imply that seeds from the most advanced and well described sources will give the highest yield in a new environment where the seed source has not yet been tested.

2. PRINCIPLES IN SEED-SOURCE CLASSIFICATION

In this section the above mentioned five criteria for classification of seed sources will be discussed.

2.1 Collection units and mixing of seed lots

A seed lot may be derived from collections on one single tree or - to go to the other extreme - from collections over a wide forest area with significant variations in ecological conditions and races.

Ideally a seed-collection unit should be delimited so that it is (i) composed of a community of interbreeding trees of common origin, (ii) growing on sites where the prevailing ecological conditions are more uniform within each unit than between different units, (iii) sufficiently large for collections of seed in commercial quantities and (iv) defined by boundaries which can be identified in the field (Barner, 1975 1). For most purposes a seed zone denotes the maximum geographic limits of a collection unit. Smaller units, each of which could be included within a seed zone, are different categories of stands, seed orchards and single trees.

Seeds from each collection unit within a seed zone can be kept separate or mixed with seed from other collection units within the same zone and category, before or after processing. One of the purposes of classifying seed sources is the wish to keep seed from different seed sources separate in order to be able to trace the ancestors of future plantings. In many cases it is not possible or necessary to keep seed lots separate, but it should be kept in mind that (1) the more precisely one wants to trace the ancestors of future plantings the more important it is to keep seed lots separate, (2) the more the genetic composition of seed lots differ the greater the importance of keeping them separate, and (3) the more the ecological conditions of future planting site and those of the collection unit differ the more important it is to keep trace of the seed source. Mixing of seed from different seed orchards is not recommended.

2.2 Development and composition

The following factors should be considered:

A seed source must consist of trees of such an age and development that adaptation and other criteria for selection can be clearly judged.

A seed source must consist of well-distributed and sufficiently numerous trees on a given area making possible adequate inter- pollination so as to avoid increased risk of future inbreeding.

Selection criteria should be limited to a few phenotypic important traits esti-

mated to have a relatively high heritability (the ability of the parents to transmit their characteristics to the progeny).

In a survey on selection of seed stands the items (i-iii) are the first to be checked. If the stands fulfil most of the above requirements the subjects covered in the following must be considered.

2.3 Geographic history

Geographic history deals with the location (provenance) of the stands used for seed collections and the origin of these stands (Jones and Burley 1973).

Natural stands have been adapted to the environment over generations, whereas the local adaptation of a stand of introduced species, especially in its first generation, is much less certain. The main discussion is therefore between seed collected in a natural stand and in a stand established outside its natural environment. To keep these two cases separate it is important to define and distinguish between the concepts, origin and provenance.

According to the OECD Scheme for the Control of Forest Reproductive Material Moving in International Trade (OECD, 1974) the definitions are:

Origin: For an indigenous (natural) stand the origin is the place in which the trees are growing. For a non-indigenous (introduced) stand the origin is the place (in the natural forest) from which the seed or plants were originally introduced.

Provenance (location of the seed source): The place in which any stand of trees is growing. The stand may be indigenous (natural provenance) or non-indigenous (derived provenance).

Although these definitions have been accepted by a number of countries adhering to the OECD Scheme, they are not entirely satisfactory, since they refer only to the origin or provenance of "trees", not of "seeds". It is necessary to insert a reference to "parents".

Common sense suggests **that the provenance of seeds is the place where the parents were growing** not the place where the seeds happen to be.

The following definitions are therefore suggested:

> **Provenance**. The geographic location of the immediate parents of the seeds, plants or trees in question.
>
> **Origin**. Indigenous (natural) seed sources: for stands and seeds of such stands, origin is identical with provenance.
>
> **Non-indigenous (introduced) seed sources**: for stands of first generation developed from introduced seeds or plant material, origin is identical with

provenance. For seeds harvested from trees of first generation and for stands and seeds of subsequent generations, origin is the geographic location of the ancestors in the natural forest from which the seeds or plants in question have descended.

The concepts are illustrated in Table 1.

Table 1. *Pinus caribaea*

	Origin	**Provenance**
Natural stand, Belize		
Mountain Pine Ridge	Mountain Pine Ridge	Mountain Pine Ridge
Introduced to Australia		
Queensland, Byfield = 1st generation 2nd generation = seed collected in Byfield	 Mountain Pine Ridge Mountain Pine Ridge	 Mountain Pine Ridge Byfield, Queensland
Introduced to Thailand from Byfield		
Hue Bong, N. Thailand = 1st generation 2nd generation = seed collected in Hue Bong	Mountain Pine Ridge Mountain Pine Ridge	Byfield, Queensland Hue Bong, N. Thailand

The location of the seed source must be described, the boundaries of the source should be identified and preferably demarcated in the field. It is very important to keep trace of information on the provenances used for plantations. This allows for ordering more seed to repeat successful plantations or to avoid ordering more seed from sources which have been failures. Unfortunately, information on the provenance of the seed source used is often lacking.

Information on the origin of introduced seed sources is even more difficult to provide. In default of information on origin careful estimation of the adaptability, as judged by survival, health, growth and reproductive ability of the stand must be carried out. It should be noted that with increasing numbers of generations of natural and artificial selection in plantations in new environments, the genetic history (see below) of the stands may be of more importance than the origin.

2.4 Genetic history

Genetic history concerns population size and structure, contamination from foreign pollen and the natural and artificial selection to which the natural stand and subsequent plantations have been subjected (Jones and Burley, 1973).

The following should be investigated:

I. natural and artificial selection and mating patterns.

II. number and kind of parents represented in the seed source and in the seed collected in that source.

III. isolation of the stand from contaminating pollen from outside sources.

IV. results of provenance testing of the seed source in question.

(i) Natural and artificial selection and mating patterns. The main division is between seed collected in a natural stand and in a plantation. In natural stands, particularly in species with limited pollen and seed dispersal, neighbouring trees tend to be related. The populations may be subdivided into neighbourhoods with mutual inter-breeding between related individuals (Falconer, 1967). See Fig. 1. In contrast to this, in plantations established from bulked seed, the neighbourhoods are broken up already from the first generation and therefore seed harvested from plantations are progenies from crossings between unrelated individuals, or selfings.

If the described difference in population structure between natural stands and plantations is pronounced, the progeny from the natural stands will have a degree of inbreeding, regardless of the number of trees collected from. This inbreeding will not occur in progenies from plantations. For a stand planted in a new environment the selection factors or management are different from those of the natural forests, creating changes in gene frequencies of the stand. See Fig.1. For instance the natural selection for adaptation may be particularly severe in the establishment phase of large-scale plantations as compared to natural regeneration.

(ii) Parent trees represented. Seed from a stand may be collected from one, a few or many mother trees. If a great amount of seed can be collected from a few trees, such as in Eucalypts, there is a risk that stands derived from such seed will have a very narrow genetic base. This implies an extra risk in survival of future generations and decreases the possibilities of selection for future breeding programmes.

Due to these considerations it is desirable that for seeds for research and tree improvement purposes it is stated how many trees are represented in the seed collected, approximate distance between the trees and whether the trees were superior, equal or inferior to the adjacent trees.

(iii) Isolation from outside pollen sources. Most authors stress the importance of providing some degree of isolation from foreign pollen sources, at least from inferior pollen sources or from hybridising species. Complete isolation is impossible in most cases. In Finland a maximum contamination of 20% foreign pollen has been accepted for Pinus sylvestres (Koski 1973). This implies 10% foreign genes influencing the offspring as the mother trees are part of the desirable seed source. The percentage of contamination

may be reduced by increasing the distance between the seed source and the undesirable sources of pollen, e.g. by clear-felling the undesirable sources, by imposing a physical barrier such as planting isolation strips of a different species or, in larger seed sources, by collecting the seed furthest away from the contaminating pollen source.

Where there is a risk of contaminating foreign pollen, it is important that the pollen production in the seed source has been prolific in years when seed is collected, the selected stand has a minimum size of not less than 3-5 ha and seed is not harvested on trees near the border of the stand.

(iv) Results of provenance testing. Provenance research aims at defining the genetic and environmental components of phenotypic variability of stands from different geographic locations (Callaham 1964). The most obvious and important use of provenance research is to identify sources of seed that will give well-adapted, productive trees for afforestation and reforestation on a given site. Only results of comprehensive provenance trials on well-sampled sites can provide a safe basis for choice of seed source. Such trials are in progress in many countries. They should reveal the extent and pattern of variations in the species under trial. Provenance research will be dealt with in detail in lectures on Tree Improvement.

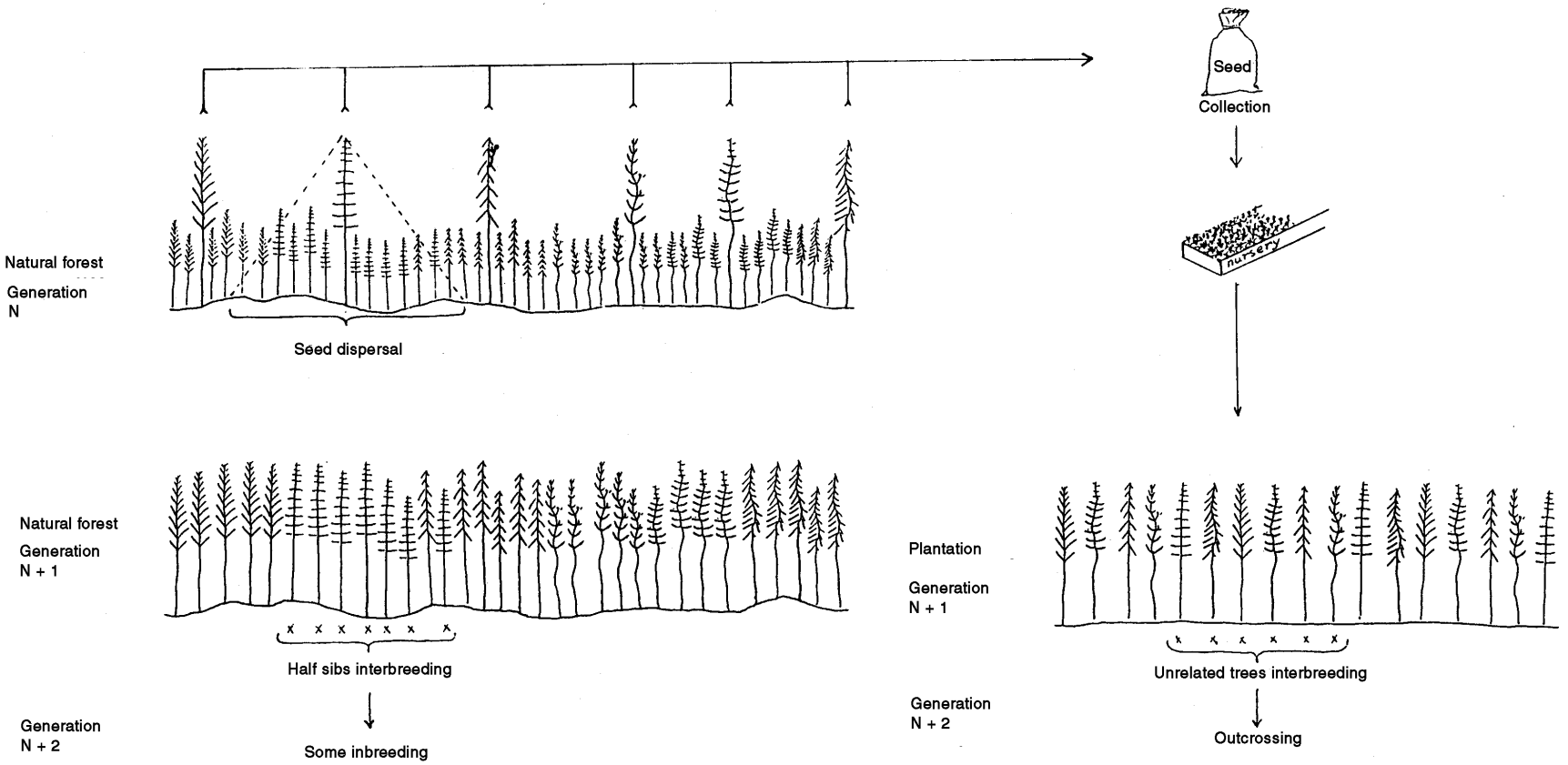
In some cases provenance research results may not be available for the species in question. In such cases the use of local and well-adapted seed sources is recommended. In other cases where results are available, tests may not have been conducted in environments similar to the major site types relevant for the actual planting programme. If this is the case, the choice of seed source will depend on the particular species' response to varying environments, i.e. whether the provenance environment interactions are pronounced. With pronounced interactions the provenance ranking will differ on new and contrasting sites.

The user could classify seed sources that have been under test according to whether the tests were conducted in environments similar to the planting area or not and whether the sources were superior to the accepted standard in desirable specified traits.

2.5 Seed documentation

Seed documentation provides information on species, varieties, geographic and genetic history of the seed source, year of ripening of the seed collected and seed lot number etc. Seed certification schemes are superstructures ensuring that the information provided is unequivocal and formally attested by a designated authority. This item will be dealt with in the lecture note on Control Measures in Transfer of Forest Seeds.

Figure 1


Natural forest
Generation
N
Seed dispersal
Seed
Collection
nursery
Natural forest
Generation
N + 1
Half sibs interbreeding
Generation
N + 2
Some inbreeding
Plantation
Generation
N + 1
Unrelated trees interbreeding
Generation
N + 2
Outcrossing

3. SEED COLLECTION ZONES

3.1 Definitions

Ideally a seed collection zone should be defined in such a way that it fulfils the requirements set out under 2.1, page 2. In practise however it is not possible to fulfil all of these requirements. The following definition is a compromise adapted by the OECD Scheme for the Control of Forest Reproductive Material Moving in International Trade (OECD, 1974).

A seed zone (also called a region of provenance) for a species is defined as the area or groups of areas subject to sufficiently uniform ecological conditions on which are found stands showing similar phenotypic or genetic characters (OECD, 1974).

3.2 Characteristics

3.2.1 Collection unit

The collection unit is a seed collection zone. In mountainous areas where the ecological conditions vary with elevation and slope direction, each zone should be subdivided into subzones or elevation belts, for instance with 300-500 m intervals. The boundaries of each zone should be described and identified, but are usually not demarcated in the field.

A seed-zoning system should provide:

I. information on seed sources available and on the ecological conditions prevailing in each zone.
II. information on the maximum geographic limits for the zone and its subzone or elevation belt.
III. guidelines for transfer of seed and planting material.
IV. guidelines for sampling of seed and location of test areas for testing provenances or progenies (offspring from single trees).

Within each zone and elevation belt, all kinds of stands can be used for seed collection and the seed is bulked. Areas where collections actually take place may vary from year to year. The collections are not limited to superior stands, but more by access and abundance of seed.

3.2.2 Development and composition

The seed zone system was intended for natural forests. The system must be used with great care if applied to plantation forests with introduced provenances of different origin.

In natural forests adaptation to the local environment is taken for granted. In case of introduced stands the degree of adaptation is often an open question and must be judged by survival, health, growth and reproduction.

3.2.3 Geographic history

Zone and elevation give the location of each seed collection unit only. The origin should be indicated as applicable but may be difficult to ascertain for introduced stands.

3.2.4 Genetic history

The genetic history is not checked. Provenance testing should not be established with seed collected in a zone as such but with seed from properly sampled and well-identified stands within the zones.

3.2.5 Seed documentation

Information should be provided about seed zone and, where applicable, elevation belts. Origin should be indicated as indigenous (natural), non-indigenous, if possible name of origin for introduced stands, or unknown. Year of ripening of seed collected should be provided. If a seed-certification scheme is in operation, the information available should be attested by the certifying agency.

For summing-up of 3.1 to 3.2.5, see Appendix 1.

3.3 Delimitation of seed zones

Wherever a tree species has a natural distribution within which environmental conditions vary, it will probably show genetic variation associated with site variation, due to the process of natural selection and migration. Each site will tend to have the individuals of a genetic makeup, or genotype, that are best able to regenerate and perpetuate themselves under the conditions prevailing, whereas the genotypes not well-adapted to that particular site will tend to die out.

This environmental effect acts through natural selection on the genotypes of a population of individuals over many generations, and is distinct from the modifying effect that the environment also has on the expression of the genotype of an individual during its lifetime.

The degree of genetic variation resulting from natural selection will depend on 1) the mating system of the species, 2) the degree of environmental variation, and 3) to what extent stands are isolated from one another (Robbins and Hughes, 1983).

If the variation between provenances is to be taken into account effectively, **the best approach is to study the natural distribution of the species in terms of the 3 factors mentioned, and attempt to delineate zones within which the genetic variation for important characters are less than between zones.**

The real problem in delimiting seed zones is in trying to fit a system of large discrete units and clearly defined boundaries, which would be operationally most convenient to the pattern of natural variation. A typical feature of many tree species is a continuous distribution over a broad range of climates. As components of climate normally vary gradually for instance with latitude, elevation and direction of slope, the resulting genetic variation of adaptation will be mostly clinal

(continuous) but in some cases complex and small scale (ecotypic) (Barner and Willan, 1983). Results from comprehensive provenance trials on replicated sites may adjust initial delineations of seed zones. Such trials are in progress in some countries but are still rare.

A survey of the ecological conditions must be based either on information on climatic factors like precipitation, temperature and physiographic structure or on plant-geographic description of the most important vegetation types of forest trees and the variation in physiognomy and composition of the dominant species or even better on a combination of both.

Information on climate is important, but there are particularly two things that restrict the applicability. Firstly, meteorological stations are often missing in the areas that are of greatest interest to afforestation. Secondly, it is difficult to know how to "weight" the different climatic factors that may be available. See Lecture Note on Matching Seed Source and Planting Site.

Plant-geographic units such as forest regions or forest types can often be used as the basis for a division into seed zones. As guidelines for the procedure of zone delineation the following main points can be stated:

I. Remember that a seed zone denotes a much narrower ecological area than a forest region or section.
II. Use maps of forest regions and sections or similar classification systems as a framework.
III. Decide which of the species occurring should come under the scheme.
IV. Procure maps of the distribution of these species. Aerial photography may be used.
V. Utilize available information on racial pattern, interaction with planting site and environmental factors.
VI. Estimate whether significant differences in racial variation and adaptation may be expected in and between the species.
VII. Decide whether one system of seed zones should be used for all species.
VIII. Superimpose map of species distribution on map of forest regions and sections. Delineate seed zones by using geographic landmarks as boundaries for the most important forest areas suited for procurement of forest reproductive material.
IX. Establish and print maps of seed zones with code numbers and a brief description of the prevailing ecological conditions in the zones.

In Appendix 2 an outline is given of the procedures applied in Honduras for establishing seed zones (provenance regions) in *Pinus caribaea* and *Pinus oocarpa* (Robbins and Hughes, 1983).

4. IDENTIFIED STANDS

4.1 Definition

An identified stand is any stand of average quality, occasionally used for seed collection, for which the location can be precisely described see Fig. 2. It is obvious that the use of a stand within a seed collection zone as a collection unit will facilitate the identification of the seed source actually used. Therefore, identification and demarcation of stands within seed collection zones denote a refinement of the zoning system providing information on where seed was actually collected.

4.2 Characteristics

4.2.1 Collection unit

The collection unit is a single identified stand. The stands may be found in either natural forests or plantations. For several identified stands within one seed zone and elevation belt, seeds from natural stands or from introduced stands of common origin may be mixed, but it is preferable to keep them separate in most cases.

4.2.2 Development and composition

The identified stands have been established or managed for other purposes than seed production. The adaptability may have been checked. The stands must be old enough to bear substantial seed crops, but are only occasionally used for seed collection. The appearance of a stand very often equals the average standard within the zone.

4.2.3 Geographic history

The location of the seed source must be described and the boundaries should be identifiable, but not demarcated in the field. For plantations information on origin is normally not available.

4.2.4 Genetic history

Information about genetic history, including the risk of contaminating pollen from foreign sources, is not requisite.

The great advantage of seed from a particular identified stand, represented in evaluated provenance tests, is that it is possible to return to successful identified stands for large-scale seed collections.

4.2.5 Seed documentation

Information should be provided about the seed collection zone and, where applicable, elevation belts. The location of the stand must be described precisely enough to identify the stand and its boundaries. Origin should, if possible, be stated. If no information is available, the origin should be classified as unknown. Year of ripening of the seed collected should be provided.

If a seed certification scheme is in operation covering identified stands, the information available should be attested by the certifying agency.

For summing-up of 4.1-4.2.5 see Appendix 1.

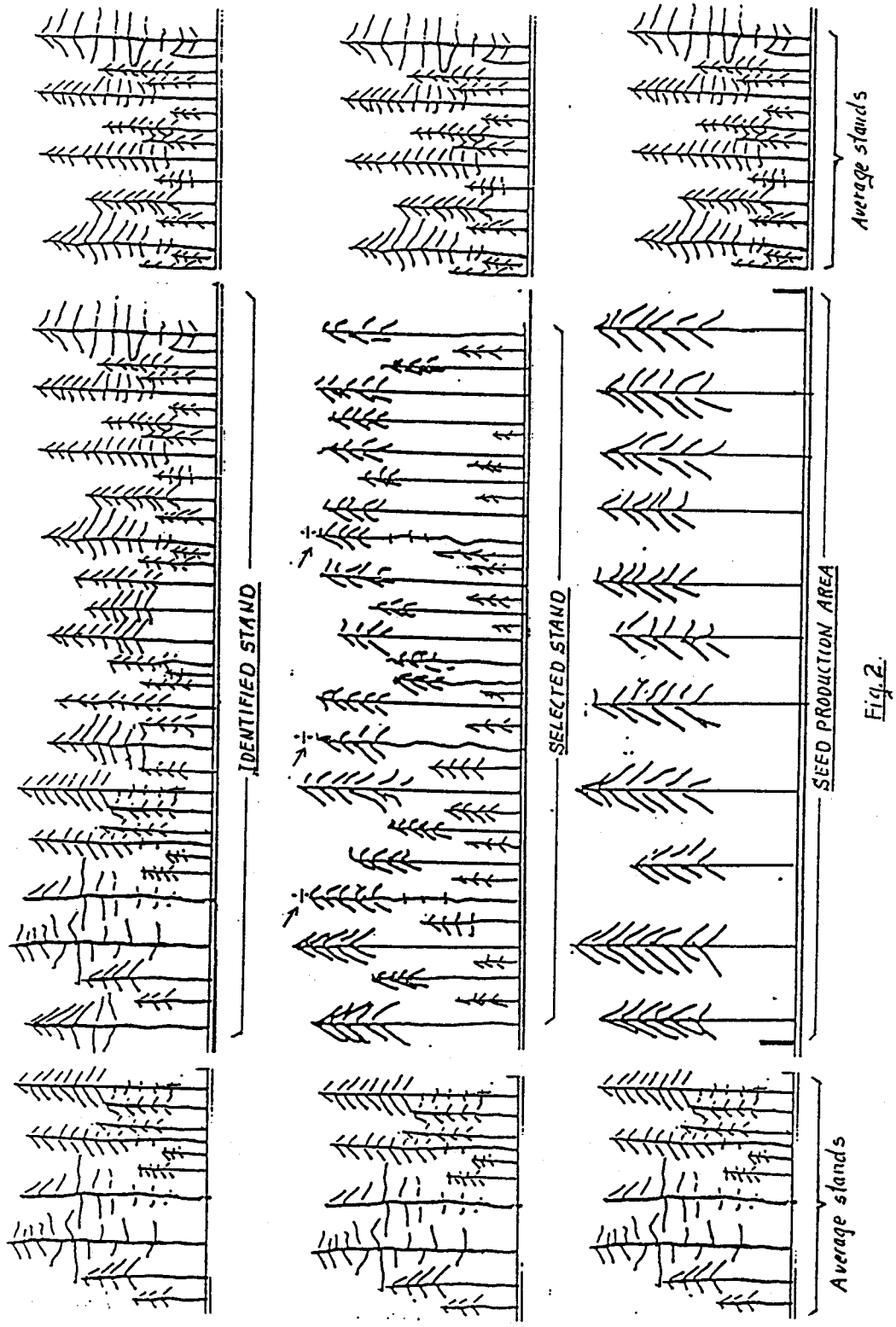


Figure 2.

5. SELECTED STANDS

5.1 Definition

A selected stand is a stand of trees superior to the accepted mean for the prevailing ecological conditions when judged by the selection criteria (OECD, (1974), see Fig 2, page 13.

The stands may be selected in either natural forests or plantations. The stands are selected because of their phenotypic superiority in specified important traits. Where necessary the approval would be dependent on the removal of inferior trees which should be few. It is important to select stands in which there is likely to be a significant genetic component in the phenotypic superiority, for instance, a stand should not be selected solely because it is growing well on an exceptionally good site. The selection should be made in areas where the ecological conditions are similar to the potential planting sites.

5.2 Characteristics

5.2.1 Collection unit

The collection unit is a single, selected stand. In case of shortage of seed, seeds from selected natural stands or from introduced selected stands of common origin may be mixed within each zone and elevation belt, but in most cases it is preferable to keep them separate.

5.2.2 Development and composition

The stands have been established or managed for other purposes than seed production. Upon approval of the stands for seed production, selective thinnings may be applied, but this is not requisite, except for removal of a few extremely inferior trees. Where applicable, the stands may be kept as seed sources beyond the normal rotation age. The stands must consist of trees well distributed and sufficiently numerous to make possible adequate inter-pollination. The stands must be of such an age and development that adaptability and the criteria for selection can be clearly judged. The stands must be bearing, or be about to bear, substantial seed crops. Stands which are too young for seed bearing should be kept on record as candidate stands.

Selection criteria should be limited to a few important traits. In many countries in the temperate zone the following minimum requirements used by the OECD Scheme for the Control of Forest Reproductive Material (OECD, 1974) are recognised:

Uniformity: The stands must show a normal degree of individual variation in morphological characters.

Volume production: Volume production of wood is normally an essential

criterion for the acceptance of selected stands. Volume production of wood must normally be superior to the accepted mean under similar ecological conditions.

Wood Quality: The quality of wood shall be taken into account and, in some cases, may become an essential criterion.

Form or Growth Habit: The trees in selected stands must show particularly good morphological features, especially straightness and circularity of stem, favourable branching habit, small size of branches and good natural pruning. In addition, the proportion of forked trees and those showing spiral grain should be low.

Health and Resistance: The trees in selected stands must in general be free from attack by damaging organisms and show resistance to adverse conditions of climate and site in the place where they are growing.

The above requirements are very general and have to be specified for each species. Further it must be taken into account that volume production has a low heritability.

5.2.3 Geographic history

The location of the seed source must be described and the boundaries must be easily identifiable in the field, where necessary by demarcation. As regards origin, it must be carefully checked whether the stands are of local origin or introduced. For introduced stands information on the origin should, if possible, be stated. Very often the information on origin is lacking. In such cases efforts should be concentrated on the adaptability to the local environment as judged by survival, health, growth and reproducibility. Only well-adapted stands should be approved.

5.2.4 Genetic history must be carefully checked

Above all it is important to study the artificial selection to which the stands have been subjected and to clarify whether the stand had derived from a seed lot representing a few parent trees only or from a larger population. Measures must be taken to reduce the risk of contaminating pollen from foreign sources. Where isolation is difficult, a minimum size of 3-5 ha of the stand may be recommended and seed should not be collected along the borderline of the selected stand. Last but not least it should be checked whether some of the stands selected are represented in provenance trials. If the trials are evaluated, the provenance tests may give valuable information - positive or negative - of the performance of the offspring in specified environments.

5.2.5 Seed documentation

Information should be provided about the seed collection zone and where applicable, elevation belt. The location of the stand must be described precisely enough to identify the stand and its boundaries. Origin should, if possible, be stated. If no information is available, the origin should be classified as unknown. Information should be provided about criteria for selection and genetic history.

The above information should be available in published lists of selected stands. Year of ripening of the seed collected should be provided.

If a seed certification scheme is in operation covering identified stands, the information available should be attested by the certifying agency.

6. SEED PRODUCTION AREAS (= SEED STANDS)

6.1 Definition

A seed production area is a plus stand (i.e. selected stand) that is generally upgraded and opened by removal of undesirable trees and then cultured for early and abundant seed production (Snyder, 1972), see Fig. 2 and Appendix 3. The stands have shown outstanding performance and are converted to seed production areas with emphasis on seed production only.

6.2 Characteristics

6.2.1 Collection unit
The collection unit is a single seed production area and the seed from each stand should be kept separate. The stands may be selected in natural forests or plantations.

6.2.2 Development and composition
The stands have usually been established for other purposes than seed production.

In USA the following requirements and treatments are recommended for Southern Pines:

The stand must initially contain a sufficient number of trees of the desired species to permit rigorous selection of trees to be retained for seed production. The stand must be of sufficient age and diameter for reliable crop tree determination. Stands shall not have been previously thinned, except where it can be shown that thinning was from below or from the co-dominants of poor quality, for the species to be used in seed production.

All trees infected with diseases of economic importance to timber production shall be removed from the area. Trees of below average vigour (based on the dominant and co-dominant trees in the original stand) and trees having undesirable form characteristics as specified for the species and end use will be removed.

Only trees of average or above vigour and form and average or below in branch size and free from pests shall remain. Minimum requirements are ten trees per acre to minimise selfing and maximise cross-pollination.

It appears from the above that a seed production area, when selected and especially after thinning, is of a higher phenotypic standard than a selected stand, see Fig. 2.

6.2.3 Geographic history, see 5.2.3 selected stands.

6.2.4 Genetic history, see 5.2.4 selected stands.
The treatments applied must be recorded. As regards isolation the following requirements are set out for Southern Pines:

The area shall be free of contaminating pollen. An isolation strip shall be maintained. A strip 400 feet wide adjacent to the seed production area shall be free of all species of trees which will normally cross-pollinate naturally with the species of the production area, except that this strip may contain trees of the same species providing that it meets the standards of rouging and stand composition of the production area.

The requirements for isolation from contaminating pollen will be difficult to fulfil.

6.2.5 Seed documentation, see 5.2.5 selected stands.

For summing-up of 6.1-6.2.5, see Appendix 1.

7. PROVENANCE SEED STANDS

7.1 Definition

A provenance seed stand is a stand of known provenance which is under test or already tested and found superior (Willan, 1984), see Appendix 4.

The provenance seed stand is equivalent to the "Provenance Resource Stand" used in Queensland for *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."

As stated by Willan (1984) the provenance seed stand differs from the seed production area in several ways:

The primary purpose, seed production, is already known before planting. This has the big advantage that the stand can be sited to provide an appropriate com-

bination 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.

7.2 Characteristics

7.2.1 Collection unit

The collection unit is a single provenance seed stand and the seed from each stand should be kept separate.

7.2.2 Establishment, development and composition

As mentioned above the stands should be planted on sites which will promote early and abundant seed production. Right from the start the stands should be treated for seed production and the best quality trees be favoured by selective thinnings. As the stands reach seed-bearing age, they will be very like the seed production areas in development and appearance and should be treated in the same way.

While selected stands and seed production areas are approved due to their phenotypic appearance in important characters, provenance seed stands are derived from seed of well-identified and promising provenances, which are under test or already tested. Their possible superiority is therefore judged from the results of these provenance trials.

7.2.3 Geographic history

Provenance seed stands are established with seed from well-identified stands, which have been carefully checked as regards origin. The location of the provenance seed stands must be well described and the boundaries must be easily identifiable and demarcated in the field.

7.2.4 Genetic history of the parent stands must be carefully checked.

The artificial selection applied in the provenance seed stands must be recorded. It must be ensured that the seed provided for the establishment of the provenance seed stands was collected from a sufficient number of well- distributed parent trees. The criteria for selection of the parent trees should be recorded. The parent stands must have been tested or be under test in comparative provenance trials, see Fig.3.

Provenance seed stands should be properly isolated from contaminating sources. When necessary isolation strips as mentioned under seed production areas should be established.

7.2.5 Seed documentation, see selected stands.

Where applicable a summary of test results should be given. Number and kind of parent trees used for seed collection must be stated if so required.

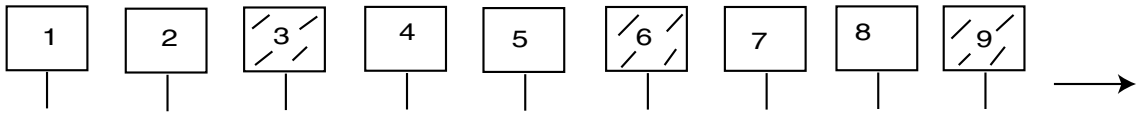
As it appears from the above, establishment of provenance seed stands is a follow-up of provenance research, aiming at ensuring mass production of seed of proven superior sources.

For summing-up of 7.1-7.2.5, see Appendix 1.

Provenance testing and establishment of provenance seed stands

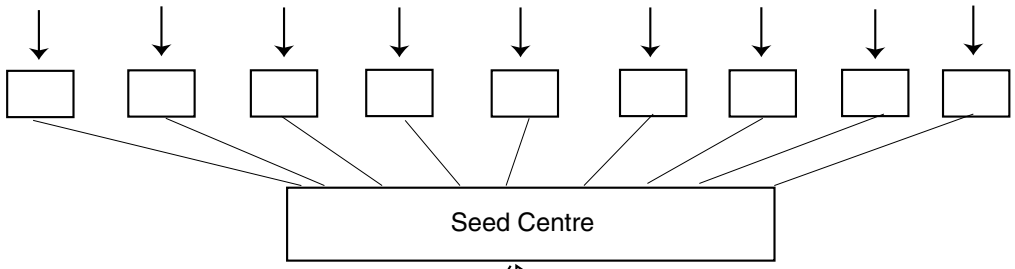
Selection of stands

Include a few commonly used stands as standards; include promising stands (3, 6, 9)



Seed collection

Collect representative seed samples in good crop years, if possible collect additional seed for establishment of provenance seed stands etc.



Seed processing

Process and test the seed and store until seeds from all stands have been collected. If possible store extra seed for 3-10 years to cover future requirements and follow-up activities.

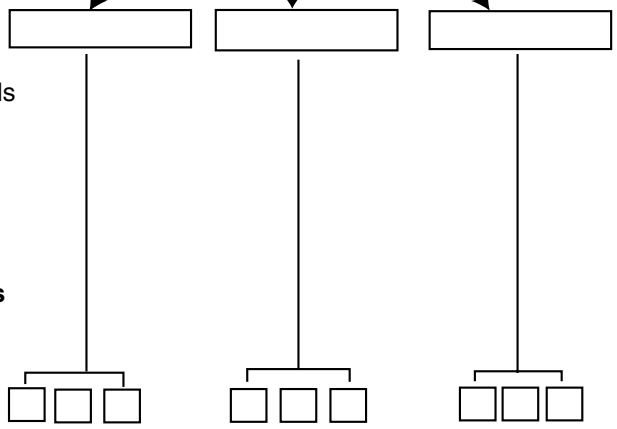
Seed distribution

Distribute seed to best nurseries within each region. Supply additional seed of most promising stands for each region.

Nurseries

Grow plants for the trials and for provenance seed stand of no. 3, 6 and 9

Establishment of trials



All stands represented in all trials

Establishment of prov. seed stands from

3 6 9

Only promising stands are uded for provenance seed stands.

1st assessment of provenance trials

After the assessment additional seed may be procured from the seed centre stock for establishment of provenance seed stands of three best provenances compared with the mean of all provenances under test.

Figure 3

8. SEED ORCHARDS

8.1 Definition

Zobel et al. (1958) have defined a seed orchard as a plantation of genetically improved trees, isolated to reduce pollination from genetically inferior outside sources and intensively managed to produce frequent, abundant and early harvested seed crops. It is established by setting out clones or seedling progeny of trees selected for the desired characters. Seed orchards are often established while genetic evaluation of the parent material is still under way. In such cases components shown by progeny testing to be genetically undesirable will subsequently be removed from the seed orchards.

The OECD definition reads (OECD, 1974): "a plantation of selected clones or progenies which is isolated or managed to avoid or reduce pollination from outside sources, managed to produce frequent, abundant and easily harvested crops of seed" see Appendix 5 and 6.

In as much as seed orchards are planted with seed production as the explicit object of management, they resemble provenance seed stands, but the intensity of selection of the individual parent trees is typically much higher for seed orchards. In seed orchards each component (clones or families) planted must be identifiable in the field, whereas seeds from individual trees collected for establishment of provenance seed stands are bulked.

Seed orchards represent a high degree of selection. If genetic gains should be achieved through seed orchard seed, it is essential that the seed is used on sites similar to the sites where the parent trees for the seed orchards were selected e.g. within the same or similar zones, or where test locations indicate successful growth of the seed-orchard offspring.

8.2 Characteristics

8.2.1 Collection unit
The collection unit is a single seed orchard and the seed from each orchard should be kept separate. Due to its relative narrow genetic base seed orchard seed should not be used in practice until the orchard is of such an age and development that a reasonable stability in flowering and seed production has been achieved. Measures may be taken to ensure that each component is not unduly over or under represented in the seed lot collected.

8.2.2 Establishment, development and composition

Seed orchards should be planted on sites which will promote early and abundant seed production. The clones or seedlings shall be planted in such a way that each component can be identified in the field.

Due to the impact of natural selection, seedling seed orchards should however be established on sites representing the environments where the seed is planned to be used. In order to favour heavy seed production, clonal seed orchards may be established in particularly flower-promoting environments, provided survival of clones is not seriously affected.

8.2.3 Geographic history

First generation seed orchards should be based on selection in well-adapted base populations of common origin and growing on similar sites which match future planting sites. Where results of provenance research is available, stands which have proven superior in important characters should be used as base populations for selection. The base populations must be well-identified and described. The selection criteria for the parent trees used must be described and recorded. With increasing generations of selective breeding the genetic history of the base populations becomes more important that the geographic history.

The location of seed orchards must be well described and the boundaries must be easily identifiable or demarcated in the field.

8.2.4 Genetic history

of the base populations and the parent trees must be carefully checked and recorded with the criteria for selection. Progeny testing of the components of the orchards may be initiated and components removed if their progenies are below specified standards. Any significant changes in the components of the orchards must be recorded.

Seed bulked from commercial collections within each seed orchard or seed for progeny testing of individual components can be used for testing of seed orchards. The first kind of tests will provide information on the offspring of the seed orchard as a whole. The latter kind of tests will provide information on the progenies of the individual components and may provide material for future selection and breeding.

8.2.5 Seed documentation

See provenance seed stands. For further information a registration sheet should be provided, see Appendix 7.

For summing-up of 8.1-8.2.5 see Appendix 1.

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Appendix 1

CHECKLIST FOR CLASSIFICATION OF SEED SOURCES AND SEED

Criteria for classification	Seed zones	Stands				Seed orchards
		Identified	Selected	Seed production areas	Provenance seed	
1. Collection unit						
(i) Collections identified to	Zone and elevation belt only	← Well identified, single stands →				Well identified single orchards
(ii) Collections kept separate within each zone and evaluation belt or mixed	Mixed or kept separate, coll. areas not specified	← Collections kept separate from each single stand →				Kept separate from each orchard
(iii) Seed kept separate within each zone and elevation belt or mixed	Mixed or kept separate after processing	Seeds from natural stands or introduced stands of common origin may be mixed, but preferably kept separate		Seeds from each single stand kept separate		Kept separate from each orchard
2. Development and composition						
(i) Adaptability	← Not carefully checked →	← Carefully checked → Tested or to be tested				
(ii) Compositon (iii) Development	← Not carefully checked →	Designed for optimal compositions ← Carefully checked →				Each component identified
(iv) Phenotypic standard	← Not considered →	Above local standard	Above selected stands	Parent stand carefully selected		Parent trees carefully selected
				← Tested or to be tested →		
3. Geographic history						
(i) Origin	← Not carefully checked →	Carefully checked, for introduced stands origin often unknown				
(ii) Location of seed source	Not specified within seed zone	Location of seed source given by latitude, longitude and elevation and other details, where seed zoning systems are in operation, reference to zone and elevation belt				
(iii) Boundaries	Described and identifiable	← Boundaries identifiable in the field → Where necesary, boundaries demarcated in the field				
4. Genetic history						
(i) Natural selection	← Judged by the ecological conditions prevailing within each zone and elevation belt →	← Studies of natural distribution, population size, test results, etc. →				
(ii) Artificial selection	← Not considered →	Studies of number of generations and selection criteria etc. → Treatments applied recorded				Breeding history recorded
(iii) No. and kind of parent trees represented in seed source	← Not considered →	← Most often unknown →		Numerous parents kind recorded		Number and kind recorded
No. and kind of parent trees represented in seed lot collected	← Not considered →	Information may be provided, if request submitted prior to collection				
(iv) Isolation from contaminated pollen sources	← Not checked →	← Measures taken to prevent contamination → Established in locations where risk of foreign pollen is low				
(v) Provenance or progeny testing	Only well identified stands within each zone to be tested	Testing of a range of stands, including standards in different planting sites. Stands which have been widely used as seed sources to be used as standards. In interpretation of results achieved it should be noted if the tests were conducted in or outside an environment similar to the planting site where the seed is to be used. Criteria for assessment and age of trials must be stated. Tested or under test				
5. Seed documentation	Seed will be classified according to information submitted and the formal attestation of facts					

Seed zoning system followed in Honduras (Robbins and Hughes, 1983)

The provenance regions have been deduced from environmental and genetic data. Environmental data has been well-covered for Honduras by various national and international organisations, and comprises topography, rainfall, temperature, geology, soils and vegetation. A considerable amount of genetic data has also been available.

Honduras comprises three main topographical regions (1) the central highlands, (2) the Caribbean coastal plains and valleys to the north and (3) the Pacific coastal plains to the south. Rainfall is determined principally by the NE trade winds, so that the NE coastal plains tend to be the wettest (3000 + mm), reducing towards the centre of the country (700mm), with a corresponding increase in length of dry season (from 3 to 7 mts). Rainfall increases again on the Pacific coast, but is more concentrated with the dry season remaining long. Interior valleys tend to be drier than surrounding hills due to orographic effects. Temperature varies greatly due to topography from a mean annual of 24 + °C down to 12°C at the highest altitudes (max. 2849 m).

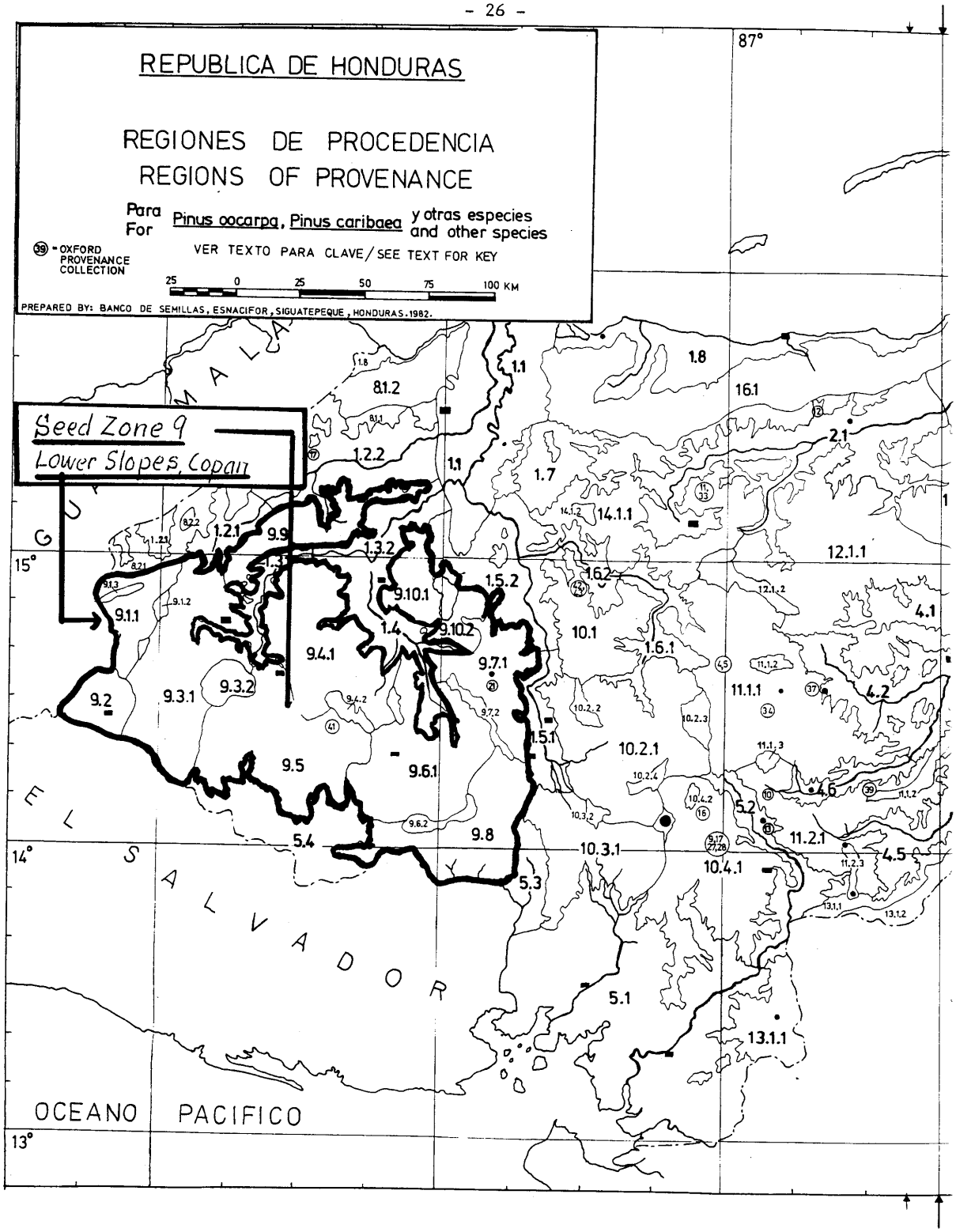
Method of Delineation see figure on next page.

The first step taken in delineation was to produce an accurate map of the distribution of *P. caribaea* and *P. oocarpa*, since only maps and aerial photographs of the pine distribution in general were available, without differentiation into species. Since the two species occupy fairly well-defined altitudinal ranges, this was done by superimposing topography on distribution, and assuming that from 0-500 m corresponded to *P. caribaea*, 500-700 m was either or both species, and 700 m and above was *P. oocarpa*.

The second step was to determine the original, large scale populations that were present during the evolution and colonization of the species, before being broken up by human interference. Since the distributions are largely controlled by altitude and hence topography, this in effect required division of the country into main physiographic zones, representing several discontinuous valley and plain populations of *P. caribaea*, and larger, more continuous populations of *P. oocarpa* on the mountains.

These main poopulations were then examined for lesser discontinuities resulting from soil types, mountain ridges (out of range of *P. oocarpa*) and human interference.

Many large populations of *P. oocarpa* could be subdivided into two, following mountain ranges which tend to isolate one half of a population from another. Since such populations naturally take the form of a circular band around the mountain ridge, it was sometimes difficult to decide where the main population should be divided on the lower slopes. As a rule, the division was made where the two sub-populations were most limited in interconnection.


REPUBLICA DE HONDURAS
REGIONES DE PROCEDENCIA
REGIONS OF PROVENANCE
Para Pinus oocarpa, Pinus caribaea y otras especies
For and other species
39 = OXFORD PROVENANCE COLLECTION
VER TEXTO PARA CLAVE/SEE TEXT FOR KEY
25 0 25 50 75 100 KM
PREPARED BY: BANCO DE SEMILLAS, ESNACIFOR, SIGUATEPEQUE, HONDURAS. 1982.
Seed Zone 9
Lower Slopes, Copan
GUATEMALA
EL SALVADOR
OCEANO PACIFICO
87°
15°
14°
13°
1.8
8.1.2
1.1
16.1
1.2.2
1.7
2.1
14.1.1
1.2.1
9.9
1.3.2
12.1.1
1.6.2
1.5.2
9.10.1
4.1
9.1.1
1.4
9.10.2
10.1
1.6.1
9.4.1
9.7.1
11.1.1
4.2
9.2
9.3.1
9.3.2
1.5.1
10.2.1
9.5
9.6.1
4.6
5.2
11.2.1
5.4
9.8
10.3.1
4.5
10.4.1
5.3
5.1
13.1.1

The valley populations of P. caribaea were generally long and discontinuities occurred because of soil changes or removal by man for agriculture. Suitable sub-divisions were made on the basis of these breaks.

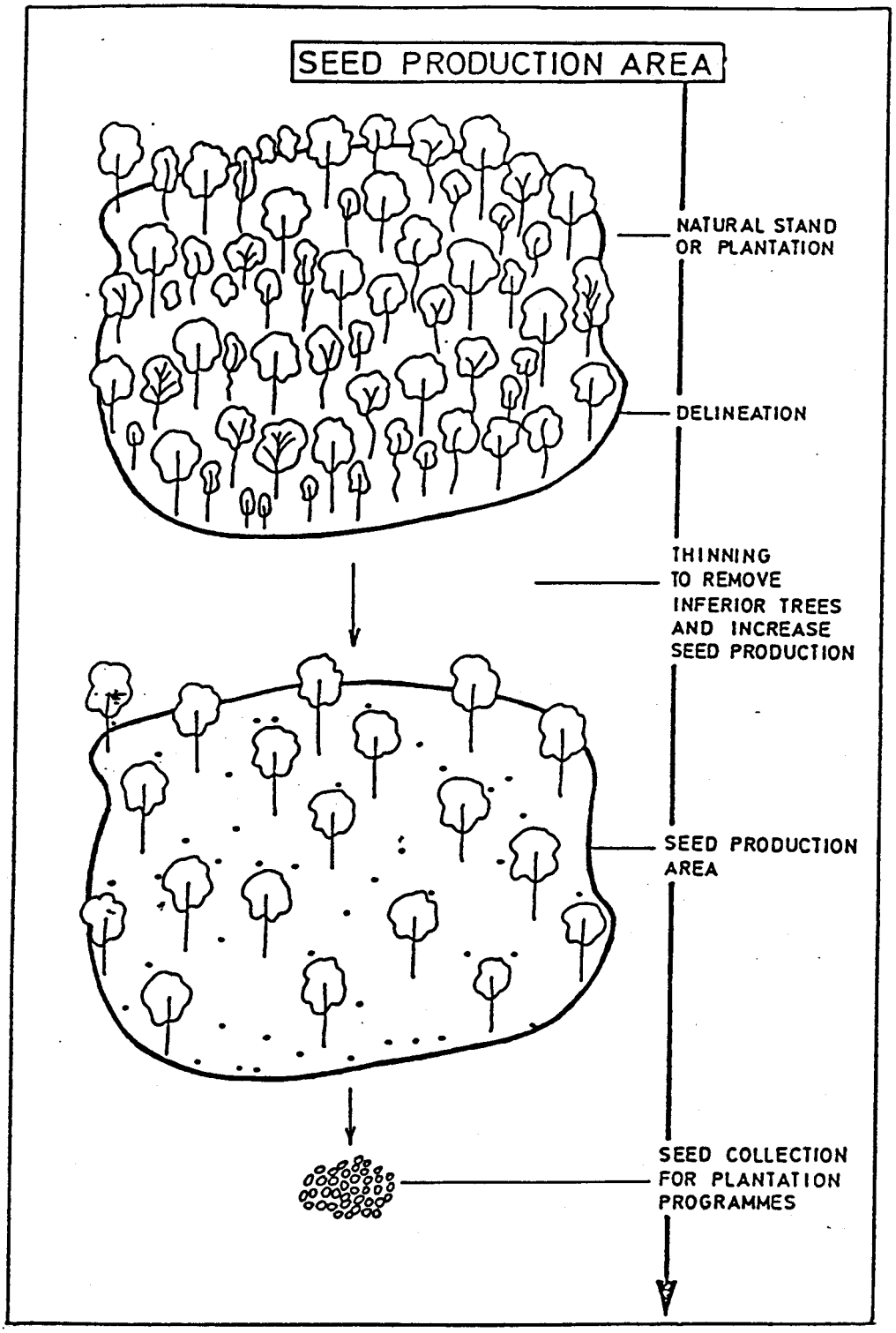
As a final step, soil, temperature and rainfall, were examined to see how these varied within the regions so far defined and to determine if further division was necessary.

In general, the regions tended to coincide with soil changes, and so no further division was made on this factor alone. Rainfall and temperature are mainly controlled by altitude, which is especially variable for the *P. oocarpa* regions. This variation could have been taken into account by defining fixed altitudinal belts, but this in effect would have given very long narrow regions in the form of concentric rings around ridges that would have been impractical to delineate and implement in the field. It therefore seemed more appropriate to leave the divisions so far delineated as the final provenance regions, and define limits to individual seed collections based on a maximum range of altitude and, since some regions are quite extensive, on areal extent as well. The limits recommended are that altitude should not exceed 300 m, or horizontal extent not more than 50 km (along contour lines) for any one collection, similar to those proposed for Canada (Piesch and Stevenson, 1976).

During the above process of delineation, note was taken of the result of the C.F.I. provenance trials and associated studies, which in general confirmed the proposed divisions.

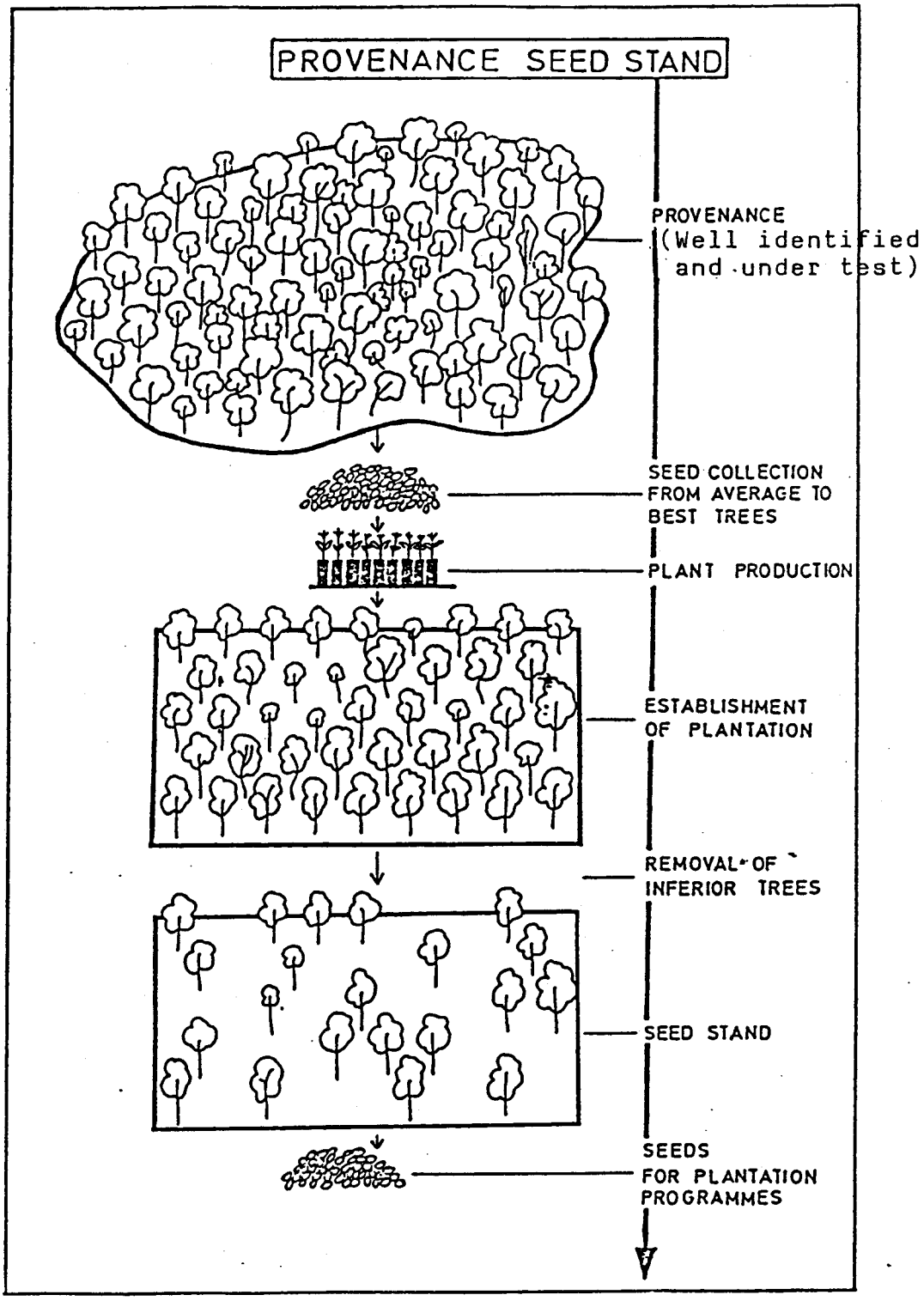
The regions have been numerically coded on the basis of the main physiographic zones, using three digits, so that the location and relationship of the regions may be readily appreciated, and so that further sub-divisions can be added easily. The region names also refer to principal geographic features (mountain ranges, valleys etc.) so that the location is easily understood in the same way.

The coding is a three digit classification, see map on previous page. The first digit refers to broad physiographic zones, see zone 9 which is indicated on the map, representing the South West Mountains. The second digit refers to a further physiographic division, e.g. 9.1 Copan. The third diget 9.1.1. refers to Lower Slopes in Copan.



Source: Robbins in Ditlevsen et al. 1988

Appendix 4



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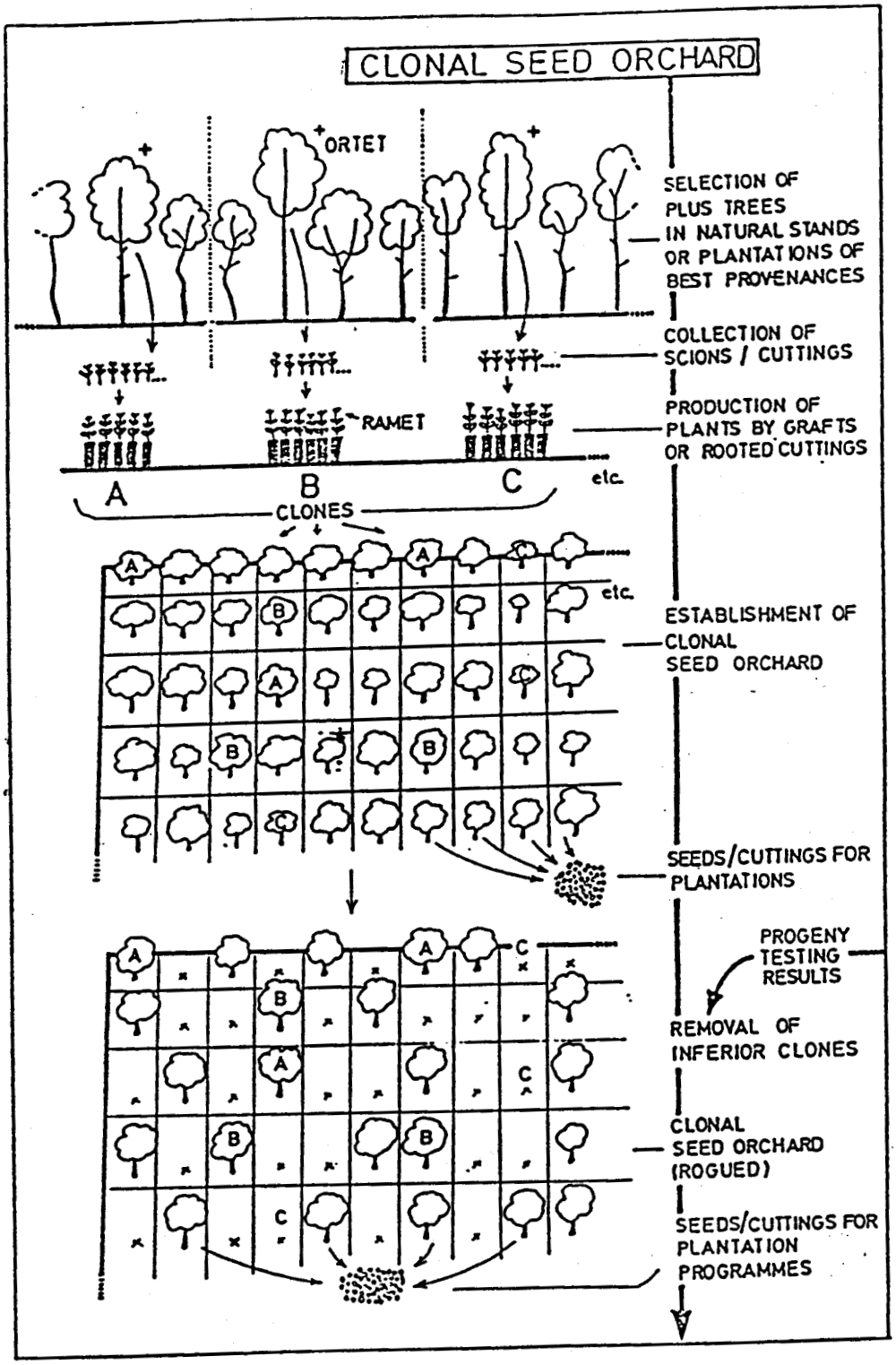
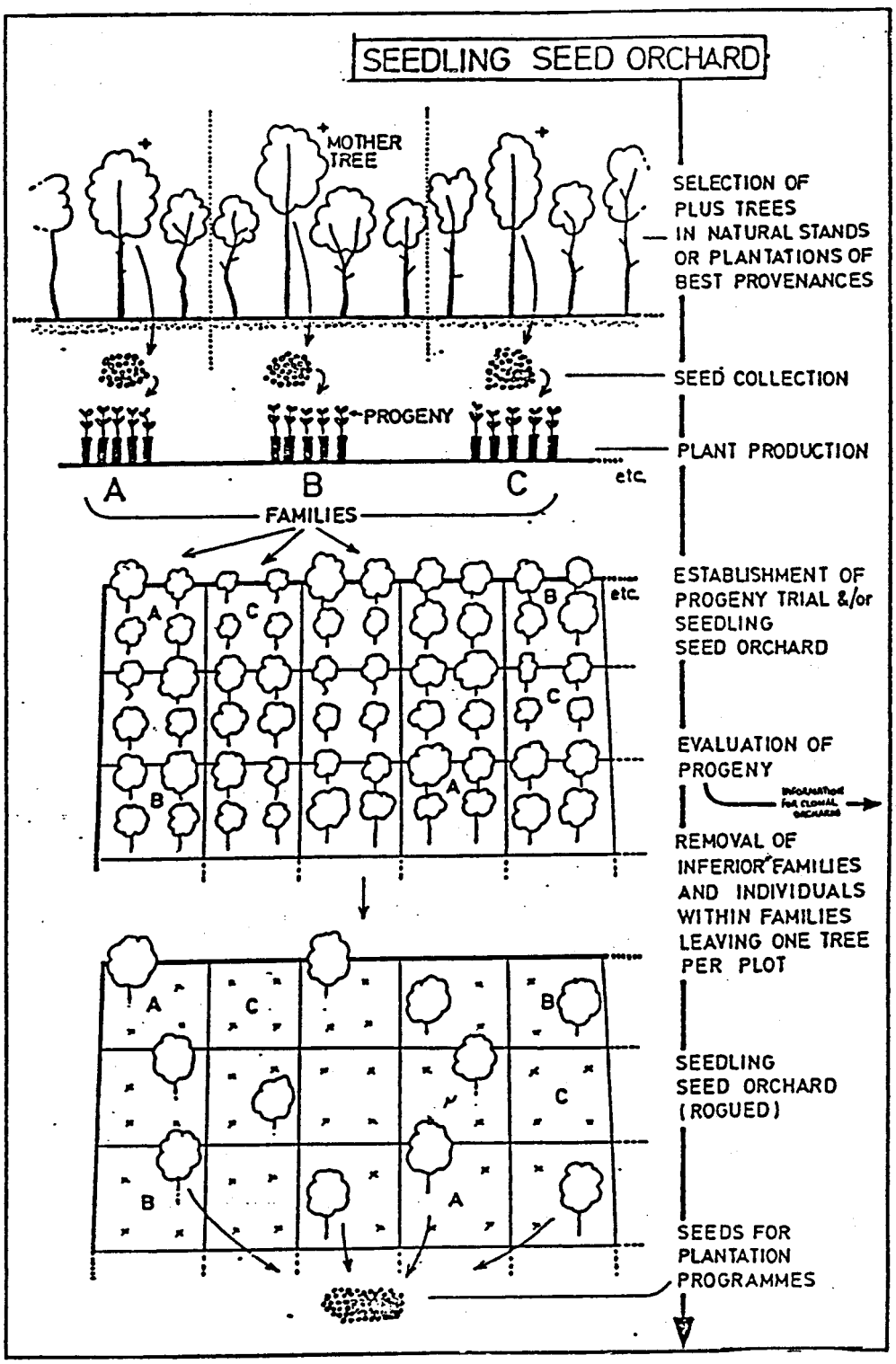


Source: Robbins in Ditlevsen et al. 1988

Appendix 6



Source: Robbins in Ditlevsen et al. 1988

Appendix 7

Country: Denmark

Reference No: 240

Approved as Untested 19 .....
Tested 19 ....

1. Identification:
Species: *Norway spruce* *Picea abies*
(Common name) *(Botanish name)*
Ownership: Hofmansgave foundation and tree improvement station in collaboration with the Danish health association.
Supervisor:
Location: hofmansgave "timeglasmarken", NE-Funen
Latitude: 55°32' E Longitude: 10°29' N Elevation: 0-10 m
Area: 6 ha Map references: A 3416, 1313 II

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2. Objective: Production of western continental spruce adapted for DK conditions
Selection criteria: Volume, specific gravity, straightness and branch qulity
Regions of probably adaptation: Denmark

Seed yield, estimated at age ..... = ... kg annually

3.

Composition	Parent trees represented at establishm.	Parent trees represented removed 19 ...	Year of propagation or ripening	Year of establish-ment	Spacing m^2 1980	Spacing m^2 19...
Clones	*100*		*1973-1982*	*1980-84*	*15*	
Full sibs						
Half sibs						

Design and layout: Permutated neightbourhood designs, see bell and fletcher silvae genetica 1978 27

Isolation: Good to 500 m as well as to 1000 m, apart from a few small patches of spruce in the park

---

4.

Basic material Please turn over
The information can be pooled for parent trees of same origin, growing under similar ecological conditions. For more advanced seed orchards, breeding records should be submitted. Use back of paper.

Parent trees	Provenance latutude	Provenance longitude	Provenance Elevation	Provenance Region	Origin Indegen.	Origin Unknown	Origin Introduced from

Basic material:

Parent trees	Provenance				Origin		
	Latitude	Longitude	Elevation	Region of provenance	Indegen.	Unknown	Introduc. from
4, Fussingø	56°27′	9°47′	50	ø jylland		x	
1, Viuf Skov	55°36′	9°31′	70	-		x	
2, Omberg	58°20′	14°40′		Sweden		x	
1, Ålvan	58°29′	15°18′		-		x	
1, Boserup	56°01′	13°55′		-		x	
1, Tönnarsjöh	56°44′	13°04′	100	-		x	
9, Silkeborg	56°08′	9°32′	100	M-Jylland			
8, Frijsenborg	56°16′	9°56′	75	Ø-Jylland			
13, Palsgård	56°04′	9°23′	50	M-Jylland			
11, Nødebo	55°59′	12°19′	50	N-Sjælland			
4, Grane	56°01′	12°19′	100	M-Jylland			
3, Lindenborg	56°48′	9°48′	100	N-Jylland			
3, Kongsø	56°0′	9°28′	100	M-Jylland			
15, Buderupholm	56°48′	9°51′	100	N-Jylland			
4, HDS, Bjørslev	56°01′	8°47′	50	V-Jylland			
11, HDII, Stilde	55°32′	8°57′	70				
4, HD5, Hogildg. 5, HD5, Hareskov	56°03′	8°56′	75	V-jylland		x	

x where applicable