PART 6

GROWING YOUR OWN TREES

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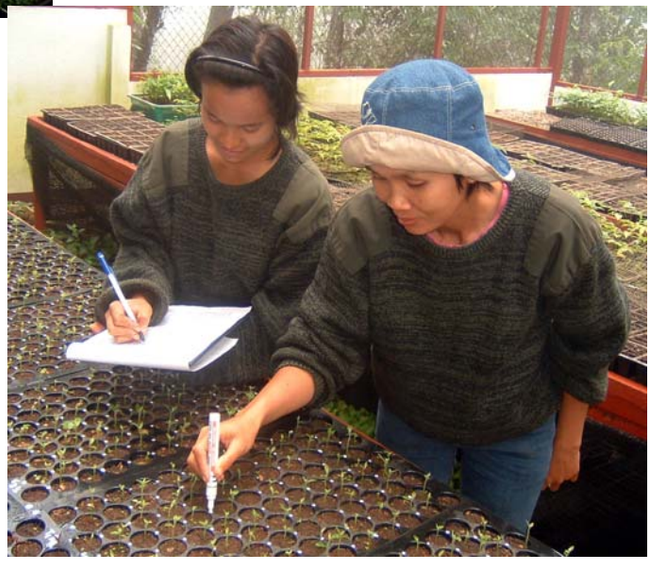
DESIGNING AND BUILDING A TREE NURSERY
COLLECTING SEEDS
HANDLING FRUITS AND SEEDS
GERMINATING SEEDS
POTTING SEEDLINGS
CARING FOR TREE SEEDLINGS IN NURSERIES
QUALITY CONTROL

Working in the Nursery - Processing Seeds

Top left - Seeds are easily extracted from the woody indehiscent pods of Cassia fistula *by gently hitting them with the flat blade of a machete.*

Top right - The method also works for the tough but fleshy fruits of Trewia nudiflora. *Removing fruit flesh prevents fungal infection.*

Above - Nicking the soft coat of Ormosia sumatrana *seeds with nail clippers greatly accelerates germination. It is one type of scarification.*



Above - Sowing seeds in modular trays makes it easy to monitor germination rates.

Right - A white marker pen is used to keep track and count each seed that germinates.

GROWING YOUR OWN TREES

A vital consideration, when planning a forest restoration project, is obtaining high quality trees for planting. Although, commercial nurseries may stock some economic tree species, they rarely grow framework trees. So, for forest restoration, growing trees in community nurseries may be the only option. Although establishing a tree nursery requires a lot of effort, it has many advantages over buying in trees from existing nurseries:

- The community controls all aspects of tree production, including species selection, quality and quantity of trees produced and production costs.
- The community takes pride in the trees produced and, therefore, takes good care of them.
- The nursery becomes a focal point for educational and social activities, which encourage greater community involvement in forest restoration projects.
- Community tree nurseries can be established close to planting sites, so transportation costs and damage to the trees when moving them are minimized.

When any group of people starts a tree nursery, a lot more happens than just the production of trees. The community spirit is strengthened, social relationships develop and participants learn as much about each other as they do about trees and forests.

In this Part, we present the basic skills and knowledge needed to produce mixed crops of framework tree species in small-scale nurseries, of the kind that can be easily managed by a community or by the staff of a protected area. Although the techniques described have been scientifically tested in northern Thailand, they are probably suitable for neighbouring regions, especially with some experimentation to adapt them to local conditions.

Starting a community tree nursery is as much about building a social concensus for environmental conservation as it is about producing trees.

Section 1 - Designing and Building a Tree Nursery

A nursery must provide ideal conditions for the growth of tree seedlings, whilst protecting them from stresses. It should also provide a comfortable and safe place for nursery workers.

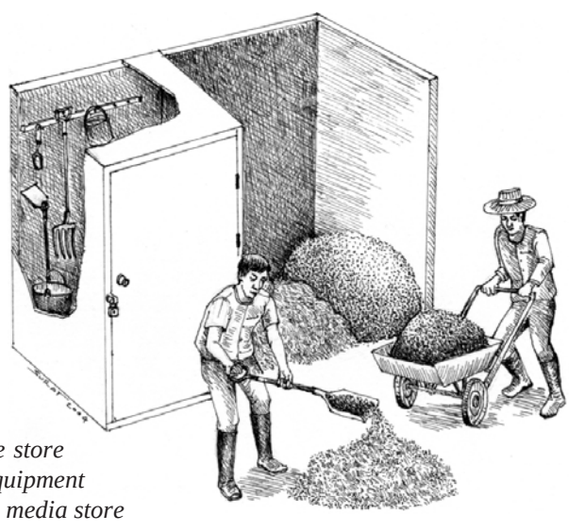
Where should a nursery be built?

A nursery site should be protected from extremes of climate. It should be:

- flat or slightly sloping, with good drainage (steeper slopes require terracing);
- sheltered and partially shaded (a site protected by existing trees is ideal);
- close to a permanent supply of clean water (but free from the risk of flooding);
- large enough to produce the number of trees required and to allow for future expansion;
- accessible by motor vehicle for convenient transportation of young trees and supplies and
- close to a supply of suitable soil.

How much space is needed?

The size of the nursery ultimately depends on the size of the area to be planted, which in turn determines how many trees must be produced each year. Other considerations include seedling survival rates and growth rates (which determine how long plants must be kept in the nursery).



A lockable store to keep equipment safe and a media store are essential parts of a tree nursery.

The table opposite relates the size of the area to be planted per year to the size of the nursery required. These calculations refer to seeds germinated in trays and transplanted into containers. For example, if the area to be planted is 4 rai per year, 2,000 seedlings will be needed, requiring a nursery of approximately 50 m^2.

What are the essential features of a tree nursery?

A tree nursery need not be costly. Locally available materials, such as recycled wood, bamboo and palm leaves can all be used to build a simple inexpensive nursery. The essential requirements include:

- a shaded area with benches for seed germination, protected from seed predators by wire mesh;
- a shaded area where potted seedlings can be grown until ready for planting (shade should be removable to allow hardening of the young trees prior to planting);
- a work area for seed preparation, pricking-out etc;
- a reliable water supply;
- a lockable store for materials and tools;
- a fence to keep out stray animals and
- a shelter and toilet for staff and visitors.

How should the nursery be designed?

Careful consideration of nursery layout can greatly increase tree production efficiency. Think about the various activities to be carried out and the movement of materials around the nursery. For example, position container beds near to the main access point, where trees will eventually be loaded on to vehicles before planting. Likewise place the lockable store and media store near the potting area.

Table 6.1 The space needed for a tree nursery depends on the size of area to be planted each year.

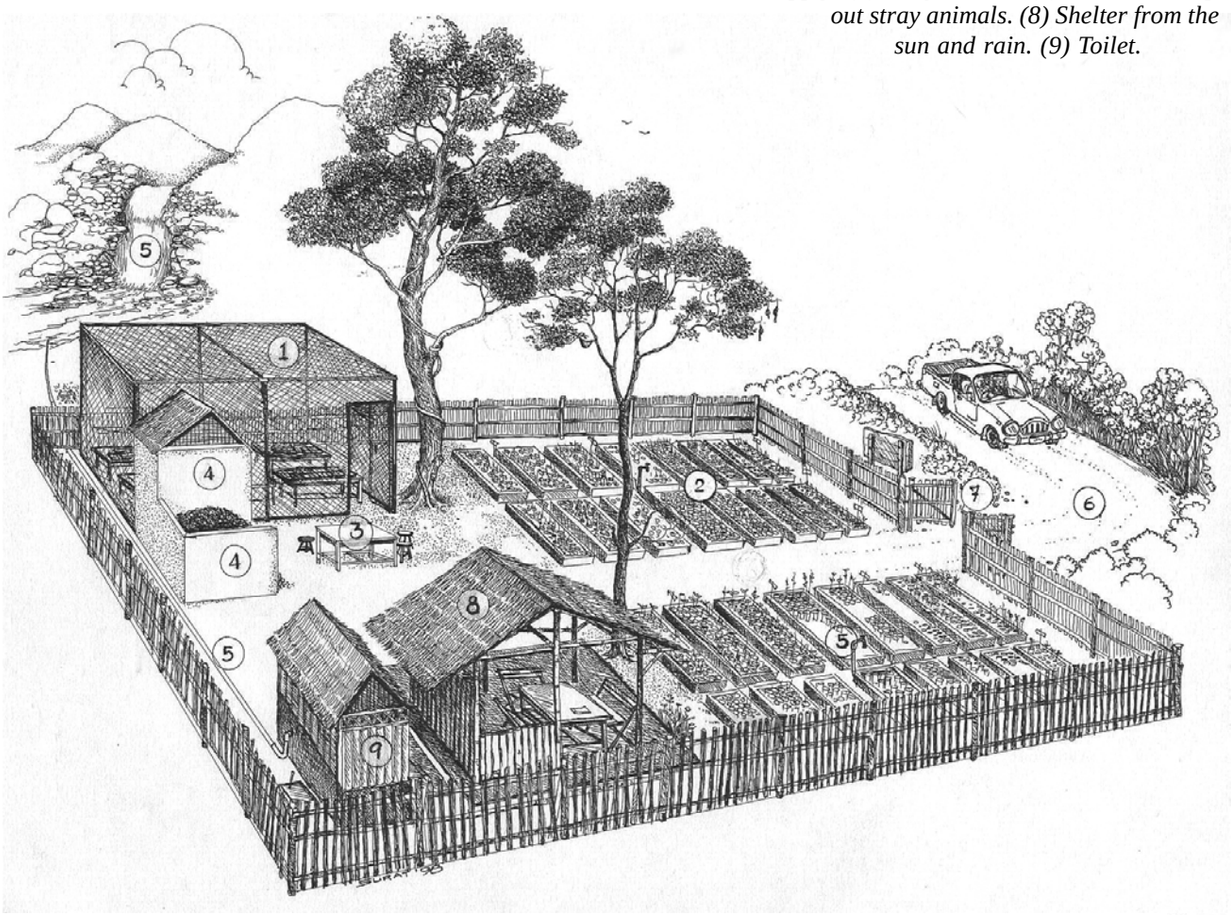
Area to be planted (rai/yr)[1]	Number of trees needed	Seed germination area (sq m)	Standing-down area[2] (sq m)	Storage, shelter, toilet *etc.* (sq m)	Total nursery area needed (sq m)
1	500	2	7	15	24
2	1,000	4	14	15	33
4	2,000	8	28	15	51
20	10,000	40	140	15	195
40	20,000	80	280	15	375

[1]6.25 rai = 1 ha

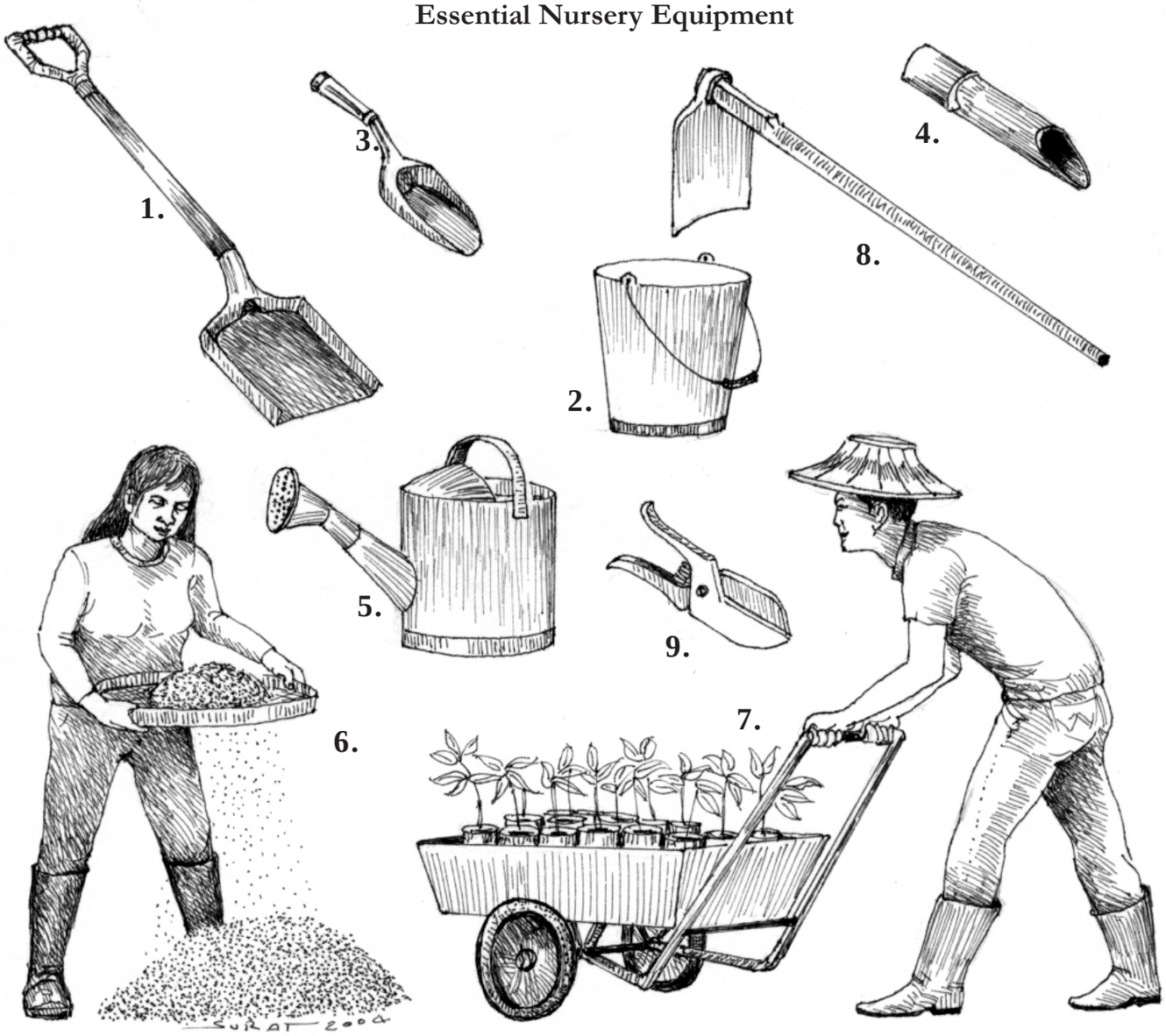
[2]An additional area of similar size for hardening-off seedlings might be required if removal of shade from the area for containerized seedlings is not possible.

Nursery Design

Essential features of a simple tree nursery: (1) Germination shelter protected from seed predators. (2) Standing-down area (shade removed). (3) Potting work area. (4) Medium store and lockable equipment store. (5) Reliable water supply. (6) Easy access. (7) Fence to keep out stray animals. (8) Shelter from the sun and rain. (9) Toilet.



Essential Nursery Equipment



What tools are required?

Growing trees requires simple, inexpensive equipment. Many of the items illustrated above will already be available in an average agricultural community and could be borrowed for nursery work:

- shovel (1) and buckets (2) for collecting, moving and mixing potting media;
- trowels (3) or bamboo scoops (4) for filling containers with potting medium;
- a watering can (5) and hose, both with a fine rose;
- spatulas or spoons for pricking-out seedlings;
- a sieve (6) for preparing the potting medium;
- a wheelbarrow (7) for moving plants and materials around the nursery;
- hoes (8) for weeding and maintaining standing-down area;
- secateurs (9) for pruning seedlings and
- a ladder and basic construction tools for erecting shade netting *etc.*

SECTION 2 - COLLECTING SEEDS

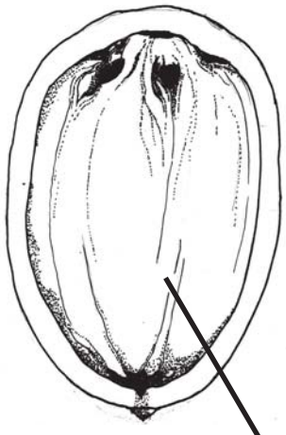
What are fruits and seeds?

The structure sown in a germination tray is not always just the seed. Sometimes the whole fruit is sown *e.g.* the nuts of oaks and chestnuts (Fagaceae) or sometimes it is the pyrene. Pyrenes consist of one or several seeds enclosed within the hard inner wall of the fruit (endocarp). For example, up to five seedlings can emerge from a single pyrene of *Spondias axillaris*. Germination of seeds within pyrenes can be difficult, since the pyrene wall prevents water from penetrating the seed(s). So, a basic understanding of fruit and seed morphology can be helpful in deciding appropriate pre-sowing seed treatments.

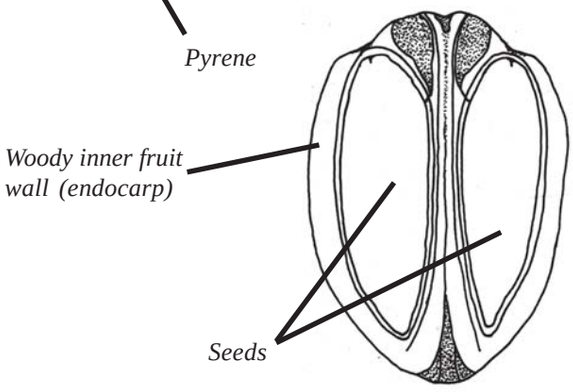
A seed develops from a fertilized egg cell (ovule) contained within the ovary of a flower, usually after pollination and fertilization. Being the products of sexual reproduction, during which the genes of the two parents are combined, seeds are an essential source of genetic diversity within tree populations.

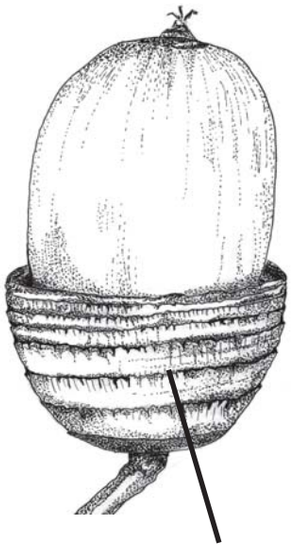
Seeds consist of three main parts: the covering part, the storage part and the embryo. The seed coat or testa protects seeds from harsh environmental conditions and plays an important role in dormancy. Food reserves, to sustain metabolism during and immediately after germination, are stored in the endosperm or the cotyledons. The embryo consists of a rudimentary shoot (plumule), a rudimentary root (radicle) and seed leaves (cotyledons).

Fruits are derived from the ovary wall. They may be broadly classified as "simple" (from the ovary of a single flower); "aggregate" (from the ovary of a single flower, but several fruits fused into a larger structure) or "multiple" (from ovaries of several flowers fusing). Each broad category contains several fruit types.

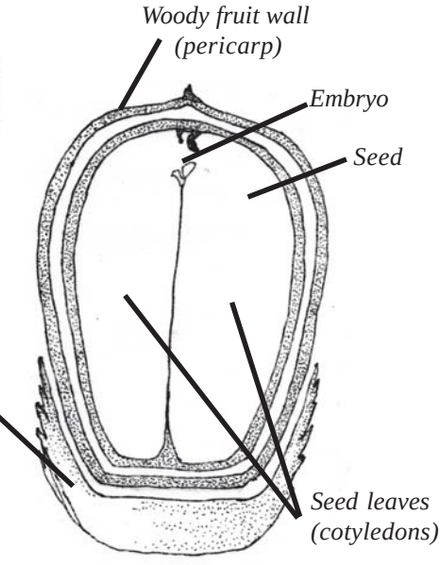


It is impractical to extract seeds from the fruits of Spondias axillaris, *so after removing the outer fruit flesh, the whole pyrene is sown, including the inner fruit wall (endocarp) enclosing up to five seeds.*

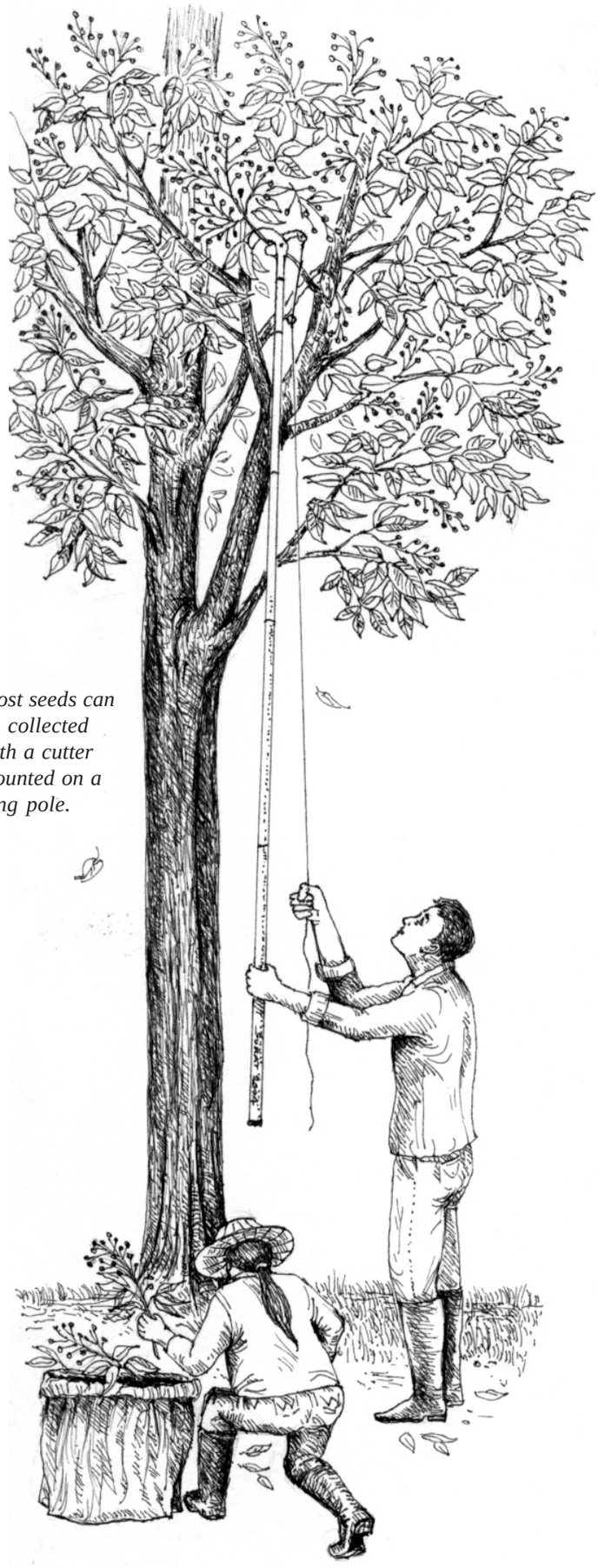




Acorns are the particular form of nuts produced by the genus Quercus *(Family Fagaceae).*



For growing oaks, such as this Quercus semiserrata, *the entire fruit (nut) is sown (after removing the cupule). Nuts are fruits with woody outer walls, which do not split open to release the single seed inside (drawn by Susan Doust).*



Most seeds can be collected with a cutter mounted on a long pole.

When should seeds be collected?

In the seasonally dry forests of northern Thailand, many tree species fruit in every month of the year, so at least one seed collection trip is needed every month. Fruiting peaks at the end of the dry season and at the end of the rainy season (see Fig. 3.1), whereas reduced numbers of fruiting tree species in the early rainy season means that fewer seed collection trips are needed then.

For northern Thailand, the fruiting months of individual tree species can be found in Part 9 of this book and also in Maxwell and Elliott (2001). For other regions, phenology studies are needed.

Find seed trees in the forest and monitor them frequently, from flowering onwards, to judge the best time to collect fruits. Collect fruits once they are fully ripe but just before they are dispersed or consumed by animals. Seeds collected too early will be undeveloped and fail to germinate, whereas those collected too late may have lost viability.

For fleshy fruits, ripeness is usually indicated by a change in the colour of the fruit usually from green to a brighter colour, to attract seed-dispersing animals (*e.g.* the fruits of *Prunus cerasoides* turn from green to red). If animals are seen eating the fruits, it is a sure sign that the seeds are ready for collection. For dehiscent fruits, ripeness occurs when they start to split open (*e.g. Erythrina subumbrans*).

It is usually better to cut fruits from the tree branches rather than to pick them up from the ground.

Climb the tree to cut down ripe fruit. Use a safety harness and never do this alone. A more convenient method of seed collection is to use a cutter mounted on the end of a long pole. Fruits can also be dislodged by shaking the whole tree or some of the lower branches.

For very tall trees, collecting fruits from the forest floor may be the only option. If so, make sure the seeds are not rotten, by cutting them open and looking for a well developed embryo, and/or a solid endosperm (if present). Do not collect any fruits or seeds with signs of fungal infection, teeth marks from animals or small holes made by seed-boring insects. Collect fruits/seeds from the forest floor, when the first truly ripe fruits begin to fall.

Where should seeds be collected and from how many trees?

Genetic variability is essential to enable species to survive in changeable environments. Maintaining it is one of the most important considerations in any tree planting programme for biodiversity conservation. It is therefore crucial that planted trees are not all closely related. The best way to prevent this is to collect seeds from at least 10 parent trees. If seeds are collected from just one, or a few trees, all the seedlings are essentially siblings. Once they mature in the planted plots, they may inbreed with each other, reducing genetic variability in subsequent generations. Cross-pollination with unrelated trees can restore genetic diversity, but only where such trees grow near to planted sites.

Various international organizations advise that to maintain genetic diversity in tree planting programmes, seeds should be collected from as many trees as is practicable (preferably 25-50), situated as close as possible to the planting site. Equal numbers of seeds from each seed tree should be mixed together prior to sowing to ensure equal representation of all the seed trees.

How many seeds should be collected?

The number of seeds collected depends on the number of seedlings required, seed germination percentage and seedling survival rates. Keeping accurate records will help determine the numbers required in future collections.

What precautions should be taken when collecting seeds?

Seed collection trips require planning and liaison with the people responsible for treating and sowing the seeds, because the seeds are vulnerable to desiccation and/or fungal attack, if they are not processed quickly. Sow seeds as soon as possible after collection. Do not leave them in sun, where they may dry out and do not leave them in damp places, where they may rot or germinate prematurely.

What information should be recorded when collecting seeds?

Each time you collect seeds from a new species, give that species a unique species number. Nail a numbered, metal tag on to the tree, so that you can find it again. Collect a specimen of leaves and fruits for species identification. Place the specimen in a plant press, dry it and ask a botanist to indentify the species. Use a pencil to write the species name (if known), date and species number on a label and place the label inside the bag with the seeds.

On a data sheet (example below), record essential details about the seed batches collected and what happens to them from collection time until they are sown in germination trays. This information will help to determine why some seed batches germinate well, whilst others fail and thus improve seed collection methods in the future.

Species number: **Batch number:**

SEED COLLECTION RECORD SHEET

Family:

Species: **Common name:**

Date collected: **Collector's name:**

Tree label no.: **Tree girth:**

Collected from ground [ ] or from tree [ ]

Location: **Elevation:**

Forest type:

Approximate no. seeds collected:

Storage/transport details:

Pre-sowing treatment: **Sowing date:**

Voucher specimen collected [ ]

Notes for herbarium label

Section 3 - Handling Fruits and Seeds

How should fruits be processed before collection?

Seeds of most tree species are usually removed from their fruits and cleaned before sowing. Failure to remove fruit pulp, for example, encourages fungal infection. The type of processing required depends on the fruit type.

Fleshy fruits

Remove as much flesh as possible with a knife and wash off remaining flesh with water. Soak firm fruits, such as *Melia toosendan*, in water for 2-3 days to soften the pulp sufficiently to ease seed extraction. Once the fruit pulp has been removed, seeds may germinate quite quickly, so either sow them immediately, or process them for storage.

In some species, removal of the pulp reveals a pyrene containing one or more seeds (*e.g. Prunus cerasoides* and *Spondias axillaris* respectively). If seeds are to be planted immediately, crack open the tough woody endocarp to allow water to penetrate into the embryo and trigger germination. Use a vice, hammer or knife to gently crack open pyrenes without damaging the seed(s) inside.

Dry dehiscent fruits

Dry dehiscent fruits, such as pods of trees in the Leguminosae family (*e.g. Erythrina subumbrans*), split open naturally, so lay them out in a dry, sunny place until they open naturally and the seeds either fall out on their own or can be easily shaken out.

Dry indehiscent fruits

Dry fruits that do not split open naturally (*e.g. Cassia fistula*) must be cut open or prized apart with secateurs or other tools.

Seeds of some indehiscent fruits, such as samaras and nuts, are not usually extracted. Place whole fruits in germination trays. In some cases, remove fruit appendages for easier handling *e.g.* the wings of samaras (*e.g. Acer* spp) and the cupules of nuts *e.g.* of acorns or chestnuts (*Quercus* spp and *Castanopsis* spp, respectively, Family Fagaceae).

Species number: **Batch number:**

GERMINATION RECORD SHEET

Species:

Date sown: **Number of seeds sown:**

Germinated	Date	Days since sowing
First seed		
Median seed		
Final seed		

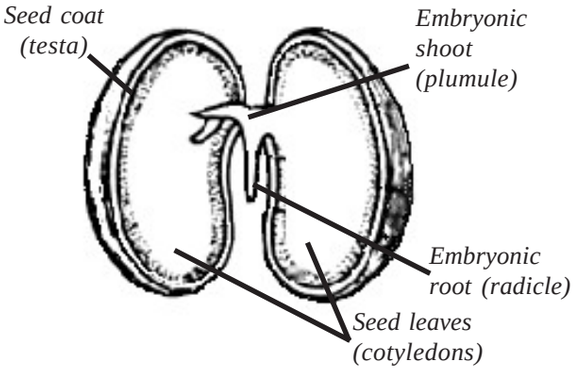
Number germinated: **% Germination:**

Pricking-out date:

No. seedlings pricked out:

Date	No. Germinated	Date	No. Germinated

Seed Structure



Fruit Types of Some Native Forest Tree Species of Northern Thailand


Sarcosperma arboreum *(drupe)*


Phoebe lanceolata *(drupe)*


Alstonia scholaris *(capsule)*,


Shorea siamensis *(nut)*


Heynea trijuga *(capsule)*


Aphanamixis polystachya *(capsule)*

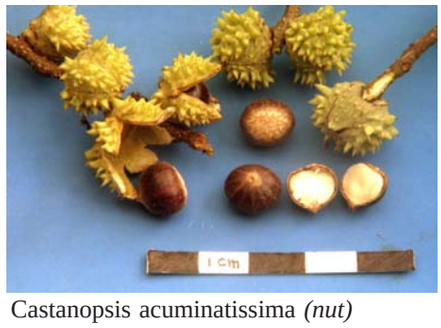

Anneslea fragrans *(capsule)*


Cratoxylum formosum *ssp.* pruniflorum *(capsule)*

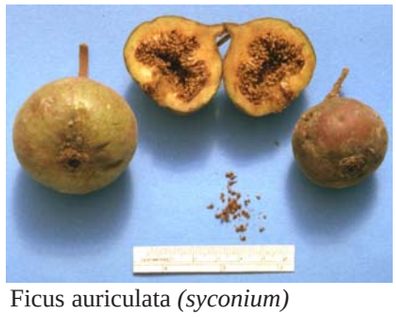

Archidendron clypearia *(pod)*

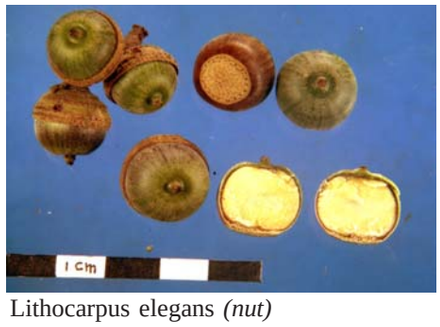

Quercus semiserrata *(nut)*


Manglietia garrettii *(aggregate capsules)*


Castanopsis acuminatissima *(nut)*


Albizia odoratissima *(pod)*


Ficus auriculata *(syconium)*


Lithocarpus elegans *(nut)*

Knowing which fruit type you are dealing with can help you decide on effective treatments to remove seeds from the fruit, break dormancy and maximize germination.

Working in the Nursery - Potting

Top left - Mixing soil with peanut and coconut husks produces a well-structured potting medium with good drainage.

Top right - Lift seedlings fom the germination tray with a spoon, holding them by a leaf, so as not to damage the stem.

Place the seedling in a container and top up with potting medium.

Bang the container on the ground to settle the medium and top up again if necessary.

Why should seed be stored?

Storing seeds usually reduces their viability, so in most cases, sowing seeds immediately after collection is the best strategy. However, seed storage may be necessary for three reasons.

Firstly, seed storage allows seeds of framework tree species to be distributed to areas where they may be unavailable.

Secondly, seed storage can shorten the length of time that fast-growing tree species need to be kept in nurseries. Sowing seeds immediately after collection sometimes results in seedlings of faster-growing trees reaching a plantable size several months before the optimum planting time. Such seedlings must be pruned to prevent them from outgrowing their containers and they must be stored in the nursery for several months, wasting space and resources. Storing the seeds of such species for a few months before sowing them enables seedlings to be grown to the optimum size just in time for the planting season.

Thirdly, some tree species produce large fruit crops in some years and no fruits in others (*i.e.* masting). Obviously, for such species, storing seeds collected during masting years for sowing in non-masting years enables a steady supply of seedlings to be maintained.

During seed storage, the main objective is to maintain seed viability. So seed must be protected from insect attack or fungal infection and held in an environment, which reduces seed respiration and metabolism."Orthodox" seeds can be stored easily in dry, cool (or even refrigerated) conditions and still maintain their viability for a long time. On the other hand, "recalcitrant" seeds pose considerable problems.

What's the difference between orthodox and recalcitrant seeds?

Orthodox seeds may be dried to a very low moisture content, without significantly reducing their viability. They can also be stored at low temperatures (usually a few degrees above freezing).

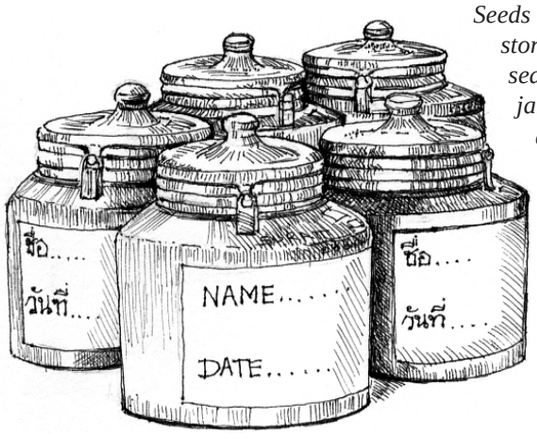
In contrast, recalcitrant seeds are much more sensitive to drying and chilling. Some have no dormancy at all and are relatively short lived. Most cannot be dried to moisture contents lower than 60-70% and they cannot be chilled. The opportunity to store recalcitrant seeds is therefore very limited and usually requires technologies that are impractical in simple village tree nurseries. So, if you want to experiment with seed storage, first try to confirm from the literature that the seed species you want to work with is orthodox.

How can orthodox seeds be stored?

Storage of dried seed at ambient temperatures should be sufficient to maintain viability for 12 - 24 months. Longer periods of storage may require low temperatures, but this is usually not necessary for most short-term forest restoration needs.

Slowly dry seeds in the sun, over several days, to at least 5-10% moisture content, but preferably lower. This reduces the metabolism of the seeds and prevents growth of fungi. To make sure that the required level of dryness has been reached, weigh a small sample of seeds and place them in an oven at 120-150□ C for an hour. The weight of the seed sample, after it has been removed from the oven, should not have decreased by more than 10%. Throw away the sub-sample of seeds used to confirm dryness.

Immediately after seeds have been dried, place them in airtight containers. Fill containers to the top with seeds to minimize the volume of air (and moisture) trapped inside them. Efficiently sealing containers is crucial, to prevent any moisture or fungal spores from entering. If containers are likely to be opened frequently, store seeds in small sealed packets within larger containers, to minimize exposure of remaining seeds to air and moisture. Putting a small sachet of silica gel in containers helps maintain dryness.



Seeds should be stored in well-sealed, labelled jars with as little air as possible.

How can seed dormancy be shortened?

Dormancy protects seeds during dispersal and ensures germination at the optimal time of the year in their natural habitat (see Part 3). However, for efficient tree production in nurseries, immediate germination is often requried. In the forest, dormancy is a survival mechanism; in the nursery, it unnecessarily prolongs tree production time. Therefore, after seeds have been extracted from fruits, various treatments may be applied to break dormancy. The treatment used for each species depends on the particular dormancy mechanism(s) present.

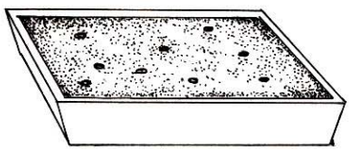
Germination is triggered when the embryo inside the seed absorbs water. A thick, impervious seed coat can prevent this, so one of the simplest techniques to break dormancy is to cut away a small piece of the seed coat with a sharp knife or nail clippers. For smaller seeds, gently rubbing them with sandpaper can be equally effective. These techniques are called scarification. During scarification, great care must be taken not to damage the embryo within the seed. Soaking seeds in hot water or sulphuric acid can have a similar effect, but there is a greater risk of damaging the embryo with these treatments.

Some species have "mechanical" dormancy *i.e.* the seed coat is too strong for the growing seedling to push through. For such species, acid treatment is recommended. Acid can kill the embryo, so seeds must be soaked in acid only long enough to soften the seed coat, without penetrating to the embryo.

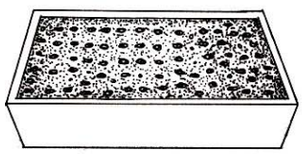
In some seeds, germination is inhibited by chemicals, which must be removed to break dormancy. Chemical inhibitors can be present in the pulp of fleshy fruits, so simply ensuring complete removal of fruit pulp may solve this problem. However, if the inhibitors are within the seed, they must be washed out. Repeated soaking and drying is the appropriate treatment.

Some suggested treatments to break seed dormancy for each framework tree species are presented in Part 9. For other species, try some simple experiments. Apply various treatments to replicate batches of 50-100 seeds (at least 3 replicates per treatment) and compare mean germination percent and median length of dormancy (Part 3, Section 5) with "control" replicates (no treatments applied) placed next to each treatment replicate. Use paired t-tests to analyse the results.

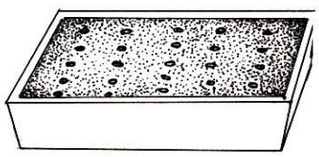
Sowing Density



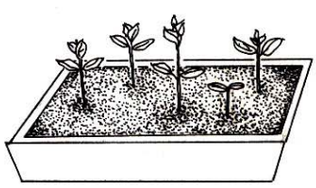
Too sparse - a waste of space and resources in the nursery.

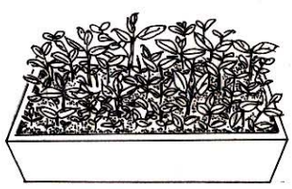


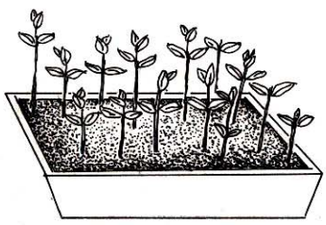
Too dense - creates ideal conditions for the spread of diseases. Seedlings shade each other and compete for nutrients.



Just right - allows air circulation between the seedlings and reduces competition among them.







SECTION 4 - GERMINATING SEEDS

Germination consists of three overlapping processes. Absorption of water causes swelling of the seed and splitting of the seed coat. Food reserves are mobilized (from the endosperm) and transported to the embryonic root (radicle) and shoot (plumule) (see p 82), which begin to grow and push against the seed coat. The final stage is actual emergence of the radicle and plumule through the seed coat. In germination trials, seeds are counted as having germinated when the radicle and/or plumule can be seen emerging.

Sowing seeds is the final stage of seed handling, and marks the start of the growing process. The time of seed sowing is determined by the fruiting time of each particular species or, in the case of stored seeds, the estimated growing time required in the nursery.

The three major factors that influence seed germination are moisture, temperature and light. It is important to maintain environmental conditions that will encourage rapid and synchronous germination. Seedlings are at their most vulnerable just after germination. They are particularly susceptible to disease, mechanical damage, physiological stress and predation. Consequently, great care has to be taken to avoid these problems.

How can I ensure high quality seeds are sown?

It is very important to sow only the highest quality seeds available. They should have no signs of fungal growth, teeth marks from animals or small holes made by seed-boring insects, such as weevils. For larger seeds, a quick way to get rid of the dead ones is to throw the seeds into a bucket of water and wait for 2-3 hours. Skim off the ones that remain floating; as they have air inside instead of dense cotyledons and a functioning embryo. Sowing poor quality seed is a waste of time and space, and may encourage the spread of disease around the nursery.

How should seeds be sown?

Sow seeds into germination trays, filled with a suitable medium. The trays should be 6-10 cm deep, with plenty of drainage holes in the bottom. The germination medium must provide support for the germinating seedlings until they are ready for pricking-out and have good aeration and drainage. Seedling roots need to breathe, so the germination medium must be porous. Too much water fills the air spaces in the medium and suffocates seedling roots. It also encourages disease. Compacted soil inhibits both germination and seedling growth. Therefore, forest soil must be mixed with organic materials such as rice or coconut husk to create a well-structured medium.

FORRU-CMU recommends using a mixture of two thirds forest soil to one third coconut husk. A mix of 50% forest soil with 50% coarse sand is more suitable for small seeds, especially those susceptible to damping-off (*e.g. Ficus* spp). It is important to include some forest soil in the medium, since it provides a source of mycorrhizal fungi, which are very beneficial to the growth of young tree seedlings. Do not add fertilizer to the seed germination medium.

Sow small to medium-sized seeds just below the surface of the medium, to a depth of approximately two to three times their diameter. This protects seeds from predators and drying out and prevents them from being washed away during watering. If rats or squirrels are a problem, then cover germination trays in wire mesh.

If the seeds are sown too closely together, the seedlings may be weakened, and more susceptible to disease. Space the seeds at least 1-2 cm apart (more if the seeds are large) to prevent over-crowding. Water the germination trays lightly, immediately after sowing the seeds and regularly thereafter. Use a spray bottle or a watering can with a fine rose to avoid compacting the surface of the medium. Watering too frequently encourages fungal and bacterial diseases. Place the trays in shade to reduce drying out and scorching of leaves.

Larger seeds with high germination rates (*e.g. Quercus semiserrata*) can be sown directly into individual containers, filled with potting medium.

How can damping-off be prevented?

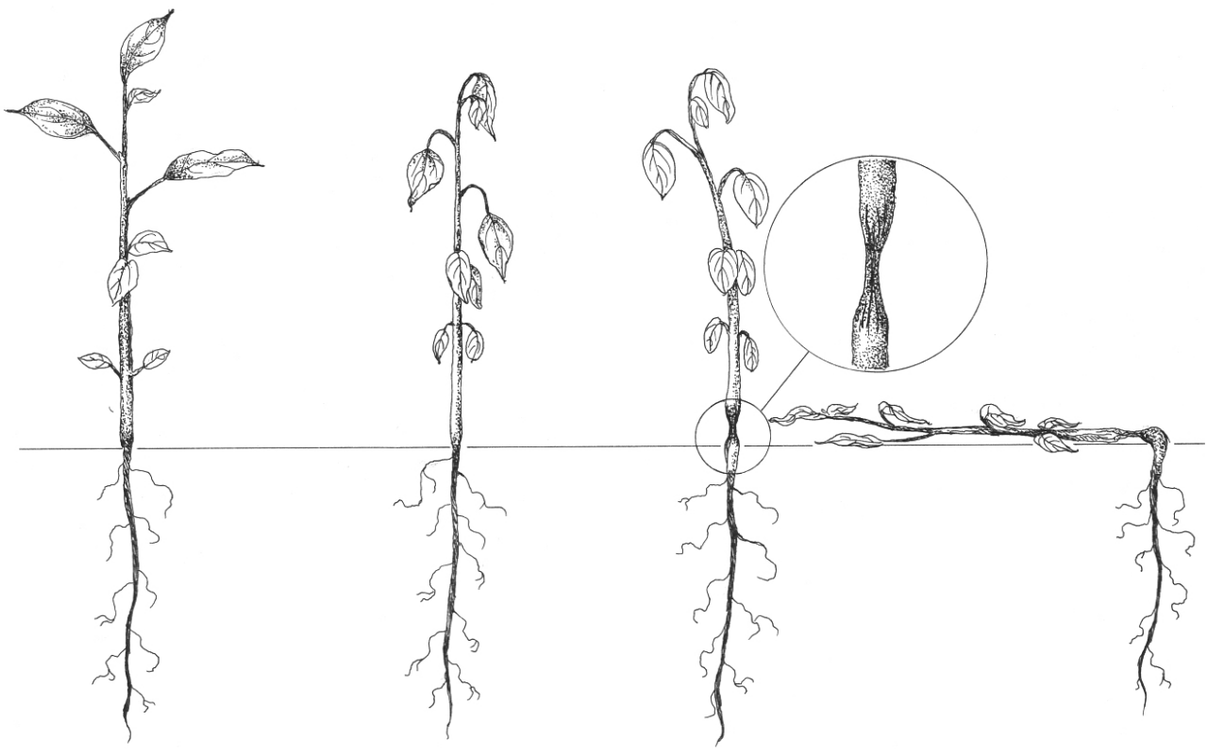
The term "damping-off" refers to a wide range of soil-borne diseases, which attack seeds, pre-emergent sprouts and young seedlings. Pre-emergence damping-off causes seeds to become soft and turn brown or black. Recently germinated seedlings are most vulnerable to post-emergence damping-off in the soft stem tissue at or just above the soil surface. Infected seedlings look like they have been pinched at the base of the stem, which turns brown.

If damping-off disease becomes a serious problem, apply a fungicide. Although use of chemicals is never desirable, prompt application of small quantities of fungicide at the outbreak of disease could mean the difference between saving an entire tree crop or having to wait another year to collect seeds again.

Seeds may be pre-soaked (dressed) in Captan or Thiram to reduce the incidence of damping-off. Once a seedling has become infected, it must be removed from the germination tray immediately and destroyed, to prevent the disease from spreading. Basic hygiene measures can significantly reduce the incidence of damping-off diseases and reduce the need to apply fungicides. These include; not sowing seeds too densely, maintaining a well-structured germination medium, not over-watering, ensuring free air movement around the seedlings and disinfecting any nursery tools that have come into contact with soil.

For species that are particularly susceptible to damping-off, particularly *Ficus* spp, FORRU-CMU recommends using a germination medium of 50:50 sand:forest soil, without coconut husk, since there is some evidence that it may increase the risk of damping-off. Apply Captan to the soil surface, when the seeds are sown and again one month afterwards.

Damping-off Disease



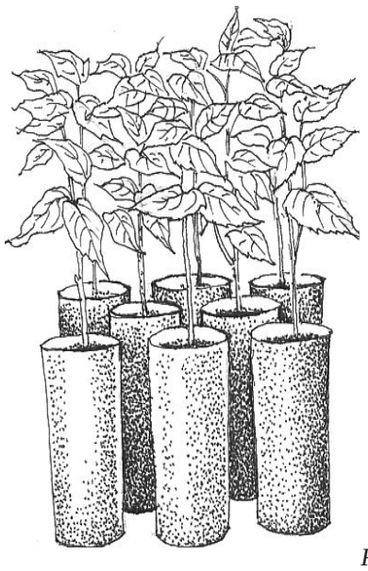
Damping-off disease, caused by various fungi, often first manifests itself with the appearance of brown lesions on the stem, at or just above the soil surface. The lesions spread and the leaves begin to wilt. Finally the stem collapses and the seedling dies.

SECTION 5 - POTTING SEEDLINGS

Should seedlings be grown in containers or soil beds?

There are two ways to grow tree seedlings: i) in containers (containerized) and ii) in beds of soil (bare-rooted). Containerized seedlings are preferred for forest restoration projects, since digging up seedlings from a soil bed and transporting them to the planting site in a bare-rooted state increases transplantation shock. An experiment carried out by FORRU-CMU found significantly lower growth amongst bare-rooted seedlings compared with containerized ones, during the first year after planting out.

With a containerized system, seedlings are first germinated in trays and then transplanted into containers for "growing on", until they grow large enough to be planted out. Containers protect the trees during transportation to the planting site. Within the container, the root ball remains intact and in contact with soil the whole time during transportation and planting, thus minimizing transplantation stress.



Black plastic bags (9 x 2 inches) are cheap but not reusable and can cause root curling.

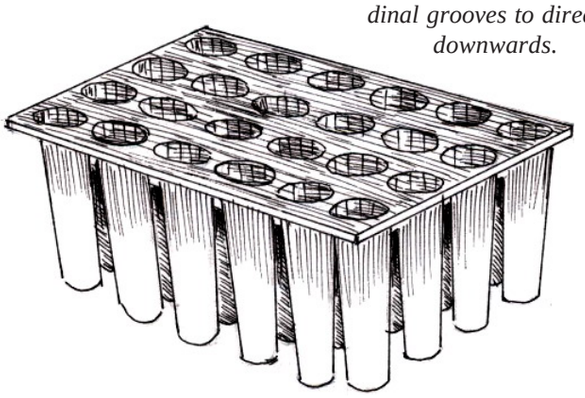
What kind of containers are recommended?

Containers must be large enough to allow development of a long and dense root system. They must have sufficient holes to permit good drainage, be lightweight, inexpensive and readily available.

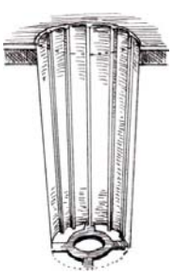
Black plastic bags (9 x 2 inches) are strong, lightweight, cheap and effective and have been used successfully at FORRU-CMU with a wide range of species. However, they do have some disadvantages. The bags can bend easily, particularly during transportation, which may damage the root ball, causing it to crumble during planting. Root spiralling may occur at the base of the bag, increasing vulnerability of the tree to wind-throw later in life. Roots can grow through the drainage holes into soil beneath, so that roots are severed when the tree is lifted. These problems can be minimized by following the nursery practices described in Section 7.

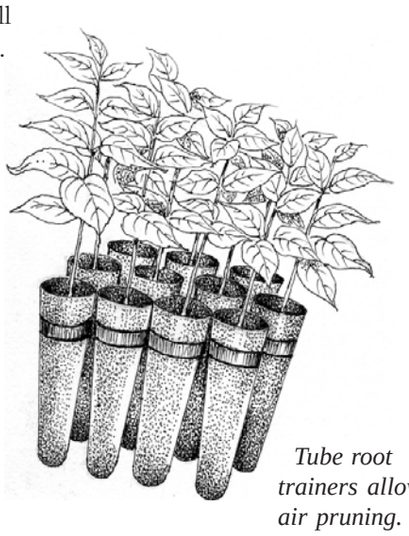
How useful are root trainers?

Root trainers are rigid plastic pots with grooves down the sides to direct root growth downwards thus preventing root spiralling. REX trays, made in Thailand, are recommended. They consist of blocks of 24, tough, plastic pots with vertical grooves and large holes in the bottom to allow air pruning (see Section 7). Although initially more expensive than bags, they can be reused many times and their rigidity protects the root ball during transportation.



REX tray root trainers have deep longitudinal grooves to direct root growth downwards.





Tube root trainers allow air pruning.

What makes a good potting medium?

The potting medium consists of solid particles with pores between them for aeration and drainage. The medium must physically support a vigorously growing tree and supply the roots with oxygen, water and nutrients.

The roots of trees growing in containers have access to only the limited volume of medium in the container. Forest soil alone is unsuitable as a potting medium, because it is easily compacted and the container prevents free drainage. This causes water-logging, which suffocates roots. Good drainage is essential, but the medium must also retain enough water to supply the plants between watering times.

Although forest soil alone is a poor potting medium, some forest soil should always be included in the medium, since it carries the spores of mycorrhizal fungi that help tree seedlings to grow.

To prevent compaction, mix forest soil with bulky organic matter *e.g.* rice husk charcoal, coconut husk, peanut husks or coarse sand or try making your own compost from locally available organic waste. Mixing forest soil with these ingredients will "open out" the medium and improve drainage and aeration. Whichever materials you choose, they should be locally available throughout the year and cheap.

Sieve the soil and organic materials to remove large lumps and stones and mix them together on a hard, flat surface using a shovel. Store the medium in a moist condition.

One medium that has been used successfully at FORRU-CMU for many species consists of forest soil, peanut husk and coconut husk, mixed in the ratio of 2:1:1.

Never re-cycle the potting medium. When disposing of weak or diseased seedlings, the potting medium, in which they grew, must also be discarded well away from the nursery, to prevent the spread of diseases.

Box 6.1 – Alternatives to seeds: 1. Wildlings

Growing a mixed crop of framework tree species from seeds takes at least 18 months. Waiting for trees to fruit and for seeds to germinate requires great patience. So, is there a faster way to produce framework tree saplings? Wildlings are seedlings dug up from the wild and cultivated in a nursery. Forest trees produce vast numbers of surplus seedlings, most of which die. So, digging up a few for transfer into a nursery does not harm the forest ecosystem. Transplanting wildlings from a cool, shady forest directly into an open deforested site usually kills them. So wildlings must be potted, cared for in a nursery and hardened off before planting-out. At FORRU-CMU, Kuarak (2002) determined how to use wildlings to produce framework trees for planting:

"In the forest, locate a suitable parent tree of the required species, which fruited heavily the previous fruiting season. Dig up seedlings, no taller than 20 cm (larger ones have high mortality due to severe transplantation shock), within a 5-m radius of the parent tree (those seedlings would die anyway from competition with the parent tree). To minimize damage to the root system, do this at the beginning of the rainy season, when the soil is soft.

Prune the wildings, just after digging them up, to significantly reduce mortality and increase growth rate. Cut back the stem by one third to one half. Make a 45 cut about 5 mm above an axillary bud and cut back remaining leaves by about 50%. Trim secondary roots until seedlings can be potted easily into 9 x 2 -inch black plastic bags, filled with the standard potting mix described above, without bending the tap root.

Keep the potted wildlings under deep shade (20% of normal sunlight) for about 6 weeks. Then, follow the same procedures described below for care and hardening-off saplings grown from seed.

Compared with producing planting stock from seed, these techniques can shorten the time needed to grow trees to a plantable size by several months to a year."

How much potting medium is needed?

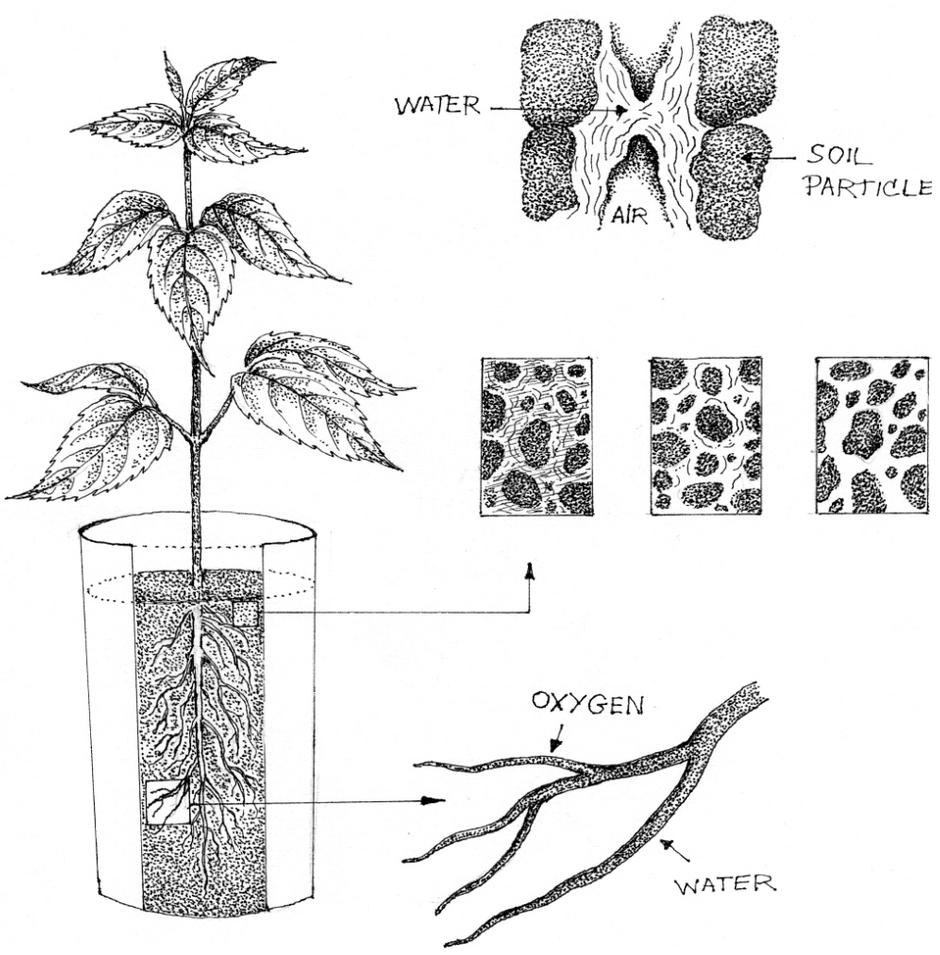
Do not underestimate the amount of soil and other materials required. For example, for approximately 2,000 black plastic bags (9 x 2□ inches), 1 m^3 of forest soil plus 1 m^3 of organic materials are required. Measure the radius and height of the containers you are using and apply the following formula:

Total volume of medium required = (container radius)^2 x container height x 3.142 x nunber of containers.

How do I fill containers with potting medium?

First, make sure the medium is moist, but not too wet. Spray it with water if necessary. For pricking-out small seedlings, fill containers to the brim with medium using a trowel or bamboo scoop. Bang each container on the ground a few times to allow the medium to settle. Then, top up containers with more medium until they are full again. The medium should not be so compact as to inhibit root growth and drainage, but neither should it be too loose. Plastic bags should stand up straight, unsupported. With plastic bags, check for correct consistency by firmly grasping the bag. The impression of your hand should remain after you let go.

Medium Properties



Spaces or "pores" are just as important as solid particles in a potting medium. Interconnected pores of different sizes deliver both water and oxygen to the root system. Mixing soil with organic materials (e.g. husk of coconut, peanut or rice) creates a medium of ideal porosity.

Box 6.2 – Alternatives to seeds: 2. Cuttings

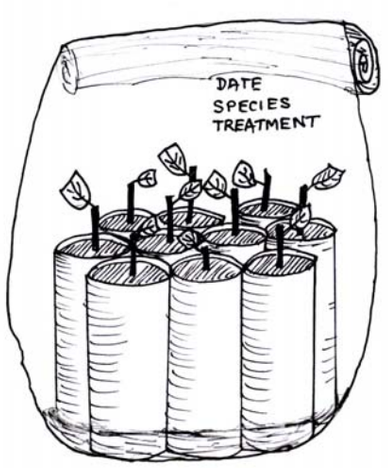
For tree species that fruit rarely, or for those with seeds that are difficult to germinate, planting stock can sometimes be produced from cuttings. Trees grown from cuttings often mature early – a desirable "framework characteristic". However, since cuttings are clones of the trees from which they are collected, they must be collected from many trees, to maintain genetic diversity. Commercial nurseries use high-tech mist propagation systems to mass-produce trees from cuttings, but excellent results can be achieved with simpler methods. Longman and Wilson (1993) provide a guide to these, but bear in mind that little work has been done on vegetative propagation of most forest tree species in Thailand, and for many, vegetative propagation may be difficult, especially if juvenile shoots are not readily available. However, for her PhD at FORRU-CMU, Vongkamjan (2003) successfully adapted a simple method, using plastic bags, for some of northern Thailand's framework tree species:-

"Cut medium-sized, vigorous juvenile shoots (such leafy shoots can often be found on stumps after chopping or burning) from several trees with a sharp, clean pair of secateurs. Place them in plastic bags with a little water and take them to a nursery immediately . In the nursery, trim cuttings into 10-20 cm lengths. Remove lower, woody parts and the fragile apical section. If each node has a leaf or bud, single nodes can be used, but for cuttings with short internodes, lacking buds, the cutting can include 2-3 nodes. Cut back the leaves transversely by 30-50%. Cut the bases of the cuttings into a heel shape just below a node. Immerse the prepared cuttings in a solution of the fungicide Benlate (3 g/10 l) for 5-10 minutes. Try experimenting with these steps to stimulate rooting. For example, retaining the apical meristem and varying the leaf area may be effective.

Hormone treatments are usually required to stimulate the cuttings to root. Each species responds differently to the various hormone preparations that are available, so some experimentation may be necessary. Products containing the artificial auxins, IBA and NAA in various concentrations are most likely to be effective. These products are usually powders, which should be dusted lightly on the bases of the cuttings. Follow the instructions on the packet.

Species	Rooting (%)	Best Rooting Treatment
Colona flagrocarpa	63	IBA 8000
Debregeasia longifolia	68	Seradix 3
Eurya acumminata	18	Seradix 2
Ficus hirta	45	Seradix 2
Ficus superba	72	IBA 3000
Macaranga kurzii	25	Seradix 2 & 3
Morus macroura	90	None
Saurauia roxburghii	65	Seradix 3
Trema orientalis	48	None

Mix 50% sand with 50% rice husk charcoal to make a rooting medium and place it in small, black, plastic bags. Push the bases of the cuttings into the medium. Water the medium and press it to make it firm around each cutting. Put groups of 10 small bags into larger plastic bags (20 x 30 cm). Add one litre of water and seal the larger bag. This provides an atmosphere with 100% humidity, until roots grow to feed water to the cuttings' shoots. Label each bag with the species name and starting date. Keep records of how many cuttings develop roots and shoots. Top up the bags with water weekly if needed and remove dead cuttings and dried leaves. Once cuttings show vigorous root and shoot development, transplant them into 9 x 2□ inch plastic bags"... (and care for them as described in Section 6).

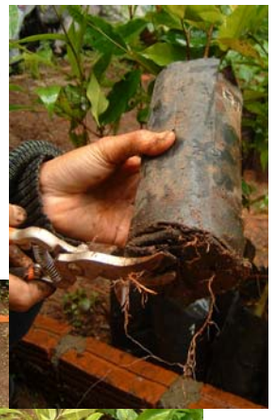


Bags within bags to maintain 100% humidity, while the cuttings grow roots.

Working in the Nursery - Caring for Seedlings

Above - Standing-down. Edging standing-down beds with bricks or bamboo helps keep the containers upright.

Below and right - Root pruning is necessary to prevent roots from growing into the soil beneath containers. It also encourages root branching and development of a compact ball of fine roots within the container.



Below left - Watering is a skilled art. A fine rose produces small water droplets, which prevent soil compaction.

Below right - Applying a slow release fertilizer (Osmocote) to accelerate seedling growth - only 10 granules every 3 months is enough.

Working in the Nursery - Caring for Seedlings

Top left: Noctuid caterpillar on Balakata baccata. *Remove by hand (wear gloves) or use insecticide.*

Top right: Remove weeds well before they grow this dense.

Middle right: Mosses and liverworts invading containers are an indication of over-watering.

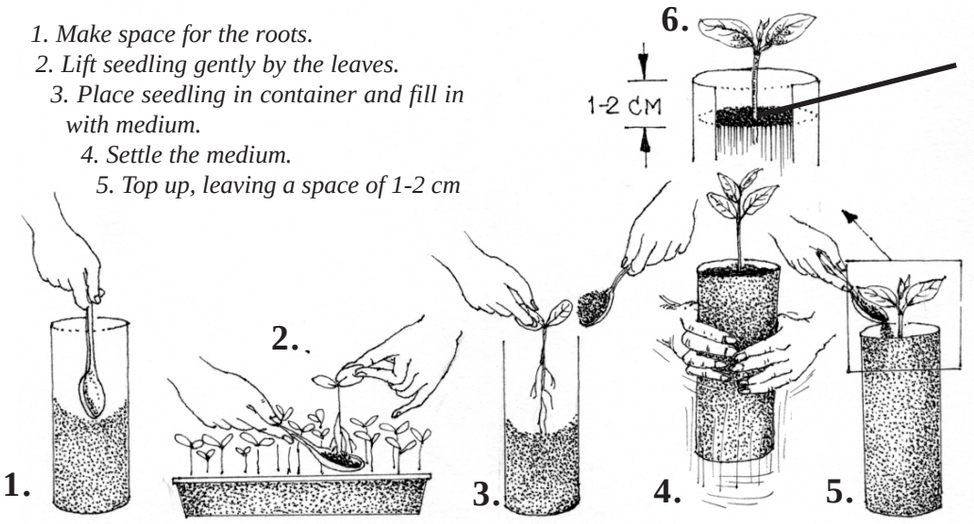
Middle left: Rust fungus on Morus macroura. *Remove infected plants or spray fungicide.*

Above: Grading is a form of quality contol.

Left: Monitoring growth and mortality of samples of seedlings enables nursery managers to develop efficient production schedules.

Pricking-out

1. Make space for the roots.
2. Lift seedling gently by the leaves.
3. Place seedling in container and fill in with medium.
4. Settle the medium.
5. Top up, leaving a space of 1-2 cm



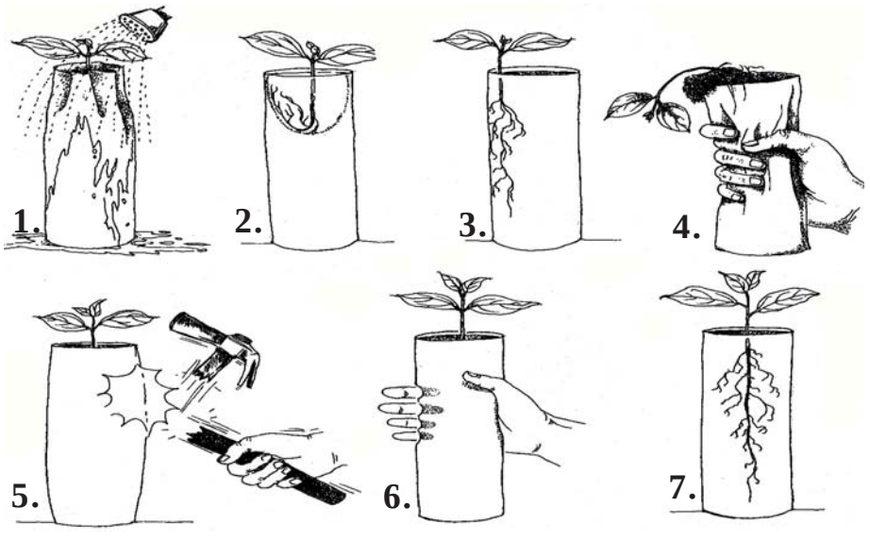
The seedling's root collar should be at or just below the medium surface.

What is "pricking-out"?

"Pricking-out" (potting) is transferring seedlings from germination trays into containers. Do this in shade, late in the day. Fill containers as previously described. Make a hole in the medium, big enough to take the seedling's roots without bending them. Handle the fragile seedlings with care. Gently grasp a leaf (not stem) of a seedling and slowly prise it out of its germination tray with a spoon. Place the seedling's root into the hole in the potting medium and fill the hole with more medium. Bang the container on the ground to settle the medium. Top up with more medium, until the medium surface is 1-2 cm below the container's rim and the seedling's root collar is at the medium surface. Then, press the medium to make sure the plant is upright and centrally placed. With larger plants, partly fill containers with medium. Place plants in containers and add medium around the roots.

What is standing-down"?

"Standing-down" refers to the time that containerized seedlings are kept in the nursery – from potting until transportation to the planting site. After potting seedlings, place containers in a shaded area and water the seedlings with a weak solution of urea (1 dessert spoonful of urea per 20 litres of water) twice per day for 2 weeks. If using plastic bags, make sure that they are placed upright and take care not to squeeze them together. At first, the containers can be touching each other (*i.e.* "pot thick"), but as the seedlings grow, space the containers a few centimetres apart, to prevent neighbouring seedlings from shading each other. Separate rows of containers with strips of bamboo. A layer of gravel in the standing-down bed helps with drainage and makes root pruning easier.



Problems with Potting

1. Medium has settled; rim of plastic bag collapses, blocking watering.
2. Curled roots will make the adult tree susceptible to wind throw.
3. Seedling not placed centrally.
4. Medium too soft.
5. Medium compacted.
6. Excellent medium consistency.
7. The perfectly potted seedling!

SECTION 6 - CARING FOR TREE SEEDLINGS IN NURSERIES

How much shade is necessary?

After pricking-out, place seedlings under about 50% shade to prevent scorching of the leaves and wilting. Shade netting called "slan", graded according to the percent shade cast, can be bought at most agricultural supplies stores. Hang it on a frame 0.5 - 2.5 m above the seedlings. If slan is unavailable or too costly, local materials, such as coconut palm leaves, thin strips of bamboo or even dried grass are also effective. However, take care not to provide too much shade with these materials. More than about 50% shade will produce tall, weak seedlings, which are susceptible to disease.

Even when well established in containers, seedlings are still vulnerable to high temperatures and full sunlight. Consequently, they are usually grown under light shade until they are ready for hardening-off.

How often should seedlings be watered?

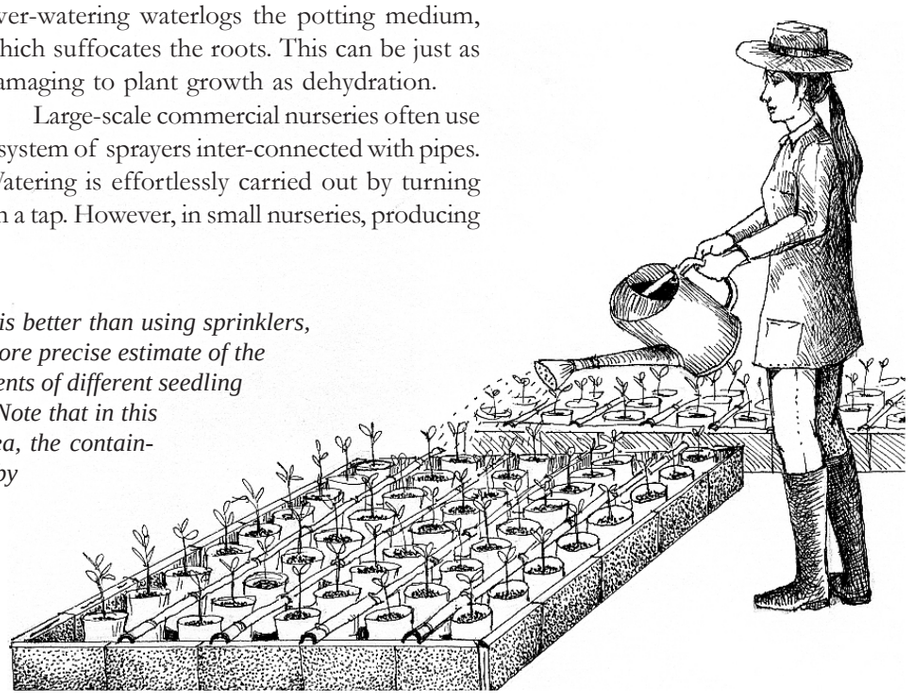
Watering is one of the most important tasks in nurseries. It is a skilled job, and should be recognized as such. Each container holds a relatively small amount of water, so seedlings can dry out rapidly, if watering is interrupted for more than a day in the dry season. In contrast, over-watering waterlogs the potting medium, which suffocates the roots. This can be just as damaging to plant growth as dehydration.

Large-scale commercial nurseries often use a system of sprayers inter-connected with pipes. Watering is effortlessly carried out by turning on a tap. However, in small nurseries, producing a wide range of native forest tree species, with different water requirements, watering by hand, using a watering can or a hose with a fine rose, is recommended. This allows nursery workers to assess the dryness of each batch of seedlings and adjust the amount of water delivered accordingly.

The person responsible for watering the saplings must judge how much water to provide. If the potting medium is still moist, watering may not be necessary that day. If the soil surface is starting to dry out, the saplings are ready for water. Mosses and liverworts, growing on the surface of the potting medium, indicate that the seedlings are being given too much water. They also make it difficult to assess the water status of the medium in each container and so they should be removed and watering reduced.

During the rainy season, in an open nursery, it may be possible to go several days without watering the saplings. In contrast, in the dry season, it may be necessary to water the saplings twice per day.

Watering should be carried out early in the morning or in the late afternoon. It is important that the watering regime is properly implemented. Nursery workers, responsible for watering, should record on a calendar each time watering is carried out.



Watering by hand is better than using sprinklers, since it allows a more precise estimate of the different requirements of different seedling species for water. Note that in this standing-down area, the containers are separated by bamboo strips to prevent over-crowding.

Should fertilizer be applied?

For high growth rates, trees require large amounts of nitrogen (N), phosphorus (P) and potassium (K). They also need moderate quantities of magnesium, calcium and sulphur and trace amounts of other elements *e.g.* iron, copper and boron. There may be adequate supplies of these nutrients in the potting medium but if not, fertilizer must be applied. Your local agricultural extension service or agriculture college may be able to analyze the nutrient in the medium you use and advise you on fertilizer requirements.

The decision to apply fertilizer depends on the growth rate required, or the appearance of the seedlings. In some cases, it may be necessary to accelerate seedling growth, so that seedlings grow tall enough by planting time. Also, weak seedlings, or those with symptoms of nutrient deficiency, such as yellowing leaves, may be suffering from a nutrient shortage.

Slow-release fertilizer granules are recommended. At FORRU-CMU, good results have been achieved by adding about 10 granules of Osmocote NPK 14:14:14 (approx 0.3 g) to each container every 3 months. Nutricote is also recommended. Although slow-release fertilizers are expensive per kilogram, only very small quantities are applied every 3-6 months, so the labour costs of applying them are very low.

Alternatively, ordinary fertilizer (*e.g.* Rabbit Brand 15:15:15) can be used. Dissolve 3-5 g of fertilizer per litre of water and apply with a watering can. Then, water the saplings again with fresh water to wash off any fertilizer solution from the leaves. This treatment must be repeated every 10-14 days, so it requires much more time and labour than using slow-release granules.

Do not apply fertilizer to rapidly growing species that reach a plantable size before the optimal planting time *e.g. Prunus cerasoides*, since it encourages seedlings to outgrow their containers. In addition, nitrogen-fixing species in the Family Leguminosae rarely require fertilizer *e.g. Erythrina subumbrans*.

Do not apply fertilizer immediately prior to hardening-off, as new shoot growth should not be encouraged at this time.

Too much fertilizer can damage roots and if fertilizer particles come into direct contact with plant tissues, chemical burning occurs.

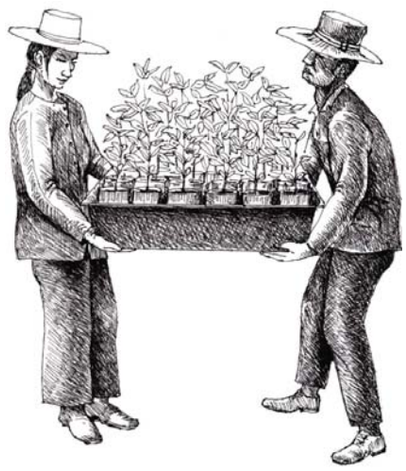
Should a mycorrhizal inoculum be applied?

Research at FORRU-CMU has found that, provided forest soil is included in the potting medium, all forest tree species become naturally infected with mycorrhizal fungi. Liquid and granulated products, containing a mixture of common mycorrhizal fungi species are just becoming available in Thailand, but they are very expensive. Philachanh (2003) found that application of a granulated mycorrhizal inoculum to the roots of seedlings during pricking-out, increased seedling mortality (probably due to disturbance of the root system when applying the product) and did not accelerate growth of surviving seedlings. Therefore, we do not recommend use of mycorrhizal inoculae for the production of forest trees in nurseries at this time.

How should weeds be controlled?

Weeds, growing around the nursery, harbour pests and may produce seeds, which invade nearby containers. So, remove all weeds before they flower.

Any weeds that colonize the containers compete with tree seedlings for water, nutrients and light. Weeds in containers are difficult to remove without damaging tree seedling roots. So, check containers frequently and use a blunt spatula to remove weeds, while they are still small. Also remove any mosses and algae, growing on the medium surface. Controlling weeds with a herbicide is not an option in a nursery full of valuable tree seedlings!



The ultimate achievement of a well-run nursery - a basket of healthy, vigorous saplings ready for planting at the beginning of the rainy season.

What are the causes of disease?

There are three main causes of disease:

- **Fungi**: although some species are beneficial, others can cause damping-off, root rot and leaf-spot (blights and rusts).
- **Bacteria**: most are harmless, but some may cause damping-off, canker and wilts.
- **Viruses**: most are unlikely to cause serious problems in the nursery, but some may cause leaf-spots.

How are diseases detected and minimized?

Constant vigilance is needed to prevent disease outbreaks. Learn how to recognize the symptoms of common plant diseases and inspect the young trees weekly. To prevent disease spread, make sure that the plants are not being over-watered, that there is adequate drainage within and beneath the containers and that the plants are well spaced to allow air movement around them and to prevent direct transfer of pathogens from plants to their neighbours. Use disinfectant to wash tools or rubber gloves that come into contact with the plants.

If a disease outbreak occurs, remove infected leaves or dispose of diseased plants. Burn them well away from the nursery. Do not recycle either the medium in which they grew or plastic bags. If using rigid containers, wash them with disinfectant and dry them in the sun for several days before re-using them.

Routine spraying with chemicals should not be necessary. Chemicals are expensive and they are a health hazard if not handled properly. If it is necessary to spray an infected batch of seedlings, first try to identify the type of disease (fungal, bacterial or viral) and select an appropriate chemical. For example, prodione is active against fungal leaf-spots, whereas Benomyl is a more general fungicide. Captan is particularly effective against damping-off. When using any pesticides, read the health warnings on the packet and follow all the protective precautions recommended.

How can pests be controlled?

Whilst most insects are harmless, some can rapidly defoliate young trees or damage their roots enough to kill them. Not all pests are insects. Nematode worms, slugs and snails and even domestic animals can all cause problems.

The most important pests include leaf-eaters such as caterpillars and crickets; shoot borers, particularly beetle and moth larvae; juice-suckers, such as aphids, mealy bugs and scale insects and root-eaters such as nematode worms. In addition to eating the plants, these pests transmit diseases.

Regular inspection of the growing trees, as recommended above, will alert nursery workers to pest infestations before they get out of control. Remove harmful animals or their eggs by hand, or spray the saplings with a mild disinfectant.

If this fails to prevent an infestation from spreading, then spray the saplings with an insecticide, observing all the health precautions on the packet. Select the most appropriate chemical for the particular pest species present. For example, Pirimicarb is active against aphids, whereas Pyrethrin is a more general insecticide. For weeds, pests and diseases, ***prevention is better than cure***.

Not all pests are small. Dogs, pigs, chickens, cattle and other domestic animals can wreak havoc in a tree nursery in just a few minutes. So, where such animals occur, make sure that the plants are protected within a sturdy fence.

Protect your nursery from pests both large and small. Fence out domestic animals.

What is grading and why is it important?

Grading is an effective method of quality control. It involves arranging the growing trees in order of size, whilst at the same time removing stunted, diseased or weak ones. In this way, only the most vigorous and healthy trees are selected for hardening-off and planting-out. This maximizes post-planting survival. Alternatively, when more space is required in a nursery that is full, the smallest and weakest plants can be easily identified and removed to make room for new seedlings that are likely to grow better.

Carry out grading at least once per month. Root pruning and disease inspection can be carried out at the same time. When carrying out grading or root pruning, wash hands, gloves and secateurs in disinfectant frequently to prevent spreading diseases from one block of plants to another.

Dispose of poor quality plants by burning them, well away from the nursery. Do not recycle the medium or plastic bags. There is sometimes a reluctance amongst nursery workers to throw away poor quality seedlings or saplings. However, keeping them is a false economy, as they waste space, labour, water and other nursery resources that would be more efficiently provided to healthy plants that are more likely to survive when planted out.

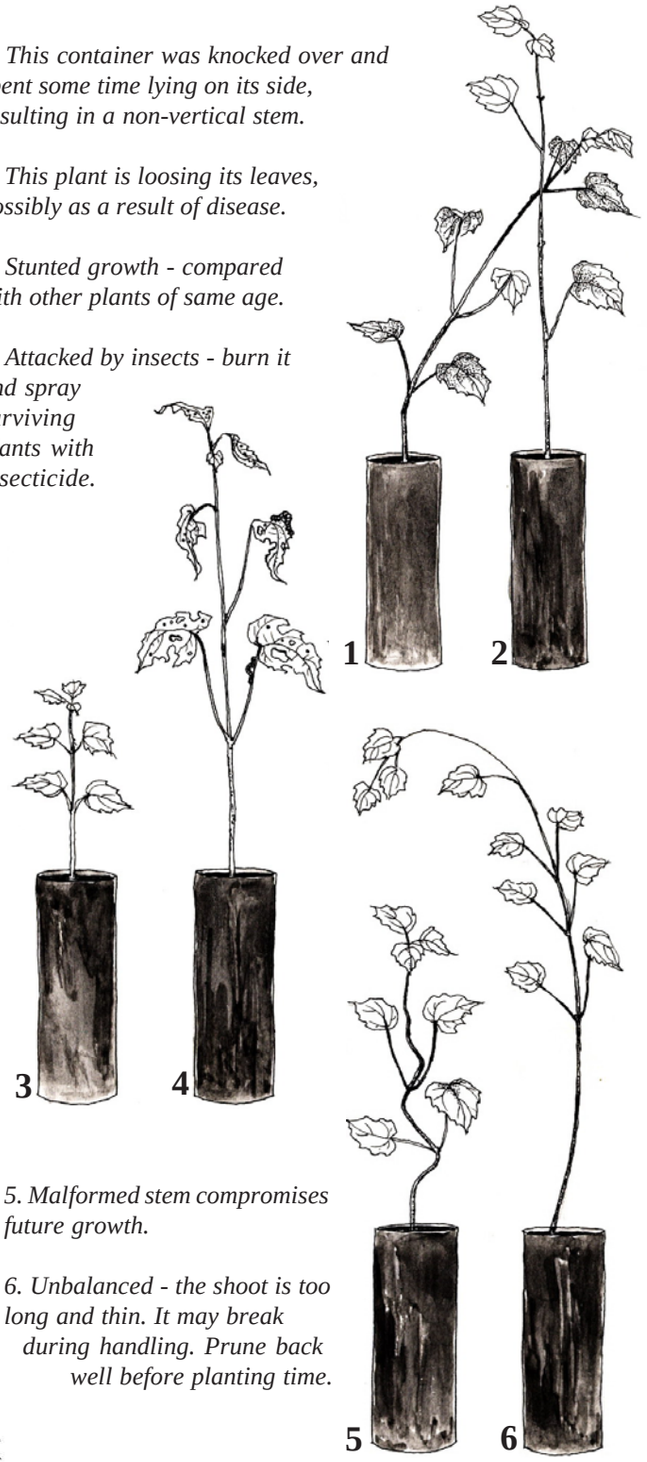
Problem Plants

1. This container was knocked over and spent some time lying on its side, resulting in a non-vertical stem.

2. This plant is loosing its leaves, possibly as a result of disease.

3. Stunted growth - compared with other plants of same age.

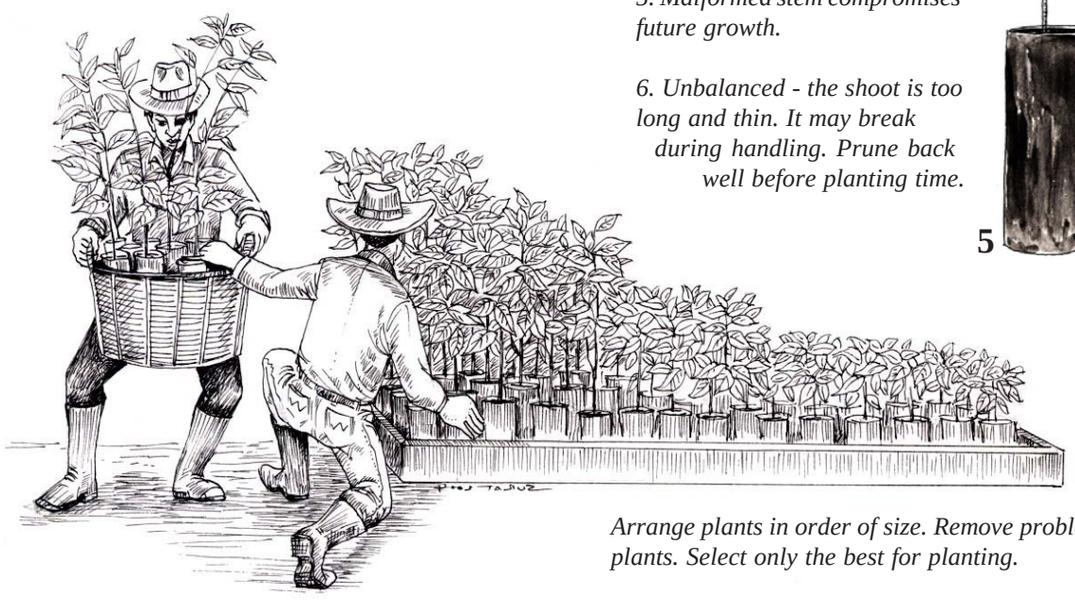
4. Attacked by insects - burn it and spray surviving plants with insecticide.



5. Malformed stem compromises future growth.

6. Unbalanced - the shoot is too long and thin. It may break during handling. Prune back well before planting time.

Grading



Arrange plants in order of size. Remove problem plants. Select only the best for planting.

SECTION 7 – QUALITY CONTROL

The nursery manager must produce high quality seedlings, which have the best chance of establishing in the field and growing rapidly when planted out in the unforgiving environment of a deforested site. Both the shoot and root systems of young trees should be healthy and in balance with each other. This reduces transplantation stress, tree mortality and the risk of having to replant the following year. It is a false economy and a waste of time to plant poor quality seedlings.

The root system - what are we trying to achieve?

Root systems are far more critical to the ultimate survival of trees than shoot systems are. They are also more vulnerable to damage. Roots must grow into surrounding soil, whilst maintaining a supply of water and nutrients to shoots during establishment. Root growth is affected by the choice of container, the choice of potting medium, the watering regime and by pests and diseases. Root systems of containerized trees, ready for planting, must:

- be free of pests and diseases;
- be densely branching with balance between thick, supporting roots and fine ones, which absorb water and nutrients;
- form a compact root ball, which does not fall apart when the tree is removed from its container;
- **not** be spiralling at the base of the container;
- be able to support the shoot system and
- be inoculated with mycorrhizal fungi.

How can a good root system be achieved?

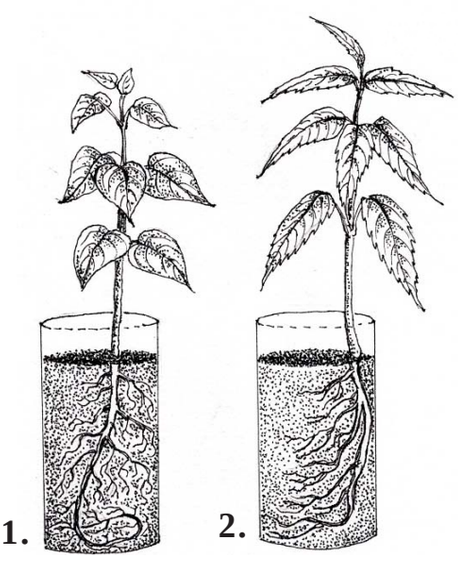
If tree roots grow through the bottom of their containers and into soil beneath, they become broken when containers are lifted at planting time. The young trees go into shock, wilt and may die even before they reach the planting site. This can be prevented by:

- lifting containers frequently and using a clean pair of secateurs to prune back any roots seen growing outside the containers (do this in the late afternoon to minimize moisture loss);
- standing containers on concrete or gravel to inhibit roots growing out and
- scheduling production so that trees are transplanted as soon as they grow large enough.

What is air pruning?

Another way to inhibit root growth outside containers is called "air pruning". Containers are placed on raised wire grids, with plenty of ventilation beneath. Dry air kills any roots that protrude from the containers, so there is no need for manual root pruning. However, the costs saved by not having to prune roots manually must be weighed against the cost of building the wire-grid benches. Both manual and air root pruning stimulate branching of finer roots within containers, thus helping to create a dense root ball.

Root Deformities



Poor root development in containers leads to problems after trees are planted out. Root spiralling (1) and asymetrical development of the root system (2) makes trees vulnerable to wind-throw later in life.

The shoot system - what are we trying to achieve?

Containerized trees, ready for planting, should have well-balanced root and shoot systems, with very active root growth and a reduced rate of shoot growth. This enables planted trees to overcome transplantation shock and become established in their new environment.

How tall should the saplings be at planting time?

The actual height of saplings is less important than their capacity to produce vigorous new growth. Some fast-growing tree species (*e.g. Erythrina subumbrans, Gmelina arborea, Prunus cerasoides, Melia toosendan etc.*) can be planted out when only about 30 cm tall but for most species, it is better to plant them when they are about 40-60 cm tall. Smaller saplings (less than 30 cm) have much higher post-planting mortality rates than larger ones do, because of competition with weeds, but very large saplings are much more susceptible to transplantation shock.

Is shoot pruning necessary?

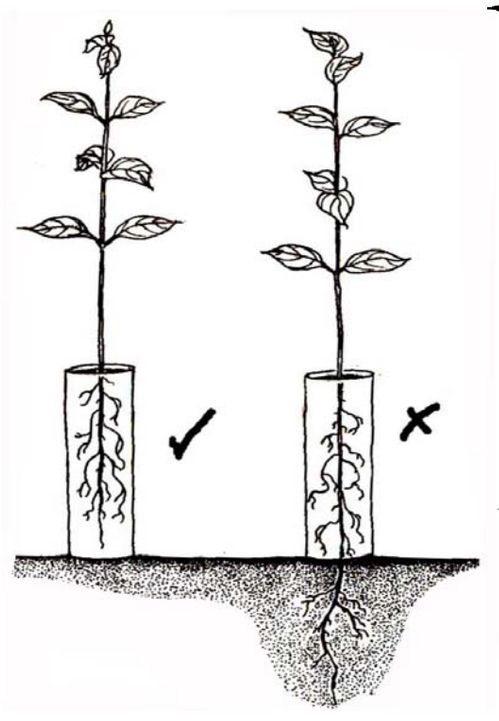
Shoot pruning is necessary for those fast-growing species, which (due to the time of seed availability) have to be kept in the nursery for a long time. Such trees may become too large for their roots to support or too cumbersome to handle during transportation and planting. The stems of tall saplings are easily broken when they are being moved.

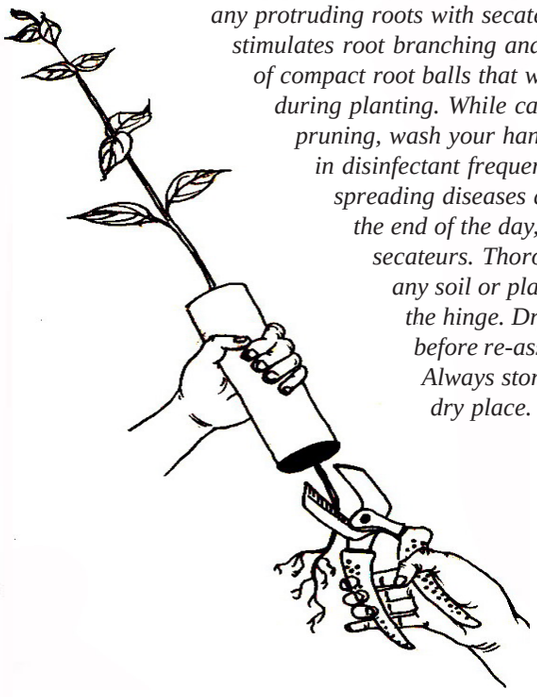
In some species, such as *Erythrina subumbrans* and *Prunus cerasoides*, pruning has the additional benefit of encouraging branching. This is a desirable response since, after planting out, spreading crowns shade out weeds and rapidly form a closed forest canopy.

Never prune shoots within a month before planting out, because it promotes growth of new leaves, just as saplings are about to be stressed by transplantation. Immediately after planting, the root system may not be able to take up enough water to supply new leaves, so anything which stimulates bud break shortly before planting out should be avoided.

Some species do not respond well to pruning or become highly susceptible to fungal infections (*e.g. Melia toosendan, Magnolia baillonii, Balakata baccata, Macaranga denticulata etc.*). So before attempting to prune large numbers of saplings, experiment with a few to test the effects of pruning.

Root Pruning





During grading, lift plastic bags and trim back any protruding roots with secateurs. This stimulates root branching and the development of compact root balls that will not fall apart during planting. While carrying out root pruning, wash your hands and secateurs in disinfectant frequently to prevent spreading diseases among plants. At the end of the day, dismantle the secateurs. Thoroughly clean out any soil or plant material from the hinge. Dry the pieces before re-assembling them. Always store secateurs in a dry place.

What is "hardening-off" and why is it necessary?

Weaning, or 'hardening-off', is the process of preparing saplings for the difficult transition from the ideal nursery environment to the harsh conditions of deforested sites. If they are not toughened up, to cope with the hot, dry, sunny conditions of planting sites, they will suffer transplantation shock and die.

About 2 months before planting, move all saplings to be planted to a separate area in the nursery and gradually reduce shade and the frequency of watering. They should stand in full sunlight for their final month in the nursery.

Watering should be gradually reduced, by approximately 50%. The aim is to slow down shoot growth, and encourage smaller new leaves. Thus, saplings normally watered in the early morning and late afternoon, should be watered just once, in the late afternoon during the hardening-off period. Saplings normally watered once a day should be watered every other day. Do not reduce watering to the point at which leaves wilt, as that stresses and weakens saplings. Regardless of the normal schedule, water the saplings as soon as any wilting is observed.

Species number: **Batch number:**

SAPLING PRODUCTION RECORD SHEET

Species:

Potting Date: **No. Seedlings Potted:**

Fertilizer treatment:

Pruning treatment:

Pests and Diseases:

DISPATCHED

No. of Plants	On Date	To Place	Average Height of Plants

What records should be kept?

Learning from experience is only possible if accurate records are kept of nursery activities and the performance of each species. Records are essential to prevent new nursery workers from repeating the mistakes of previous ones. They are also used to assess the productivity and achievements of the nursery (numbers of species/saplings grown) and for the development of species production schedules.

Label seed trays and plants in the nursery with species names, batch numbers and dates of seed collection and pricking-out. Use the record sheet formats on pages 81, 82 and below to record when and where each batch of seeds was collected, seed treatments applied, germination rates, seedling growth rates, diseases observed and so on. Finally, record when and to where saplings are dispatched for planting.

What are production schedules?

Growing a wide range of native forest tree species is complicated by scheduling problems. Different species fruit in different months and have different growth rates, yet saplings of all species must grow to a plantable size by the optimum planting time. For example, a fast-growing species, which seeds in January, might be ready for planting in June, if fertilizer is applied after pricking-out. But, if seedlings fail to grow as fast as expected, they will have to be kept in the nursery until the following year, by which time they might outgrow their containers and require pruning.

Based on nursery records, a species production schedule describes how to manipulate seed germination and seedling growth of each tree species to ensure that saplings grow tall enough for planting out by the first or second rainy season after seed collection. It includes details of optimal seed collection time, seed treatments required to break dormancy, time from germination to pricking-out, standing-down time required for adequate sapling growth, optimal fertilizer application, pruning treatments or other steps necessary to manipulate sapling growth. The production schedule is a working document, requiring continual adjustment as variations in seed availability, seedling growth rates and so on become known.