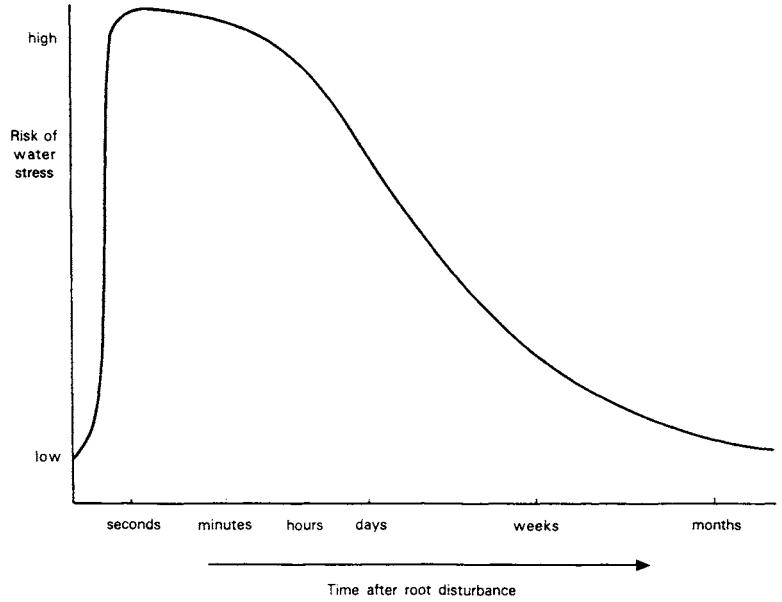
PROTECTING GROWING TREES

Protecting growing trees C 40
- introduction: care and checks

Do young trees really need much looking after?

Yes they do, because it's quite easy for them to be damaged or killed, especially when their root systems have been disturbed (C 2).



But trees in the wild have to survive without help!

That is so; but most of them don't make it.

Doesn't nursery stock need to be hardy, though?

Yes, in the sense that young trees for planting have to be able to stand up to various kinds of stress; ***but***

No, in another way, since they are ***more*** likely to survive and grow well if they are:

(A) first given favourable environments to grow in (C 10-14);

(B) protected from damage and stress (C 41), especially through key stages in their development; ***and then***

(C) *hardened* to prepare them for being taken to the planting site (C 47).

How can I provide good growing conditions for nursery trees?

This is best achieved by:

(1) understanding something of how trees grow (C 10-15);

(2) choosing the site and planning the nursery carefully (C 20-26);

(3) producing favourable environments for germination of seeds (Manual 2) and rooting of cuttings (Manual 1);

(4) preparing good soil mixtures and using appropriate containers (C 6) and nursery beds for growing on good planting stock (C 4);

(5) keeping up an adequate supply of nutrients, taking close associations with root systems into account (C 30-34); ***and***

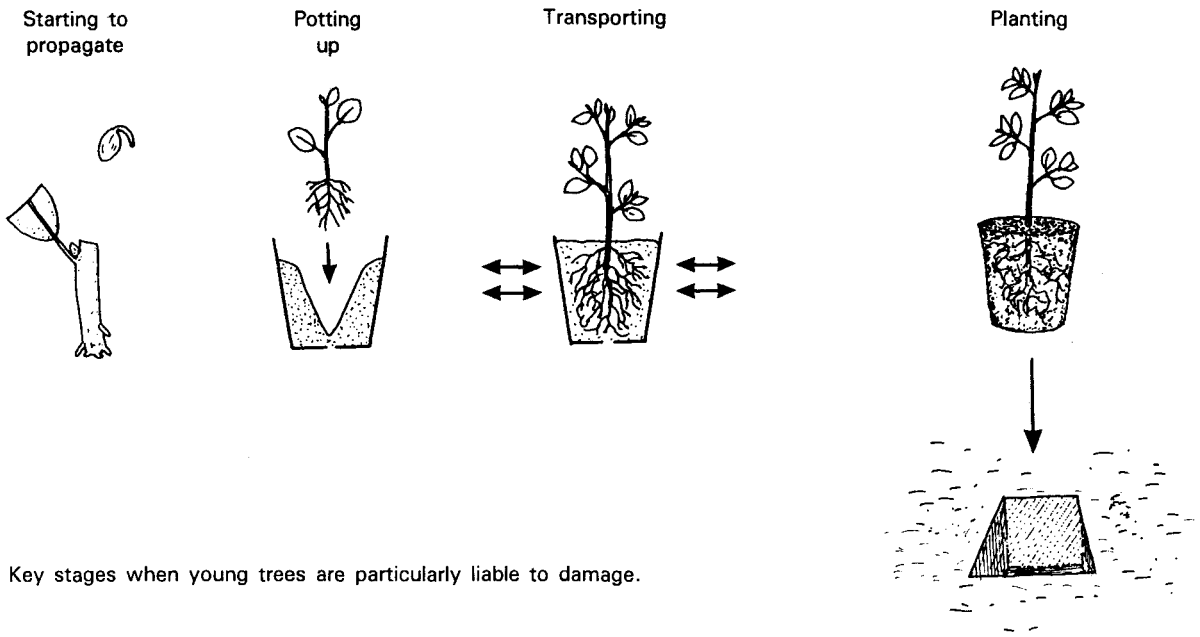
(6) overcoming various obstacles (C 3, C 60) which can sometimes hamper nursery work.

Remember that environments that suit one species may not be appropriate for another.

Which are the key stages when special care is needed?

(a) Germination of seeds (Manual 2);
(b) Root formation in cuttings (Manual 1);
(c) Potting up (C 42) and other transplanting of young trees;
(d) Transporting planting stock (C 47); ***and***
(e) Planting, and the hours and days immediately after it (Manual 5).

Special care is needed when growing trees for research (C 7, C 48), and throughout the period of a potted plant experiment (C 15).



Key stages when young trees are particularly liable to damage.

Does hardening mean taking away the shade?

It usually involves **gradually** removing some shade from shade-bearing species, and all of it from light-demanding trees (C 47), but also includes:

(1) making sure that the root system is developed within and not outside containers, and that roots in nursery beds have been periodically pruned (C 6, C 11, C 34);
(2) keeping the nutrient supply adequate but not excessive (C 33-34); ***and***
(3) slightly reducing the frequency of watering or the amounts given (C 43).

What sort of checks are needed in a tree nursery?

Checks can be divided into those that need doing:

(A) before, during and after a particular job is done; ***and***
(B) regularly, throughout the year.

Which things need checking beforehand?

If you are going to do a job in the tree nursery, you need to know whether:

(a) the weather and the season of the year are suitable;
(b) there is not a more urgent job needing to be done (C 54);
(c) adequate supplies of water, materials and tools are at hand (C 24, C 51);
(d) staff and workers understand how the job should be done (C 52); ***and***
(e) enough space is available to work in, as well as for the young trees to grow in.

What kind of things need thinking about at the time a job is done?

For example, you could keep an eye on whether:

(1) the work is being done well, not carelessly; too slowly or in a rush; ***and***
(2) the young trees might be starting to suffer from climatic stress (C 41).

And which items need looking at afterwards?

You might check if:

(a) the job has been properly finished;
(b) the young trees have been left in suitable conditions; ***and***
(c) tools have been put away (C 51) and the area tidied up.

Does this apply to potentially damaging events as well?

Yes, it can do. For example, for severe storms you could:

(1) notice that one was approaching, or had been forecast, and take appropriate action;
(2) move valuable potted trees inside that were beginning to be damaged; ***and***
(3) afterwards stand up trees that had been blown over, firm in any loosened soil, check labels and remove broken shoots.

What about regular nursery checks?

These are very important indeed (C 66). They can often be **combined with the daily work,** especially if you get into the habit of looking out for:

(a) drying soil and any leaves beginning to wilt or close up during the day (C 41, C 43);
(b) water standing above the soil level in a container, or algae or moss at the soil surface, indicating poor drainage (C 6, C 11);
(c) holes in the foliage or other indications of insect pests (C 45);
(d) changes in leaf colour, premature shedding of leaves, or die-back of shoots (C 60), and any signs of infection with micro-organisms that cause disease (C 45);
(e) breaks in overhead shade, fences and hedges, or the presence of animal droppings (C 46; and D 15 in Manual 4).

How often do I need to check up?

Most tree nurseries need visiting (C 66):

(A) **once or twice every day** for watering, when experienced members of the nursery team (C 52) could also check points (a) to (e) above; ***and***
(B) **each week** for more thorough checks, and for record keeping (C 54, C 64-65).

What are some examples of weekly checks?

(1) Any tendency towards choking of beds or pots by weeds (C 44);
(2) Testing whether trees are starting to root through from containers into the ground;
(3) Indications that trees are beginning to shade each other too much, which would make the stems spindly and weak, and perhaps let the branches become entangled;
(4) Signs of major damage to roots or stems, or death of whole trees (C 60);
(5) Whether some batches of plants (C 65) need potting on (C 42) or feeding (C 33-34);
(6) Need to prune hedges, clear fire-lines or remove troublesome items;
(7) Evidence of jobs being neglected or done poorly, especially watering (C 43).

Are records really necessary?

It is usually worth keeping a simple nursery diary or notebook (C 54), because after a week or two, few people can remember just what was done, on what date, and how long it took; unless there is a written record.

With records, you will be able to:

(a) check the origin of promising batches of plants (C 64-65);
(b) avoid some problems (C 3, C 60) when growing a species for a second time;
(c) find out how long it took for young trees of different species to reach a suitable size for planting (C 34);
(d) know roughly how long a particular job should take; ***or***
(e) detect whether some plants are missing, and perhaps stolen.

But shall I really need all that information?

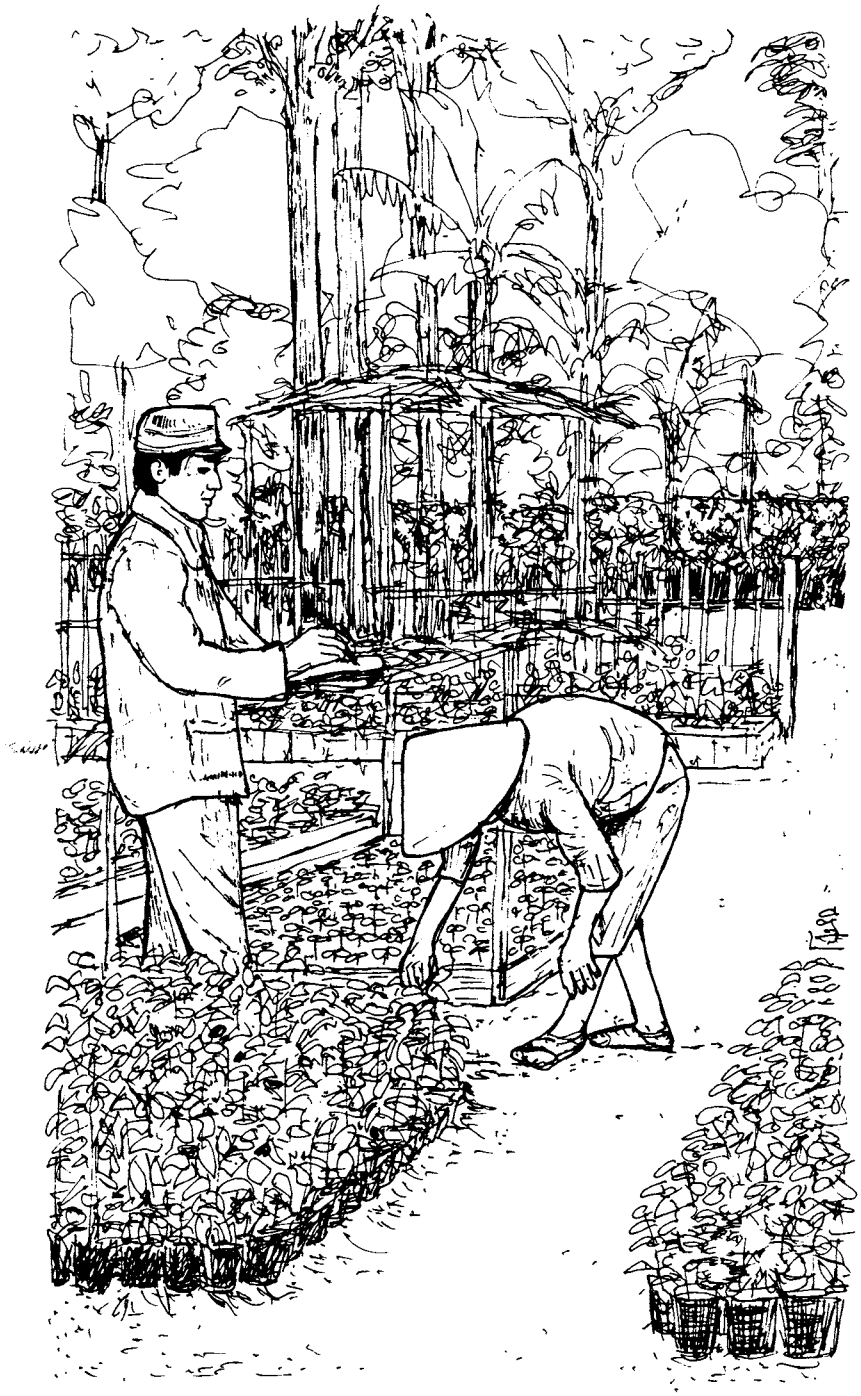
In one way no, as you may never look at some of it again; ***but***
In another way yes, since you generally can't tell beforehand what is going to prove valuable.

For some nurseries, sets of record sheets (C 64-67) may be convenient, while for others a brief note in a diary may be sufficient.

Are there some general hints on nursery problems?

Here are a few:

(A) Checking regularly is usually easier than correcting problems afterwards.
(B) Learning to spot the common symptoms of stress and damage is not difficult (C 60), and removing some of the causes is well worthwhile.
(C) After a time, one can learn to anticipate likely recurring problems, and take steps to avoid them.



Protecting growing trees C 41
- avoiding various kinds of stress

What sorts of stress can affect young trees?

(A) **Climatic stress,** especially the interlinked positive and negative effects of light, temperature and moisture;
(B) **Nutrient stress,** including both too little and too much;
(C) **Mechanical damage,** due to wind, heavy rain, animals or humans;
(D) **Attack by pests** or **diseases** (C 45).

How can light harm young trees?

If they receive **too little** light for several weeks, trees can be directly damaged by:
(1) running short of sugars (C 10), so that all aspects of growth are checked;
(2) producing small, sometimes yellowish-green leaves (C 60); ***and***
(3) making elongated but weak stems.

If the light is **too bright,** even for an hour or less, trees can be indirectly damaged by high temperatures and/or moisture stress.

What harm can high temperatures do?

Indirect damage: by high air temperatures inducing very rapid loss of water from the leaves, which cannot be replaced quickly enough to prevent severe water stress and wilting (C 13). This usually interrupts growth; and can sometimes lead to browning or die-back of young leaves and shoot tips.

Direct damage: may be caused to growing cells (C 10) by air temperatures over about 40°C (D 11 in Manual 4), which can begin to disrupt their control over various chemical reactions. The tissues most liable to damage include:
(A) roots in exposed topsoil and in the atmosphere:
(B) young expanding leaves and elongating stems; ***and***
(C) dividing cells underneath thin bark.

Young trees could also be harmed or killed if they were anywhere near a fire (C 3).

Is the temperature of the soil important?

Yes. Exposed to full sunlight, the surface layers of the topsoil can exceed 40°C or even 50°C, damaging or killing the network of fine roots there, and also the mycorrhizal threads (C 31) and other important micro-organisms. Similar problems might occur if trees were watered using a supply which had become too warm in the sun (C 43).

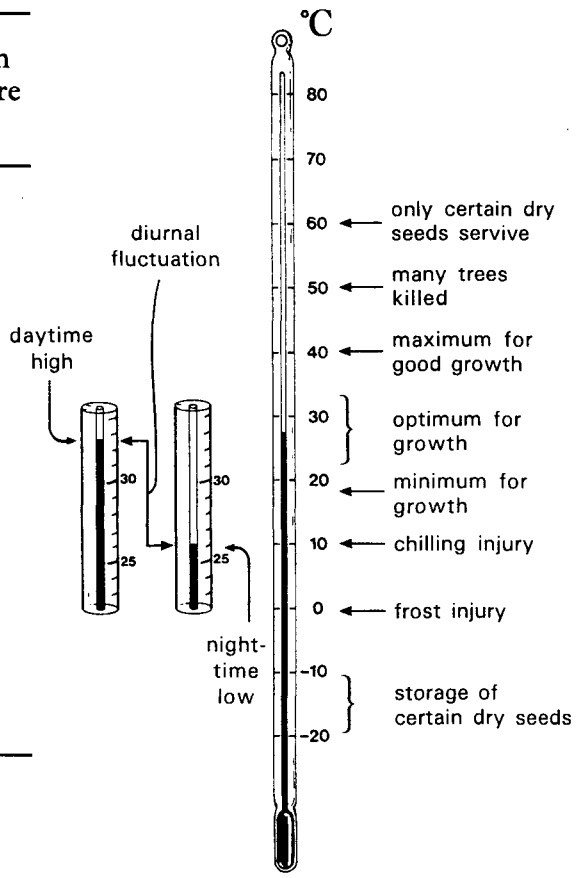
Do low temperatures matter?

Root systems can also be harmed by the sudden drop in temperature if they are drenched with cool water in the heat of the day.

In many tropical tree species, the roots are severely damaged by temperatures of about 10°C or below, which interferes with the uptake of water (C 11, C 13) and nutrients (C 14). Such conditions could happen for example:
(a) when lowland tropical species are grown in the subtropics or in mountains;
(b) if cold water from mountain streams is used for watering; ***or***
(c) during temperature experiments in controlled environments (C 48).

Species	Minimum temperature (°C)	Maximum temperature (°C)
Acacia albida	6	42
Acrocarpus fraxinifolius	*19	*28
Albizia chinensis	-1	32
Alnus acuminata	4	27
A. nepalensis	13	26
Cajanus cajan	*18	*28
Calliandra calothyrsus	18	30
Cassia siamea	13	35
Euphorbia tirucalli	9	37
Gliricidia sepium	14	41
Grevillea robusta	6	28
Jacaranda mimosaefolia	8	34
Leucaena leucocephala	16	32
Maesopsis eminii	16	32
Morus alba	0	43
Prosopis chilensis	10	30
Sesbania sesban	10	45

From Egli and Kalinganire (1988)—see sheet C 61-D.
(* = mean annual or preferable temperatures.)



What about water stress?

Shortage of water is probably the commonest source of damage to young trees. Because we cannot see it, we often underestimate how much water is lost (C 13). For instance, a single leaf 7 cm by 7 cm could be losing as much as 1 ml an hour.

If you pull up a weed during a hot day, it may be only a minute or two before it is starting to wilt. That doesn't matter with weeds, but the same is true for most nursery trees, and a substantial check to growth can occur ***even before*** any signs of wilting.

Why is this?

Because the *guard cells* (C 12) generally close in leaves under pronounced water stress. Although this restricts further loss of water, it also means that *photosynthesis* (C 10) is interrupted (C 13). Because hormones are released (C 14), the effects of a single period of wilting may last for several days.

What other things alter the amount of water a tree loses?

In general, more water will be lost:

(1) the more **light** reaches it;
(2) the higher the **temperature** of its leaves, though above a certain point the guard cells often close;
(3) the lower the **humidity** of the air around the leaves; ***and***
(4) the greater the amount of **wind.**

Can the tree do anything else itself?

Yes, it can. For example, less water is lost when:

(a) the guard cells close during the night (and sometimes for an hour or so in the middle of sunny days);
(b) smaller rather than larger leaves are formed (C 12, C 34); ***or***
(c) the tree naturally loses some or all its leaves at a particular time of year.

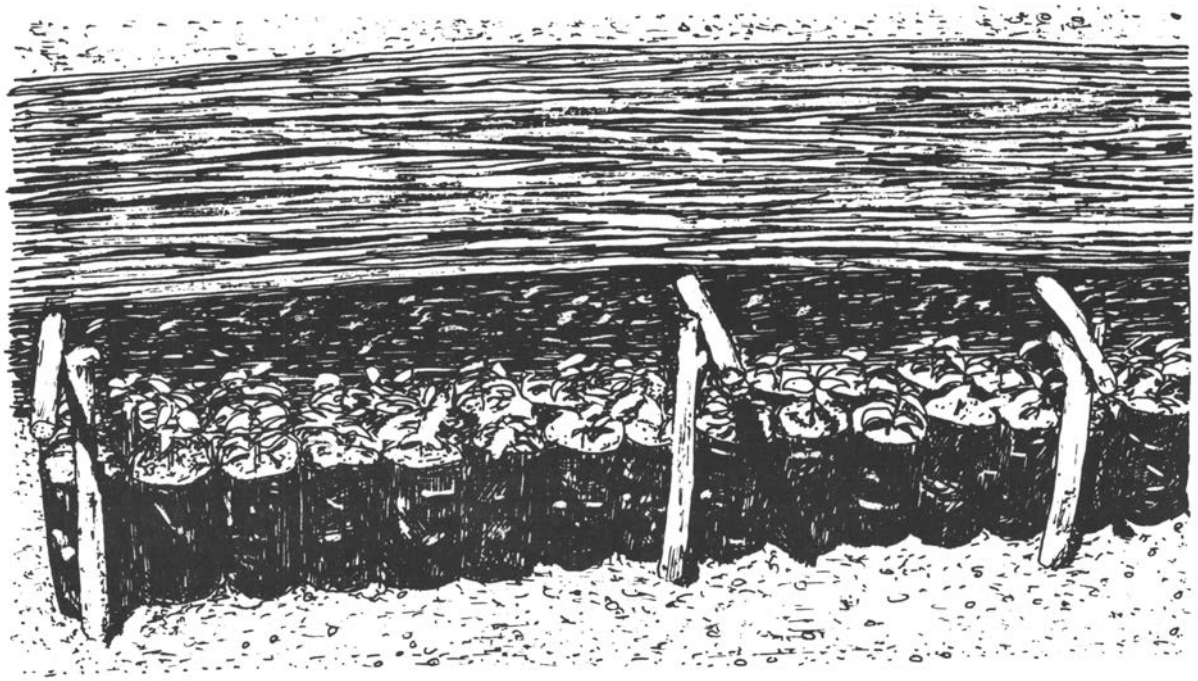
Isn't too much water bad for trees, too?

Yes, stress can also be caused if all the air is forced out of the soil, leaving it waterlogged (C 6, C 23).

How can I avoid climatic stress?

The most important ways of limiting its likelihood and severity are by:

(A) **Shading** the young trees, particularly for:
  (1) species that are shade-tolerant; ***and***
  (2) all species during the key stages when special care is needed (C 40);
(B) **Watering** young trees regularly and carefully (C 43), weeding containers and beds (C 44), and using mulches where appropriate (C 33; and Manual 5);
(C) **Protecting** the whole nursery area against wind (C 25);
(D) **Preventing** roots from getting long instead of well-branched (C 4, C 11); ***and***
(E) **Avoiding** *sudden* exposure of young trees to more stressful conditions.



(Shading removed at the front to show the young trees.)

Which type of shading is best?

Firstly, you could leave a few suitable large trees around the nursery, and plant some smaller shade trees, shrubs or hedges (C 46).
Secondly, you will need to put up shading over the young trees themselves, which could either be:

(a) *low shade,* at a height of about 30-50 cm above the tops of the trees; ***or***
(b) *high shade,* at about 1.5-2.0 m.

How is it put up?

(A) A supporting structure is usually made out of small poles, bamboo or sawn wood, preferably extending over a somewhat larger area than the young trees beneath;
(B) The shade is placed on top, consisting of such materials as palm or banana leaves, coarse grasses, shading mats or plastic shadecloth (A 24 in Manual 1). Hanging mats may be added if needed to exclude direct early morning or late afternoon sunshine.

What is meant by nutrient stress?

There are two main kinds:

(1) a pronounced ***shortage*** of one of the 12-13 essential nutrient elements (C 14; and D13 in Manual 4), which can severely restrict tree growth; ***or alternatively***

(2) ***too much*** of one or more nutrients in the soil, so that the:

(a) levels in the soil solution are toxic to the roots;

(b) uptake of a different nutrient is hampered; ***or***

(c) water intake is restricted (C 13).

How would I know what was wrong?

Both a shortage and an excess of a nutrient can show up as distorted and abnormally coloured leaves as well as in poor height growth (C 60).

However, it is usually clear whether the soil is poor or over-rich.

What should I do about it?

For a nutrient shortage: you could add compost, mulch or a little fertiliser (C 33) to the topsoil of beds, or make up an improved potting mixture (C 6). Remove vigorous weeds, as these can quickly deplete the soil of its fertility (C 44).
For an excess of nutrients: work in some washed sand to nursery beds, and reduce the proportion of rich materials and any fertilisers used in the potting mix.
For an imbalance between different nutrients, try changing any fertiliser used, or replacing it with a suitable compost (C 33).

Do I need to know which nutrient is causing the trouble?

Generally no, because all the nutrients (C 14) are usually present in reasonable nursery soils (C 23) and potting mixes (C 6), and seldom occur to excess in them; ***but***
Occasionally yes, for instance if the local soil is:

(a) seriously lacking in a nutrient, in which case both crops and trees are likely to be suffering from the same problem;

(b) based on a type of rock that contains unusual proportions of chemicals; ***or***

(c) polluted with a chemical (such as a heavy metal like lead or mercury) that disturbs the uptake of nutrients.

If problems remain, you might need a chemical analysis of the soil to detect the cause.

Can very acid soils cause trouble?

Yes, and so can strongly alkaline conditions (C 23), except for tree species that are well adapted to the one or the other. In very acid soils, aluminium may be released in large amounts, disturbing the structure of the soil and nutrient uptake by the roots.

An acid pH may need to be changed to around neutral (C 6, C 23) for such trees as *Wrightia religiosa,* since iron in the *ferric* form makes the leaves go yellow or even whitish in colour, whereas they turn green when it is in the *ferrous* condition.

What kinds of mechanical damage can the wind cause?

Strong winds can harm young trees in several different ways, such as:

(1) clashing leaves and twigs against each other, causing shredding and breakages;

(2) loosening the soil around the root system;

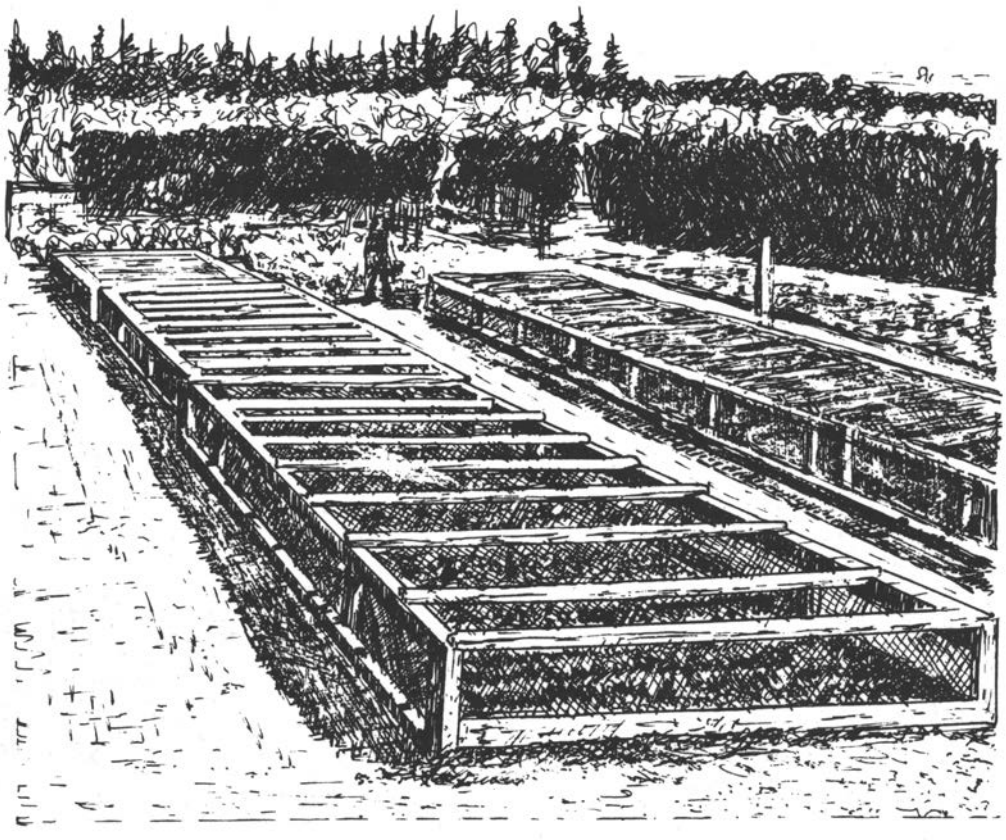
(3) knocking over potted plants, and rolling them about;

(4) uprooting the tree altogether or snapping off the main stem; ***and***

(5) throwing other unfixed items around the nursery, and dropping branches on top of young trees or buildings.

How can I protect young trees from storm damage?

(A) Through careful choice of the nursery site (C 20), and by protecting it well (C 25);
(B) By securing loose items, using temporary covers or moving particularly valuable or vulnerable plants inside.



Protection from wind and birds.

Supposing there is heavy rain as well?

This can also damage young nursery trees in a number of ways, for instance by:

(a) bending down or breaking the shoots of recently germinated seedlings;
(b) making the foliage temporarily heavier, so that wind damage is greater, particularly in slender or brittle plants;
(c) washing away soil so as to loosen and expose roots;
(d) removing soluble nutrients from containers and the topsoil of seed beds; ***and***
(e) if prolonged, making waterlogging and *damping-off* disease more likely (C 45).

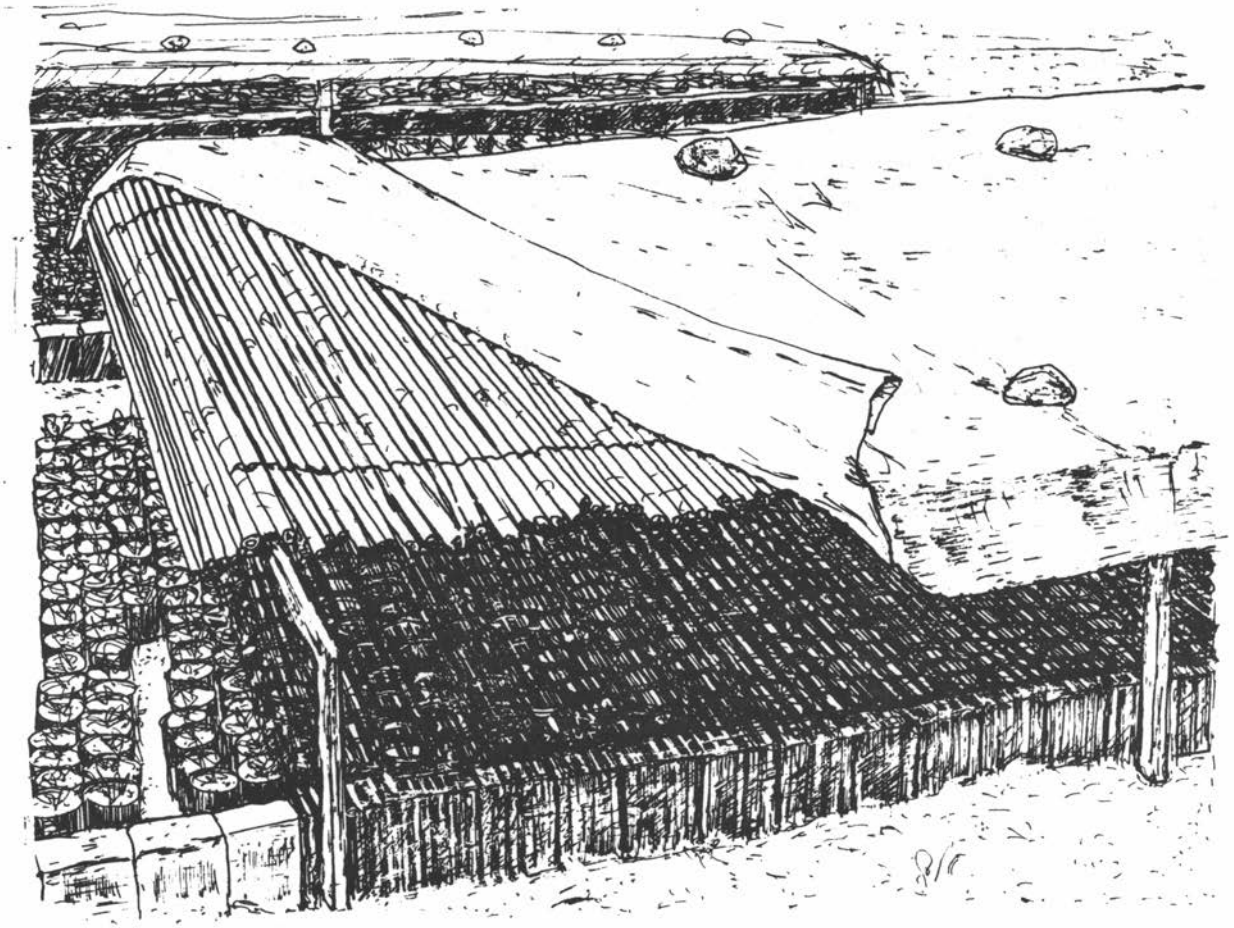
What kind of protection is possible?

(A) **Permanent translucent covers,** made for example of palm leaf or shadecloth, can give some protection, especially when they are not far above the young trees. Robust covers of strong polythene sheeting can also protect, but you will then need to water the plants underneath.
(B) **Temporary opaque covers,** such as matting, boards or aluminium roofing sheets, could be used for the night or for short periods in the daytime.
(C) **Moving plants temporarily into a building,** especially if it has windows, might be worthwhile for seed trays, and for selected valuable or vulnerable trees in containers. Special shadehouses or greenhouses are sometimes used for germinating small seeds (Manual 2) and for experimental work (C 48).

In addition, shelter belts and hedges may check the force of driving rain, and free drainage of rainwater can be encouraged by raising beds above the level of paths (C 23), making sure containers have sufficient holes (C 6), and including some coarse sand and fine gravel in the soils used.

How about damage by animals?

For protection against insects, birds and other small animals, see C 45; and A 52 in Manual 1;
For larger domesticated and wild animals, see C 46; and D 15 in Manual 4;
For accidents and damage by humans, see C 3; and D 16, D 66 in Manual 4.



Bamboo mat shade, and polythene sheet giving temporary protection from heavy rain.

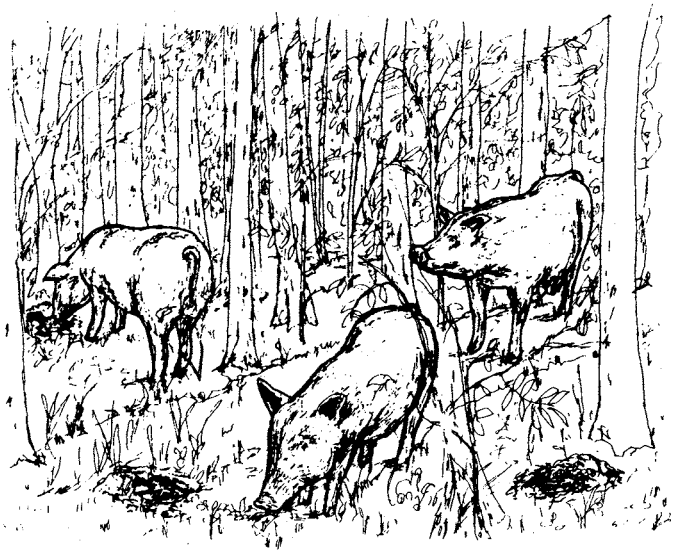
Are there any other kinds of damage?

If weeds (C 43) multiply in containers or nursery soil, there might be problems with:

(1) shortage of water and nutrients and light for the young trees;

(2) direct constriction of tree growth by twining climbers, or damage from chemical substances produced by the weed (D 14 in Manual 4); ***or***

(3) attraction of grazing animals to eat the weeds, with incidental damage to the young trees.



Protecting growing trees C 42
- potting up and transplanting into beds

Aren't potting up and transplanting trees easy?

Yes, in the sense that there is nothing complicated about them; ***but***
No, in that this is a critical stage when the young trees can very easily be damaged (C 3, C 40; and A 53 in Manual 1).

What is particularly important when doing this work?

(A) Choosing a time of day, and if possible a stage of shoot growth (C 12), when climatic stress is likely to be low (C 41);
(B) Minimising exposure of the root systems to sun and wind;
(C) Handling the plants carefully, avoiding unnecessary damage to the roots; ***and***
(D) Having a good potting mixture (C 6) or beds with a well-prepared topsoil (C 22-23).

Can I avoid disturbing the trees at all?

Some species with large seeds are best sown directly into containers or beds (Manual 2). Direct sowing in the field is occasionally possible (C 2), and direct planting of leafless cuttings is regularly used for certain species (A 4 in Manual 1).

With other trees, how should I decide which method to use?

(a) Find out what techniques have been used locally, and check whether or not they produce really good planting stock;
(b) Consider whether the nursery soil (C 23) would be suitable for making transplant beds (C 22), or could be improved sufficiently;
(c) See whether enough of the components to make up a good potting mixture can be obtained locally (C 6, C 63-D).

One approach might be to grow some of a batch in containers, plant others in beds, and compare the results (C 55).

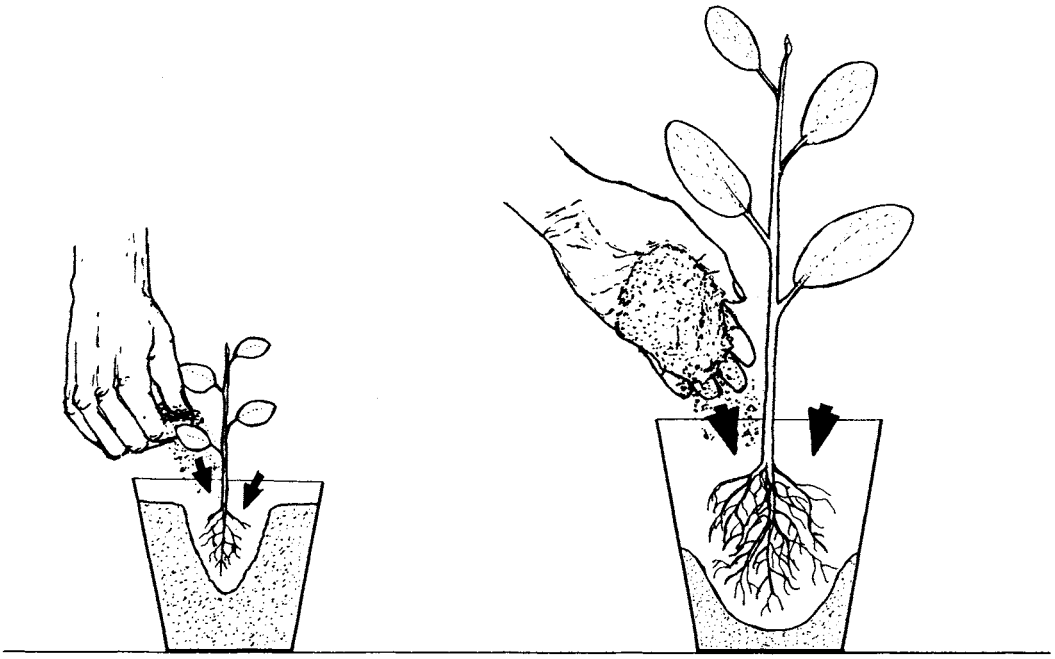
When potting, should I fill up the containers with the soil mix first?

Sometimes yes *with small seedlings and leafy cuttings,* where a suitable funnel is useful (C 51) and a pointed stick can be used to make a big enough hole for the root system; ***but***
Usually no *with larger plants,* where it is better to hold the plant in the partly filled pot, and then add the rest of the soil around the roots.

How should the roots be arranged?

As far as possible, they should be spread out so that they can easily grow into a good root system (C 4, C 11, C 34). They should *not* be:

(1) needlessly bent and broken;
(2) put all on one side;
(3) twisted together like a piece of string;
(4) left going round and round.



Different methods for potting plants with small and with larger root systems.

Won't that slow down the job too much?

It is slower only while a good technique is being learnt (C 50, C 52). Afterwards the work can be done quite rapidly.

How firmly should the soil be pressed down?

Moderately firmly, so that:

(a) the young tree is supported in an upright position, near the middle of the pot; ***and***
(b) water will reach all the soil in the container, rather than quickly running away through large air spaces (C 43); ***but***

Not too firmly, which might cause:

(1) breakage of a lot of roots; ***and***
(2) over-compaction of the potting soil.

What level should the soil reach?

It is usually best to end up with the soil level:

(a) 1-3 cm below the top edge of the pot, to allow for watering (C 43);
(b) at the same position on the young tree as it was previously. In seedlings, this should be at the *root collar,* the junction between shoot and root. In rooted cuttings, pot them up so that the highest root is covered by 1-2 cm of soil.

Should I water the plants in?

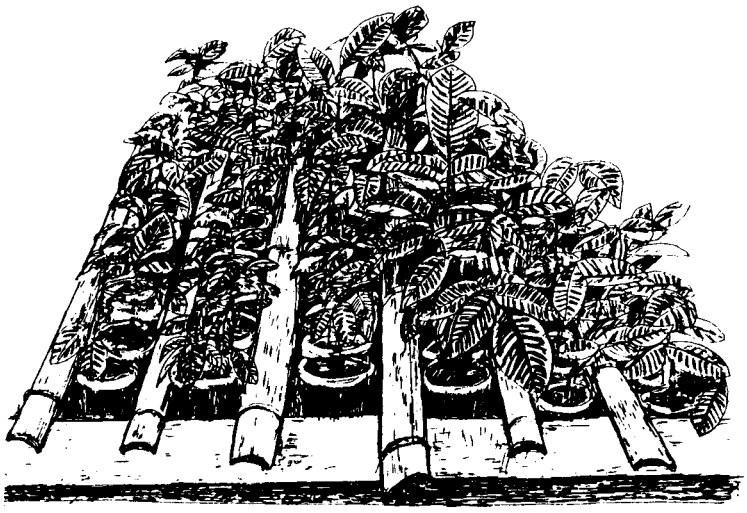
Sometimes no, leave it until the next day for very small or leafless plants potted into moist soil in cloudy weather; ***but***
Often yes, water the plants well when a batch of them has been potted, for example with larger leafy plants during a spell of sunny weather.

Where should I put the newly potted plants?

(A) Straight under moderately heavy **shade** (C 41) for the first 2-4 weeks after potting up, while the roots grow and branch in the potting mixture;
(B) Where they are unlikely to **root through** into the ground (C 6); ***and***
(C) With some **shelter** from the wind (C 25, C 46), so that water loss is reduced and the young trees will not blow over; and protected from heavy rain (C 41) if the trees are still very small. (See sheet C 63-B for estimating the space needed.)

Should I set the pots close to each other?

Potted plants are often put in rows close together, so that they support each other, and this also tends to stop the containers heating up and affecting the roots inside. However, lines of pots need to be separated with strips of wood or bamboo for species in which the shoots need more room if the stems are not to become spindly (C 40, C 60).



Is it advisable to stake the trees because of the wind?

For pots or beds, only do this if it is really necessary, and remember to avoid:

(1) breaking a large root when putting in a supporting cane; ***and***

(2) fastening the tree too tightly to the support, or it may strangle itself as it grows in thickness.

What differences are there when transplanting into beds?

In general, the techniques are similar. Some differences include:

(a) Potting up is best done at a table or workbench in a covered working area (C 22), whereas transplanting has to be done into the bed;

(b) Transplanting usually needs to be done in lines, while pots can be put into rows afterwards;

(c) Root pruning (C 4, C 34) can be done by lifting the pots, but requires skilled use of a pruning tool for young trees in beds;

(d) Trees in containers can be moved to a more sheltered position, whereas those in beds depend on hedges and the choice of a favourable nursery site (C 20, C 25);

Is anything else important?

(A) Make a note of the date and the approximate numbers of trees of each batch potted up or transplanted (C 40, C 54, C 65), as this record will allow you to look back accurately when:

(1) seeing how many survived and how well they grew; ***and***

(2) improving methods next time.

(B) Label the batches if:

(1) they could easily get mixed up; ***or***

(2) the trees may be used in research.

What should I do if the young trees don't grow well?

(a) Use sheet C 60 as a check-list for possible reasons, and what to do about them;

(b) Perhaps try some simple experiments (C 7, C 15).

At a later stage, one of the commonest problems is that the trees have become 'pot-bound', and suffering from nutrient stress (C 41). Generally, the roots will be going round and round inside the container, which also makes for problems when they are planted out (Manual 5).

Will I need to repot trees into larger pots?

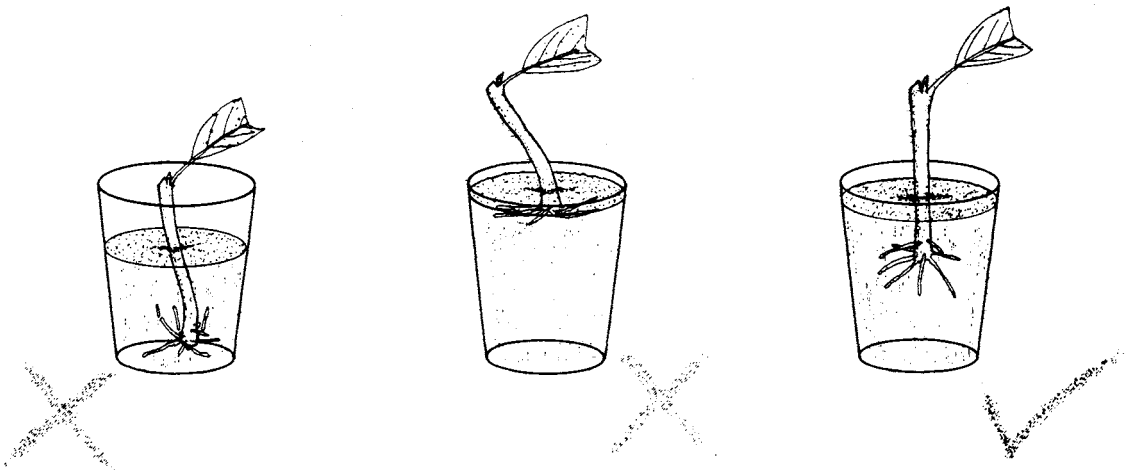
Generally no, because it is better to use a large enough pot the first time, to avoid the extra handling; ***but***

Sometimes yes, for example when:

(1) they are pot-bound, and the root system needs to be improved (C 4, C 34);

(2) the trees are to stay in the nursery longer than expected; ***or***

(3) the particular species grows very slowly.



Protecting growing trees - *watering nursery trees* C 43

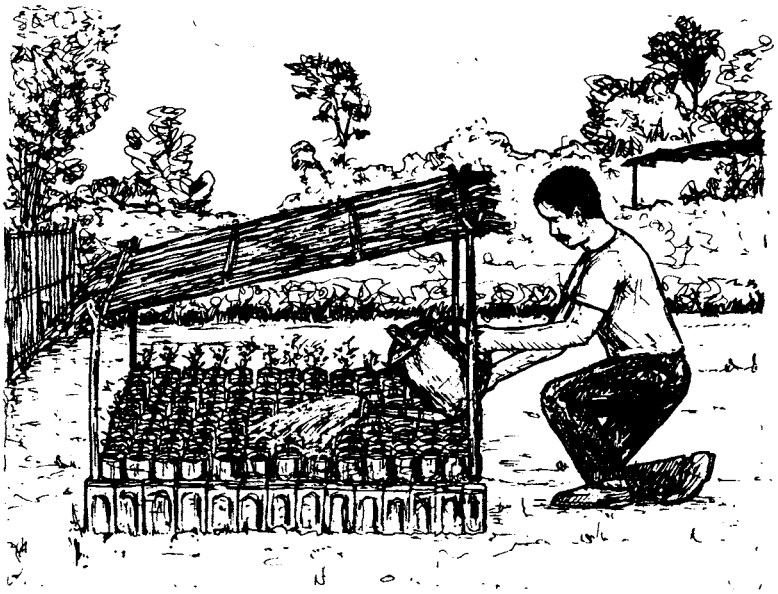
Isn't watering very easy to do?

Well, it looks easy, and doesn't involve difficult concepts; ***but***
There are plenty of potential problems, such as:

(A) requiring a secure water supply throughout the year, with acceptable water quality (C 24);

(B) making sure that the watering is done at the specified time, all the year round (C 40, C 66);

(C) ensuring that it is done properly, so that enough water actually reaches each root system, not too little or too much (C 41).



What can I do to avoid breaks in the water supply?

(1) Keep several big containers (for example cleaned oil-drums) filled with water as a reserve;
(2) Consider the possibility of constructing a small pond or dam to collect rainwater, catch excess from watering, or retain stream or river water;
(3) Install larger plastic or metal tanks, preferably above the level of the nursery growing areas, and put in fixed piping, taps and hose-pipes that can reach all the young trees;
(4) If the supply is pumped, then regularly clean the filters, service the motor and pump, and check for leaks and repair them (C 50).

As a last resort, you could move the tree nursery to a more suitable site (C 20).

How about avoiding breakdowns in the regular watering procedures?

The best way is to combine:

(a) an understanding by those involved of the requirements for the growth of trees (C 10-15);

(b) thorough training (C 50, C 52), with clearly explained watering procedures; ***and***

(c) a 'feel' for the watering needs of plants, rather than simply 'following the book'.

It is very helpful to have a calendar or sheet (C 66) to be ticked off when each watering has been completed. This could be double-checked by another responsible person, with special attention given to weekends and holidays.

Is it really worth bothering with all that?

Occasionally no, if the young trees are close to your home, and everyone knows what needs to be done; ***but***
Generally yes, because a day or two missed in the dry season could undo much careful work throughout the rest of the year.

What can go wrong with the watering itself?

Here are some examples:

Problem (1) - involving the types of seed trays and pots (C 6), or the kinds of nursery beds used (C 22);
Problem (2) - an unsuitable potting mixture (C 6) or unimproved nursery soil (C 23);
Problem (3) - how the potting up or transplanting was done (C 42); ***and***
Problem (4) - the watering techniques themselves.

How can they be overcome?

Here are some hints for avoiding:

Problem (1) - try out alternative containers or types of bed, on a small scale at first.
Problem (2) - change to better potting mixtures, or improve the topsoil in beds, so that they contain organic matter, but are freely drained. Then water will tend to be retained in the soil, but any excess can run through (C 23).
Problem (3) - when potting up, firm the soil sufficiently, and leave enough room at the top of the container for it to be filled up with water (about 1 cm for pots of 5 cm diameter, increasing to about 3 cm for containers 20 cm across).
Problem (4) - train staff and workers (C 52), and use more convenient methods for the actual watering, as this can often improve the standard of watering **and** shorten the time it takes. There may also be less waste of water and reduced mechnical damage to the young trees.

Well, how should the water be put on the plants?

There are various possibilities, including:

(A) buckets, with a half coconut shell, gourd or old cup to distribute the water;
(B) watering cans, preferably with a long spout and 'roses' giving a spray of water;
(C) fixed standpipes and flexible hoses, with watering 'lances' or with the ends attached to bamboo canes to make it easy to reach every tree;
(D) various irrigation techniques; ***or***
(E) automatic watering.

Do small seedlings need a different method?

Yes they do, because heavy drops of water can easily damage them (C 41, C 45, and Manual 2). Small seedlings are sometimes watered by:

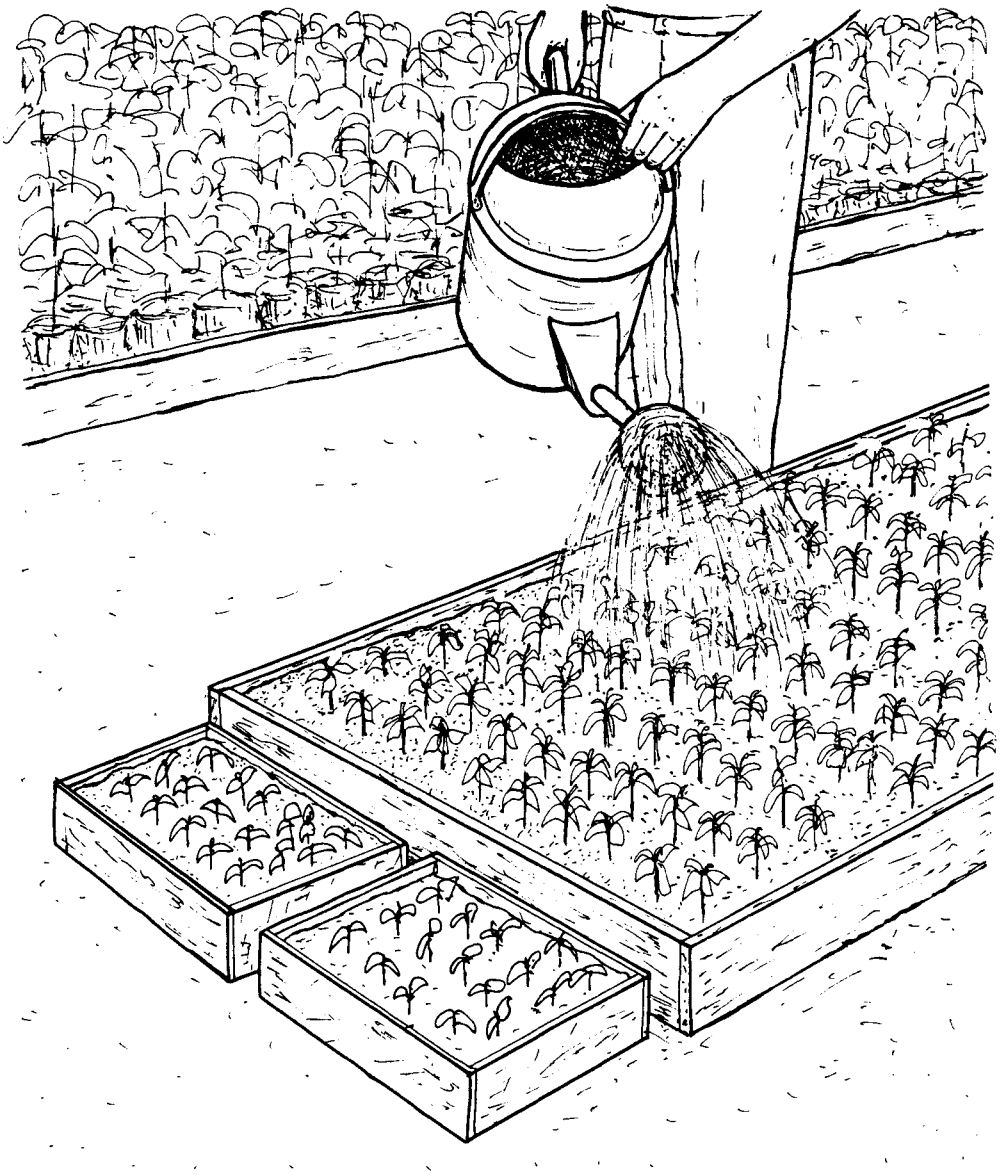
(a) using a bunch of leafy twigs dipped in a bucket of water and then shaken over them;
(b) fitting a very fine 'rose', directed upwards, and passing it rapidly over them; ***or***
(c) standing seed trays in water, removing them after a few minutes, and letting them drain well.

Also, be careful about the watering of newly potted or transplanted trees (C 42).

What might interfere with water reaching the roots?

When watering larger plants, watch out for water not wetting the soil properly because:

(1) the leaves of the trees act like a 'roof';
(2) a larger tree screens a smaller one;
(3) it is difficult to reach pots at the back of a bed;
(4) the edges of polythene bag pots fold down across the soil surface;
(5) the potting soil is too loose, or has dried and formed large cracks; ***or***
(6) the work has been done carelessly.



Then isn't it best just to pour on a lot of extra water?

No, this is not advisable, because over-watering can:

(a) interrupt the supply of oxygen to the roots (C 13), which checks growth and makes root-rots more likely;

(b) increase the risk of *damping-off* disease in young seedlings (C 45; and Manual 2); ***and***

(c) wash away valuable nutrients from the soil (C 33-34).

Avoid directing a jet from a high-pressure hose at the base of a young tree, as this may expose its collar and roots, and also involve an unnecessary waste of water.

Do you mean one should add a little water often?

No, because then there could well be a dry area of soil which one can't see.

Then how can one avoid the risk of some trees getting water stress?

The best solution is to:

(A) add sufficient water to wet all the soil, with any excess draining out of the bottom of the container or soaking deeper into the bed; ***and***

(B) wait until the soil surface is getting dry, but there are no signs of wilting, before watering thoroughly again.

When should watering be done?

(a) In the early morning and/or the late afternoon, not in the heat of a sunny day (except for emergencies); ***and***
(b) Checking whether it is needed once or twice every day (C 40, C 66).

But the pots may not need watering every time!

No, that's right, because:

(1) it might have just rained heavily;
(2) the weather may have remained misty and cool all day;
(3) some of the young trees could be growing under considerable overhead shade (C 41);
(4) certain species may have few or no leaves on them for part of the time, so they do not take up much water (C 13);
(5) some containers might be large, requiring less frequent watering.

Remember to check any plants that are growing under cover, such as seed trays with delicate germinating seeds (Manual 2), newly potted cuttings (A 51 in Manual 1) or plants in greenhouses (C 48).

Isn't it a bother checking every pot?

Three kinds of watering regime can be applied:

Method (A). Pre-set times: all trees are watered at pre-arranged, fixed times;
Method (B). Conditional: each pot is checked, and only those which need it are watered; ***or***
Method (C). Pre-set/Conditional: a few sample pots are checked, and a decision then made to water all or none of the batch.

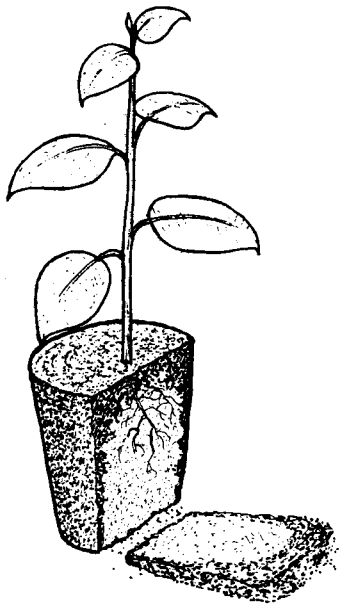
Which is the best?

Method (A) in hot, dry weather, when most pots would be getting dry later in the day.
Method (B) for small numbers of plants, valuable specimens, batches of trees for research (C 7), and especially to avoid serious water stress affecting plants during experiments (C 48).
Method (C) for tree nurseries with a well-trained team (C 52).

What is the best way of checking whether watering is needed?

(a) Looking closely for a paler colour and drier appearance of the soil surface; ***and***
(b) Testing with a finger to see whether the surface soil is becoming dry and loose.

When choosing an appropriate method, or when training staff and workers, it may be worth breaking up a sample root ball or digging into a bed to see how moist the soil is.



Cutting a test plant shows that water did not reach all the soil.

Is it different when watering nursery beds?

The basic principles are similar, though it is usually simpler to do because:

(A) it is easier to see when watering is needed;
(B) beds often dry out more slowly than containers; ***and***
(C) adequate, even, watering can be achieved more readily.

What should I do if some plants do wilt?

(1) *If the soil is dry,* water them thoroughly, and check whether they are starting to recover after an hour or two.
(2) *If the soil is moist,* **do NOT water them,** but try:
(a) repairing or increasing the shading over them (C 40-41);
(b) covering affected plants temporarily with a polythene bag;
(c) moving them for a while to a cool, shady and moist place such as a poly-propagator (A 31 in Manual 1);
(d) looking for signs of damage to the stem or root-rot (C 45) that might be responsible for the wilting.
(3) *If you have just moved the pots, or root-pruned trees in beds,* then:
(a) water the trees well;
(b) treat them as under (2 a-c); ***and***
(c) do future root control (C 4, C 34) at more frequent intervals, so the stress is less drastic.

When are irrigation methods useful?

(A) In areas with a long dry season;
(B) Where plenty of water is available; ***and***
(C) If the beds can be constructed with an even, slight slope with irrigation ditches between to carry the water.

Many methods of applying water have been installed in large tree nurseries (see pp. 133-142 in Goor and Barney, 1968; sheet C 61-A).

How about automatic watering systems?

Because these are expensive and can easily break down, they are not generally appropriate for tropical nurseries, unless:

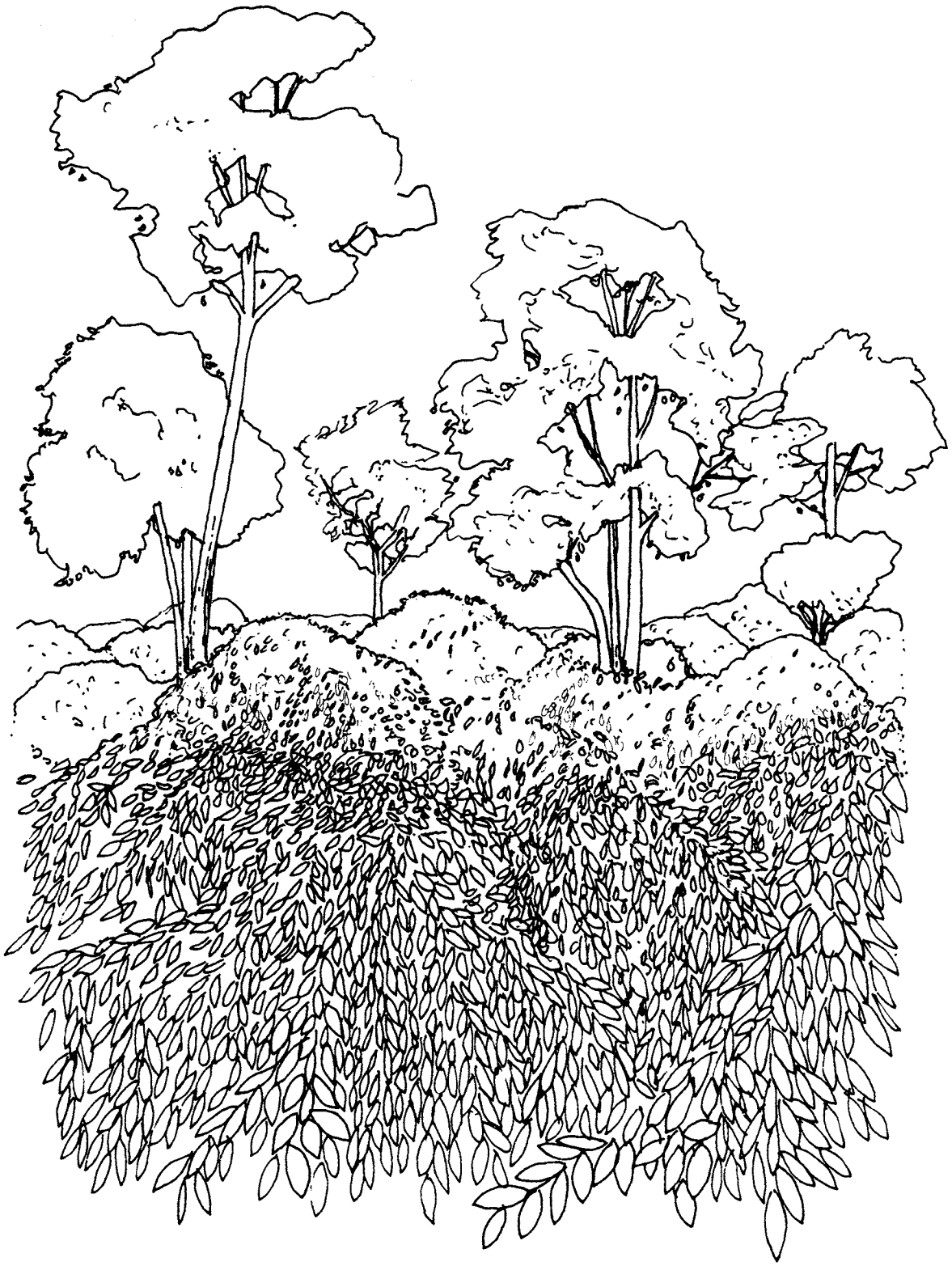
(1) an electricity supply (mains, generators or batteries) can be guaranteed;
(2) the water supply is reliable and can be well filtered (C 24);
(3) there are large numbers of young trees, in sizeable uniform batches; ***and***
(4) the system can be adequately maintained (C 50) and is checked each day (C 40).

What else needs to be considered with automatic watering?

(a) 'Pop-up' sprinkler systems may be better than 'drip' kinds, as ants may tend to build their nests in the latter.
(b) If flexible plastic piping is used, note that this can be disturbed when pots are checked or weeded, and could be chewed for instance by mice (C 45).

Are there some other hints that might help?

(A) Stand the containers upright on level ground, even if the nursery is on a slope (C 20), so that the water does not always run to one side of the pot.
(B) Leave sufficient paths (C 22) between rows of containers, so that all can be reached easily.
(C) Water experimental plants particularly carefully (C 7, C 48), to reduce unnecessary variation between them (C 15, C 55, C 68-69).
(D) Take out weeds regularly (C 44), as some have aggressive root systems that remove water rapidly from the soil.
(E) Disturb any algae or mosses on the surface, as these make it hard to tell whether the soil is dry, moist or wet.
(F) Consider rewarding those doing the watering on the basis of how many good trees are produced.
(G) Try and reach a level of skill where other checks can be carried out while watering (C 40, C 60).



Protecting growing trees C 44
- weeding

What makes some kinds of plants turn into weeds?

Human disturbance of land allows certain species to become weeds. They often:

(a) produce large numbers of small seeds that are distributed widely and repeatedly, and are usually long-lived and dormant (Manual 2), germinating quickly when favourable conditions occur;

(b) are colonising species, with aggressive root systems that quickly 'take over' new soil, and with rapid growth of new leaves and stems; ***and***

(c) have the ability for detached or broken parts to regenerate, so that the weed re-grows quickly after cutting, grazing or burning.

Such features allow weeds to compete successfully with young trees in cleared land.

How do they compete?

(A) By removing water and nutrients from the limited supplies in the container or bed;
(B) Because they take away growing space, and shade the leaves of the young trees;
(C) By twining around their stems; ***and sometimes***
(D) Through release of toxic substances.

Which kinds of weeds are particularly troublesome?

(A) Grasses, especially those that form clumps;
(B) Fast growing herbs and woody plants;
(C) Twining vines; ***and***
(D) Plants like *Lantana camara* that produce chemicals which can inhibit the growth of trees growing nearby (D 14 in Manual 4).

What is the easiest way of dealing with them?

Pulling or digging them out when they are still small. However, make sure you know they <u>are</u> weeds.

If they are left too long, many weeds will break off when pulled, and then rapidly grow up again from the base.

Which tools can be used to get out the whole plant?

A flat, pointed piece of cane, wood or metal of a convenient size. Smooth off the bottom to reduce damage to the roots of the young trees, and the upper end to avoid extra wear and tear on the hand.

A pair of fairly thin but strong gloves may be an advantage if some of the weeds have sharp-edged leaves, contain toxic chemicals, or are thorny like the sensitive plant *(Mimosa pudica)*.

How about cultivating the whole soil surface?

For seed and transplant beds, and for root-pruned soil blocks, the whole surface could well be cultivated before the seeds or young trees are put in; ***but***
Once the trees are growing, the soil should be disturbed as little as possible.

Is it necessary to weed containers?

Generally yes, to avoid competition with the young trees, and to remove any mosses or algae forming a crust on the soil surface, which disturbs watering (C 43); ***but***
Occasionally no, if the only weeds are small and harmless.

When should I weed?

(a) Frequently enough for the job to be easy, and to avoid much competition to the young trees; ***and***
(b) In the morning rather than later in the day, so that the damaged remnants of weeds are more likely to dry up in the heat of the day.

How can weeding be speeded up?

By doing it:

(1) when the weeds are so small they can be pulled out quickly;
(2) after watering, when the soil is softened; ***and***
(3) at the same time as other jobs, such as:
    (a) potting or repotting (C 42);
    (b) moving or turning pots to break off any emerging roots (C 40);
    (c) sorting into clones, sizes or other categories (C 7); ***or***
    (d) assessing the growth of experimental plants (C 55).

In some cases it could be quicker to move trays of plants in turn to a table at a convenient height for working.

What damage can weeding do?

If weeds are large or weeding is done carelessly, removing the weed and the soil held on its roots may mean:

(A) complete uprooting of small tree seedlings (Manual 2);
(B) disturbing and breaking the roots of older planting stock (C 4, C 11), leading to water stress (C 41) and perhaps to easier entry of disease (C 45); ***and***
(C) loosening of the soil, so water runs away without wetting it properly (C 42-43).

NOTE: since weeding usually involves putting one's hands near the ground, take steps to avoid any poisonous insects or snakes which might be amongst the containers.

How about chemical weed-killers?

Occasionally these may be needed for dealing with a serious nursery weed; ***but***
In most circumstances they:

(a) are an extra unnecessary cost;
(b) might damage beneficial soil organisms or the young tree;
(c) could leave residues that continue to pollute the environment.

NOTE: because they are very toxic, weed-killers need to be handled and applied using protective clothing, and stored in a safe place (see C 45).

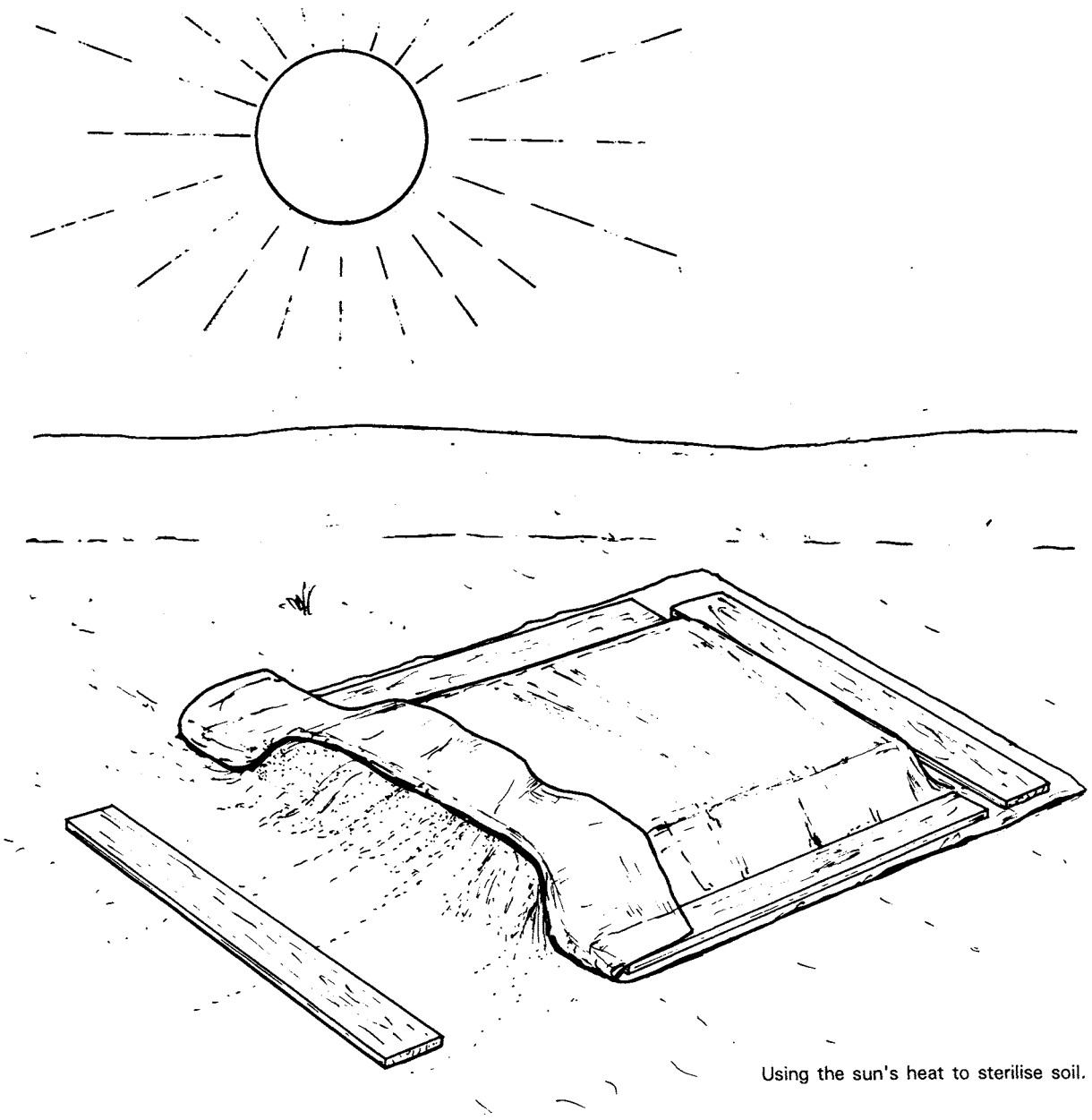
What about soil sterilisation?

Heating soil for several hours can be used to kill the weed seeds in potting mixtures. Since it also kills beneficial micro-organisms (C 30), it might be avoidable by changing to a different potting mix.

If it is absolutely necessary, then:

(1) heat-sterilise only the component of the potting mix (C 6), rooting medium (A 35 in Manual 1) or seed compost (Manual 2) that contains the weed seeds or other parts that can regenerate; ***and***

(2) consider re-inoculating the sterilised soil after cooling, using a weed-free source of useful fungi (C 31) or bacteria (C 32).



Using the sun's heat to sterilise soil.

How is soil sterilisation done?

(A) **Solar sterilisation.** The soil component is spread out on the ground in full sun, completely covered with a sheet of clear polythene, and left for 2-3 days; ***or***

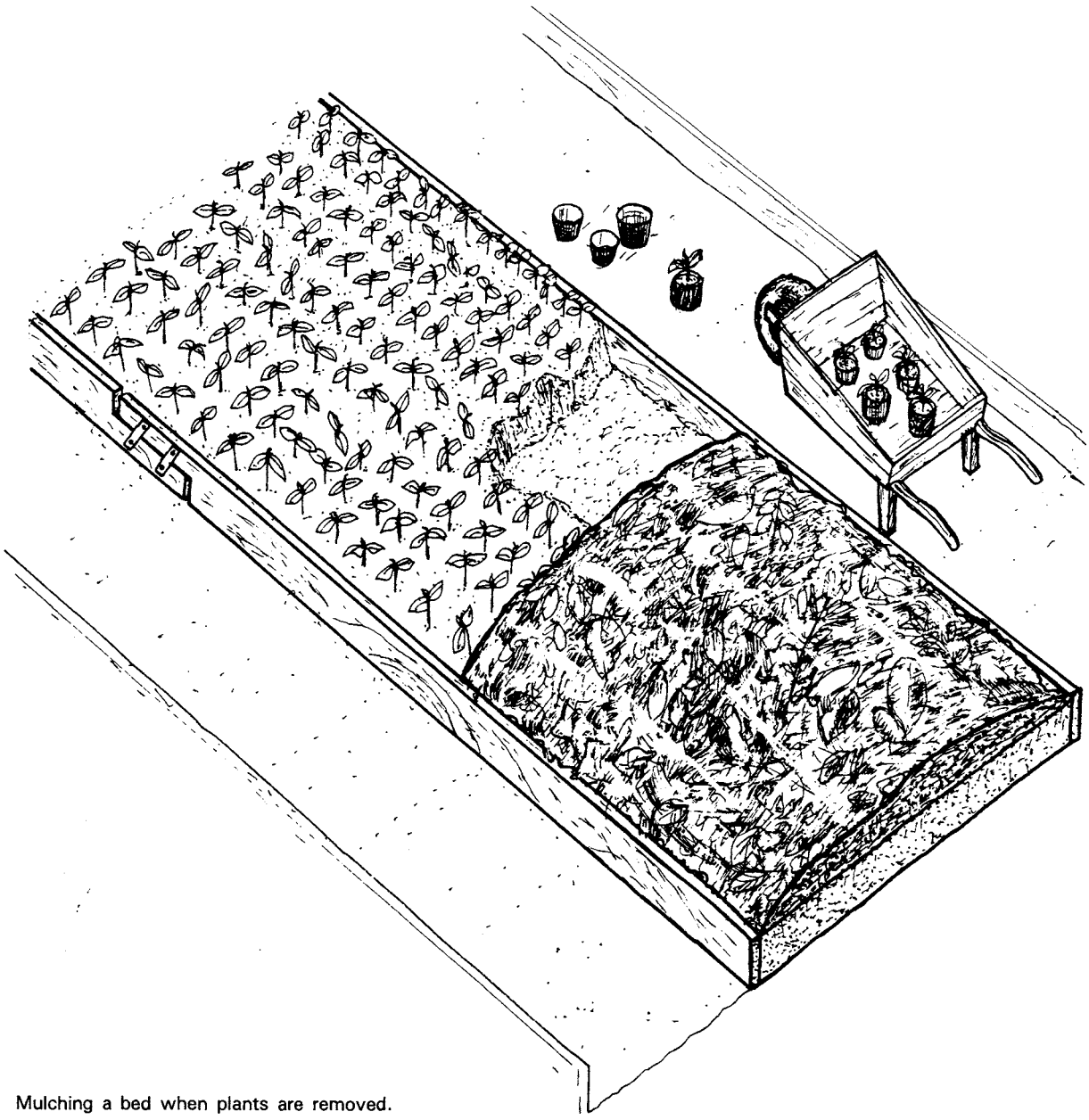
(B) **Sterilisation with boiling water.** The soil component is put in a metal container inside a larger one, which is then filled with water. The whole thing is set on a fire to boil for several hours or a day.

The sterilised soil needs to be kept covered and allowed to cool thoroughly before use.

Are there any other ways of counteracting weeds?

Yes, several things can be done:

(1) Cutting weeds back before their seeds ripen, outside as well as inside the nursery, including on paths and along fences;
(2) Growing tall hedges (C 46), which can reduce the entry of windblown seeds;
(3) Avoiding collecting topsoil or sand (C 24) from weedy sites;
(4) Sieving out underground parts of weeds that might regenerate;
(5) Putting mulch on beds where possible, and while they are not being used (C 33);
(6) Not putting troublesome weeds into compost or mulch; ***and***
(7) Considering retaining or planting trees that cast a light shade over the nursery (C 22, C 25), since most weeds are strong light-demanders.



Mulching a bed when plants are removed.

Protecting growing trees C 45
- dealing with diseases and pests

Which kinds of disease can cause problems in a tree nursery?

Amongst those that may occur from time to time are:

(A) **Damping-off** disease of germinating seeds and young seedlings (Manual 2);
(B) **Rotting** of the root, root collar or stem; ***and***
(C) **Leaf-spots** on the foliage.

What causes them?

Certain species of *fungi, bacteria* and *viruses.* For instance:

(A) Damping-off is often caused by the fungus *Phytophthora* or by bacteria;
(B) Root-rots can be caused by the fungus *Rhizoctonia;*
(C) Leaf-spots can be caused by fungi called blights or rusts, or by viruses.

The 'spike disease' of sandalwood is caused not by a virus but by an unusual type of self-duplicating micro-organism.

How do these things damage young trees?

By getting inside and attacking some cells (C 10), disturbing their growth or killing them. In some cases the disease remains localised, but often it may spread to other nearby cells, and sometimes to different parts of the plant.

When trees are still very young, diseases can often be fatal, and may also spread easily from one seedling to the next.
Older trees could still be damaged and their growth checked, but they are usually more likely to survive.

Is there anything I can do about diseases?

Yes, there are several things. They are much more likely to occur when the conditions for tree growth are poor, so try and avoid:

(1) poorly-drained potting mixes (C 6) and nursery soils (C 23);
(2) over-firming of the soil when potting up or transplanting into beds (C 42);
(3) too heavy a shade (C 41);
(4) frequent over-watering (C 43);
(5) not enough air circulation around the young trees;
(6) seedlings growing too close to each other.

These either lead to waterlogging of the soil, or to very high humidity of the air close to the young trees, both of which tend to encourage diseases.

What else could I do to avoid problems?

(A) Learn the symptoms of common tree diseases (C 60, C 61-C), and look out for any signs of them during regular checks (C 40, C 66);
(B) Water early in the morning, rather than at the end of the day;
(C) To reduce the risk of damping-off, try watering seed trays from below (Manual 2), and don't leave them soaking for more than 10-15 minutes;
(D) To reduce the risk of root-rot, improve the drainage beneath containers, if possible raising them clear of the ground, for instance on wire mesh;
(E) Avoid contaminating the potting mix, compost or mulch with soil or vegetation from young trees that have been attacked by a serious disease, because its spores or other stages may persist in such material.

But what should I do if disease starts to attack my trees?

(a) Isolate trees showing symptoms of disease from the rest of the batch, with identity labels as needed to avoid later confusion (C 54);
(b) Collect and burn damaged leaves that have been shed and plants that have died;
(c) Keep a close daily watch (C 40) to see whether the disease is spreading or diminishing;
(d) Use a disinfectant regularly, and consider heat-sterilising the potting soil;
(e) If really necessary, spray the affected plants with a *fungicide.*

Spraying wearing protective clothing.

Why not spray them all anyway?

Because using a fungicide:

(1) may not be necessary;
(2) would be expensive to continue doing to the whole batch every time you saw a diseased leaf; ***and***
(3) could kill valuable micro-organisms in the soil (C 30-32).

Another reason is that organisms causing disease can sometimes build up resistance to the chemical, and then you might have nothing in reserve against a serious attack.

Which items would need disinfecting?

Anything that can carry the disease to a new set of young trees, such as:

(a) tools (C 51) used in digging up or handling diseased plants;
(b) containers (C 6) that are to be re-used;
(c) tables or benches used for potting up (C 42).

If the disease is persistent, also wash boots and treat the floor of the potting area.

What's the best disinfectant?

A suitable one that may be readily available is a 2% solution of ordinary domestic bleach. Add 200 millilitres of concentrated bleach to 10 litres of water, and then rinse off with water after disinfecting. Avoid getting bleach on your hands or in your eyes, and wash yourself well with plenty of water afterwards.

How is soil sterilised?

(A) *For seed and potting composts:* in the same ways as to kill weed seeds (C 44); ***or***
(B) *For micropropagation* (A 5 in Manual 1), when transferring plantlets from the medium to soil: in a laboratory *autoclave,* where the soil is heated under pressure at a high temperature for a short time.

Doesn't heat-sterilisation kill everything living in the soil?

Yes, if the temperature stays above about 75°C for an hour or so, diseases, pests and weeds (C 44) are likely to be eliminated. However, the disadvantages are that:

(a) the valuable micro-organisms that form close associations with tree roots (C 30-32) will die too;
(b) the useful *decomposers* that break down dead organic matter and release nutrients (C 14; and D 13 in Manual 4) are also killed; ***and***
(c) it is tedious sterilising large quantities of potting soil.

How soon will such organisms recolonise the soil?

The spores of fungi and bacteria will start reaching the soil as soon as it is exposed, but for some time there will many fewer than before. The risk of disease will be reduced, but so will the chance of effective close associations with beneficial micro-organisms.

Which chemicals can stop disease spreading?

There are many different substances that are strong fungicides, each of which may be given different brand names by the company selling them. One active ingredient may be effective against some disease organisms, but not against others. Some examples are:

(a) *Propamocarb* which deals with some of the common damping-off fungi;
(b) *Iprodione* is effective against fungal leaf-spots;
(c) *Benomyl* and *sulphur* are more general fungicides.

Note that the first three of these chemicals act *systemically;* that is, they are taken up in solution by the roots, and are then transported within the young tree (C 14).

What is the best way of spraying?

(1) Obtain an appropriate fungicide and a few small hand-sprayers;
(2) ***Read the instructions on the fungicide packet carefully!***
(3) Choose a windless day, or take the potted plants inside a shelter;
(4) Put on appropriate protective clothing (plastic or rubber gloves, eye-shield or face-mask and a long-sleeved shirt);
(5) Make up a sufficient amount of the fungicide, and put it into the sprayer;
(6) Spray the plants according to the instructions;
(7) Wash out the hand-sprayer where the fungicide can do no harm, and leave it to dry;
(8) If necessary, repeat the spraying after 2 weeks, if possible with another fungicide that has a different active ingredient.

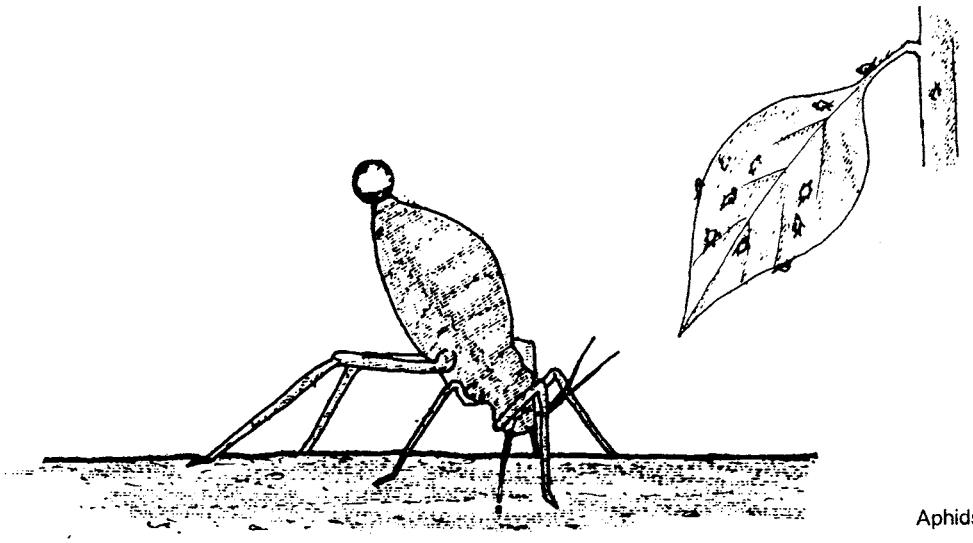
A *soil drench* is an alternative way of applying systemic fungicides.

How about nursery pests?

Like fungi and bacteria, most of the very small animals that live in the soil are harmless to trees, and many are useful decomposers. However, certain kinds of insects can cause root damage, or death of young trees, particularly if their numbers build up. Similarly, some insects attack the shoots and weaken the young tree.

Which sorts can be troublesome?

(1) **Plant-sucking insects,** like aphids (greenfly), psyllids, thrips, mealy bugs and scale insects, withdraw food from the sugar-conducting cells (C 10), and can sometimes infect the young tree with a virus disease.
(2) **Leaf-eating insects,** such as caterpillars, grasshoppers, weevils and some kinds of beetles, eat young leaves and stems. Large swarms of locusts are especially damaging.
(3) **Shoot-boring insects** harm trees when they attack the leading shoot, as in *Milicia (Chlorophora)* and many plants of the mahogany family.
(4) **Cut-worms** (the young stage of a kind of moth) may break off young seedlings just above the soil level at night.
(5) **Termites** can sometimes attack young nursery trees, and they may also bore into and destroy seed boxes, planks, wooden posts and buildings.



Aphids

How can harmful insects be dealt with?

(a) By looking out for any signs of them during daily and weekly checks (C 40, C 66), particularly during seasons and at stages of tree growth when attacks are more likely;
(b) Through removing or squashing any groups of insects that are starting to build up on the young trees or on nearby vegetation, or by spraying them with water containing a little detergent;
(c) Through disinfecting tools and the working area, as this will kill the eggs of many pests, and by removing dead leaves and other materials where insects might hide; ***and if necessary***
(d) By applying an appropriate *insecticide.*

Locust swarms can only be tackled on a district and regional scale.

Which insecticides can be used?

Sometimes local plants may be useful for this. For instance, aphids can be controlled by pounding up the fruits (and especially the seeds) of the neem tree *(Azadirachta indica).* Mix with water and splash the liquid over the affected plants (C 61-C).

What kinds of sprays can be bought?

As with fungicides, there are many different insecticides, which are effective against various pests. For example:

(A) *Pirimicarb* and *Dimethoate* deal with aphids;
(B) *Nicotine* is effective against thrips and some caterpillars;
(C) *Aldrin* can be used to protect young trees against termites.
(D) *Pyrethin* plus *piperonyl butoxide ('Pyrethrum')* forms a more general insecticide, which works by contact with the insect. It is also:
(1) less toxic to human beings; ***and***
(2) unlikely to remain in the nursery environment as a pollutant (D 16 in Manual 4), as it is quickly broken down in sunlight.

Are most insecticides poisonous, then?

Yes; and it is therefore ***particularly important to:***

(a) ***read the instructions carefully;***

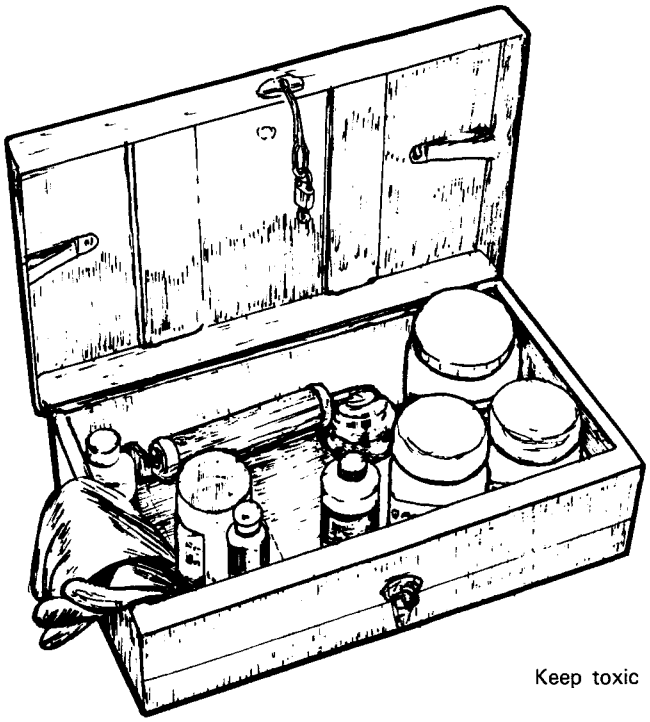
(b) use protective clothing (rubber gloves and a long-sleeved shirt, long trousers and rubber boots. A hat, an eye-shield and a cloth tied across the mouth may be needed for insecticides that are very poisonous to humans;

(c) avoid unnecessary spraying;

(d) dispose of unused insecticide thoughtfully, and wash out the sprayer carefully;

(e) label insecticide containers clearly, avoiding any confusion with those containing drinks, and keep them locked away; ***and***

(f) wash hands before eating, drinking or smoking.



Keep toxic chemicals locked up!

Will soil sterilisation kill insect pests?

Yes, if the temperature exceeds about 75°C for an hour. On a small scale you could try pouring boiling water on to insects or their eggs, provided that any young trees are at least 0.5 m away.

What other pests can cause problems?

(A) **Nematodes,** which are small thread-like soil organisms that can attack the roots;
(B) **Small rodents,** such as mice and rats, which can eat, break off or disturb young trees;
(C) **Seed-eating birds,** which can dig up and eat newly sown or germinating seeds.

How can I deal with them?

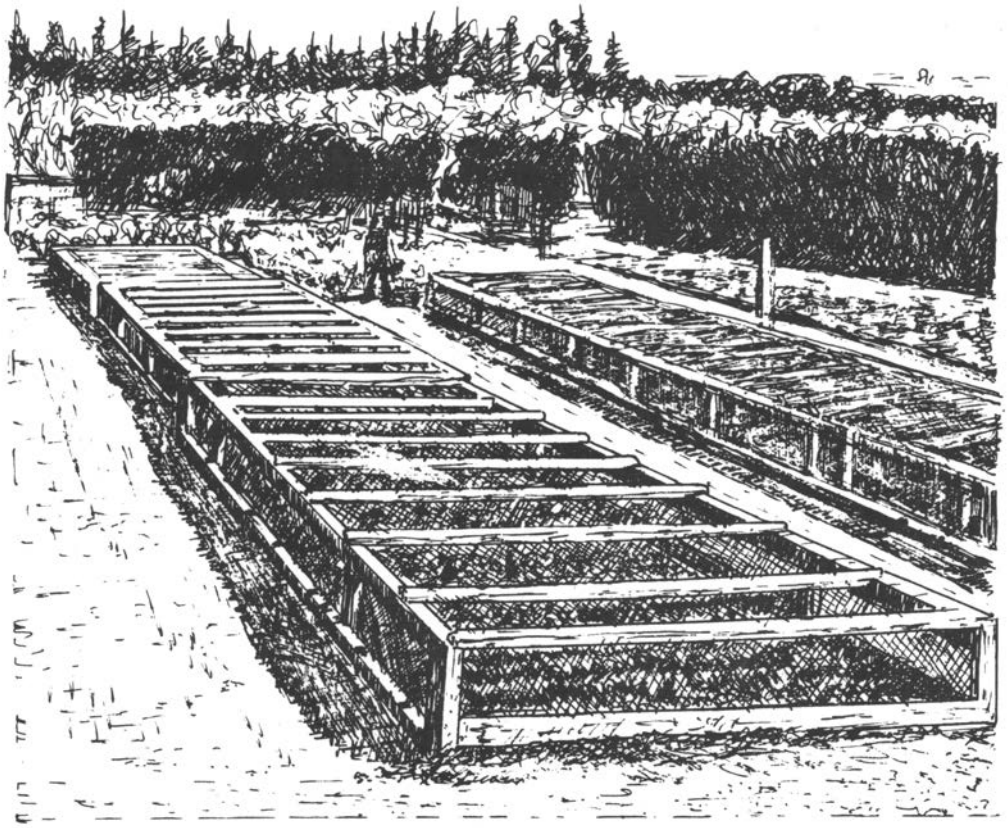
(A) Nematodes can be treated by drenching the soil with a *nematocide,* if necessary. *Carbofuran* is effective, but is **very poisonous.**
(B) Rodents can be checked by wire netting, and by trapping or poisoning.
(C) Birds can be kept off by:

(1) spreading netting over the seed beds or seed trays until well after germination;

(2) using people or gadgets to scare them away.

Is there anything else I can do about diseases and pests?

(A) One cannot eliminate them entirely, so concentrate on keeping the risks low.
(B) Try scattering individual *Milicia* and mahogany amongst other species.
(C) Avoid growing only one tree species in a large nursery, as a disease organism or an insect pest could build up more easily, increasing the risk of losing all the plants.



Protection from wind and birds.

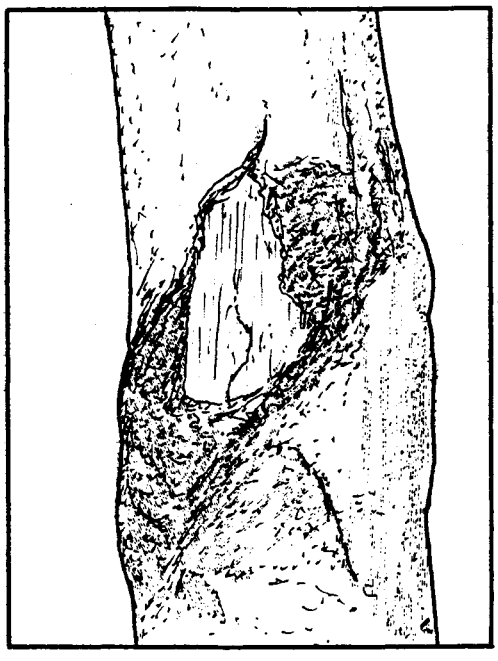
Are some trees more resistant to nursery diseases and pests?

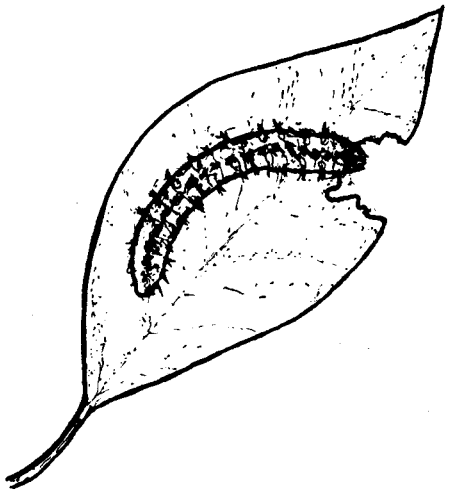
In each tropical region there are likely to be some:

(a) **tree species** that are seldom attacked, and others in which the risk is higher;

(b) **provenances** and **individual trees,** within a species, with greater or lesser tolerance or resistance to a specific disease or pest.

In time, superior trees could be identified, multiplied and tested. Then it might be possible to grow that species even where there are persistent nursery problems (C 3-5).





Canker.

Protecting growing trees C 46
- *fences, hedges and gates*

What are the main reasons for having fences?

They are often needed to keep out:

(a) **domesticated animals** that could eat or break the young trees, for example cattle, hens and especially goats;
(b) **wild *herbivores*** (D 15 in Manual 4); ***and/or***
(c) **humans,** especially thieves and vandals (D 66 in Manual 4).

Fencing can also be used to support lines of young nursery trees in windy sites.

Does a nursery always need fencing?

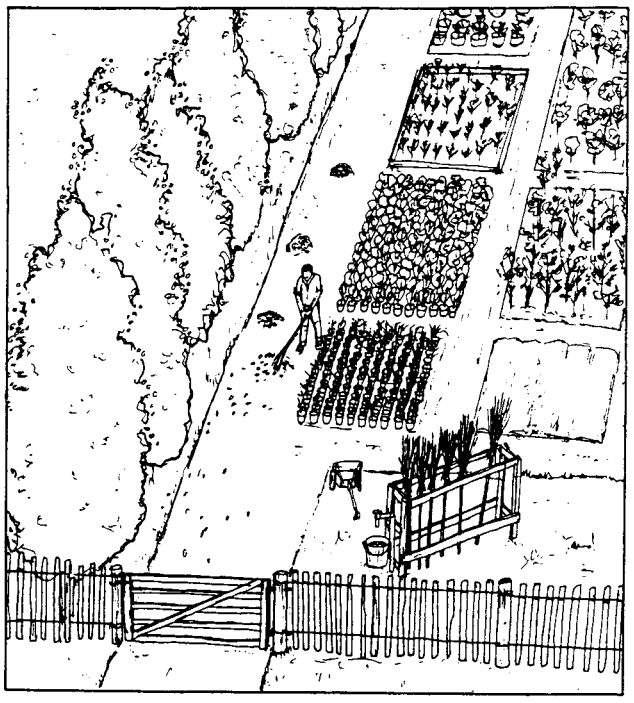
Temporary nurseries (C 21) are often left unfenced, especially if there are few animals in the neighbourhood, or if they are near the house where someone can keep an eye on them;
Permanent nurseries, small or large, often need protection, although sometimes it may be unnecessary;
Research nurseries generally need to be fenced to protect the experimental trees. This is essential if the trees are being treated with radioactive or other toxic substances, where only the research personnel should have access.

What sort of fences could be used?

There are many possibilities, such as:

(1) Palm fronds, close together, with their bases inserted into the ground;
(2) Wooden posts, with wooden palings and cross-beams;
(3) Wooden posts with strands of wire between them;
(4) As in (3), with wire netting or chain-link fencing attached;
(5) Electric fences.

Support against the wind for a line of nursery trees can be provided by wooden posts with horizontal poles.



How can I get hold of chain-link fencing?

Simple fence-making machines are now available, which themselves can be built locally (C 61-D).

Supposing there is only a little money for buying fencing materials?

It is still possible to build a fence round your nursery plants, using palm fronds or small poles, split bamboo or pieces of sawn wood. These need to be put in close to each other, and interwoven or held together with lianes, rope or wire (D 38-39 in Manual 4).
However, such fences perhaps might:

(a) not last very long;
(b) blow down in strong winds; ***and***
(c) not keep out certain kinds of animal.

What can I do to make a fence last longer?

(1) Use durable wood, or treat it with a preservative against rotting and termites;
(2) Make sure that some pieces go well into the ground, and are fixed firmly to anchor the fence;
(3) Close up any holes that appear, particularly at the bottom, by weaving in small branches or pieces of wood; ***and***
(4) Plant grass to hold the soil at the base, keeping it cut to avoid increasing the risk of fire.

How tall does it need to be?

For cattle and many wild animals, 1.5-2 metres might be enough.
For goats, hens and antelopes, 2.5-3.5 metres may be needed.

How could I build a strong fence against animals?

(a) Align the fence to make use of any buildings, gate-posts and existing trees that are available, making the sides as straight as you can;
(b) Dig holes for main posts every 15-20 m, placing them where the direction changes, and using a metal crowbar or pickaxe to put them 30-60 cm deep;
(c) Fix these posts firmly by hammering stones into the hole, and by bracing them with a slanting pole on either side, or at the middle of the angle where there is a change of direction. If you concrete them in, wait 2-3 days before stage (e);
(d) Drive in smaller, pointed stakes every 1.5-2.5 m, using a heavy hammer;
(e) Starting from a main post, attach lines of fencing wire at vertical intervals of about 30 cm loosely to the smaller posts, and then strain the wires as tightly as you can to the next main post (with wire-strainers if available) before fixing them all firmly;
(f) Now attach wooden palings, wire netting or chain-link fencing securely to this strong structure, going about 3-5 cm into the ground to discourage burrowing animals.

What problems might I have in putting up fences?

(1) **Steep ground** can make it difficult to get posts vertical and well fixed, and the fencing materials might need to be cut on the slant;
(2) **Rocky patches** can mean problems in making holes for the fence posts, though once made the fence may be stronger;
(3) **Soft soil** can cause difficulties in fixing posts, unless they can be made longer and driven into firmer soil beneath.

How about animals that might cause special problems?

(A) **Animals with strong teeth,** such as mice, rats, porcupines and some insects, may eat holes in the fence. Metal fences are more resistant than wood, but may not be immune to damage.
(B) **Climbing and jumping animals,** such as monkeys, squirrels and sometimes even goats, can be very difficult to keep out, especially if there is little to eat outside the nursery. You could try having someone to scare animals, secure tethering of goats, or covering the entire area with shadecloth (C 41; and A 24, A 33 in Manual 1), with the strips securely joined together.
(C) **Large, strong animals,** such as cattle and elephants, can push over a fence unless it is very strong. Battery-operated electric fences could be a relatively cheap solution, or you might even dig a broad ditch around the nursery, as they may be unwilling to cross it.

Are there any other alternatives to fences?

Yes; planting tight, often thorny hedges, sometimes called "live fences".

What kinds of woody plants are best for that?

Those which:

(1) are in use locally, and have been found effective and robust;
(2) have a habit of shoot growth with a lot of strong low branches, which do not lose all their leaves at once (C 12);
(3) can respond to repeated pruning by producing new shoots near the ground; ***and***
(4) are easily propagated, especially from leafless cuttings (A 4 in Manual 1), like *Euphorbia tirucalli* and species of *Baphia, Ficus* and *Spondias.*

How close together should they be planted?

If there are plenty of plants or material to make leafless cuttings, you might try planting ***two*** rows, 10-15 cm apart, with the hedging plants 3-6 cm apart in the rows, and *staggered,* so that the second row fills the gaps in the first.

However, a spacing of 25 cm is recommended for some species, so first check what has succeeded locally.

What height should hedges be?

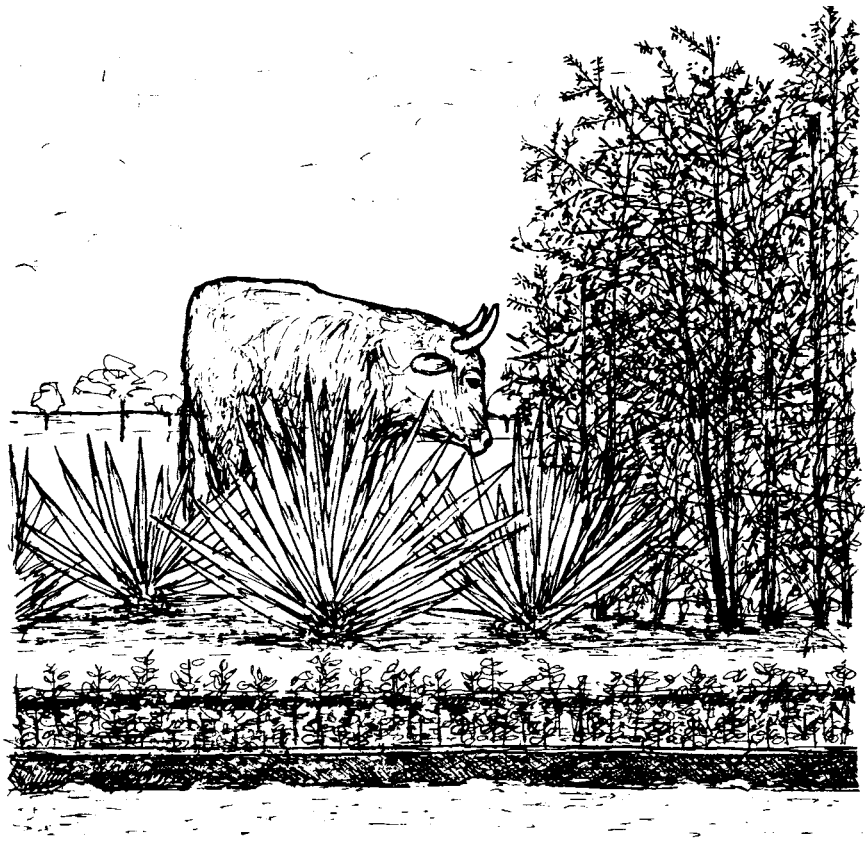
As a rough guide, start trimming the tops at 1-1.5 m, to encourage bushy growth.

Do hedges need much maintenance?

They need regular attention, especially:

(A) **Pruning** at intervals, to stop them getting too tall and/or too wide; and to encourage strong new growth from near the base of the hedge; ***and***
(B) **Replenishing** at the bottom with new plants, if parts have been broken.

Plants like Sisal can form an effective, low-maintenance barrier.



What other effects can hedges have on the nursery?

(1) Checking the run-off of water and the erosion of soil (D 23 in Manual 4);
(2) Lessening wind speed over the young trees, and so;
    (a) reducing the amount of water the young trees lose (C 13, C 41);
    (b) decreasing the risk of direct damage (C 25); ***and***
    (c) discouraging the spread of wind-blown weed seeds (C 44).

Hedges might also cast some shade on the young trees, which may or may not be an advantage.

How about access to the nursery?

It may be best to have only one gate to the nursery, at the most convenient point in the fence or hedge (C 22), because:
    (A) gates are potential weak points in the line of protection;
    (B) it is difficult to stop small animals from getting under them; ***and***
    (C) stiles can be built if people need to enter from another side.

It may also be easier to discourage vandals and thieves if there is only one padlock.

What else could I do to keep out such people?

You might try a combination of:
    (a) high fences and notices;
    (b) training staff and workers (C 52);
    (c) discussions with the local community (C 53; and D 5 in Manual 4); ***and***
    (d) employing guards at night and during weekends and holidays.

Are there some hints about putting in gates?

(1) If possible, choose a flat place, so that the gate will not have to be slanting;
(2) Decide whether a wooden or metal gate will be best, and which way will be most convenient for it to open;
(3) Use a very strong, durable main post to hang the gate on, and another post for the closing device;
(4) Fit the hinges so that the gate will hang slightly high, as gates always settle a little after a few days or weeks;
(5) In order to exclude small animals, attach some trailing strips of wood or folded wire netting to the bottom edge of the gate; ***and***
(6) Consider fitting a device to prevent the locked gate being opened simply by lifting it off its hinges.

How do I maintain a gate?

By treating it with a wood preservative or paint, oiling the hinges occasionally, and by mending it if it becomes weakened or broken (C 50). You could also fill in any ruts in the road beneath the gate with crushed stones, to continue keeping out small animals.

Is there a cheaper alternative to a gate of this kind?

Yes, you could make a separate piece of fencing that fits between double poles on both sides, but can be lifted out.

See Fearnside and Drew (1977) in C 61-D for more information on gates, fences and hedges.

Protecting growing trees C 47
- preparing young trees for planting

What is needed before young trees are sent out from the nursery?

Giving them the best chance of:

(A) coming through the journey with minimal damage and stress (C 41);
(B) tolerating poorer conditions while waiting to be planted (Manual 5); ***and still***
(C) surviving and growing well after planting, and becoming quickly established.

But what can be done about such things in the nursery?

Quite a lot; especially by:

(a) planning to grow the young trees to a suitable size (C 34);
(b) progressively modifying shading and watering regimes to *harden* them;
(c) continuing regular pruning of the roots (C 4); ***and sometimes***
(d) last-minute alterations to their size and leafiness.

How should shading be changed?

Young nursery trees need enough shade at critical stages (C 40). Then:

- *for light-demanding species* (D 14 in Manual 4): shading should generally be reduced **gradually in stages** every 2-4 weeks, so that they have been hardened to grow in full sunlight for at least a month before they leave the nursery.
- *for shade-bearers:* shading should be similarly reduced, but the hardening taken **only to a level of shading** suited to young trees of that species.

Does the intended planting site not make some difference?

Yes, it can do. For example, during the last month in the nursery, you might:

(1) keep even the light-demanders **under some shade,** if the site will be a shady one. Examples could include various situations where one or more *storeys* of tree crowns already exist overhead (D 52 in Manual 4), such as:
  (a) *underplanting* in uniformly thinned plantations (D 51);
  (b) growing trees in small groups or narrow strips in woodland (D 24, D 54);
  (c) certain agroforestry situations (D 3, D 21); ***and***
  (d) some ornamental and park planting (D 28).

(2) consider **removing most or all the shade** even from shade-bearers, if they have to be planted in large, open clearings (D 2, D 50) or on degraded land (D 22).

Why is this?

Because the leaves of trees (C 12) are usually *adapted* to the conditions prevailing at the time when they expanded. The new leaves which grow during the last month in the nursery will be those that provide most of the sugars which will sustain the tree during the first month after planting. So they need to be adapted as far as possible to the conditions that will apply in the planting site.

What changes should I make to watering regimes?

Continue to give plenty of water each time, but reduce the **frequency** of watering, for instance:

(a) from twice a day to once a day;
(b) from once a day to once every 2-3 days; ***or***
(c) from pre-set times to a conditional regime (C 43).

However, don't take this to the point where the young trees wilt, or come under severe water stress without showing it (C 13, C 41).

Will less frequent watering improve the chances of survival?

Yes it may, particularly by:

(A) discouraging very rapid extension of shoots (C 4, C 12), which might be more liable to damage; ***and***

(B) encouraging smaller leaves that are likely to lose less water, thus helping to preserve the water balance (C 13, C 34) of the young tree during its transition from nursery to the field.

Can I avoid watering them beforehand to make them lighter to carry?

Generally no; because:

(1) the roots will usually be less damaged by travelling in moist, firm soil than if it dries and becomes loose; ***and***

(2) you may not know when the young trees will be getting any more water; ***but***

Sometimes yes; when they are going to another nursery or to a planting site with water close by, and someone to look after them.

How about adding fertilisers?

Usually none should be added at this stage, because they are:

(A) likely to encourage too vigorous growth and large leaves (C 34) at an unsuitable moment; ***and***

(B) more likely to be washed away and wasted than if applied when the tree is potted up (C 42) or planted (Manual 5).

If nutrient stress (C 41) is severe, you could for instance:

(a) insert a little slow-release fertiliser with high P and K (but low N) into the root ball;

(b) apply a micronutrient (C 14) that was needed, perhaps by foliar feeding; ***or***

(c) delay planting out until the trees have recovered.

Why does root pruning help?

Because **regular, moderate pruning** encourages the formation of a good, bushy root system (C 4, C 11, C 34) that will go into the planting hole (Manual 5) with little disturbance.

NOTE: **this is crucial to successful growing of planting stock in containers and in soil-block beds.**

But aren't trees sometimes planted as 'stumps'?

Yes, a few tolerant kinds, such as teak, *Gmelina* and *Albizia chinensis* can be grown quite large, and then both root and shoot cut right back to a few centimetres.

However, with most species it is best to avoid getting into a position where you need to chop off big roots.

What about cutting back the shoots?

This can sometimes be a useful method, if:

(a) the trees have a good root system, but are rather tall; ***and***

(b) there are buds at the base, and adequate reserves, for the shoots to regrow.

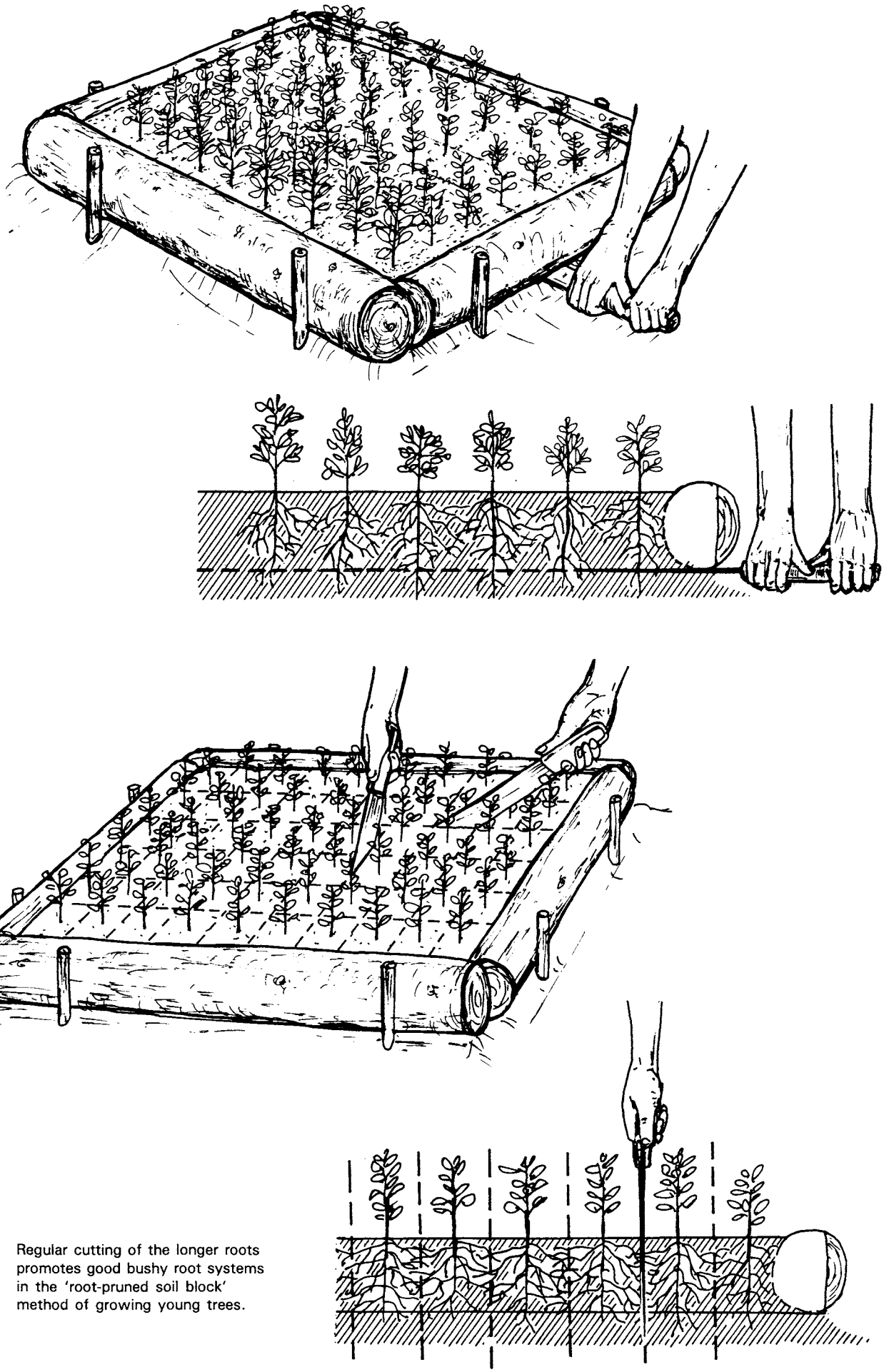
Conifers such as *Pinus* should not be cut back, as they seldom have any basal buds. On the other hand, cypresses such as *Cupressus* or *Callitris* might be able to re-grow from green branchlets near the base.

Couldn't I just take the leaves off and plant 'striplings'?

Often, it is better to avoid this technique, because the young trees lose not only the materials and energy used to make the leaves (C 10, C 12), but also most of their ability to manufacture sugars. (In one trial, **removing all the leaves** was actually found to kill healthy plants of *Triplochiton scleroxylon,* even though they were not taken out of their containers.)

Sometimes, however, **reducing the amount of foliage** is helpful, because this decreases water stress (C 13, C 41) during the period before and after planting.

Occasionally, it is unnecessary, because the nursery trees naturally lose some or all their leaves or leaflets at the right time for planting.



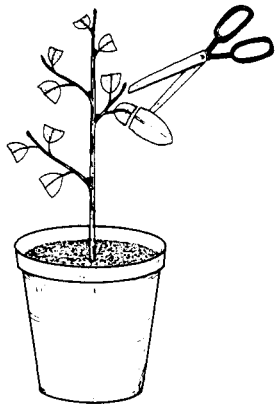
Regular cutting of the longer roots promotes good bushy root systems in the 'root-pruned soil block' method of growing young trees.

How should I reduce the amount of foliage, if this is needed?

In general, it is much better to reduce the size of leaves than to take them right off. Shortening them, by cutting (or even tearing) off half to three-quarters of the tip part:

(1) reduces water loss considerably; ***but***
(2) keeps the basal part of each leaf functioning properly;
(3) tends to discourage the premature outgrowth of side branches (C 12); ***and***
(4) is less likely to allow micro-organisms causing disease to enter (C 45).

For valuable research plants, you might consider keeping more foliage, and using a 'transplanting spray' which temporarily reduces the amount of water lost from the leaves.



What about the transport of bare-root seedlings?

In cool climates, the soil is sometimes removed from the roots, because this greatly reduces the weight to be transported. This method is sometimes used in the humid tropics (for example for rooted cuttings of *robusta* coffee), but it needs to be done at night in order to reduce water loss, with the plants covered with polythene sheeting or moist leaves. To protect them from disease (C 45), drench in a weak fungicide solution before sending them out from the nursery.

Unless you know it can be successful, transport bare-rooted plants only on a trial basis, because:

(A) root damage is likely to be much more severe; ***and***
(B) the planting holes need to be already dug, and all the young trees planted before the sun is up next day.

Supposing the young trees are going to another nursery in containers?

There should be less stress than when they go to a planting site, but the same preparation is advisable because the soil and roots will still be disturbed during transport.

Don't forget to send a note with the young trees, listing the species, origin and the source of the seeds or cuttings, date of potting up, and any other relevant details (C 54, C 64-65).

And if they are to be planted in a field experiment?

In that case, you need to:

(1) alter the shading and watering regimes of the whole batch with extra care;
(2) keep them all in uniform conditions (C 48) while they are waiting to go;
(3) re-check the numbers of each species, batch or clone; ***and***
(4) make sure that any labels are clear and securely attached.

What else might I need to do before trees leave the nursery?

(A) **Weeding:** remove any sizeable or serious weeds, but with as little disturbance as possible to the soil;
(B) **Checking:** at the same time check for broken or burst containers;
(C) **Avoid stress:** don't keep shade-bearers in the sun unnecessarily;
(D) **Support:** think about how taller, 'floppy' trees might be protected in a carrying tray or vehicle from falling over, sliding about and getting broken, or rubbing against ropes or parts of the vehicle.

Protecting growing trees C 48
- special conditions for research trees

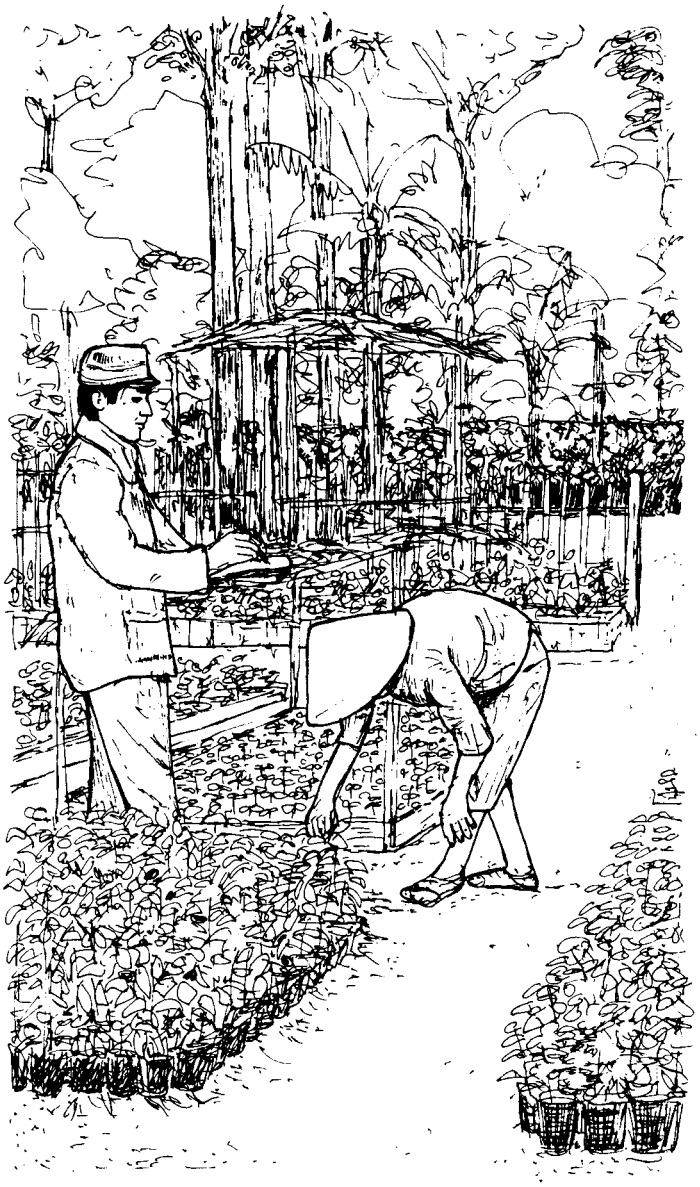
Why do young trees for research need special attention?

Because:

(a) their general environment should be as uniform as possible, to reduce unnecessary variation (C 7, C 69-N);

(b) the risk of various kinds of stress (C 41) needs to be kept to a minimum, so that damage and interruptions to growth are less likely;

(c) attack by pests or diseases (C 45), and damage from larger animals, wind or fire (C 3, C 40, C 46) all need to be avoided.



Are more uniform conditions needed just during an experiment?

That is when the care and checks described in sheets C 40-47 need to be especially well covered. But they are also needed when growing batches of trees to use later on in experiments (C 7), or for non-experimental research.

What is particularly important about the general conditions?

(A) *Light and shade.* The total amount of light that reaches each tree is likely to influence its growth:
(1) **directly** through the amount of sugars produced in photosynthesis (C 12, C 14); ***and***
(2) **indirectly** by affecting for instance:
(a) leaf and root temperatures (D 11 in Manual 4); ***and***
(b) the amount of water lost (C 13).

(B) *Moisture.* The drying power of the air also affects how much water is lost by each tree, while the availability of water in the soil is crucial to how quickly it can be replaced.
If severe water stress develops within a tree, hormones usually reduce its growth by:
(1) the closing of many guard cells (C 12) for several days, checking further water loss but also restricting the entry of carbon dioxide and so the formation of sugars; ***and***
(2) a slowing down of cell division and other processes (C 10, C 14).

(C) *Nutrients.* The amounts and availability of important nutrients in the soil of containers or beds can also influence growth considerably (C 14, C 33-34).

But won't the research trees differ from each other, anyway?

Yes they will, because of differences in:
(1) genetic constitution, unless they are all of one clone (C 5; and A 11 in Manual 1);
(2) previous environments; ***and***
(3) size, leafiness, extent of root system, inoculation with micro-organisms, and so on.

The aim is to have a set of research plants where all these sources of variability are kept as small as possible, so that effects of experimental treatments and other differences are more likely to show up (C 55, C 69).

How can I let each plant get roughly the same amount of light?

(a) By choosing a place in the nursery which is fairly evenly lit throughout the day (not too close to buildings, hedges or trees);
(b) By arranging the batch of research trees in an appropriate way within that area, spacing them out if necessary to avoid taller plants shading shorter ones;
(c) If shade is provided, by using a uniform material such as shadecloth, and extending it well beyond the batch of trees; ***and***
(d) By putting rows of other plants around the research trees to avoid 'edge effects'.

For some detailed research (C 62-A), young trees are grown (continuously, or from about 17.00 to 7.00 hours) in growth chambers where the environment can be closely controlled.

Should I water all the trees in the same way?

Generally yes, in order to keep the water balance (C 13) similar in all of them; ***but***
Sometimes no, for instance when some trees have a much greater leaf area than others, because of differences in initial size, genetic variation or experimental treatment.

Here a **conditional** method of watering (C 43) is needed, with some pots getting more frequent watering than others, which will help to keep the water balance similar.

What is the best way of applying nutrients evenly?

Depending on the circumstances, you could:
(1) Thoroughly mix in some rich soil, or a slow-release fertiliser, before potting or transplanting (C 6); ***or***
(2) Water the plants evenly once every 1-3 weeks with a **dilute** liquid feed, obtained from organic wastes or a dissolved, balanced fertiliser (C 33); ***or***
(3) Sprinkle small quantities of a solid fertiliser evenly on the soil around but not touching the trees, using the same weight or volume for each container or m^2 of bed.

Can I do anything about air humidity?

This can be increased to some extent around the plants by:

(a) choosing a sheltered site for the nursery (C 25), and protecting the research plants from the wind by planting shelter-belts and hedges (C 46); ***and***

(b) watering the ground around the young trees during dry weather.

Greater control over air humidity can be achieved by growing the plants in a greenhouse.

What's the point of having greenhouses in the tropics?

They can have several advantages when growing plants for research (C 7), and doing experiments with potted plants (C 15), through having:

(A) **more control over the growing environment,** for example:

(1) higher air humidity, except during periods of bright sunshine when even a shaded greenhouse will need to be well-ventilated to prevent temperatures becoming too high;

(2) preventing temperatures from dropping below a given value (C 41);

(3) having more uniform conditions, repeatable in each of a series of experiments;

(B) **protection from wind,** which could otherwise:

(1) mechanically damage or break leaves and stems (C 3);

(2) tend to loosen root systems and blow containers over;

(3) increase the risk of water stress within the young trees (C 41);

(C) **protection from rain,** for instance when:

(1) doing research on soil moisture or nutrients;

(2) making detailed measurements;

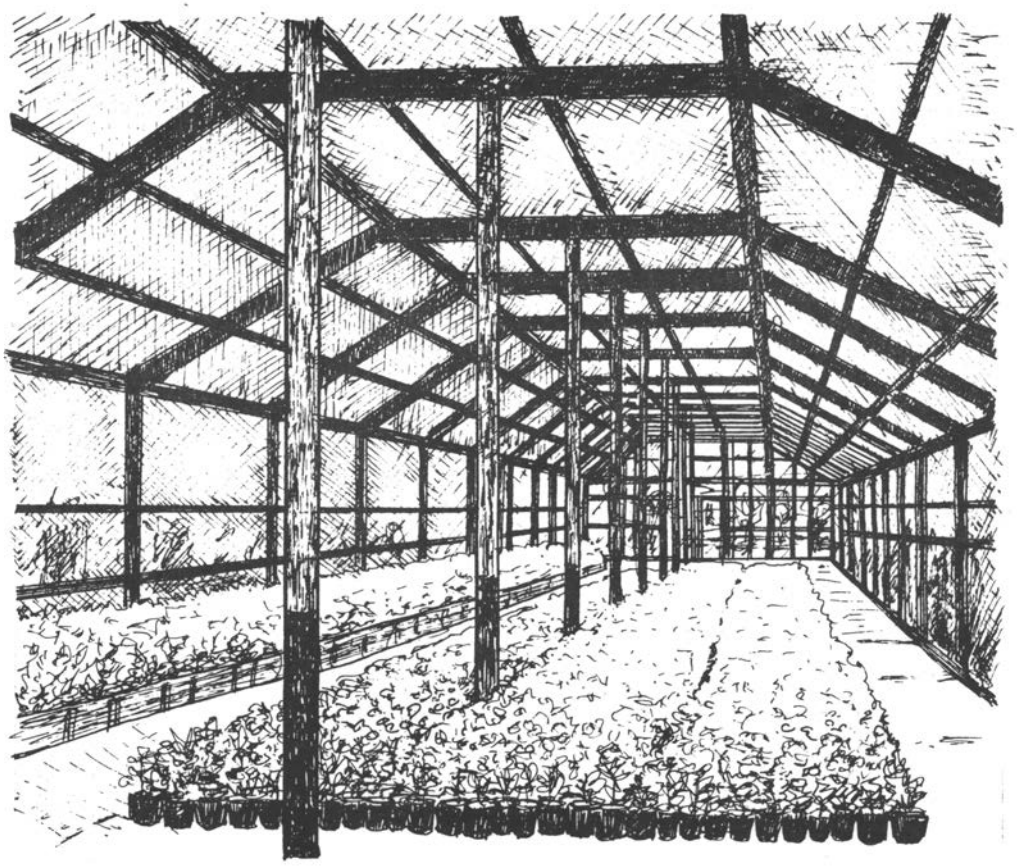
(3) using equipment that needs to be kept dry;

(D) **protection from animals,** such as:

(1) insects, particularly those that damage trees (C 45);

(2) larger animals that might eat or knock over research plants, or damage equipment (C 25, C 46); ***and***

(3) unwanted pollinators when making genetic crosses (C 5 and Manual 2).



Isn't the temperature hot enough anyway?

Not necessarily. Cool temperatures can occur, for instance:

(a) in the night, and sometimes on cloudy days;
(b) during periods when cooler air is drawn into tropical weather systems; ***or***
(c) at higher elevations, and on slopes near to mountains.

The optimum temperature for rapid shoot growth of tropical trees is often quite high. For example in young *Ceiba pentandra* it was found to be around 36°C, in the night as well as during the day. At 15°C, many species grow poorly, and at about 10°C most are damaged (C 41; and D 11 in Manual 4).

How can a greenhouse be heated?

(A) *By capturing the sun's heat,* and regulating the amount of ventilation according to cloudiness and the outside air temperature; ***and***
(B) *By using supplementary heaters,* when (A) is insufficient.
An experienced greenhouse attendant can adjust (A) and (B) manually, using appropriate heaters as needed.

If sufficient funds and a reliable electricity supply are available, the most accurate control system uses heaters and motors that open vents, both controlled by thermostats.

Waste of energy can be avoided by:

(a) avoiding draughts at night (for example under the door);
(b) using a time-switch to isolate the heating when it will not be required; ***and***
(c) including a switch that automatically cuts heat off when the vents are open.

Aren't greenhouses very expensive?

The cost of importing a large aluminium-frame greenhouse plus the sheets of glass from abroad could be quite considerable. However, polythene tunnels and their curved metal supports are much less expensive, and could easily be produced locally.

An even cheaper option is to make a 'home-made' greenhouse, as used for instance by families growing vegetables in Peru. This could be made out of curved plastic piping supported by wooden poles and covered with pieces of polythene sheeting stapled together (see A 31 in Manual 1). Another alternative is to make a 'lath house' with split bamboo roofing that gives some protection from the weather.

What about running costs?

Unless electricity is used, these are unlikely to add greatly to the running costs of the nursery, while savings can be expected through:

(1) better survival and growth of the young trees; ***and***
(2) advantages resulting from more precise research.

Some extra running costs could result from:

(a) maintenance of the greenhouse and its fittings; ***and***
(b) allowing for the *depreciation* of its value, in the expectation that replacement might be needed, say after 3-15 years.

Is it difficult to build a greenhouse?

Not particularly. Some useful hints are:

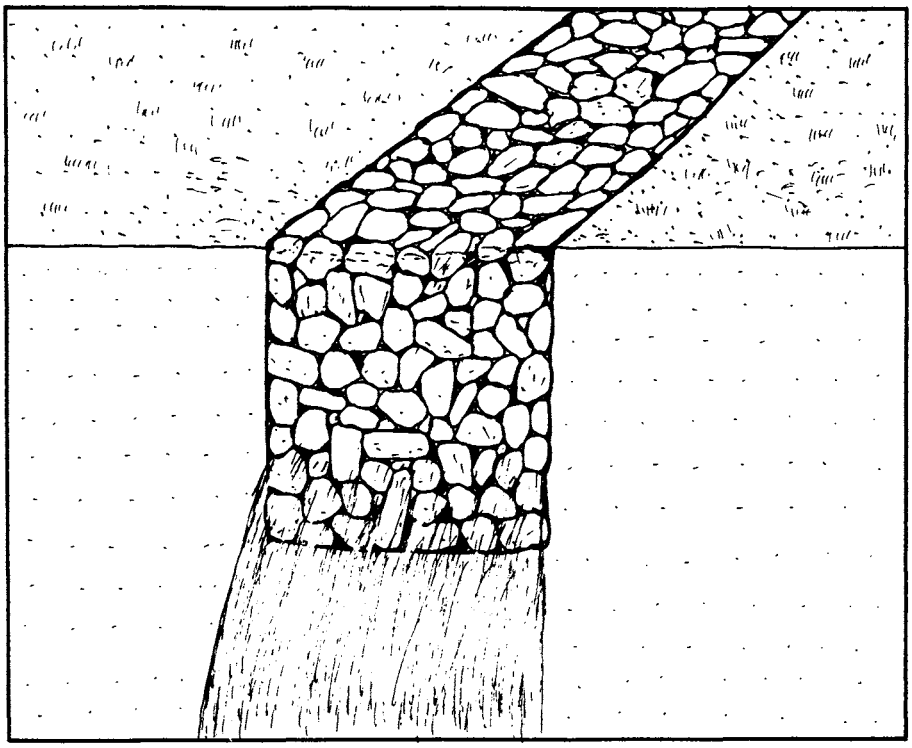
(1) choose a site that is nearly flat, but not liable to get waterlogged (C 20);
(2) avoid very heavy, poorly drained soils (C 23);
(3) sink some of the supports well into the ground, and secure them with concrete or stones hammered down, so that the greenhouse won't fall down or be blown away;
(4) face the door away from the prevailing wind direction, and take polythene sheeting under the soil level all around, to stop it being blown loose;
(5) make a well-fitting but easily movable door, to be opened when ventilation is needed; and consider the need for vents that can be opened and closed;
(6) check the air temperature inside on a hot day before putting in valuable trees.

Does it need any drainage?

Yes, this needs to be considered before building the greenhouse, or its soil may become too wet. Remember to think about the water from both:

(A) *rain outside,* which could be collected for use in a large drum, and the overflow carried away; ***and***

(B) *the excess from watering inside,* which might be dealt with by a slightly sloping 'blind' drain (C 23), covered with smaller stones or coarse gravel. This could run down the middle of the greenhouse, serving also as a path, and then provide water to a drier part of the nursery.



Blind drain.

Should I put good soil on the floor of the greenhouse?

Yes, when plants are to be sown and/or planted directly into it; ***but***
No, if trays are going to be used for germinating seeds (Manual 2), and containers (C 6) for growing on the young trees, where you could use ordinary soil, gravel or concrete slabs on the floor.

A convenient alternative for experiments is to put the containers on *staging* or old tables that raise them 0.75-1.0 m above the ground.

Will the young trees in the greenhouse need more frequent watering?

Often they may, because they will generally not get any from the rain, and the temperature inside may be higher, so that they may lose more water; ***but***
Sometimes they may not, for instance in windy, dull weather.

Do greenhouses need a lot of maintenance?

Not a great deal, provided that they have been carefully erected. Points to check on (C 40) include:

(a) mending any tears in the polythene at once, and replacing broken panes of glass;
(b) periodically firming-in any loose supports, and replacing those that have become weak;
(c) avoiding any accumulation of dead leaves and waste materials inside or nearby;
(d) repainting non-durable wood in dry weather, and watching out for termite attack.