INTRODUCTION

Introduction C 1

- *why grow tropical trees?*

Why are tropical trees important?

Because they play many crucial roles, especially in:

(A) creating and maintaining conditions in which other living organisms can thrive (D10-16 in Manual 4); ***and***

(B) providing numerous everyday products (D 33-40) that people need.

In spite of this, trees are disappearing very rapidly throughout the tropics, which is undermining the support systems for human life. Large numbers of young trees are needed as replacements, in order to restore land that has become degraded (D 22).

But don't young trees just come up by themselves?

Sometimes yes; but more often no.

Why not?

Tropical trees may fail to *regenerate naturally* (D 1-2 in Manual 4) for many reasons, including:

(a) lack of enough parent trees to provide pollen and seeds (Manual 2);

(b) site conditions having become harsher (Manual 4);

(c) repeated clearing, cultivation and/or burning by people;

(d) excessive browsing by animals; ***and***

(e) strong competition from aggressive weeds (Manual 5).

As a result, planting is now generally needed to supplement the natural regeneration of trees.

How do tropical trees actually benefit people?

(A) ***Indirectly,*** *by protection from sun, wind and heavy raindrops:*

(1) greatly reducing the blowing and washing away of fine soil particles (Manual 4);
(2) discouraging wholesale erosion of the soil on slopes;
(3) protecting lower land, rivers and lakes from sudden flooding and excessive silt deposits;
(4) ameliorating local, regional and probably global climates;
(5) shading the soil, so that it does not get so hot and dry, but is a favourable environment for the roots of young trees to establish and grow (C 11);
(6) encouraging the close associations between tree roots and micro-organisms (C 30-32) that lead to effective recycling of nutrients;
(7) providing better conditions for many farm crops and animals (D 3, D 21 in Manual 4); ***and so***
(8) maintaining the potential for ***sustainable management.***

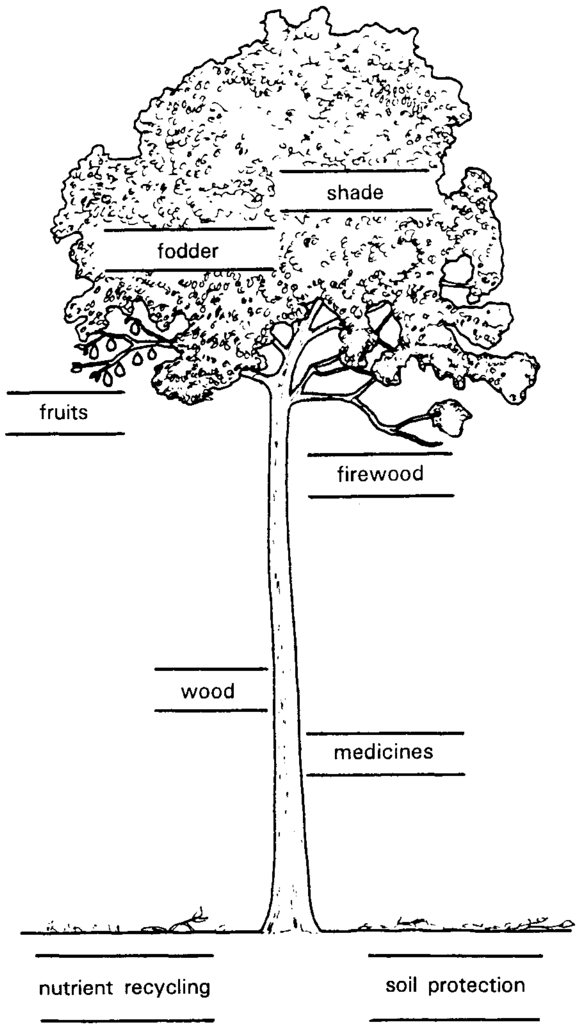
(B) ***Directly,*** *by producing many items that may be:*

(1) essential for the lives of local inhabitants;
(2) sold in local and city markets, supporting people who collect, transport and trade in them; ***or***
(3) exported, which **should** benefit all those involved.

What kinds of products?

Hundreds of different kinds of items (D 33-40 in Manual 4), including for example:

(a) foods and medicines for humans and forage for farm animals;
(b) materials for building houses and fuel for cooking;
(c) wood for diverse agricultural and domestic uses and for export.



Could we really go on having these things for ever?

Yes! They were freely available from natural woodlands for many centuries.
Bare, degraded sites, now covering more than 20% of tropical land, can no longer meet human needs, but properly managed trees could do so in perpetuity.

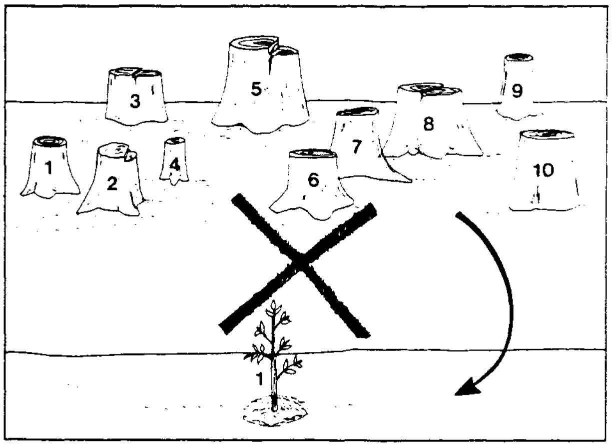
Then why are trees disappearing so fast?

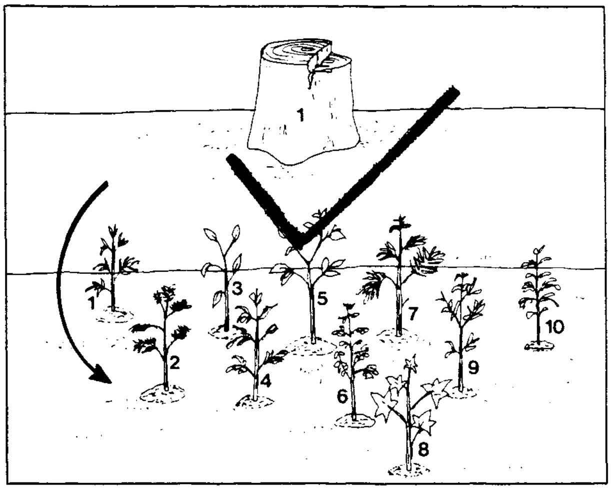
That's a question many people are asking. There are many answers, including:

(1) taking into account only a few of the multiple functions of trees;
(2) misunderstandings about:
  (a) how trees grow (C 10-15); ***and***
  (b) how tropical vegetation functions (D 10-16 in Manual 4);
(3) people concentrating on:
  (a) exploiting for timber; ***and***
  (b) clearing the land for agriculture and industry; ***instead of***
  (c) sustainable management of a valuable *renewable* resource;
(4) shortage of money, by individuals, businesses and governments; ***and***
(5) the fashion during recent decades for basing decisions on short-term economic indicators (D 1 in Manual 4), rather than the benefits of longer-term investment.

Aren't a lot of trees being planted?

Not enough, so far. Tropical trees are disappearing about **ten times faster** than they are being replaced.





What is needed is at least **ten times more trees planted than cut,** to achieve a net rebuilding of the resource, allowing for those young trees that will not survive.

But surely it's no problem to plant more!

In one way, no, since growing and planting young trees is not hard to do; ***but***
In other ways, yes, because successful establishment of trees depends on solving a series of problems (C 3). Here are some examples:

(a) **Land tenure** - frequent problems about who owns the land, and whose trees they would be;
(b) **Expectations** - the various people involved may have conflicting ideas about how the land should be used (D 5 in Manual 4), and might not be familiar with the idea of planting trees;
(c) **Planting stock** - enough ***good*** plants (C 4) are not always available;
(d) **Thought before planting** - if the young trees are to thrive on a particular site, choices need to be made about the kinds of tree species and their usefulness, and the most appropriate planting patterns and methods to use (Manual 4);
(e) **Protection** - the young trees need looking after if they are not to be choked by weeds, eaten by animals, attacked by pests and diseases or killed by fire (C 40-48 and Manual 5).

What else do I need to consider when growing trees?

(A) Appropriate genetic origins of the seeds or cuttings (C 5 and Manuals 1-2);
(B) The general principles that govern the growth of trees (C 10-15);
(C) Where to put the tree nursery (C 2, C 20-26), and how to run it (C 50-54);
(D) Giving the young plants a good start (C 4, C 30-34);
(E) Getting them to the planting site in good condition (C 47 and Manual 5); and
(F) Planting them well (Manual 5).

Can you give a few general hints?

(1) Draw on local experience of growing woody plants, and look out for demonstrations about tree nurseries, useful publications (C 61-62), or other sources of help (C 53).
(2) Don't assume it will cost too much - small nurseries near the house may not involve much expenditure (C 2). For larger nurseries, there might be a financial incentive scheme, usually dependent on the successful establishment of the trees in the field.
(3) Try new things out on a small scale first, and don't be put off if you don't succeed at once.
(4) Remember that although most steps in growing trees are straightforward, each of them needs attention if the risks of losses and damage are to be minimised (C 4, C 60).

Introduction C 2
- *do I need a tree nursery?*

What are tree nurseries?

Places for raising good young trees, which are then planted out where they are to grow.

Is that the only way of growing trees?

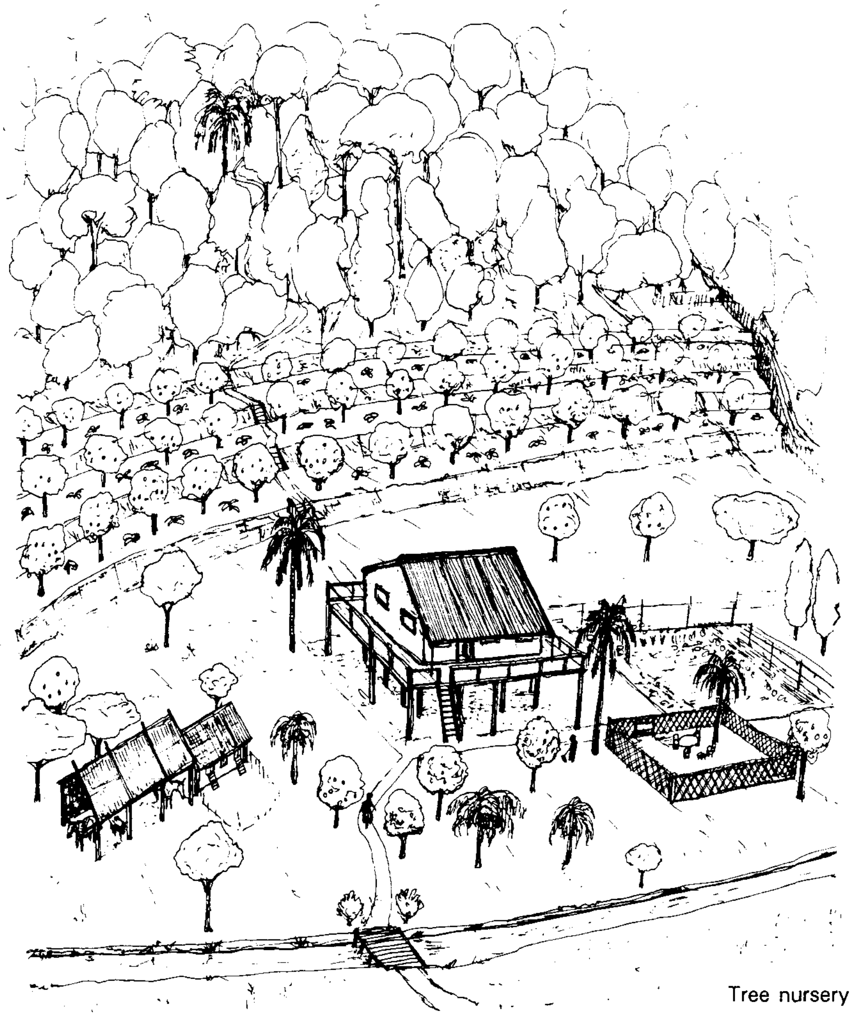
No - trees can also become established by natural regeneration (C 1; and D 2 in Manual 4). For *artificial regeneration,* nurseries are generally used, although for a few species you could also consider the possibility of:

(1) collecting wildings (Manual 2) and planting them directly in place;
(2) direct planting of leafless cuttings where they are to grow (A 4 in Manual 1); ***or***
(3) direct sowing of seeds (Manual 2).

Wouldn't such direct planting be easier?

Occasionally yes, if one of these methods has been well tried out for the particular tree species (as with various hedging and shade plants grown by method 2); ***but***
Generally no, for most kinds of trees, because:

(a) they are not suited to methods (1) or (2);
(b) method (3) typically requires a lot of seeds, to allow for failures; ***and***
(c) protecting directly planted young trees may be difficult (Manual 5).



Tree nursery near the house.

So what does the tree nursery really do?

Looking after the young trees first in a nursery can allow planting stock to be raised that is much more likely to establish well than if directly planted.

But with direct methods you wouldn't have to disturb the roots!

That's very true, and it means that you are exchanging one problem for another. So one of the most important things about tree nurseries is to find ways of temporarily **changing** the way the roots grow so that the root system is compact and can be planted without much damage. Then the roots can support vigorous stem and leaf growth (C 4, C 11-12, C 34).

Are there different kinds of tree nursery?

Yes, they can be:

(1) temporary or more permanent (C 21);

(2) of very different sizes (C 22), ranging from very small (dealing with about 10-100 young trees at a time) to very large (producing hundreds of thousands or millions of plants a year); ***and***

(3) used for a variety of different purposes, such as growing young trees for:

- (a) planting around the family home, garden and farm;
- (b) school and community planting (D 27 in Manual 4);
- (c) larger scale programmes by the government or private owners;
- (d) sale to other people; ***or***
- (e) use in experimental research (C 7).

What are the most important things about nurseries?

(A) Where they are put (C 20), particularly in relation to the planting site(s);

(B) Having reliable sources of clean water and of materials for making good soil mixes (C 6, C 23-24);

(C) Thinking carefully about the internal layout (C 22) before setting up the nursery (C 26);

(D) Producing favourable environments in them, so that the young trees have root systems that will give them a good chance of thriving (C 4, C 11, C 47);

(E) Protecting the young nursery trees against various kinds of stress, damage and loss (C 25, C 40-48); ***and***

(F) Building up a team of people (C 52) who understand the running of the nursery (C 50), the importance of regular watering (C 43) and care of the trees (C 40).

Will it be rather expensive?

Not necessarily - smaller nurseries at home or a school need not cost much, because:

(1) most of the materials required may be cheap or free (C 6, C 33), and can usually be obtained locally; ***and***

(2) some of the work can be done part-time, or by people who are prepared to work without cash payment because they will soon benefit from the tree planting (C 1).

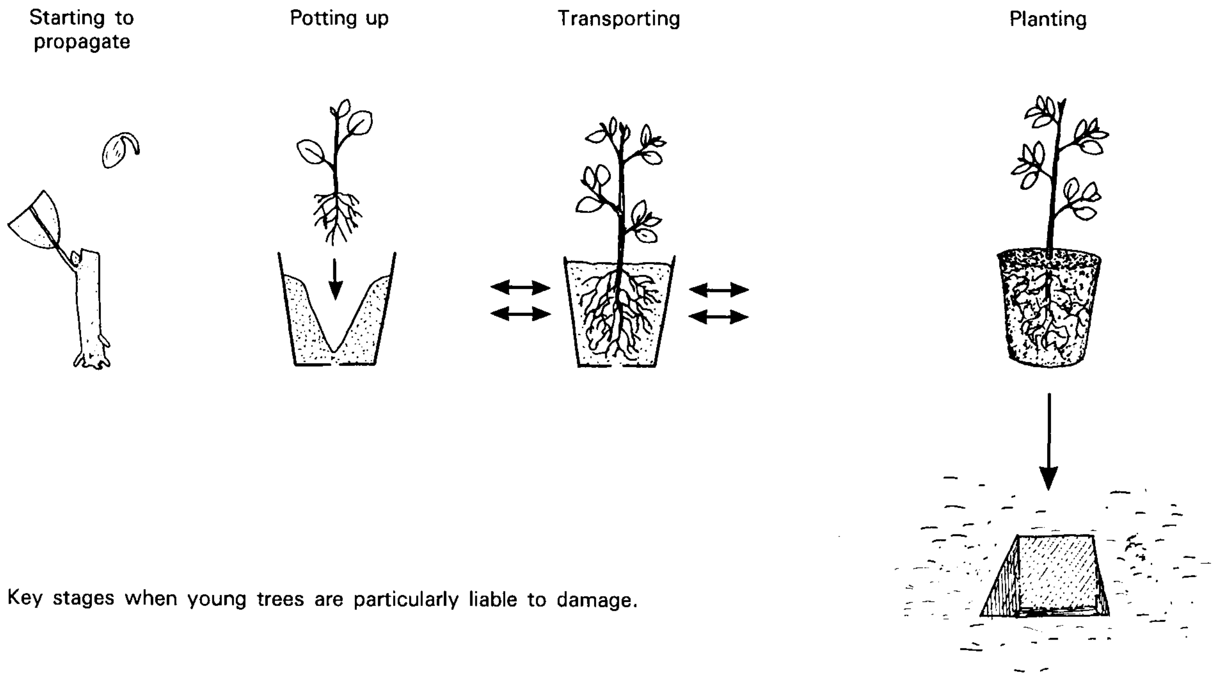
Larger, permanent nurseries involve more expenditure, for instance to employ and train staff and workers (C 52) and install a water supply (C 24). Other costs could be involved in putting up buildings or making roads, and buying equipment or a greenhouse (C 48) for detailed research.

What sort of nursery problems could I face?

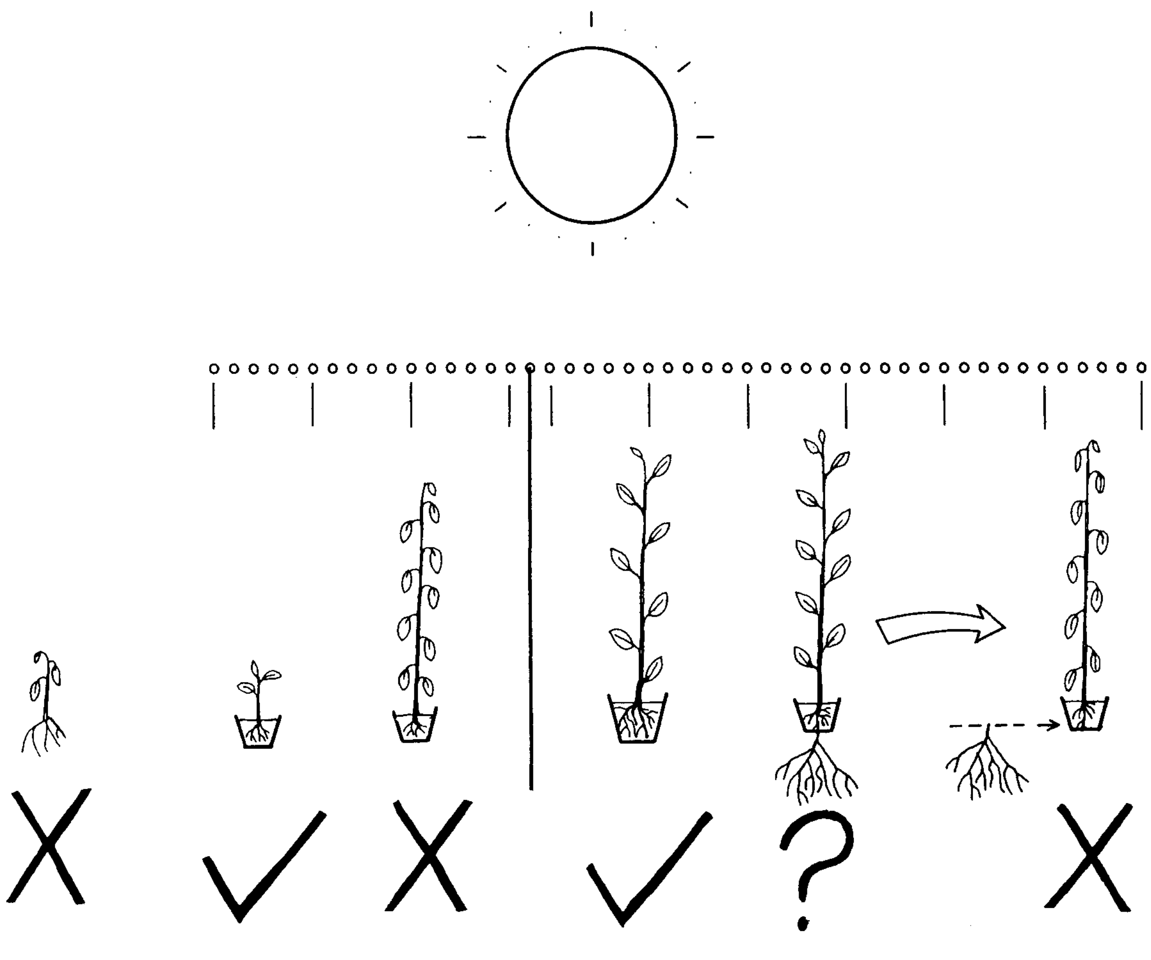
Most nursery problems are fairly easy to understand, foresee and correct (C 3, C 60; and A 2 and A 60-61 in Manual 1).
Some of the publications listed in sheets C 61-62 might help you avoid or cope with difficulties, and so could various useful contacts (C 53).

Are there some general guide-lines?

(A) The choice of which species to propagate depends strongly on the conditions in the planting site (D 20-29 in Manual 4), as well as the desired products and other benefits (D 30-42).
(B) Each young tree could grow into a large one, but to have a good chance of doing so it needs help, especially at key stages in its development (C 3, C 40).
(C) Care during these early stages does not mean that afterwards it will be unable to stand up to climatic stresses such as drought (C 41, C 47).
(D) Besides difficulties of a biological kind, think about possible problems involving people's differing views (D 4-5 in Manual 4), changing markets, breakdown in the systems for checks and care (C 40, C 66), and the risk of accidents (C 3; and D 66).



Key stages when young trees are particularly liable to damage.



Importance of maintaining the water balance.

Introduction C 3
- *overcoming problems when growing trees*

Are there a lot of nursery problems?

Yes, if you make a list of all the things that could go wrong; ***but***
No, in the sense that most of them can easily be avoided.

When are young trees most at risk?

(A) When they are very small;
(B) If watering is neglected or done badly (C 41, C 43);
(C) Whenever their root systems have been disturbed (C 40); ***and***
(D) If their shoots are repeatedly damaged by pests or larger animals (C 45-46).

What does that mean in practice for nursery problems?

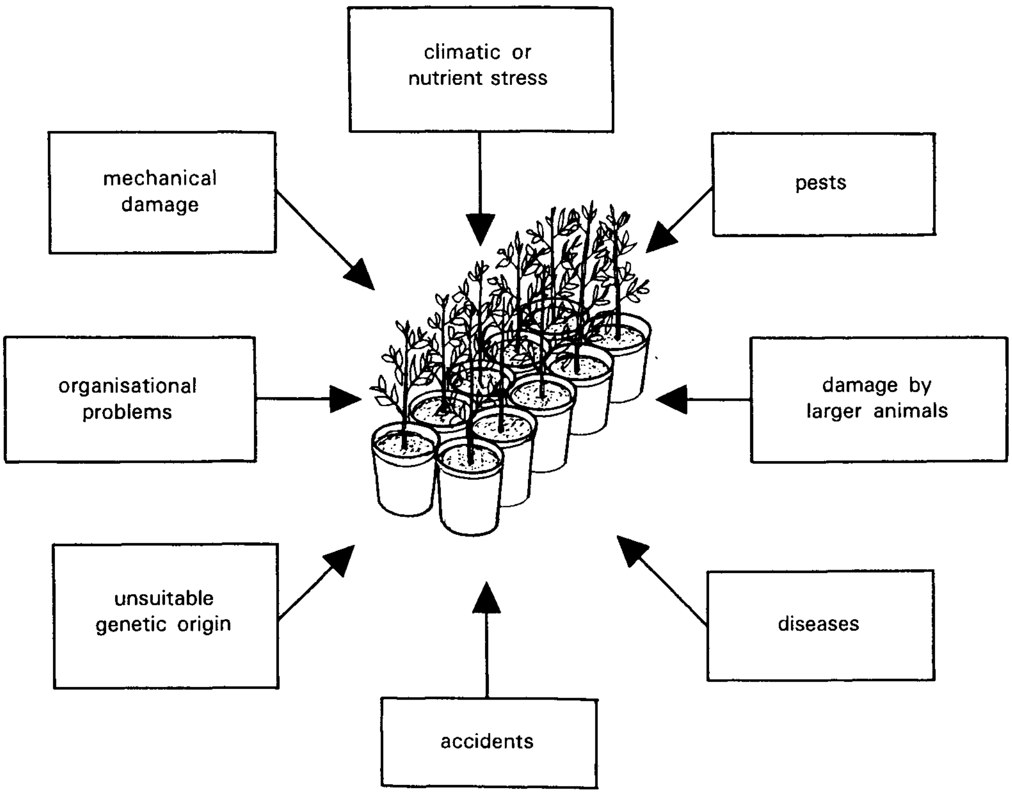
Stages at which young trees are most susceptible to damage include when:

(a) seeds are just germinating (Manual 2);
(b) cuttings have not yet formed roots (A 40-45 in Manual 1);
(c) seedlings and newly rooted cuttings are being potted up or transplanted (C 42);
(d) plants are being prepared for transporting to the planting site (C 47).

What about after they leave the tree nursery?

Young trees are particularly at risk:

(1) during transport and before planting (Manual 5);
(2) especially for the first few days after planting, and during the next 2-4 weeks.



And how about before nursery work starts?

Yes, success also depends on decisions taken beforehand, such as:

(a) choosing appropriate tree species for the site and the expected usefulness (D 30-42 in Manual 4);
(b) using suitable genetic origins (C 5 and Manuals 1-2);
(c) planning the way seeds are to be handled and stockplants managed; ***and***
(d) arranging for frequent, regular visits to the nursery.

But aren't there bound to be problems?

Yes, but for instance you could:

(A) think about potential snags that might come up in your situation;
(B) make frequent checks (C 40), and keep on the lookout for signs of trouble (C 60);
(C) try to reduce the likelihood of problems occurring (C 50; and D 4 in Manual 4); ***and***
(D) make plans to lessen the impact of those that do happen.

What sort of things might go wrong?

You could think about three different kinds of problem (A 2, A 61 in Manual 1):

(1) **accidental hazards,** such as drought, flooding, storms or fire (C 25, C 40-41, C 46);
(2) **organisational difficulties,** including a lack of information, experience or skills; or a shortage of finance, manpower, tools or materials; ***and***
(3) **biological problems,** as for example:
- (a) difficulties with seed germination (Manual 2);
- (b) poor rooting of cuttings (A 50 in Manual 1);
- (c) death or unsatisfactory growth of young trees (C 60);
- (d) competition from other plants (C 44);
- (e) damage from pests or diseases (C 45); ***or***
- (f) eating and breaking by larger animals (C 46; and D 14-15, D 34 in Manual 4).

Is there anything I can do to prevent accidents?

Yes there is, though the risks will always remain, whatever one does. However, one could lessen the chance of accidents happening for instance by:

(A) careful selection of the nursery site (C 20);
(B) maintaining tools (C 50) and fences (C 46) well, and any buildings and vehicles;
(C) removing inflammable materials, and digging drains or building barriers against floodwater (C 23, C 25; and D 65 in Manual 4) ***and***
(D) learning about various kinds of risks, training people in safety measures (C 50, C 52, C 54; and D 66 in Manual 4), and not leaving the nursery unattended for long periods.

What about reducing the losses?

Examples of ways to reduce the consequences of accidents are:

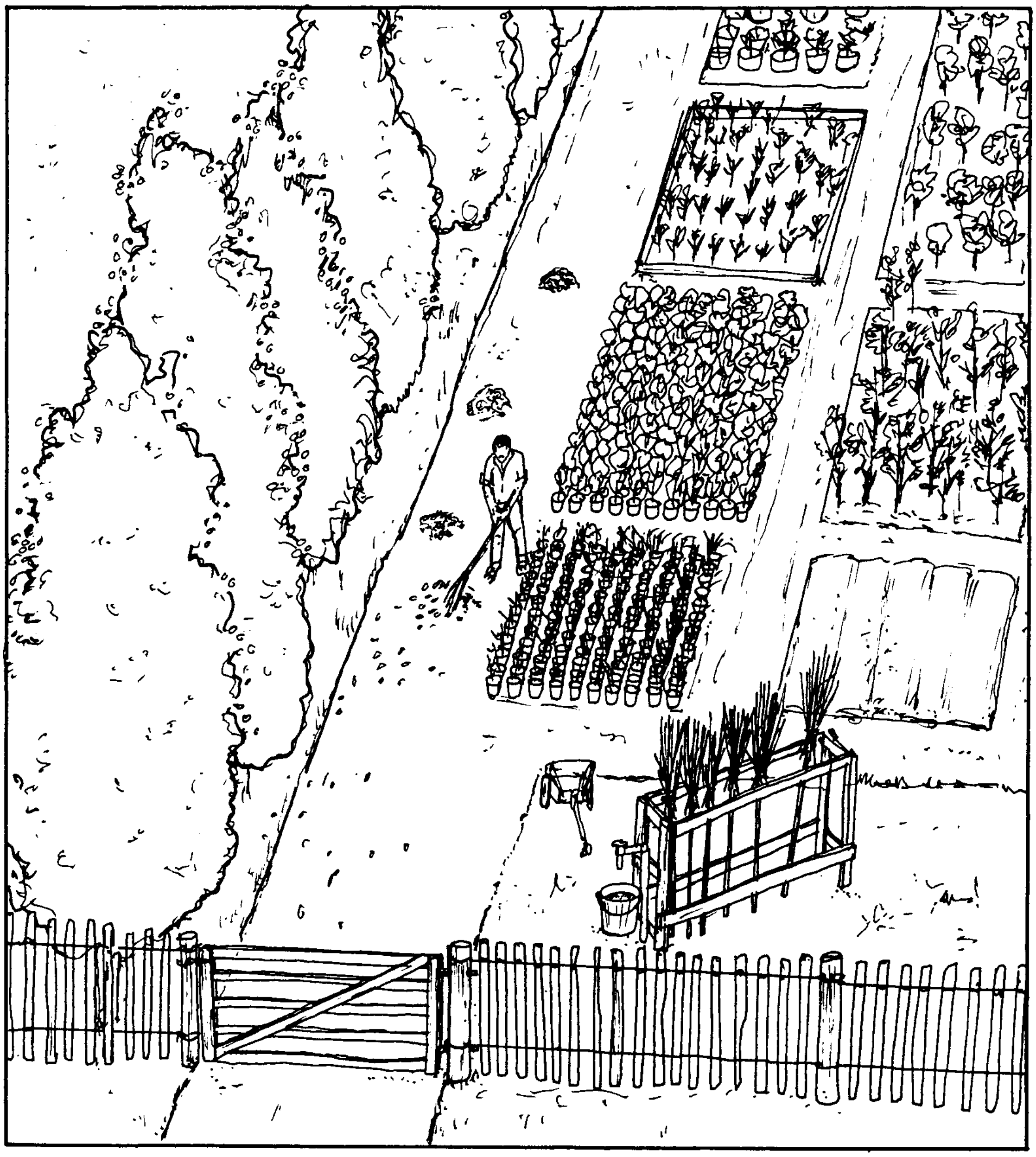
(1) planting shelter belts or hedges on any exposed sides of the tree nursery (C 25);
(2) not keeping all the young trees of one batch in the same place (C 65);
(3) keeping a first aid box handy;
(4) stopping fires that start outside from spreading far into the nursery by:
- (a) growing strips of suitable trees as *fire-breaks;* ***and***
- (b) having fire brooms and water easily available in the nursery.

Items (A-D) above may also help to lessen the scale of damage.

How about problems of organisation?

Some of these are discussed on sheets D 4-5 in Manual 4. Hints that are particularly relevant to tree nurseries include:

(a) making sure the land will be available for as long as it is needed;
(b) using locally available materials and tools (C 24, C 51), and if possible keeping a sufficient stock of them;
(c) starting on a fairly small scale and then building on your experience (C 21-22);
(d) spending enough time on checks (C 40, C 66) and training the nursery team (C 52);
(e) making plans and keeping adequate records (C 54, C 64-66).



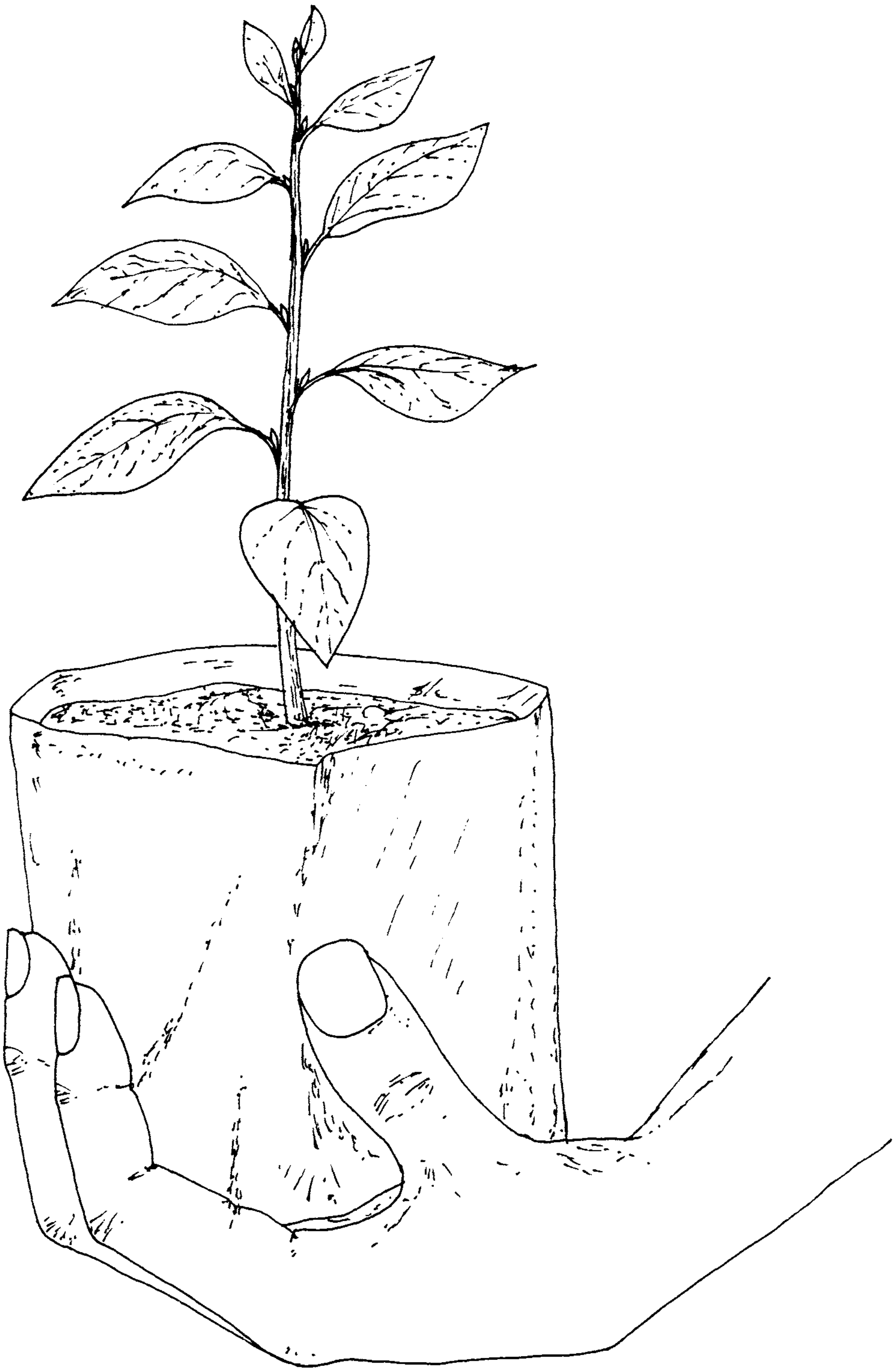
Supposing my plants don't grow well?

Amongst problems that might be involved are:

(A) an unsuitable **tree species** for the climate of the area (C 10-15; and D 10-11 in Manual 4);
(B) an inappropriate **genetic origin** for the region or the intended purpose (C 5);
(C) unfavourable **potting mixtures** (C 6) or **nursery soil** conditions (C 23; and D 12-13 in Manual 4);
(D) poor **watering regimes** (C 13, C 43);
(E) lack of important **nutrients** and/or **micro-organisms** (C 30-34);
(F) **bud** or **seed** ***dormancy*** delaying growth or germination (C 12; and Manual 2);
(G) damage by **weeds** (C 44; and D 14 in Manual 4), larger **animals** (C 40, C 46; and D 15 in Manual 4) or **pests** and **diseases** (C 45; and A 52 in Manual 1).

This all sounds rather difficult!

Well, in practice, one seldom has to deal with more than a few problems at a time!
Sheet C 60 summarises various symptoms of poor nursery growth and their likely causes. *(For poor rooting of cuttings see A 50 and A 61 in Manual 1. For germination problems see Manual 2.)*



Introduction C 4
- *what makes a good tree for planting?*

What are the features of good planting stock?

The young trees should be:

(A) of appropriate **species** for the particular planting site (D 20-29 in Manual 4);
(B) from suitable **genetic origins** (C 5) for the intended purposes (D 30-42); ***and***
(C) in a favourable **physiological condition** (C 10-15) for being planted (C 47).

Isn't it really just the species that matters?

No, the other two points are also important, because:

(1) a lot of losses and unnecessary problems can be avoided; ***and***
(2) good planting stock is more likely to establish quickly and grow well, and to give increased benefits and yields.

Is it difficult to grow good nursery trees?

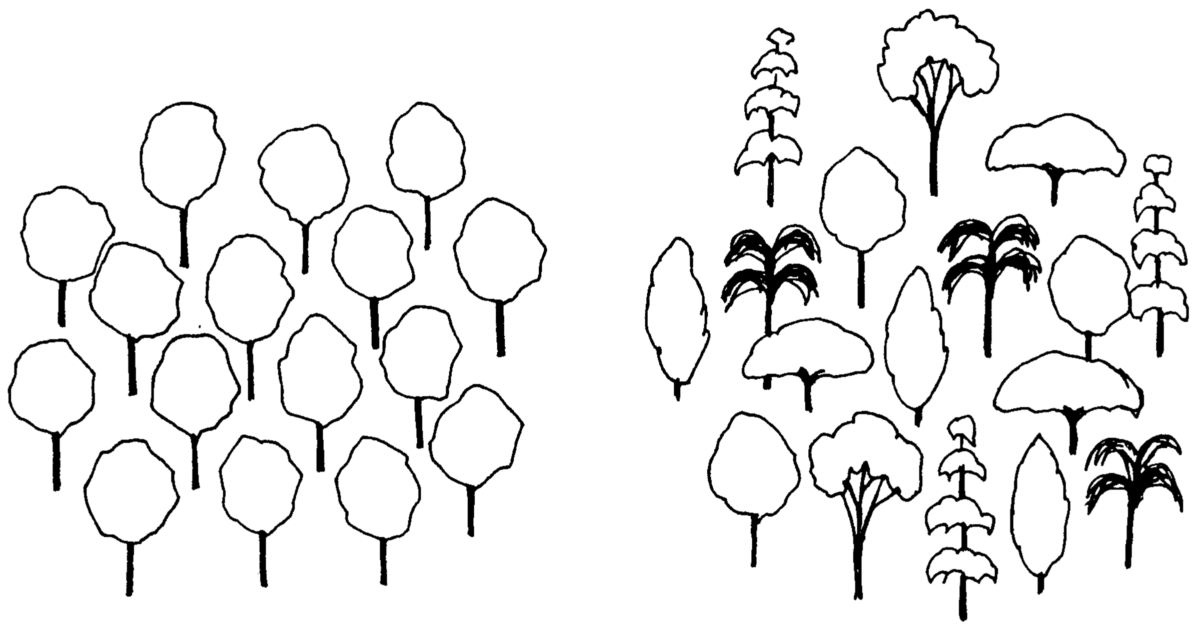
No; it mostly involves setting up and following straightforward procedures (C 50-54, C 63-66), and gaining experience of dealing with problems (C 3, C 60).

Improvements in approaches and techniques can also come through training courses (C 50), local contacts (C 53), publications (C 61-62) and by doing informal or formal experiments (C 15; and D 6 in Manual 4).

Which tree species might I choose?

Those which are likely to:

(A) thrive in the average climate experienced in the planting site (D 11, D 30 in Manual 4), and also survive extreme conditions that could occasionally occur;
(B) fit in with the existing patterns of vegetation and land use (D 14, D 50-54), and preferably improve the soil (D 32); ***and***
(C) provide the desired products and benefits (D 30-42).



Should I concentrate on just one kind of tree?

Occasionally yes, for example in specific situations, such as:

(1) establishing shelter belts in dry areas (D 41 in Manual 4);
(2) restoring patches of mangrove woodland (D 26); ***or***
(3) reclaiming degraded farmland (D 21-22); ***but***

Generally no, because:

(a) mixtures of trees usually provide better soil protection and maintenance of fertility than pure stands (C 30; and D 30, D 53 in Manual 4);
(b) even on a small piece of land there can be a variety of conditions, suitable for different tree species (D 12, D 20-29);
(c) you may well want several benefits and products, and prefer to have yields spread out over time; ***and***
(d) Because unexpected things may happen, it is risky to "put all your eggs in one basket". Species diversity acts as an 'insurance' against market changes as well as possible heavy losses from unusual weather conditions, pests or diseases.

Don't natural stands have hundreds of different species?

This is often true of tropical forests, and most of them can give useful products. However, when starting a tree nursery, you can choose a selection of several local and introduced trees (D 31 in Manual 4):

To provide young trees for your farm, you might begin with perhaps 4-6 species for fruits, fodder, shade and marking boundaries.

For a medium-sized nursery, you could decide on 5-10 main species and 3-8 grown on a smaller scale, plus a few new kinds for trying out.

For nurseries selling young trees, and those in parks and Botanical Gardens (D 28, D 41 in Manual 4), many more species of tree and shrub will usually be propagated.

Does this Manual give specific instructions for growing the major plantation trees?

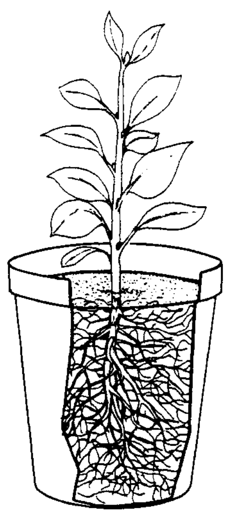
No, it aims to present **the general principles upon which** trees of the humid and semi-arid tropics can be raised as good planting stock.

Like the other Manuals in the series, it may encourage the writing of local sheets on the many other valuable tree species that have often been neglected in favour of a few plantation crop trees.

Why do different genetic origins matter?

Individual trees generally vary so much within a species that it would be a big advantage to use those which are most suitable for the purposes in hand (C 5).

While these are being chosen and tested, one can still make considerable progress by excluding inferior types.



What is "a favourable physiological condition for being planted"?

This term includes many points (C 10-15) which together give the tree a good chance of becoming established, tapping the available soil moisture and nutrients, and growing well. Amongst the most important are that each tree should:

(A) have a **good, bushy root system** (C 6, C 11) that is not *pot-bound,* but is compact enough to be planted without too much damage;

(B) have a **moderate-sized shoot system** (C 34) that can, without dying back, produce new growth rapidly once the roots have recovered from planting shock;

(C) be free of **pests** and **diseases** (C 45); ***and***

(D) have been suitably **'hardened'** (C 47) and recently **watered** (C 43), so that it can tolerate moderate climatic and mechanical stress (C 13, C 41) in transit.

Shouldn't trees be treated roughly for them to survive planting out?

No, this is a common but mistaken idea. The basic function of a nursery (C 2) is to:

(1) raise seedlings and root leafy cuttings under **favourable** conditions in a protected environment (Manuals 1-2);

(2) encourage good growth to the size required (C 34); ***and then***

(3) harden the young trees off gradually (C 47) before they go to the planting site.

How important is the root system?

It is the main key to success (C 11, C 34). A desirable root system can generally be obtained by:

(a) using suitable containers and an effective potting mix (C 6);

(b) watering carefully and regularly (C 43);

(b) minimising other kinds of stress (C 41); ***and***

(d) pruning back longer roots to encourage many branch roots to form ***inside*** the pot (C 6, C 11).

Alternatively, young trees can be grown in good soil in a nursery bed with more frequent root pruning. The trees are then taken for planting complete with the soil block around the roots.

Isn't a strong tap root best?

No, only with direct planting (C 2), and for occasional species where it is needed. Contrary to another common misconception, they are generally unsuitable for nursery grown trees that will be planted out later on, because:

(A) **tap roots** often occur singly, have few branch roots at an early stage, can get twisted round and round inside a pot, and are difficult to plant intact; ***whereas***

(B) **branch roots** can occur in larger numbers, usually produce many side branch roots rapidly, are less prone to become set in a coil, and are easier to plant undamaged.

Branch roots can also be inoculated with useful micro-organisms (C 30-32).

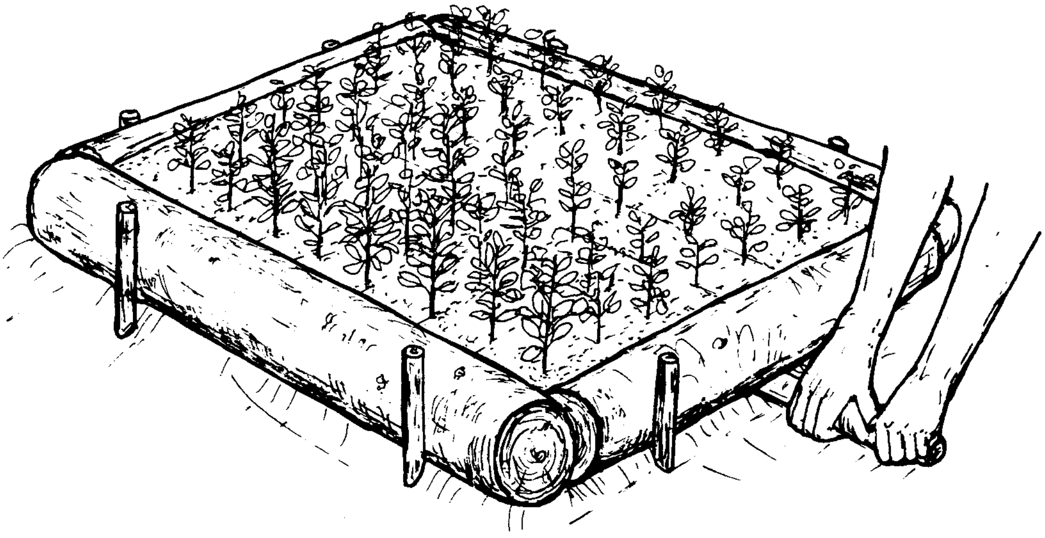
What about the shoots?

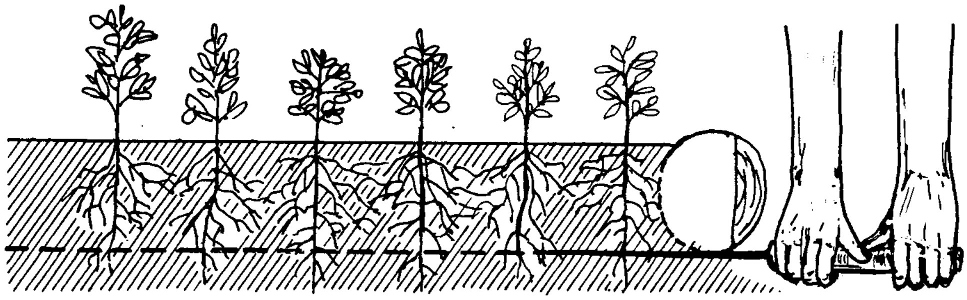
Rapid early growth in the nursery is desirable, but later the rate of shoot growth should slow down or even stop temporarily (C 12, C 34). This is because a sturdy stem and moderate area of dark green leaves mean less water stress than a tall plant with a lot of large, paler-coloured leaves (C 41). In order to maintain water balance after planting (C 13), the roots first need to have time to grow and branch into the soil before strong shoot growth is made.
However, vigorous growth in the nursery is not a problem if striplings or stumps are to be planted (C 47).

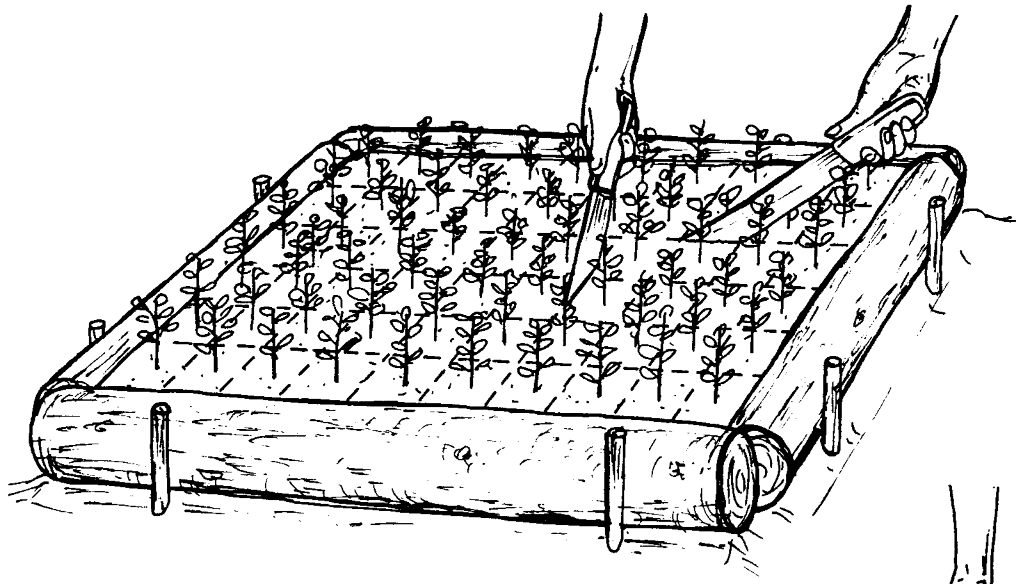
In general, the tree's capacity to produce vigorous new shoots **after** planting is more important than its starting height.

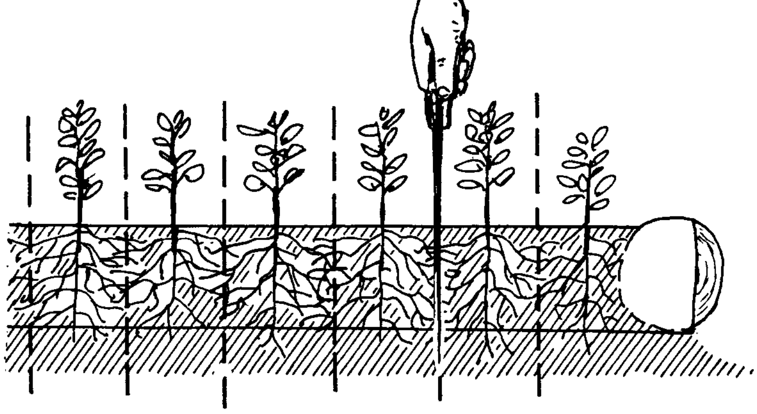
Are pests and diseases very important?

Most of them can be avoided or dealt with by simple methods (C 45), but there are a few that can do a lot of damage. It is a good idea to learn how to spot early stages of an attack, and to check the young trees frequently (C 40, C 66).









Regular cutting of the longer roots promotes good bushy root systems in the 'root-pruned soil block' method of growing young trees.

Is more research needed on growing good trees?

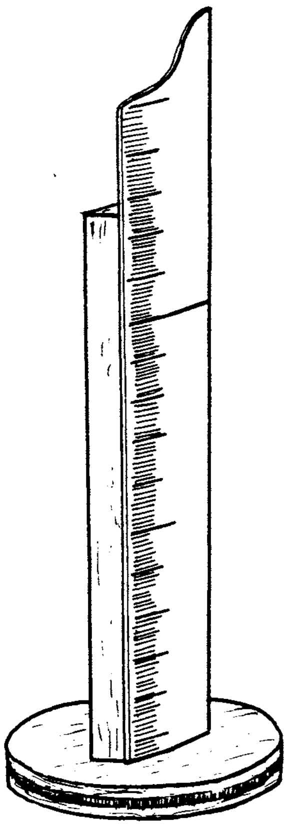
Yes it is (C 7). A fair amount is known about the underlying principles of tree growth (C 10-15, C 62-A) and general methods for tree nurseries (C 61), but much less work has been done on:

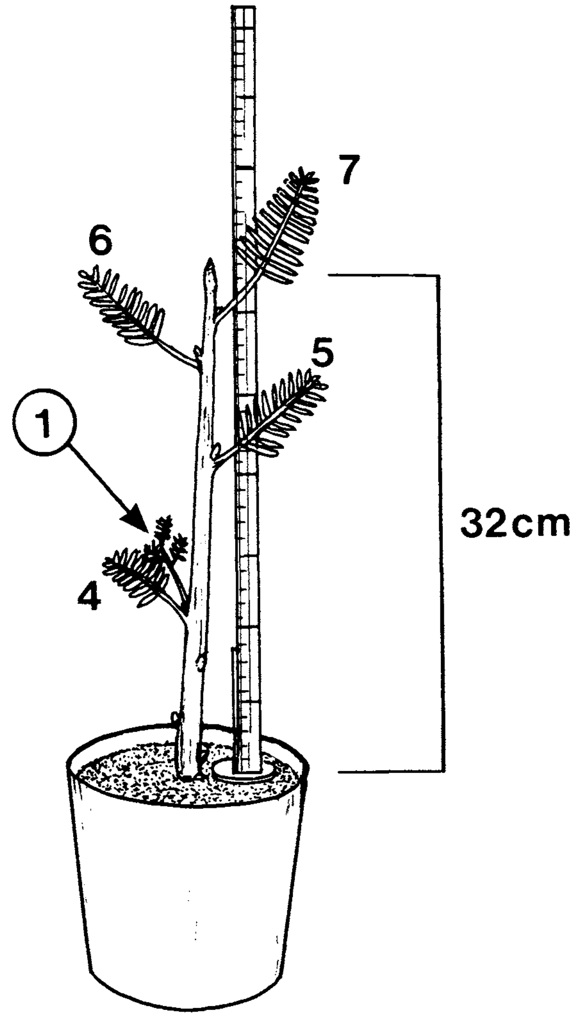
(1) which factors particularly affect the growth of individual tree species;
(2) how these may indicate the need for different nursery practice;
(3) achieving the most useful close associations with micro-organisms (C 30-32); ***or***
(4) stimulating flowering in the desired parent trees (Manual 2); ***and***
(5) studying variations in the underlying processes within the cell (C 10, C 14).

Why haven't most local trees been looked into?

Because:

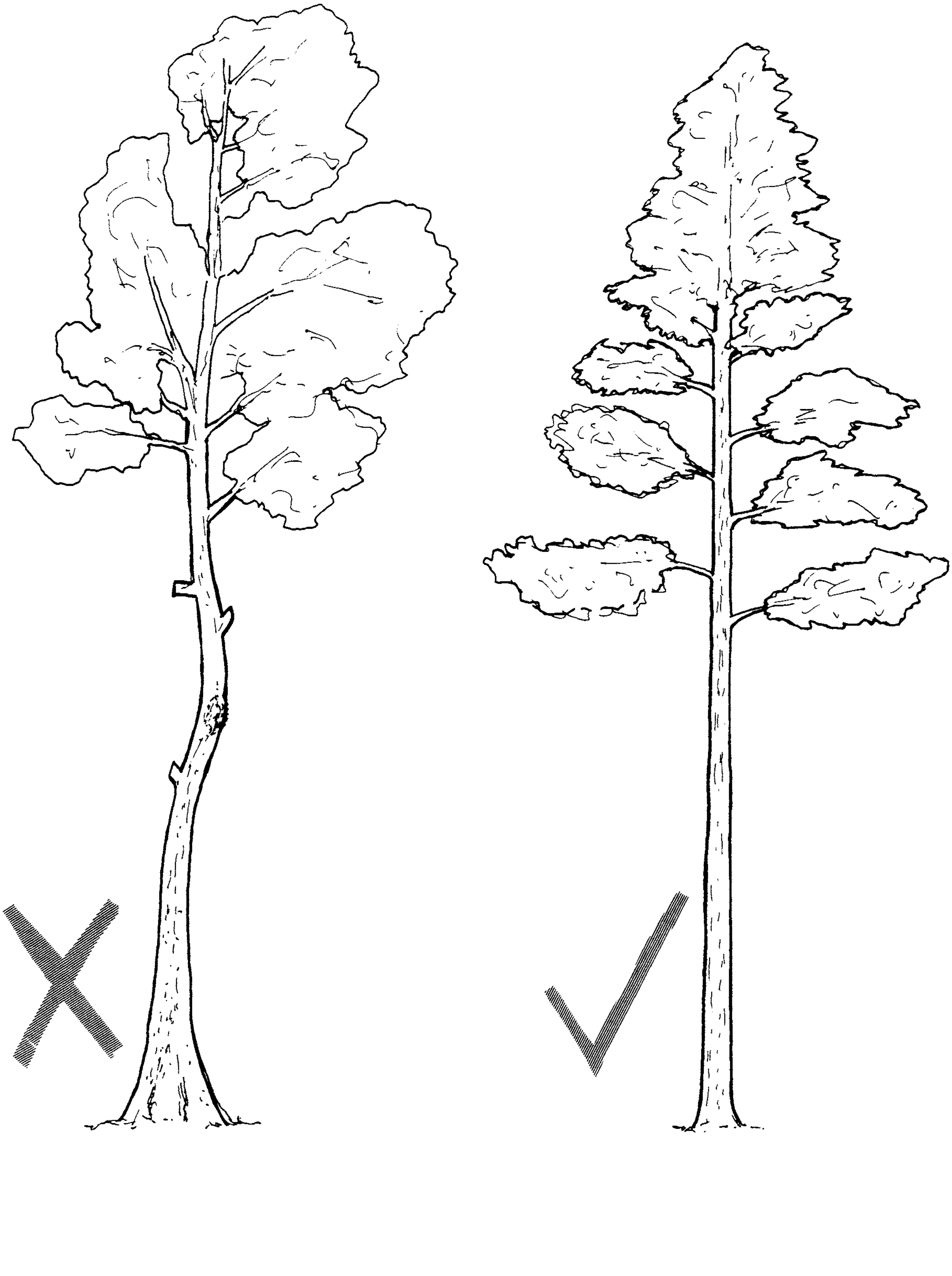
(a) many of these species used to come up by themselves (C 1);
(b) most research effort and funds were directed at cereals and plantation crops; ***and***
(c) hardly anyone had thought about doing it.





Assessing shoot growth.

1 — one branch has been produced
4-7 — leaves at nodes 4-7
(the bottom 3 have fallen off)



Introduction — 'domestication' of trees C 5

What is 'domestication'?

Improving a tree species that has grown only in the wild, by finding or producing particular varieties, populations or clones that are more suited to the local environment and the purposes for which the trees are to be planted.

Is that important?

Yes it matters quite a lot, because:

(A) big differences often exist between individual trees within a 'wild' species;

(B) this variability is generally found in important features such as height and diameter growth, stem form and branching habit, fruiting characteristics and tolerance to disease;

(C) such features are usually strongly influenced by genetic characters inherited from the male and female parent trees.

The features of trees also depend on the environment they have grown in, internal changes within them, and chance occurrences (A 10 in Manual 1).

Isn't it a good thing to keep a lot of genetic diversity?

Yes, in the sense of:

(a) not clearing most of the sites where a tree species grows naturally;

(b) not cutting down all the best trees; ***and***

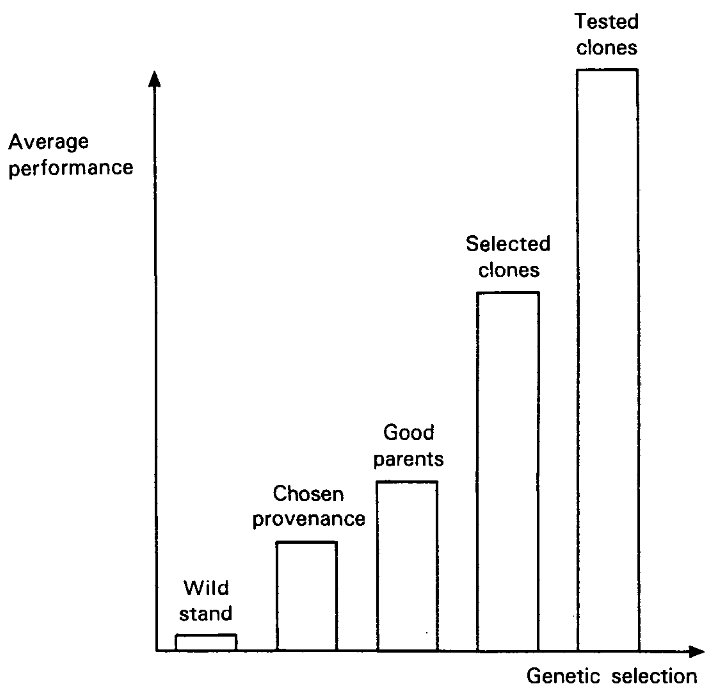
(c) not planting closely related seedlings or a single clone in large blocks; ***but***

No, for the practical grower, because:

(1) all the available diversity need not go into each planting (C 62-E), provided some is conserved for the future in *gene banks* and natural stands (Manual 2); ***and***

(2) a domesticated stand can still contain plenty of genetic variability to protect it against the risks of over-uniformity.

Genetically uniform planting stock is very useful for experiments (C 7).



How can I improve the genetic quality of my nursery trees?

The first steps in domestication can be taken fairly easily, for instance by:

(a) choosing a suitable *provenance* (part of the natural range) to use (Manual 2);

(b) taking seeds from a sizeable group of healthy trees with favourable characteristics; ***and***

(c) rooting cuttings of selected clones (A 11 in Manual 1).

Will that give me the highest yields?

An improvement over unselected material is likely, but definitely not the full potential at these early stages of the process. Moreover:

(1) if the *selection* has been based only on observing the features of the parent trees or stockplants, testing in field trials (D 29 in Manual 4) will be needed to confirm whether and to what extent they are *genetically* superior; ***and***

(2) yields tend to be influenced by more than one genetic characteristic.

How much difference can selecting the provenance make?

Quite a lot, especially if the species has an extensive natural range. One provenance may do very poorly or die, while others thrive.
In other cases, differences can be much smaller, or hard to detect.

So how do I choose the best provenances for seed collection?

For local trees (D 31 in Manual 4):

(a) where possible, use **natural stands in the locality** as seed sources;

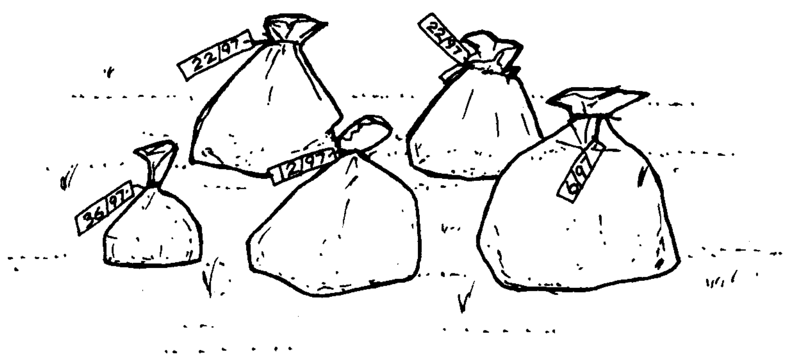
(b) if not, collect seed from good **plantations made with local seed.**

For introduced species:

(1) preferably use seed collected in the area **where the species grows naturally,** of provenances that have done well in trials in your region;

(2) alternatively collect seed **from trees thriving locally,** but avoid using only one or two trees or a small group that might be too closely related to one another.

For a provenance trial, make sure you record the origins of the various seed lots, label them and grow separated batches of seedlings under uniform conditions (C 7, C 54, C 64-65).



Suppose nothing is known about any of the available origins?

It is still worth selecting your seed sources. You could:

(a) look for thriving groups or stands of the species; ***and***

(b) choose at least 10-20 of the best individuals as parent trees for pollen production and seed collection.

Why is selecting provenances only the start of domestication?

Because your young trees may still contain much of the genetic variability of the species. There will be *inherently* poor trees as well as good ones.

Is that why one collects seeds from the best parent trees?

Yes, this is the next step, especially if you can make a *seed stand* (Manual 2), where:

(1) the inferior trees have been removed; ***and***

(2) there are plenty of above-average trees.

However, the potential for further domestication will generally still be large.

Why is this so?

There are several reasons, including the following:

(1) one seldom knows where the *pollen* has come from, so *mother-tree selection* covers only half the inherited characteristics;

(2) the genetic features of the two parents are not all passed on to the young trees, and become considerably mixed during flowering and seed formation;

(3) if the parent trees are closely related, their *progeny* (the seedlings resulting from crossing them together) could show *inbreeding depression* (Manual 2);

(4) when a few of the trees in a stand produce a lot more pollen and/or seed than the others, the seed you collect may not reflect the features of the stand as a whole, and might well have a greater tendency to flower than their parents; ***and***

(5) the best trees may not produce much pollen or seeds, so may not be represented.

How can one get over these problems?

(A) By **open-pollinated progeny trials** to compare the seed from individual mother trees;

(B) By **controlled breeding** (crossing) of parent trees, followed by **full progeny trials** to test the seed originating from a particular male or female parent tree, or from specific combinations of parents; ***and***

(C) By direct **vegetative propagation** of selected trees.

What are the advantages of progeny testing?

(1) It can take domestication further than provenance selection, particularly when both parents are known, and they flower or can be stimulated to do so (Manual 2);

(2) It may allow *hybrids* to be bred between related tree species or between provenances of the same species. These may show considerable *hybrid vigour* and can sometimes combine desirable features of each parent.

How about the disadvantages?

There are several of these, particularly with controlled pollination, including:

(a) having to wait many years, and then climb high up in a large tree to reach the flowers, and again later to collect the ripe fruits, because young trees and shaded lower branches are usually not reproductive (Manual 2);

(b) a lack of flowering on the chosen parent trees, flowering times that do not coincide, or *incompatibility* between them;

(c) some crosses not producing enough viable seed for the progeny trial;

(d) uncertainty about whether early performance of a progeny is necessarily linked to how it will grow later on; ***and***

(e) difficulties in obtaining adequate and regular supplies of improved seed after the trial has been done.

But all this sounds much too difficult!

Yes it is really only feasible for large research organisations that can plan a long-term breeding programme. However, some success has been achieved with pines and other tree species that start regular flowering early in life.

Can't one get improved seed from the progeny trial?

No, it is usually **unsuitable** as a seed source, since the characteristics of a second generation of progeny could be quite different.

What has to be done, then?

Following the progeny trial, *mature* clones are made by grafting shoots from the crowns of the best parent trees on to seedlings (A 3 in Manual 1). Several of these are then planted in a *seed orchard* (Manual 2), with the aim of producing quantities of improved seed.

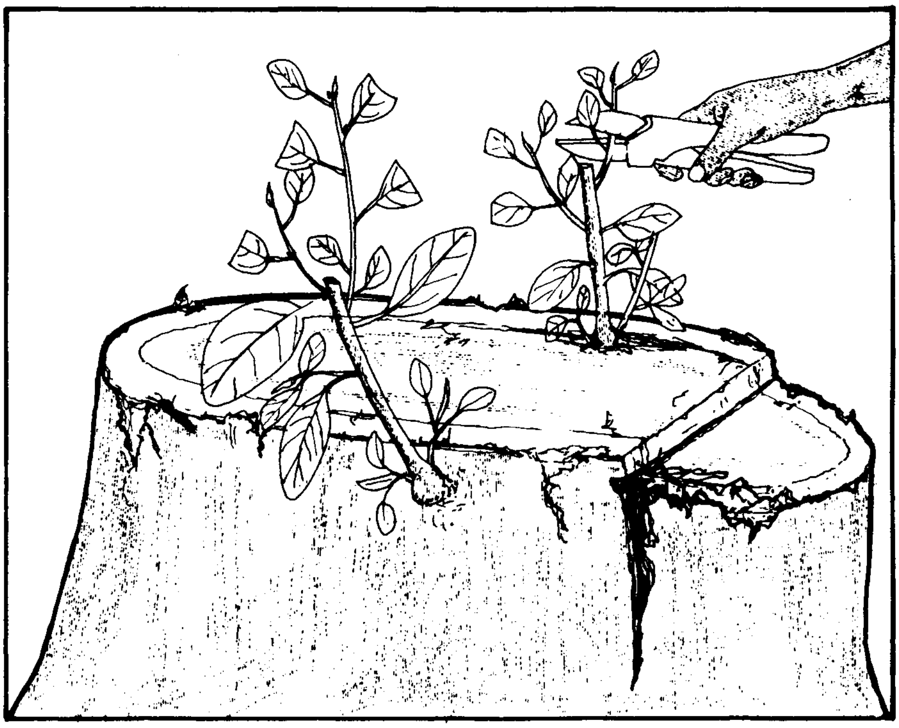
Wouldn't it be better to use rooted cuttings as planting stock?

Yes, once suitable provenances are known, vegetative propagation of *juvenile* shoots often offers quicker, cheaper and more reliable domestication.

For instance, taking coppice shoots and rooting them as cuttings (A 21 in Manual 1) offers the double opportunity of:

(A) growing the 'same' trees over again; ***and***

(B) multiplying them into many new trees, each with the same genetic potential as the original ones.



How else could I get a supply of cuttings?

Suitable juvenile shoots can also be taken from:

(1) young seedlings, preferably those that were found to be superior in a selection test (A 13 in Manual 1);

(2) stockplants that are managed to provide plenty of suitable shoots (A 20-27); ***and sometimes***

(3) plantlets from micropropagation (A 5).

Isn't this a much more direct way of selecting trees?

Yes it is, because:

(a) one is using clonal sets of young trees with the **same genetic potential** as the selected trees, rather than seedlings that are all different from their parents; ***and so***

(b) clonal trials are a **more precise check** on domestication than progeny tests, because the 'same' tree can occur many times over, whereas each seedling in a given progeny is different.

Vegetative propagation is the way farmers and scientists have selected crops like banana, cassava, mangoes, tea, coffee and rubber.

Aren't there some disadvantages with vegetative propagation?

There are a few; for example that:

(1) a good tree has to be cut down in order to start a clone from coppice shoots; ***and***

(2) rooting may prove difficult in a small proportion of tree species.

Note: there are considerable risks in planting stands that consist of only one or two clones (A 11 in Manual 1). Between 10 and 30 clones is advisable.

But can rooted cuttings grow into tall trees?

Yes they normally do, as long as they:

(a) are of a species and clone with the potential to grow tall;

(b) originate from juvenile stockplants (A 6 in Manual 1); ***and***

(c) have formed several roots, rather than only one (A 40).

Then why aren't they utilised more often?

They should be! Although widely used in agriculture and horticulture, this method of domestication has been neglected for most other kinds of trees, perhaps because:

(1) most have a longer life-cycle than farm crops and ornamental shrubs;

(2) by the time you know you have a good tree, its crown shoots usually do not root;

(3) if these are grafted on to a seedling the plants would be expensive, and the adult growth habit could be unsuitable for growing tall trees; ***and***

(4) there were several mistaken assumptions about vegetative propagation (A 3 in Manual 1).

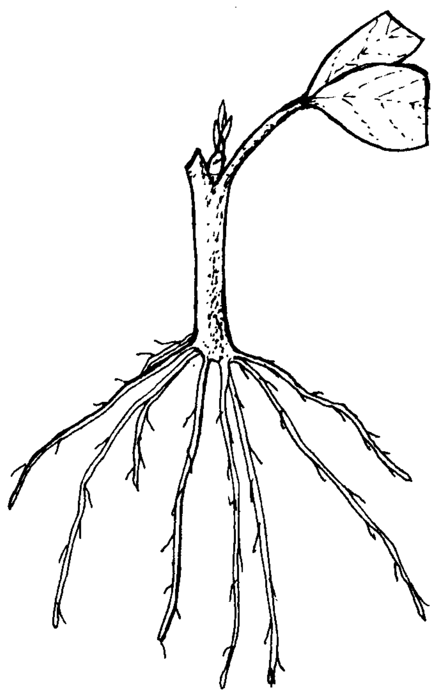
But won't domestication be too expensive to bother about?

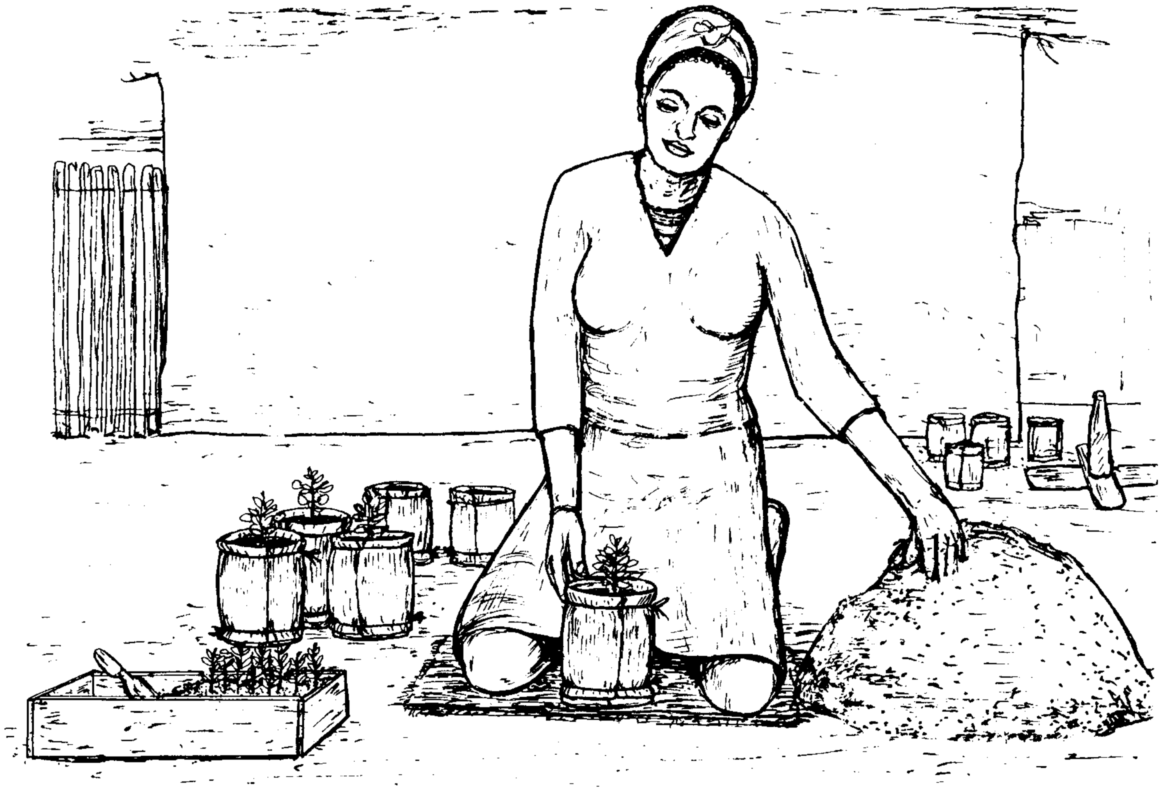
No, because:

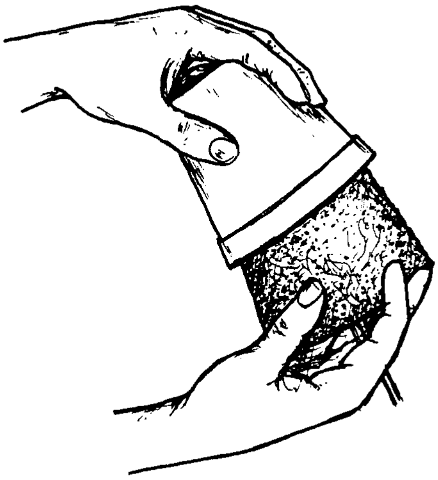
(A) cuttings can usually be rooted very effectively without costly equipment (A 30-31 in Manual 1);

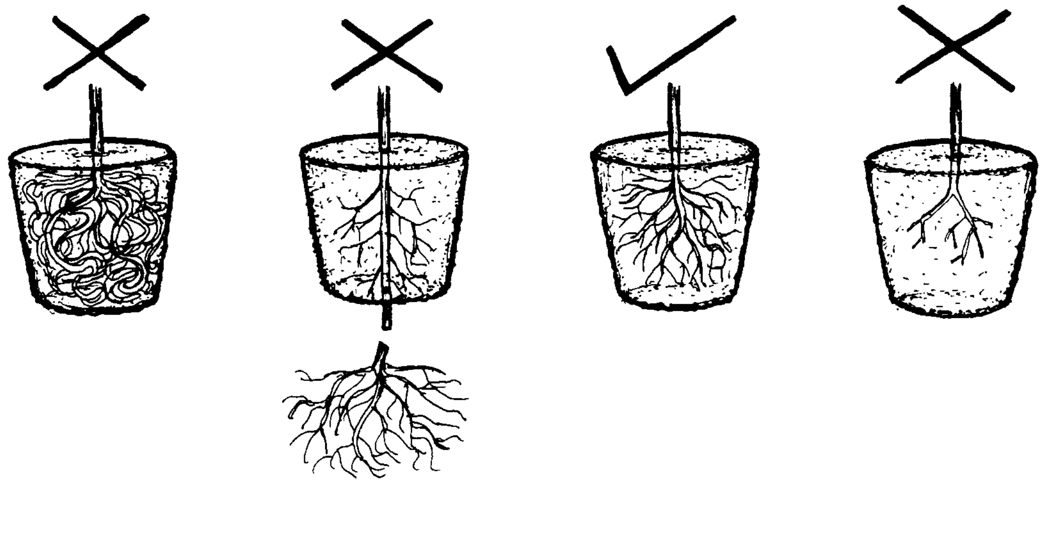
(B) using undomesticated planting stock generally means inferior trees; ***and***

(C) genetic improvement continues to provide benefits into the future.









Introduction C 6
- *containers and potting mixes*

Will I need containers for my trees?

Yes, in many circumstances. Transplanting young trees directly from a nursery bed:

(A) is easy only when they are still too small for planting in the field; ***and***

(B) usually disturbs the root systems too much when they are big enough to plant out; ***but***

No, if longer roots are regularly pruned back to stimulate plenty of branch roots, and the young trees are then taken to the planting site complete with a block of soil (C 4); or if stumps or striplings are to be planted (C 47).

Why wouldn't very small plants succeed in the field?

Because they would usually:

(1) be badly damaged in transit (Manual 5);

(2) have too small a root system (C 4, C 11) to support the young tree in the harsher environment of the planting site;

(3) be quickly overgrown, even by low-growing weeds;

(4) have a low chance of surviving if parts were eaten by animals; ***and***

(5) be difficult to find during weeding, and therefore easily cut off.

Aren't larger plants sometimes used as bare-rooted planting stock?

Yes they are. However, the exposed root systems of young trees can lose quite a lot of water within a minute or two, in humid as well as in drier parts of the tropics (C 13). So for this method to be successful:

(a) the trees leaving the nursery need to have a very good root system (C 34);

(b) their *leaf area* generally has to be reduced, so that there is less water loss (C 12-13);

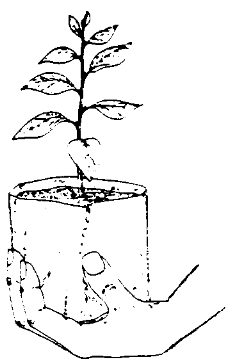
(c) the roots have to be covered with wet leaves, cloth or polythene sheeting, and preferably transported at night.

Bare-rooted plants are sometimes moved for planting during the cooler season in the temperate zones, sub-tropics and tropical uplands, when *climatic stress* is less (C 41).

How do containers help?

(A) they can hold enough good soil to allow small plants to grow large enough root systems for successful planting (C 4, C 34);

(B) the young trees can be moved around without much damage to the roots, and then the whole *root ball* removed from the pot at planting time. (*Biodegradable* pots are not removed before planting, but gradually rot away, so that root disturbance is minimal.)



What are the features of a good container?

(1) Permitting good root and shoot growth by allowing excess water to drain out;
(2) Being strong enough to last a reasonable time, but light in weight;
(5) Being cheap and readily available; ***and***
(3) Releasing the root ball easily at planting time.

What can pots be made of?

They are manufactured out of several different materials, including:

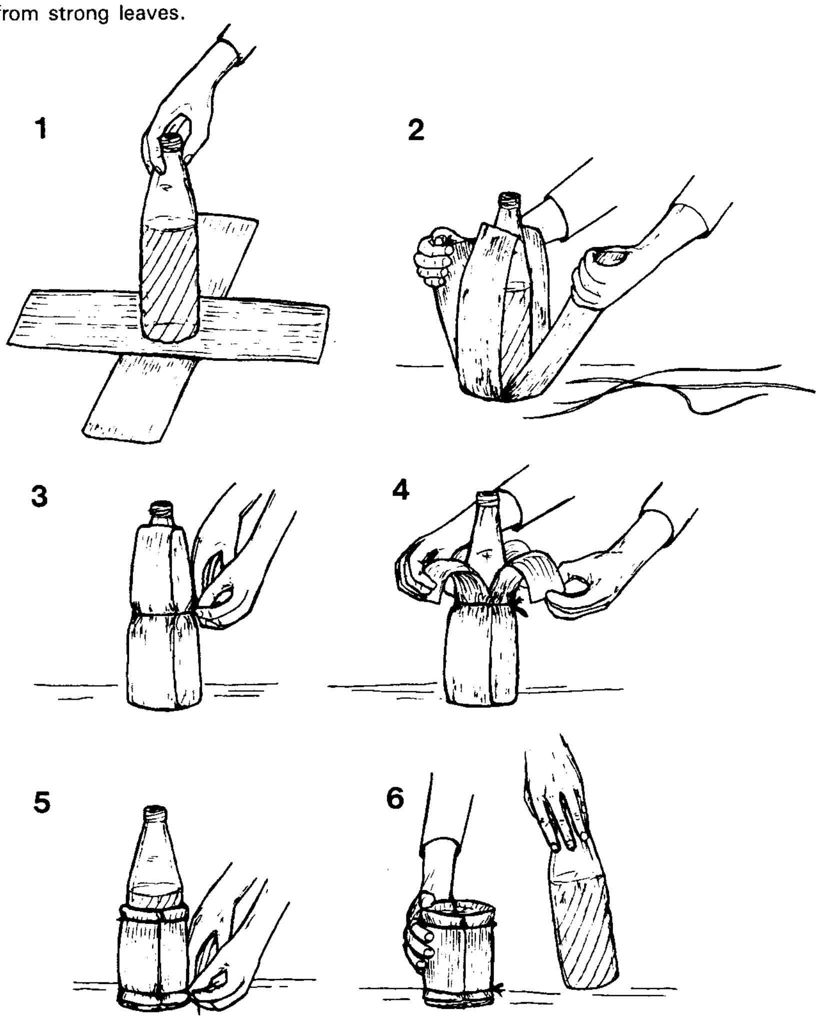
(a) fired or unfired clay;
(b) polythene sheeting;
(c) many other kinds of thicker plastics;
(d) various biodegradable substances, such as compressed paper or peat.

But what if I can't afford to buy pots?

This need not matter, as serviceable pots can be made out of such things as:

(e) sections of bamboo stems, with a hole made through the cross wall for drainage;
(f) small baskets, made for instance out of woven raffia, split cane or bamboo;
(g) strong leaves, such as *Bassia, Dyospyros* or banana, which can be shaped and tied around a bottle that is subsequently removed;
(h) suitable soil, moulded into shape with a press;
(i) waste veneer (C 33) rolled into a tube and stapled;
(j) small pieces of waste wood nailed together;
(k) used cardboard milk or fruit juice cartons;
(l) the lower parts of used plastic bottles or recycled polythene bags; ***or***
(m) old cans, preferably sterilised in a fire.

Stages in making pots from strong leaves.



Are open cylinders any good?

Yes, if they are either:

(A) stacked together in a shallow box; ***or***

(B) given a base by adding about 3 cm of soil containing silt or clay, and tamping this down with a stick to compact it. (Don't forget to make drainage holes!)

Which kinds of pot are most commonly used?

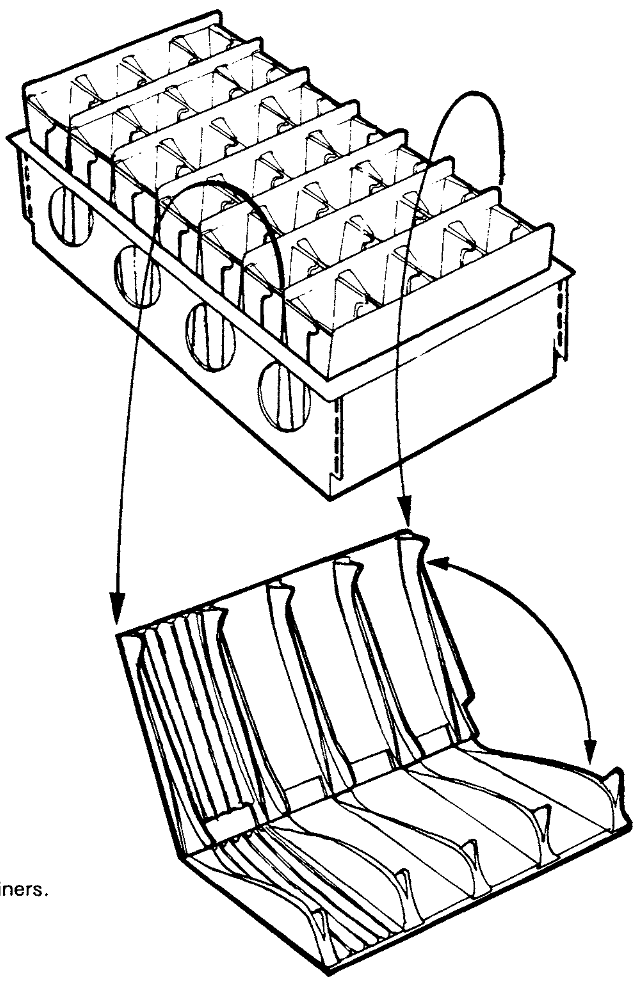
This differs a lot from place to place, and depends on the size of the nursery (C 22). A common type is a thin bag made out of polythene sheeting (black, white or clear), with some small drainage holes punched in it.

What are its advantages?

These poly-bags are very light in weight and quite strong. They can be made in various sizes, manufactured in quantity, and are relatively cheap and easy to transport.

Do they have some disadvantages?

(1) Since the poly-bag has to be torn to release the root ball, it cannot be used again;
(2) Because the material bends easily, the root ball is more liable to be damaged in the nursery and in transit, and can break apart during planting;
(3) As with many other containers, the roots may go round and round the bottom, producing poor planting stock (C 11, C 34, C 47); ***and***
(4) If the drainage holes are in the bottom of the pot, *rooting through* into the soil beneath can easily occur. Such trees may grow well in the nursery, but when they are moved and the roots broken they quickly wilt, and often die (C 13, C 41).



Example of root-trainers.

Can such difficulties with the root system be avoided?

Not altogether, since one is restricting it to a confined space (C 2). However, the problems can be reduced, for instance by:

(a) discouraging the roots from emerging by putting the containers on flat stones, concrete or polythene sheeting (without having standing water on it), or by keeping the containers clear of the ground on wire mesh;
(b) moving the pots regularly, to break off young emerging roots before they grow long, or by using another method of root pruning;
(c) not leaving young trees too long in very small containers, but potting them on (C 42) into somewhat larger pots;
(d) using 'Root-trainers', various types of containers that have vertical grooves and ridges that encourage the roots to grow downwards rather than in circles (C 61-B).

Outgrowth of roots can also be restricted and branching promoted if the inside of the pot is treated with *copper carbonate.* However, although copper is a micro-nutrient (C 14), it is toxic to plants except at very low concentrations. This technique should therefore only be tried by a well-trained nursery team (C 52), taking care not to pollute the environment (D 16 in Manual 4).

How big should the pots be?

Not too small, so that:

(1) there will be a reasonable *rooting space* and enough reserves of nutrients (C 14-15, C 33) to produce good planting stock;
(2) the pots do not dry up too quickly (C 13, C 43); ***but***

Not too large, resulting in:

(a) root systems that are too big to be planted well (C 34 and Manual 5);
(b) shoot systems that are liable to die back (C 41);
(c) a lot of unnecessary weight to carry to the planting area.

For most purposes, the volume of soil in a container should not be less than 250 cm^3 or more than 2500 cm^3 (0.25 to 2.5 litres - see C 63-D).

What else is important when choosing pots?

(1) **Drainage holes:** types with *several smaller holes* are usually better. A single hole may get blocked, making the potting soil waterlogged and damaging or killing the young tree (C 11, C 13). If rooting through is a problem, you could try pots with small holes *near the base of the sides.*
(2) **Colour:** *light* colours reflect heat away from the pot, reducing the risk of the roots overheating (C 41). *Dark* colours and *opaque* pots prevent much light reaching the roots, but may get hotter. *Clear* containers sometimes encourage the growth of algae and mosses.
(3) **Shape**: *tapered* pots make it easier to get the root ball out intact, which may allow you to use them again; *square* pots utilise the growing space efficiently; and reasonably *wide* containers are less likely to fall over easily in the wind, and provide more space for the shoots (C 12, C 34).
If tall, narrow pots are used, they will need temporary supports and perhaps spacing out (C 42).

When might I need particular types of containers?

(A) **Standardised containers** can be helpful when growing a set of similar plants for research (C 7, C 15);
(B) **Larger pots than usual** can be useful when trees need to remain in the nursery for a longer time, for example:

(1) if planting had to be put off because of drought;
(2) when there have been problems with a particular species; ***or***
(3) for growing potted stockplants to produce repeated harvests of cuttings (A 23 in Manual 1).

Where should empty pots be stored?

Preferably inside a simple store (C 20), because:

(a) pots made out of leaves, wood, bamboo and other biodegradable materials need to be kept dry;

(b) most plastics become brittle after a time if left in the sun, and tins will rust away;

(c) most containers need protection from domesticated animals, while mice and other *rodents* may chew most kinds, even plastic ones.

Poly-pots do not take up much space when stored flat, and tapered plastic containers usually stack conveniently inside one another.

Should I use nursery soil to fill the pots?

Occasionally yes, if it is **really** suitable for the purpose; ***but***
Generally no, because a **potting mix** will give much better results.

But young trees planted in the nursery would grow all right!

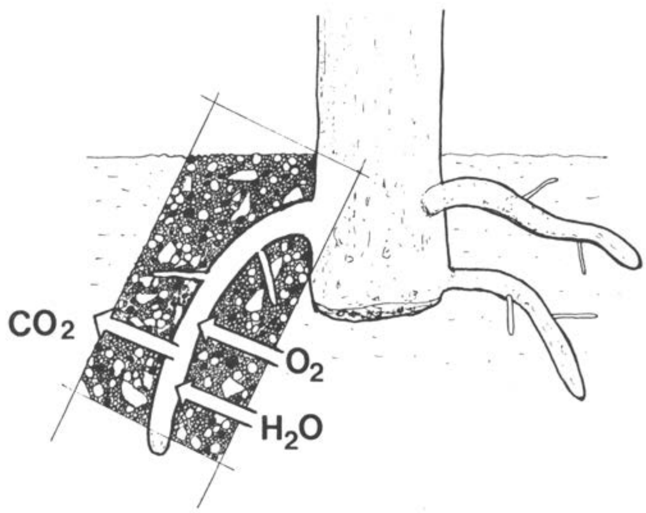
Yes they might, but with the restricted rooting conditions in a container you would generally get poor planting stock and many losses, because the young trees:

(A) could easily get too little water, or too much (C 13, C 43);

(B) might have their roots deprived of good aeration (C 11);

(C) may not receive enough nutrients to make reasonable growth (C 14, C 33); ***and so***

(D) are unlikely to produce a good, well-branched root system and sturdy top (C 34).



What is a good potting mix like?

Good growth of the young trees generally occurs in a mixture that:

(1) has some coarse as well as **smaller soil particles** in it (D 12 in Manual 4), to provide adequate but not excessive **air spaces** (with an *aeration porosity* of 25-35% - see Landis et al., 1990 in C 61-B), so that:

(a) *oxygen* from the air can reach the roots easily;

(b) excess water drains away freely, not leaving the soil waterlogged (C 11);

(c) the roots can grow and branch without restriction; ***but***

(d) the root ball holds together after the pot has been removed;

(2) contains enough **organic matter** and **nutrients** to:

(a) retain sufficient water within the soil between successive waterings;

(b) release nutrients gradually (C 33-34), partly through the activities of *decomposers* in the soil (D 13 in Manual 4); ***and***

(3) is neither **alkaline** nor **strongly acid** (the desirable pH is usually between 4.5 and 6.5).

Most nursery soils (C 23) cannot perform all these important functions, though a few can form part of a suitable potting mix.

Isn't it hard to get a soil with all those features?

No, it is usually quite easy, using locally available materials. *Mixing these together in suitable proportions* is the way to obtain a good potting soil.

What components are useful?

(1) Coarse sand and fine gravel from a river or beach, washed to remove salt or other impurities;
(2) Loamy topsoil, collected in closed woodland rather than from open ground;
(3) Sawdust or bark chippings that have been allowed to weather for about a year, so that any toxic substances have been broken down (C 33);
(4) 'Black' soil from waste tips, sieved to remove glass and other undesirable items;
(5) Coconut or sugar-cane fibre that has partly rotted;
(6) Rice hulls: ***and***
(7) Composts of various kinds of waste vegetable matter and/or animal droppings (C 33).

Note: potting soils sometimes need the addition of small quantities of fertiliser if certain nutrients are lacking (C 14, C 33), or inoculation with micro-organisms (C 30-32) if particular tree species are to thrive.

How do I decide what potting mix to use?

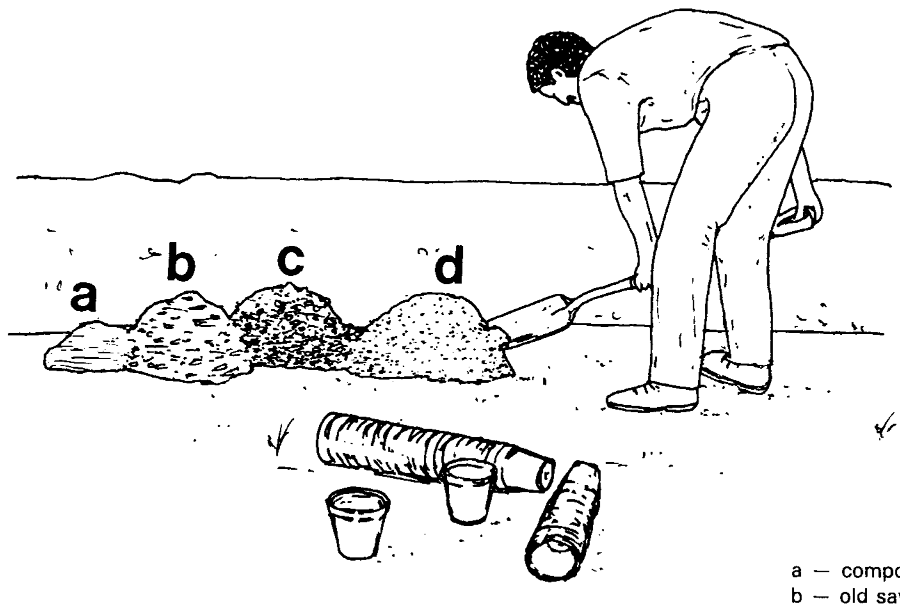
You could:

(A) start with potting mixtures that have already been found satisfactory; ***and***
(B) do some simple pot experiments (C 7, C 15) to compare them with others that might produce better planting stock, such as:
(1) 20% coarse sand, 40% loamy topsoil, 30% weathered sawdust, 10% compost;
(2) 25% coarse sand, 25% loamy topsoil, 25% rotted coconut fibre, 25% black soil.

The proportion of coarse sand needs to be reduced when the loam is sandy, and increased with clayey loams.

Are there some well-tried examples?

The booklet by Josiah and Jones (1992) listed in sheet C 61-B includes details for making potting mixes from waste sugar-cane (developed in Haiti), coconut husk (Thailand) and pine bark (South Africa).



a — compost
b — old sawdust
c — loamy topsoil
d — coarse sand

How do I mix the components?

(1) Wash coarse sand and fine gravel beforehand;
(2) Sieve items (2) - (7) above, to remove any large lumps or stones, and sharp items that might cut people's fingers and perhaps transmit disease;
(3) Add the required amounts of each component (for example, to make 10 bucketfuls of potting compost (B 1) above, add two bucketfuls of coarse sand, four of loamy topsoil, three of weathered sawdust, and one of compost); ***and***
(4) Mix everything together thoroughly.

Preparing the potting mix is best done with a shovel on a flat surface such as concrete, hard soil or an old sheet of plywood. Small quantities can be mixed with a trowel on a table or workbench, while a cement-mixer can be handy for large quantities, especially if uniformity is needed for an experiment (C 7).

And what about water?

The mix should not be ***too wet,*** and so:
(a) wash the sand and allow it time to drain before using it; ***and***
(b) cover components or keep them inside a shed to protect them from rain; ***but***
Nor should it be ***too dry,*** and so:
(1) water some of the stored components occasionally during dry weather; ***and***
(2) add water gradually to the potting mix until it is **moist** but not wet.

Is a potting mix also suitable for sowing seeds?

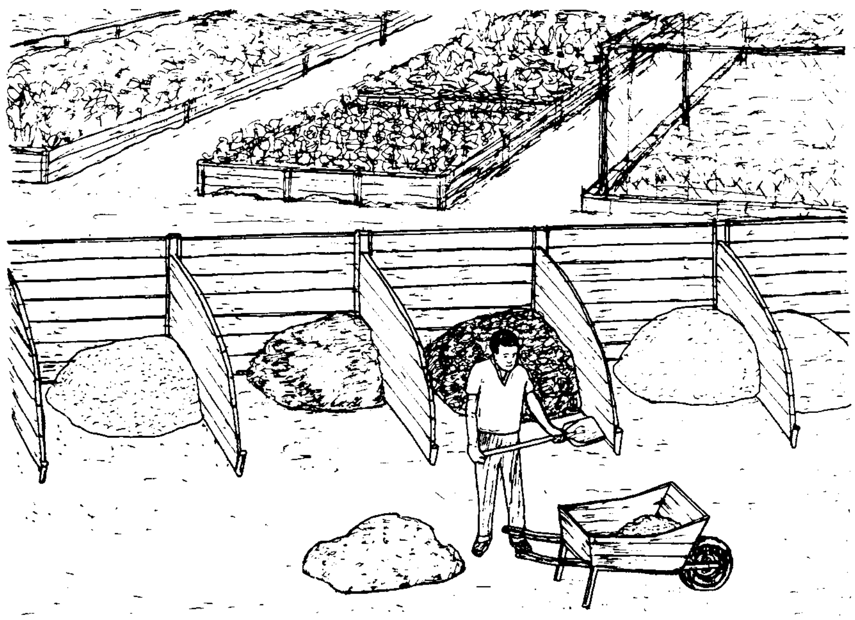
Yes, if it is finely-sieved and not too rich in nutrients (C 14, C 33), it can be put in seed trays for smaller sized seeds, or into pots for larger seeds.

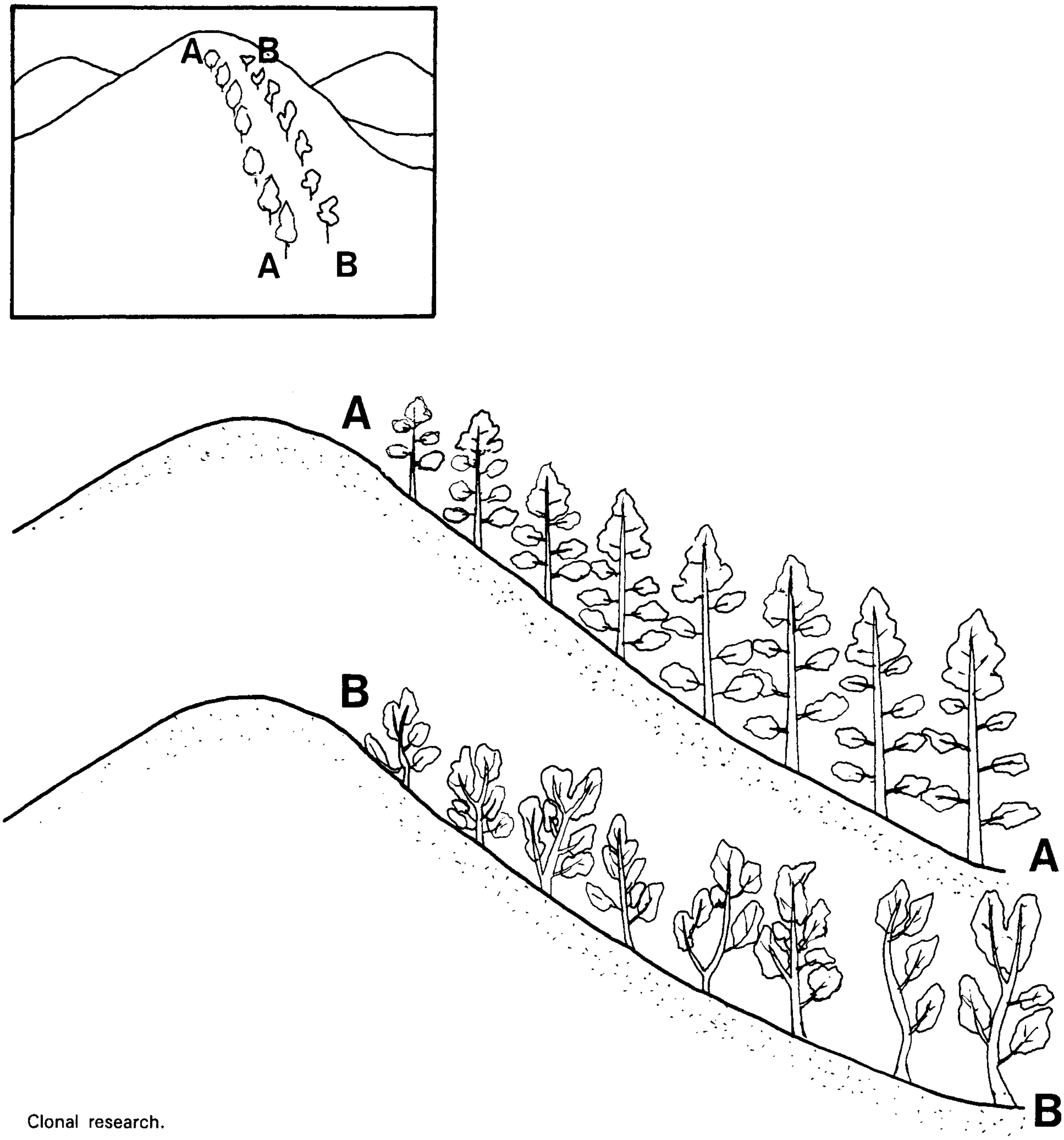
What should not be put into a soil mix?

(a) Stones or large pieces of gravel;
(b) A lot of clay;
(c) Salt;
(d) Fresh manure or sawdust;
(e) Broken glass or thorns;
(f) Numerous weed seeds;
(g) Known pests or harmful micro-organisms.

How about potting up the young trees?

This is covered in sheet C 42.





Clonal research.

Introduction - *growing trees for research* C 7

Is research on trees really required?

Yes it is (C 4). Relatively little work has been done in the tropics on:

(1) the many factors that influence tree growth (C 10-15) and survival (D 10-16 in Manual 4), and how they interact with one another (C 69-K);

(2) the ways in which the different aspects of tree growth are internally controlled and co-ordinated (C 14); ***or on***

(3) propagating and planting the great majority of tree species.

Which kinds of research are particularly needed, then?

Many different approaches, especially formal and informal experiments (D 6 in Manual 4). In Universities, research stations and international projects, it is important that some basic studies of (1) and (2) above are included. Since many aspects of tree biology are little known for many species, these could include important subjects like:

(A) possibilities of vegetative propagation (C 5; and Manual 1);

(B) times of flowering and fruiting (Manual 2); ***and***

(C) seed physiology in relation to seed handling.

What might practical tree growers and planters concentrate on?

Investigating for instance:

(a) nursery problems and new techniques in **potted plant experiments** (C 15);

(b) establishment problems and new methods in **planting experiments** (Manual 5);

(c) the performance of new species and genetic selections in **field trials** (D 29 in Manual 4).

Are there any hints on useful treatments to apply?

(A) **Potted plant experiments** (C 15) might for instance examine, for a species that is slow or difficult to grow, the effects on root and shoot development of various:

(1) potting soils or containers (C 6);

(2) levels of shading, or the rate at which shade is reduced (C 41, C 47); ***or***

(3) frequencies and amounts of watering (C 43), or the spacing of containers (C 42).

(B) **Planting experiments** need uniform batches of good young trees, and could investigate such subjects as:

(1) the best sizes for planting stock (C 34);

(2) tree growth and establishment on contrasting sites (D 20-29 in Manual 4); ***or***

(3) planting techniques or timing (Manual 5).

(C) **Field trials** (both formal and informal) could explore matters like:

(1) the growth and form of various promising species;

(2) which provenances, seed-lots or clones perform best (C 5); ***and***

(3) spacing, thinning and yields.

What's different about growing trees for research?

One needs to follow the best available methods for growing ordinary planting stock, but to take extra care (C 48) in order to produce batches containing plenty of good, uniform trees that have not been subject to marked climatic or other stress (C 41).

How can I grow uniform sets of young trees?

(a) By selecting from a restricted genetic range;

(b) By propagating and growing all the batch in very similar conditions; and

(c) By producing more than enough, and then excluding the biggest and smallest trees, as well as poorly growing or unhealthy plants.

In what ways could I restrict the genetic range?

(1) By collecting **seed** from one or a few closely-related mother trees (C 5); ***or***
(2) By using one or a few **clones** (A 10-11 in Manual 1).
If neither is available, use a single seed-lot (or if necessary 2-3 that have been well mixed).

But isn't it a mistake to have too little genetic variation?

Yes *for planting stock,* though neither should there be too much (C 5); ***but***
No *for experimental trees,* except when studying the range of *inherited* differences.

Why should I use a narrower genetic base for most experiments?

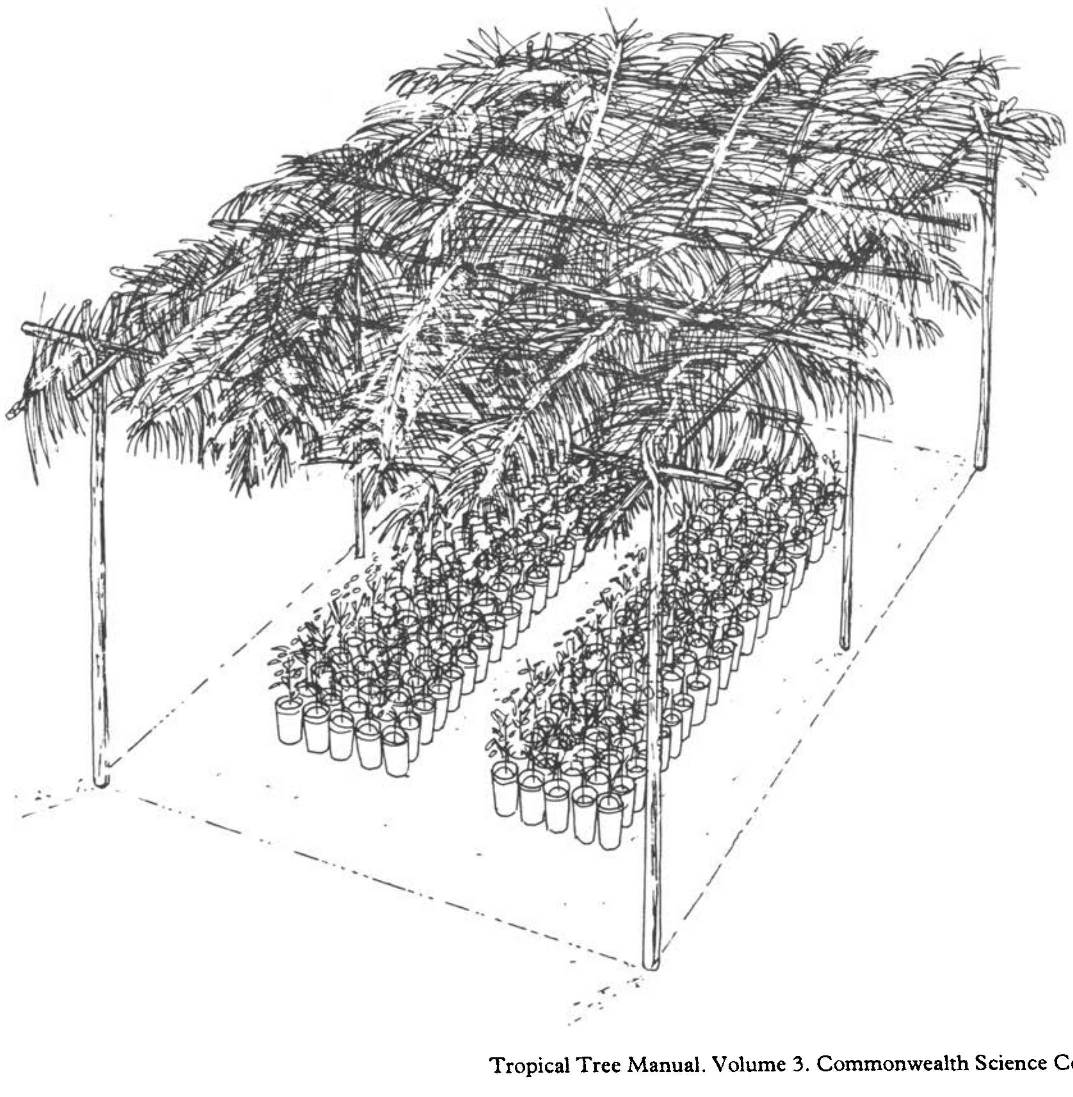
Because it reduces the overall variation in the experiment, making it more likely that *significant differences* will show up between treatments (C 55, C 69).

But will the results apply to the whole species?

Strictly speaking, the results of any experiment apply to the time it was done, the particular plants used and the conditions they experienced. This is one of the reasons why a series of simple, straightforward experiments can be more informative than a single complex trial. Try and build up reliable information by:

(a) starting with strongly limited genetic variability;
(b) concentrating on finding out whether the chosen treatment has any effects on the growth of the young trees; ***and***
(c) leaving the question of how representative the results are until a later stage.

In due course, one might then be able to use several clones, derived from provenances (C 5) across the whole range of the natural distribution of the species.



How should I try and maintain similar conditions for growth?

By raising the experimental trees from either:

(1) seeds sown on the same day in similar germination conditions (Manual 2); ***or***

(2) cuttings that were taken and rooted at the same time (Manual 1);

Growing them in:

(3) containers of the same type, size, shape and colour (C 6);

(4) a good potting soil, all of which has been thoroughly mixed together; ***and***

Keeping them under:

(5) light and temperature conditions that are as uniform as possible, such as a large area of uniform shade, a special shade house (C 48) or full sun;

(6) particularly careful checking (C 40) and watering (C 43) regimes; ***and***

(7) protection from wind, fire, grazing animals and vandals (C 46).

Whenever possible, set up the experiment in one day, and have the same person doing a particular task on all the trees.

Should I add extra nutrients to the potting mix?

Not unless it is needed, for example:

(a) to obtain reasonable growth rates in poor soil (C 33);

(b) to have the trees ready for the date of planting out (C 34, C 47); or

(c) if the young trees are going to be used for experiments in containers (C 15), where they could be given equal amounts of a dilute liquid fertiliser at intervals.

What else is needed?

(1) Extra planning beforehand (C 50, C 54, C 62-F);
(2) More regular weeding (C 44);
(3) Fuller records (C 55, C 64-67).

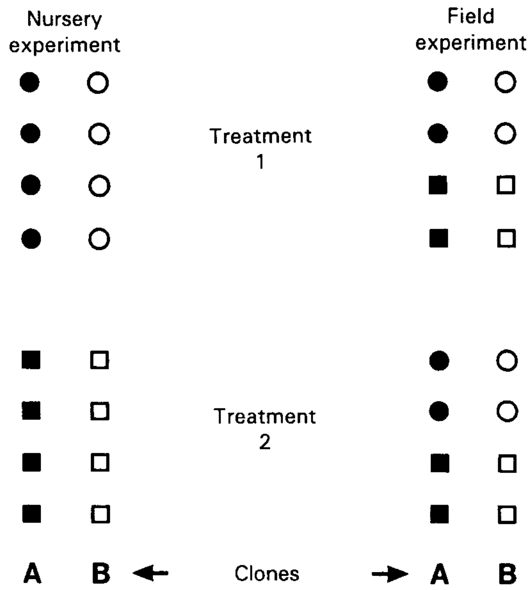
Why exclude the biggest trees from the experiment?

Because it helps to have experimental trees of more or less the same size.
If the batch is not large enough for such 'standardising', you could 'grade' the trees into size classes (A 45 in Manual 1).

And how will I judge the results of the experiments?

For potted plant experiments, see sheets C 55 and C 67-69;
For planting experiments and field trials, see Manual 5.

Avoiding bias when using research plants twice.



Could I use plants from a potted plant experiment for a field trial?

Yes, if they are in reasonable condition, and:

(A) other suitable young trees are in short supply; ***or***

(B) they are clonal plants that are particularly appropriate.

However, make sure that the labels are retained (C 54), as the new experiment will have to be laid out 'across' the old one, to avoid bias and improve precision.

How would that be done?

The surviving healthy plants which formed the controls in the potted plant experiment would need to be equally divided between each treatment of the field trial. The same would then be done with the trees from each of the other potted plant treatments.

If sets of plants of different genetic origin were used in the potted plant experiment, a similar procedure would need to be followed so that they were evenly spread amongst the treatments in the field trial.