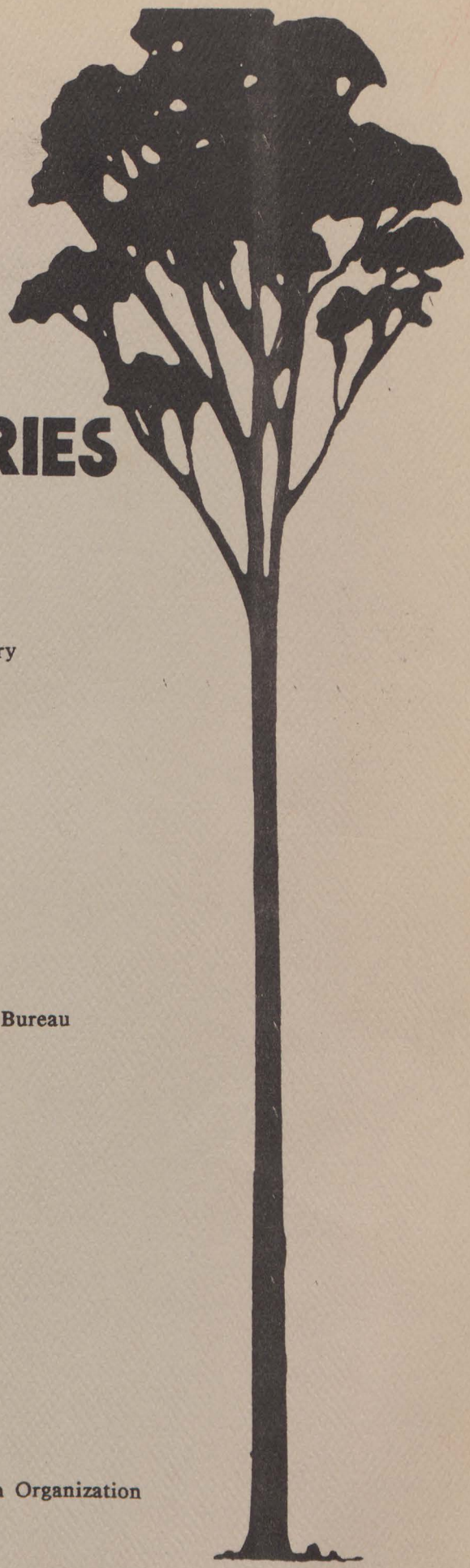


DFR USER SERIES

Number 2

FROM SEED TO TRIAL ESTABLISHMENT

A handbook giving practical guidelines in nursery practice and the establishment of simple species and/or provenance trials.

E.J. Carter

December, 1987

Published with the assistance of the
Australian International Development Assistance Bureau
under the
Seeds of Australian Trees for Developing
Countries Project

Forest
Research
CSIRO

Commonwealth Scientific and Industrial Research Organization

Australian Tree Seed Centre
CSIRO Division of Forest Research

Number 2

FROM SEED TO TRIAL ESTABLISHMENT

A handbook giving practical guidelines in nursery practice and the establishment of simple species and/or provenance trials.

E.J. Carter

December, 1987

Published with the assistance of the
Australian International Development Assistance Bureau
under the
Seeds of Australian Trees for Developing
Countries Project

ACKNOWLEDGEMENTS

Many people have contributed towards the writing of this manual, but I would like to acknowledge in particular the support, encouragement and advice given by Alan Brown, Doug Boland, John Doran, Ken Eldridge, Rod Griffin, Colin Matheson, Stephen Midgley, Lex Thomson, David Spencer and Tim Vercoe of the CSIRO Division of Forest Research, Emlyn Williams of the CSIRO Division of Mathematics and Statistics and Grahame Applegate of the Queensland Department of Forestry. Others who have given particular assistance include Roger Ellyard and Ruth Kerruish of the Horticulture Section of the Weston Technical and Further Education College and Peter Ollerenshaw of the National Botanic Gardens. The invaluable, although indirect, contribution of the officers of the Sri Lankan Forest Department with whom I worked for two years must also be mentioned.

Finally, my thanks to Marlene Risby for her enthusiastic work on the illustrations in this manual, and to Eva Morrow and Anita Gracie for their patient typing.

Jane Carter
Tree Seed Centre
August 1986

CONTENTS

FIGURES

APPENDICES

1.0 INTRODUCTION

Why carry out species and provenance trials?

The role of plantation forestry is becoming more important in meeting the increasing demand for wood products, as human populations grow and natural forests are cleared for agriculture, become degraded and unproductive, or become unavailable for wood production.

Establishing and maintaining plantations requires major capital investment and administrative commitment. It costs just as much to establish a plantation with genetically poor seed as with a more suitable species or provenance. A 25% improvement in yield per hectare through using more suitable genetic material identified in trials is easily obtained in many cases. Such an improvement is equivalent to establishing 25% more plantation area at no additional cost. Identification of the most appropriate species and provenances is therefore one of the most effective ways of improving the economic viability of forest plantations, but it is also one of the most neglected.

It is generally understood that some species will outgrow others in a particular environment, but it is not so well known that within a single species there is often a great range of genetic variation, with some provenances (populations from particular geographic areas) growing much faster than others. Species and provenance rankings will often change between different environments, so trials should be made on the particular soil type and climate in which plantations are to be established.

The role of this manual

The CSIRO Tree Seed Centre has been supplying high quality seed for research purposes to institutions and research bodies overseas, particularly in developing countries, for over 20 years. During this period, it has become increasingly apparent that a relatively low proportion of this seed has been utilised in well designed, maintained, and monitored trials. There appear to be high losses of plant material in the nursery and in the field, whilst not all of the trials that have been established have been designed to allow the collection of statistically reliable data.

This handbook has been written to provide some practical advice on the raising of Australian tree species (chiefly eucalypts, acacias, casuarinas and melaleucas), and how to design and establish simple species and/or provenance trials. Some of the nursery techniques suggested are particularly appropriate for raising small numbers of seedlings for research purposes, and may need to be modified for large scale application. The handbook is intended primarily for use in conjunction with a propagation kit (containing basic nursery equipment) which will be supplied with research seedlots by the Tree Seed Centre. The distribution of these seedlots and the propagation kit is supported through the Australian International Development Assistance Bureau (AIDAB) under the Seeds of Australian Trees for Developing Countries (SATDC) project.

The propagation kit will be supplied only to selected projects and countries, but it is hoped that this handbook may find wider use by those who have limited knowledge and experience in the raising of Australian tree species, and in the establishment of species and/or provenance trials. Whilst the handbook is

intended for use by personnel involved in supervising the practical aspects of this work, its use will be limited to those who have a knowledge of the English language. The translation of the handbook into local languages by responsible bodies such as state forest departments is therefore encouraged.

The establishment of a species and/or provenance trial is a commitment to many years of work. Even a short term trial is likely to require regular maintenance and monitoring for about five years. The acceptance of research seedlots from the Tree Seed Centre should also be considered as a commitment to keep the Centre informed of the performance of the seedlots supplied. It is only through such feedback that sound advice can be given to others wishing to grow Australian tree species, and future seed collection programmes of promising species can be planned.

Before embarking on the establishment of a species and/or provenance trial, ensure that resources and enthusiasm are adequate for the task ahead.

2.0 PLANNING THE TRIAL

It is essential to clearly define the objectives of the trial in the first stage of planning. Points to consider include:

- What type of trial is intended?
- What are the end uses required from the trees?
- What will be the life span of the trial?

2.1 What type of trial?

Ideally, species and provenance trials should be sequenced through a series of trials, first selecting and proving the most suitable species, and then the most suitable provenance. In practice, this sequence is usually simplified into one of the following:

Species elimination trial – comparing the performance of a large number of different species, in order to select the most suitable species. In species with a wide natural distribution, it may be advisable to include several different provenances even at this initial stage.

Provenance trial – comparing the performance of a large number of provenances of a few, selected species, in order to determine the most suitable provenance

Pilot plantation – testing the performance of a selected provenance in a small-scale plantation. The trial may be used for demonstration or for investigating silvicultural and management techniques.

2.2 Which products are required?

Possible end uses required include sawn timber, fuelwood, poles, pulp and fodder, as well as benefits such as soil conservation, windbreaks and others.

The tree characteristics monitored in the trial will depend upon which end uses are considered the most important.

2.3 How long?

The trial may be intended to last:

- 1-5 years (short term)
- 5-10 years (medium term)
- more than 10 years (long term).

The choice of experimental design and layout will be influenced by all three of these factors; this is discussed in more detail in Section 5. In summary, the objectives of the trial should take the form of a statement, such as the following:

'To compare the survival, growth rate and biomass production of twenty Australian *Acacia* species on two contrasting sites in Sri Lanka, over a period of 5 years'.

3.0 SELECTING THE TRIAL SITE

When selecting trial site(s), it is important to consider the following:

- site representativeness
- accessibility
- tenure
- availability of meteorological data.

3.1 Site representativeness

The trial site should be as representative as possible of the planned planting areas. Factors to consider include:

- rainfall – quantity and seasonality
- temperature – maxima and minima, including incidence of frosts
- topography
- soils
- past land use.

Although it is far easier to set up a trial on a flat, uniform site, there is little value in such a trial if the site selected is unrepresentative of the areas on which the chosen species will later be expected to grow.

If several sites are to be used, they should cover the range of variation within the intended planting areas as well as possible.

3.2 Accessibility

Ease of accessibility is important to facilitate:

- future maintenance and protection operations
- regular monitoring
- demonstration visits.

3.3 Tenure

It is desirable that the trial site should be fully owned by the institution or body which is setting up the trial. However, if this is not possible, full written agreements should be entered into with the owner(s) of the land in order to ensure security of tenure throughout the intended life span of the trial. Responsibility for trial maintenance should also be properly defined at this stage.

3.4 Availability of meteorological data

Basic meteorological data will be required for the site for:

- the interpretation of field data
- comparisons between different trial sites.

The minimum data required will be:

- monthly rainfall
- monthly maximum and minimum temperature.

These figures can be obtained from the nearest meteorological station, if such a centre is situated nearby and is subject to similar climatic conditions. However, it is preferable to record basic meteorological data on site.

4.0 TIMING NURSERY OPERATIONS

All nursery operations must be carefully planned so that suitably sized plants are raised by the beginning of the main rainy season.

4.1 Nursery construction

If a new nursery is to be constructed specifically for the trial, rather than using existing facilities, adequate time must be allowed to complete all work at least one month before the seed is due to be sown.

Factors to consider include:

- site preparation
  - levelling and/or terracing the site
  - drain cutting
  - construction of water supply channels and tanks
- fencing around the nursery (the points covered in Section 17.2 are also relevant for nursery fencing)
- buildings
  - germination hut
  - potting shed
  - stores shed
- construction of
  - shade and other protective structures (see Section 11.2 and Appendix 6)
  - stand out bed surfaces (see Section 12.2).

4.2 Procuring nursery equipment and supplies

It may help to prepare a check list of all necessary equipment and supplies; these should be obtained well before the time that they will be required. Items which must be considered include:

- seed
  - arrangements for obtaining local seed may need to be made, in addition to the CSIRO seedlots
  - when ordering seed from the CSIRO, allow at least three months for its dispatch
- germination trays
- potting bags *
- pesticides *
- fertiliser
- labels
- thermometer (for use when heat treating potting mix)

These are provided in the propagation kit in limited quantities. It may be necessary to obtain further supplies of some items, particularly those marked *

- nursery tools such as spades, rakes or the appropriate local tools

- back-pack sprayers for
  - watering small plants
  - pesticide applications
- watering cans or hoses with spray nozzles (for watering older seedlings only)
- several (44 gallon or 200 litre) oil drums, to be cut in half and used when
  - heat treating the soil mix (longitudinally cut; see Section 9.3)
  - subirrigating germination trays (cut crosswise; see Section 11.1)
- firewood, or other fuel, for heat treating the soil mix
- soil mix components
  - forest soil
  - river sand
  - organic matter
  - inoculum material

  } (see Section 9.1)
- materials for shade and protection, e.g.
  - coir matting, woven bamboo, 'Sarlon' shade cloth, etc. (see Section 13.2)
  - polythene sheeting (see Sections 11.3 and 13.3).

4.3 Raising the plants

The aim should be to raise healthy, vigorous stock which will be 15-20 cm tall by the onset of the main rainy season. A healthy plant should have a root : shoot ratio of about 1:1. This ratio will be upset if the plants are kept in the nursery for too long, as many root pruning operations will be necessary; this will tend to result in the roots being smaller in mass than the stem. As the imbalance in the root : shoot ratio increases, plant vigour will decrease; any seedlings over 25 cm high are badly oversized for planting. Any seedlings less than 12 cm high are badly undersized for planting, as they will be too small to withstand competition with weeds.

Give thought to the following factors when planning the time required for raising plants in the nursery:

Seed presowing treatment may involve a time delay. Check whether the seed requires cold moist stratification (see Appendix 3). If it does, allow adequate time (some species require up to 10 weeks).

Different species will vary in their rate of growth. Table 1 gives a very general indication:

Note that in species elimination trials where a range of species are being compared, it may be necessary to commence germination of the different species at different times to achieve seedlings of uniform size at the time of planting out.

Table 1. Variation in growth rate of different species.

Species	Germination period (days)	Period to pricking out (weeks)	Period in potting bags (months)	Total time in the nursery (months)
Eucalyptus spp.	4-14	2-8	1½-4½	2-6
Acacia spp.	3-14	-	2-5	2-5
Casuarina spp.	8-14	4-6	1½-4	3-6
Melaleuca spp.	3-10	4-8	3-5	4-7
Araucaria spp.	8-12	5-6	12-23	12-24
Grevillea robusta	14-56	6-12	4-7	6-12

Climatic conditions at the nursery will have a very marked influence on the rate of plant growth; hence the table above should only be used as a guide. Particularly important climatic factors are:

- temperature; seedlings will tend to grow more slowly in cold conditions
- days of sunshine; many species will exhibit a growth check during prolonged cloudy periods (for example, during monsoonal weather).

4.4 Site preparation

The preparation of the trial site also requires forward planning; this is discussed in Section 17.

A possible schedule of operations is illustrated in Figure 1, but the exact timing of operations will depend upon local conditions and the schedule should be adapted accordingly.

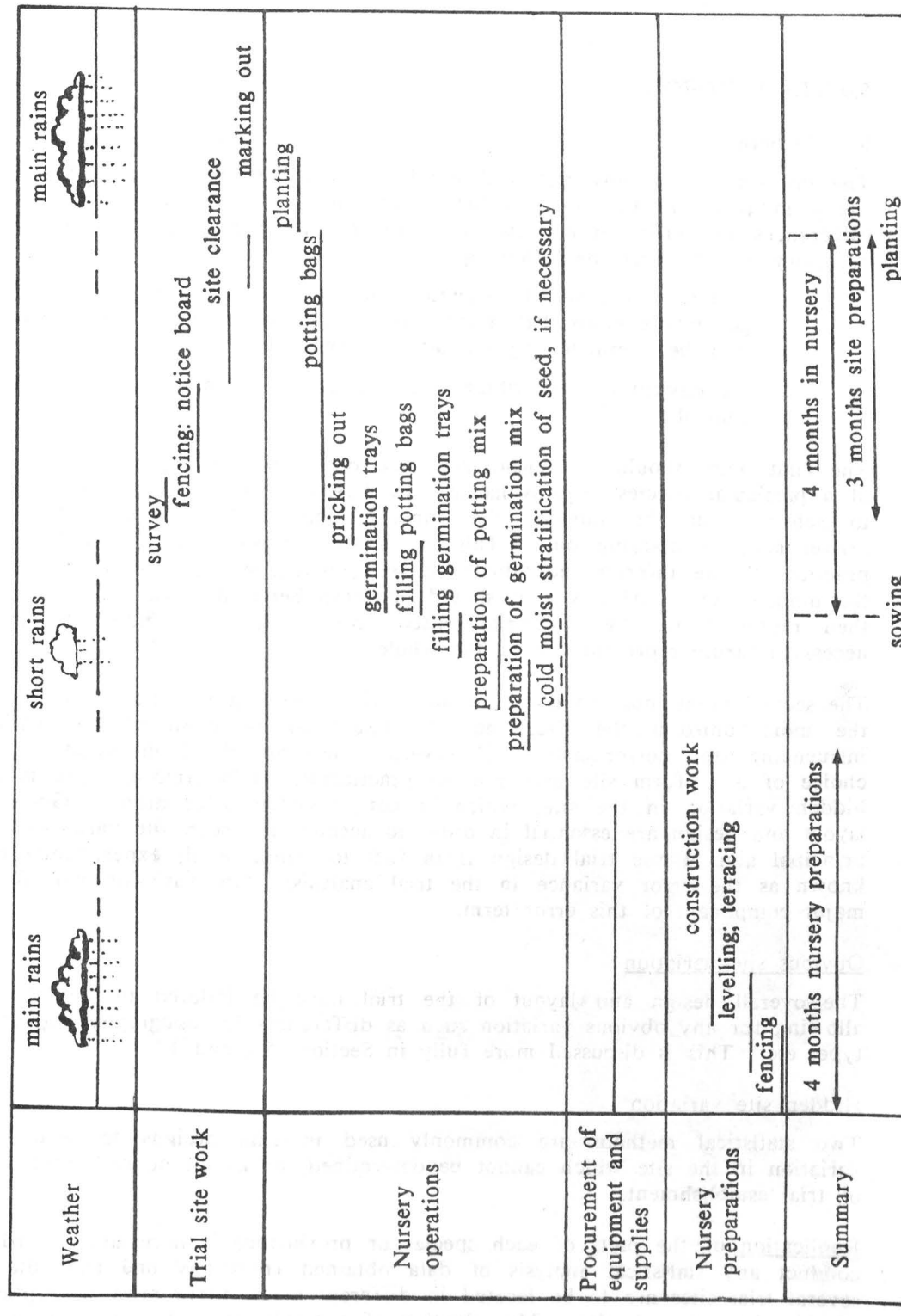


Figure 1. A possible schedule of nursery operations and site preparations for a species and/or provenance trial

5.0 TRIAL DESIGN

5.1 General

The performance of any tree will be determined both by its genetic make-up (its genotype), and by the environment in which it is growing. In assessing differences in performance between different genotypes at a given site, it is necessary to remember the following:

- a large amount of variation observed in seedling trees will be genetically controlled; this type of variation between individuals will only be eliminated by the use of clones
- the environment in which trees are grown is impossible to completely control.

The first point should be considered when determining a representative sample of a particular species or provenance. In forestry trials, it is common practice to select from the nursery the superior individuals of each species or provenance for planting out. This is largely consistent with normal forestry practice, as the inferior individuals, at least, would normally be culled out at the nursery stage. However, it should be remembered that the stock used may then represent the best material raised from a given seedlot, and is not necessarily truly representative of the whole.

The second point must be borne in mind when selecting the site(s) for the trial; the more uniform the site, the less likelihood of environmental variables influencing tree performance. However, it has already been noted that the choice of a uniform site may not be practicable; furthermore, there may be hidden variation in the site, which is not immediately apparent. Good trial layout and design are essential in order to account for such site variation. The principal aim of the trial design is in fact to minimise all experimental error, known as the error variance in the trial analysis. Site variation will form a major component of this error term.

Obvious site variation

The overall design and layout of the trial must be tailored to suit the site, allowing for any obvious variation such as differences in topography, aspect, soil type, etc. This is discussed more fully in Sections 5.4 and 17.

Hidden site variation

Two statistical methods are commonly used in trial designs to account for variation in the site which cannot be determined, or is not noticed, at the time of trial establishment.

Replication of the plots of each species or provenance is necessary in order to conduct any statistical analysis of data obtained from any one trial site. If several trial sites are to be located in different areas, there must be replication of the plots at each site. The planting of a single plot of each of a number of species or provenances at a number of different sites is merely repetition; it is not the same thing as replication. When analysing the results of a trial, the underlying variation in the site must be determined before the statistical significance of the differences observed between species or provenances can be

estimated. No determination of site variation can be made unless the plots of species or provenances have been replicated. The reliability of the information gained from the trial will increase with increasing numbers of replicates, but this must be balanced against the cost in time, labour and money of a very large trial.

Randomising the occurence of plots of species or provenances within replicates is a further precaution against one species or provenance always being unknowingly located in more favourable positions.

5.2 Types of design

As noted in Section 2.0, species and provenance trials may be conducted in a sequence of trials. The appropriate design will depend upon the type of trial being conducted. General factors to consider include:

- the level of variation expected between seedlots
- the anticipated life span of the trial
- obvious variation in the site.

The expected variation between seedlots will have considerable bearing upon the type of trial design, number of replicates, trial life span, and plot size that is most appropriate for the given trial. For trials in which the differences between seedlots are expected to be large and easily detected, the sample population of each seedlot need not be very large, the number of replicates does not need to be high, and the life span of the trial need only be short (as differences will be quickly determined). Plot size may need to be fairly large as competition between trees which have very different growth rates is likely to be intense, and there will be edge effects. However, this will depend upon the life span of the trial (see below). If strong interplot competition is suspected, it is usual to ignore the outer row of plants in each plot when conducting measurements; if this is to be done, there must still be enough plants in the centre of the plot to form an adequate sample population.

For trials in which differences between seedlots are expected to be fairly small and difficult to detect, the sample population of each seedlot should be quite large, the number of replicates should be high, and the life span of the trial should be medium to long term, in order to allow time for differences to become fully apparent. Interplot competition is not likely to be a major concern between seedlots with similar growth rates, and thus there is no need on this account for plots to be large.

The anticipated life span of the trial is important, as a separate factor in influencing the choice of plot size. In short term trials, interplot competition will not be a serious problem as there will be insufficient time for the trees to develop to a size at which they will begin to compete strongly with one another. Small plots may therefore be used in trials in which variation between seedlots is likely to be large as long as the trial is intended to last no more than a maximum of about 5 years. Spacing will also be an important consideration (see Section 5.3), as the closer the spacing between plants, the more quickly interplot competition will develop.

The degree of obvious variation in the site should also be taken into account when deciding upon plot size. On a highly variable site, plots must be small in order to maintain site uniformity within each statistical unit, or block (see also Section 5.4). On a fairly uniform site, it may be possible to use larger plots.

BLOCK I

13	x x x x x x x x x x	18	x x x x x x x x x x	6	x x x x x x x x x x
20	x x x x x x x x x x	8	x x x x x x x x x x	10	x x x x x x x x x x
9	x x x x x x x x x x	5	x x x x x x x x x x	28	x x x x x x x x x x
29	x x x x x x x x x x	26	x x x x x x x x x x	4	x x x x x x x x x x
11	x x x x x x x x x x	12	x x x x x x x x x x	25	x x x x x x x x x x
27	x x x x x x x x x x	2	x x x x x x x x x x	14	x x x x x x x x x x
17	x x x x x x x x x x	20	x x x x x x x x x x	22	x x x x x x x x x x
19	x x x x x x x x x x	7	x x x x x x x x x x	15	x x x x x x x x x x
23	x x x x x x x x x x	16	x x x x x x x x x x	3	x x x x x x x x x x
1	x x x x x x x x x x	21	x x x x x x x x x x	30	x x x x x x x x x x

BLOCK II

22	x x x x x x x x x x	27	x x x x x x x x x x	6	x x x x x x x x x x
3	x x x x x x x x x x	9	x x x x x x x x x x	21	x x x x x x x x x x
7	x x x x x x x x x x	4	x x x x x x x x x x	17	x x x x x x x x x x
28	x x x x x x x x x x	30	x x x x x x x x x x	23	x x x x x x x x x x
14	x x x x x x x x x x	11	x x x x x x x x x x	15	x x x x x x x x x x
27	x x x x x x x x x x	5	x x x x x x x x x x	19	x x x x x x x x x x
20	x x x x x x x x x x	26	x x x x x x x x x x	2	x x x x x x x x x x
12	x x x x x x x x x x	18	x x x x x x x x x x	24	x x x x x x x x x x
1	x x x x x x x x x x	25	x x x x x x x x x x	13	x x x x x x x x x x
10	x x x x x x x x x x	29	x x x x x x x x x x	8	x x x x x x x x x x

BLOCK III

5	x x x x x x x x x x	30	x x x x x x x x x x	8	x x x x x x x x x x
14	x x x x x x x x x x	15	x x x x x x x x x x	20	x x x x x x x x x x
25	x x x x x x x x x x	23	x x x x x x x x x x	9	x x x x x x x x x x
24	x x x x x x x x x x	19	x x x x x x x x x x	16	x x x x x x x x x x
6	x x x x x x x x x x	27	x x x x x x x x x x	12	x x x x x x x x x x
18	x x x x x x x x x x	13	x x x x x x x x x x	21	x x x x x x x x x x
2	x x x x x x x x x x	11	x x x x x x x x x x	29	x x x x x x x x x x
10	x x x x x x x x x x	22	x x x x x x x x x x	7	x x x x x x x x x x
1	x x x x x x x x x x	17	x x x x x x x x x x	28	x x x x x x x x x x
26	x x x x x x x x x x	4	x x x x x x x x x x	3	x x x x x x x x x x

BLOCK IV

18	x x x x x x x x x x	14	x x x x x x x x x x	21	x x x x x x x x x x
7	x x x x x x x x x x	24	x x x x x x x x x x	1	x x x x x x x x x x
12	x x x x x x x x x x	9	x x x x x x x x x x	4	x x x x x x x x x x
13	x x x x x x x x x x	19	x x x x x x x x x x	5	x x x x x x x x x x
20	x x x x x x x x x x	8	x x x x x x x x x x	30	x x x x x x x x x x
17	x x x x x x x x x x	6	x x x x x x x x x x	10	x x x x x x x x x x
15	x x x x x x x x x x	29	x x x x x x x x x x	3	x x x x x x x x x x
28	x x x x x x x x x x	27	x x x x x x x x x x	11	x x x x x x x x x x
2	x x x x x x x x x x	25	x x x x x x x x x x	26	x x x x x x x x x x
23	x x x x x x x x x x	22	x x x x x x x x x x	16	x x x x x x x x x x

Number of species: 30

Number of trees per plot: 10

Number of replicates: 4

Figure 2. A single row plot, Randomised Complete Block design, suitable for a species elimination trial.

Designs for species elimination trials

The purpose of a species elimination trial is to test a large number of different species to gain a broad indication of their potential on the given site. The expected variation between these species will be high, and therefore the number of plants of each species (the sample population) does not need to be large, the time span of the trial can be short, and the trial design can be very simple.

The recommended design for a species elimination trial is a Randomized Complete Block (RCB) design, whereby the trial is divided into blocks, within which each species is represented by one plot. Each block (or replicate) is thus called a complete block because it contains every seedlot. The positioning of the plots within the blocks must be completely random. For this type of trial, each plot of a species need only be a single row plot, of a minimum five, and maximum ten, plants. The advantage of single row plots is that they are very easy to monitor, and are good for demonstration purposes. However, because interplot competition is likely to be a significant factor influencing plant growth after a short while, single row plots should ONLY be used for SHORT TERM trials. A large number of replications is not necessary for species elimination trials. The number will depend partly upon plot size (there should be more replications if few trees are planted per plot), but if ten tree plots are used, four replicates should be adequate.

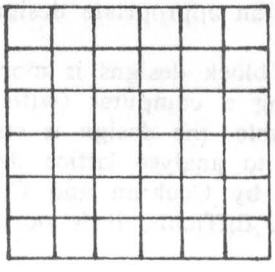
A suitable design for a species elimination trial is illustrated in Figure 2 for a hypothetical example in which thirty species are being tested; each single row plot contains 10 plants, and there are four replicates.

Analysis of the data obtained from such a trial is readily carried out without a computer. Clear instructions for carrying out one's own analyses with a pocket calculator are contained in the set of forms and worked examples of the Oxford Statforms (Dawkins 1975).

Designs for provenance trials

A trial evaluating a small number of provenances (say ten) of one or a few species can normally by carried out with a Randomised Complete Block design (RCB). However, for a large number of provenances (say more than 20) a more complicated design should be seriously considered. This is because the differences between the various provenances are likely to be relatively small; therefore the comparison between them must be highly precise. For such trials, the sample population of each seedlot will need to be larger, the number of replicates greater, and the life span longer, than for a species elimination trial.

The optimum plot size for provenance trials will depend upon individual circumstances, as should be apparent from the previous discussion. However, a useful and commonly adopted size is the square plot of 36 trees (6 × 6), as illustrated below.



For ease of future discussion it will be assumed that this plot size will generally be used in provenance trials. It has the advantages of being large enough to:

- ensure an adequate sample population (unless mortalities are exceptionally high)
- reduce the effect of interplot competition, which may be necessary to consider if provenances of several different species are being tested, or if the trial is expected to have a long (rather than a medium) life span.

The use of a square plot (rather than, for example, a rectangular one) also minimises edge effects such as interplot competition.

A RCB design is not generally recommended for provenance trials with large plot size and more than ten different seedlots, as site variation within each complete block will increase as it increases in size. The reliability of the information obtained will thus decrease. Note, however, that this can be compensated for to some extent by using smaller plots (achieved by using fewer trees per plot or by closer spacing between trees), increasing the number of replicates, and choosing a particularly uniform trial site; under these conditions the RCB design is suitable for as many as 20 provenances, or sometimes more.

For testing more than ten seedlots, a design known as the Incomplete Block design is often preferred. In this type of design the problem of large site variation within large complete blocks is overcome by breaking each complete block, for the purpose of analysis, into a number of smaller, incomplete blocks. Site variation within these smaller blocks will usually be reduced, and four replicates should be adequate to obtain statistically reliable data. Incomplete block designs require even greater care in their design, layout and analysis than do RCBs.

Various designs for incomplete blocks are possible, but for the purpose being described, lattice designs (see Cochran and Cox, 1957, listed under 'Further Reading') are recommended. Four examples of Incomplete Block designs are given in Appendix 1. They are for 12, 16, 20, and 25 provenances, and the designs are such that they CANNOT BE ALTERED to accommodate a different number of provenances or replicates. Thus, if say 18 provenances were to be tested, two additional seedlots of the same or a similar species should be added to take the number up to 20, so that the third design could be used. The positioning of the plots within the lattices has been randomised, and should also NOT BE ALTERED.

The construction of other incomplete block designs should be left to a statistician. If it is thought that another incomplete block design is required, and competent statistical advice is unavailable locally, persons responsible for establishing trials are invited to correspond with the CSIRO Division of Forest Research to help determine an appropriate design.

The analysis of incomplete block designs is more complicated than RCB designs, and is best conducted using a computer (with a package such as GENSTAT). If a computer is not available, the design is still strongly recommended as it is possible, though laborious, to analyse lattice designs by hand. The method is detailed in the publication by Cochran and Cox (1957), listed under 'Further reading'. If this seems too difficult, it is possible to treat the data as if from

a simple RCB design, and to analyse it as such. The data may later be reanalysed in full if and when computer facilities become available.

Designs for pilot plantations

It may be appropriate at the pilot plantation stage to conduct a number of investigations into silvicultural or management techniques such as fertilization, weeding and thinning.

Trial designs most suitable for this purpose include split plot designs and factorial designs. Details of such designs may be found in some of the texts listed under 'Further reading'.

The normal size of a pilot plantation will be from five to twenty hectares.

5.3 Espacement

The most suitable spacing will depend upon factors such as the purpose for which the trees are required, the silvicultural management systems to be adopted, the anticipated life span of the trial and the area of land available. The following may be used as a general guide:

Initial espacement (m)	Comments
1 × 1	. suitable for very short-term trials . allows the trial to be accommodated in minimal space
2 × 2	. suitable for short-term trials . suitable if fuelwood, shelter and light poles are required as end products
2 × 3	. allows access for mechanical cultivation . may be useful for single-row plots (2 m spacing within rows; 3 m spacing between rows)
3 × 3	. suitable for long-term trials (if no thinning is intended) . suitable for trials on poor-quality sites, where mortality is a problem at closer spacings . may be appropriate for trials in which a form of agroforestry (e.g. intercropping) is envisaged.

5.4 Trial layout in relation to site topography

All obvious site variation should be carefully evaluated when laying out the trial. It is most important that the smallest statistical grouping of plots in the trial (in RCB designs, the complete block; in incomplete block designs, the incomplete block) is as uniform as possible. Single row plots should always be orientated with the rows running downslope, not across the slope. This ensures that downslope gradients in soil properties do not favour some of the seedlots over others. Square plots must be kept square, but the blocks that they form do not have to be positioned regularly across the land; the important thing is to fit them to the site so that variation within the blocks as a whole is minimised. This is illustrated for a hypothetical situation in Figure 3, which

shows a layout for an incomplete block design for a trial of twelve provenances, with four replicates; the lattice design used is that given in Appendix 1.

The practical details of trial layout are discussed more fully in Section 17.

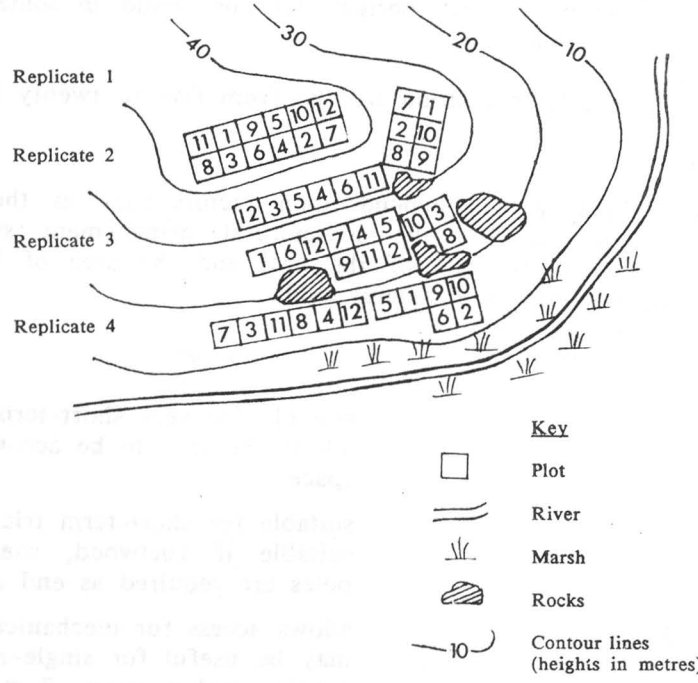


Figure 3. Hypothetical layout of a provenance trial

5.5 Number of species or provenances

The CSIRO normally supplies about twenty seedlots for a species and/or provenance trial, but the total number of seedlots in the trial may be increased by the inclusion of some local seedlots or other exotics for comparative purposes (see Section 7.1).

Species elimination trials

Although the purpose of a species trial is to test a large number of species, the need to test all those which have potential must be balanced against the size of the trial that is feasible. It is not normally practical to conduct a trial with more than forty different species, and it is more usual to focus upon twenty to thirty species.

Provenance trials

Four possible lattice designs, for 12, 16, 20 or 25 different provenances, are provided; this allows for some flexibility in the number of provenances

6.0 NURSERY LOCATION AND DESIGN

The seed provided by the CSIRO for research purposes is of high quality and very valuable. The following are guidelines on the location and design of the nursery which should help to ensure good nursery practice and make best use of research seedlots.

6.1 Biological requirements

Seed germination, and the healthy growth of young seedlings, has certain biological requirements.

Water

An all-season, plentiful supply of water should be ensured

The water supply should be of permanently high quality. Ideally it should be:

- fast flowing and clear (stagnant or polluted water is not acceptable)
- of slightly acid to neutral pH
- low in dissolved salts (saline water is not suitable).

The nursery should be located on a well drained site. Adequate drains to remove excess water during periods of heavy rain are essential.

Light

Light requirements vary with the stage of growth of the young plants. During germination and early seedling growth it will be necessary to provide shade; this topic is discussed more fully in later sections.

Temperature

It is recommended that the nursery is located in an area close to, and subject to similar temperatures, to the trial site. As young seedlings are particularly sensitive to frost, it is advisable not to locate a nursery in a frost hollow. Temperatures must be borne in mind when designing nursery structures.

Air

Free movement of air around young seedlings is important in avoiding the rapid spread of pests and pathogens.

Strong winds can dessicate and break young seedlings; protection against this must be provided in the nursery.

6.2 Physical (structural) requirements

Germination shed (or greenhouse, if climatic conditions demand

A suitable germination shed should have:

- protection on four sides and a roof
- windows allowing adequate ventilation
- benches within, at waist height, upon which the germination trays can be placed.

included in the trial. It is quite possible that, due to germination problems or poor performance in the nursery, less than the intended number of provenances will be available for planting out.

Any adjustment necessary in order to utilise one of these designs should be made bearing the following points in mind:

- The number of seedlings of each provenance needs to be sufficient for initial planting purposes only, i.e. 144 plants (4 replicates × 36 plants), as no vacancy infilling ('beating up') is recommended.
- If seedlings of one particular seedlot are insufficient in number for four replicates, but the seedlot is nevertheless considered worthy of inclusion in the trial, this is still possible. Plant the seedlings in the first replicates in the design given; the remaining replicate(s) may be planted with another seedlot, preferably one which is showing particular promise. Due allowance for the missing plot(s) of the seedlot(s) in limited supply can be made subsequently in the statistical analysis.
- If it is necessary to exclude one or more seedlots from the trial due to exceptionally poor nursery performance, ensure that all records of these seedlots are kept.

Any alterations to the originally intended design should be CLEARLY DOCUMENTED.

Pilot plantations

A pilot plantation will normally only comprise one provenance of one species.

5.6 Allocation of species and/or provenances within the trial design

Each suggested trial design shows the species and/or provenances labelled 1, 2, 3, 4, etc. When allocating these numbers to the seedlots, do so completely randomly. To facilitate randomisation, a table of random numbers is given in Appendix 2.

5.7 Arboretum establishment

If a number of species and provenance trials are being established in a locality, the planting of a small arboretum is recommended. Several individuals of every species raised should be planted in this arboretum, which will fulfil the following functions:

- to serve as a long-term record of species introductions
- to provide a ready demonstration of all species ever tested in the locality
- in some cases, to preserve specimens of seedlots which performed too poorly in the nursery to be included in the trial.

It should also be rodent-proof.

Protected area for young seedlings

Most young seedlings require a shaded environment during their early growth and, particularly, at transplanting. The amount of shade required will vary from 30% to 70%, depending upon local conditions and the species concerned.

Adequate protection against wind and rain is also necessary.

Potting shed

The mixing and storage of potting mix, and the filling of containers, should be conducted under cover. However, the potting 'shed' may need to be no more than an open-sided, roofed structure.

Stand out beds

Ideally, stand out beds should be designed to encourage root pruning and good drainage. This may be achieved by:

- raising the potting bags just above ground (air pruning)
- placing the potting bags on a structure impenetrable to seedling roots, e.g. concrete or heavy duty (0.2 mm) black polythene sheeting, and grading the surface to allow good drainage.

Depending upon the climate, time of year and species, provision may need to be made for shading and other protection of the stand out beds.

7.0 SEEDLOTS SUPPLIED

7.1 Choice of seedlots

The selection of seedlots for the trial may be made by:

- the CSIRO (based upon information provided by the client regarding site, climatic, soil and topographic conditions)
- the client
- others.

Wherever possible, it is recommended that the following are included in the trial:

- several 'standards' – locally-adapted genotypes of any of the species under trial which have been introduced to the locality previously and are known to perform well
- indigenous species which are considered valuable locally
- exotic, non-Australian species which are considered valuable locally.

These should provide a useful reference point when comparing the performance of recently-introduced species or provenances.

When selecting seedlots other than those supplied by CSIRO for inclusion in trials, it is recommended that each seedlot to be tested should be made up using equal quantities of viable seeds from at least 10 parent trees. The parent trees selected should be no closer than 100 metres to one another. Collection from only one or a very few parent trees does not give an adequate representation of the range of genetic potential of the population being tested.

7.2 Description of CSIRO seedlots

Collection

Seed is collected by trained personnel, who select suitable parent trees. Collections are made from natural stands and the botanical identity of the trees is always checked.

The seed from individual trees is kept separate, tested in the laboratory, and only later mixed to form a bulk seedlot. The number of parent trees for each seedlot is given in the consignment listing.

A detailed description of the collection site is recorded against the seedlot number in CSIRO files. In the consignment listing, only latitude, longitude and altitude at the point of collection are given; these can be used to obtain an indication of the climatic conditions at the site.

Testing and storage

All seedlots are cleaned and tested for germination before entering the seed store. Hence the number of viable seed per 10 g of seed (as given in the consignment listing) is determined. This figure is periodically checked and updated as necessary. As it is a figure determined under ideal laboratory conditions, it represents the maximum potential germination rate, rather than that which will actually be found in the nursery.

The figure for the number of viable seed per 10 g is particularly important for eucalypts, as the seedlot will contain a high proportion of chaff (unfertilized ovules), which is often difficult to distinguish from the seed itself.

The CSIRO normally provides roughly four times the number of viable seeds as the number of seedlings required. This is a generous allowance; with good nursery practise, wastage for most species should be much lower than 75%.

All seed entering the store is fumigated with carbon dioxide (CO_2) for two weeks to kill any insect pests. Fumigation in carbon disulphide (CS_2) for 2 hours is similarly effective. Certification of seed fumigation is enclosed with each consignment of seed for quarantine purposes.

Seed is stored at the Tree Seed Centre under controlled conditions. As a general rule, seed viability is decreased by:

- high temperatures
- high humidity
- fluctuations in both temperature and humidity.

The effect of temperature and humidity are inter-related; at a given moisture content, seed viability will deteriorate more rapidly with increasing temperature. At lower storage temperatures, there is a greater tolerance of high moisture content.

All seed is stored in airtight containers to protect it from high or changing humidity levels, but suitable storage temperatures vary according to species. This is summarised in Table 2.

Table 2. Recommended storage temperature for various species of tree seed.

Recommended storage temperature	Species
25°C (room temperature)	most *Acacia* spp, *Albizia* spp, *Eucalyptus* spp, and *Melaleuca* spp.
1°-4°C (cold storage)	*Allocasuarina* spp, *Casuarina* spp, most *Araucaria* spp, and some *Eucalyptus* spp.
-15°C (freezer)	*Acacia harpophylla*, *Eucalyptus deglupta*, *Eucalyptus microtheca* and *Grevillea robusta*

The seed provided in the propagation kit has been sealed inside a polythene bag to maintain airtight conditions. Do not open this bag until the seed is due to be sown. Store the seed away from direct sunlight and vermin, and, if possible, follow the recommendations given for storage temperatures. The viability of seed of species requiring storage at -15°C will decrease particularly rapidly if it is not placed in a refrigerator, at least.

8.0 SEED PRESOWING TREATMENTS

The seed of certain species may require special treatment before sowing to promote good and rapid germination. Such treatments include:

- the breaking down of hard seedcoats
- cold moist stratification

Another treatment that may be necessary for certain species is the inoculation of the seed with beneficial microorganisms.

8.1 Seed with hard seedcoats

Most acacias, albizias, cassias and a few other Australian tree species have seed with hard seedcoats which require presowing treatment in order to make them permeable to water and oxygen and to promote germination. Species with seed of this type are marked on the consignment listing.

Amongst the acacias, there are certain species which do not have seed with very hard seedcoats. These exceptional species may be divided into two groups:

- seed with semi-hard seedcoats, which are sensitive to the harsher treatments, notably:

Acacia excelsa	*A. pachycarpa*	*A. tephrina*
A. hemignosta	*A. pendula*	*A. xiphophylla*
A. jennerae	*A. peuce*	

- seed with soft seedcoats, which require NO pretreatment:

Acacia agyrodendron	*A. georginae*	*A. maconochiana*
A. cambagei	*A. harpophylla*	
A. cyperophylla	*A. latzii*	

Several treatments for hard-coated seed are possible; they include boiling water treatment, manual scarification or the use of acid.

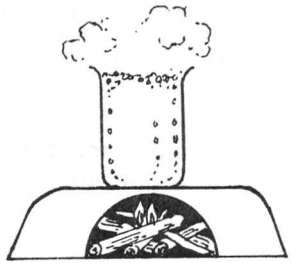
Manual scarification is the most time-consuming method, but it is also the most reliable. It is strongly recommended if only small quantities of seed are available.

Both the boiling water and acid treatments are too harsh for seed with semi-hard seedcoats. For such seed, either manual scarification, or treatment in hot water at 90°C for one minute, is necessary.

Boiling water treatment

This should be conducted as follows:

. Select a container which is large enough to contain ten times the volume of seed. Fill the container with tap water and bring the water to the boil over a flame.



. Once the water is boiling vigorously, pour in the seed and allow the water to boil for one minute.

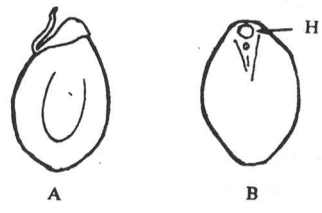
. Remove the container from the heat source and allow the seed to soak in the gradually cooling water for several hours.

. Sow the treated seed without delay.

Manual scarification

This requires the individual clipping of every seed. The procedure is as follows:

. Find the hilum on the seed. This is a scar, often appearing as a light-coloured spot, which marks the point at which the seed was formerly attached to the seed pod; it is found under the funicle. This is shown in Figure 4.

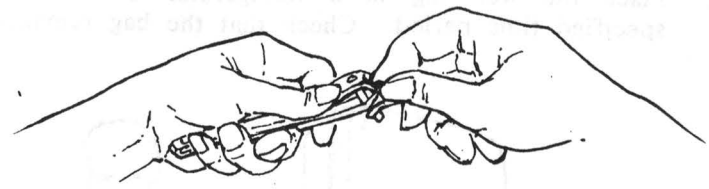


A. An acacia seed with the funicle
B. An acacia seed with the funicle removed, showing the position of the hilum
H hilum

Figure 4. An acacia seed with and without the funicle, showing the position of the hilum.

Do not damage the hilum, as it is from near here that the young root (radicle) will emerge on germination.

. Make a small cut (1 mm^2 is sufficient) at the end of the seed opposite to the hilum. Nail clippers or nail scissors are useful tools for this purpose.



The cut should be sufficient to just expose the white tips of the cotyledons (the embryo's food source).

Accidental removal of a small part of the cotyledons will not affect germination, but if a large part is removed seedling growth will be retarded.

Acid treatment

Whilst this is a useful treatment for many African acacia species, acid treatment is not recommended for most Australian species.

8.2 Cold moist stratification

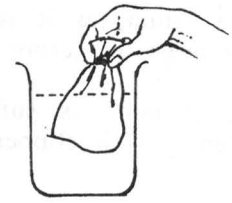
The seed of certain species which experience frost or snow during part of the year in their native environment require a period of cold, moist conditions before they will germinate. The technique of breaking seed dormancy by

simulating these natural conditions is known as cold moist stratification. If stratification is not carried out, the seed may not germinate, or will germinate very slowly and unevenly.

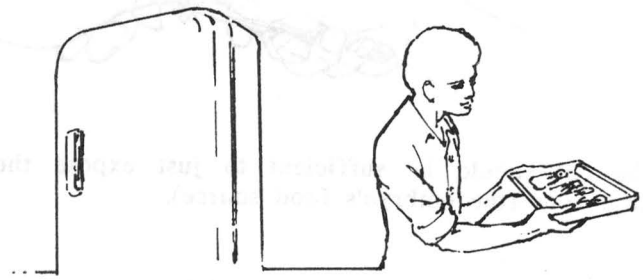
In the batch of seedlots supplied, the species which have seed requiring cold moist stratification are marked on the consignment listing. The time period required will vary according to the species; details are given in Appendix 3.

Stratification is carried out as follows:

. Place the seed in a calico bag, and dip it in water.



. Place the wet bag in a refrigerator at 1-4°C, and leave for the specified time period. Check that the bag remains moist at all times.



. Remove the bag from the refrigerator and sow the seed immediately. Germination should commence 3-5 days after transfer to warmer conditions.

8.3 Inoculation with beneficial microorganisms

Many plants require the presence of certain beneficial soil microorganisms for optimum growth. Of particular note amongst these microorganisms are:

Rhizobia spp. (symbiotic relationship with many Leguminosae, including *Acacia* and *Albizia* spp.)

Frankia spp. (symbiotic relationship with Casuarinaceae).

Both these microorganisms:

. form relationships with their hosts

. induce the formation of root nodules by the host plant, in which the microorganisms live

- fix nitrogen from the atmosphere, converting it to soluble nitrates, which can be taken up by the host plant.

In many areas, *Rhizobia* spp. and *Frankia* spp. occur naturally in the soil, and nodulation of the host plants readily takes place. However, in some circumstances it may be necessary to ensure the presence of these microorganisms by deliberately introducing them. One method of doing this for *Rhizobia* spp. is to inoculate the seed of the host plants using a peat preparation of the microorganisms; the addresses of recommended suppliers, and instructions on the method of application, are given in Appendix 4. Unfortunately, such inoculum is not currently available for *Frankia* spp.

Other methods of ensuring the presence of beneficial soil microorganisms, which are suitable for *Frankia* spp. as well as *Rhizobia* spp., include:

- the use in the nursery soil mix of soil taken from around the roots of a mature tree
- the addition of a preparation of the microorganisms (extracted from the nodules) to the nursery soil mix.

The nursery soil mix should be treated against pests and pathogens BEFORE the use of either of the above methods, as the heat treatment involved (see Section 9.3) would kill the microorganisms if applied after their addition.

- the addition of an aqueous preparation of the microorganisms to the young seedlings, once they are 2-3 cm tall.

Of these methods the most convenient is the last, details of which are outlined in Section 13.4.

9.0 NURSERY SOIL MIXES

9.1 Components

A nursery soil mix will comprise a mixture of some or all of the following:

- Local soil This is best obtained from a nearby forest, and should be:
  - loamy (see Appendix 8 for a definition of a loam)
  - non-calcareous (low in calcite).

  Avoid collecting soil from around villages, or areas frequented by many cattle, as such soil is likely to be heavily contaminated with fungal pathogens.

- River sand This should be clean sand, with a low silt and clay content. The inclusion of sand in a nursery soil mix will promote good drainage.

- Organic matter e.g. leaf litter or cow manure. It is important that any organic matter used is WELL ROTTED to a compost. A good compost is a rich brown crumbly substance free of any strong odours. Organic matter that does not conform to this description should not be used, as it could contain many pests and pathogens. Organic matter is used to improve the fertility and structure of nursery soil mixes.

9.2 Proportions

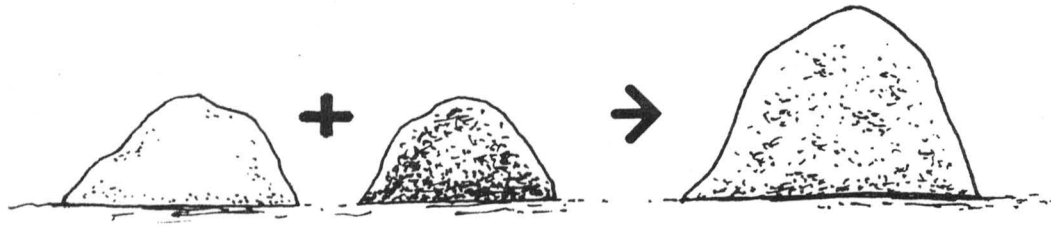
Germination mix

A good germination mix should be:

- freely draining (to reduce the build-up of fungal problems)
- free of particles more than 2mm in diameter (which could impede the germination of small seedlings)
- non-calcareous (neutral - slightly acid pH)
- friable, with a fairly low organic matter content.

The exact mix will depend upon the type of material locally available.

As a guide, 1 part river sand : 1 part loamy forest soil should make a good mix.



If the 'bog technique' of irrigation is to be used (see Section 11.1), a mix of 2 parts sand : 1 part loam is more suitable.

Potting mix

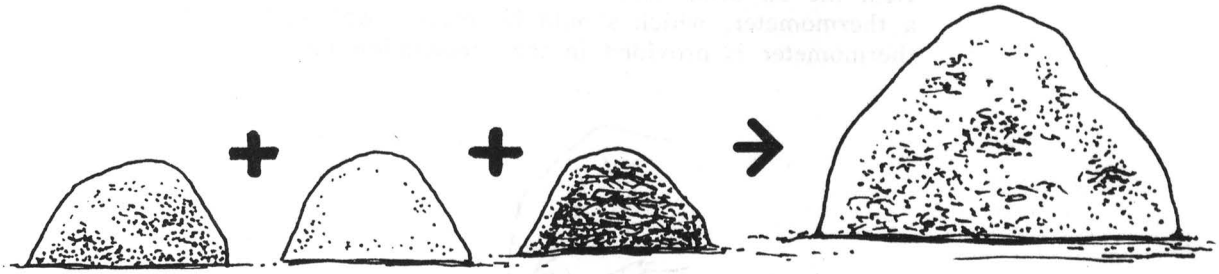
A good potting mix should be:

- free of particles larger than 5 mm diameter
- firm enough not to disintegrate around the root ball of the seedling when it is handled
- sufficiently friable to allow the ready penetration of water, and for root growth to be unimpeded.

The exact mix will depend upon the type of material locally available.

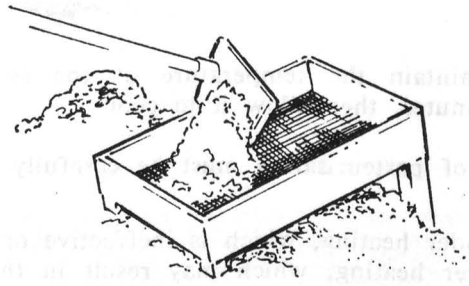
For example, a useful mixture is:

1 part sandy loam : 1 part river sand : 1 part well rotted organic matter



9.3 Treatment

Sieving



ALL nursery soil mixes should be seived to remove large particles.

For germination mixes, use a sieve with a 2 mm mesh.
For potting mixes, use a seive with a 5 mm mesh.

Anti-pest/pathogen treatment

Seedling mortality will be reduced by treating nursery soil mixes against pests (chiefly insects, and weed seed) and pathogens. Suitable methods are outlined below. However, they are effective only if conducted precisely by trained staff using the correct equipment.

Heat treatment requires the heating of the soil mix, usually by steam, to 60°C for 30 minutes. This process, known as pasteurisation, kills most harmful soil microorganisms, insects and weed seed.

A simple method for heat treating soil is as follows:

. Cut a (44 gallon or 200 litre) oil drum in half lengthwise; ensure that the inside is clean. Place the moist, but not wet, soil mix inside.

. Heat the oil drum from below to 60°C. Check this temperature with a thermometer, which should be pushed well into the heated soil. A thermometer is provided in the propagation kit for this purpose.

. Maintain the temperature of the soil mix at 60°C for a full 30 minutes, then allow it to cool.

The process of pasteurisation must be carefully monitored, as there is otherwise a danger of:

. under heating, which is ineffective or
. over heating, which may result in the destruction of the soil texture and the death of beneficial soil microorganisms. It can also lead to the release of excess amounts of nitrogen and micronutrients, which are toxic in large quantities.

Solarisation, the pasteurisation of nursery soil mixes using the heat of the sun, is an appropriate method in some countries. It is achieved as follows:

. Wet the soil mix to normal potting dampness.
. Spread it evenly on a flat surface, to a thickness of 5-7 cm, in open sunlight.
. Cover the soil mix with clear polythene sheeting.
. Seal down the edges by heaping soil, or placing stones or logs, along them.
. Leave the soil mix in position for several days.

In order to be effective, the temperature of the mix should reach 60°C for at least 30 minutes. This will only be achieved if the daytime temperature is over 30°C. Solarisation treatment is thus only suitable for hot, sunny countries.

Furthermore, the weather must be reliably sunny at the time of year when the nursery soil mix is prepared.

Chemical treatment may comprise one of two methods:

- Chemical sterilization, in which nursery soil mixes are completely sterilized using chemicals such as methyl bromide or chlorpicrin. The use of these chemicals is not recommended, however, as they are highly dangerous, and great care is required in their use. Furthermore, the treatment results in the killing of all soil microorganisms, including beneficial ones.

- Fungicidal treatment, in which certain fungicides are added to the germination tray mix before sowing to control or kill pathogenic fungi. This method is not recommended as there is a danger of reducing or inhibiting seed germination by the use of such chemicals.

In summary, there are difficulties associated with all methods of treating nursery soil mixes against pests and pathogens. However, both heat treatment and solarisation can give excellent results if properly conducted, and are well worth the time and effort required.

9.4 Fertiliser

Many of the nutrients that a plant needs to grow are supplied via the soil mix. They are usually categorised according to the amount in which they are needed, into macro and micro nutrients, and are as follows:

Macronutrients:	Nitrogen (N)
	Phosphorus (P)
	Potassium (K)
	Calcium (Ca)
	Magnesium (Mg)
	Sulphur (S)
Micronutrients:	Iron (Fe)
	Zinc (Zn)
	Copper (Cu)
	Manganese (Mn)
	Boron (B)
	Molybdenum (Mo)
	Chlorine (Cl)

It is quite possible that a nursery soil mix that is high in organic matter will contain adequate amounts of nutrients for a young seedling. However, many nursery soil mixes will not contain sufficient nutrients to optimise plant growth, and for this reason artificial fertiliser is added to the mix, or to the growing plants.

A supply of fertiliser is included in the propagation kit. This particular fertiliser, 'Osmocote Plus', is a slow-release fertiliser which supplies virtually all the nutrients (micro as well as macro) necessary for plant growth. It should be added to the nursery potting mix at the rate of 1.5 kg per cubic metre (m^3). Important points to note when adding the 'Osmocote Plus' to the potting mix are:

- Always add the fertiliser AFTER anti pest/pathogen treatment has been conducted. Any heat treatment will break down the specially prepared granules of 'Osmocote Plus', resulting in the rapid release of all the nutrients. This could be toxic to young seedlings.

- Mixing of the fertiliser with the potting mix should be done as evenly and thoroughly as possible, to avoid patchy concentrations of fertiliser. If available, an old concrete mixer may be used for this purpose very effectively.

Caution

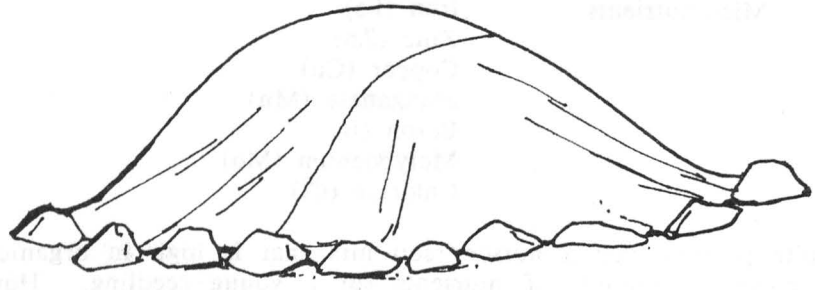
- Always store fertiliser in a COOL, DRY place, preferably in an air-tight container. It will lose its effectiveness if you do not.

- Although 'Osmocote Plus' is not a highly toxic substance, it should nevertheless be treated with care. Therefore:
  - do not inhale the dust
  - wash hands after using the fertiliser
  - keep it away from young children or domestic animals; it is harmful if swallowed.

9.5 Storage

Store prepared nursery soil mix in a covered area or under plastic until it is required, in order to prevent fresh contamination with insect pests, weed seeds or fungal spores.

It is best to use the mix as soon as possible after preparation, for the same reason.



10.0 SOWING SEED

The sowing of all seed, pretreated if necessary, should be timed so that appropriately-sized plants become available at the onset of the wet season (see Section 4).

It is convenient to sow the seed of some species, usually those with very small seed, or seed of low viability, into germination trays (or seedbeds). The germinants are then pricked out later into potting bags. Other seed may be sown directly into potting bags.

The seed of species of the following genera should be sown in germination trays:

Allocasuarina	*Casuarina*	*Hakea*
Araucaria	*Eucalyptus*	*Leptospermum*
Callitris	*Grevillea*	*Melaleuca*

Direct sowing into potting bags is more suitable for seed of species of the genera:

Acacia
Albizia
Cassia

10.1 Sowing germination trays

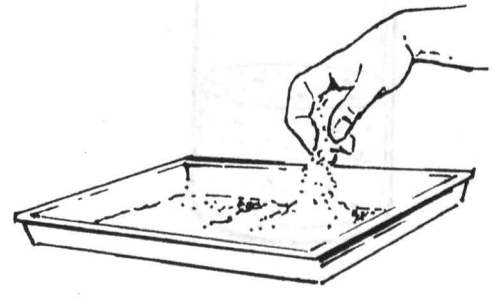
Included in the kit are a number of 29 cm × 35 cm plastic germination trays for seedlots that are to be sown in this manner. The use of such trays is more convenient and efficient than the sowing of seed in seedbeds.

Each tray is punctured with holes at the bottom, which are sufficient to allow good drainage without the addition of any loose 'fill' in the bottom.

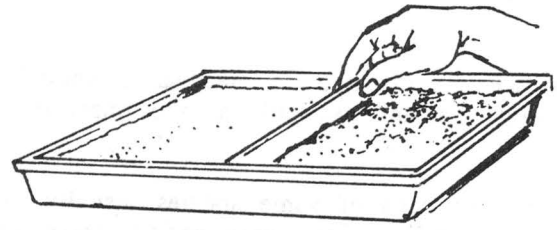
The number of trays provided for each seedlot varies according to the optimum sowing density. This information is detailed in Appendix 5.

The sowing of the germination trays should be conducted as follows:

. Fill the trays with germination mix; shake down the mix to ensure that there are no air pockets.



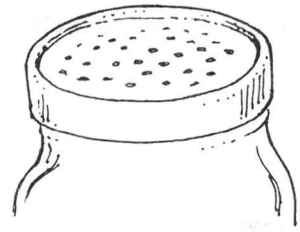
. Level the surface of the mix using a flat piece of wood or plastic.



. Water the mix, so that it is moist but not sodden.

Excepting *Araucaria* spp., follow the procedure outlined below:

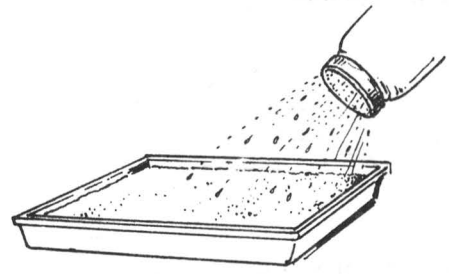
. A convenient device for sowing seed is a small screw-topped jar (such as a coffee jar), with holes punched in the lid. These holes should be of a diameter of about 2 mm (no more), scattered over the lid.



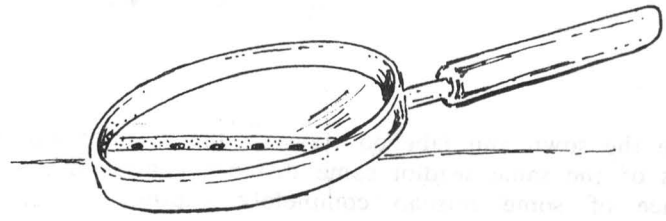
. Take ONE seedlot, and the number of trays that are recommended for that species. For 10 g seed, this will usually be one to four trays. If necessary, divide the seed into equal portions, one for each tray.

. Place one portion of seed in the jar, and add a small quantity of fine white sand (two or three times the volume of the seed). This will make it easier to sow the seed evenly and to see which part of the tray has been sown. Mix the sand and the seed well.

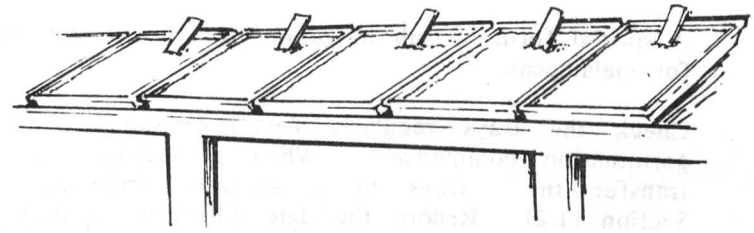
. Carefully sprinkle the sand and seed mixture over the soil mix in one germination tray as evenly as possible.



. Cover the seed with a thin layer of fine sand. The thickness of this layer should be no more than the diameter of the seed itself. For eucalypt and melaleuca seed, very little sand will be required.

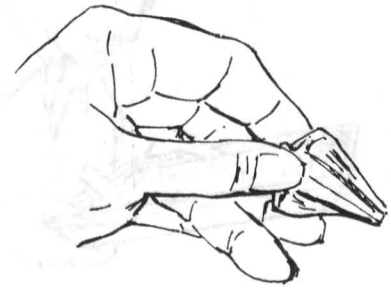


. Repeat the process for the other portions of seed, sowing them in separate trays. LABEL all the trays with the seedlot number and the date of sowing.



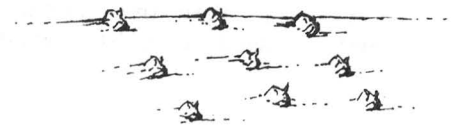
For most *Araucaria* spp., a different sowing technique should be adopted:

. Hold each individual seed at the wide, flattened end, and tilt the pointed end as illustrated.



. Push the seed down into the soil in the manner illustrated, leaving the flattened end just visible above the soil surface. No covering of the seed with sand is required.

. Repeat the process for the other seeds, sowing them at a distance twice the length of one seed apart.



For all species:

. Place the sown and labelled trays in the germination shed, positioning trays of the same seedlot some distance apart; this should reduce the chance of some mishap completely wiping out all seedlings of a particular seedlot.

. Water the trays regularly, so that the soil mix is always moist, but not wet. Take care not to disturb the seed. The best method of achieving this is to water by sub-irrigation, which is detailed in Section 11.1.

A special form of sub irrigation, the 'bog technique' is recommended for melaleucas.

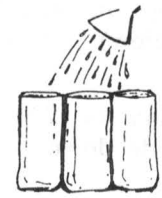
. Check the trays regularly for germination, and record the date germination commences. When germination is largely completed, transfer the trays to a separate protected, shaded area (see Section 11.2). Record the date when germination is completed. A suitable form for making these records is given in Appendix 7.

10.2 Direct sowing

Follow the procedure outlines below:

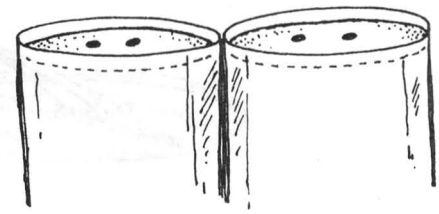
. Fill the potting bags according to the guidelines given in Section 12.1. Place them in the protected area for young seedlings.

. Water the soil mix, so that it is moist but not sodden.

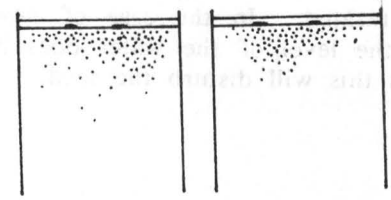


The level of the soil mix should be about 6-8 mm below the top of the bag.

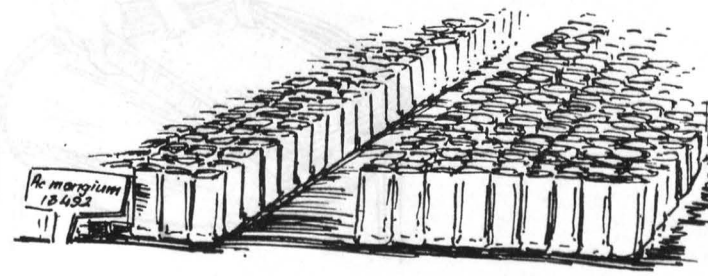
. Place two seeds flat onto the soil mix surface in each bag, as shown.



. Cover the seeds with fine sand, taking care that the thickness of the cover is no more than the diameter of the seed.



. When all the seed of one seedlot has been sown, LABEL the bed, and make a clear division between the sown and non-sown parts of the bed before commencing sowing the next seedlot.



. Record when germination commences and is completed.

11.0 CARE OF SMALL SEEDLINGS

11.1 Watering

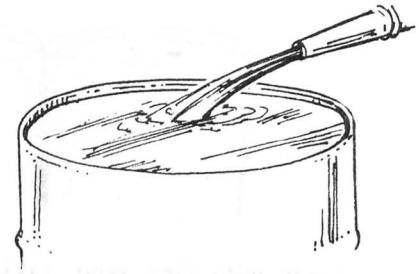
Germination trays

Watering of seed and seedlings in germination trays is best conducted by sub-irrigation (watering from below). A simple method of achieving this is as follows:

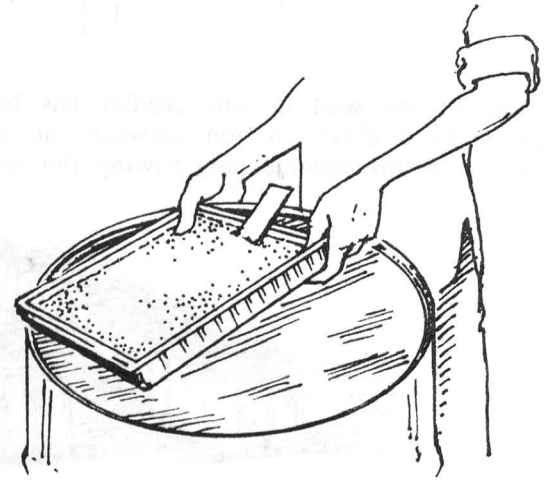
- Cut several (44 gallon or 200 litre) oil drums in half crosswise. Turn each half cut side down in the open.

- Clean the tops and bottoms of the drums (now facing upwards), using boiling water to remove fuel residues if necessary.

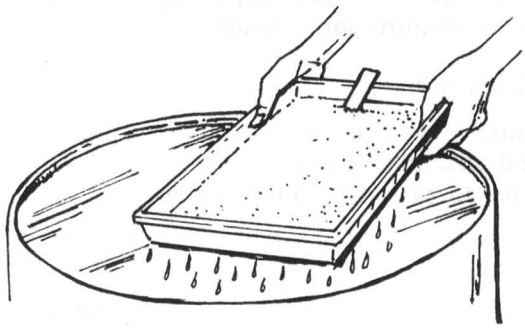
- Fill the tops and bottoms with water. The rims around the drum edges should hold about 2 cm of water.



- Place the germination trays in the water, and allow the soil mix to become saturated. In the case of newly sown seed, take particular care that the level of the water does NOT come as high as the soil surface, as this will disturb the seed.



. Remove the trays, and return them to the germination shed, where they can drain.



. Repeat watering as necessary. The frequency required will depend greatly upon local climatic conditions.

The bog technique

This technique is suitable for species which:

. are adapted to swampy conditions in their natural habitat, and are therefore not highly susceptible to 'damping off' (see Section 11.6)
. have very fine seed, which is very susceptible to drying out.

The technique should be used for all melaleucas.

Instead of being watered periodically, the germination trays are constantly sub-irrigated by placing them in a larger tray filled with water. The level of this water should be maintained at 2 cm. This will allow the soil mix in the trays to be kept constantly moist, but not saturated at the surface.

Important points to note when using the 'bog technique' are that:

. the germination soil mix allows good aeration; a suitable composition is 2 parts sand : 1 part loam
. if signs of 'damping off' occur, the germination trays should be removed from the water, and the system of periodic watering by sub-irrigation adopted instead.

Direct-sown seedlings in potting bags

Sub-irrigation of seedlings in potting bags requires more elaborate equipment; hence seedlings may need to be watered from above, instead.

Use only a fine spray to water young seedlings. A watering can with a normal type of rose is not recommended; the large drops of water will batter the young seedlings, and expose their roots.

General points on watering are as follows:

. Avoid over-watering, as this will greatly increase the incidence of fungal pathogens
. Never allow the soil mix to dry out completely.
. Water in the morning and late afternoon, NOT during the heat of the day, when young seedlings may be susceptible to scalding.

11.2 Shade

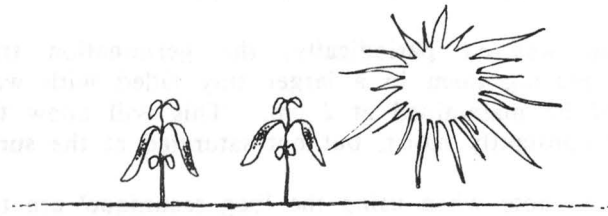
Shade requirements will vary according to local climatic conditions, but young seedlings always require some shade.

Too much shade will:

- cause etiolation of seedlings – that is, they become spindly, yellow and generally weak
- tend to promote fungal disease.

Too little shade will:

- result in rapid dessication of young seedlings
- increase the likelihood of scorch (especially if the plants are watered in full, midday sun).

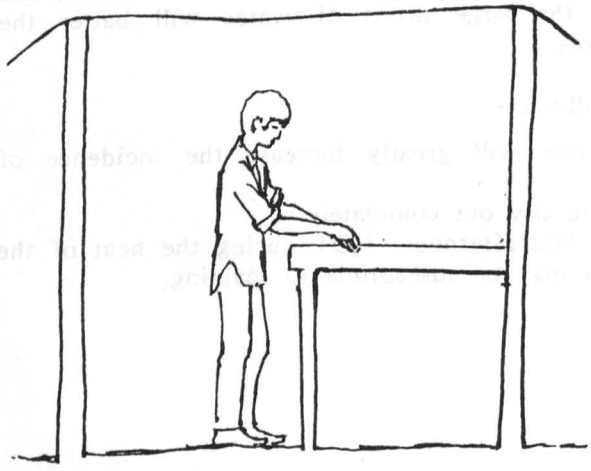


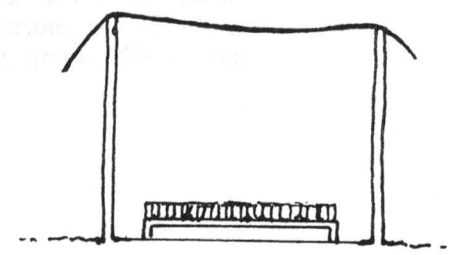
As a general rule, young seedlings will require about 70% shade. This may be provided by high or low shade.

High shade is provided in the form of a permanent structure, about 2m above the ground, under which workers can move about freely.

Low shade is positioned 0.5-1.0m above seedling beds. Ideally, it should be possible to remove it, as required.

These two forms of shade are illustrated below.





Suitable materials for shade include:

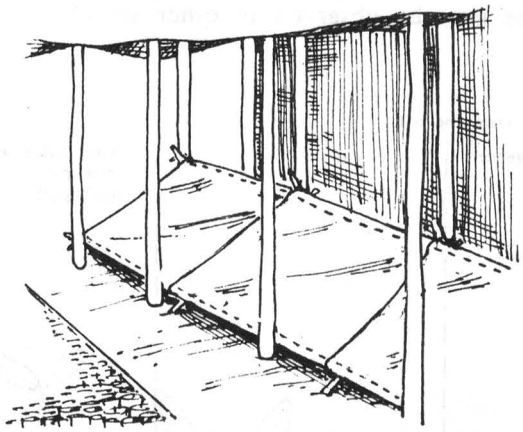
- coir matting
- hessian
- woven bamboo
- 'Sarlon' shade cloth.

Materials which are NOT so suitable are those which readily disintegrate, littering the young seedlings with debris, for example:

- fern fronds
- reeds
- woven coconut palm leaves
- herbaceous plant material, particularly weed species which may shed their seed on the seedlings (e.g. *Eupatorium* spp.).

11.3 Protection from heavy wind and rain

Sudden storms can be devastating to nursery stock unless proper precautions are taken. Heavy-duty clear plastic sheeting is the best material to use against strong winds and rain, if it is available. One method of erecting such protection is illustrated below.



A detailed description of one method of constructing such a protective structure is given in Appendix 6.

11.4 Fertiliser

Rapid growth of the young seedlings may be assisted by the application of fertiliser in aqueous solution; a 200 g pack of 'Aquasol' is included in the propagation kit for this purpose.

'Aquasol' contains both the macro- and micronutrients necessary for plant growth, and should be applied at the rate of 8 g (a measuring spoon is provided inside the pack) per 5 litres water. Water the plants with the solution at fortnightly intervals.

Spraying should be done in the early morning or evening on a non-rainy day.

11.5 Weeding

Any weed seedlings growing up amongst the young tree seedlings should be removed WITH CARE, avoiding disturbance to the roots of the tree seedlings.

Do not remove any small plants unless you are sure that they ARE weeds.

11.6 Fungal problems

Common fungal diseases in young seedlings

A variety of fungal diseases may attack young seedlings at different stages in development. This is illustrated in Figure 5 for *Eucalyptus* spp., although a similar pattern of disease may be observed in other species.

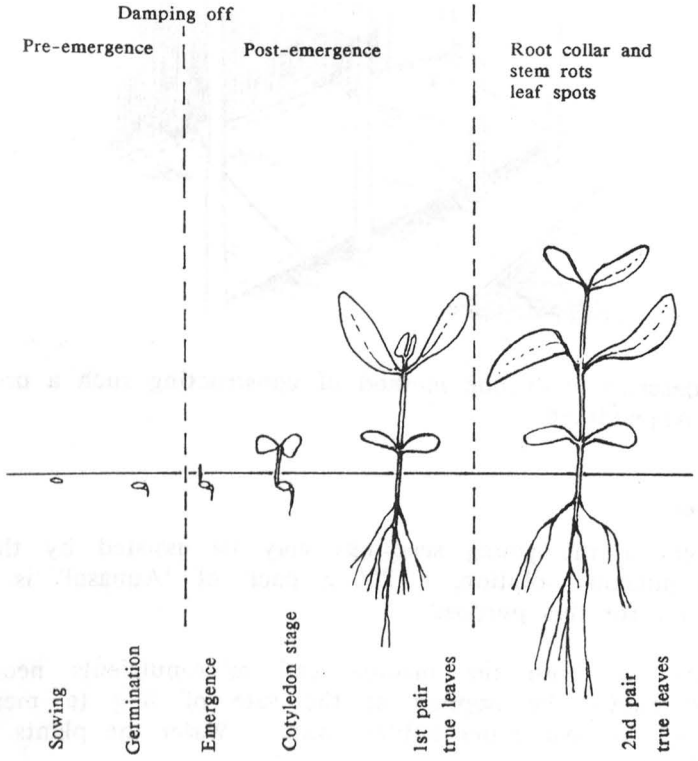
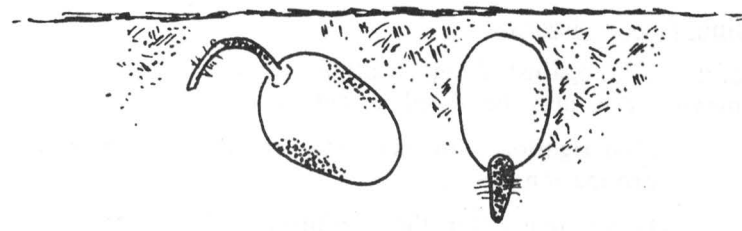


Figure 5. The succession of certain common fungal diseases in young eucalypt seedlings

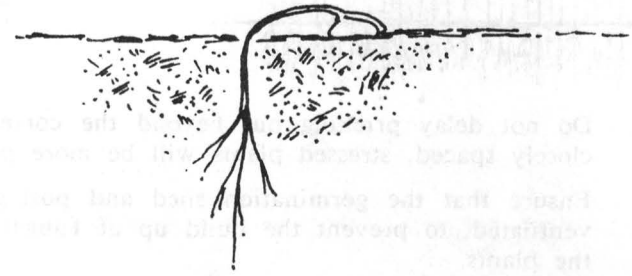
Damping off may occur either before or after the young seedlings emerge from the soil.

. Pre-emergence damping off is caused by several fungi and bacteria. The seed either rots before it germinates, or once it has sprouted but not broken through the soil surface. This is most common in cold wet soil, and often goes undetected, poor germination being blamed on poor quality seed.



Pre-emergence damping off often occurs in patches, resulting in a very uneven germination pattern.

. Post-emergence damping off is characterised by a rotting of the stem of young seedlings at ground level, causing them to fall over and die.



Fungi responsible for this disease include *Rhizoctonia* spp. and the phycomycetes *Pythium* spp. and *Phytophthora* spp.

Both forms of damping off tend to occur in patches. These patches enlarge rapidly, resulting in the whole germination tray becoming infected, unless preventative measures are taken QUICKLY.

Root, root collar and stem rots are caused by a variety of fungi, chief amongst which are *Phytophthora* spp., *Cylindrocladium* spp., and *Rhizoctonia* spp.

Infection may occur in the roots, working up to the stem; at the collar; or in the lower part of the stem. The tissue becomes soft and brown, and the seedlings soon die.

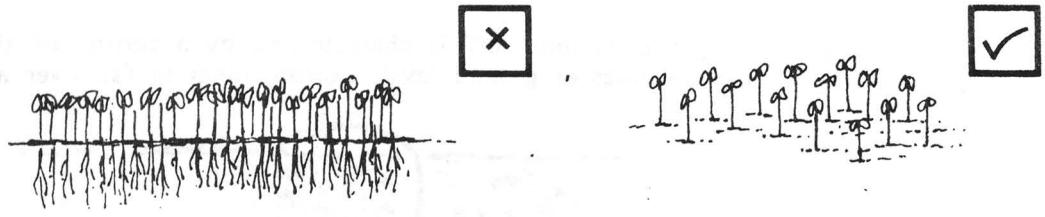
Moist conditions will favour the build-up and spread of rot-causing fungi.

Leaf spots, comprising brown, dead patches of tissue on seedling leaves, are caused by a variety of fungi. They include *Cylindrocladium* spp., *Alternaria* spp. and *Cercospora* spp. Heavy infection of young seedlings can badly retard growth, and, in some cases, cause death.

Avoiding fungal diseases

The best tactic against fungal pathogens is to prevent their occurrence. Ways of achieving this may be listed as follows:

- Sub-irrigation will markedly reduce the incidence of damping-off in germination trays.
- Do not overwater the seedlings.
- Ensure that the nursery soil mix is freely draining.
- Do not sow the seed too densely, as this will result in closely spaced plants, amongst which disease will spread rapidly.



- Do not delay pricking out beyond the correct size, as the oversized, closely spaced, stressed plants will be more prone to disease.
- Ensure that the germination shed and post-germination area are well ventilated, to prevent the build up of fungal spores in the vicinity of the plants.
- Practice good nursery hygiene. Practical guidelines are listed in Section 15.
- In certain cases, it may be wise to spray fungicide at fortnightly intervals as a means of preventing fungal epidemics. However, unless the risk of such epidemics is severe, this is not recommended.

For comments upon the types of fungicide available, and guidelines on their use, REFER TO SECTION 14.

Treatment of fungal diseases

In the event of disease occuring:

- ISOLATE the infected seedlings
  - Germination trays containing diseased seedlings should be removed from others.
  - Potting bags containing diseased seedlings should also be removed, LABELLED (if not already), and isolated from others.

- Spray ALL seedlings with the appropriate fungicide, taking all necessary precautions. REFER TO SECTION 14 FOR DETAILS.
- Any dead seedlings, should be removed and burnt, to prevent the spread of fungal spores.

11.7 Insect problems

Most insect problems in the nursery are likely to occur once the plants are larger (beyond the pricking out stage).

Insect pests are described in Section 13.9.

11.8 Other pests

Although fungi and insects are the most common pests in tree nurseries, other potential pests include viruses, bacteria, nematodes, mites, snails, slugs and rodents such as mice and rats.

Methods of control of these pests are detailed in some of the publications listed under 'Further reading'.

12.0 PRICKING OUT

12.1 Filling potting bags

Filling procedure

Black plastic potting bags, size 10 mm diameter when filled × 200 mm height, with 25 mm drainage slits, are included in the propogation kit. It is recommended that a simple funnel is made so that these bags can be easily filled; this is illustrated in Figure 6.

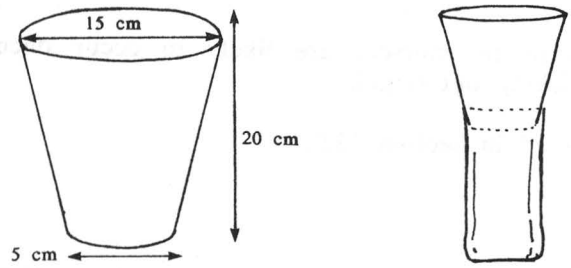
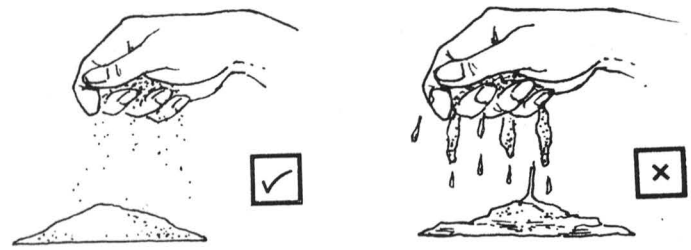


Fig. 6. A funnel for filling potting bags.

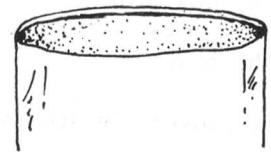
When filling the bags:

. Use only dry potting mix.



. Shake down the soil so that there are no wrinkles in the plastic, and no air pockets.

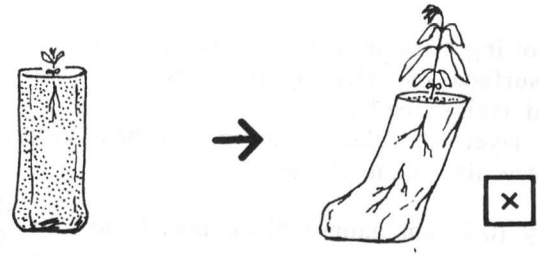
. Fill right to the top of the bag.



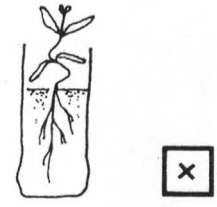
. Stand the bags upright in the beds, and water heavily.
. Leave to drain overnight before using the bags the following day.

The following are to be AVOIDED:

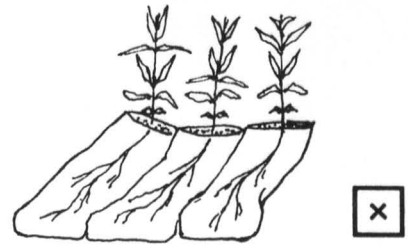
. Air pockets, since these create a line of weakness in the soil along which the seedling roots may be easily broken later on.



. Inadequate filling of the bags; this will later result in the seedlings being too low in the bags when the soil mix settles.



. Poor stacking of the bags in beds, leading to bent seedlings.



Volume of mix required

One cubic metre (1 m^3) of potting mix will fill about 2200 bags of the size provided. The number of seedlings pricked out should be at least twice the number of seedlings required for the trial.

For example, the calculations for a provenance trial with 20 seedlots, using 36-tree plots and four replicates, are:

- Number of seedlings required for trial = 20 × 144 = 2880
- Minimum number of seedlings to be pricked out = 2880 × 2 = 5760
- Minimum volume of potting mix required = 2.6 m^3 (prepare at least 3 m^3).

The volume of mix would obviously have to be adjusted for different bag sizes.

12.2 Stand out beds

Suitable surfaces

Surfaces on which potting bags may be placed include:

- a raised surface of wire mesh or wooden slats, about 10 cm above the ground (raised beds)
- a 10 cm layer of clean, sieved crushed coral, crushed bricks or gravel, piece size about 2 cm
- concrete
- heavy duty (0.2 mm gauge) black polythene } sloped to give good drainage
- bare soil.

These possibilities are given in order of preference; they are shown diagramatically in Figure 7.

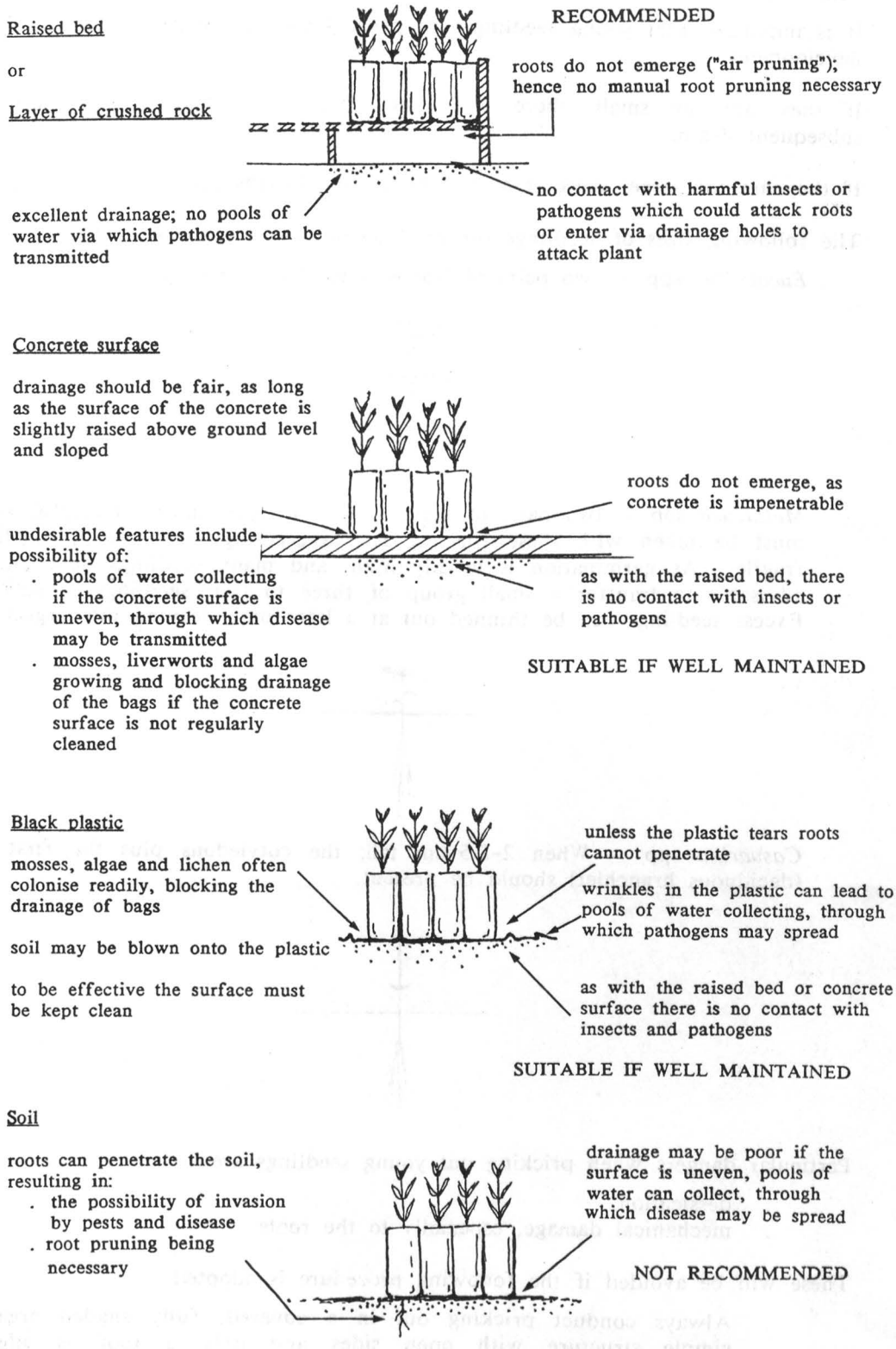


Figure 7. Stand out bed surfaces

12.3 Pricking-out technique

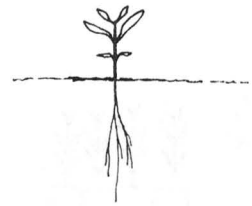
It is important that young seedlings are pricked out at exactly the right stage in development.

If they are too small, there is a very high risk of moisture stress, and subsequent death.

If they are too large, there is a very high risk of damaging the young roots.

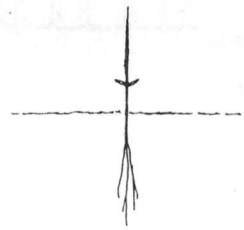
The following sizes of seedlings for pricking-out are recommended:

Eucalyptus spp. – two pairs of leaves, plus the cotyledons.



Melaleuca spp. – two pairs of leaves, plus the cotyledons. Exceptional care must be taken with these species, as the seedlings tend to be small and fragile. As germination is usually high, and many seedlings develop, it is advisable to transfer a small group of three to four seedlings to each pot. Excess seedlings can be thinned out at a later date, leaving the largest.

Casuarina spp. – When 2-2.5 cm tall; the cotyledons plus the first 'leaf' (deciduous branchlet) should be present.



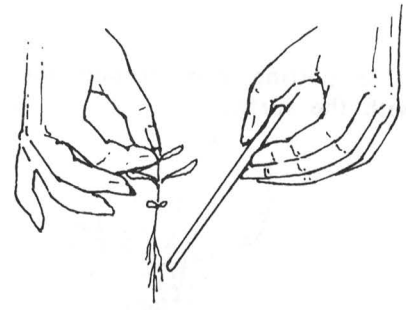
Particular dangers when pricking out young seedlings are:

- dessication
- mechanical damage, especially to the roots.

These will be avoided if the following procedure is adopted:

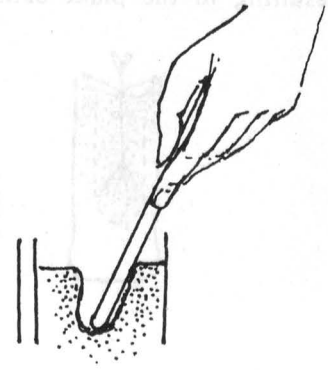
- Always conduct pricking out in a covered, fully shaded area. A simple structure with open sides and only a roof is adequate, although seedlings should also be protected from strong, dessicating winds.

- Water the germination trays, as the roots of the seedlings are more easily removed from wet soil.
- Have at hand a small container (a dish, half a coconut shell, a plastic carton, or whatever available), full of water.
- Take ONE germination tray, and carefully uproot some of the seedlings using a dibbling stick (a few sticks are enclosed in the propagation kit, as samples). Each seedling should be held gently by a leaf, NEVER by the stem. If one leaf is crushed, the seedling may recover; if the stem is crushed, the seedling will be killed.

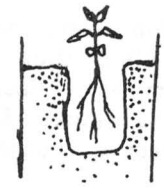


- Transfer the seedlings, one at a time, to the container of water; ensure that the roots are fully immersed in the water, so that they do not dry out. About 15-20 seedlings should be uprooted at one time and transferred to the potting bags.

- Using the dibbling stick, make a hole in the potting mix in each bag. The hole should be large enough for the seedling root to go straight down into the potting mix.



. Place the roots of the seedling in the hole, TAKING CARE THAT THEY ARE NOT BENT.



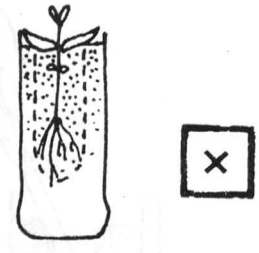
. Carefully firm the potting mix around the roots, so that the root collar is level with the surface.

. Pour on a little water; this helps ensure that no air pockets are left around the roots.

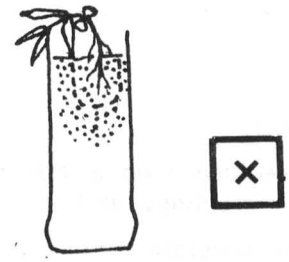
. Always finish one tray and clearly label the pricked-out seedlings, before moving on to the next tray. Keep all seedlots SEPARATE.

The following are common mistakes; take care to avoid them:

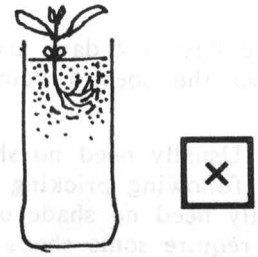
. Hole too deep, resulting in the plant being half buried.



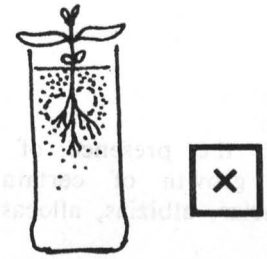
. Hole too shallow; the plant will dessicate rapidly.



. Hole too shallow, resulting in the roots being bent. The growth of the plant will be permanently retarded. Furthermore, plants with this defect will be prone to windthrow when planted out in the field.



. Air pockets left around the roots; this will cause rapid dessication of the plant.



13.0 CARE OF OLDER SEEDLINGS

13.1 Watering

General points are as follows:

- Water younger seedlings with a gentle spray; a watering can is only suitable for larger seedlings, at least 7-8 cm in height.
- The frequency of watering can usually be reduced once the seedlings are larger.
- Watering should be further reduced, as a means of 'hardening off', a week or so before the plants are transported to site.

13.2 Shade

Shade is required during the first 3-4 days after pricking out, but may then be unnecessary, depending upon the species being raised and the local climatic conditions. As a guide:

Eucalyptus spp. *Casuarina* spp.	Usually need no shade after the first fortnight following pricking out
Acacia spp.	Usually need no shade once 2-3 cm tall
Melaleuca spp.	May require some shade for the first month after pricking out.
Araucaria spp.	Require shade throughout the nursery period.

13.3 Protection from heavy wind and rain

This may be necessary, at least whilst seedlings are still quite small (refer to Section 11.3).

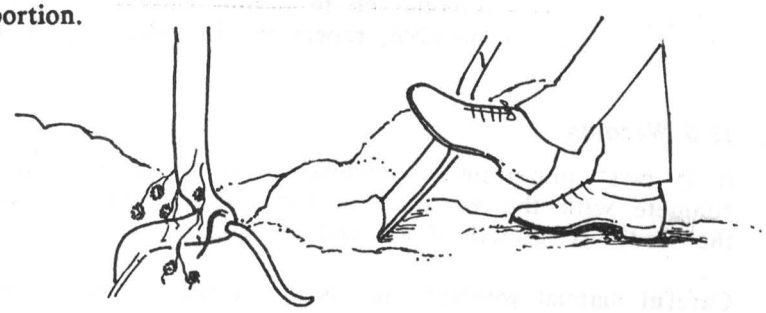
13.4 Soil microorganisms

As noted in Section 8.3, the presence of beneficial soil microorganisms is required for the healthy growth of certain Australian tree species, notable amongst which are the acacias, albizias, allocasuarinas and casuarinas.

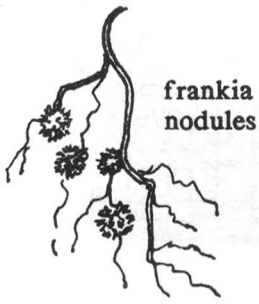
If mature specimens of these trees are growing locally, it is advisable to ensure inoculation of the young seedlings being raised by introducing some of the microorganisms isolated from the mature trees. (This is assuming that no seed inoculation treatment was conducted; if it was, further inoculation of the young seedlings should not be necessary.)

Seedling inoculation should be carried out just after pricking out, when the young seedlings are about 3 cm tall. The procedure is as follows:

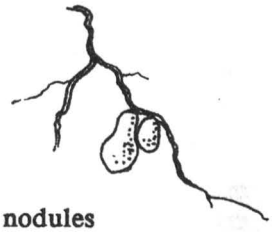
. To obtain a sample of nitrogen-fixing nodules, select a healthy, preferably 3-12-year-old tree. Dig down to the smaller, finer roots, and remove a portion.



. Wash the roots free of soil with water; this should reveal the nitrogen-fixing nodules. The rhizobial nodules on acacia or albizia roots vary in size and shape according to species, but are generally rounded or spherical. The nodules formed by frankia on casuarina and allocasuarina roots have a more spiky appearance. Both are illustrated below.



frankia nodules



Acacia nodules formed by rhizobia

. Remove the nodules from the roots; place them in a bowl and grind them to a paste. If both rhizobial and frankia nodules are being collected, take care to keep them completely separate.

. Add the paste to water in a watering can or sprayer, and water the solution onto the appropriate seedlings. About 10 g of nodules will be adequate to nodulate at least 1000 plants as long as the nodules have been well ground and thoroughly dispersed in the water.

. Nodulated plants will grow well, and will appear green and healthy. Non-nodulated plants will often exhibit stunted growth, and will tend to have a brownish or yellowish coloration. If a lack of nodulation is suspected, examine a few seedlings for nodules. If nodules are not present:

- ensure that the plants are not overwatered or waterlogged, as this will tend to inhibit nodulation
- if possible, repeat the inoculation process.

13.5 Weeding

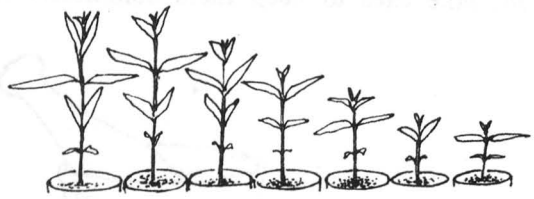
It is most important to remove weeds from the beds regularly. Weeds will compete with the young trees for water, light, and nutrients, and will reduce the seedlings' growth if allowed to flourish.

Careful manual weeding, and NOT chemical weeding, is recommended.

13.6 Grading of beds

By the time some plants are 7-10 cm high, the larger individuals may be shading out the smaller ones; this will tend to make the small plants grow even more slowly.

The seedlings should therefore be graded, placing the larger plants at one end of the bed, and the smaller plants at the other end.



Depending upon the length of time that the plants are kept in the nursery, this process may need to be repeated several times.

13.7 Root pruning

If a nursery is being well run along the guidelines recommended, root pruning should never be necessary.

However, if plants have been stood on bare soil, torn plastic sheeting, or wet concrete, their roots will begin to penetrate the plastic potting bags as they grow. It is necessary to prune these roots regularly, in order to promote a fibrous root system and prevent any roots growing into the ground. Pruning should be conducted as follows:

. Use a SHARP knife, razor, or pair of scissors to cut the roots.

. After pruning, the plants will tend to wilt. This is normal and only temporary. Water them thoroughly.

. Repeat root pruning every fortnight or so, as necessary.

13.8 Fungal problems

Common fungal diseases in older seedlings

A number of these are outlined below.

Stem rots may be caused by a variety of fungi, including *Cylindrocladium* spp., *Rhizoctonia* spp. and *Botrytis* spp.

Cylindrocladium spp. infections occur in the lower part of the stem, causing the seedlings to wilt and eventually die. Under warm and humid conditions, a white powdery mass (of conidia) may be visible over the infected area. The disease is particularly common in over-shaded seedlings.

Rhizoctonia spp. attack seedlings near ground level. Greyish, water-soaked lesions appear on the stem, whilst reddish brown fungal threads may be seen in association with the rotted areas, and on the potting mix surface. Infected seedlings wilt and die. The disease is encouraged by moist, warm conditions and poor ventilation.

Botrytis spp. will develop on stems and leaves when dead or dying tissues are left in contact with healthy tissue. The disease is characterised by a soft rot covered with grey coloured mould; if not controlled, it can result in seedling death. It is favoured by overcrowding of seedlings, and poor ventilation.

Powdery mildews form a dense white powdery layer (of spores) on leaf surfaces, readily visible to the naked eye. They are encouraged by shaded, warm conditions and generally weaken the host plant. If left uncontrolled, they can cause seedling death.

Leaf spots may be caused by many different fungi; some of the more common are *Cylindrocladium* spp., *Phaesoseptoria* spp., *Alternaria* spp., *Cercospora* spp. and *Septoria* spp. Most cases of leaf spotting will weaken a seedling and possibly cause some leaf shedding, but will not usually kill the plant.

Avoiding fungal diseases

The same points apply as in Section 11.6 (for younger seedlings). Refer also to Section 15 on Nursery Hygiene; this is MOST important.

Treatment of fungal diseases

Follow the procedure outlined in Section 11.6 (for younger seedlings).

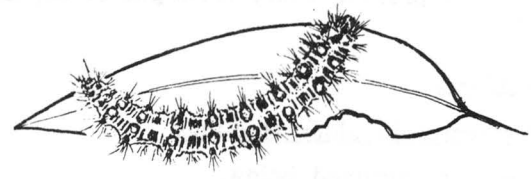
BEFORE APPLYING ANY FUNGICIDE, FIRST READ SECTION 14.

13.9 Insect problems

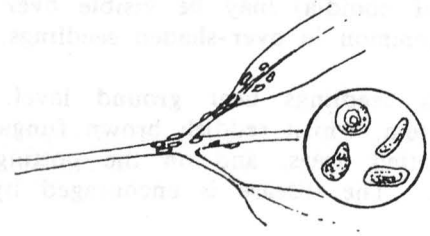
Common insect pests on older seedlings

A number of these are outlined below.

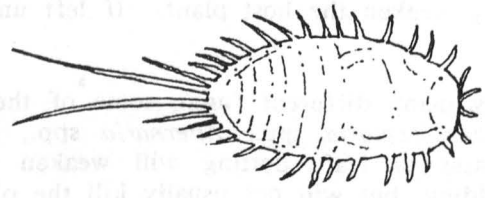
Caterpillars are the larvae of moths or butterflies; they feed by chewing leaf tissue.



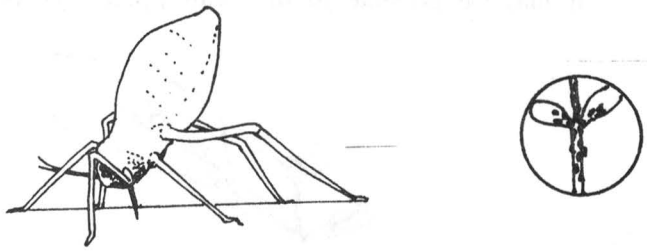
Scale insects are sedentary, sap-sucking insects which cover themselves with a mantle of wax-like material; this may be white or brown. The pest is vulnerable to chemical control only when the larvae have just emerged from beneath the adult females, and are free moving.



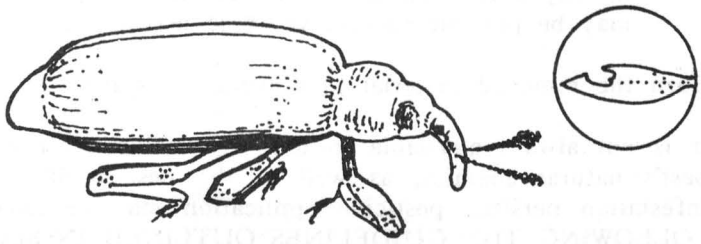
Mealy bugs are scale-like, sap-sucking insects, but they are free living, and can move slowly. The females form a mass of mealy-coloured or white fluffy material, into which the eggs are laid.



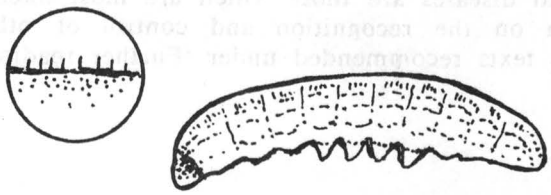
Aphids are small green or black sap-sucking insects which attack young plant tissues, clustering along the stems and leaves.



Weevils may attack the shoots and leaves of young tree seedlings.



Cut worms are moth larvae which inhabit the soil by day, and attack young seedlings above ground level by night, often biting through the stems just above the soil surface.



Termites may cause damage to young seedlings in the nursery, but they are usually a more serious problem when the seedlings are planted out on site.

Avoiding insect pests

Follow good nursery hygiene. (Refer to Section 15)

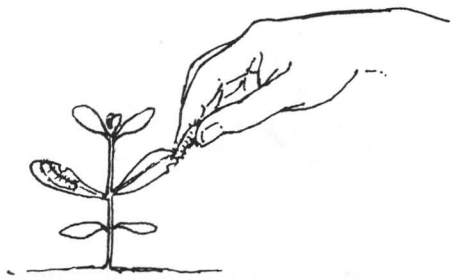
Locate the nursery in a position away from larger trees, which can act as hosts for insect pests.

Treatment of insect pests

Plants infested with insect pests should be treated as follows:

. ISOLATE the infested seedlings, taking care that they are all labelled with their seedlot number, to avoid later confusion.

- If practicable, physically remove the pest from the seedling. For example:
  - it may be possible to pick caterpillars off the leaves



  - if only a few leaves on the seedling are infested with a pest it may be possible to remove these leaves.

  Burn the removed material to prevent the spread of the pest.

- It is not always advisable to use a pesticide, as this can destroy the pest's natural enemies, as well as the pest itself. However, if the infestation persists, pesticide application may be necessary. Do this FOLLOWING THE GUIDELINES OUTLINED IN SECTION 14.
- Any dead seedlings should be removed and burnt.

13.10 Other pests

Insect pests and fungal diseases are those which are most likely to occur in the nursery. Information on the recognition and control of other pests may be found in some of the texts recommended under 'Further reading'.

14.0 APPLICATION OF PESTICIDES

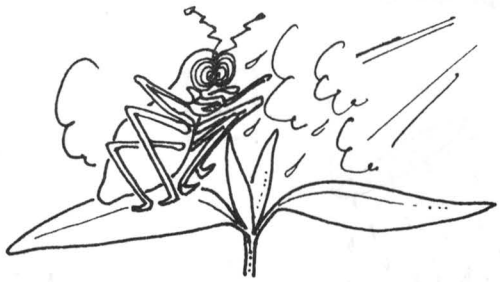
14.1 General points

How do pesticides work?

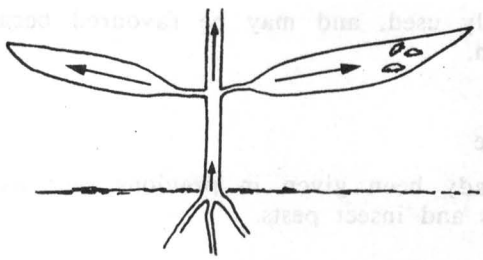
Broadly speaking, pesticides may by grouped into two types:

- contact
- systemic.

Contact pesticides only work if the pest comes into direct contact with the chemical.



Systemic pesticides are chemicals which are taken up by the leaves or roots of plants, rendering them poisonous to pests which feed on this tissue. They may thus serve to protect plants against future, as well as present, attack; the duration of protection will vary according to the chemical used.



How poisonous are pesticides to man?

Different pesticides have different levels of toxicity to man, but all should be handled with CAUTION.

In Australia, there is strict legislation upon poisonous substances, which are graded in a poison schedule according to their toxicity. This tells a person immediately what precautions should be taken when using the chemical. Pesticides on sale in other countries may not give such specific warnings; whatever you use, use it with care, following at least the minimum safety precautions outlined in this section.

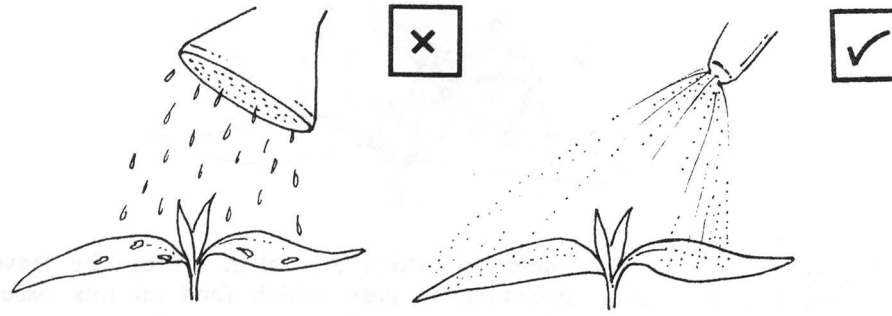
How are pesticides applied?

Pesticides are available in a variety of formulations, notably as:

- sprays
- dusts
- granules
- fumigants (smokes).

Often the most convenient formulation is that for sprays; most pesticides currently on sale today for use as sprays are prepared as either powders or liquids which readily disperse into fine droplets when added to water.

The finer the spray that is used to apply the pesticide, the more even the cover over the plant will be; furthermore, less pesticide will be required for effective results. It is therefore far better to use a spray rather than a watering can to make applications.



A very efficient type of spray is the ultra low volume (ULV) spray, which produces extremely fine droplets and is very economical in its use of pesticide.

Granules are also widely used, and may be favoured because of their ease of handling and application.

14.2 Choice of pesticide

Some details have already been given in previous sections on more commonly occuring fungal diseases and insect pests.

Try to identify the nature of the problem.

Fungal diseases

The propagation kit contains two fungicides:

'Previcur' Effective against phycomycete fungi, mainly *Pythium* spp. but also *Phytophthora* spp. and downy mildews.
Active constituent: Propamocarb

'Rovral' Not effective against phycomycetes; used mainly against *Botrytis* spp., fungal leaf spots, etc.
Active constituent: Iprodione

Both these fungicides act systemically, and are currently exempt from the Australian poison schedules. This means that no evidence has been found to date to indicate that they are poisonous to man. Nevertheless, use them carefully.

The following points should be noted in the method of their use:

- When using fungicides on a regular basis as a precautionary measure, alternate the compound used. For example, use 'Previcur' first, and 'Rovral' the following fortnight.
- When treating a fungal attack, it is also good practice to use two suitable fungicides alternately, as this helps to avoid any build-up of resistance to the chemical by the fungus. In this case, it will be necessary to purchase another suitable fungicide to use alternately with one of those provided. Choose one which has a different active constituent.
- Make applications fortnightly, at the dosage recommended. In very severe attacks, applications may be made once a week. Do not apply fungicides more often than this, as the risk of a build-up of resistance to the chemical by the fungus will be increased.

Insect pests excluding termites

The propagation kit contains one insecticide:

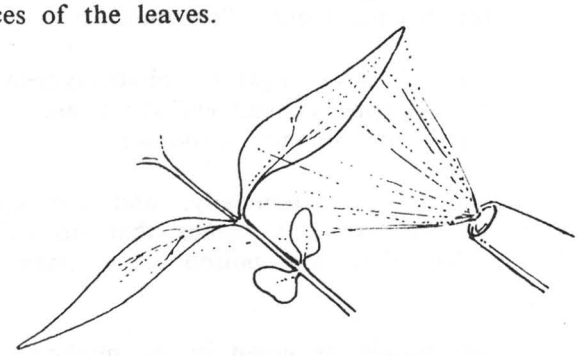
'Pyrethrum' Controls caterpillars, ants, aphids, leaf hoppers, etc.
Active constituents: Pyrethrin and piperonyl butoxide

This compound contains a natural insecticide derived from pyrethrum flowers, which is deadly to many insects but of low toxicity to man. Nevertheless, certain precautions should be followed:

- If 'Pyrethrum' is accidentally swallowed
  - induce vomiting
  - seek the advice of a doctor.
- Do NOT place the bottle near a naked flame; it is highly flammable.

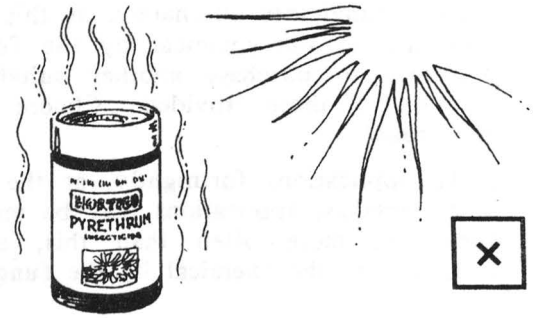
The following points should be noted if using 'Pyrethrum':

- 'Pyrethrum' is a contact insecticide. It is therefore important to ensure that the insects come into contact with the chemical. When spraying, make sure that all parts of the plant are covered, including the undersurfaces of the leaves.



- 'Pyrethrum' can only be used to treat insect attacks when they occur; it is of no use as a preventative spray, as if it rapidly inactivated by sunlight.

NEVER leave the bottle in sunlight.



- Spray 'Pyrethrum' once a week as long as the insect pests are noted.
- Do NOT spray 'Pyrethrum' on very young seedlings, as it could damage them.

As 'Pyrethrum' is only of limited use against insect pests, it may be necessary to purchase or prepare other insecticides, to be used alternately with 'Pyrethrum', or as a remedy against pests which it does not control, e.g. cutworms and scale insects.

Compounds of use in controlling scale insects, and of low toxicity to man, include the following (adapted from Beeson 1941):

soap solution	The solution is prepared by dissolving 500 g soap dissolved in 5 litres of warm water, and diluting it with a further 25 litres of cold water.
tobacco solution	This is prepared by dissolving 25 g of soap in 2 litres of hot water, pouring this over 100 g of dry tobacco leaves, and leaving the mixture to soak overnight. The liquid is then poured off, and diluted with a further 7 litres of cold water before use

kerosene oil solution	This is prepared by dissolving 35 g soap in 1 litre of boiling water, adding 1.5 litres of kerosine, and stirring furiously. The mixture is then diluted with a further 29 litres of cold water before use.

All these preparations are contact insecticides, and must therefore be sprayed directly onto the pest to have any effect. They are not useful for controlling pests such as cutworms which live below ground. Note that most suitable systemic insecticides are VERY POISONOUS.

Termites

Termites are not usually a severe problem in the nursery, but it may be advisable to take precautions against subsequent termite attack before planting seedlings out in the field.

All currently-available pesticides which are effective against termites are highly dangerous compounds. One of those most commonly used is aldrin; the use of this compound is barred in many countries except in very limited circumstances, and it should ONLY be used as prescribed below if termites are a very serious problem, and no alternative is available.

The most effective method of applying aldrin is as a root drench, just before the seedlings are transported to the field. The seedlings should have already been placed in the planting boxes described in Section 18 at this stage.

The nursery should be set up with a tank, an upturned half, crosswise cut (44 gallon or 200 litre) oil drum is sufficient; and a slightly sloping drainage table, with an outflow channelled back into the tank. This is illustrated in Figure 8.

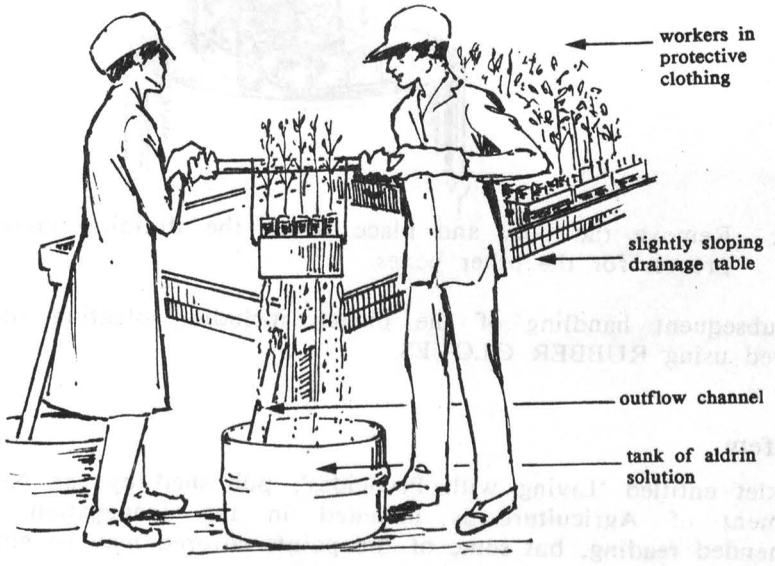
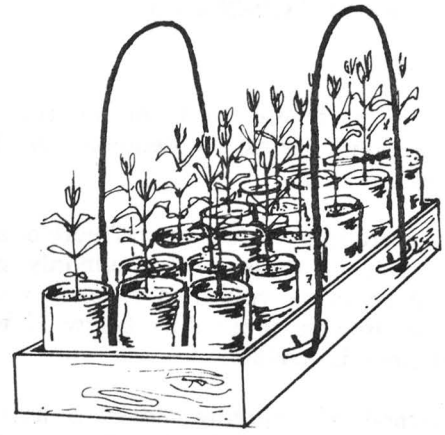


Figure 8. The equipment needed for root drenching young seedlings

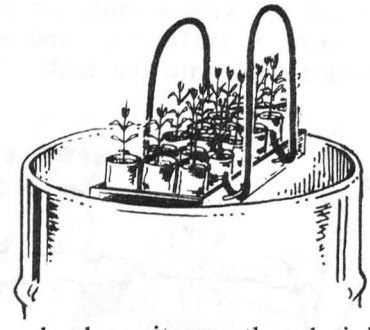
All persons coming near the area from this time on should wear AT LEAST the protective clothing recommended in Section 14.3, i.e. a hat, a long sleeved shirt, long trousers (or overalls), rubber gloves and rubber boots.

Follow the procedure outlined below:

- Prepare the aldrin mix in the tank by making up a 1% solution in water. For example, use 1 litre of concentrate in 100 litres of water. The volume prepared should be sufficient to allow for the plants to be fully immersed in the solution.
- Hook the first planting box to the handles, as illustrated.



- Lower the box into the tank, so that the soil and roots are fully immersed. Leave the box in the solution for 3 minutes.



- Remove the box, and place it on the draining table. Repeat the process for the other boxes.

ALL subsequent handling of the plants, including planting itself, should be conducted using RUBBER GLOVES.

14.3 Safety

A booklet entitled 'Living with Pesticides', published by the New South Wales Department of Agriculture is included in the propagation kit. This is recommended reading, but some of the points covered may be emphasised.

Protective clothing and equipment

The minimum protective clothing that should be worn when using pesticides is illustrated in Figure 9.

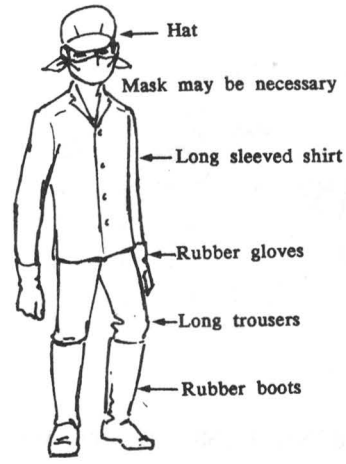


Figure 9. The minimum protective clothing to be worn when handling pesticides.

Mixing and applying pesticides

The following points are particularly important:

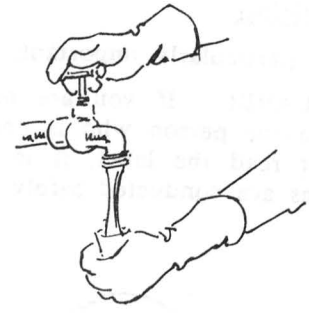
. READ THE LABEL. If you are not personally using the pesticide, make sure that the person who is understands EXACTLY what to do. If they cannot read the label, it is your responsibility to check that ALL operations are conducted safely.

. Measure out the amount of pesticide to be used PRECISELY, using the measuring cap provided with the pesticide.

Use NO MORE and NO LESS than the amount stated on the packet.

. Some pesticides may be mixed and applied together. However, some pesticides do not mix. It is best to always apply pesticides separately, to avoid the risk of mixing incompatible chemicals.

. Rinse out the measuring container, and the bottle, if empty, and add the rinse water to the spray container.



. Spray only on a fine, calm day.

Do NOT spray:
- . on a wet day; all the pesticide may be washed away
- . on a windy day; spray drift can be harmful.

. If you are spraying inside an enclosed area (e.g. a germination hut), ensure that ventilation is adequate.

. After spraying, all containers that have been used must be washed out at least three times.

. Dispose of empty bottles and packets by burying them in a pit.

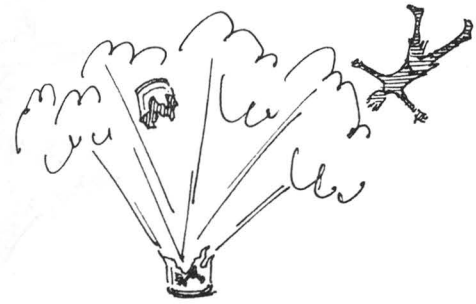
. Ensure that the person who has applied the pesticide washes him or herself and his/her clothes THOROUGHLY and IMMEDIATELY.

General precautions

Always follow the precautions outlined below:

. NEVER eat, drink or smoke anywhere near the pesticide.

. NEVER place a naked flame near pesticides; some of them are highly flammable.

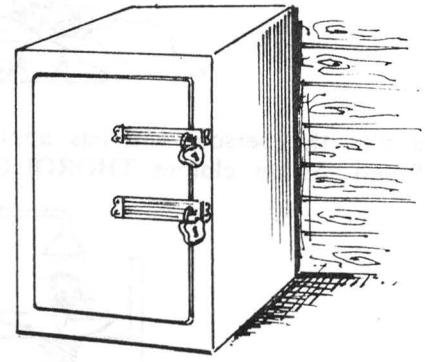


. NEVER leave spraying equipment unattended.

. NEVER clean spray nozzles or filters by putting them to the lips and blowing down them. A pin or a small brush will serve the purpose.

. NEVER put pesticides or old containers in streams, canals or ponds.

. Always store pesticides in a secure place, out of reach of children and domestic animals.



15.0 NURSERY HYGIENE

The risk of insect pests and disease being introduced to, or spread within, the nursery can be greatly reduced by good nursery hygiene. Points to note include the following.

Potting mix

If possible, this should be pasteurised; refer to Section 9.3.

Do NOT reuse old mix unless it has first been pasteurised.

Disinfection of equipment and the working area

Nursery equipment and the general working area should be regularly disinfected to prevent the build up of pests and disease. A suitable disinfectant is a 2% bleach solution which can be made up by, for example, diluting 200 millilitres of bleach concentrate in 10 litres of water. Use rubber gloves when handling the concentrate.

Ensure that nursery tools are washed and disinfected daily. A good practice is to locate a washing area at the nursery entrance, and insist that labourers arriving for work first wash their tools and then dip them in bleach solution. The bleach solution should be renewed regularly, the frequency depending on the number of tools being used, although once a week may be taken as a guide.

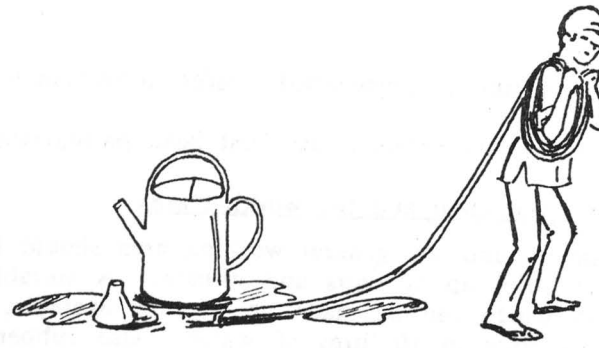
If old germination trays are to be re-used, clean and soak them in the bleach solution for 5-10 minutes.

Keep the nursery area clean by washing down the benches in the germination hut with the bleach solution after every batch of seedlings. Similarly, wash down container beds with bleach solution once the seedlings have been moved out.

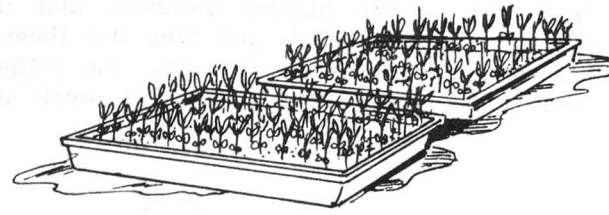
Handling excess water

Do not allow muddy water to splash into the potting bags.

Do not allow the ends of hoses to be dragged along the ground before watering the plants. Similarly, do not place watering can roses on the ground before using them.



Do not sit germination trays or potting bags on surfaces on which water can pond.



REMEMBER - fungal spores are readily transmitted by contaminated water.

Surfaces of stand out beds

As noted in Section 12.2, potting bags may be placed on a variety of surfaces. The best surfaces to use are either concrete or, best of all, raised beds.

Disposal of diseased plants

NEVER retain old and diseased plants in the nursery; they will serve as a source of infection for other stock.

Diseased plants should be disposed of by burning.

Personal hygiene

Nursery workers can transmit fungal spores or insect eggs under their fingernails, or on their skin. This risk will be greatly reduced if workers are able to wash their hands and dip them in a disinfectant such as 0.5% bleach solution or 'Dettol' every day before commencing work.

Water

The water supply to the nursery should be as clean as possible. Stagnant water is highly likely to be contaminated with fungal spores such as *Pythium* spp. and *Phytophthora* spp.

16.0 NURSERY RECORDS

Accurate records of seedlot performance are essential throughout the duration of the trial, and should be commenced at the nursery stage.

It is strongly recommended that a copy of the nursery records form (Appendix 7) is completed for each seedlot. The 'observations' column may need to be extended to a further sheet; points to note when filling it in include:

- applications of fertiliser: type, amount and date
- applications of inoculum (if required): type, amount, method and date
- incidence of insect pests or disease, with a brief description of the problem, and the date first observed
- applications of pesticide: type, amount and date.

17.0 LAYING OUT THE TRIAL

17.1 Site information

Site survey and mapping

The site should be fenced off and surveyed at least 3 months before the proposed planting date.

Two maps should be drawn up, one showing the location of the trial and the other, the site details.

The recommended specifications for the location map are:

Scale: 1:100,000

The heading of the map should include the:

- name and location of the trial
- scale.

Mark in:

- the direction of north
- major location features such as roads, tracks, rivers, streams, bodies of water, forest, nearby settlements, etc.

A hypothetical example of a location map is given in Figure 10.

The recommended specifications for the site map are:

Scale: 1:1000 (or 1:2000 for larger trials)

The heading of the map should include the:

- name and location of the trial
- scale
- design used
- date planted
- spacing
- total area of the plots
- total area of site

Mark in:

- the direction of north
- all noteworthy features of the site, e.g. access routes, rocky areas, waterlogged areas, streams, etc.
- the position of all plots, and the species therein. If a key is used for labelling species and or provenances, this should be detailed on the map.

A hypothetical example of a site map is given in Figure 11.

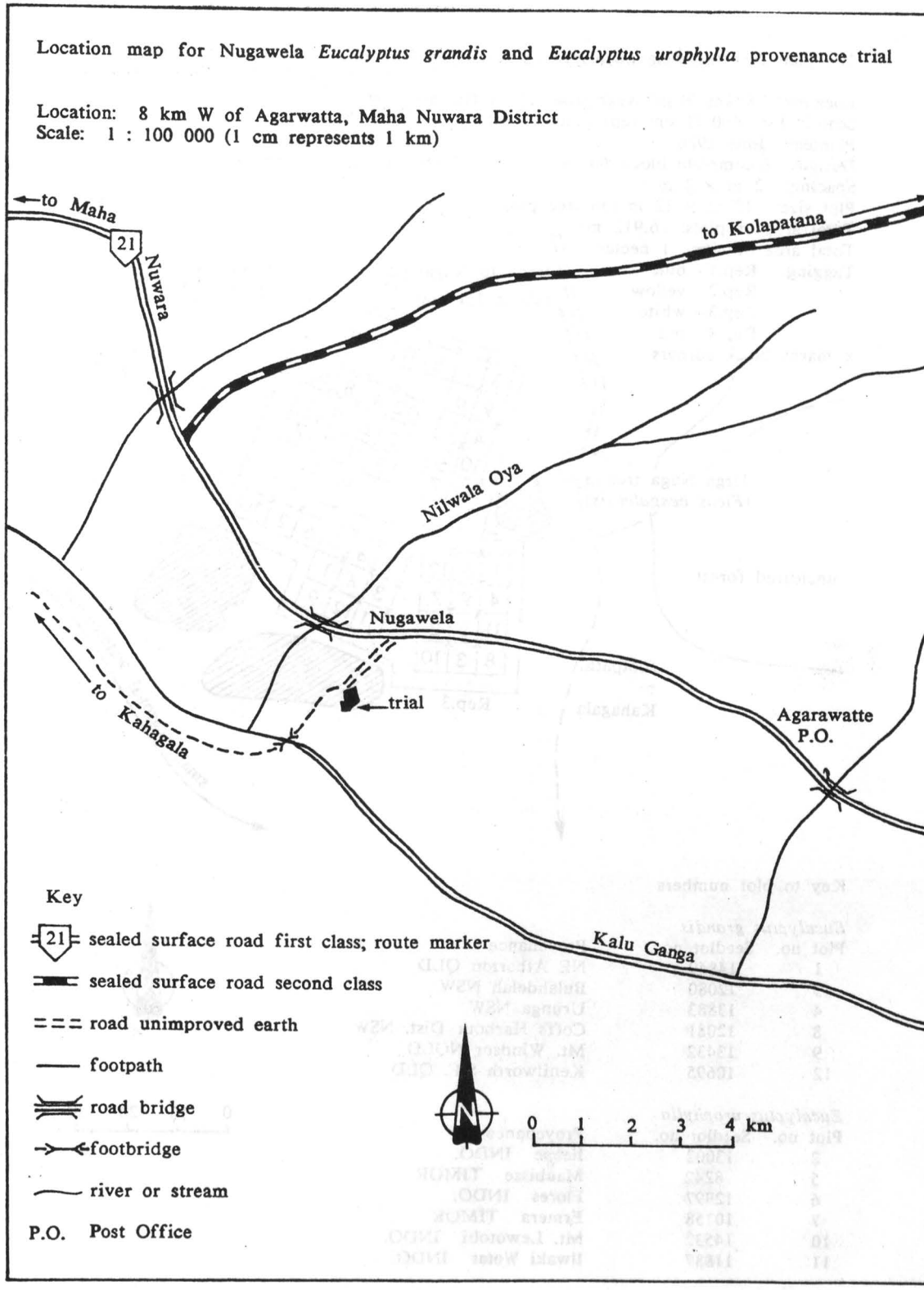
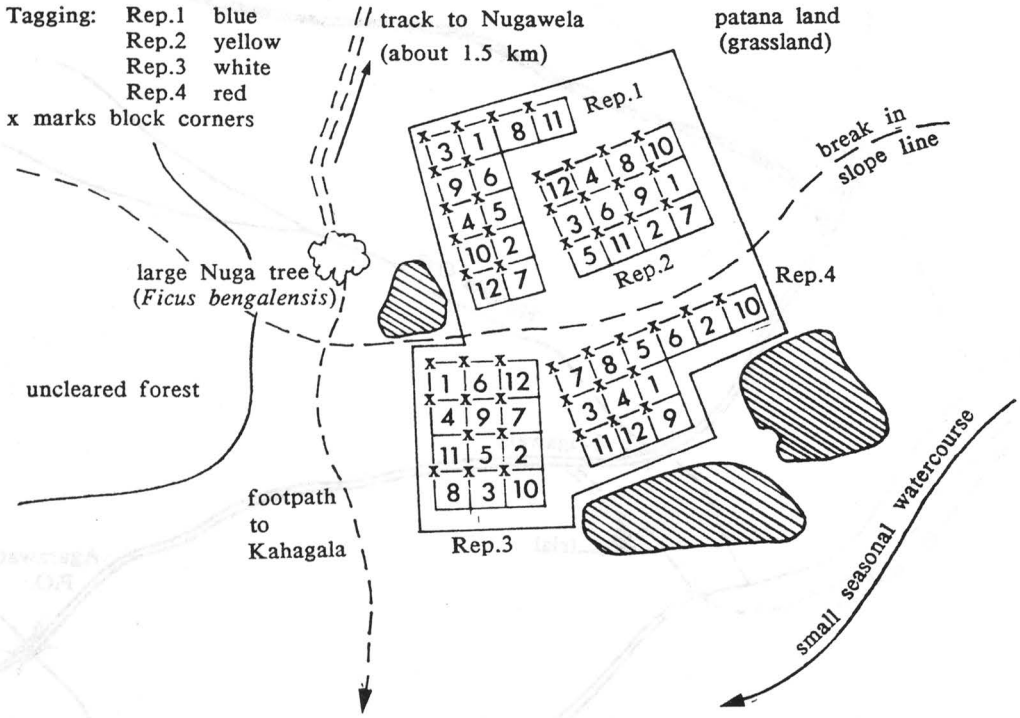


Figure 10. A hypothetical location map

Site plan for Nugawela *Eucalyptus grandis* and *Eucalyptus urophylla* provenance trial

Location: 8 km W of Agarwatta, Maha Nuwara District
Scale: 1 : 1000 (1 cm represents 10 m)
Planted: June 1986
Design: Incomplete block lattice design 12 treatments; 4 replicates
Spacing: 2 m × 2 m
Plot size: 12 m × 12 m (36 tree plots)
Total area of plots: 6,912 m²
Total area of site: 1 hectare
Tagging: Rep.1 blue
Rep.2 yellow
Rep.3 white
Rep.4 red
x marks block corners



Key to plot numbers

Eucalyptus grandis

Plot no.	Seedlot no.	Provenance
1	14849	NE Atherton QLD
3	12080	Bulahdelah NSW
4	13883	Urunga NSW
8	12081	Coffs Harbour Dist. NSW
9	13432	Mt. Windsor NQLD
12	10695	Kenilworth S.F. QLD

Eucalyptus urophylla

Plot no.	Seedlot no.	Provenance
2	13002	Ileape INDO.
5	8242	Maubisse TIMOR
6	12997	Flores INDO.
7	10158	Ermera TIMOR
10	14532	Mt. Lewotobi INDO.
11	11887	Ilwaki Wetar INDO.

Figure 11. A hypothetical site map

Meteorological data

It is useful to have past meteorological data for the site, over a period of at least five years, but data for the duration of the trial is particularly important. As noted previously, this may be obtained from the nearest meteorological station, but if a meteorological station is not located very close to the site (within a few km), meteorological records from the site itself are preferable.

The equipment necessary for taking basic meteorological measurements on site comprises:

- a rainfall gauge, graduated in mm
- a Stevenson's screen containing
  - a thermograph
    or
  - a thermometer which records the daily maximum and minimum temperature

Rainfall readings must be taken regularly at the same time each day or each week. The thermograph records temperatures continuously, and requires little maintenance beyond the replacement of the graph paper as it is finished, and occasional spot checks comparing the temperature reading with the thermometer. If only a thermometer is being used, daily readings must be made. Thermographs and thermometers should be calibrated against a reliable reference standard before use.

Soil data

It is recommended that a number of soil profiles, to a depth of 1.0 m, are examined for each of the smallest statistical group of plots in the trial. In an RCB trial design, this will be for each complete block; in an incomplete block design, for each incomplete block. The number of soil profiles required will depend upon the size of the smallest statistical group of plots, and the topography that it covers; the aim is to check for any major variations in soil type between or within the groups. Variation between the groups can be accounted for in later analysis. Variation within the groups must be avoided, as each group must be as uniform as possible. If necessary, adjust the position of the group.

Look for changes down the profile in soil colour and texture; in addition, the pH of the soil at each sample site should be tested.

Soil colour should be defined on moist soil, using the simple description outlined in Appendix 8.

Soil texture can be determined by taking a small handful of soil; adding water, if necessary, and rubbing it into a ball. Feel the soil between the fingers to see whether it feels predominantly gritty (sand); sticky (clay); or smooth and almost greasy (silt). Then attempt to roll it into a thread.

The soil is further described by the second most common constituent. For example, soil which is predominantly clayey but feels gritty is described as a sandy clay. Details on the definition of soil texture are given in Appendix 8.

Soil pH may be determined adequately using a simple barium sulphate pH testing kit. Test a representative mixed soil sample taken from the top 30 cm of the profile.

General site description

An overall description of the site should be recorded in a site description form. An example of such a form, completed for a hypothetical trial, is given in Appendix 9.

A broad indication of climatic conditions at the site may be gained from its latitude, altitude and rainfall (annual and seasonal pattern). Other factors that will influence plant growth of the site include the geology (and hence the soil parent material), topography, soil type, past history of land management, and present vegetation.

For the geology, indicate the type of rock found in the area, such as granite, sandstone, limestone or shale.

The description of topography should give the position of the site in relation to the overall local topography, such as at the bottom of a wide valley, or at the top of a steeply-sloping ridge. An indication of the degree and range of slope, and the aspect (the direction which the site faces) if it is on any slope at all, should also be given.

The soil type may be described using whatever classification system is used locally, but this should be clearly stated. If several soil types occur within the site, they should all be given. In addition, state the pH of the soil (taken from a representative sample of the top 30 cm); if this varies over the site, give the full range.

Describe the past history of the site briefly, as far as it is known. The type of former management will have a strong bearing upon the present fertility of the site.

The present vegetation on the site is also an indication of its fertility, as well as having important implications concerning future weeding operations. If possible, specify the dominant species present.

Observations

It is suggested that observations on the trial are recorded continuously from the time of trial establishment. Points to note include:

- site preparations
- condition of stock at planting time
- fertiliser applications – date, type, method and rate of application
- weeding operations – date conducted and method employed
- measurements – date and type
- unusual occurrences, if any (in, say, more than 5% of the sample population) e.g. insect pests, disease, wind damage, etc.

The information recorded on this form will be necessary to compile the trial reports (see Section 20.4).

17.2 Fencing

Necessity of fencing

A fence will serve as a psychological barrier to local people, who may have used the trial site in the past, and might look on it as an area for gathering fuelwood and/or fodder, and for grazing their livestock. A fence serves to indicate that the site is no longer accessible, but it will also be necessary to:

- inform the local community of the purpose and nature of the trial
- if possible, make alternative arrangements for access to fuelwood, fodder and grazing areas
- endeavour to employ local personnel in the establishment and maintenance of the trial, in an attempt to reduce any possible hostility towards the trial.

In a few cases it may be possible to involve local people in the trial itself, for example in weeding operations, when local people might be allowed to remove cut material for fodder (note that the weeding operation itself should be conducted systematically, with equal treatment to all plots).

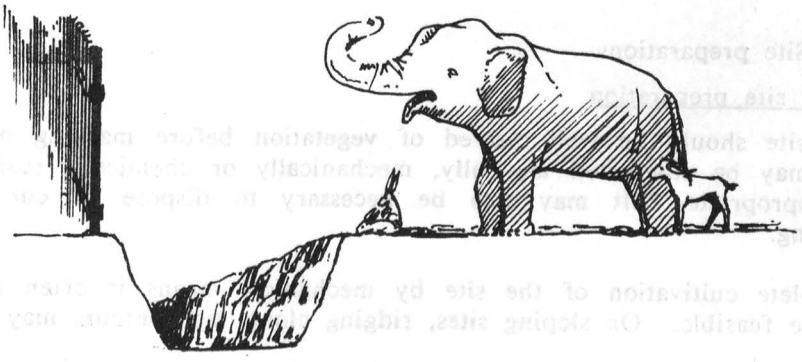
Fencing is also most necessary to protect young seedlings from livestock, both wild and domestic, which may browse or trample the trial. The degree of hazard will vary widely according to the area concerned, as will the necessary precautions.

Type of fencing

The type of fencing required will depend upon what is to be kept out of the trial site.

Examples of suitable fencing include:

- deep ditches and heavy fencing – against wild elephants (ditches are the most effective deterrent)
- partly buried wire mesh fence – against rabbits
- three or four strand barbed wire fence, or a stone wall – against cattle
- combination of barbed wire and wire mesh – against goats.



In a few cases, it may also be worthwhile investigating the feasibility of using tree guards, giving individual protection to trees.

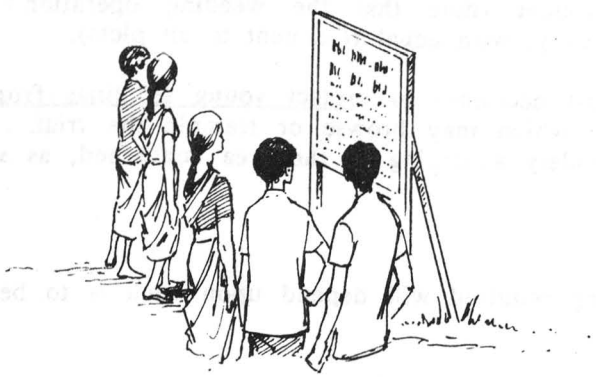
Cost of fencing

Although fencing is expensive, it may be essential to ensure the success of the trial. Expenditure on adequate fencing is thus strongly recommended.

Expense can be minimised by a careful choice of the trial site. Both the size and shape of the site will have considerable influence upon the length of fencing required; a single, regularly shaped block is more efficient than a number of small, scattered, irregularly-shaped blocks.

17.3 Notice boards

As part of a general public relations policy, a notice board should be erected at the trial to explain its purpose in the local language, as soon as the fence around the site has been constructed (preferably at least 2 months before the scheduled planting time).



Once the trial has been established, other boards, for the purpose of professional visitors, may be erected. These include:

- a board giving the trial layout
- individual species or provenance boards. Botanical names are best written in Roman (English) script; they translate poorly, and have little meaning in other languages.

17.4 Site preparations

Initial site preparation

The site should be well cleared of vegetation before marking out commences; this may be conducted manually, mechanically or chemically (using herbicides), as appropriate. It may also be necessary to dispose of cut vegetation by burning.

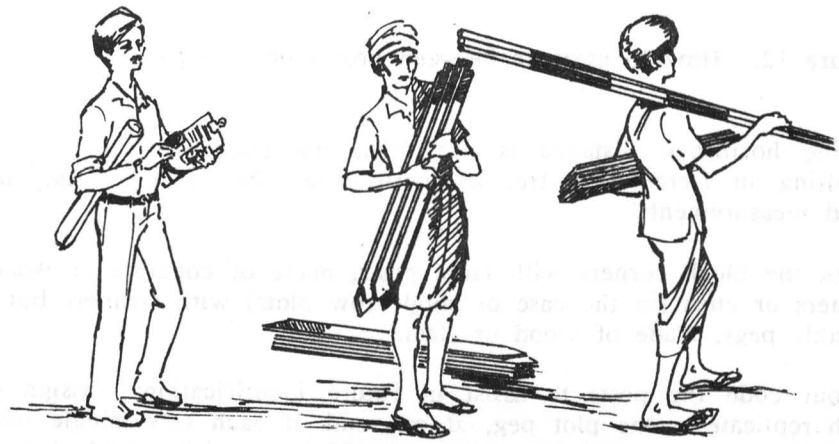
Complete cultivation of the site by mechanical means is often ideal, but may not be feasible. On sloping sites, ridging along the contours may be necessary.

Site preparations should be largely consistent with usual local management practices.

Equipment for marking out the trial

The following equipment is the minimum required for marking out the trial on the ground:

- measuring tapes
- compass
- marking stakes
  - posts, for marking block corners
  - large pegs, for marking plot corners
  - small pegs, for marking planting positions (posts and large pegs must be colour-coded)
- sighting poles
- a plan of the trial design.



At least three people are required for marking out.

Positioning the blocks

If available planting space is limited, it may help to try to work out the positioning of the blocks in the office beforehand, by cutting up a paper plan of the blocks and trying to superimpose them onto the site map in a suitable manner.

Remember that it is important that the smallest statistical grouping of plots in the trial (in RCB designs, the complete block; in incomplete block designs, the incomplete block) is as uniform as possible. Factors to consider include variation in:

- slope
- soil type
- block orientation (aspect; prevailing wind)
- drainage
- temperature (for example, frost hollows)
- competition from other vegetation outside the trial area.

Pegging out

Peg out the blocks and plots as accurately as possible, checking that the corners are square using a compass.

Remember to measure out the horizontal distance, rather than the distance along the ground, if working on a slope (see Figure 12).

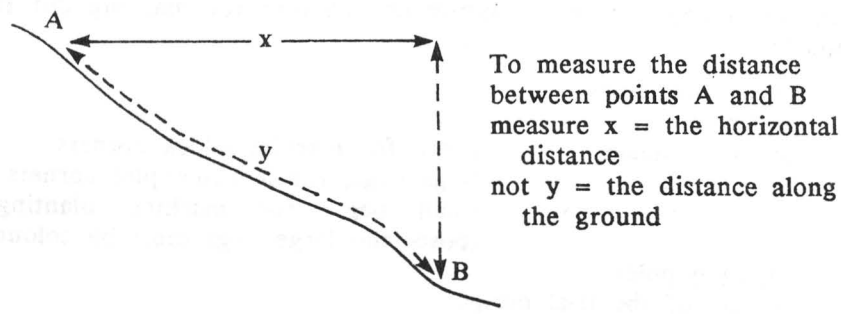


Figure 12. How to measure between points on a slope.

If the horizontal distance is not used, the trees will be too closely spaced, resulting in fierce inter-tree competition as they mature, and inaccuracies in yield measurements.

Mark the block corners with large posts, made of concrete or wood. Mark plot corners or ends (in the case of single-row plots) with smaller, but easily visible, durable pegs, made of wood or steel.

Colour code the posts to assist in future identification; assign one colour to each replicate. One plot peg, at one end of each row (single row plots) or in one particular corner (square plots) should be specially marked as a marker peg for orientation when taking measurements of the trees at a later date.

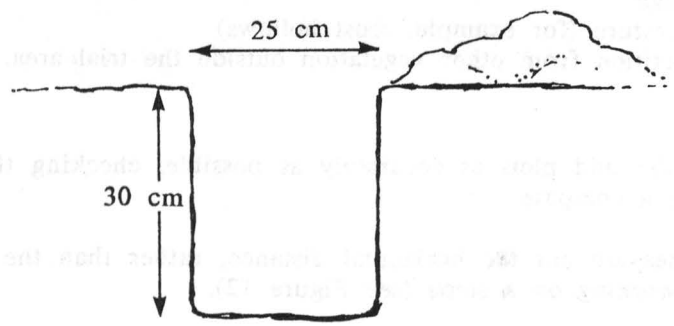
Only once the blocks and plots have all been marked out, peg out each planting position, using small pegs.

Weeding and pitting

If full cultivation of the site is not possible, weeding must be conducted as follows:

either . strip weeding – at least 2.0 m wide (aligned across the slope)
or . patch weeding – the weeding of the individual planting spots to a diameter of at least 2.0 m.

Planting holes should be dug to a depth of at least 30 cm and a width of at least 25 cm.



18.0 PLANTING

18.1 Transport from the nursery

Hardening off

The seedlings should be 'hardened off' 1-2 weeks before they are due to be transported to the site by:

- reducing the watering regime to a minimum
- removing any shade still present
- discontinuing any foliar fertiliser applications (none, in any case, are suggested for older seedings)

Anti-termite treatment

If anti-termite treatment is considered really necessary, the seedlings should be treated at this time, following the procedure outlined in Section 14.2.

Transporting containers

Packing seedlings loosely into a vehicle for transport, or carrying bundles of seedlings by hand, will result in a high number of dead and damaged plants.

It is strongly recommended that planting boxes made from wood, steel mesh, or plastic are prepared. It is convenient for the planting boxes to contain the number of plants required for one plot; thus planting boxes for a species elimination trial might contain only 10 seedlings. Boxes for a provenance trial with 36 tree plots should contain 18 seedlings, as boxes containing 36 seedlings would be too heavy.

Specifications for a suitable box are given in Figure 13; the dimensions given are suitable for 18 seedlings raised in bags of the size provided.

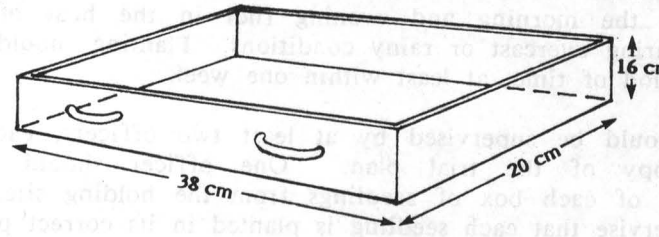


Figure 13. Specifications for a planting box.

Selecting seedlings in the nursery

From each seedlot, select out the required number of plants. Choose the best individuals, according to:

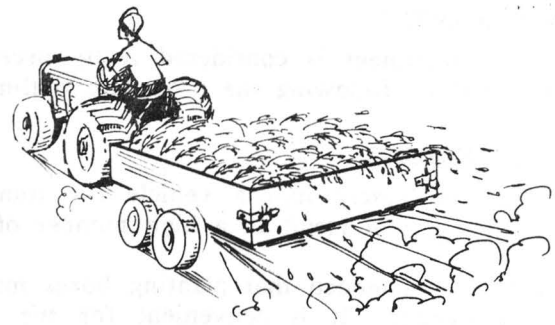
- size (optimum 15-20 cm)
- general good health (check for nodulation in nitrogen-fixing species)
- freedom from pests and diseases

Each plant should then be individually labelled with its seedlot number, using the labels provided. These labels are designed so that they can be easily fitted around the stem of the seedling. There is no need to ever remove them since, as the plant grows, the labels will eventually be shed automatically.

The labels are provided in four different colours, one colour for each replicate (assuming four replicates). If there are only three replicates, use three colours only. Assign the coloured labels to the selected plants of each seedlot COMPLETELY RANDOMLY.

Mode of transport

If possible, plants should be transported to the planting site in a covered vehicle, avoiding exposure to strong winds or heavy rain during the journey. Travelling at high speed should also be avoided.



Any transport of the plants by hand should be supervised, to ensure that handling is conducted carefully. The seedlings should never be handled by the stem or foliage; they should always be carried by the bags.

18.2 Planting procedure

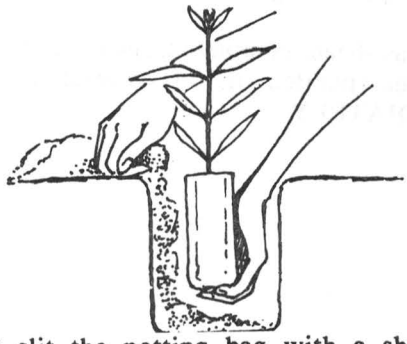
Keep the plants moist and sheltered on their arrival in the field. Conduct planting in the morning and evening (not in the heat of the day), and if possible, during overcast or rainy conditions. Planting should be completed over a short period of time, at least within one week.

Planting should be supervised by at least two officers, each of whom should have a copy of the trial plan. One officer should ensure the correct despatching of each box of seedlings from the holding site; the other officer should supervise that each seedling is planted in its correct plot.

Start with one replicate, i.e. one colour code, and work through all the plots before starting on the next replicate. Plant all the seedlings in one plot before commencing planting the next plot.

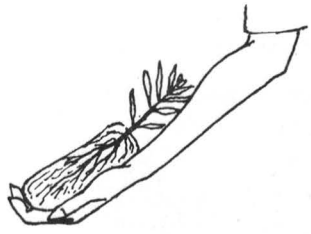
Ensure that all workers follow correct planting procedure. This should be demonstrated before planting commences, as follows:

. Hold the plant (inside its potting bag) inside the planting hole, and fill in the bottom of the hole with earth so that the plant, when it is in position, will have its root collar level with the ground surface.



. Remove the plant, and slit the potting bag with a sharp knife or one sided razor blade, as shown below.

. Remove the polythene and, holding the plant carefully with its stem resting along your arm, place it in the hole. Avoid damaging the root ball.



In some circumstances, particularly when the seedlings have been kept in the nursery too long, a thick fibrous mat of roots may form at the bottom of the soil core. This mat must be removed by slicing through it with a sharp knife, about 3 cm from the bottom of the core.

. Fill in the soil around the roots of the plant, taking care that:
    . the root is going straight down into the soil, and has not been bent
    . no air pockets form around the roots
    . the root collar is level with the ground surface; NOT buried in the soil, or exposed to the air.

. The soil should be firmed down well around the plant.

If it seems likely that no rain will fall on the day of planting, it is strongly recommended that the seedlings be watered. This is critical in ensuring early contact between the roots and the soil water.

Once planting has been completed, make a thorough check to ensure that each seedling has been planted in its correct position. Any mistakes should be rectified IMMEDIATELY.

19.0 POST-PLANTING CARE

19.1 Weeding

Weed growth should be controlled for AT LEAST two years after trial establishment. Eucalypts, in particular, are highly sensitive to weed competition, and will not thrive if weeds are allowed to flourish.

The frequency and method of weed control will depend upon the given site conditions. Its necessity should be determined by regular inspections.

Mechanical weeding

If feasible, mechanical weeding between rows, combined with chemical weeding around the plants, is highly effective.

Manual weeding

Patch weeding should be to a diameter of at least 1.5 m around the plant. Strip weeding should be at least 1.5 m wide.

Chemical weeding

A variety of herbicides are available, but if they are to be employed, GREAT CARE must be taken to:

- avoid damaging the young tree seedlings (a useful device is lipped conical cover which is placed over the seedlings to protect them from contact with the herbicide)
- ensure workers' safety when handling the chemicals (READ SECTION 14 before embarking on a spraying programme).

19.2 Fertiliser

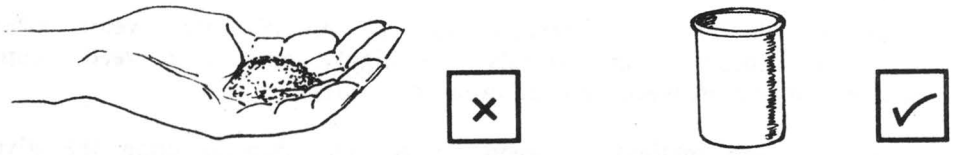
At least one application of fertiliser to the young trees is strongly recommended, unless fertiliser use is not a normal silvicultural practice in the area. A suitable fertiliser mix is N:P:K 8:16:9.

The optimum method of application is in two doses of a minimum 30 g one week after planting, and a further 30 g three months after planting, as long as the ground is still moist. Fertiliser applications should be timed to coincide with at least some rain, so that the young seedlings can take maximum advantage of the nutrients provided. On poor sites larger applications of fertiliser may be necessary; the amount required will depend upon local conditions.

Ensure that the amount of fertiliser applied is standardised. A simple way of doing this is to use a measuring container. If available, empty film cartons are very useful for this purpose, as a standard 35 mm film carton contains almost exactly 30 g of most types of powdered N:P:K fertiliser (level measure). Cut off tin cans can be used to measure out larger quantities.

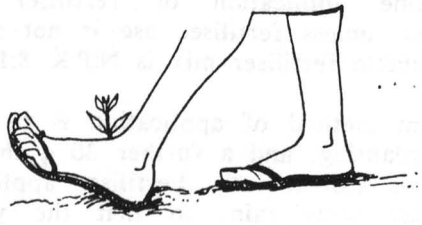
Just applying 'a handful' of fertiliser to each tree is NOT good enough; handfuls may vary greatly in size, and this may be reflected in an uneven

growth of the young trees, entirely independent of their suitability to the given site conditions.



When applying fertiliser, each worker should carry a stick, and use this to push a hole about 15 cm deep into the soil, about 15 cm away from the stem. If on a slope, the holes should be made across the slope, rather than up or downhill. Make all holes either slightly to the left, or slightly to the right, of the tree.

Pour the standard amount of fertiliser into the hole, and cover it over with soil using the heel of the foot.



When the second application is made after three months or so, the hole should be made on the opposite side of the tree to that previously used. This method of fertiliser application is superior to applications made to the soil surface and 'worked into' the soil as

- it ensures that the nutrients are made available to the at the point of uptake (the roots)
- there is less liklihood of the fertiliser being washed away by heavy rain
- it is rapidly and easily conducted.

A quicker and more efficient means of applying fertiliser manually is to use a fertiliser dispenser. Details of such a dispenser, as designed by R.V. Woods, are given in Appendix 10.

19.3 Employment of field personnel

In the first few years of a trial, supervision should be regular and constant. A person should be available on site to:

- ensure that the fence is not broken, and animals do not enter the trial
- act against fire (during the fire season)
- take regular meteorological readings at the site (if recording instruments have been installed)
- maintain good community relations with the local people.

19.4 Protection from fire

In many countries, fire may be a major danger to trial plots, particularly in the early years of establishment, when the young trees are most vulnerable.

A number of protective steps against fire may be taken, including:

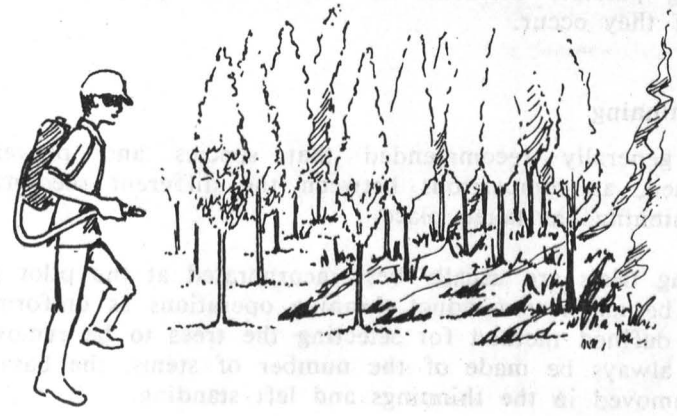
- reducing the amount of available fuel
- preventing access by fire
- providing fire fighting equipment.

Reducing available fuel

During the dry season, long grasses and other herbaceous material may dry out and become highly combustible. This fire hazard should be removed before it becomes completely dry, either by:

- controlled burning, or
- cutting and removal from site.

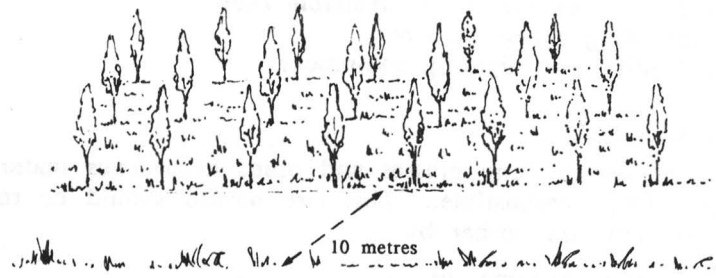
Controlled burning is NOT recommended until the young trees are at least 3 m in height. Controlled burning is a skilled operation and must be undertaken under suitable weather conditions in order to obtain a 'cool' burn, which will not damage the trees.



Cutting and removing ground vegetation from the site is an operation in which local people can be involved, particularly if the vegetative material is suitable for fodder. If the material cannot be utilised for fodder, it should either be piled up and burned, with care; or disposed of by some other means.

Preventing access by fire

Access to the trial by fire may be prevented by cutting fire lines around the perimeter and, if necessary, between blocks. Effective fire lines need to be 10 m wide, and should be maintained completely free of vegetative cover throughout the fire season.



Fire fighting equipment

A simple set of fire fighting tools, of the type normally used locally, should be available at the trial site throughout the fire season. Local staff should be trained in their use.

Good community relations are important in fire prevention activities, in both avoiding possible incidents of arson and supplying volunteer labour to fight fires, if they occur.

19.5 Thinning

It is generally recommended that species and provenance trials are left unthinned, as comparisons between the different seedlots become less reliable once thinning has taken place.

Thinning trials are usually best incorporated at the pilot plantation stage. Care should be taken to conduct thinning operations as uniformly as possible using a clearly defined method for selecting the trees to be removed. A careful record should always be made of the number of stems, the basal area and the volume both removed in the thinnings and left standing.

20.0 MEASUREMENTS AND ASSESSMENTS

Assessment is a time-consuming and potentially extremely lengthy process. The characters assessed, and the frequency of assessment, will depend upon the objectives of the trial, and should be clearly determined at the time of designing the trial.

20.1 Characters assessed

Species and provenance trials

The following assessment schedule is recommended as the minimum requirement for species and/or provenance trials:

Character	Frequency of Assessment
Height	1. 6 months 2. 12 months 3. Annual thereafter, up to about 7 m 4. Then every 2-5 years.
Survival	1. 6 months 2. 12 months 3. Annual thereafter, in conjunction with height assessments.
Health	Continuous, but score health when conducting height measurements.
Diameter at breast height (1.3 m), or at ground level*	1. When tree height averages 2-3 m 2. Annually thereafter, up to about 7 m 3. Then every 2-5 years.
Stem form and number of stems	1. When tree height averages 3 m 2. Thereafter at 3-5 year intervals.
Branching habit	1. When tree height averages 3 m 2. Thereafter at 3-5 year intervals

* depending upon the species being tested

The frequency of assessment is given as a guide only; it may be necessary to tailor the schedule of assessments to local climatic conditions, both for ease of working, and in order to coincide with the growing season(s). It may also be necessary to measure other characters, depending upon the trial objectives. Multipurpose trees, particularly ones being tested for biomass production (such as fuelwood and fodder) may be difficult to measure accurately without destructive sampling. Assessment techniques are discussed in more detail in some of the recommended 'Further reading'.

Pilot plantations

Assessments of pilot plantations will vary according to whether any, or which, silvicultural or management trials are being conducted. Usually only height and diameter measurements will be necessary.

20.2 Methods

Species and provenance trials

Height measurements should be taken for every tree. Use measuring poles for trees up to 7 m tall; above this height, use optical instruments, aiming for an accuracy of ±5%.

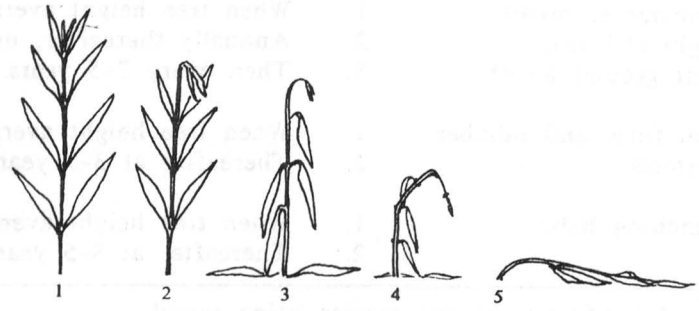
Below 2 m height, measure to the nearest centimetre.
Above 2 m height, measure to the nearest decimetre.

From the individual measurements, calculate the mean height per plot.

Survival should be assessed with care; record death only if the tree is completely missing, or if it is obviously dead.

Health should be scored for each individual tree whenever height measurements are conducted, using the following system:

1. Excellent health
2. Fair health, but one minor problem, e.g. physically broken, minor pest attack, etc.
3. Poor health, e.g. some signs of dessication, disease or pest problems, etc.
4. Very poor health, e.g. dessicated, badly diseased or pest infected, etc.
5. Dying.



In addition, observations should be made continuously on any health problems, such as the incidence of pests and disease, frost or wind damage, etc. All pests and pathogens should be identified, if possible.

Diameter at breast height (1.3 m) or at ground level should be recorded for every tree. Diameter tapes are the most convenient equipment to use. Diameter at breast height is a suitable measurement for single-stemmed trees, but is inappropriate for multistemmed trees, which should be measured at ground level. Adopt a UNIFORM assessment technique throughout the trial, i.e. if some species or provenances are multistemmed, tree diameter should be measured at ground level in all plots. Measure diameters to the nearest centimetre.

Stem form is best classed for species elimination trials using the following system:

1. Straight; material potentially useful for transmission poles
2. Very slightly crooked; potentially useful as a long pole and for most other purposes except transmission poles
3. Slightly crooked; suitable for short poles
4. Crooked; suitable for fence-posts and fuelwood
5. Very crooked and bushy; suitable for fuelwood only.

In provenance trials of a single species, variations in stem form may be quite small. It is therefore more appropriate to use a 1-5 scale in which stems are graded relative to the average form for the particular species, taking 3 to be the average. A value of 1 would thus represent exceptionally good form, and 5, exceptionally poor form, for the species concerned. When assessing stem form, notes should also be made of multiple stems (forks from ground level).

Branching habit is also best classified using a 1-5 scale. The following classes may be appropriate:

1. Very light branching; no forks below breast height
2. Light branching; no forks below breast height
3. Moderate branching, commencing below breast height
4. Heavy branching; two or three forks below, and many above, breast height
5. Very heavy branching; many forks above and below breast height

Pilot plantations

The assessment of pilot plantations is normally conducted by taking a representative sample population, rather than measuring all the trees planted. The method used for measuring heights and diameters is as detailed above.

20.3 Recording systems

Record forms should be specifically designed for the experiment. All data should be clearly identified, and it should be possible to trace back each measurement entered to the tree from which it was taken.

Suitable forms for recording measurements of species and provenance trials in the field are given in Appendix 11; each has been completed for a hypothetical situation. The grid format is suggested for provenance trial records so that data can be easily traced to individual trees, if necessary. It is also convenient to be able to refer back to previous assessments on one form to reduce the chance of entering data in the wrong grid positions.

Data can subsequently be collated into more general forms, giving all information for one species or provenance on one sheet; or it may be typed directly into a computer. Although measurements for all trees in all plots should be taken, it may be necessary in the 36-tree plots of provenance trials to use only the inner 16 trees for assessment purposes. This is in order to reduce the influence of edge effects around each plot, as was discussed in Section 5.2. If data recorded from each tree have been kept separately, as on the forms suggested, this will not be difficult to do.

20.4 Use of results

Details on the methods of analysis of trial results are given in some of the publications suggested under 'Further reading'.

It is essential that throughout the life span of the trial, regular written reports are made giving details of current progress. It is recommended that an establishment report is written within six months of trial establishment (usually coinciding with initial measurements); a progress report should then be made every year or every two years until the trial is completed, when a final report should be compiled. Each report should serve as a summary of the current progress on the trial, giving details of any measurements taken and any analysis of the data obtained. The report should also give adequate information to fully describe the trial without reference to other documents. A guide to the layout of trial reports, adapted from recommendations made by Dr D.A.N. Cromer, is given in Appendix 12.

It is important that trial reports are compiled on time, and are circulated to:

- management personnel within the forest service, so that appropriate management decisions may be taken
- other forestry research organisations in the country, to avoid any unnecessary duplication of trials
- interested research organisations in other countries, in particular the CSIRO.

As noted previously, the Tree Seed Centre requests details of all data obtained on the performance of its seedlots in trials. Such feedback is an essential part of the 'Seeds of Australian Trees for Developing Countries' project.

APPENDIX 1: Lattice designs suitable for provenance trials (of one or more species)

12 Provenances

		Block		
Replicate 1.	A	B	C	D
	11	3	5	2
	8	9	4	12
	1	6	10	7
2.	A	B	C	D
	12	4	8	10
	3	6	9	1
	5	11	2	7
3.	A	B	C	D
	1	7	11	10
	6	9	5	3
	12	4	2	8
4.	A	B	C	D
	7	8	5	6
	3	4	1	2
	11	12	9	10

16 Provenances

Block

Replicate 1.	A	B	C	D
	13	9	1	5
	15	11	3	7
	16	12	4	8
	14	10	2	6

2.	A	B	C	D
	3	8	14	9
	16	11	1	6
	10	13	7	4
	5	2	12	15

3.	A	B	C	D
	12	13	6	3
	8	1	10	15
	16	9	2	7
	4	5	14	11

4.	A	B	C	D
	16	14	15	13
	1	3	2	4
	11	9	12	10
	6	8	5	7

20 Provenances

	Block				
Replicate 1.	A	B	C	D	E
	2	6	16	11	1
	14	18	9	4	13
	20	5	15	10	19
	8	12	3	17	7
2.	A	B	C	D	E
	19	3	12	4	10
	8	14	1	15	16
	5	6	20	7	13
	11	17	9	18	2
3.	A	B	C	D	E
	5	11	17	6	12
	16	9	15	4	10
	14	2	8	20	3
	7	18	1	13	19
4.	A	B	C	D	E
	9	7	10	6	8
	19	17	20	16	18
	4	2	5	1	3
	14	12	15	11	13

25 Provenances

		Block			
Replicate 1.	A	B	C	D	E
	17	5	13	9	21
	14	22	10	1	18
	6	19	2	23	15
	25	8	16	12	4
	3	11	24	20	7
2.	A	B	C	D	E
	12	13	11	15	14
	17	18	16	20	19
	2	3	1	5	4
	22	23	21	25	24
	7	8	6	10	9
3.	A	B	C	D	E
	15	17	8	1	24
	22	4	20	13	6
	3	10	21	19	12
	16	23	14	7	5
	9	11	2	25	18
4.	A	B	C	D	E
	24	14	9	19	4
	25	15	10	20	5
	22	12	7	17	2
	21	11	6	16	1
	23	13	8	18	3

APPENDIX 2: Random numbers table*

(Permutations of 40)

3	31	2	4	32	2	5	7	34	31	19	17	23	10	24	27	10	25
2	34	1	34	16	31	23	23	20	23	7	16	9	9	18	17	37	19
9	20	28	22	17	17	8	13	9	13	12	13	28	40	21	6	28	5
12	23	23	27	33	40	20	38	40	38	36	1	26	12	8	16	8	33
29	38	9	23	25	26	18	11	29	30	27	11	40	27	12	32	3	11
11	26	22	19	31	30	31	40	4	11	5	3	24	21	2	13	34	18
39	13	12	14	4	8	14	34	27	32	6	14	4	36	10	38	15	35
15	9	3	39	20	32	16	2	32	28	18	7	13	6	16	37	21	37
32	40	35	20	22	39	19	29	3	19	13	20	38	5	9	11	19	12
10	07	10	35	37	15	38	10	26	15	34	6	22	34	5	2	5	27
16	27	7	30	3	5	33	1	11	5	39	36	32	14	19	20	24	17
13	33	18	33	38	19	37	21	25	16	40	26	17	15	26	9	29	8
21	29	17	28	28	13	30	14	24	12	23	8	14	38	22	10	14	13
6	21	19	15	18	6	32	31	6	34	16	5	16	28	28	22	38	7
14	15	29	36	9	22	34	35	36	20	35	24	11	25	27	4	39	22
36	6	38	12	30	34	29	26	33	6	24	28	36	4	15	7	7	2
22	37	34	38	7	28	11	24	35	24	37	9	3	29	3	1	27	32
5	12	40	2	1	12	9	32	38	10	3	32	34	35	23	39	9	4
33	28	30	7	13	18	2	37	15	17	28	27	2	37	30	18	18	28
28	7	5	10	19	14	17	36	18	31	2	29	7	22	11	36	31	16
40	36	21	25	11	36	1	28	22	27	30	39	19	20	36	5	12	38
23	22	36	40	8	28	21	4	1	9	22	34	15	11	34	23	22	26
20	10	14	11	23	24	22	20	19	26	1	35	21	16	25	40	20	3
30	11	11	21	36	11	13	8	14	33	4	37	33	39	7	28	30	9
26	32	13	8	12	29	15	17	31	14	26	30	37	26	1	26	26	34
7	19	37	26	29	0	12	18	12	36	21	12	10	1	33	29	23	24
4	3	20	32	15	23	28	30	23	35	9	10	20	23	17	19	32	21
8	5	26	24	40	4	24	33	5	1	20	18	31	18	20	25	36	36
25	30	15	1	2	16	3	19	13	25	11	31	39	19	37	8	35	23
17	4	27	13	10	37	40	6	28	3	8	40	27	13	14	34	16	10
27	24	24	31	27	38	39	27	2	39	14	25	18	3	40	15	2	29
37	8	31	6	39	25	4	22	10	7	31	4	25	31	29	21	11	1
24	35	32	17	6	35	7	25	8	22	10	2	6	24	4	33	33	40
34	18	25	3	34	25	39	7	4	25	22	8	33	32	3	13	15	23
1	39	6	16	25	7	10	9	17	2	17	15	5	32	35	31	17	14
18	2	39	5	5	21	35	16	21	37	29	38	12	8	38	12	4	6
38	1	16	9	21	20	36	3	30	40	15	21	1	2	6	24	1	20
19	14	4	18	14	9	6	12	37	29	38	19	30	30	31	35	25	31
31	16	8	29	26	1	27	15	39	18	33	23	35	17	39	14	40	30
35	25	33	37	24	33	26	5	16	8	32	33	29	7	13	30	6	39

* Taken from Green, J.W. (1968)

APPENDIX 3: Cold moist stratification requirements for eucalypts

Details of the method of cold moist stratification are given in Section 8.2.

Species		Period required (weeks)
E. amygdalina		4
E. delegatensis		6
E. dives		6
E. flocktoniae		4
E. glaucescens		6
E. kybeanensis		6
E. mitchelliana		6
E. nitens		3
E. pauciflora	ssp. *debuezevillei*	4
	ssp. *niphophila*	4
	ssp. *pauciflora*	3
E. perriniana		3
E. regnans		3
E. stellulata		3

APPENDIX 4: Directions for inoculating seed of leguminous tree species with rhizobia

Suitable species for this treatment are acacias and albizias. The directions given below are for using the peat inoculum and methyl cellulose adhesive supplied by the New South Wales Department of Agriculture.

The peat inoculum contains a high population of rhizobial bacteria, at least 1×10^9 per gram of peat, and should ALWAYS be stored in a refrigerator. The rhizobia may die if it is not. The methyl cellulose adhesive is supplied in powder form, and is available in different viscosities, 1.5% 4000 cP being that supplied by the NSW Department of Agriculture (cP, Centipoise is a unit of viscosity). It is possible to use alternative adhesives, if this is more convenient; gum arabic and sucrose solution are two examples.

Inoculated seed should be sown as soon as possible after treatment, at least WITHIN ONE WEEK.

The procedure outlined below gives amounts that are adequate for coating 20 seedlots each of 10 g, that is, 200 g seed:

- If the seeds to be treated have hard seedcoats, they should be first pretreated to promote germination (with boiling water, by manual scarification, or as otherwise appropriate). DO NOT proceed with the inoculation process until you have done this.

- Add 1.5 g of the methyl cellulose powder to 20 ml of hot water (80°C) in a beaker. Stir the mixture to form an even suspension.

- Add 80 ml of cold water, and stir well. The adhesive will dissolve, becoming opaque and viscous.

- Add 25 g of peat inoculum to the adhesive; stir the mixture well, to form a suspension.

- Divide the suspension into 20 equal portions (in the case of 20 seedlots), placing each in a separate beaker. Place ONE seedlot in each beaker, and stir well to ensure that the seed is thoroughly coated.

- Drain any surplus suspension from the seed, and spread each seedlot on a flat, preferably absorbent, surface (such as blotting paper or newspaper). Take care to keep the seedlots separate.

- Leave the seed to dry in a cool, airy place. Do NOT place it in the sun, as this may kill the rhizobia.

- Once the seed is dry, which should only take a few hours, sow it without delay.

When sowing seed into acid soils, it may be beneficial to lime pellet it. This is achieved by adding powdered lime (calcium carbonate) to the seed when it is

still wet; each seed will thus have an outer coating of lime. 1 kg of lime will be sufficient to lime pellet 200 g seed.

Further information on rhizobial inoculation techniques, and a supply of inoculum, may be obtained from:

Dr R. Roughley
New South Wales Department of Agriculture
Horticultural Research Station
Gosford NSW 2250 AUSTRALIA

or from:

Nitrogen Fixing Tree Association
PO Box 680
Waimanalo
Hawaii 96975
U.S.A.

APPENDIX 5: Recommended sowing densities (number of germination trays required)

The number of germination trays required for sowing 10 g seed is calculated according to the average number of viable seeds in this weight. The following very general rule has been used, based on a maximum of 2000 viable seeds per germination tray:

Average number of viable seeds per 10 g seed	Number of germination trays required per 10 g seed
less than 500	1
500 – 3000	2
3000 – 6000	3
6000 – 8000	4
8000 – 10000	5

For species with an extremely high number of viable seeds per 10 g, a smaller quantity of seed will usually be provided. The same general rule of no more than 2000 viable seeds per germination tray is recommended.

The recommendations given below are based on average viability figures for seed of each species; however, it should be noted that different seedlots of a single species vary widely in their viability. Therefore, if a particular seedlot has a significantly higher or lower number of viable seeds per 10 g than the average for that species, one more, or one less, tray will be required. Viability figures may be checked on the consignment listing.

Allocasuarina spp.

Two germination trays for 10 g seed for ALL species, EXCEPTING:

Species	Number of trays for 10 g seed
A. campestris	3
A. decaisneana	1
A. dielsiana	3
A. littoralis	3

Casuarina spp.

Three germination trays for 10 g seed for ALL species, EXCEPTING:

Species	Number of trays for 10 g seed
C. cristata	2
C. stricta	2

Eucalyptus spp.

Two germination trays for 10 g seed for ALL species, EXCEPTING:

Species	Number of trays for 10 g seed	Number of trays for 5 g seed (high viabililty seed)
E. aggregata	3	
E. alba	3	
E. amplifolia	3	
E. argophloia	3	
E. badjensis	3	
E. benthamii	4	
E. botryoides	3	
E. brassiana	3	
E. brookerana	3	
E. camaldulensis	4*	
E. crebra	3	
E. deanei	3	
E. deglupta		20 (4 trays for 1 g)
E. dunnii	3	
E. elata	3	
E. grandis	3*	
E. gunnii	3	
E. macarthuri	3	
E. miniata	1	
E. microtheca	3	
E. nitens	3	
E. paniculata	3	
E. polybractea	3	
E. propinqua	4	
E. pyrocarpa	1	
E. raveretiana		10 (2 trays for 1 g)
E. resinifera	3	
E. robusta	3	
E. rubida	3	
E. saligna	3*	
E. salmonophloia	3	
E. sargentii	3	
E. siderophloia	3	
E. sideroxylon	3	
E. smithii	3	
E. stellulata	3	
E. tereticornis	3*	
E. tetrodonta	1	
E. torelliana	3	
E. urophylla	3*	
E. viminalis	3	

* Viability particularly variable. High-viability seedlots may be provided in smaller quantities.

Melaleuca spp.

Melaleucas have very small seeds, and will normally be sent out in 5 g or 1 g amounts.

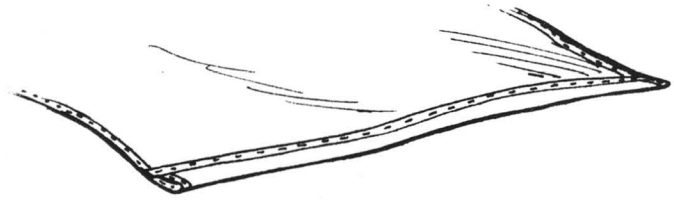
Unless the viability figures indicate otherwise, use:

10 trays for 5 g seed
2 trays for 1 g seed

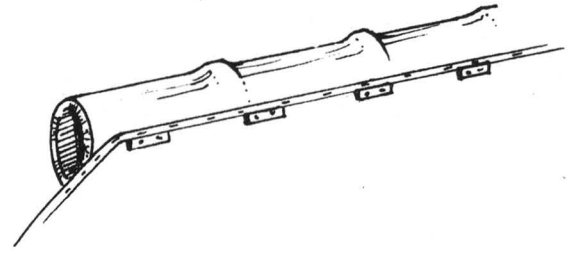
APPENDIX 6: Protection from heavy wind and rain in the nursery: details of one possible method

The following are guidelines for erecting a protective cover over nursery beds, in high shade areas, as mentioned in Section 11.3. The method can be modified to fit individual circumstances, but for the purpose of description, a fixed set of measurements will be used. It will be assumed that stand out beds are 6 m long, and that shade support posts are positioned at intervals of 2 m alternating with a 1 m interval between every second set of posts.

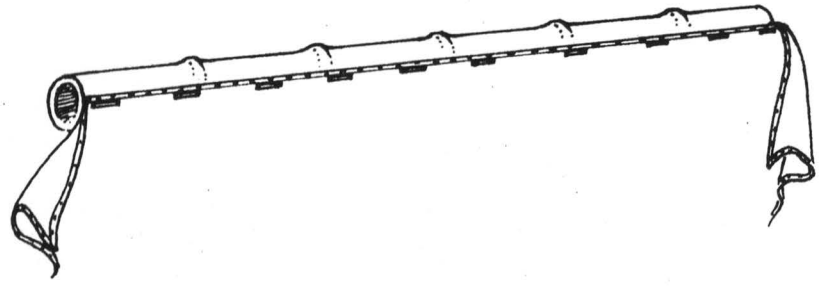
- Use 0.2 mm heavy duty clear plastic sheeting, 180 cm wide and 3.5 m long. Hem the ends and sides of the sheeting with adhesive tape and staples to prevent tearing.



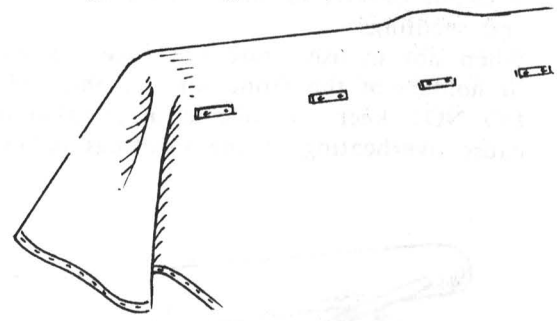
- Take a straight bamboo or wooden pole 3 m long, and of a diameter no less than 8 cm. Fasten one long edge of the sheeting to this pole, using bamboo or wooden battens 2 cm wide, rather than nailing straight through the plastic. This should prevent the plastic tearing away from the nails.



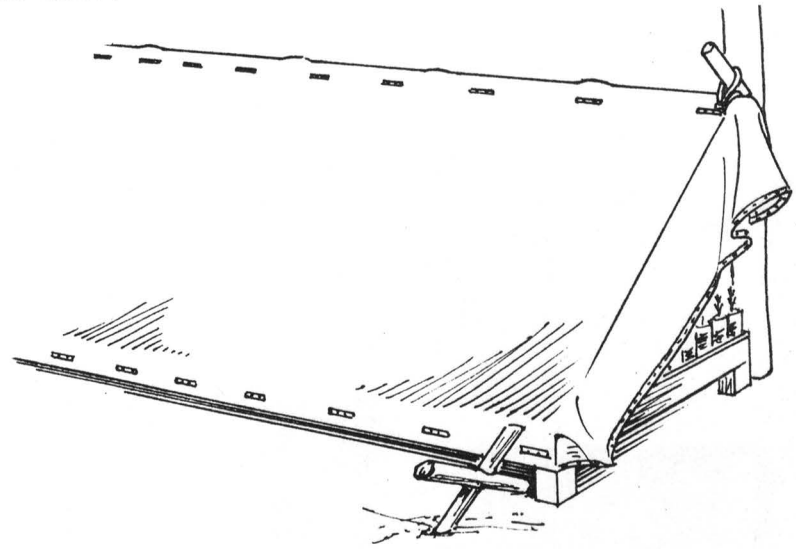
- Leave the last 25 cm at either end unfastened.



. Give the bamboo a three-quarter turn, so that the strain is not directly upon the fastening. Tack again.



. Fix the bamboo pole to the shade supports at the back of the bed, about 80 cm above the bed. A simple method of achieving this is to drive a large nail or wooden dowel into the post at an angle of about 40°, and to loop a piece of rope attached to the bamboo pole around this. The point at which the rope passes through the plastic sheeting should be covered with a batten, to prevent tearing. This is illustrated below.

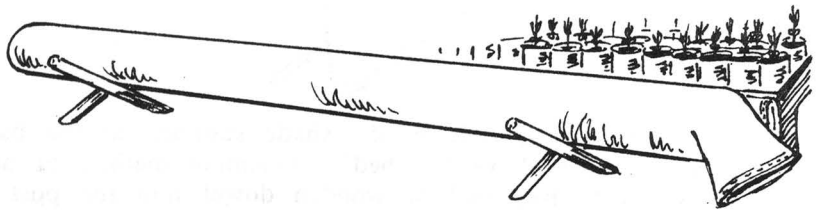


. If raised beds are not being used, it will be necessary to edge the front of the stand out bed with a wooden plank. Fasten the lower edge of the plastic sheeting to this plank, or the front of the raised bed, using battens as before. It is best to fasten the plastic sheeting once, turn it over on itself and fasten it again. When doing this:

  . start from the middle of the bed, and work to either end simultaneously
  . pull the sheeting tight, so that no water can collect in any wrinkles
  . ensure that no sharp edges are jutting out along the sides of the nursery bed which could cut the plastic.

. It may be necessary to slightly adjust the height of the fastening on the shade supports from time to time, to ensure that the sheeting is kept taught.

- When in position, the end flaps of each sheet should overlap with adjacent covers, or hang down at the ends of the bed, protecting the end seedlings.
- When not in use, store the covers rolled up around the bamboo pole, in holders at the front edge of the bed.
- DO NOT keep the plastic in position during fine weather, as it may cause overheating of the seedlings below.



APPENDIX 7: Nursery records form

Name of trial:

Nursery:

Officer in Charge:

Species:

Seedlot Number:

Provenance:

Weight sown:

Method of sowing:

Type of potting mix:

Date sown:

Date germination commenced:

Date germination completed:

Date pricked out (if applicable):

Number of plants raised:

Date transported to site:

Date	Observations

APPENDIX 7: Nursery records form

(Completed for a hypothetical example.)

Name of trial: *Dombagastrine species trial*

Nursery: *Agarawatte*

Officer in Charge: *M.N. Perera*

Species: *Acacia melanoxylon*

Seedlot Number: *14428*

Provenance: *Tallaganda S.F. NSW*

Weight sown: *10 g*

Method of sowing: *Direct sown into potting bags*

Type of potting mix: *2 parts sandy loam : 1 part river sand, with 1.5 kg 'Osmocote Plus' per m^3 mix. Mix was pasteurised by heat treatment at 60°C for 30 minutes.*

Date sown: *10/2/85*

Date germination commenced: *15/2/85*

Date germination completed: *26/2/85*

Date pricked out (if applicable): -

Number of plants raised: *510*

Date transported to site: *12/6/85*

Date	Observations
10/2/85	*Seed pretreated before sowing by manual clipping of each seed. Seed sown under shade.*
29/3/85	*'Aquasol' (0.5 litres) applied at a rate of 8 g in 5 litres*
12/4/85	*" " " " "* *Shade covers removed.*
20/4/85	*Suspension of crushed rhizobial nodules (obtained from locally growing mature trees) watered onto the seedlings.*
30/4/85	*Minor outbreak of powdery mildew noted on some seedlings.*
6/5/85	*Powdery mildew noted on more seedlings. Sprayed with 'Rovral' (0.5 litres) at the rate of 2 ml in 3 litres water.*
12/5/85	*Incidence of powdery mildew markedly reduced. Plants generally in good health; inspection of 10 randomly selected plants revealed all to be nodulated.*
12/6/85	*Best 144 plants selected for transport to site; all 18 cm-20 cm tall, and in good health.*

APPENDIX 8: Notes on the description of soils

Soil colour

This should be determined on moist soil. The following system of description is suggested:

Y	yellow	lt	light
R	red	dk	dark
B	brown	du	dusky
O	olive	m	mottled
W	white	sl	slightly
G	grey		
BL	black		

The less prominent colour should be given first. For example:

YB = brown soil, with a tinge of yellow
OG = grey soil, with a tinge of olive

In mottled soils (soils with odd patches of a different colour), the colour of the mottles is stated last. For example:

YBmR = brown soil with a tinge of yellow and mottled red.

Soil texture

The definitions given below are adapted from Leeper (1952); the publication is listed in the references section.

Sand	feels coarse to the touch; not sticky.
Loamy sand	feels very slightly sticky; can just be shaped into a ball without crumbling, but cannot be rolled into threads.
Sandy loam	feels sticky, but crumbles easily; individual sand grains can be felt. Can only be rolled into threads with great difficulty.
Silty loam	feels like a loam, but has a particularly smooth, almost greasy feel when moist; can be hard when dry.
Loam	feels both sticky and crumbly; individual sand grains can be felt. Can only be rolled into threads with great difficulty.
Sandy clay loam	feels like a clay loam, but sand grains can be felt.
Silty clay loam	feels like a clay loam, but smoother.
Clay loam	feels somewhat crumbly, but also somewhat plastic; can be rolled out into threads.
Sandy clay	feels like a clay, but sand grains can be felt.
Silty clay	feels like a clay, but smoother.
Clay	feels tough and plastic; can be rolled into long threads, which can be shaped into rings.

APPENDIX 9: Site description form

Country:

Latitude: Longitude: Altitude (m):

Name of trial:

Location:

Rainfall Annual (mm):

Seasonality:

Geology:

Topography: General:

Slope:

Aspect:

Soil type:

Past history:

Vegetation:

Date of trial establishment:

Site description form

(Completed for a hypothetical trial)

Country: *Sri Lanka*

Latitude: *07° 55' N* Longitude: *080° 74' E* Altitude (m): *1,200*

Name of trial: *Dombagastenne species trial*

Location: *4 miles east of Agarawatte; Maha Nuwara District, Up country division*

Rainfall Annual (mm): *3100 (average 10 years)*

Seasonality: *Bimodal monsoon rain; main rains June-July with secondary rains in October-December*

Geology: *Granite*

Topography: General: *Trial located towards the top of a ridge.*

Slope: *20° – 30°*

Aspect: *Trial faces South West*

Soil type: *'normal' red earth (Australian soil classification) pH 6.0 - 6.5*

Past history: *Formerly planted with tea; the tea estate closed in 1973, and the area has not been cultivated since.*

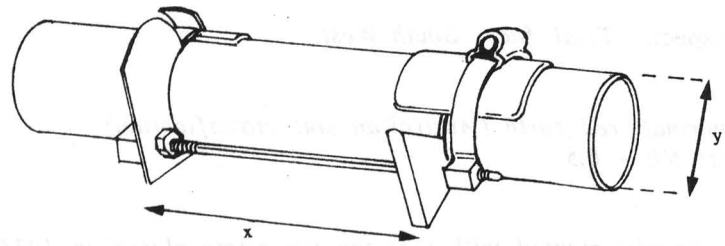
Vegetation: *Mainly guinea grass (Pannicum spp.), with odd tea bushes and shrubs of Lantana spp. No large trees.*

Date of trial establishment: *June 1985*

APPENDIX 10: Fertiliser application in the field : details of the Woods back pack fertiliser dispenser

The dispenser described below was designed by consulting forester Mr R.V. WOODS, (formerly of the Woods and Forest Department of South Australia), and has been adopted as a quick, safe and accurate method of manually applying fertiliser to plantations both in Australia and overseas (notably in Madagascar). The original design comprised a modified fire fighting back pack from which the pump was removed and replaced with a magazine calibrated to dispense a precise amount of fertiliser. However, the back pack can be made out of any locally available material; in Madagascar, discarded soya oil cans have been utilized for the purpose. Each pack was made out of two opened and flattened tins, which were soldered together to form a container with an open top and sloping bottom. A flexible hose was then attached to the bottom, and the dispensing magazine fitted to the end of the hose. Straps fitted to the container enabled workers to carry it on their backs. Both the South Australian and the Madagascar design are illustrated below.

The magazine must be made of rust proof materials; plastic piping for the body, and stainless steel or brass for the moving parts are recommended. The magazine operates by a system of two shutters attached to a rotating shaft. The shutters are attached at right angles to each other, so that when one is opened the other is closed, resulting in the alternate emptying and filling of the magazine. This is controlled by the top shutter, which can be flicked backwards and forwards by the thumb of the right hand (for right-handed operators). The dosage applied is determined by the volume between the shutters, which may be altered by changing the distance between the shutters (x) and/or the diameter of the tubing (y). The magazine is illustrated below.



For example, if using a tube with a diameter (y) of 3.0 cm, the distance x should be about

5.0 cm	to dispense	30 g	fertiliser
8.5 cm	" "	50 g	"
17.0 cm	" "	100 g	"

These measurements are approximate as they will depend upon the type of fertiliser being used; the volume occupied by a given weight of fertiliser should always be checked.

Points to note when constructing and using the fertiliser dispenser are as follows:

- If the fertiliser is transported to the field by truck or trailer, the filling of the backpacks may be facilitated by hanging them on steel hooks on the side of the truck. They are then filled by bucket over the truck side. This saves workers from back strain, by avoiding the lifting of the full packs from the ground.

- It is essential that the fertiliser is kept dry at all times; otherwise it will 'cake' and block the dispenser. If rainfall during the time of application is likely, the back pack containers must have lids and be fully waterproof.

- If the fertiliser being used is very lumpy, then lumps should be removed by passing it through a 5 mm wire mesh when filling the back packs.

- It is suggested that the back packs are made large enough to accommodate about 17 kg of fertiliser. Fertiliser is normally supplied in 50 kg bags, and it is convenient to make three fillings of the back pack per bag (each filling will thus be of 16 2/3 kg). A lighter load of 12½ kg will necessitate four fillings per bag of fertiliser.

- The flexible hose leading from the container to the magazine must be long enough for the magazine to reach the ground. Applications should be made using a stick to dig a hole by the side of each tree, as discussed in Section 19.2.

- Good maintenance of the dispenser magazines in the field is essential for smooth operations.

Further information on the Woods back pack fertiliser dispenser can be obtained from:

Mr R.V. Woods
PO Box 155
Kangarillia
South Australia 5157

APPENDIX 11: Field records forms

11.1 Species elimination trials

Name of trial:
Location:
Date of establishment:
Species: Block number:
Provenance: Plot number:
Seedlot number:

1. Height, survival and health

Tree	Date: Height (cm)	Health	Date: Height (cm)	Health	Date: Height (cm)	Health	Date: Height (cm)	Health
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

Mean:
Survival:
Assessed by:

2. Diameter at breast height/ground level (delete as applicable), stem form and branchiness

Tree	Date: Diam. (cm)	Stem form	Branch-iness	Date: Diam. (cm)	Stem form	Branch-iness
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Mean:
Assessed by:

Field records forms

11.1 Species elimination trials
(Completed for a hypothetical trial)

Name of trial: *Dombagastenne species trial*
Location: *Near Agarawatte: Maha Nuwara District: Up country division*
Date of establishment: *June 1985*
Species: *Acacia melanoxylon* Block number: *4*
Provenance: *Tallaganda S.F. NSW* Plot number: *3*
Seedlot number: *14428*

1. Height, survival and health

Tree	Date: *19/12/85* Height (cm)	Health	Date: *22/6/86* Height (cm)	Health	Date: *10/12/86* Height (cm)	Health	Date: *18/6/87* Height (cm)	Health
1	*105*	*1*	*220*	*1*	*300*	*1*	*450*	*1*
2	*110*	*1*	*210*	*1*	*320*	*1*	*470*	*2*
3	*92*	*1*	*190*	*1*	*300*	*1*	*430*	*1*
4	*87*	*2*	*190*	*2*	*310*	*2*	*460*	*1*
5	*96*	*1*	*180*	*2*	*300*	*1*	*460*	*1*
6	*98*	*1*	*200*	*1*	*330*	*1*	*480*	*2*
7	*101*	*1*	*210*	*1*	*340*	*2*	*490*	*1*
8	*71*	*2*	*180*	*2*	*290*	*1*	*400*	*1*
9	*68*	*2*	*200*	*1*	*340*	*2*	*500*	*1*
10	*89*	*1*	*210*	*1*	*350*	*1*	*520*	*1*
Mean:	*92*	*1.3*	*200*	*1.3*	*318*	*1.3*	*452*	*1.2*
Survival:	*10/10*		*10/10*		*10/10*		*10/10*	
Assessed by:	*R.G. Sumanasiri*		*R.G. Sumanasiri*					

2. Diameter at breast height/~~ground level~~ (delete as applicable), stem form and branchiness

Tree	Date: *10/12/86* Diam. (cm)	Stem form	Branch-iness	Date: *18/6/87* Diam. (cm)	Stem form	Branch-iness
1	*5*	*2*	*3*	*8*	*2*	*3*
2	*6*	*2*	*3*	*9*	*2*	*3*
3	*5*	*3*	*3*	*8*	*3*	*3*
4	*5*	*2*	*3*	*8*	*3*	*3*
5	*4*	*2*	*2*	*7*	*2*	*2*
6	*5*	*3*	*3*	*9*	*3*	*2*
7	*6*	*2*	*3*	*10*	*3*	*3*
8	*4*	*2*	*3*	*7*	*3*	*3*
9	*5*	*2*	*3*	*8*	*3*	*2*
10	*6*	*1*	*2*	*9*	*3*	*3*
Mean:	*5.1*	*2.1*	*2.8*	*8.3*	*2.7*	*2.7*
Assessed by:	*R.G. Sumanasiri*					

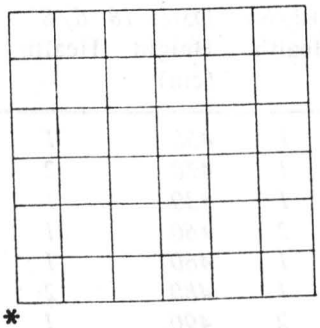
11.2 Provenance trials (of one or more species)

Name of trial:
Location:
Date of establishment:
Species
Provenance:
Seedlot number:

Block number:
Plot number:

1. Height, survival and health

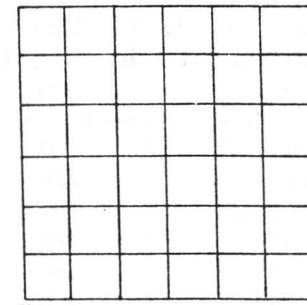
Height (cm)



*

Date:
Assessed by:
Mean height (all trees):
Mean height of inner
16 trees only:

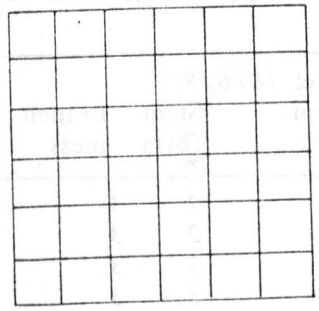
Health



*

Mean health class:
Survival:

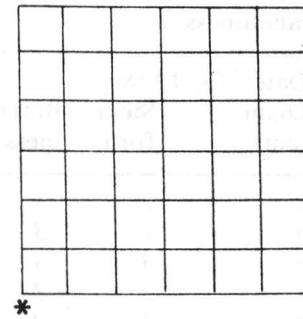
Height (cm)



*

Date:
Assessed by:
Mean height (all trees):
Mean height of inner
16 trees only:

Health



*

Mean health class:
Survival:

* indicates position of marker post

11.2 Provenance trials (of one or more species)
(Completed for a hypothetical trial)

Name of trial: *Mtito Moru Provenance Trial*
Location: *Near Moto Pani, Kibwesa District, Voi Division*
Date of establishment: *September 1982*
Species: *Acacia auriculiformis* Block number: *2*
Provenance: *Normanby River, Qld.* Plot number: *5*
Seedlot number: *13862*

1. Height, survival and health

Height (cm)

70	80	91	89	87	62
99	107	94	92	81	88
95	98	85	87	84	97
85	96	75	-	74	92
82	88	43	52	75	101
84	73	91	88	83	95

*

Health

2	1	1	1	1	2
1	1	1	1	1	1
1	1	2	1	1	1
1	1	1	-	2	1
1	1	3	3	1	1
1	2	1	1	1	1

*

Date: *17/9/82*
Assessed by: *R.M. Milimo*
Mean height (all trees): *82*
Mean height of inner
16 trees only: *77*

Mean health class: *1.2*
Survival: *35/36*

Height (cm)

200	200	230	210	250	230
250	220	220	210	200	250
240	240	220	220	210	230
230	260	210	-	200	240
220	230	130	150	190	260
240	230	250	240	240	250

*

Health

2	1	1	1	1	1
1	1	1	1	1	1
1	1	2	1	2	1
1	1	1	-	2	1
1	1	3	3	1	1
1	1	1	1	1	1

*

Date: *22/3/83*
Assessed by: *R.M. Milimo*
Mean height (all trees): *220*
Mean height of inner
16 trees only: *190*

Mean health class: *1.2*
Survival: *35/36*

* indicates position of marker post

2. **Diameter at breast height/ground level (delete as applicable); stem form and branching habit**

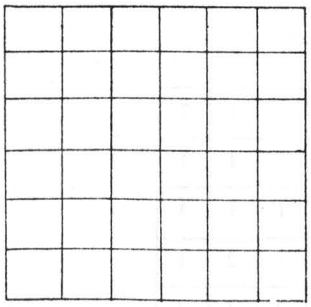
Species:
Provenance:
Seedlot number:

Block number:
Plot number:

Date:

Assessed by:

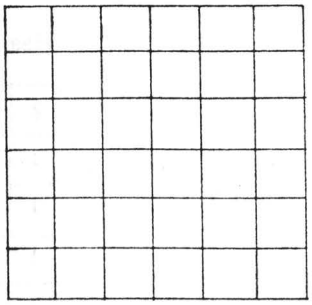
Diameter (cm)



*

Mean diameter (all trees):
Mean diameter of inner 16 trees only:

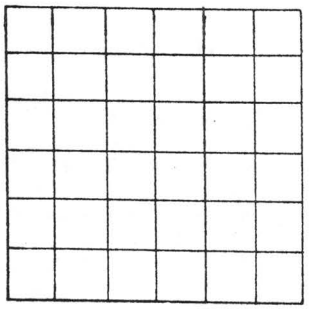
Stem form



*

Mean stem form Class:
†Number of single stemmed trees:
†Number of multistemmed trees

Branching habit



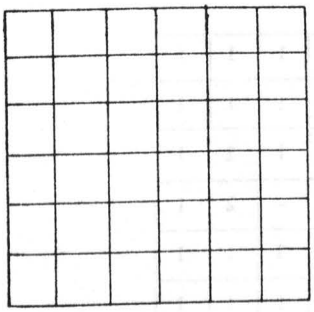
*

Mean class for branching habit:

Date:

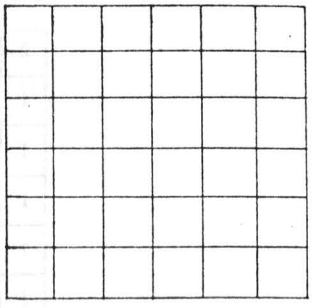
Assessed by:

Diameter (cm)



Mean diameter (all trees):
Mean diameter of inner 16 trees only:

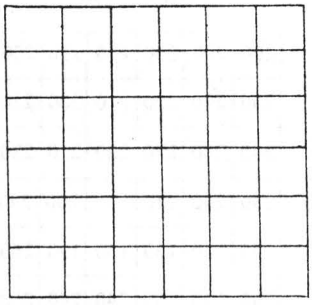
Stem form



*

Mean stem form Class:
†Number of single stemmed trees:
†Number of multistemmed trees

Branching habit



*

Mean class for branching habit:

† if applicable to species being tested
* indicates position of MARKER POST

2. **Diameter at breast height/ground level (delete as applicable); stem form and branching habit**
(Completed for a hypothetical trial)

Species: *Acacia auriculiformis*
Provenance: *Normanby River, Qld*
Seedlot number: *13862*

Block number: *2*
Plot number: *5*

Date: *22/3/83*

Assessed by: *R.M. Milimo*

Diameter (cm)

4	4	5	3	4	4
5	4	4	3	4	4
4	4	3	4	3	4
4	5	3	-	4	5
4	4	2	3	4	4
4	4	5	4	3	5

*

Mean diameter (all trees): *4*
Mean diameter of inner 16 trees only: *4*

Stem form

3	4	3	4	3	3
2	3	3	4	3	3
3	3	5	3	4	3
3	3	4	-	3	3
3	4	5	5	4	3
3	4	3	4	3	3

*

Mean stem form Class: *3.4*
†Number of single stemmed trees: *33*
†Number of multistemmed trees: *2*

Branching habit

3	3	3	4	3	3
3	3	3	3	3	4
4	3	4	3	4	3
3	3	4	-	3	4
3	4	5	5	4	3
3	4	3	4	3	3

*

Mean class for branching habit: *3.4*

Date: *21/3/86*

Assessed by: *R.M. Milimo*

Diameter (cm)

10	11	14	8	12	11
11	11	13	11	13	14
11	9	9	12	10	11
11	13	10	-	9	12
12	12	7	6	10	11
10	10	12	11	12	13

*

Mean diameter (all trees): *11*
Mean diameter of inner 16 trees only: *10*

Stem form

3	3	3	5	3	3
2	3	3	4	3	3
3	3	5	3	4	3
4	3	4	-	3	3
3	4	5	5	4	3
3	3	3	4	3	3

*

Mean stem form Class: *3.4*
†Number of single stemmed trees: *33*
†Number of multistemmed trees: *2*

Branching habit

3	3	3	4	3	3
3	3	3	3	3	4
3	3	3	3	4	3
3	3	3	-	3	4
3	4	5	5	3	3
3	4	3	4	3	3

*

Mean class for branching habit: *3.3*

Note: Number of single or multistemmed trees only to be given if applicable to species being tested.

† if applicable to species being tested
* indicates position of MARKER POST

APPENDIX 12: Guide to layout of establishment reports, progress reports and final reports

These headings may be helpful in writing reports on species and/or provenance trials and have been adapted from the recommendations of Dr D.A.N. Cromer* (first written in 1955).

1. Identity project no., file no. etc.
2. Objectives
3. Reference to published papers or other unpublished work
4. Historical summary; introduction to present work
5. Design
   - treatments (in statistical sense)
   - layout
   - replications
   - unit plot
   - spacing
6. Demarcation, location, ownership
7. Site description
   - vegetation
   - altitude, aspect, slope, drainage
   - soil description
   - experimental site preparation; method of clearing, any reheaping, ploughing etc.
8. Work performed
   - stock used (species, provenance, give full cross reference to files etc.); nursery history, condition at planting time
   - planting date
   - fertilising, weeding, maintenance
9. Initial measurements
10. Future measurements
11. Analysis of results (if applicable)

* CSIRO Division of Forest Research

REFERENCES

Beeson, C.F.C. (1941). Ecology and Control of Forest Insects of India and the Neighbouring Countries. Beeson, C.F.C., Dehra Dun.

Burley, J. and Wood, P.J. (1976). A Manual on Species and Provenance Research with Particular Reference to the Tropics. Commonwealth Forestry Institute, Oxford.

Dawkins, H.C. (1975). Statforms Pro-formas for the guidance of statistical calculations. Edward Arnold, London.

Doran, J.C. (1986). Seed, Nursery Practice and Establishment – extract from Multipurpose Australian Trees and Shrubs – lesser known species for fuelwood and agroforestry. Turnbull, J.W. (ed.). ACIAR, Canberra.

Doran, J.C. and Gunn, B.V. (1986). Treatments to Promote Seed Germination in Australian Acacias Proc. of ACIAR Workshop on the Role of Australian Acacias in Developing Countries, 1986. ACIAR, Canberra.

Goss, O.M. (1983). Practical Guidelines for Nursery Hygiene. Australian Nurserymen's Assoc., Parramatta.

Green, J.W. (1968). Tables of Random Permutations. Bulletin No.44 Forestry and Timber Bureau, Canberra.

Grossbechler, F. (1982). Direct seeding of native trees and shrubs. *Australian Horticulture* 80(4), 53-61.

Hendreck, K. (1985). Potting Mixes and the Care of Plants Growing in Them. Discovering Soils No.9. CSIRO Division of Soils, Adelaide.

Kerala Forest Research Institute (1984). Nursery Diseases of Eucalypts in Kerala and Their Control. Information Bulletin No.9.

Laos-Australian Reafforestation Project (1972). Manual of Operations. Department of Forestry, Australian National University, Canberra.

Leeper, G.W. (1952). Introduction to Soil Science. Revised edition. Melbourne University Press, Melbourne.

Midgely, S.J. and Weerawardane, N.D.R. (1986). Termites and their Control in Eucalypt Plantations of the Community Forestry Project. *Sri Lankan Forester* 16 (in press).

White, K.J. (1982). Forest Nursery Strategies and Practices in the Bhabar Terai of Central Nepal. Sagarnath Forest Development Project Manual No. 3. Ministry of Forests, Kathmandu, Nepal.

FURTHER READING

The following publications and papers may assist in the raising of Australian tree species, and the establishment of species and provenance trials:

Trial designs and statistical analysis

Forest Research Institute (1986). Simple Experimental Design for Forestry Trials. Forest Research Institute, Bulletin No. 71, revised edition. New Zealand Forest Service, Rotorua, New Zealand.

Burley, J. and Wood, P.J. (1976). A Manual on Species and Provenance Research with Particular Reference to the Tropics. Tropical Forestry Paper No. 10, Commonwealth Forestry Institute, London.

Cochran, W.G. and Cox, G.M. (1957). Experimental Designs. 2nd edition. Wiley, New York.

Cox, D.R. (1958). Planning of Experiments. Wiley, New York.

Huxley, P.A. (1983). Systematic Designs for Field Experimentation with Multipurpose Trees. ICRAF Working Paper No. 12. International Centre for Research in Agro-Forestry, PO Box 30677, Nairobi, Kenya.

John, J.A. and Quenouille, M.H. (1977). Experiments: Design and Analysis. Griffin, London.

Patterson, H.D. and Williams, E.R. (1976). A new class of resolvable incomplete block designs. *Biometrika* 63, 83-92.

Patterson, H.D., Williams, E.R. and Hunter, E.A. (1978). Block designs for variety trials. *J. Agric. Sci.* 90, 395-400, 1978.

Tree seed

Boland, D.J., Brooker, M.I.H., Turnbull, J.W., and Kleinig, D.A. (1980). Eucalyptus Seed. CSIRO, Australia.

Doran, J.C., Boland, D.J., Turnbull, J.W. and Gunn, B.V. (1983). Handbook on the Seeds of Dry Zone Acacias. FAO, Rome.

Nursery practice

Aho, T.Te and Hosking, M.R. (1983). Workshop on Nursery and Plantation Practices in the Asean. Asean-New Zealand Afforestation Project, Jakarta, Indonesia.

Baker, K.E. (1979). The UC system of Producing Healthy Container-grown Plants. Australian Nurserymen's Association, Parramatta, Australia.

Hartmann, H.T. and Kester, D.E. (1983). Plant Propagation – Principles and Practices. 4th edn. Prentice Hall, New Jersey.

Kleinig, D. and Doran, J. (1981). Eucalypt Propagation on a Small Scale. CSIRO, Australia (leaflet).

Control of pests and diseases

Goss, O.M. (1983). Practical Guidelines for Nursery Hygiene. Australian Nurserymen's Association, Parramatta, Australia.

Hadlington, P.W. and Johnston, J.W. (1977). Australian Trees – A Guide to their Care and Cure. N.S.W. University Press Ltd. Sydney.

Department of Primary Industry (1980). A Manual of Safe Practice in the Handling and Use of Pesticides. Document PB377. Pesticides Section, Department of Primary Industry, Canberra.

Trial measurement and assessment

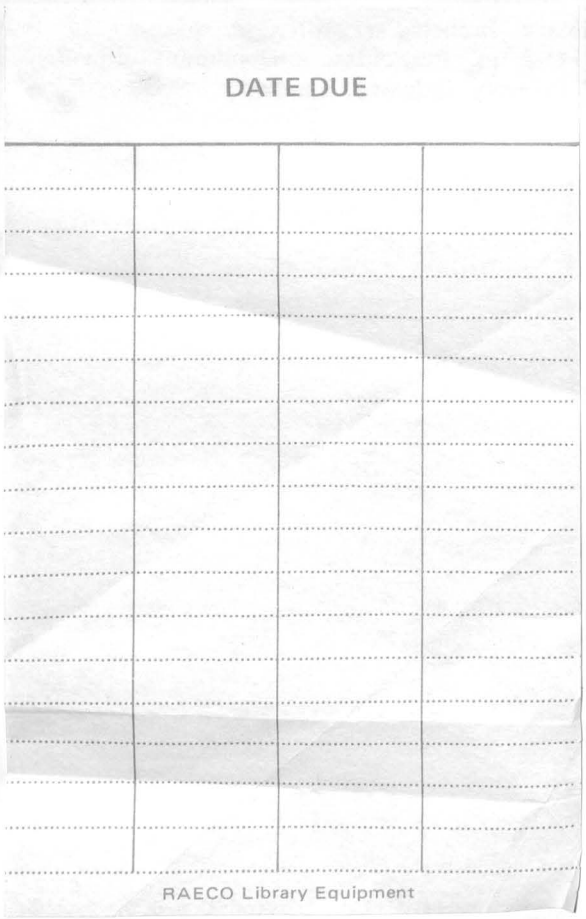
Burley, J. and Wood, P.J. (1976). A Manual on Species and Provenance Research with Particular Reference to the Tropics. Tropical Forestry Paper No. 10, Commonwealth Forestry Institute, Oxford.

Huxley, P.A. (ed.) Assessment Methodologies Section 3, Part 3E in Methodology for the Exploration and Assessment of Multipurpose Trees. International Centre for Agro-Forestry/Commonwealth Forestry Institute, Oxford. Available from ICRAF, P.O. Box 30677, Nairobi, Kenya.

General silvicultural practice

Brown, A. and Hall, N. (1968). Growing Trees on Australian Farms. Forestry and Timber Bureau, Canberra.

FAO (1981). Eucalypts for Planting. FAO, Rome.


DATE DUE
RAECO Library Equipment