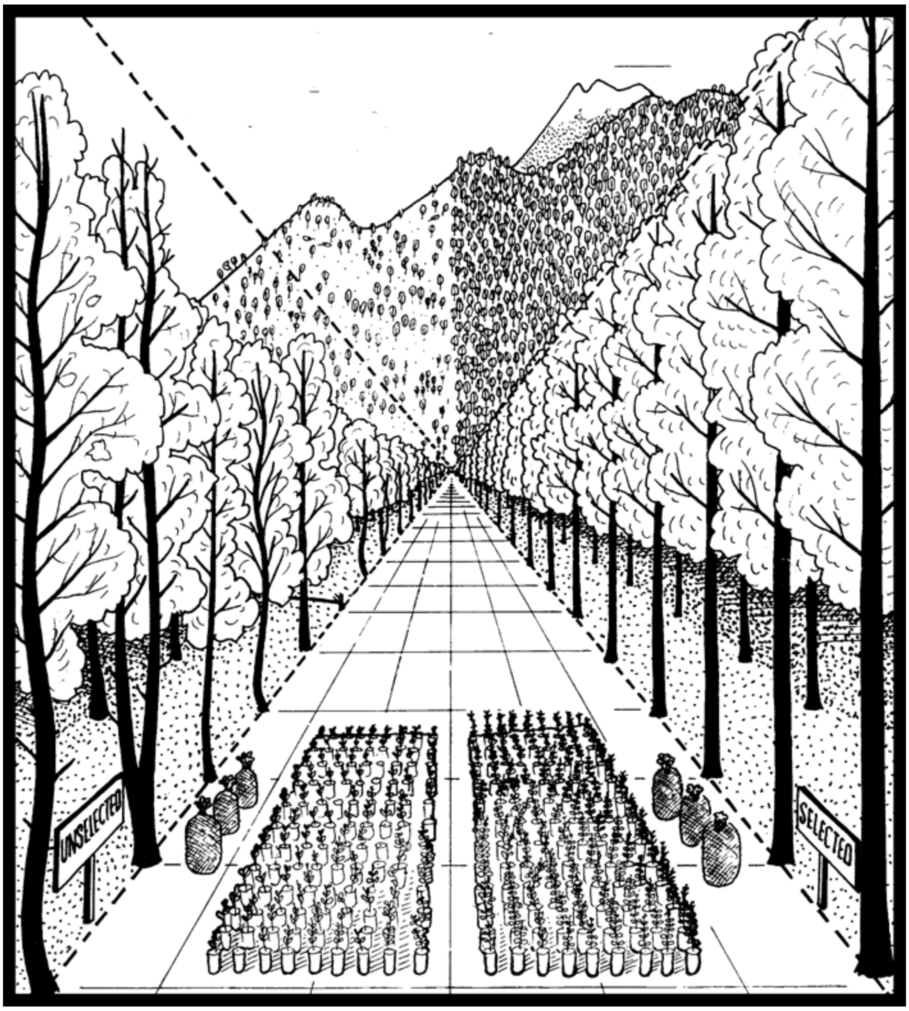
NR Study-note 122

AN OUTLINE OF TREE IMPROVEMENT



Graphics and part of text reproduced from:

Tree Improvement: an outline and plan of action for Nepal.
A.M.J.Robbins and B. Ditlevsen 1988.
HMNG/EEC/ODA National Tree Seed Project.

Revised September 2004

AN OUTLINE OF TREE IMPROVEMENT.

Note: A diagram of general tree improvement is provided at the end of this text and should be referred to while reading. ID letter/numbers in the text correspond to boxes in the diagram. Solid arrows indicate the logical sequence of activities, and broken lines indicate transfer of information. Time increases from left to right. Improvement of sources and production of seeds/cuttings from them are put at the earliest possible time. The actual time scale depends on species and techniques used. Each type of tree improvement activity is illustrated in the subsequent diagrams.

Tree improvement is based on the science of genetics (i.e. the study of genes), and makes use of the natural variation of characters that are under genetic control. The variation of a character (e.g. growth rate, stem straightness, fodder value) is determined, not only by genes, but also by the development (age) of the tree, and the environment in which it is growing (see first illustration at end of text)

Genes are passed from parents to offspring (inherited) and therefore the more a characteristic is under genetic control, the more it will be expressed by the offspring. However, if the environment is the major cause of variation, then differences will be less expressed.

Genetic variation is responsible for many of the differences between: species; separate populations of the same species (ie. provenances); and individual trees. Once such variation is identified, the quality of plants used in future afforestation can be improved by restricting seed collection, breeding and/or vegetative propagation to trees with genetically superior characters.

Tree improvement activities can be divided into three main PHASES

A. SELECTION AND TESTING - Identifying genetic variation.

The classical way of improvement is through SELECTION, TESTING and EVALUATION. These are the basic research studies that must be carried out to distinguish genetic variation from developmental and environmental variation. They are done progressively at different LEVELS (top line of diagram) i.e. SPECIES, PROVENANCE and SINGLE TREE, each requiring an increased depth of study.

Al-3

At species level, the aim is to determine the best species for each of the main sites to be planted.

A4-6

Once these have been identified, their provenances are examined, and the best selected - also for each of the main sites.

A7-9

Then, plus trees can be selected from one or more of the best provenances, and tested in progeny or clonal trials.

A10

Advanced breeding activities are not detailed since these are considered to be of minor importance for Nepal in the near future.

It is important that all three levels are considered to obtain maximum improvement. If a species is known to be suitable for afforestation through common use, testing can start at provenance level. Plus tree selection and testing should normally be restricted to the best provenances, once known.

In principle, the activities should be carried out in the sequence shown in the diagram. However, it may be possible to make short cuts by combining species and provenance testing, or provenance and plus tree testing. Such tests may be more complicated to carry out. Improvement at single tree level may be feasible before provenance testing, if, for example, local provenances are obviously well adapted.

B. IMPROVEMENT OF SEED SOURCES.

The results from selection, testing and evaluation will enable improved sources to be identified and established. These will be the "machines" of the improvement programme, by which improved seeds or cuttings can be produced for routine use.

B0

Afforestation programmes often start using seed collected from any source and any tree. This is the baseline of genetic quality from which improvement is made.

B1

Before selection and testing is started, existing LOCAL sources of commonly used species should be used and the quality improved by collecting from the best trees and/or stands. This need not requirp prior selection and demarcation of the seed trees, as is required for progeny or clonal testing (A7), but may help for control purposes. When possible, good stands should be converted into SEED PRODUCTION AREAS by thinning to remove inferior trees and increase seed production.

B2

Some sources may be difficult to conserve or will be of insufficient area for adequate seed production. In such cases SEED STANDS should be planted and protected.

B3

When provenance testing is started, the sources used should be demarcated and documented, and converted into seed production areas, when possible. Seeds from these stands should be restricted to local use until results are available.

B4

Provenance tests are of little value if the best sources no longer exist when the results become available. This could be the case for many sources in Nepal, where protection of the forest is difficult. If there is any doubt about their future protection, the amount of seed collected should be increased, and part used to establish PROVENANCE CONSERVATION STANDS. Such stands will be used, not only for genetic conservation, but also for routine seed production, and future plus tree selection.

B5

When provenance test results are available, PROVENANCE SEED STANDS should also be established of the most promising provenances, with the main objective of satisfying seed demand. These can be improved further by thinning (see annex 2e).

B6

If improvement continues to single tree level (selection and testing of plus trees), SEED ORCHARDS will be established immediately after selection, either from seed (SEEDLING seed orchards) or from vegetative material (CLONAL seed orchards) (see annexes 2f/g). If the species is easy to mass produce vegetatively, clone banks for production of cuttings will be established.

B7

When plus tree test results are available (from progeny tests), seed orchards and clone banks can be "rogued" ie thinned to remove inferior families or clones.

B8

New seed orchards or clone banks can be established using only superior clones, if demand for seeds or cuttings is high enough.

It is important to maintain a broad genetic base (breeding population) for selection of new gene combinations in the future. Provenance conservation stands are important in this respect, but also seed production areas and provenance seed stands are valuable. After starting single tree improvement and establishment of seed orchards etc., progeny, clonal trials or clone banks can serve as future breeding populations.

C. PRODUCTION OF IMPROVED SEEDS AND CUTTINGS - Possible gains.

The final phase is the actual mass production of seeds or cuttings, in sufficient quantities for afforestation. This output enables the forester to benefit from the improvements made. The genetic quality of the seed or cuttings will increase, according to the grades shown. The degree of improvement between each grade will vary considerably depending on species and characteristics, and is not necessarily uniform (See Willan 1988 for experience in other countries). The arrows indicate from which source the seeds or cuttings originate, and the relative time at which they will be available.

C0

Without supervision of seed collection, the quality of seeds used for afforestation may be inferior to the average quality of local sources. Inferior seed trees may produce seedlings more susceptible to disease, with poorer survival and growth rate.

C1

When seeds of commonly used species are collected from the best trees or stands in local sources only, a significant improvement can be obtained over the 'baseline1 . This can be further increased through removal of inferior trees in stands that are used for seed collection. Survival, growth rate and form will be improved.

C2

After testing, inferior species are discontinued. The potential for improvement here is great, particularly if the original choice of species was inappropriate. For example, survival rates between species in current use may vary from 20% - 90%, and the growth rate of those with best survival may vary by 100%. Thus selection of the best species could increase production by more than 400%.

C3

After provenance testing, only the best provenances will be used. Improvement will vary, depending on the variation of the species in its natural distribution. It can be as great as the difference between species. Growth rate, for example, can vary by 100% between the best and worst provenances and some may be total failures.

C4

After plus tree selection, seeds for routine use can be collected from them and bulked, providing further improvement, limited by open pollination. The gains will be best for characteristics such as form, where a 5 ~ 10$ improvement could be expected.

C5

Cuttings will be available immediately after selection of plus trees, whereas seeds from non-rogued clonal seed orchards first become available after adequate flowering has started. This provides further improvement, as pollination can only occur between the ramets of the plus trees. Gains will depend on the characteristic being selected. Stem straightness could be improved to an acceptable level in 90$ of the progeny instead of 20%. Growth rate could be increased by

C6

After testing plus trees, the seed orchards are rogued and seeds collected from the best plus tree clones or progenies. Cuttings could be collected in the same way from the superior clones or progenies. This will further increase improvement, the gains being dependent on how well the original selections were made.

C7

Seed provided from the next generation breeding will show improvement particularly for individual characteristics.

This outline refers to native (indigenous) species, but applies equally well to exotic species introduced from outside Nepal. For these, provenance and plus tree selection must be carried out in cooperation with the country where the natural stands are found.

D. TIME SCALE

The time arrow has not been given a scale, as this changes according to the species being improved and the level of improvement being undertaken.

Species trials may yield useful results after one growing season, enabling unsuitable species to be rejected within a year. Comparisons between those species that look promising may take up to 5 years or more if characteristics such as growth rate are to be examined.

Provenance trials can be started at the same time as species trials if the species is already known to be suitable. Otherwise they must wait until the species trials are completed. Since differences between provenances (as compared with species) is often less pronounced, 3 ~ 7 years may be required to produce reliable results.

Plus tree selection should wait until the best provenances are confirmed, but can start simultaneously with establishment of provenance trials or even earlier if local, well adapted provenances are available. Results from progeny trials will usually take a minimum of 3 years, depending on which characteristics are being examined, and usually 7 or more years.

Thus the total time scale for the selection and testing phases for species through to evaluation of progeny trials will be at least 8-20 years.

The time scale for establishment of improved sources and production of seed from them will be largely dictated by the selection and testing stage. Establishment of plantations or seed orchards will usually take 1-3 years and is dictated by the time required to collect the seeds or cuttings, raise the plants, and plant out.

Production of seeds from seedling plantations will depend on the time that abundant flowering starts, and may take at least 8 years, and usually 10-15 years. In the case of clonal seed orchards where vegetative material is used, seed production can be much earlier, perhaps after as little as 3 years.

STATUS OF PRESENT TREE IMPROVEMENT IN NEPAL

A. ROUTINE SEED COLLECTIONS.

Seed collection in Nepal has been carried out with little consideration to genetic quality, since priority has had to be given to quantity. The seed has been collected from any available source, usually the most easily accessible and climbable trees with abundant fruit production, which in many ways may be genetically inferior (slow growth rate, excessive branching, diseased etc). Collections made in the districts are usually used locally, but those arranged centrally have been from a range of sources throughout the country, distributed to all parts of the country with little attempt made to match provenance with site.

The seed of some indigenous species have been imported from outside the country when local supplies have been insufficient. In the case of Chir pine, large quantities have been obtained from India, and as far afield as Pakistan. These are now known to show inferior performance compared with local provenances. Some imported exotic species have come from doubtful origin, or else (in the case of Pinus patula) from highly bred sources that have not been properly tested within Nepal, and could be unsuitable for further genetic improvement.

As a result, it is possible that seeds used for many afforestation programmes in Nepal have been actually inferior to seeds available locally. The National Tree Seed Project is attempting to promote the collection of locally available seed, and control the distribution of seed around the country, and thus this situation should improve in the immediate future.

B. SELECTION AND TESTING.

Many projects have already carried out a considerable amount of research about choice of species and provenances. A large part of this work has been carried out by HMGN's Research Office, in particular by the Silvicultural Research Project (now the Forestry Research Project). Most of the trials have been established in the central region from the Terai up to the higher mid-hills.

Until a few years ago, emphasis has been on the testing of exotic species (eg tropical and subtropical pines, and eucalypts), and in some' cases, the different provenances of these. The logic of this was that exotic species would probably show better performance than local species. With the exception of Eucalyptus camaldulensis (in the Terai) and Ptnus patula (in the high mid- hills) there are few other exotics that are clearly better, and so emphasis is

now turning to testing indigenous species, and for a few of these (eg Dalbevgia sissoo, Alnus nepalensis, Ptnus roxbuTeghii) provenance trials have been started.

Full details of the species and provenances tested in Nepal can be found in the Forest Research and Information Centre's (FRIG) Forestry Research Compendium (Hudson 1987)•

C. CONSERVATION

The Department of Parks and Wildlife Conservation has been active in creating preserves many of which include large areas of natural forest, within which are found species and provenances of importance to foresters. The objective of these preserves has usually been to protect a particular habitat and its associated fauna, and not to protect an individual forestry species.

PRIORITIES FOR FUTURE TREE IMPROVEMENT

The resources available for tree improvement limit what can be done, and therefore priorities must be assigned to various aspects of improvement, so that they reflect the needs of the country.

A. WHICH SPECIES ARE OF HIGHEST PRIORITY FOR AFFORESTATION?

To answer this, several factors relating to the use of the species for afforestation should be considered:

SOCIO-GEOGRAPHIC AREA: Nepal can be divided into three areas, reflecting the priorities of the national development plans: the Terai; the middle hills; and the mountains. Each area has its own range of species that provide forest products. The middle hills are of highest priority, due to high population pressure and rapidly diminishing forest resources. The Terai is of second priority, where resettlement is taking place, and demand for forest products is increasing. The mountains, although suffering from acute shortages in some areas, have lowest priority due to the smaller population.

END USE: The species found in these areas provide a variety of end uses eg. timber, poles, fodder, fuelwood, medicinal products, fruit, soil stabilisation. Many have several end uses, and can be classified as multipurpose. Priorities given to species according to their end use depend on the areas in which they are found. In the middle hills, the greatest demand is for fodder, followed by fuelwood. In the Terai, the situation is reversed, and species for fuelwood have highest priority. In both areas, species providing poles and timber are of lower priority for planting, but will increase in importance as existing natural timber stands are depleted.

USER'S PREFERENCE: For any given end use, there are often many suitable species, and the local users will rate them on a scale of preferences. This will be based on the users' assessment of the quality of the end use product; availability; and sometimes tradition. Importance must be given to users' preference, but some preferred species may not be suitable for afforestation, since conditions under which they are to be raised and used will have changed. In such cases, another species, perhaps unknown to the user group but having an end use of equal value, must be substituted.

CURRENT PLANTATION PROGRAMMES: The relative amounts of species actually planted at present should reflect the priorities given to them by development area, end use, and users' preference, and so could be taken directly as a guide. However, this may be misleading in certain cases where current forestry practices are determined by technical ease rather than social need. For example, a species may be widely planted, simply because seed is easily available and plantation targets can be fulfilled, although the end product is of low priority for the users.

TECHNICAL IMPORTANCE: Some species may need to be given priority even though the immediate needs of the users are not met. Such is the case for species used for land reclamation and soil stabilisation. If only poor degraded sites are available for afforestation, pioneer species will be needed that are easily established, and can stabilise and improve the sites initially. Later, they can act as a nurse crop for species that are more difficult to establish, but which can then satisfy the needs of the local users (this is the justification for using Chir pine).

DISTRIBUTION OF SPECIES: If two species appear to have equal priority according to the foregoing points, then further consideration should be given to the area over which the species is found or used. Priority should be given to those species covering the widest geographical area, since the benefits will be appreciated by a wider range of the population.

REGIONAL IMPORTANCE: After national priorities have been considered, the regional importance of the species should be considered - ie how much it is used outside the country. Thus if two species are given equal importance within the country, preference should be given to the one that is of greater importance outside.

B. WHICH OF THESE SPECIES CAN BE IMPROVED?

All species have the potential for being improved but there are certain constraints that must be taken into account. The natural variation of the species must be considered. If this is small, it may not be worth doing any improvement work. If large, then improvement may be worthwhile. The breeding systems of some species may make it difficult or impossible to establish seed orchards, and so only improvement by clonal means can be considered. It is therefore important to obtain background information about a species in relation to its potential for improvement before starting a programme.

C. WHAT CHARACTERISTICS SHOULD BE IMPROVED?

This depends on various points, such as the end use of the species, the natural variation of the characteristic, and its genetic heritability. In the initial stages of tree improvement, the aim will be to maximise the survival of the species planted, its subsequent growth rate, and its resistance to disease. Thereafter, the characteristics will be determined by end use:

TIMBER: The quality of the wood should be improved in such respects as stem straightness, lightness of branching, natural pruning, wood density and straightness of grain.

FODDER: Maximum height growth and form will not be important, but rather maximum production of leaves and/or nutrient content of the leaves, variation in lopping season, and facility for regrowth after lopping.

FIREWOOD: The calorific value of the timber and ease of seasoning and splitting will be important. Whereas prolific and persistant branching will be a disadvantage for timber trees, it may be an advantage for firewood production. A bushy habit may be an advantage over an upright form, since lopping can be carried out easily (as for fodder species).

SOIL STABILISATION: Since the aim is to cover the area as quickly as possible, survival and initial growth rate will be of greatest importance. The actual form of the tree will be of lesser importance.

MULTIPURPOSE TREES: In the case of species that have several end uses, a compromise will have to be reached with regard to which characteristic is improved.

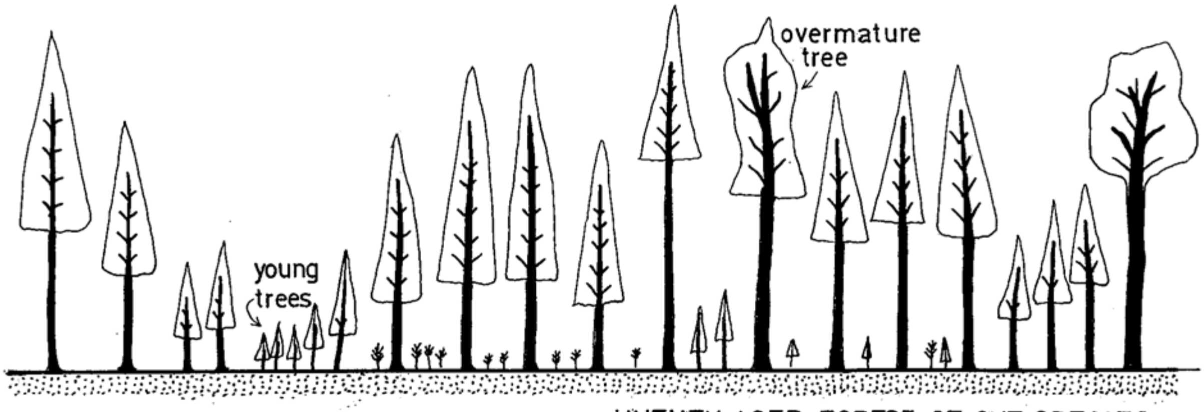
Other end uses will have additional characteristics which may need to be considered.

D. WHAT LEVEL SHOULD IMPROVEMENT BE TAKEN TO?

This will depend on the priority given to the species; the time taken to carry out the improvement; and the costs and technical feasibility of continuing to the higher levels of improvement. A full answer can only come after the initial stages of improvement have started, and more is known about the potential for each species for improvement. It may be advisable to use the resources available to carry out initial improvement on several species where large gains can be expected, rather than concentrate on improving a few species to higher levels, where improvement will not be so great.

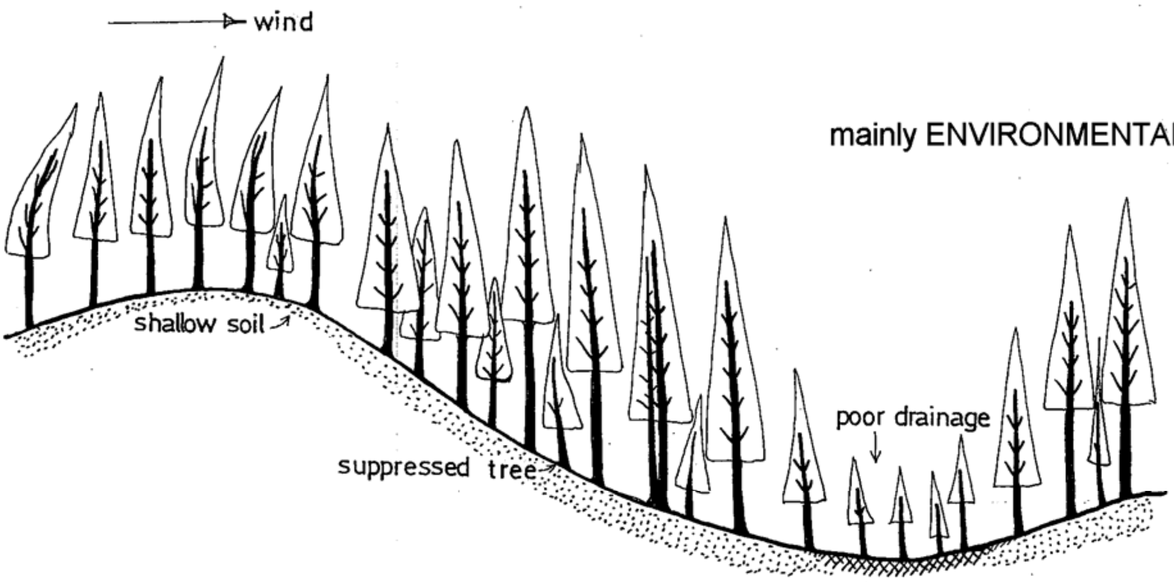
CAUSES OF VARIATION

mainly DEVELOPMENTAL



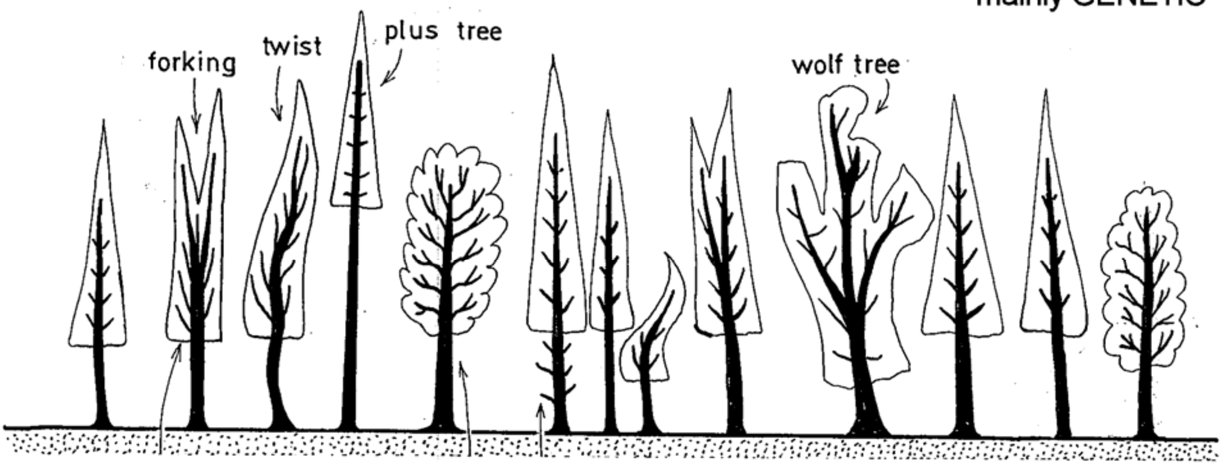
UNEVEN-AGED FOREST OF ONE SPECIES ON UNIFORM SITE

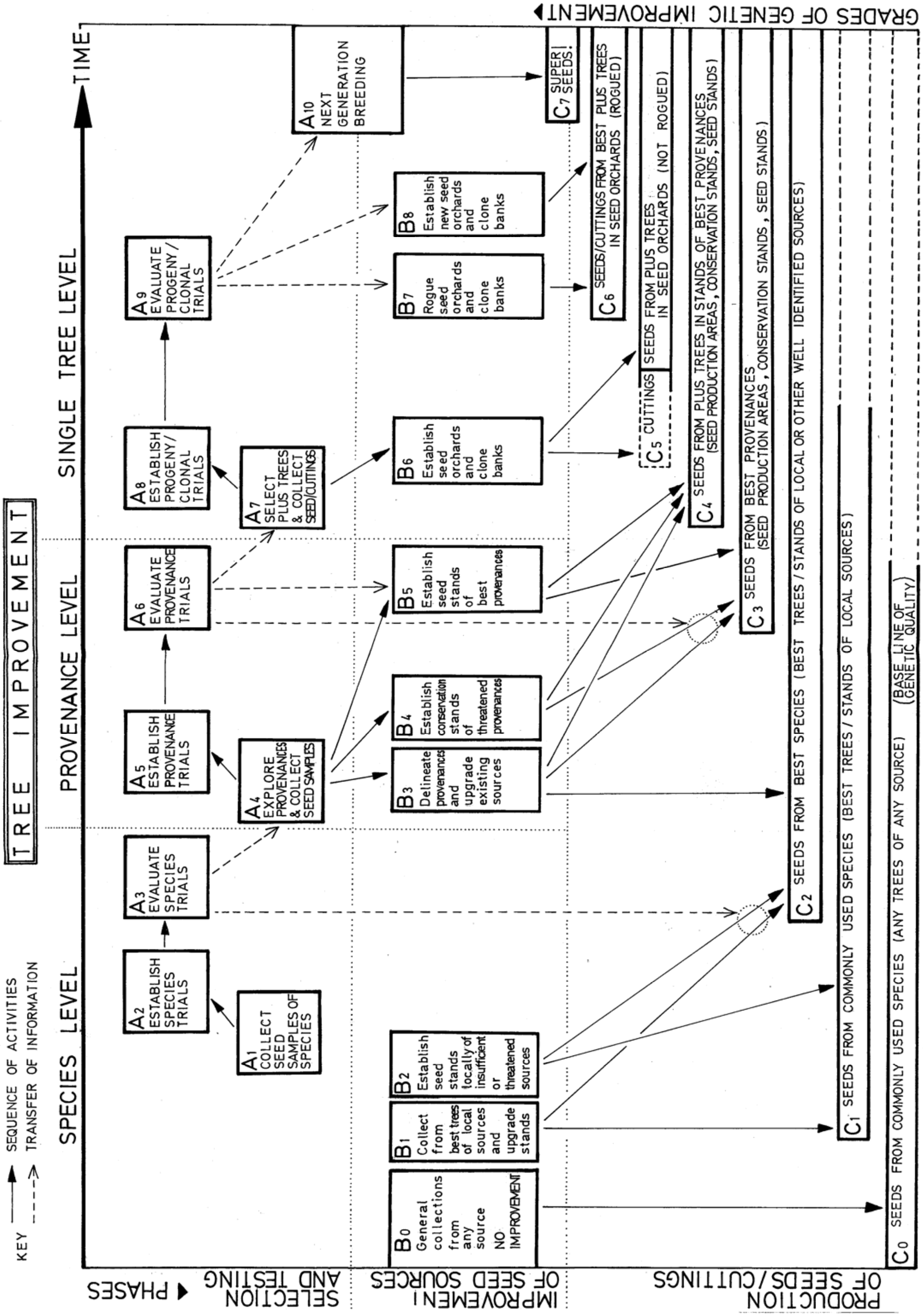
mainly ENVIRONMENTAL

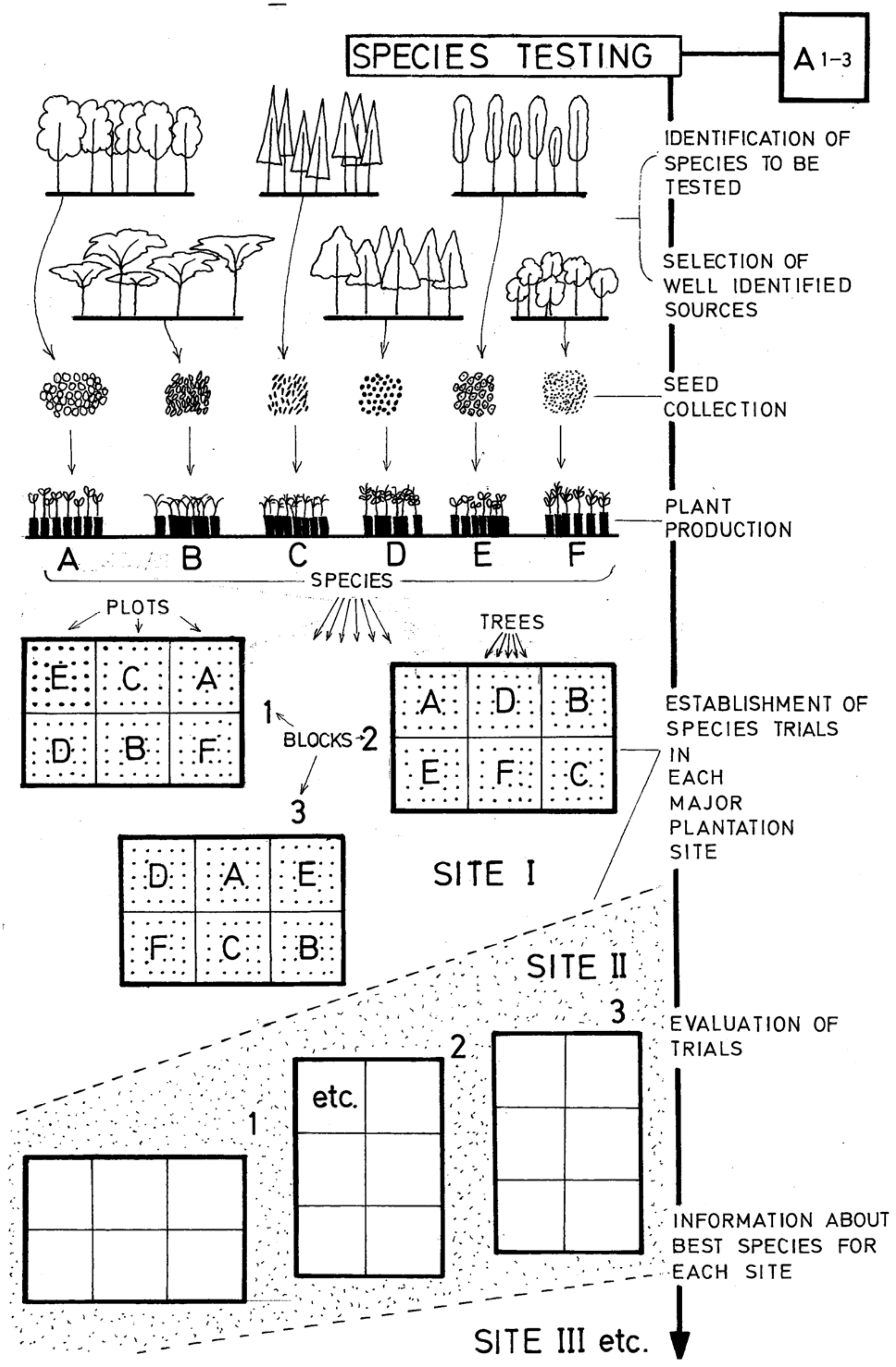


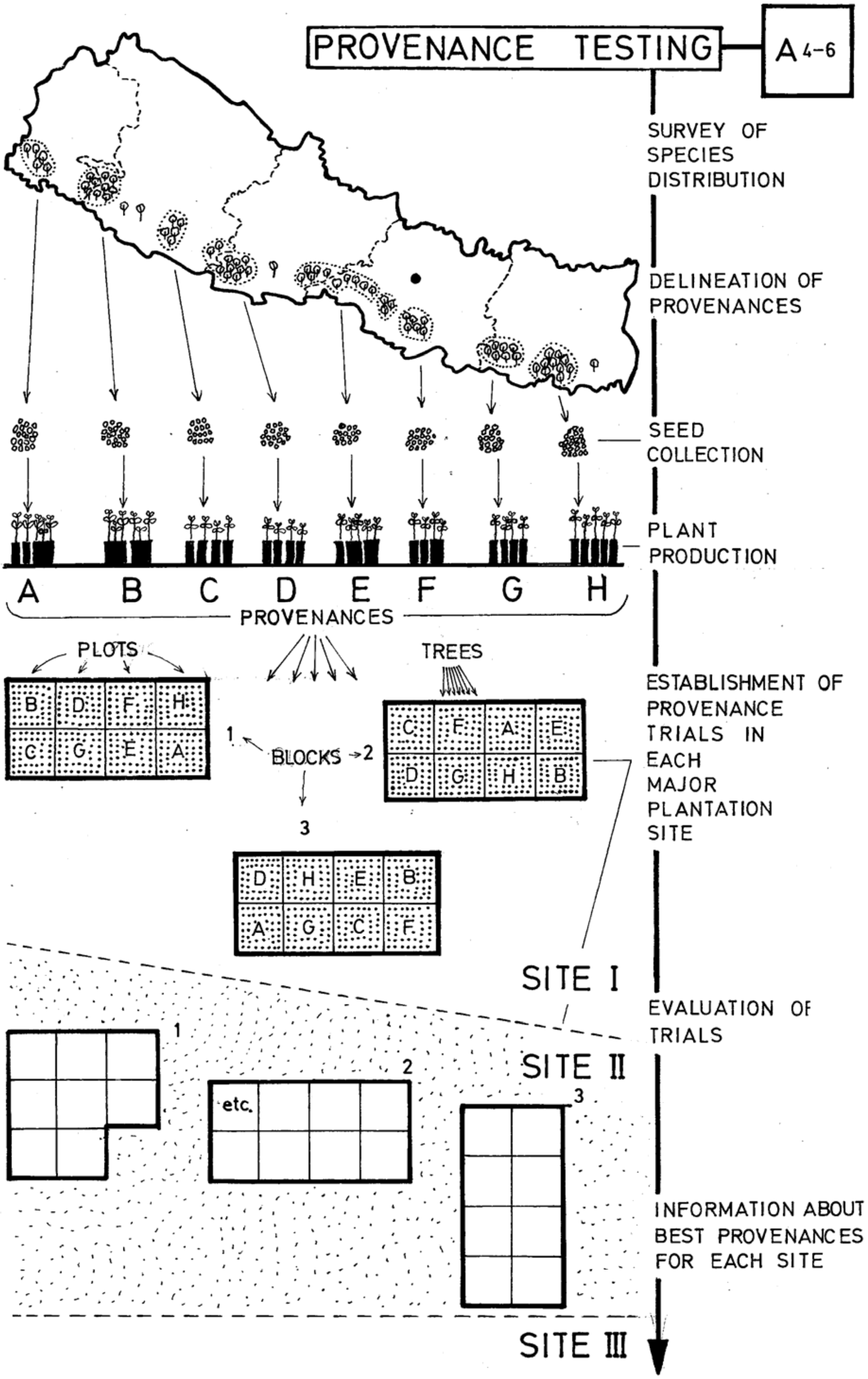
EVEN-AGED FOREST OF ONE SPECIES ON VARIABLE SITE

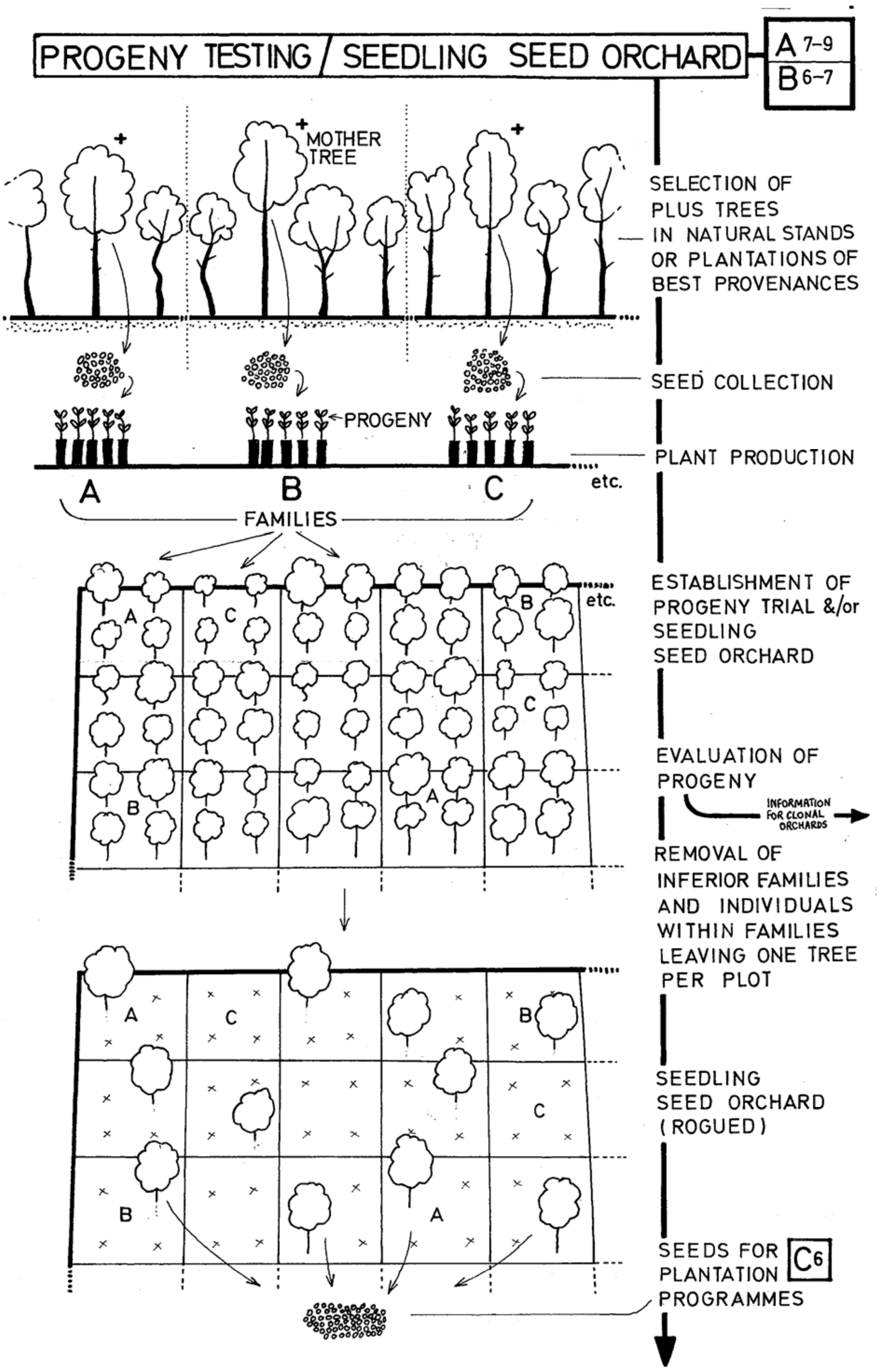
mainly GENETIC

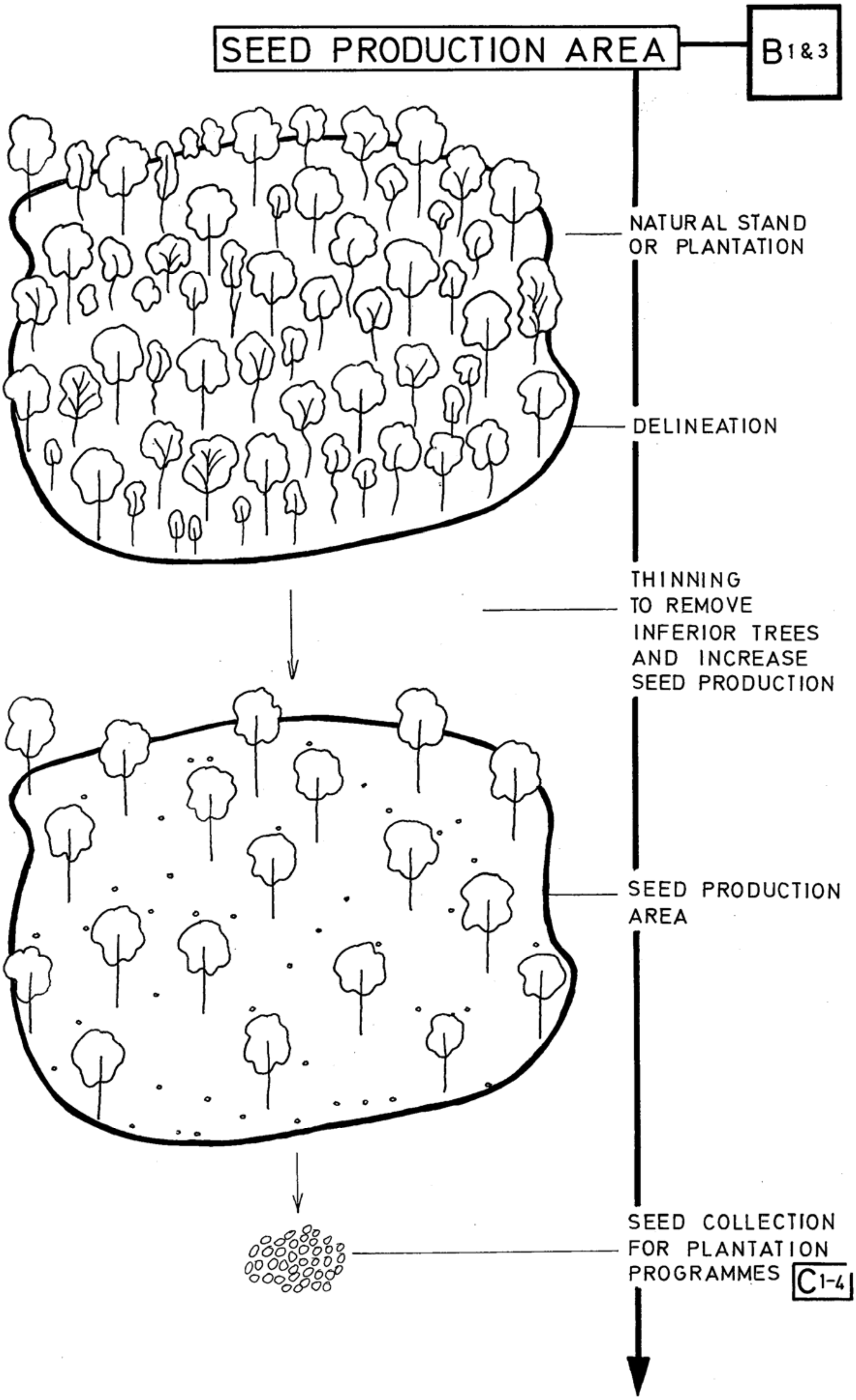


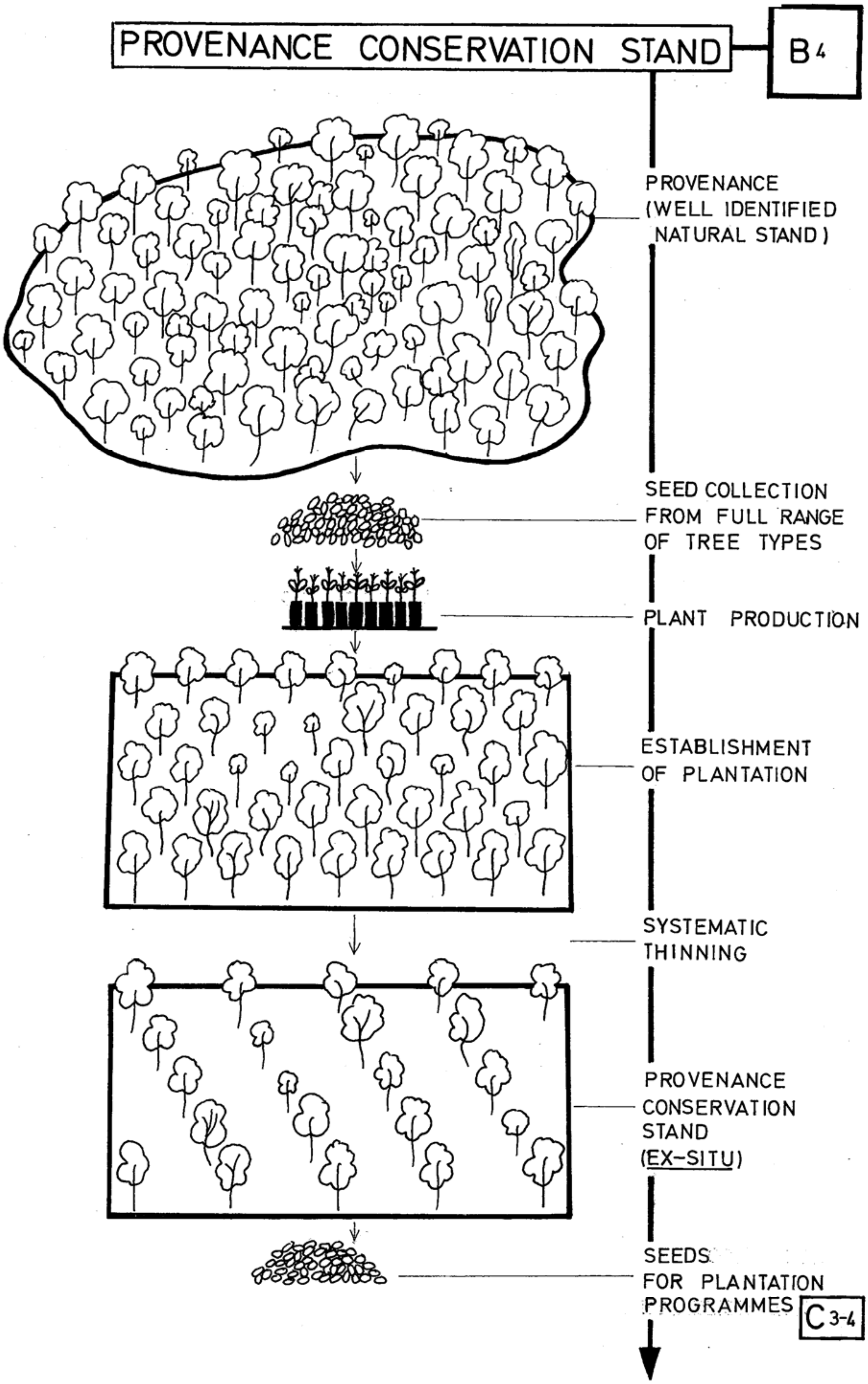

TREE IMPROVEMENT
KEY
SEQUENCE OF ACTIVITIES
TRANSFER OF INFORMATION
SPECIES LEVEL
PROVENANCE LEVEL
SINGLE TREE LEVEL
TIME
PHASES
SELECTION AND TESTING
IMPROVEMENT OF SEED SOURCES
PRODUCTION OF SEEDS/CUTTINGS
GRADES OF GENETIC IMPROVEMENT
A1 COLLECT SEED SAMPLES OF SPECIES
A2 ESTABLISH SPECIES TRIALS
A3 EVALUATE SPECIES TRIALS
A4 EXPLORE PROVENANCES & COLLECT SEED SAMPLES
A5 ESTABLISH PROVENANCE TRIALS
A6 EVALUATE PROVENANCE TRIALS
A7 SELECT PLUS TREES & COLLECT SEED/CUTTINGS
A8 ESTABLISH PROGENY/ CLONAL TRIALS
A9 EVALUATE PROGENY/ CLONAL TRIALS
A10 NEXT GENERATION BREEDING
B0 General collections from any source NO IMPROVEMENT
B1 Collect from best trees of local sources and upgrade stands
B2 Establish seed stands locally of insufficient or threatened sources
B3 Delineate provenances and upgrade existing sources
B4 Establish conservation stands of threatened provenances
B5 Establish seed stands of best provenances
B6 Establish seed orchards and clone banks
B7 Rogue seed orchards and clone banks
B8 Establish new seed orchards and clone banks
C7 SUPER! SEEDS!
C6 SEEDS/CUTTINGS FROM BEST PLUS TREES IN SEED ORCHARDS (ROGUED)
C5 CUTTINGS
SEEDS FROM PLUS TREES IN SEED ORCHARDS (NOT ROGUED)
C4 SEEDS FROM PLUS TREES IN STANDS OF BEST PROVENANCES (SEED PRODUCTION AREAS, CONSERVATION STANDS, SEED STANDS)
C3 SEEDS FROM BEST PROVENANCES (SEED PRODUCTION AREAS, CONSERVATION STANDS, SEED STANDS)
C2 SEEDS FROM BEST SPECIES (BEST TREES / STANDS OF LOCAL OR OTHER WELL IDENTIFIED SOURCES)
C1 SEEDS FROM COMMONLY USED SPECIES (BEST TREES / STANDS OF LOCAL SOURCES)
C0 SEEDS FROM COMMONLY USED SPECIES (ANY TREES OF ANY SOURCE)
(BASE LINE OF GENETIC QUALITY)

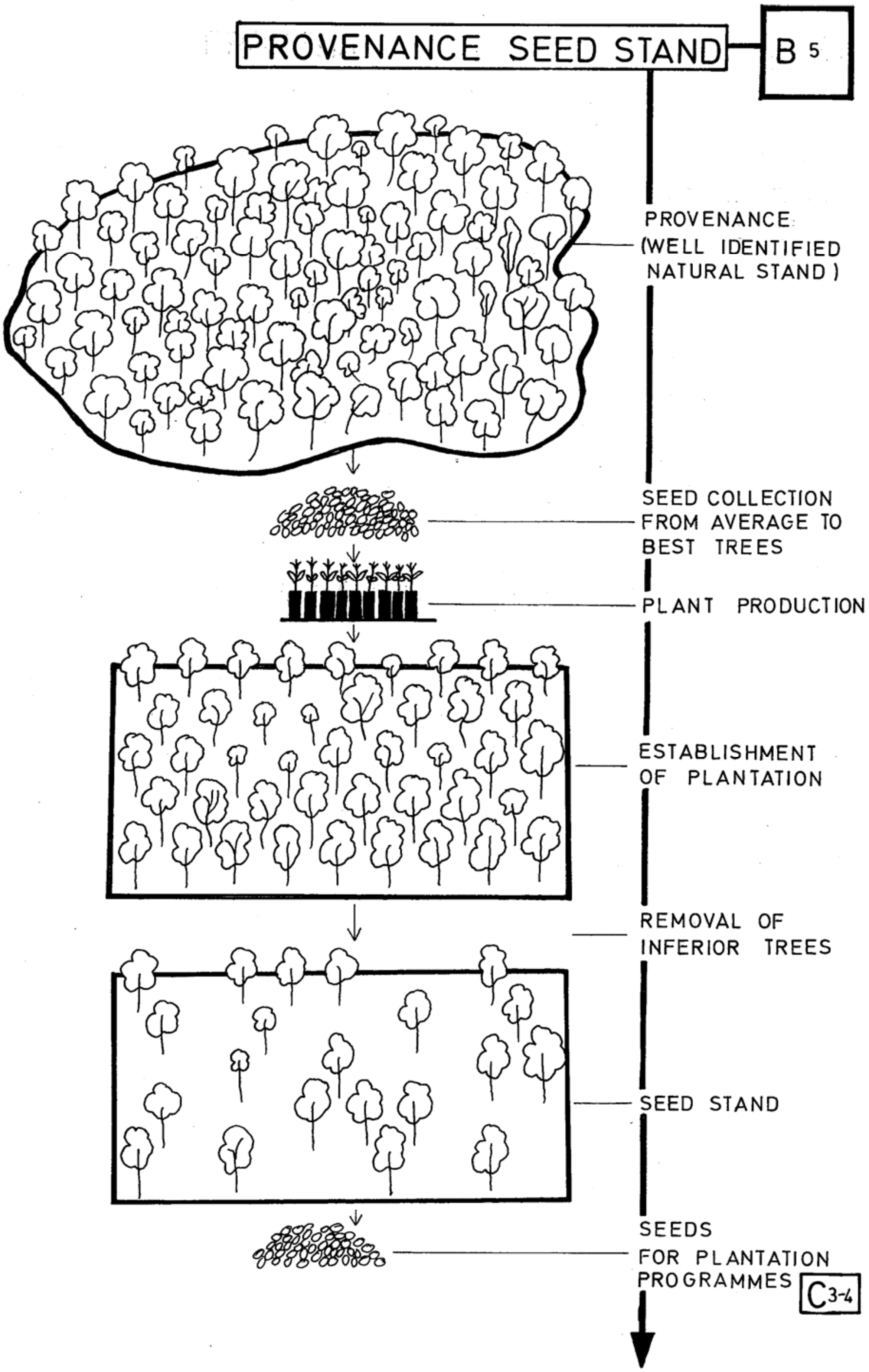

SPECIES TESTING
A 1-3
IDENTIFICATION OF SPECIES TO BE TESTED
SELECTION OF WELL IDENTIFIED SOURCES
SEED COLLECTION
PLANT PRODUCTION
A B C D E F
SPECIES
PLOTS
TREES
E C A
D B F
A D B
E F C
1
BLOCKS 2
3
D A E
F C B
SITE I
ESTABLISHMENT OF SPECIES TRIALS IN EACH MAJOR PLANTATION SITE
SITE II
1
2
3
etc.
EVALUATION OF TRIALS
INFORMATION ABOUT BEST SPECIES FOR EACH SITE
SITE III etc.

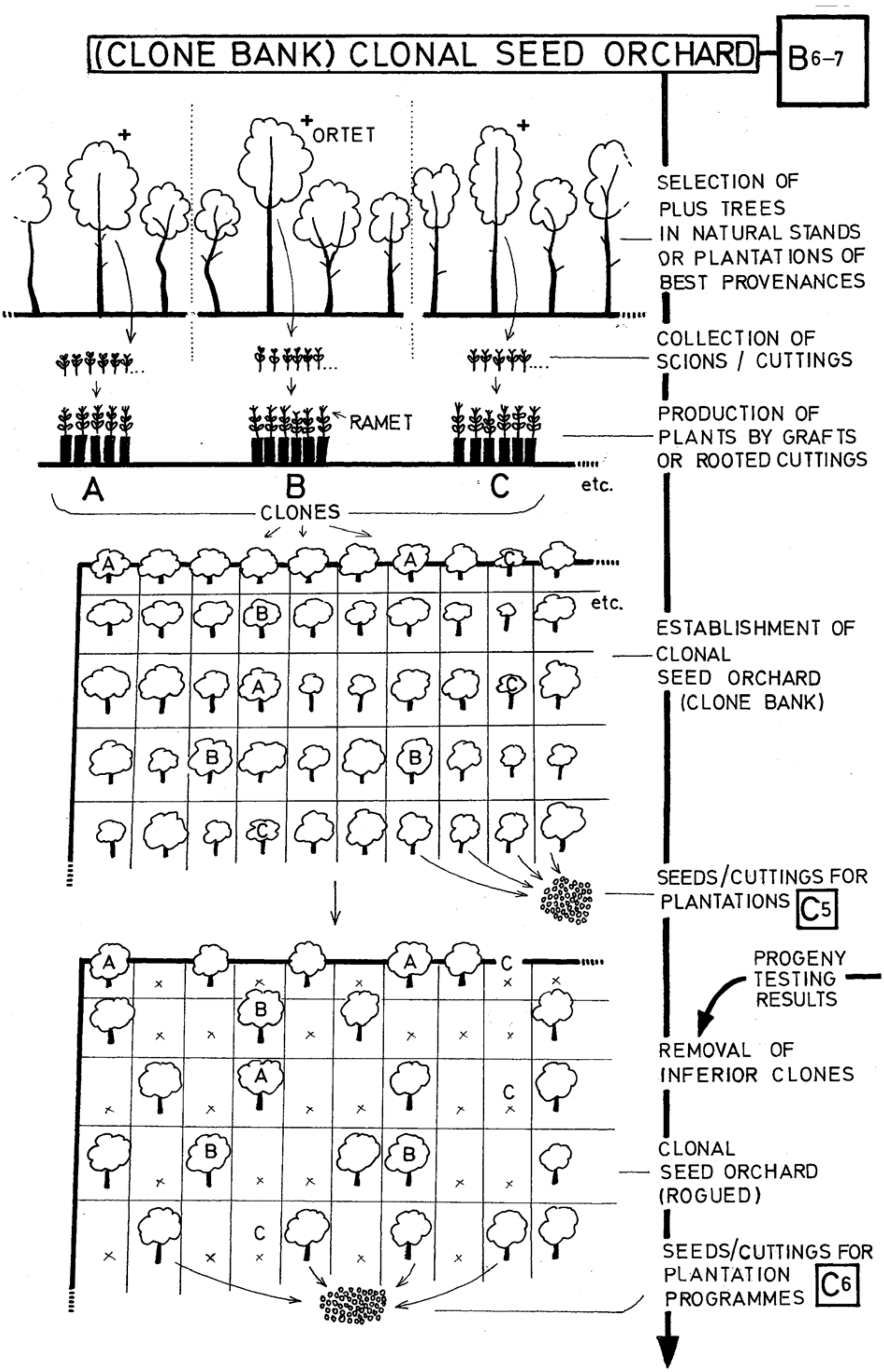

PROVENANCE TESTING
A 4-6
SURVEY OF SPECIES DISTRIBUTION
DELINEATION OF PROVENANCES
SEED COLLECTION
PLANT PRODUCTION
A B C D E F G H
PROVENANCES
PLOTS
TREES
B D F H
C G E A
1
BLOCKS
2
3
C F A E
D G H B
D H E B
A G C F
ESTABLISHMENT OF PROVENANCE TRIALS IN EACH MAJOR PLANTATION SITE
SITE I
EVALUATION OF TRIALS
SITE II
1
2
etc.
3
INFORMATION ABOUT BEST PROVENANCES FOR EACH SITE
SITE III


PROGENY TESTING / SEEDLING SEED ORCHARD
A 7–9
B 6–7
MOTHER TREE
SELECTION OF PLUS TREES IN NATURAL STANDS OR PLANTATIONS OF BEST PROVENANCES
SEED COLLECTION
PROGENY
PLANT PRODUCTION
A
B
C
etc.
FAMILIES
ESTABLISHMENT OF PROGENY TRIAL &/or SEEDLING SEED ORCHARD
EVALUATION OF PROGENY
INFORMATION FOR CLONAL ORCHARDS
REMOVAL OF INFERIOR FAMILIES AND INDIVIDUALS WITHIN FAMILIES LEAVING ONE TREE PER PLOT
SEEDLING SEED ORCHARD (ROGUED)
SEEDS FOR PLANTATION PROGRAMMES
C6


SEED PRODUCTION AREA
B1 & 3
NATURAL STAND OR PLANTATION
DELINEATION
THINNING TO REMOVE INFERIOR TREES AND INCREASE SEED PRODUCTION
SEED PRODUCTION AREA
SEED COLLECTION FOR PLANTATION PROGRAMMES
C1-4


PROVENANCE CONSERVATION STAND
B4
PROVENANCE
(WELL IDENTIFIED
NATURAL STAND)
SEED COLLECTION
FROM FULL RANGE
OF TREE TYPES
PLANT PRODUCTION
ESTABLISHMENT
OF PLANTATION
SYSTEMATIC
THINNING
PROVENANCE
CONSERVATION
STAND
(EX-SITU)
SEEDS
FOR PLANTATION
PROGRAMMES
C3-4


PROVENANCE SEED STAND
B 5
PROVENANCE (WELL IDENTIFIED NATURAL STAND)
SEED COLLECTION FROM AVERAGE TO BEST TREES
PLANT PRODUCTION
ESTABLISHMENT OF PLANTATION
REMOVAL OF INFERIOR TREES
SEED STAND
SEEDS FOR PLANTATION PROGRAMMES
C3-4


(CLONE BANK) CLONAL SEED ORCHARD
B6–7
ORTET
SELECTION OF PLUS TREES IN NATURAL STANDS OR PLANTATIONS OF BEST PROVENANCES
COLLECTION OF SCIONS / CUTTINGS
RAMET
PRODUCTION OF PLANTS BY GRAFTS OR ROOTED CUTTINGS
A
B
C
etc.
CLONES
ESTABLISHMENT OF CLONAL SEED ORCHARD (CLONE BANK)
SEEDS/CUTTINGS FOR PLANTATIONS
C5
PROGENY TESTING RESULTS
REMOVAL OF INFERIOR CLONES
CLONAL SEED ORCHARD (ROGUED)
SEEDS/CUTTINGS FOR PLANTATION PROGRAMMES
C6

NOTES on diagrams:

SPECIES TESTING: (A1-3)

Each species seed sample must come from well identified sources and a sufficient number of mother trees (usually 20 or more), typical of the natural range and variation of the species. The sites chosen for the trials must be representative of the plantation areas. They must be as uniform as possible, and well protected. The trials can be laid out in a variety of ways, of which only one is illustrated. Plot size is frequently 5x5 = 25 plants. If 4 replicates are used, 100 saplings will be needed per site. The spacing will depend on the species, and is usually close (e.g. 1.5 -2m) since the trials only run for about 5 years.

PROVENANCE TESTING (A4-6)

As with species trials, seed samples must come from well identified sources and an adequate number of mother trees. The sites for the trials must be carefully chosen in the same way as for species testing. The trials can be laid out in a variety of different ways. As differences between provenances are often smaller than between species, bigger plots are usually needed - in the example shown they are 7x7= 49 plants. If 4 replicates are used, nearly 200 saplings will be needed per site. Spacing will depend on the species, but as the trial may run for longer than species trials - 7 or more years - wider spacing is used (e.g. 2 - 3 m).

SEED PRODUCTOIN AREA (B1&3)

The natural stand or plantation that is selected will vary in size, depending on availability. 5 ha is often a minimum size. The quality of the existing trees should be better than the average of the surrounding stands. The stand should be old enough to allow differences in characteristics between trees to be expressed, but not so old that the crowns are suppressed and will therefore not respond to thinning. The actual thinning intensity will depend on the initial spacing, and may need to be done in stages. Typical final stockings will be from 100 - 500 stems per ha. to allow plenty of space for crown development. It is best if the stand is isolated from nearby pollen sources.

PROVENANCE CONSERVATION STAND (B4)

The natural stand will vary considerably in size, depending on type and extent of the species distribution. Seed collection will be from all trees so as to conserve the full range of genetic variation. The size of the plantation established from the seed will depend on the original stand area, and the no. of trees collected. A usual minimum is 5 ha, but much more may be needed. The stands must be properly isolated from other sources of pollen. The spacing between the trees will be greater than for normal plantations to allow for good crown development. Thinning is systematic so that no particular tree is favoured. If it were possible to protect the original natural stand, this would be termed 'in-situ' conservation.

PROVENANCE SEED STAND (B5)

The same-notes apply as for conservation stands, except that seed is collected from the best trees, and when thinning is carried out, the inferior trees are removed, leaving only the best genotypes.

PROGENY TESTING / SEEDING SEED ORCHARD (A7-9 / B6-7)

Number- of plus trees selected, hence families, can range from 30-200+. Spacing should be sufficient to avoid inbreeding. Thus area covered during selection can vary from 50-1000+ ha. Selection is best carried out in plantations such as PCSs, where conditions are uniform. Site chosen for orchard should also be uniform, accessible, easily protected, and of suitable climate. There are many designs of seed orchard - only one is shown. Area will vary from 1-50+ ha. Number of individual trees (progeny) per family will start at around 20. These will be planted in small plots of e.g. 4 trees, then thinned to the best trees per plot, or eliminated completely. Distribution of plots must ensure those with same family are not close so as to minimise interbreeding after thinning. It is not always possible to combine progeny trials and seedling seed orchards since progeny trial site should be typical of plantation site, but may not be suitable for abundant seed production.

CLONE BANK / CLONAL SEED ORCHARD (B6-7)

The same notes apply for the selection of plus trees as for progeny testing. In some species, vegetative propagation may only be possible by cutting the tree down and allowing it to sprout. The number of individuals (ramets) within a clone will start from around 20 upwards. These will be genetically identical. The layout of the clonal seed orchard can be done in various ways. The most important factor is to keep the ramets of a clone well spaced out so that inbreeding is minimised as much as possible. If the orchard is to be used purely for cutting production, then the individual ramets of a clone can be kept together.