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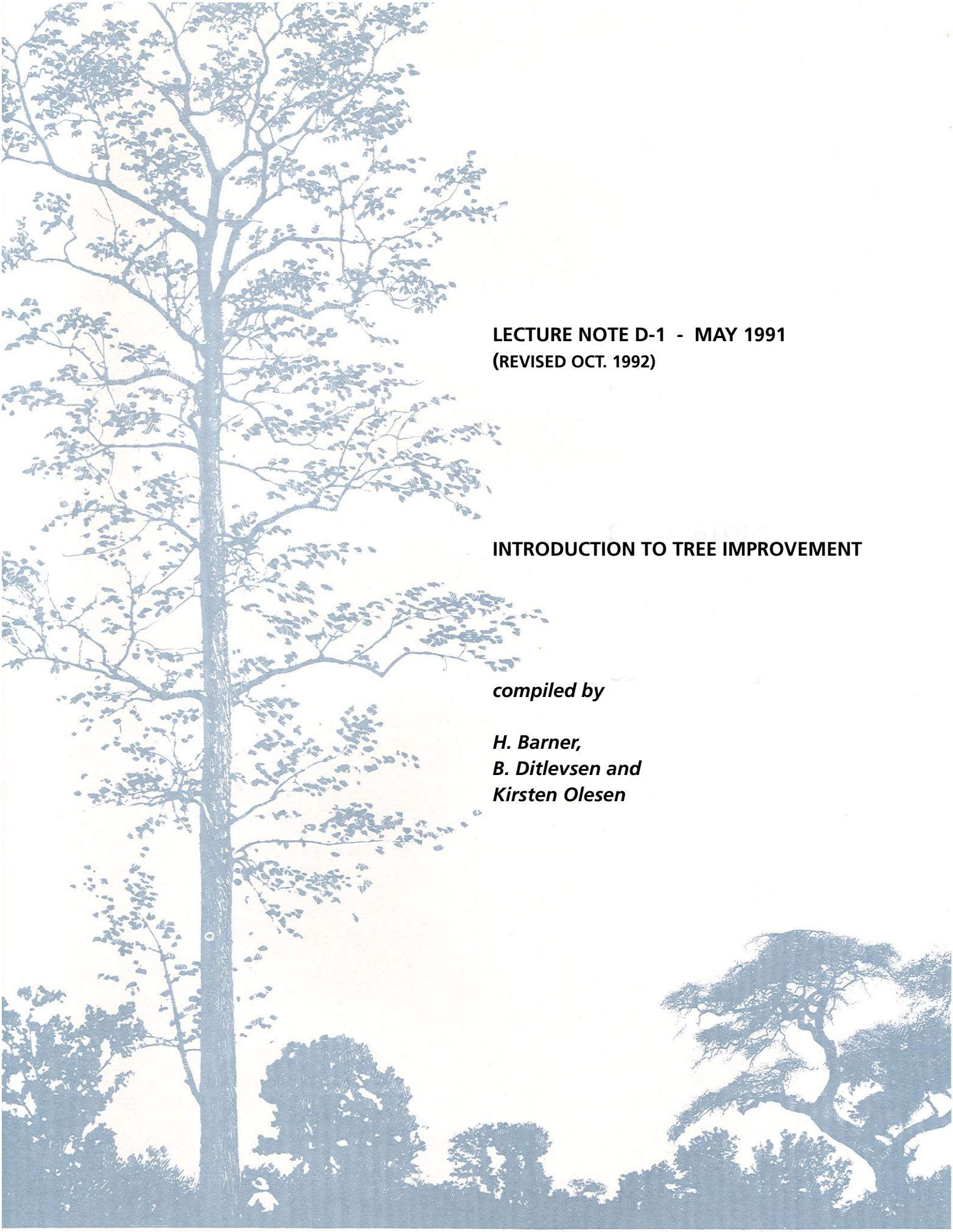

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INTRODUCTION TO TREE IMPROVEMENT

compiled by

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B. Ditlevsen and
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DANIDA FOREST SEED CENTRE

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1. INTRODUCTION

A tree improvement programme involves all practices designed to produce genetically more desirable trees.

The aim of tree improvement is to maximise (1) adaptability of a species to potential planting sites (and thus its survival), (2) its growth rate, (3) its resistance to diseases, and (4) the quality of the end use of the trees as timber, fuelwood, fodder, soil stabilizers etc.

The objectives of any tree improvement programme should be defined in accordance with the immediate as well as the short-term and long-term requirements of the national and regional afforestation programmes.

Objectives must be examined closely to ensure that biological, technical or financial constraints will not prevent or hamper the improvement programme.

Emphasis must be placed on species of present or future economic or ecological importance and on species that are expected to cover substantial areas. Otherwise it is not likely that expected gain can justify expected cost.

Tree improvement programmes must be closely related to other sectors of forest research and to the forest service because results of tree improvement interact with other research results and with silvicultural aspects.

All species have the potential for being improved, but the justification of any tree improvement programme and the amount of resources devoted to it should be largely determined by forest policy and may be revised to comply with changes in forest policy.

The possibilities of mass production of improved material must be considered in order that the results of improvement can be conveyed to practical forestry in substantial amounts.

The aspects of conserving original populations used for tree improvement must also be considered.

This lecture note presents an introduction to some tree improvement aspects, all of which are described in more detail in Lecture Notes D-2 to D-1O. See the list in appendix 1.

2 SOURCES OF VARIATION

There are three main sources of variation, see fig.1.

1. Developmental (with age)
2. Environmental
3. Genetic.

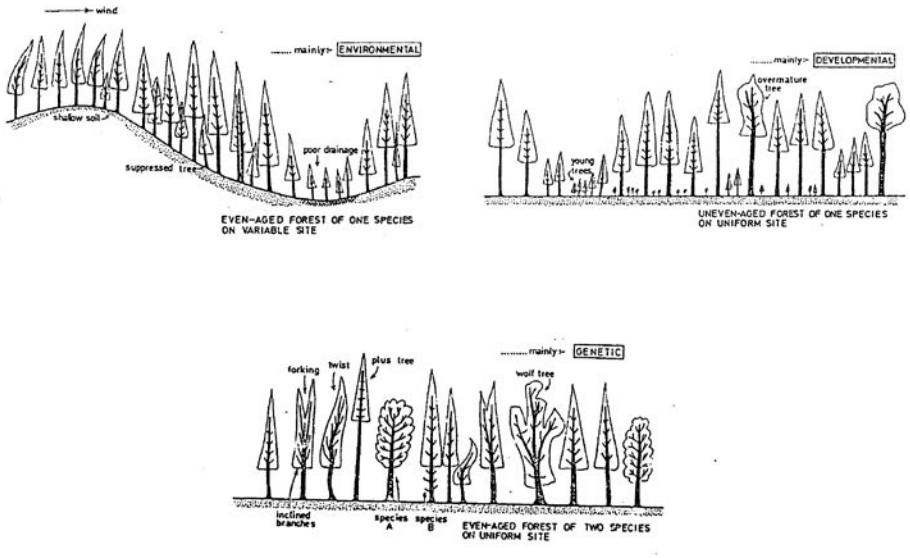


Figure 1. Sources of variation

(A more detailed description is found in Lecture Note A-3, Natural Variation as a Basis for Tree Improvement).

Genetic variation is the basis for tree improvement. It must be distinguished from developmental and environmental variation. When we study the trees, we see the product of the interaction of the genes of the tree with the environment. The phenotype of a tree is what we see, measure and work with. The genotype is the genetic potential of the tree. It cannot always be seen directly; it must be studied through well-designed tests.

The classical way to identify genetic variation and separate it from developmental and environmental variation goes through

SELECTION → TESTING → EVALUATION → NEW SELECTION

3 SELECTION, TESTING, EVALUATION AND NEW SELECTION

3.1 Selection

Species vary greatly in many characteristics. To take some extremes, no teak (*Tectona grandis*) tree can survive outdoors in northern Europe, and no Norway spruce (*Picea abies*) tree can live near the Equator. Even when climate and soil conditions are ideal, genetic potential for growth may vary enormously even between species of a single genus. As an example we may compare *Eucalyptus regnans*, with a straight cylindrical stem and capable of exceeding 90 m in height, and *Eucalyptus pyriformis*, a multi-stemmed species, seldom exceeding 6 m. It is evident that choice of species is of vital importance for the success of any afforestation programme.

It is a well-established fact that choice of seed source within a species also is of great importance. Lack of success may be due to the fact that the chosen seed source came from an area with different climate and growth conditions than those of the planting site, and that the adaptation to its original conditions has made the seed source unsuited for the new planting site. The geographic location of a seed source is called its **provenance**.

It is also evident that some **individuals** stand out from the rest of the trees in the neighbourhood in a positive or negative way because of good or bad properties.

The variation between species, provenances and individuals is used in tree improvement programmes.

Natural selection favours those best fitted for the local environment.

Artificial selection for tree improvement favours those in possession of desirable characteristics suited for specific planting purposes.

Before embarking on selection, it is important to define the object of planting, e.g. timber, fuelwood, fodder or protective function as control of erosion.

Whether selection criteria are set out for classical forestry or for multipurpose species, the following criteria are usually valid:

1. Adaptation to climatic and edaphic conditions
2. Resistance to pests and diseases
3. Productivity
4. Quality.

More specific selection criteria should be limited to a few traits estimated to have a considerable value for the objectives of future planting programmes. Because of the effect of adaptability, selection should take place in areas with an environment similar to future planting sites (for more details, see Lecture Note B-3, Matching Seed Source to Planting Site).

Timber production	Multipurpose production
Uniformity of product	Biomass yield in the form of
Volume production	fuelwood or fodder
Stem straightness	Intercrop yield
Wood density	Environmental protection

Figure 2. Examples of Selection Criteria (as an illustration only, not covering all cases)

It is emphasized that flowering and seeding ability should also be taken into account as selection criteria, because the utilization of the improved material will be difficult without a fair seed production, unless large-scale vegetative propagation is a realistic alternative.

3.2. Testing and Evaluation

To determine the extent to which differences between trees can be ascribed to genetic variation, the test material (the selected species, provenances or individuals) must be grown together in replicates in well-designed trials in a number of different environments, preferably on potential planting sites. Each site should be as uniform as possible in order to minimize environmental variation.

The techniques and procedures for testing and evaluation are described in Lecture Notes D-5 and D-6.

3.3. New Selection

The results of testing and evaluation form the basis of new selection. As the trials make it possible to distinguish genetic variation from other forms of variation, it is now possible to select the genetically best material for future use.

Successive trials and evaluations will form the basis of further selection.

4 POSSIBLE GAINS AND RISKS

4.1. Gains

Genetic variation is the basis for improvement programmes. Some species show large variation and some species are more uniform. The greater the variation, the greater gain is it likely to obtain, and it may not be worth including a very uniform species in an improvement programme.

Some characteristics, such as leaf form, stem straightness, and wood density, are likely to be carried on from one generation to the next. Other characteristics, such as branchiness and growth rate, are to a larger extent influenced by the environment.

A number of accounts have been published in the past on the economic returns to be expected from tree improvement. Most of them refer to temperate conditions, but the gains in improvement should on average be no less in tropical than in temperate species.

Most of the accounts on gain refer to improvement through selection between different seed sources (provenances) within a species and selection of individuals within superior populations. For the early stages, average gains may be conservatively, and roughly, estimated as follows (quoted from Lecture Note A-2, Benefits from Tree Improvement):

Degree of variability between provenances	Value gain expected from provenance selection (%)	Degree of variability within provenances	Value gain expected from individual selection (%)	Total value gain expected (%)
High	10-20	High	15-30	25-50
	"	Moderate	5-15	15-35
	"	Low	1-5	11-25
Moderate	5-10	High	15-30	20-40
	"	Moderate	5-15	10-25
	"	Low	1-5	6-15
Low	1-5	High	15-30	16-35
	"	Moderate	5-15	6-20
	"	Low	1-5	2-10

Figure 3. Value gain in commercial plantations from early stages of tree improvement

Later stages of improvement programmes may contribute gains of similar order, and gains will accumulate over successive generations.

4.2 Risks

Wrong choice of seed source may result in serious losses or complete failure.

When the general criteria (see p. 4) are considered, it should be remembered that wrong choice as to productivity will give less favourable results, while wrong choice as to adaptability and resistance may result in great losses or even complete diaster.

This also means that the importance decreases from choice of species through choice of provenances to choice of individuals.

When selected genotypes are used over large areas, it should also be considered that limiting the number of genotypes within species, provenances and individuals in itself poses a risk. Attacks of diseases or climatic extremes may strike a widely used genotype almost equally seriously over extensive areas, whereas different genotypes react differently to such impacts.

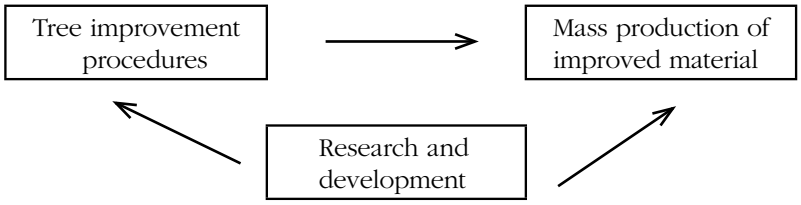
5 OUTLINE OF A TREE IMPROVEMENT PROGRAMME

As the objective is to ensure a sustained supply of seed and other propagation material of high genetic quality, it is important not only to look upon the desirability and possibility of genetic improvement, but also to consider the possibilities for **mass production of improved material** in sufficient quantities and within a reasonably short span of time.

If improved material cannot be produced in required quantities, tree improvement programmes will be of limited importance for practice. All material that is better than usual standard should be used as soon as possible, and mass production should not be postponed until 'highest possible' quality is available.

Supportive research and development are essential tools for tree improvement procedures as well as for rational mass production. It is important to remember that development without research becomes outdated and research without development is academic.

So it can be concluded that there must be well balanced connections between



In principle, tree improvement begins with selection. But it may be necessary to begin with exploration comprising botanical and other studies in order to find out where suitable material for selection can be found.

When the results of the first tests are available, the work can be concentrated on the best of the tested seed sources both for direct seed production and for further improvement. The next steps in the improvement work can now be made on much safer ground that in the initial stage.

It is vital that conservation aspects are included in the improvement programmes because the seed sources that were included in the initial test and did well must still be available and almost unchanged in composition to be used in the future.

Fig. 4 presents a logical but simplified framework of a tree improvement programme where selection is made in natural forests or in plantations.

More detailed descriptions are found in section 6, Options.

Supportive Research and Development	Tree Improvement Procedures	Mass Production of Improved Material
Botanical data Genetic structures	1. Exploration Field Survey	
Selection criteria defined according to purpose	2. Identification of basic material which fulfils the minimum criteria set out for seed sources	Seed collection in identified sources for direct use
Selection criteria. Traits to be combined. Number of trees to select. Seed biology. Propagation techniques.	3. Selection and Conservation Selection of material that appears to be well-adapted and superior. Conservation of promising and endangered seed sources	Seed collection in selected, but untested, sources for direct use
Genetic parameters, traits for assessment. Experimental design, analysis, evaluation	4. Testing and Evaluation Selected material to be tested in comparative trials on potential planting sites. Recommendations for choice of seed sources	Seed collection in tested and superior sources for direct use
Selection criteria. Seed Biology. Propagation techniques. Genetic parameters. Experimental design etc.	5. Continued Selection and Testing of material, superior on test sites. Recurrent selection in following generations. Recommendation for choice of seed sources	Seed collection in tested and superior sources for direct use
Seed Biology. Propagation techniques. Design. Siting. Treating etc.	6. Establishment of Improved Sources For further breeding and conservation	Establishment of seed stands, seed orchards, clone banks etc.

Figure 4. An Outline for a Tree Improvement Programme

6 OPTIONS

6.1. General considerations

In this section, an outline or catalogue of options is presented together with the logical framework of tree-improvement programmes, stretching from simple and inexpensive procedures to more intensive and costly ones.

Testing of species, provenances, or individual trees takes time, skill and resources. Therefore, while the programmes are still in progress, it should be considered how much the current seed supply can be improved by use of common sense until test results are available.

The options to be considered depend on the possibilities for genetic improvement and mass production of improved material under the prevailing conditions. A tree improvement programme need not be expensive or demand sophisticated equipment.

The procedure depends partly on the species. In most species, tree improvement should be initiated at the provenance level, whereas only rarely genetic gains can be accomplished directly by individual tree selection without first selecting provenance. Before genetic improvement is initiated in a given species, it is important to investigate the genetic characteristics of the species. If some important characteristics are likely to hamper the improvement of this species, it should be considered whether any other species will be better suited to fulfil the desired requirements. Choice of right species is the vital decision in any tree improvement programme.

In this section, a distinction is made between tree improvement based on species, provenances and individual trees. It should be emphasized that the three levels can be combined, and usually are.

Furthermore, it should be remembered that the aim of the whole programme is to provide the consumer with seed or plant material that is well- adapted to his specific planting sites and that will fulfil the purpose of planting. The purpose of any planting programme must be defined first.

Specific tree-improvement programmes will usually only comprise some components of the total outline.

6.2 Tree Improvement at Species and Provenance Level without Testing of Offspring

Cf. Figure 5, next page, TREE IMPROVEMENT A.

A.1 Species level

It is important to distinguish between natural and introduced populations. The natural population will normally, after generations of natural selection, be well adapted to the site. An introduced population is usually less adapted to the sites on which it is growing. However, after a number of generations, such introductions may be fully adapted and become very valuable as seed sources (land races).

The procedure may be summarized as follows (for clarity only a procedure for natural and indigenous forests is shown):

Compile information about species which might be of interest for the given environment. Based on experience locally and from elsewhere, select a limited number of species that are likely to fulfil the established criteria. Collect, initially, local seed for local use. Remember that local seed is the safest, but not necessarily the best as to desired characteristics.

Establish ecological zones and issue guidelines for where seed collected in a given zone may be used, both within the zone and outside it. (More details are found in Lecture Note B-1, Classification and Selection of Seed Sources, and in B-3, Matching Seed Source to Planting Site).

A.2 Provenance level, both in natural forests and in plantations

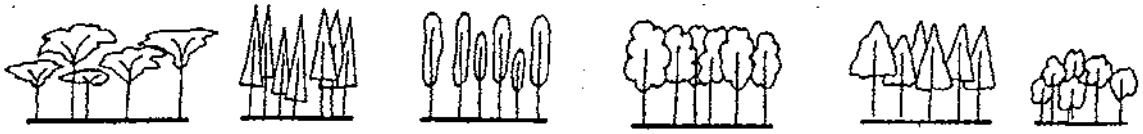
Ecological zones are large units, and collections within a single zone take place at different localities from year to year more or less randomly throughout the zone. To ensure that the individual collections can be located exactly it is recommended that collections are concentrated to smaller identified collection units although these may only be of average quality. For better quality, select seed sources the appearance of which are above average (selected sources) and concentrate the collections there. For higher seed production, young and promising seed sources should be converted to seed production areas by reducing the number of trees.

FIG. 5 TREE IMPROVEMENT A

USING WHAT IS AVAILABLE WITHOUT TESTING OF OFFSPRING

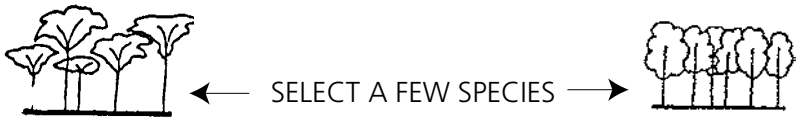
A1. SPECIES LEVEL, NATURAL POPULATIONS

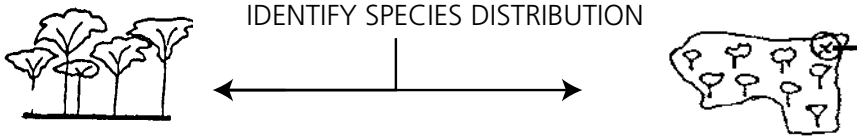
SELECTION

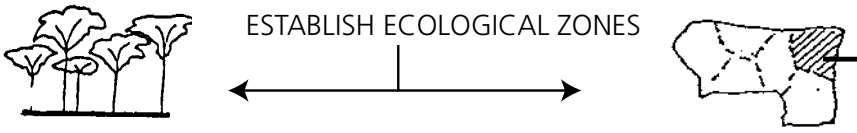


Establish criteria for species selection according to planting purpose and site

MASS PRODUCTION OF SEED





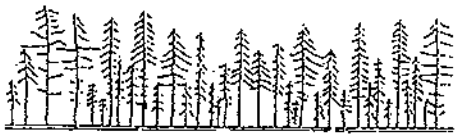


A2. PROVENANCE LEVEL, NATURAL FORESTS AND PLANTATIONS

FOR BETTER IDENTIFICATION:
DELIMINATE SMALLER COLLECTION UNITS WITHIN EACH ZONE.
WHERE APPLICABLE., USE STANDS AS UNITS

COLLECT SEED IN WELL DEFINED UNITS FOR DIRECT USE

AVERAGE QUALITY
IDENTIFIED SOURCE

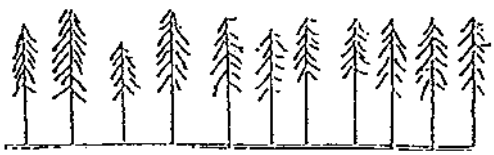


FOR BETTER QUALITY:
IDENTIFY BETTER THAN AVERAGE SOURCES

APPROVE AS SELECTED SOURCES APPLY SELECTIVE THINNINGS

GIVE HIGHER PRIORITY TO COLLECTIONS IN SELECTED SOURCES FOR DIRECT USE

FOR HIGHER SEED PRODUCTION: CONVERT BEST SOURCES TO SEED PRODUCTION AREAS BY REDUCING NUMBER OF TREES



GIVE HIGHER PRIORITY TO COLLECTIONS IN SEED PRODUCTION AREAS FOR DIRECT USE

KEEP SEED SEPARATE BY SOURCE OR ECOLOGICAL ZONE

USE SEED SOURCES FROM SITES MATCHING PLANTING SITE

6.3 Tree Improvement at Species Level Combined with Testing, Selection and Establishment of Improved Seed Sources

Cf. fig. 6, next page, TREE IMPROVEMENT B 1.

Choice of species may be based on experience or on results from species elimination trials or species testing, where a few sources of several species are tested.

In species testing, it is important to choose **a limited but sufficient number of seed sources** of each species to represent the genetic variation in adaptability and other characteristics.

Details of field testing practices for species trials are given in Lecture Note D-5.

Details for design and assessment of species trials are given in Lecture Note D-6.

After testing, some species may be regarded as undesirable and be eliminated. Other species will be considered desirable and may be used directly for new plantations, for future seed supply and further tree improvement.

The best stands of tested species may be approved for seed supply. Removal of undesirable trees in these stands are recommended.

When selected species have been tested in provenance trials, see page 16, new recommendations may be made.

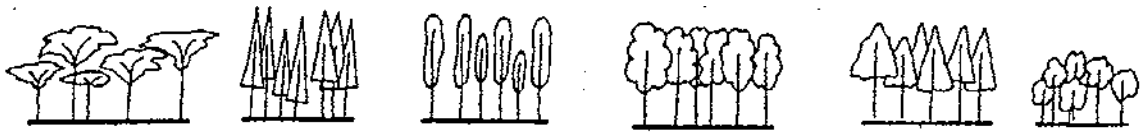
Further details in Lecture Note D-3, Tree Improvement at Species and Provenance Level.

FIG. 6 TREE IMPROVEMENT B1

USE TREE IMPROVEMENT A (Fig.5) COMBINED WITH TESTING, RECURRENT SELECTION AND ESTABLISHMENT OF IMPROVED SEED SOURCES

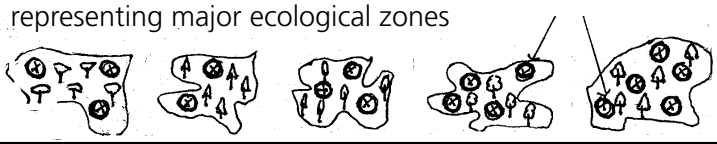
SPECIES LEVEL

ESTABLISH CRITERIA FOR SPECIES SELECTION ACCORDING TO PLANTING PURPOSE AND SITE



SELECT A LARGE NUMBER OF POTENTIAL SPECIES

SPECIES DISTRIBUTION AND SAMPLING: select 2-5 sources by species, representing major ecological zones



MASS PRODUCTION OF SEED

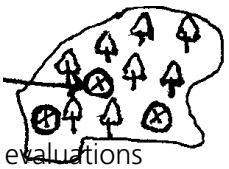
PROCUREMENT OF SEEDS AND PLANTS: fix guidelines for sampling. separation of lots and grading, collect extra seed for exchange, seed research, storage and for establishment of conservation stands → COLLECT SEED OF MOST PROMISING SPECIES FOR DIRECT USE

RAISE SEEDLINGS

ESTABLISH, ASSESS AND EVALUATE SPECIES TRIALS: specify traits for assessment and evaluation, fix rules for number and type of test sites, rotation, design and silviculture → COLLECT SEED OF BEST OF TESTED SOURCES FOR DIRECT USE

Assess and evaluate when appropriate. publish results

ISSUE RECOMMENDATIONS: for seed collections in best of tested species and sources and for use of seed sources outside local environment → CONCENTRATE SEED COLLECTIONS TO APPROVED SOURCES



Approve best of tested sources for seed supply

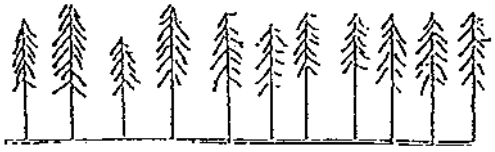
Revise recommendations in accordance with new evaluations

ESTABLISH STANDS OF BEST OF TESTED SOURCES FOR FUTURE SEED SUPPLY

APPLY SELECTIVE THINNINGS → GIVE HIGH PRIORITY TO SEED COLLECTION FOR DIRECT USE

APPROVE AS OFFSPRING OF TESTED SOURCES

CONVERT BEST OF YOUNG STANDS TO SEED PRODUCTION ARES BY REDUCING NUMBER OF TREES → GIVE HIGHER PRIORITY TO COLLECTIONS FOR DIRECT USE



KEEP SEED SEPARATE BY SOURCE OR ECOLOGICAL ZONE

USE SEED SOURCES FROM SITES MATCHING PLANTING SITE

6.4 Tree Improvement at Provenance Level Combined with Testing, Selection and Establishment of Improved Seed Sources

Cf. fig. 7, next page, TREE IMPROVEMENT B 2.

In provenance trials, **many sources of the most promising species** are tested.

A provenance trial is an essential tool for clarifying the extent of variation within a species. At the same time it may also identify promising sources for the immediate seed supply and provide information on superior sources for selection. Provenance trials are of the greatest importance for progress in the early stages of tree improvement.

Details of field testing practices for provenance trials are given in Lecture Note D-5.

Details for design and assessment of provenance trials are given in Lecture Note D-6.

Where superior sources are identified through provenance trials, new stands of these should be established for future seed supply and selection. The establishment may have one of the following objectives or a combination of these:

1) to provide enough seed of a good seed source,
2) to secure sufficient isolation to avoid contamination from inferior sources,
3) to secure protection and conservation of original seed sources that are threatened by extinction or deterioration.

For further details, see Lecture Note B-2, Identification, Establishment and Management of Seed Sources.

Further details in Lecture Note D-3, Tree Improvement at Species and Provenance Level.

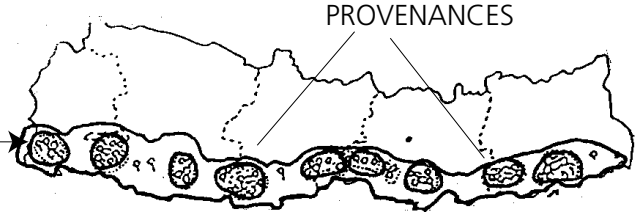
FIG. 7 TREE IMPROVEMENT B2

USE TREE IMPROVEMENT A AND B1 (Fig.5 and 6) COMBINED WITH SELECTION, TESTING AND UTILIZATION OF BEST PROVENANCES OF MOST PROMISING SPECIES

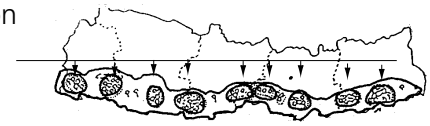
PROVENANCE LEVEL

SPECIES SELECTED ACCORDING TO B1

SPECIES DISTRIUTION



SPECIES DISTRIBUTION AND SAMPLING OF SOURCES:
establish criteria for selection
use sources representing many different ecological zones



MASS PRODUCTION OF SEED

PROCUREMENT OF SEEDS AND PLANTS: fix guidelines for sampling. separation of lots and grading, collect extra seed for exchange, seed research, storage and for conservation

RAISE SEEDLINGS

COLLECT SEED OF MOST PROMISING PROVENANCES FOR DIRECT USE

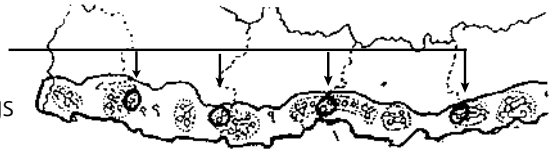
ESTABLISH PROVENANCE TRIALS AT REPRESENTATIVE SITES:
specify traits for assessment and evaluation, fix rules for number and type of test sites, rotation, design and silviculture

Assess and evaluate when appropriate. Publish results

COLLECT SEED OF BEST OF TESTED PROVENANCES FOR DIRECT USE

ISSUE RECOMMENDATIONS: for seed collections in best of tested provenances and for their use outside the local environment

Approve best sources as tested provenances
Apply selective thinnings



CONCENTRATE SEED COLLECTIONS TO APPROVED,TESTED PROVENANCES

REVISE RECOMMENDATIONS IN ACCORDANCE WITH NEW EVALUATIONS

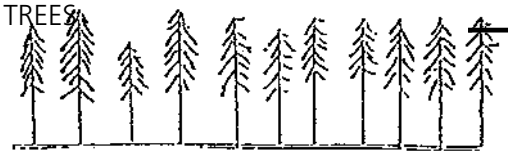
ESTABLISH STANDS OF BEST OF TESTED PROVENANCES FOR FUTURE SEED SUPPLY

APPLY SELECTIVE THINNINGS

APPROVE AS OFFSPRING OF TESTED SOURCES
ISSUE RECOMMENDATIONS FOR USE

GIVE HIGH PRIORITY TO SEED COLLECTION FOR DIRECT USE

CONVERT BEST OF YOUNG STANDS TO SEED PRODUCTION ARES BY REDUCING NUMBER OF TREES



GIVE HIGHER PRIORITY TO COLLECTIONS FOR DIRECT USE

KEEP SEED SEPARATE BY SOURCE OR ECOLOGICAL ZONE

USE SEED SOURCES FROM SITES MATCHING PLANTING SITE

6.5. Tree Improvement at Individual-Tree Level Combined with Testing and Breeding

Cf. fig. 8, next page, TREE IMPROVEMENT C.

The individual variation between trees within a population is often striking, and it may be worthwhile concentrating the collection to only the very best trees (plus trees). This procedure will be more expensive and require a larger area for collection of a certain amount of seed than traditional collection.

Plus trees may be selected within important ecological zones or in seed sources that have been tested and found better than average. Plus-tree selection in tested seed sources is of great importance in tree breeding.

Plus-tree selection in exotic species should take place in your own country's plantations of the species and not in the home country, where environments are different.

In species where the genetic diversity between trees within a seed source is more significant than between seed sources, tree improvement based on individual tree selection should be considered at an early stage.

Details of field testing practices for progeny trials are given in Lecture Note D-5.

Details for design and assessment of progeny trials are given in Lecture Note D-6.

By selection of tree species, provenances and individuals, the aim is to use the best genotypes available in nature. In specific tree breeding the aim is to create something new by crossings between selected parents, thus combining desirable properties of species, provenances or individuals.

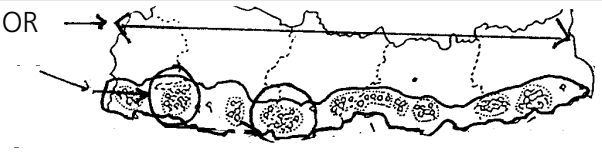
Further details in Lecture Note D-4, Tree Improvement at Family and Individual-Tree Level.

FIG. 8 TREE IMPROVEMENT C

USE TREE IMPROVEMENT A AND B (Fig.5, 6 and 7) COMBINED WITH SELECTION, OF PLUS TREES FOR DIRECT USE OR COMBINED WITH TESTING AND BREEDING

C 1. SELELCTION OF PLUS-TREES IN SELECTED SPECIES

SELECTED PLUSTREES RANGEWIDE OR CONFINED TO IMPORTANT ZONES



SPECIES SELECTED FOR BREEDING

SELECTION OF PLUS TREES: establish criteria for selection
Select plus-trees along roads and trails or systematically
Demarcate trees selected

MASS PRODUCTION OF SEED

PROCUREMENT OF SEEDS AND PLANTS: fix guidelines for collection, separation of lots and grading, collect extra seed for exchange, seed research, storage and for direct use → COLLECT SEED OF BEST PLUS-TREES FOR DIRECT USE

If considered appropriate, establish seed orchards by zone and altitude

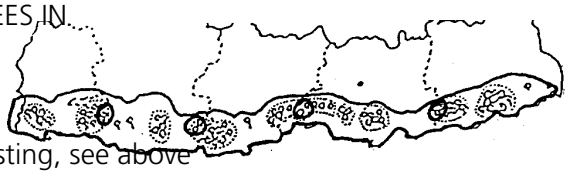
Approve orchards which fulfil the requirements, issue recommendations for zones of probable adaptation → COLLECT SEED IN APPROVED ORCHARDS FOR DIRECT USE

Raise seedlings

ESTABLISH, ASSESS AND AVALUATE PROGENY TRIALS: If feasible use trees found superior in tests for establishment of:
CONE, SEED- and POLLEN BANKS
ZONAL SEED ORCHARDS → COLLECT SEED IN SEED ORCHARDS FOR DIRECT USE
→ COLLECT SEED IN UPGRADED ORCHARDS FOR DIRECT USE
Remove inferior trees in 1st. gen. orchards according to test results

C 2. SELECTION OF PLUS-TREES IN PROMISING OR TESTED PROVENANCES

1. SELECT PLUS-TREES IN BEST OF TESTED PROVENANCES



→ COLLECT SEED OF BEST PLUS-TREES FOR DIRECT USE

Procedures for testing, see above
Establish seed orchards with plus-trees from provenances growing in similar ecological zones. Approve as above.

2. SELECT PLUS-TREES IN INDIVIDUAL PROVENANCES WHICH ARE:
i) threatened, ii) too small to cover seed demand or
iii) superior in specific traits → COLLECT SEED IN APPROVED ORCHARDS FOR DIRECT USE

Proceed as above. If feasible, establish seed orchards

KEEP SEED SEPARATE BY SOURCE OR ECOLOGICAL ZONE

USE SEED SOURCES FROM SITES MATCHING PLANTING SITE

C 3. SPECIFIC TREE BREEDING, INCLUDING E.G.

Recurrent Selection and Testing at Family Level
Breeding for Special Traits
Hybridization, Outcrossing after Inbreeding etc.

7 STRATEGIES

Tree-improvement strategies involve the challenge to combine all the evidence outlined in this paper with the human and financial resources available. Based on this evidence, realistic and balanced long- and short-term improvement plans, allocated to zones and tree species, should be formulated.

Key elements are:

1) zonation of the country
2) allocation of major plantation species to zones
3) evaluation of possibilities of genetic improvement and specification of improvement objectives
4) priority setting of species/zone combinations
5) specification and dimensioning of populations for different functions: gene conservation, breeding, mass production
6) development of working plans for long and short term improvement activities
7) if needed, development or modification of organizational framework
8) identification of major constraints and recommendations on how to overcome these, including research and development

Tree improvement strategies should comprise long term plans through many generations, which, nevertheless, are flexible and/or robust enough to engulf changes in silvicultural methods as well as innovations in genetic and propagation methods.

A crucial point is the establishment of coordination between seed procurement, tree improvement and conservation of forest genetic resources, irrespective of the institutional affiliation of these sections, cf. appendix 2, point 5.

It should be emphasized that a tree improvement programme need not necessarily be expensive or demand sophisticated equipment. In the first phase one should concentrate on a few species and make use of what is available in nature.

Further details in Lecture Note D-1O. - Reference is also made to Palmberg *et al.*, 1985.

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APPENDICES

Appendix 1

LECTURE NOTES IN THE TREE IMPROVEMENT SERIES

D-1 Introduction to Tree Improvement

D-2 Introduction to Forest Genetics

D-3 Tree Improvement at Species and Provenance Level

D-4 Tree Improvement at Family and Individual-Tree Level

D-5 Field Testing Practices of a Tree Improvement Programme

D-6 Introduction to Principles in Design and Evaluation of Tree Improvement Experiments

D-7 Mass Production of Improved Material. 1. Propagation Techniques

D-8 Mass Production of Improved Material. 2. Seed Orchards

D-9 Gene Conservation and Tree Improvement

D-1O Tree Improvement Strategies

AN INTEGRATED TREE SEED PROGRAMME

Appendix 2

ACTIVITIES — Responsibility for action ⊗ / Cooperating agency X	Forest Dept. etc.	Seed section	Improvement section	Genetic research section
1. Estimation of species priorities in future planting programmes				
For industrial and timber production	⊗			
For fuelwood and local demand for small timber	⊗			
For agroforestry, social forestry and shelter	⊗			
2. Estimation of seed demand by major species				
Current and future plant demands	⊗	X		
Current and future plant demands converted to seed demand	X	⊗		
3. Estimation of areas needed for seed production by major species				
Seed yield per ha per year by species		⊗		
Area needed: i.e. Seed demand divided by Seed yield(ha/year		⊗		
4. National seed supply potential				
Survey of major species distribution	X	⊗	X	X
Establishment of seed zones	X	⊗	X	X
Survey of seed sources and breeding material registered		X	⊗	X
Exploration of potential: seed sources and breeding material	X	X	⊗	X
5. Short and long term strategies for seed procurement and tree improvement				
Needs, possibilities and justification by species	X	⊗	X	X
Outline of a seed procurement programme by species	X	⊗	X	
Outline of a tree improvement programme by species	X	X	⊗	X
Decisions on 1st priority species for seed production	⊗	X		
Work plan for " " " " "		⊗		
Decisions on " " " " improvement	⊗		X	X
Work plan for " " " " "			⊗	
6. Selection, establishment, management, conservation of seed sources				
Registration of seed sources and breeding material established		X	⊗	
Identification of potential sources and breeding material		X	⊗	X
Selection and establishment of — new seed sources from superior mat.		X	⊗	
Selection and establishment of — base populations for future breeding			⊗	
Conservation of important, endangered species/seed sources	X		X	⊗
Testing of selected species, populations + breeding material		X	⊗	X
Establishment of sources + breeding mat., superior in tests		X	⊗	
Management and documentation: Standard seed sources		⊗		
Advanded seed sources and breeding material			⊗	
Forest genetic conservation			⊗	⊗