

GOOD TREE NURSERY PRACTICES

PRACTICAL GUIDELINES FOR
COMMUNITY NURSERIES



INTERNATIONAL CENTRE FOR RESEARCH IN AGROFORESTRY

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**PRACTICAL GUIDELINES
FOR COMMUNITY
NURSERIES**

KEYVYN ELIZABETH WIGHTMAN

INTERNATIONAL CENTRE FOR RESEARCH IN AGROFORESTRY

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***Do you have any suggestions for the second edition of this book?
Please let us know about your experiences in agroforestry nurseries.
Have you tried the methods suggested? What other information would
you like to see included in the next edition? If you have any comments
about this book, we would like to hear from you.***

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Foreword

The success or failure of agroforestry and forestry systems depends on the quality of their components, and trees are clearly a fundamental component. At ICRAF we see that the 'future of trees is on farms', but what will that future hold if farmers do not have access to high quality seed and seedlings? The opportunity for significant economic development will be missed. We believe, therefore, that developing and implementing farm- and community-based systems for the production of good tree seed and seedlings is one of our highest priorities.

In this book, Kevyn Wightman has synthesized a wealth of information about nursery practices, and added her own formidable experience and insights to offer very useful guidelines for managers of community and project nurseries. The author focuses on quality - this depends on attention to details about the seed source, physical characteristics of seedlings, proper substrates, and regulation of water, light and nutrients. The manual includes not only what to do, but also why to do it - this encourages the nursery manager to look for understanding and not simply accept recipes.

Nursery managers and others will find this a valuable reference. We also hope that readers will have useful comments and ideas for a second edition. So, please send us your suggestions and experiences of tree nurseries. In particular, have you tried the methods suggested in this book? What other methods and information would you like to see in the next edition? We look forward to hearing from you.

John C. Weber

Programme for the Domestication of Agroforestry Trees

ICRAF Latin America

Introduction

This book is written for community and project nursery managers, drawing on experience from several Latin American countries. We believe that its contents are useful beyond the Latin American region, hence this English version. A Spanish version is planned, too.

In this book we emphasize the importance of seedling quality. We concentrate on good nursery practices that produce quality seedlings. Quality seedlings in the nursery are fundamental to quality trees in the field. We depend on trees for our livelihoods and for a healthy environment. Your trees are important!

Unfortunately, many **poor nursery practices** have become common. Millions of poor quality seedlings are produced every year, seedlings that are not worth the effort to plant or maintain. Poor quality trees discourage people from planting trees and reduce the productive potential of the land.

We have not spelled out the A-Z of how to run a nursery. Nursery logistics vary depending on many environmental, social and economic factors. However, some fundamentals are the same for all nurseries: seed source quality, seedling physical quality, substrate quality, water, light and nutrient regulation. We strongly encourage wise pesticide use, suggest natural pesticide recipes, recommend monitoring the plants at the planting site, and offer guidelines on experimentation.

Throughout this manual, we stress the 'why' as much as the 'how'. Critically questioning and considering why something is done is one of the first **good nursery practices**. Observing, experimenting, and seeking the consultation of others is crucial to improving seedling quality. The quality of your work is important!

A sign outside a nursery in Peru proclaims:
*El que siembra un arbol, siembra una esperanza. **
(One who plants a tree, plants a hope.)

We would add,
One who plants a quality tree, plants a better future.

^{*}Written by Lucy Larcom (1826-1893), U. S. Poet, 'Plant a Tree'.

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Seedling quality

Quality versus quantity

A nursery manager's most important goal is to produce quality trees. Quality is more important than quantity. It is a common mistake in nurseries to concentrate on the total number of trees produced and neglect their physical and genetic quality. It is better to produce a few good trees, than many poor ones. Improving plant quality may mean that the farmer plants fewer trees, but the growth and survival of these trees will be superior.

Good plant quality is the basis for tree planting success. It is not worth a farmer's effort to transport plants to the field, prepare an area, plant and maintain trees unless they are of good quality. A poor quality tree will always be a poor quality tree even if planted on a well-prepared, good site. In the field, each poor quality tree wastes space and resources leading to low site productivity. High quality trees have a higher survival rate and faster growth in the field than poor quality trees. Fast growth allows a tree to outcompete weeds and reduces the initial labour costs of establishment. Fast growth also enables a farmer to harvest wood or tree products sooner, increasing the return on the farmer's investment. We are producing trees for people's livelihood; they depend on having high quality trees.

Seedling quality has two main aspects. The first is the **genetic** quality or the source of the seed. The second component of seedling quality is its **physical** condition when it leaves the nursery. Improving genetic quality of seedlings requires a long term strategy of seed selection, while improving the physical quality can be accomplished in just one or two seasons.

Seed source quality

Farmers select only the best animals for breeding: animals that are small and sickly do not produce good offspring. Similarly, farmers use only the superior crops that have high yields and are resistant to disease for the next year's seed. These same principles should apply to trees. The characteristics of the parent trees can greatly influence the characteristics of the seedlings. The seed can determine whether the tree will grow well or poorly. Studies from around the world have shown that good seed improves survival, timber and fruit quality, and shortens rotation or harvest times. Because trees take longer to mature than crops or animals, thus making tree planting a long-term investment of labour and land, it is even more important to select only high quality seed.

The desired characteristics of the parent trees will vary depending on whether the trees are for wood, fodder, fruit, or medicine. *A good nursery practice* is to consult farmers as

Consult farmers as well as forestry technicians when selecting the seed sources.

well as forestry technicians when selecting the seed sources. Farmers often know additional traits which make their trees more valuable. It may be difficult to find some of the trees with the best traits because these are often the first to be cut down. Conserving some of the best trees within the community will ensure a future supply of seed.

Select the parent trees well in advance, and plan a way to ensure sufficient seed is collected.

Some desirable parent tree characteristics are:

- healthy trees with a large, well developed crown
- for timber trees, a long, straight trunk with few branches
- wood quality, such as high density, or straightness of the grain
- for fodder trees, palatability and digestibility of foliage (leaves that animals like to eat and are easily converted into energy)
- for fruit trees, low branching may be desired for easier fruit harvest
- fruit quality, such as sweetness or ability to be transported with minimum damage
- fast growth rate
- low susceptibility to (or ability to quickly recover from) disease or insect attack.

Collect seed from at least 30 parent trees that are at least 100 metres apart.

A good nursery practice is to select the parent trees well in advance, and plan a way to ensure sufficient seed is collected. Permanently marking the trees as seed sources may help ensure that they will not be cut down. Only mature seed from ripened fruit should be harvested. *A good nursery practice* for each species of tree is to collect seed from at least 30 parent trees that are at least 100 metres apart. If you buy the seed, find out how

many trees were used. Using a large number of seed sources increases the gene pool or genetic diversity of the seedlings. Genes are the codes of information from the parent trees that determine how the progeny or offspring trees will grow. By using seed from many different trees, the probability of the offspring trees having good characteristics increases and ensures that the trees can better adapt to environmental changes. *A poor, but unfortunately very common nursery practice* is to collect seed from just one, two or three easy to climb trees

close to the nursery. If the seed is bad and does not germinate, the nursery crop could be lost. Collecting from just a few trees is also dangerous because it results in low genetic diversity. Trees with low genetic diversity are often more susceptible as a group to disease, or unable to adapt to changing environmental conditions such as drought. If an area is planted with trees from very few sources, in the future, our ability to choose the best seed sources and improve the characteristics of the trees is very limited.

Use seed from an area as similar as possible to the area where you are planting. For example, seed from a mountainous region should only be planted in a mountainous region and seed originating from the lowlands will grow best in lowland conditions. If you purchase the seed, ask for its origin. It is okay to mix the seed from different trees together for normal nursery production. For long term genetic improvement though, seed from each individual tree is kept separately and tested in field experiments. The best trees are then selected to serve as seed sources for the nursery.

The principles of tree domestication are similar to those used in agriculture: maximize the quality of tree products, maximize tree growth rates, ensure the adaptability of species to the planting site, and maximize resistance to diseases and pests. This is achieved by selecting the best seed sources and managing the trees under optimal conditions.

Seedling physical quality

No single characteristic determines seedling quality. Seedling quality is a combination of height, diameter, plant nutrition, health, root size and shape. Together, these characteristics determine how well the plant will establish itself in the field, and they affect the rate of survival. Height alone is often not a good predictor of how a plant will grow in the field. *A good nursery practice* is to judge seedling quality by several traits.

Judge seedling quality by several traits.

Many of these traits act together and influence one another. The goal of producing the best seedling is to optimize these traits while producing specifically what is needed for a particular site. You will need to talk to foresters and farmers to find out the most important desired traits. For example, plants for dry, rocky soils may need to be short and be produced in small containers, whereas plants for flooded sites or active pastures may need to be quite large.

1 SEEDLING QUALITY

Quality tree seedlings have the following characteristics:

- They are healthy, vigorously growing and free of diseases.
- They have a robust and woody (lignified) single stem free of deformities.
- Their stem is sturdy and has a large root collar diameter.
 - Their crown is symmetrical and dense.
 - They have a root system that is free of deformities.
 - They have a dense root system with many fine, fibrous hairs with white root tips.
 - They have a 'balance' between shoot and root mass.
 - Their leaves have a healthy, dark green colour.
 - They are accustomed to short periods without water.
 - They are accustomed to full sunlight.



A quality seedling

The following examples demonstrate how these traits enable the plants to be more resistant to transport and planting stress, and how they improve seedling growth and survival.

How quality traits work together

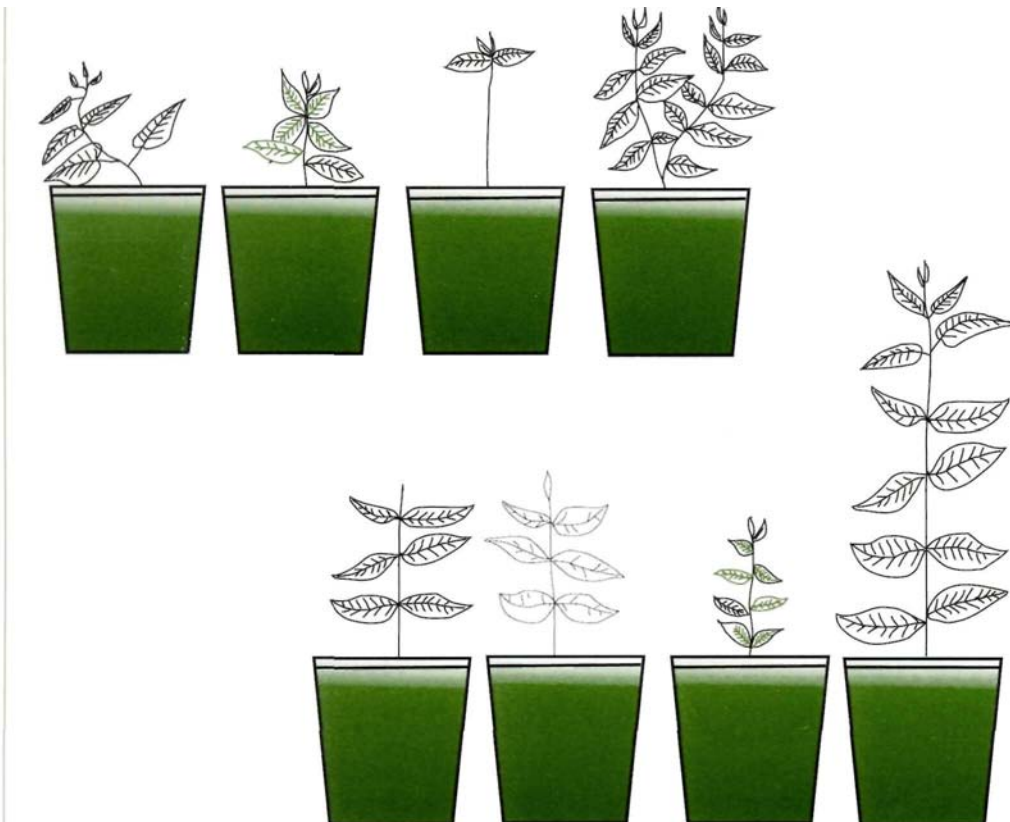
'Sturdiness' is measured by the relationship between height and diameter. If two trees are the same height and one has a larger diameter stem, then the latter is sturdier. A sturdy stem is less susceptible to transport and planting damage.

Stem diameter is often related to root size. Plants with large diameter stems often have large root systems. Diameter is a better predictor of root size than plant height is.

A 'balanced' seedling has a small to medium shoot system and a large root system. The shoot loses water through the leaves and the roots compensate for this loss by absorbing water and nutrients. 'Unbalanced' plants have too many leaves and too few roots. Balance refers to the mass or dry weight of the shoot and root — NOT to their length.

Assessing seedling quality

You do not need special equipment and it does not take long to survey seedling quality. When the seedlings are about 15 cm tall, choose at least 20 plants from each species for inspection. It is important to sample randomly, that is, not to pick only the biggest plants or only plants from one bed. Try to sample plants from all parts of the nursery and from each bed in the nursery. Choose one or two plants from each end and from the middle of each bed. Examine the plants thoroughly. Sixteen out of 20 plants (80%) should have the quality characteristics listed above. If fewer than 16 trees are of good quality, try the techniques suggested in this manual. Repeat this quality assessment at least once more about 1 month before the plants are taken to the planting site so that improvements can be made if necessary.



All of these plants exhibit poor quality. Starting at the top left they have the following problems: bent stem; too small; too few leaves; two stems; dead main shoot; yellow leaves (nutrient deficient); extremely small leaves; overgrown, 'unbalanced' shoot and root system.

1 SEEDLING QUALITY

Sacrifice a few plants to improve the quality of the total nursery production.

A good nursery practice is to sacrifice a few plants to improve the quality of the total nursery production. One of the best ways of examining quality is to cut open the container and observe the root system of several plants. Of course, these plants must then be thrown away. ***Do not plant these seedlings afterwards, because when inspecting the root system, the fine root hairs will get damaged, and the plants will either die or become badly stunted.***

Root deformities — the hidden curse

Root deformities below the soil line are the hidden curse in seedling production. They retard growth, cause the plant to lean or even fall over, and can result in the plant's death. Root deformities do not correct themselves over time — in fact, they become more acute as the tree grows.

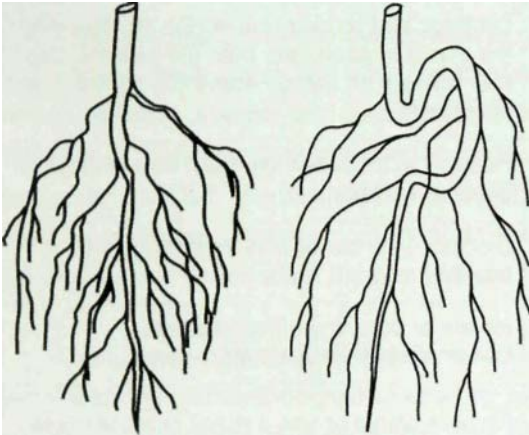
The main root should be as straight as a carrot, or if there is no main tap root, the many smaller roots should branch out without any pattern or strong bends. If the roots are in knots or coiled, they will eventually strangle the tree, or they may die, attracting insects or fungi that will damage the tree. There are two types of root deformities:

Root deformities caused by poor pricking out from the germination bed into the container

The deformities are generally within the first 10 cm under the surface of the soil or at about a finger's length. Often, seedlings are squeezed into holes that are too short for the root system. Roots are stuffed forcefully into bags or, while placing a seedling into a hole, the end of the root remains curled upwards. Because roots always want to grow downwards, they will bend back and grow into a 'knee' or even a complete loop. Nursery customers can check for these deformities by following the stem down with their finger. These plants should be refused because they will never grow well in the field.

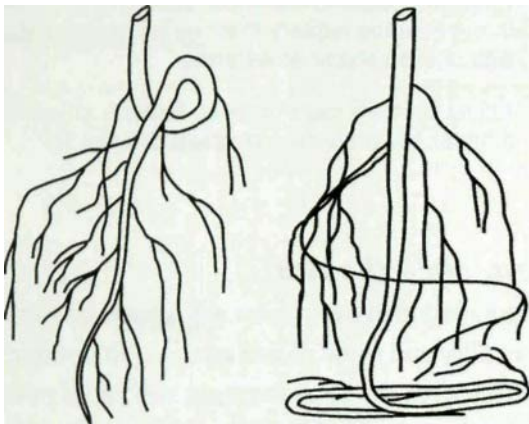
Root deformities caused by the bag

Smooth plastic bags cause the principal root to coil or spiral along the walls or at the bottom of the bag or pot. This inevitably happens when plants are left in the nursery too long. However, it can also happen to plants that are only a few centimetres tall. Plants commonly develop roots before they begin shoot growth. So even plants with small shoots may have long roots that are coiled at the bottom of the bag. These roots should be cut off immediately before planting.



Top (left) A good root system free of deformities. The tap root is straight, like a carrot. Notice the many fine root hairs that are important for the absorption of water and nutrients.

Top (right) A deformed root system caused by poor pricking out. Notice that the roots are twisted close to the surface of the container.



Bottom (left) Another deformed root system caused by poor pricking out. Here the main root was stuffed into a hole too small and the roots were twisted upwards. As the roots began to grow downwards, they formed a complete loop.

Bottom (right) A spiralled root system caused by the smooth surface of the bag. Notice that the roots are coiled at the bottom of the bag — not near the soil surface.

1 SEEDLING QUALITY

A good nursery practice is to regularly survey seedling quality to correct problems through appropriate nursery management. Some problems, and suggested solutions, are:

problem	solution
Roots knotted or twisted from poor pricking out	Discard plants immediately. Next time, direct sow, or follow procedures in chapter 2 for correct pricking out.
Roots coiled at the bottom of the bag	Cut roots with machete or pruners before planting. Remove plants in good time from the nursery. Use root trainers (see chapter 4).
Roots penetrating into the soil beneath bags	Lift bags and prune roots frequently. Remove the plants in good time from the nursery. Use root trainers on frames above the ground (see chapter 4).
Multiple plants per bag	Remove extra seedlings early, before they become very big.
Plants with multiple stems	Discard —the cause may be poor genetic quality.
Diseases or insects	Isolate or burn any affected plants. Develop a plan for pest management.
Yellow or white leaves, or leaves with dark green or purple veins and light spots in between	Fertilize plants or use a richer substrate (see chapters 3 and 7).
Large variation in plant sizes among plants sown at the same time	Check for patterns within the beds and throughout the nursery that can be associated with uneven shade or watering.
Plants grow slowly	Adjust light (try more or less), fertilize, or use a better substrate (see chapters 3,6 and 7).

Regularly survey seedling quality to correct problems through appropriate nursery management.

Keep the best, ditch the rest

In every population of trees, there will always be some plants of good quality and some of bad quality. On average, 20-30% (and often even 50%) of the trees will be of poor quality. Thus, the nursery should always produce 20-30% more plants than needed to meet a given target. Nursery managers must accept that it is quite normal to throw away plants. Unfortunately, many do not. Many people do not want

to see their hard work thrown away, or they believe that the plants still might have a chance. These ideas are false.

Discard poor quality trees as soon as you detect them.

A *good nursery practice* is to discard poor quality trees as soon as you detect them. They waste space and resources in the nursery, and can be a source of infection. The process of removing poor quality seedlings is known as 'culling'. It is a greater waste of hard work and money to maintain trees of poor quality in the nursery and in the field, than to throw away poor quality trees in the nursery.

Variable plant growth in the nursery is carried over to the field. A weak plant will never catch up with others that were strong when planted out. A *poor, but unfortunately common, nursery practice* is to select the best trees for planting, but then leave the bad ones in the nursery. These are then given to the next unsuspecting customer. This is very unfair to your customers. Only the best quality trees should leave the nursery, the others should be thrown away at that very moment. A plant that is not considered good quality does not suddenly become better when the best ones have been planted.

Another *poor, but unfortunately common, nursery practice* is to leave plants in the nursery from one production year to another. These are usually the left-over plants that no one wanted. By the next planting season they are overgrown and have severe root deformities. If plants grow very slowly during the year and remain in the nursery more than one season, throw these ones out, and try adding more compost to your substrate, or allowing your plants more sun.

Summary of seedling quality

Seedling quality is governed by two factors: the genetic make-up of the parent trees, and the physical growth of the seedling. Good nursery management can make the best use of these to greatly improve the growth and survival of seedlings. Your nursery customer deserves only the best quality seedlings.

Good nursery practices

- consult farmers as well as forestry technicians when selecting the seed sources for the nursery
- select the parent trees well in advance and design a strategy to ensure sufficient seed is collected
- collect seed from at least 30 parent trees
- judge seedling quality by several traits
- conduct regular surveys of plant quality
- sacrifice a few plants to improve total nursery production quality
- use plant quality surveys to correct problems through appropriate nursery practices
- discard poor quality trees as soon as you detect them

Poor, but unfortunately common nursery practices

- collecting seed from only a few trees close to the nursery
- selecting the best seedlings for planting out, and delivering the bad plants to the next customer rather than throwing them away
- leaving plants in the nursery from one production year to another

Seed handling, seedling germination and sowing

Seed pre-treatments and seed storage

If seeds are enclosed in a fleshy fruit, remove as much as possible of the flesh with a knife, wash off the rest under water, and plant the seeds immediately. Fruit flesh attracts insects and fungi which may damage the seed, so it's important to plant the seed as soon as you can. For seeds in a seed pod, such as a bean, let the pods split open naturally by laying them in a semi-shaded place. Similarly, for other fruits with a woody outer coating, drying them in semi-shade or gently cracking should open them and let you collect the seed. Some sun is good, but be careful not to overheat, which might kill the seeds.

A good nursery practice is to pre-treat the seeds, if they take more than a week to germinate. You will save time and resources by pre-treating seeds. Faster production time in the nursery lowers nursery costs and may also allow the farmers to plant the seedlings during the best planting times. If you are unsure how long the seed will take to germinate, sow some BEFORE you sow all of the seeds to find out. There are four basic types of seed pre-treatment used in the lowland tropics of Latin America.

Sulphuric acid is sometimes recommended as a fifth seed pre-treatment but, because of the danger and cost involved, we do not recommend it. In order to determine the best pre-treatment method, take a few handfuls of seed and try the methods described on the next page in the order given. If most of the seed germinates well with the first method, then that is probably sufficient. If not, try the next method and so on until you obtain the best germination rates.

Pre-treat the seeds, if they take more than a week to germinate.

The seeds contain two parts: an outer protective coat, and the inner embryo that develops into the plant. Germination begins when water penetrates the seed coat and the seed swells. When seeds swell, plant immediately. Discard seeds that float; they probably have air pockets caused by insects or dead embryos. Always use 2-5 parts of water for each part of seed (e.g. two to five tablespoons of water for one tablespoon of seed). Change the water every 12 hours to remove chemicals that may also slow down germination.

Do some tests to see the best orientation for sowing the seeds. This is especially important if the shoots or roots are twisted when they emerge from the seed, which is common in mahogany

and mango. In southern Mexico, the common way to sow mahogany seedlings is with the wing pointing up. But in one nursery, the manager noticed that the best way to plant was with the wing pointed down. In Puerto Rico, it is recommended by a forest research station that seed be planted flat. In such cases, you should do trials of all three methods and see what works best under the conditions you have.

Four basic seed pre-treatments

1. Cold water treatment: Soak seeds in cold water for at least 12 and up to 48 hours. You can also try soaking the seeds in water during the day, and leaving them to dry at night.

2. Hot water treatment: Boil water in a large pot, remove from heat and cool for 10 minutes. Add seed to water and let soak for up to two days.

3. Boiling water treatment: Boil water in a large pot, remove from heat, add seed and leave for two minutes. Pour off the hot water and replace with cold water. Soak the seed for up to two days.

4. Mechanical: It is important not to damage the embryo, or the part of the seed where the root will emerge (usually an indented place or a pointed area). Nick the seed with a knife, crack it with a stick, or scratch its surface on a concrete floor, or with sandpaper. For small seed, place in a jar lined with sandpaper facing the inside of the jar, and shake vigorously. It is not necessary to completely remove the tough outer seed coat — just crack it so that water can enter the seed and trigger germination.

Sow the seed immediately after collecting, or store correctly if necessary.

A good nursery practice is to sow the seed immediately after collecting, or store correctly if necessary. You should plan ahead and have containers filled, so that seed can be sown without delay. If you must store seed before sowing, make sure it is kept well ventilated in a cloth or mesh sack, or in clay pots. These materials 'breathe' and reduce the chance of mould. If a refrigerator is available, you can use plastic bags or containers.

Only clean, dry seed should be stored. Hang the sacks from a pole so that air can circulate all around them. Keep the seed in a cool dry place, out of direct sunlight. A fungicide may help reduce fungus attack. Moth balls or other strong-smelling materials like cedar wood may also help reduce insect attack. Check seed regularly for signs of decay, insect or rodent damage.

The length of time seed can be stored for varies greatly between species. Some seed can be stored for many months, while other seeds lose their viability (ability to germinate quickly). If the seed has been stored for more than one month, a **good nursery practice** is to test the germination rate to see if the seed is still good. **Apoor, but unfortunately common nursery practice** is to sow old seed in many containers, without knowing if it will germinate — you might be wasting time, labour, and resources.

Sow 100 seeds in a shady germination bed and water normally. Count the number of seeds that germinate, and this will tell you how many you need to put into each container to achieve one plant per pot. If, for example, only 25 out of 100 seeds germinate, sow four in each container.

Test the germination rate to see if the seed is still good.

Controlling germination

The most important factor for good germination is constant humidity around the seed. Seeds can be covered with sieved soil, sand, rice hulls or pine needles, to keep them moist. A light material allows the tender roots and shoots to emerge without hindrance. The substrate should be moist, but not soggy; excess water should drain off. It is often recommended that you plant large seeds deeply and small seeds close to the surface. While this is usually sensible, if the substrate dries out quickly, or water is not always available, you will need to plant the seeds deeper. If the water pressure in the hose is very high, it may wash the seeds out, so again, plant the seeds deeper. A **good nursery practice** is to carefully control the light, water and shade

conditions during initial seedling growth. Shade helps retain humidity and prevents new leaves from scorching. This can be achieved in a seed bed as well as directly in the container.

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The substrate should not receive additional fertilizer because this could increase the risk of diseases such as damping-off. Germinating seedlings generally receive all nutrients

they require from the cotyledons (or in the case of palms, from the first leaf), that are formed inside of the seed. Thus, a substrate like sand, which does not contain fertilizer, is generally a good germinating medium. Damping-off is common with small seedlings and is recognisable as either decayed seed or, more frequently, decay around the stem at the soil line. The leaves of the seedling droop as though they need water, although the substrate is wet, then the stem appears "pinched" and brown near the base. Eventually, the seedling falls over at the soil line.

Damping-off is caused by fungi which can be present on the surface of the seed or in the substrate. Seed can be sterilized by immersing it for 30 minutes in a 10% solution of clorox (1 tablespoon of bleach plus 9 tablespoons water). Hydrogen peroxide, a common antiseptic available at the pharmacy, is also an effective seed sterilant. Its advantages are that it is less toxic than bleach, and it can increase germination because it softens the seed coat allowing water and oxygen to enter more easily. Seed is soaked directly in the antiseptic for up to four hours. With both bleach and hydrogen peroxide, some experimentation may be necessary to find the most effective solution strength and soaking time. A 30 minute soak with hot (just too hot to touch comfortably — definitely not boiling) water also works well on seed. The substrate can be sterilized by wetting the area well with water then covering the

area with a black plastic sheet for several days while it stands in abundant sunshine. The heat kills bacteria, fungi, and weed seeds. You can sterilize sand by washing it several times until the wash water appears perfectly clear.

Carefully recognize the type of damage on the seedling, and control the specific problem with the right method for that particular pest.

When deciding whether sterilization is necessary, first determine whether seedling growth is being harmed by something living in the soil by carefully examining the type of damage to the plant. Is the damage at the soil line or at the roots? If yes, then sterilization may be necessary. Test the different methods to determine if seedling growth really improves. ***A good nursery practice*** is to carefully recognize the type of damage on the seedling, and control the specific problem with the right method for that particular pest. Remember that sterilization of the substrate can also kill beneficial fungi, bacteria and insects. Certain bacteria and fungi are necessary to break down organic

matter or help plants better absorb nutrients. Many insects too are useful because they eat other insects that eat plants. Read more about these in chapter 3.

Direct sowing versus seed beds

Most nurseries use seed beds to germinate seeds. In fact, many nursery manuals recommend using them for all seedlings and give specific instructions on how to build 'beautiful' seed beds. We take a different approach. We strongly recommend sowing the seed directly in the container, and using germination beds only in special cases. We do so because we believe that this is best for seedling growth.

Some of the common problems with seed beds are that:

- pricking out almost always results in root deformities
- when plants are left in the seed bed too long (which often happens), they produce long roots that are easily damaged or twisted when pricked out
- many seedlings suffer a 'shock' when they are transplanted from seed beds — their growth is slowed for 1-4 weeks before they begin to show visible new growth
- pricking out is often done by staff with little nursery experience, and even people with experience often prick out incorrectly, and
- paying people by the number of plants pricked out in one day gives no incentive to prick out correctly.

When to direct sow seed

Careful control of water, light and nutrients is required during germination *and* during the first weeks of seedling growth. Directly sowing the seeds in the container saves time, labour and money, because the extra step of preparing a seed bed and transplanting is eliminated. Even if it takes a little longer to plant small seed directly in the containers or if they have to be moved and resown, this is easier and cheaper than pricking out. Direct sowing allows undisturbed seedling growth and thus reduces stress for the seedling. In a well-managed nursery, seedlings can almost always be directly sown!

When you are direct sowing, follow these ***good nursery practices***:

- use only fresh and ripe seed
- pre-treat seed, if necessary, to speed up germination
- prepare containers and shade in advance
- mix small seed with sand or rice hulls, or use a bottle with a screen top (like a salt shaker, but larger), to make dispersing it easier
- test seed for viability before sowing. If less than 70% germinate, plant more than one seed per bag. Throw away any extra seedlings in each pot. This is a small price to pay to avoid root deformities.

When to use seed beds

Depending on the conditions in your nursery, including the tree species, number of plants produced, and labour availability, a combination of direct sowing and use of seed beds may be your best way of operating. The use of seed beds is NOT recommended simply in order to ensure every container has a seedling. Seed beds can be used:

- to select seedlings of uniform size and development for transplanting. Only plants of the same age should be compared when judging plant quality. When seed germination is highly erratic, seedlings should be transplanted in groups of the same age. Seedlings should be pricked out in groups of even ages so that later they will not be compared with plants of a different age class.
- when seed is old, or when the germination is low or unknown. Use a seed bed to test seed viability (as described above) before filling too many containers and wasting resources.
- if seed does not store well (that is, if it is 'recalcitrant').
- if containers are not available, or not filled in time to use. Seed beds can be used until the containers are ready.

Types of seed beds

There are two types of seed beds, temporary and permanent. Temporary seed beds include any tilled bed of soil. Alternatively, seeds can be germinated between bags of jute or sheets of newspaper that are kept constantly wet, but not soggy. The advantage of using newspaper or a similar material as opposed to planting in a bed of sand or soil is that you can easily check the stage of seed germination and prick the seedling out as the tap root emerges. It is not necessary to wait until the seedling grows 15 cm and produces its first true leaf, and in fact that's not a good idea, because the older, better-developed seedlings are more susceptible to damage when pricked out.

Plastic flour bags filled with a sand and soil mixture are common in the State of Yucatan, Mexico. The bag can be closed initially to provide shade and a humid micro-environment. Small seed lots can be germinated, and the substrate can be easily loosened to remove the seedlings. Another advantage of these bags is that they can be moved directly to the rows of containers where the seedlings will be planted.

Permanent seed beds are commonly constructed with cement blocks at 1 m or more height and 1.2 m width for working comfort and efficiency. They are filled starting at the bottom with stones, then gravel, then soil or sand. A common practice in Costa Rica is to

prepare wooden boxes with a fine wire mesh bottom and fill them with sand. The boxes are placed on tables in a greenhouse or under a roof. The tables are also covered with fine wire mesh to allow good drainage and aeration. Frequent watering is necessary because the sand does not retain much water. Creating the proper germination conditions in containers, and pricking out correctly, are more important than constructing tidy, permanent germination beds.

How to prick out correctly

Even when pricking out is done very carefully as described below, it is still very hard to do it correctly, especially when thousands of plants must be transplanted. Only those who are trained in correctly pricking out should attempt it. Unfortunately, many people who have

Good pricking out practices

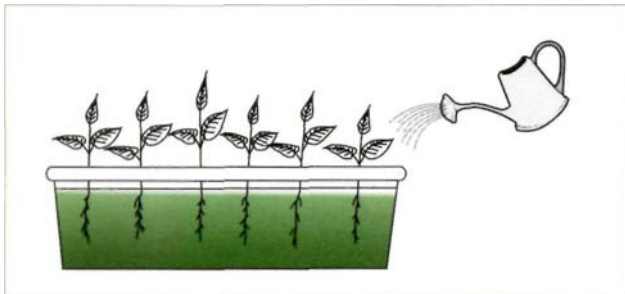
- throw away any seedlings that appear sick or deformed
- transplant when the tap root emerges or seedlings are still small (5 cm), before secondary roots are formed
- water the bags well, one night before you prick them out, so that water penetrates to the bottom of the seedbed
- ensure that the area where the transplanted seedlings will be kept is well shaded before you begin pricking out
- water the seedlings 24 hours before, and one hour before, pricking out
- on days with strong sunshine, prick out in the early morning or late afternoon
- use a shovel or stick to gently loosen the soil around the seedlings
- remove seedlings by grasping their cotyledons or lower leaves - do not lift them out by the stem
- put seedlings in water as soon as you take them from the germination bed
- prepare planting holes with a stick and ensure they are sufficiently wide and deep
- clip long or very branched roots to ensure they are pointed downwards
- gently pull the seedling upward after placing it in the hole, to straighten out roots
- pack the soil against the roots, starting at the bottom of the hole
- water the plants immediately after transplanting, and again when they wilt

2 SEED HANDLING, SEEDLING GERMINATION AND SOWING

pricked out in the past have done it incorrectly. Close supervision and revision of the plants is necessary in order to avoid root deformities. Always open a few containers after a few days to check that it has been done correctly.

Poor, but unfortunately common pricking out practices

- waiting until plants are large and have long roots
- pricking out plants into dry soil and then watering them
- constructing shade after pricking out is done
- pricking out in direct, hot sunlight
- transplanting damaged seedlings
- removing seedlings by grasping the stem, as this may permanently damage the flow of water
- carrying seedlings in your hand or on a plate without water
- preparing the holes with a finger — the hole will usually be too small
- allowing roots to bend upwards when inserting them into the hole
- leaving air pockets around the roots — the plants will die



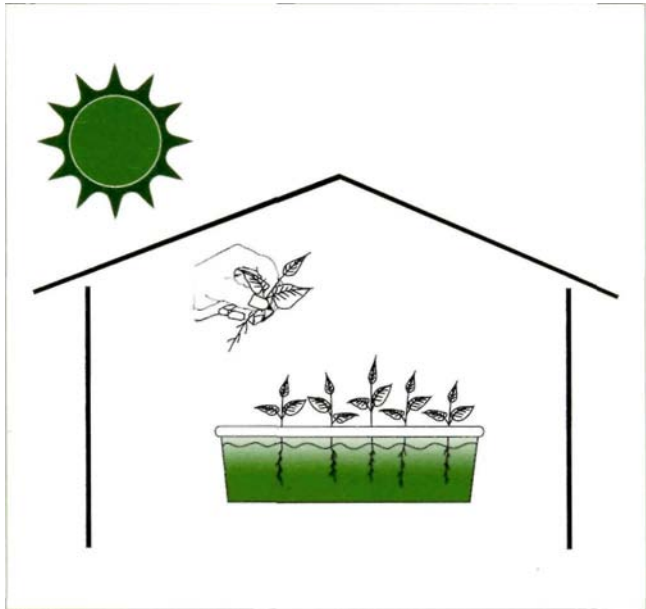
Water the plants well before transplanting them.



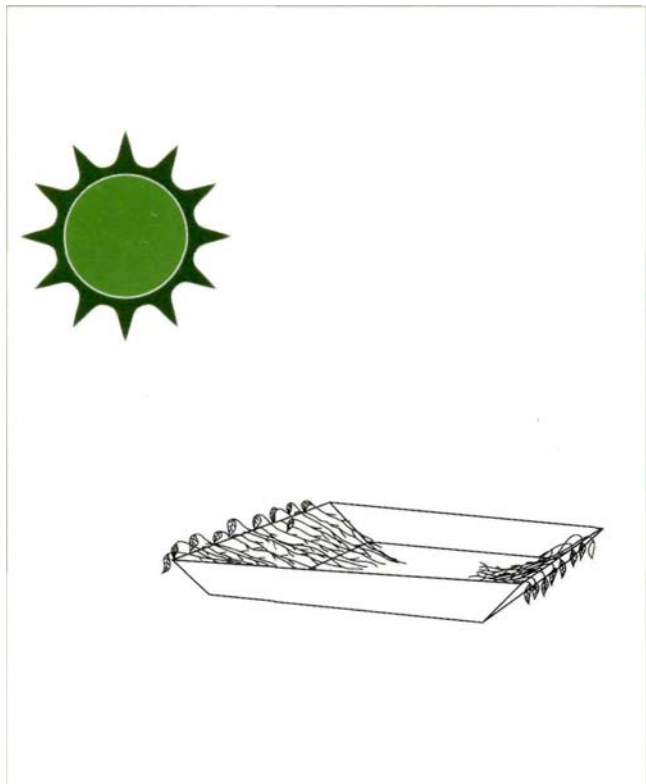
Lift the soil around the seedlings and pull them up carefully. Use a small shovel or stick to gently pull out the seedling. Don't squeeze the stems, because they are fragile.

2 SEED HANDLING, SEEDLING GERMINATION AND SOWING

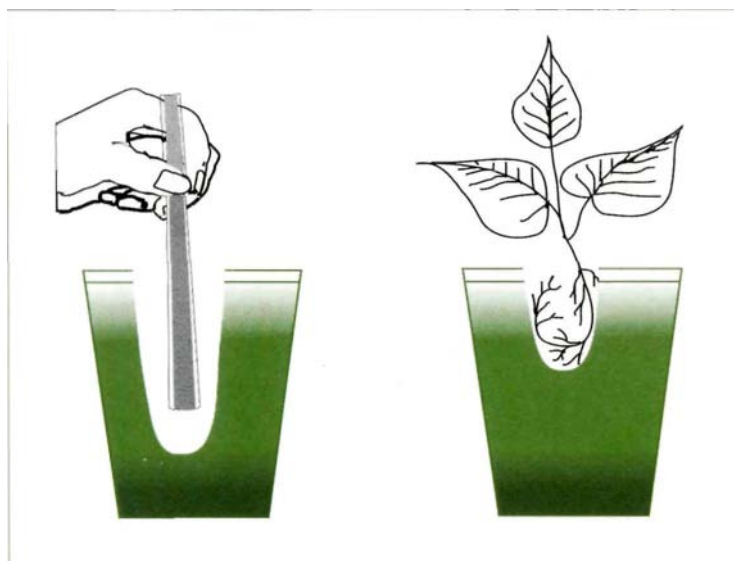
Put the plants in a dish with water.
Keep them in the shade
and plant them immediately.



Roots dry out within
minutes! When they dry out,
they die. Make sure that they
are covered with water,
wet paper or a mud slurry.



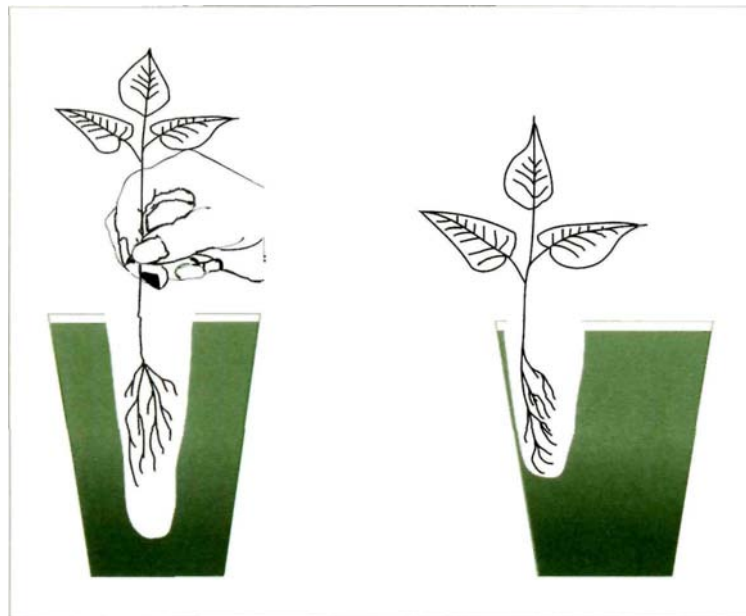
2 SEED HANDLING, SEEDLING GERMINATION AND SOWING



right

wrong

Make the hole sufficiently deep with a long stick. Do not let the roots curl upwards.



right

wrong

Plant the seedling in the middle, not at the edge of the container. Carefully pack the soil around the roots so that no air pockets are left around the roots.

Summary of sowing and seedling germination

Whenever possible, direct sow seed into containers, to avoid root deformities. Controlling the germinating environment and correctly pricking out are more important than constructing fancy seed beds.

Good nursery practices

- sow seed as soon as possible after harvest
- pre-treat seed, if it takes more than a week to germinate
- test old seed before planting to know if it will still germinate
- carefully control the light, water and shade during seedling growth
- sow seed directly in the container

Poor, but unfortunately common nursery practices

- expending a lot of effort to build fancy seed beds
- careless pricking out, resulting in damaged plants with root deformations
- leaving seedlings in the germination bed too long

Substrate quality

Physical and chemical properties of substrates

Substrate quality is one of the most important influences on seedling growth. A good substrate has both the chemical and physical properties that promote healthy and rapid plant growth. These properties work together. A substrate that has many nutrients but is very heavy and does not allow the water to penetrate is not good. Similarly, a substrate that has adequate drainage, but is deficient in plant food, is not good.

The **physical properties** of the substrate include:

- how much water it can hold
- how much air space it contains
- its texture
- its weight per container.

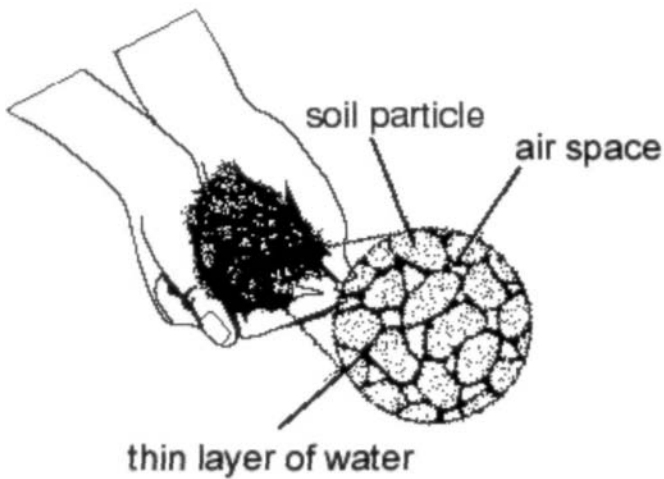
The substrate must allow a large amount of water to be held without waterlogging. Air space (porosity) is necessary to allow air to enter and leave the substrate. The roots need to 'breathe', just as the leaves do. If the substrate holds too much water, the roots will suffocate.

The substrate texture is how it feels in your hand. Can you roll it into a ball then press it flat like a tortilla? Or is it gritty and crumbly? If you can roll it out, then it probably contains a lot of clay. High clay content may cause the substrate to shrink and crack when it dries. This can damage the root tips of the seedlings. If the texture is gritty, it probably contains a lot of sand, which adds porosity, but decreases the nutrient content and the ability of the substrate to hold water. Finally, the weight (bulk density) of the substrate affects how easily the seedlings can be transported to the field.

The **chemical properties** ('fertility') of the substrate include:

- the amount of nutrients it contains
- how easily available they are to the plants
- the rate at which they are released to the plants.

The fertility depends on the amount of nutrients — or plant food — in the substrate. Soil fertility is affected by the origin of the soil, and whether it has a lot of organic matter (see chapter 7). Soil from a forest or from close to a river usually has more nutrients than soil



A good substrate has different size particles — this allows air and water to penetrate easily.

from cattle pastures. Soil from the top 10-15 cm is usually more fertile than soil from deeper down. Nutrient availability is regulated by how acidic the substrate is (measured in pH). Lemon is very acidic, chalk is very basic (or alkaline). The acidity can be adjusted by adding sulphur to increase acidity, or chalk to lower it. Rainwater is usually neutral, it is neither acidic nor basic. The rate of release of these nutrients is how quickly or slowly the soil releases these nutrients to the roots. In some soils, the nutrients are washed away quickly with each rain, in others, the nutrients are tightly bound to the soil and are difficult for the roots to extract.

A good nursery substrate has the following characteristics, the optimal substrate may vary for each species:

- it is light in weight to facilitate transport but holds cuttings and seedlings firmly in place
- it does not shrink or swell in a way that may damage the plants
- it retains water but allows proper drainage and aeration of the roots
- it contains the necessary nutrients to allow plant growth and development
- it does not contain weed seeds, high level of toxic salts, harmful fungi, bacteria or insects
- it can be sterilized without changing its characteristics
- its quality is consistent from year to year.

3 SUBSTRATE QUALITY

A *good nursery practice* is to mix soil with an inert (inactive) material like sand and a rich material such as well-decomposed organic matter. Because sand does not contain nutrients, you can leave it out entirely if a good compost is available. As general rule, the following mixtures are used in bare-root beds, or in bags, but not in root trainer containers (see chapter 4). The proportions are listed for the volume of each material. Mixing these materials also reduces soil mining.

	Soil	Sand	Compost
For heavy textured (clay) soils:	1	2	2
For medium textured (loam) soils:	1	1	1
For light textured (sand) soils:	1	0	1

Soil mining

Soil mining — excavating soil — for the nursery can cause erosion and site degradation. When soil is used, the fertile, upper layers are quickly depleted, leaving poor quality subsoil. In Mexico, 25 million m³ of soil are used every year in tree nurseries. The area where the soil was taken loses nutrients that took decades if not longer to acquire. Trees and crops do not grow well in an area where soil has been mined. As soil is depleted, the costs of buying and transporting soil rise for the nursery.

Adding beneficial fungi and bacteria

Many tree species have a special symbiosis, or mutually beneficial relationship between a fungus and the tree roots. This intimate association is called a 'mycorrhiza'. Many different kinds of fungi occur in this form, and different fungi work best for each tree species. The association helps the plant absorb water and nutrients, and protects the roots from diseases.

When growing pines, oaks or eucalypts it is important to inoculate the roots with the appropriate fungus. This is especially important if these species are being produced in an area for the first time. If they are not inoculated, the trees will be yellow and stunted and grow poorly or die in the field. The easiest way to ensure presence of the beneficial mycorrhizal

fungi is to collect soil from healthy, existing plantations of these species, and mix the soil into the nursery substrate. The mixture should contain up to 10% of the plantation or forest soil.

Similarly, many legume trees also require special bacteria called 'rhizobia', to use nitrogen, one of the most important nutrients (see chapter 7). Inoculation with these bacteria is necessary on acidic soils where legumes have not been planted before. Without inoculation with rhizobia, the plants may not grow at all or may be severely stunted. Many different strains are available and some may be more effective than others. Rhizobia for beans are commonly available at agrochemical stores. You may have to try several types before you find the correct type for your nursery trees. Keep the bacteria out of direct sunlight, store in a cool dry place, and use as soon as possible. Otherwise they will die and the supply will become useless. The living bacteria are mixed directly with seed before planting.

A good nursery practice is to apply mycorrhizal fungi or rhizobial bacteria, or both in the case of legumes, after sterilizing the soil. Heat and chemical sterilization can kill these beneficial micro-organisms.

Legumes — plants that produce their own nitrogen

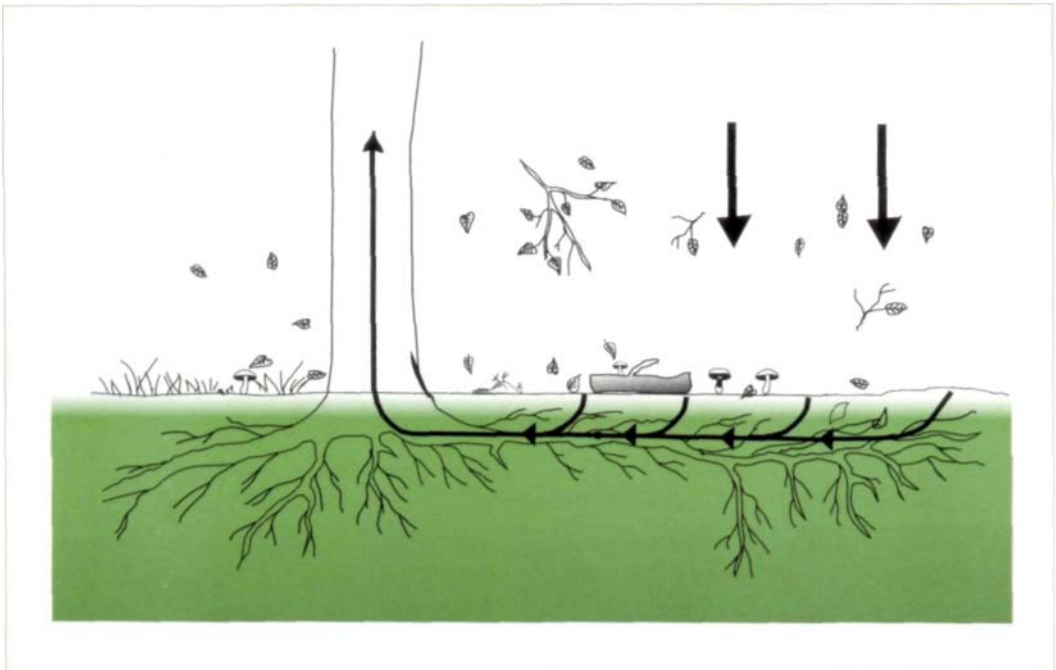
Legumes are a special family of plants that have bacteria growing in their roots. Legumes include beans, and many trees that produce seeds in pods, such as leucaena and calliandra. You can see the areas where bacteria live as little nodules or bundles on the roots. The bacteria allow the plants to use nitrogen gas that is in the air and between soil particles. Other plants can only take nitrogen that is dissolved in the water in the soil. Making use of the unique collaboration between plants and bacteria, legumes can acquire more nitrogen than other plants. Legumes make a good green manure or 'living fertilizer', because they add nitrogen to the soil.

Organic matter is a treasure

Organic matter is derived from once-living plant or animal matter. It includes leaves, weeds, and animal waste. Organic matter must be well-decomposed, or broken down, and produce no odour or heat, before incorporating into the substrate. Unfortunately, many people think of organic matter as trash or waste (commonly called 'basura' in Spanish). *Kpoor, but unfortunately common nursery practice* is to burn organic matter. The burning of organic debris in the nursery (with exception of diseased plants) is a terrible loss of valuable, rich material.

3 SUBSTRATE QUALITY

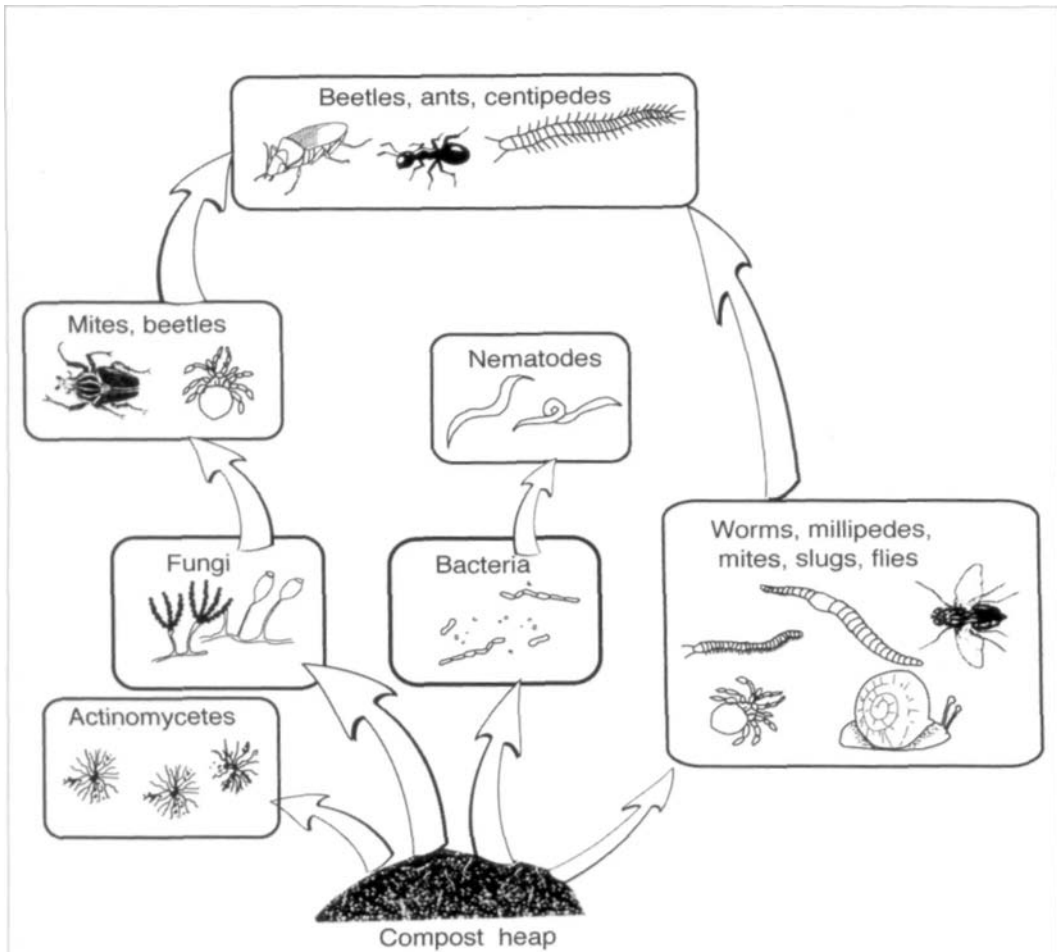
Organic matter is in fact not waste at all — the opposite is true, it is a useful source of nursery compost. ***Organic matter may be one man's trash, but to the nursery, it is a treasure.*** Organic matter can greatly improve the substrate's chemical and physical properties necessary for good plant growth. It provides plant nutrients, improves porosity and water-holding capacity, and makes the substrate lighter and easier to transport. In fact, a well-decomposed compost can actually help suppress plant diseases like damping-off. Of course, it also reduces soil mining! The idea of using compost is not new — it comes from nature.



Nature produces and uses compost all the time. When organic debris falls to the ground, it decomposes with the help of fungi and other micro-organisms living near the soil surface. The finished compost or humus is then reabsorbed by the plant roots. This is a perfect recycling system for plant nutrients.

What happens during composting?

Composting is the physical and chemical breakdown of materials. It liberates nutrients available to plants. Insects, fungi, and bacteria digest material during decomposition. They must 'eat' all of the material before it becomes finished compost. They need air and water to do this well.



A compost pile is alive with many organisms that eat the organic material. Many are too small to be seen, but they are all important in breaking down the organic matter and turning it into compost.

There are two basic ways of compost production: anaerobic and aerobic. Anaerobic methods supply minimum oxygen to the micro-organisms digesting the organic material in the heap, while aerobic methods supply maximum oxygen. The main differences between the two are time and odour. Anaerobic composting is very slow, and usually takes more than nine months. Anaerobic composting uses less labour because pits **are** filled with material, covered and **left** unattended. However, foul smelling gases (methane and sulphur) often develop.

3 SUBSTRATE QUALITY

Aerobic compost can be ready in as little as 40 days if it is regularly turned. Aerobic composting also requires regular monitoring of the temperature to ensure the best possible conditions for the most effective micro-organisms. We will only discuss aerobic composting because it is faster and more reliable.

Three distinct phases based on temperature development occur during composting. The heat comes from the proliferation of the micro-organisms — they are working hard and reproducing which causes heat, just as when people work, they get hot, thirsty and needs lots of fresh air and water. Efficient composting is all about creating the right microhabitat — the right 'house' or 'office'— so that the micro-organisms can proliferate (reproduce) and work hard (digest the organic material).

During the first 24 to 48 hours, the temperature rises to 40-50°C, destroying sugars and other easily biodegradable substances. During the second phase, as the temperature rises to 55-65°C, the initial micro-organisms die, and others specially adapted to the heat begin to break down the more difficult material, like cellulose (a component of wood). The temperature should reach a peak of 70°C for three days to kill all weed seeds and plant diseases. Keeping the temperature between 55 and 65°C as long as possible is the fastest way to produce compost because this is the phase when the most efficient micro-organisms are breaking down the hardest to digest material. Turning the pile to incorporate oxygen and ensure an even distribution of the materials and maintaining 40-60% moisture allows for optimal composting efficiency. The final stage, in which the temperature remains below 40°C, is called 'maturing' or 'curing', because the bacteria and fungi that help control plant diseases, as well as the larger organisms like earthworms, move in.

Good compost should be 'old' and well-decomposed. Young compost, which might not be completely decomposed or broken down, can harm tree seedlings. Trees planted with unfinished compost often turn yellow, because the plant cannot acquire all the nutrients it needs. To see whether compost is ready, place two moist handfuls in a plastic bag, seal it and leave in a dark, cool place. After 24 hours open the bag: if no odour or heat is present, the compost is ready. You should not be able to recognize the original material, such as an entire leaf or an orange peel. It should have the consistency and colour of coarsely ground coffee. You can then sieve the compost and return any large particles to the next compost batch.

The right ingredients for compost

Each batch will differ depending on the materials you use. Producing consistently good compost takes some practice, but is important for consistently producing high quality

trees. Not all tree species will respond in the same way to the compost, so some adjustments may be necessary. *Agood nursery practice* is to plan ahead and start making compost well before you need it. It is very important to realize that only about 40% of the fresh material by volume will become finished compost. Therefore, obtaining large quantities of fresh material at minimal costs is essential for efficient and economical composting.

**Plan ahead
and start
making
compost
well before
you need it.**

Any organic material can be composted; a mixture of materials is best. Depending on what is available in your area, grass, leaves, any fruits or fruit waste (like peels) from plantations, coconut fibres, coffee shells, sugar cane bagasse, and rice hulls can be used. Weeds and old seedlings, as long as they are not diseased, can also be included. In addition, animal manure from cows, horses, goats, chickens etc. should be added at about 25% of the total volume because it contains a lot of nitrogen. Feathers and even human hair can be used because they are high in nitrogen. Diseased plants should always be removed from the nursery and burned. *Agood nursery practice* is to test a variety of organic materials to find the right mixture for each species.

**Test a variety
of organic
materials to
find the right
mixture for
each species.**

A 'compost bank' is an area planted with a variety of 'crops' such as sugarcane and legumes like canavalia (*Canavalia* spp.), nescafe (*Mucunapruriens*), poro (*Erythrina* spp.) or madera negra (*Gliricidia* spp.). It is similar to a fodder bank that farmers plant for animals. It provides a consistent supply of organic matter and is easy to harvest. Over time, it may be necessary to fertilize this area, since the nutrients from the soil are 'exported' with the crops.

Material that is chopped, shredded, or cut into small pieces (ideally, 1-2 cm) with machetes or a mechanical shredder is easier for micro-organisms to break down. This makes decomposition faster and produces a more homogeneous mixture for filling containers.

Adding lime (calcium carbonate) is not generally recommended since it will make the compost too basic. Too much lime will also kill the micro-organisms. Adding fertilizer may speed up the process, and improve the nutrient content of the compost, but it is not necessary — and defeats the purpose of producing your own cheap fertilizer! Finished compost can be mixed with soil later, but soil and sand should not be added while making the compost. This only slows the composting process and wastes space in the composting bed. For the method described below, compost improves soil, but soil does not improve compost.

Be careful with sawdust!

Sawdust is frequently mixed with soil because it is cheap and readily available, but even old sawdust can be a problem. Sawdust and wood chips are very difficult for micro-organisms to digest because they contain the same chemicals that make the wood hard and resistant to rain. The sawdust often does not contain many nutrients, specifically, nitrogen, an essential plant nutrient. Plants grown in sawdust become yellow, unless nitrogen is applied. Nitrogen is found in many granular fertilizers, the strongest of which is urea, and in animal manure. Mixing nitrogen with the sawdust can make a good nursery substrate, however, several tests are necessary to find the right proportions because the characteristics of the sawdust vary with species and age. Try mixing a total of 3-4 kg of N in the form of urea per cubic metre of sawdust during three applications one month apart. If you use N from a different source, for example, 17-17-17, you will need to apply more because the N concentration is not as strong as in urea.

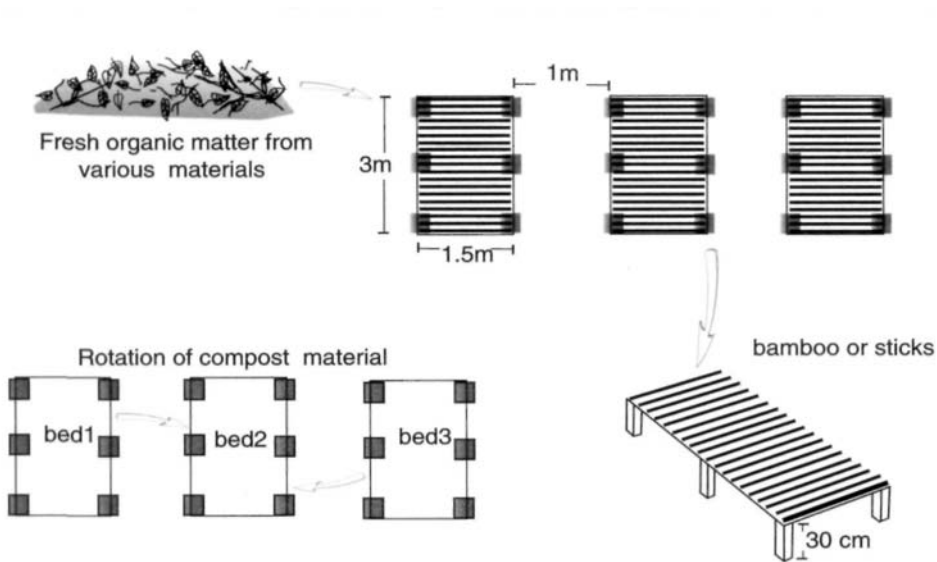
The 'three bed system' for making compost

There are many 'recipes' for making compost depending upon the climate and the materials available. It is best to experiment until you find what works best for you. This aerobic method produces compost in 2-4 months in the humid tropics. It uses less labour and time than compost made in a pit because the compost is kept well-aerated above the ground at all times and is easier to mix.

In a flat area, make three rectangles (3 m long x 1.5 m wide) side by side with large bricks, rocks or large wooden beams (at least 30 cm off the ground). Put some bricks in the centre for extra support. Allow at least 1 metre between the rectangles as a path for working. Don't make them too wide, or they will not support the weight of the compost. However, they can be as long as you want. On top of this base, construct a flat 'bed' with bamboo, wood, or metal poles. Choose a material that will not rot quickly. Chicken wire or palm leaves are very useful for covering the bed. The bed should have some holes or cracks to allow air to pass through — but not big enough for the compost to fall through.

Pile organic material to about 1 metre tall on the two outer beds. Leave the middle bed empty. Keep the piles flat, not pointed like a pyramid, in order to use the space more efficiently. After a week, the compost should become very warm. Check the temperature by placing

your hand deep inside the pile at two or three locations. It should feel warm to the touch. After the temperature drops again, in about another two weeks, use pitchforks to lightly loosen the material in each bed. This adds oxygen for the micro-organisms. After another two weeks, carefully move the material from the outside of each compost pile to the empty centre



The three bed system works rapidly because air passes below the beds. The process is also labour efficient because turning is made easy.

bed. Then remove the next layer of compost and put it on the centre bed, on top of what's already been moved. This mixes the pile, putting the material from the outside into the inside of the pile. After a week, the compost in the centre pile should become warm again. The outer two beds are ready to fill again with fresh material as soon as you have moved the piles to the central bed.

Always monitor the moisture status of the piles. Add water when dry, or build a roof if too much rainwater enters the piles. A good nursery practice is to keep the pile well-aerated, and moist at all times. Putting a plastic sheet, coconut leaves, or other covering over the piles helps conserve the water if the climate is particularly dry. After four weeks move the compost from the middle bed to a storage area. This allows it to mature

Keep the pile well-aerated, and moist at all times. Monitor it frequently.

3 SUBSTRATE QUALITY

or ripen; the chemical components of the compost will become stable. Carefully cover it, but don't seal it entirely — allow some holes so that the compost can breathe. Covering it will prevent weed seeds from landing on the finished compost. The other two beds should be ready to combine into the middle bed when you move the finished compost to a storage area, and the process can start again.

The most common problems in compost making

Once you understand the basics, practice will determine your success. *A good nursery practice* is to monitor the compost frequently. It cannot be left alone and expected to produce good, rich compost without any effort.

- If the pile smells acidic or like rotten eggs, the compost is anaerobic. Loosen the heap with a pitchfork to improve the aeration.
- If the pile is very wet or very dry, cover loosely with a plastic sheet. It should contain about 50% water. It should be moist when squeezed in your hand, like a wrung-out sponge, but water should not drip out.
- The pile may not heat up, if it is too wet or too dry or if the wrong materials — such as mostly woody branches — are used.
- The pile may not heat up or decomposition may be very slow, if it is not homogeneously mixed. Look for parts that are too wet or too dry or contain just one type of material and then mix well.

A compost pile is not a rubbish pile. Never add:

- glass
- metal
- plastic (including left-over bags from the seedlings)
- meat (it will attract rodents and dogs).

Calculating substrate quantity

First, determine the volume of the container. Cover the holes of the container and add water from a litre bottle. The amount of water you add is equal to the volume. Small bags usually hold *Ui* litre of water, large bags may hold more than 1.5 litres. Root trainers usually have a volume of less than 12 litre. A normal size bucket holds 20 litres - enough to fill 40 small bags or 13 big ones.

Second, multiply the volume of your container by the number of seedlings to be produced.

Finally, divide the resulting volume by 20, the capacity of one big bucket, to see how many buckets of substrate you need to fill all containers.

Example One. If 10,000 seedlings are needed and ¹/₂ litre (0.5 litre) bags are used:

$$10,000 \times 0.5 = 5000 \text{ litres of substrate}$$

$$5000 / 20 = 250 \text{ buckets}$$

Example Two. If 2000 seedlings are produced in 1 litre containers:

$$2000 \times 1 = 2000 \text{ litres of substrate}$$

$$2000/20 = 100 \text{ buckets}$$

When using compost, a general rule is that fresh compost has twice the volume of finished compost. This may vary depending on the material used.

First, calculate the total volume of each bed. For example, if you have three beds of fresh compost and each bed is 3 metres long, 1.5 metres wide and one metre high, then multiply:

$$3 \text{ m} \times 1.5 \text{ m} \times 1 \text{ m} = 4.5 \text{ m}^3 \times 3 \text{ beds} = 13.5 \text{ m}^3 \text{ of fresh material}$$

Second, divide this number by 2, for the total amount of finished compost.

$$13.5 \text{ m}^3 / 2 = 6.75 \text{ m}^3 \text{ (6750 litres or 338 buckets) of finished compost.}$$

Example Three. If you want to produce the 10,000 plants from example 1 with a mixture of 1:1 soil:compost, you will need 2500 litres of finished compost, or 5000 litres (5 m³) of fresh compost.

If the fresh compost reduces its volume by only 30%, then less fresh compost is needed. Similarly, if your mixture contains less compost, say in a 2:1 soil:compost mixture, less finished compost is needed.

Summary of substrate quality

Substrate quality is determined by both the physical characteristics such as good drainage, and chemical characteristics such as high nutrient content. A good nursery substrate is light, retains water, but does not become waterlogged, and does not contain weed seeds or harmful micro-organisms. Organic matter is a valuable treasure because it improves substrate quality. Composting is the controlled breakdown of organic matter that provides a good alternative to soil mining.

Good nursery practices

- improve the substrate physical and chemical characteristics with compost
- add beneficial mycorrhizae and rhizobia after sterilizing the substrate
- plan ahead and start the compost well before you need it
- test a variety of organic materials to find the right mixture for each species
- keep the compost pile well-aerated and moist at all times
- monitor the compost frequently

Poor, but unfortunately common nursery practices

- burning of organic matter
- mixing glass, metal, plastic or meat into the compost pile

Production methods

Bare-root plants and stumps

Producing seedlings without containers seems like the easiest option for the nursery. Indeed, less soil is needed and the seedlings are easy to transport to the field. But although a containerless system has some benefits, the disadvantages almost always outweigh the advantages. Remember, the choice of procedures must always be based on what is best for seedling growth.

In temperate zones where the temperature drops to below freezing, bare-root beds work well with a variety of species because these become dormant — or stop growing — for several months. Hardwood species, for example, lose their leaves during the inactive period of dormancy. Plants are often stored in refrigerated warehouses and planted in the field before they start actively growing again. This greatly reduces the shock of lifting, transporting, and planting the trees.

In the humid tropics of Latin America, bare-root beds are commonly used for hardwoods like cedro (*Cedrela odorata*). While this species is not dormant during the planting season, it seems to store a lot of water and nutrients in its stem. The stem has sufficient reserves to continue growing even after losing roots during lifting and transport.

The two major problems with bare-root production are maintaining soil fertility in the beds, and proper handling of the plants. When plants are produced for several years in the same soil, nutrients are depleted and the trees become smaller each season. Lifting the trees from the beds in the nursery, transporting them, and planting, exposes the roots

advantages of bare-roots plants	disadvantages of bare-roots plants	
• one person can carry several hundred seedlings to the field	• competition for light, nutrients and water when natural shade trees are used	
* smaller holes are dug than for plants in bags	• depletion of soil nutrients in the nursery beds	
• lower production costs because containers are not purchased and less soil is needed	• slow initial growth in the field	>
	• high mortality in the field	

Good nursery practices for bare-root production

- sow plants at a low plant density of 200 plants or less per square metre — this reduces competition for water, light and nutrients and improves seedling growth
- use a sharp wire to undercut the beds during the growth period so that cut roots heal naturally — this prunes the roots so they do not grow too deeply and promotes more lateral root growth
- use compost or fertilizer to replenish the soil nutrients throughout the growing season
- plant a leguminous cover crop or green manure such as *Canavalia* during the fallow season, then incorporate the organic material to replenish soil nutrients
- allow the bare-root beds to fallow or rest for one or more seasons to replenish the soil nutrients, and then incorporate the organic material into the soil
- dip the roots in a mud slurry after lifting seedlings from the bed
- wrap the plants in wet newspaper or jute bags
- keep plants in the shade and out of the wind at all times during transport
- plant in the field without any delay and only when the soil is very moist
- dig large holes and ensure that the roots point straight down when planted

Poor, but unfortunately common bare-root practices

- sowing seeds at a high density
- allowing the roots to grow deep into the bed
- producing seedlings in the same soil each year without replenishing soil fertility
- leaving the bed without vegetation when not used
- allowing the beds to become very weedy — weed seeds will contaminate the beds
- when lifting the seedlings, removing many roots from the plant or damaging them by stripping the outer protective layer
- allowing the roots and the leaves to dry out or become very hot during lifting
- planting in the field when the soil is dry
- digging shallow holes that do not cover the roots
- bending or twisting the roots when planting

to air and they die. Only when intensive nursery management maintains soil fertility in the beds and when the ideal lifting, transporting, and planting conditions are guaranteed, do we recommend producing bare-root plants.

Stumps or *pseudo-estacas* are bare-root plants that have been grown for, on average, 18 months in the nursery. They are often 1.5 to 2 m in height and have a diameter the size of your thumb. They are drastically cut back, ideally to about 15 cm root length and 3 cm shoot just before planting out. However, frequently, the shoots are left the same size as the root. The shoots should always be shorter than the roots. Stumps are common in Costa Rica for cordia (*Cordia alliodora*), a tree used to shade coffee, melina (*Gmelina arborea*) and teak (*Tectona grandis*). Because of the great setback in plant growth, it often takes over a year for the plants to regain their original height when cut. As this has to be added to the long time needed for their production (18 months instead of 3 or 4), their slow growth and high mortality in the field, we do not recommend producing stumps.

Plastic bags

Plastic bags are widely used for young plants in Latin America and throughout the tropics. This is principally because they are cheap and widely available, not because they result in the best plant growth. Bags come in many sizes, some with pleats so the bag stands upright, and some with no bottoms at all. Aeration holes are usually present — if not, they must be cut. The inherent problem with plastic bags is that when the roots reach the bottom of the bag they begin to spiral as described in chapter 2. Roots also grow into the soil below and later are damaged when the bags are moved.

A common, but poor nursery practice is to use large bags — 1 litre or more in volume — to improve plant quality. Plant development depends more on what is inside the bag—the quality of the substrate — than the size of the bag. In fact, as the substrate quality improves, bag size can be decreased. A good nursery practice is to use small bags with a rich substrate like compost. The only exception to the use of small bags and a rich substrate may be with trees that take longer to develop, such as grafted fruit trees.

**Use small
bags with a
rich substrate
like compost.**

The use of small bags has advantages for the nursery and for the farmer:

- they require less substrate
- they are lighter and easier to carry to the field.

Producing trees in small bags may require some nursery changes. A space should be left between rows of small bags in order to reduce the plant density. If the number of plants per square metre is high, the plants will grow tall and spindly. Plants grown in small bags may require more frequent watering than plants in large bags. Although it is always a ***good nursery practice*** to plant out trees on time, plants in small bags cannot stay in the nursery as long as plants in large bags.

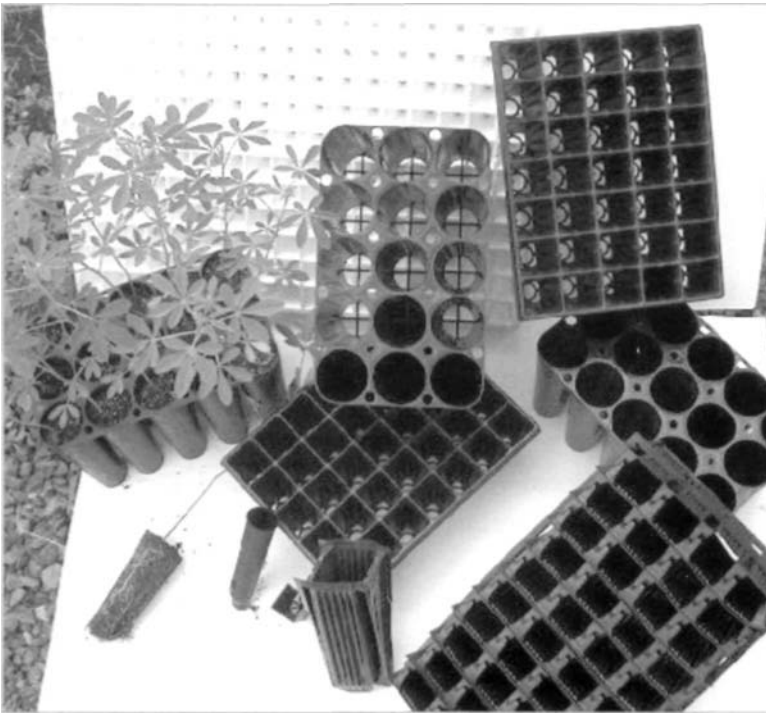
For many years in both temperate and tropical forest regions, root trainers have been used to successfully grow high quality trees. They come in many shapes and sizes, but all have two characteristics in common:

- The vertical inner ribs direct the roots straight down as they grow, thus avoiding the root deformities caused by smooth plastic bags. The containers are set on frames above the ground, so that air circulates around the bottom hole. Roots are air-pruned as they emerge from the container. This natural pruning of the main roots encourages secondary root growth so that eventually the volume of the root trainer is filled with a 'plug' of fibrous roots. When the tree is planted in the field, the pruned roots continue to grow again.

The right size of the container depends mostly upon seed size and some testing may be necessary for each species. Since the volume of root trainers, 75-250 ml, is usually much smaller than that of plastic bags (bags are usually 1/2-3 litres), only a rich organic substrate such as compost can be used. The compost must be tightly packed in each container and well-watered before inserting the seed or cutting. Another great advantage of root trainers is

that they are easy to fill which improves labour productivity. Depending on the size of the root trainers, several thousand can be filled in one hour, compared to a maximum of 200 bags per hour. Trainers are more expensive, but can be reused for many years, if properly maintained.

Root trainers are not simply a different container. They require a big change in nursery management — different substrates are used, different support systems are needed and watering regimes may increase. Their main advantage is in producing plants that are free of root deformities, with extremely fibrous root systems and a balanced root to shoot ratio. They are also easy to transport to the field.

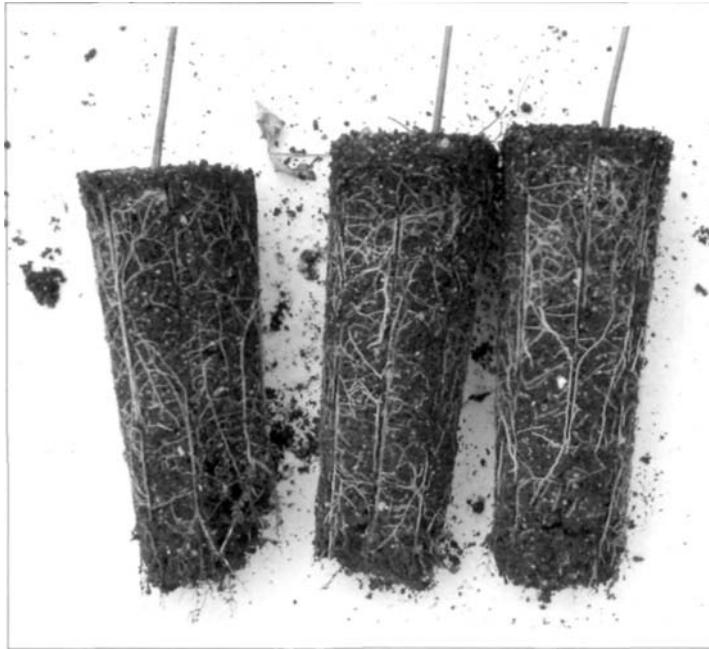


Root trainers are available in a variety of styles and shapes. The container volume is small, so a rich substrate is needed.

New developments

Like root trainers, the following two products cost more than bags. They are available in Latin America, although only through large nursery suppliers. Nonetheless, we include them here because new developments that improve plant quality may be worth the added initial cost. They may be most appropriate for private nurseries that are integrated into a plantation operation or in research nurseries.

4 PRODUCTION METHODS



Three seedlings grown in root trainers. Notice the large quantity of roots growing downwards.

Spin-Out® is a copper hydroxide paint that can be applied to the inside of bags or any plastic container. The coating is toxic to root tips; when the roots reach the side and bottom of the bag, they stop growing before they become deformed. Secondary root growth is promoted which is important in absorbing water and nutrients.

Jiffy Pellets® are individual pellets that contain compressed peat surrounded by a biodegradable net. They are container and substrate in one. Jiffy pellets have been used successfully in industrial plantations around the world. The containers expand to a maximum height of 4 cm and 2 cm width. The peat is a lightweight, porous material that allows the roots to penetrate quickly. However, it contains no nutrients, so fertilizer must be added.

Like root trainers, Jiffy Pellets® require significant changes in nursery management. Support trays are needed; fertilizer regimes must be developed, and strictly applied. The quantities of fertilizers will probably vary for each species. The main advantage of this system is that the nursery does not have to acquire the substrate or fill containers. This saves labour and possibly material costs. The pellets use less space in the nursery and are easy to transport. They can also be used for vegetative propagation.

Summary of production methods

The most common production techniques may not always be the best. Bare-root plants and *pseudo estacas* are easy to transport to the field, but their survival and growth are usually very poor. Plastic bags are cheap and easily available, but they result in coiled roots and are heavy to carry to the field. Root trainers, copper coated containers, and Jiffy Pellets® are alternative systems which may have higher initial costs for the nursery. However, the farmer will receive the benefits of fast growth and high survival in the field.

Good nursery practices

- use bare-root production only if soil fertility is maintained in the nursery beds and ideal planting conditions are guaranteed
- use small bags with a rich substrate such as compost, instead of large ones
- invest in alternative containers such as root trainers to improve plant quality

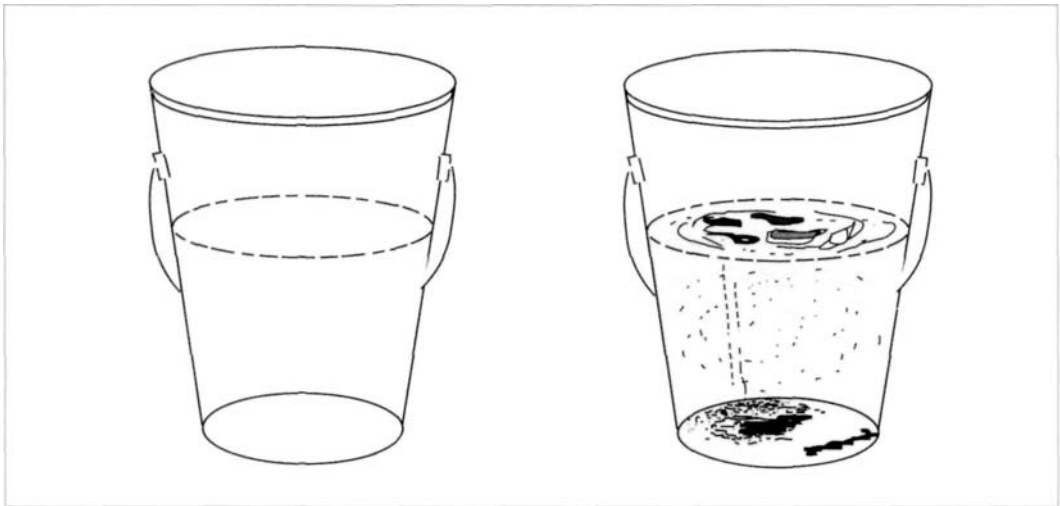
Poor, but unfortunately common nursery practices

- using stump plants
- allowing bare-rooted plants to dry out during lifting, transport, and planting
- using large bags — over 1 litre in volume — to improve plant quality

Water is life

The regular supply of clean water is essential to plant growth. Plants are made out of more than 90% water. When grown in containers, nursery plants have only a limited volume of substrate and do not have the ability of mature trees to search for water from far below the soil surface. The amount of water seedlings require depends upon:

- seedling age
- amount of sunlight
- soil type.



Use clean water. Dirty water contains many plant diseases. Occasionally clean the water tank and disinfect with clorox to remove plant diseases.

A reliable supply of clean, 'sweet' water is essential in the nursery. Water that is saline (salty), has high concentrations of dissolved minerals including possibly toxic elements from natural deposits, contains oil, or is contaminated with pesticides from local agriculture should be avoided. Water which is very acidic or very alkaline should also be avoided.

When to water

A good nursery practice is to regularly check the water status (turgidity) of the leaves to determine when to water. Leaves should be firm. A strict schedule of 'watering every two days', for example, is not recommended. It is better to monitor the plants and water them

when they need it. It is okay for the substrate to dry out a bit between waterings.

A **good nursery practice** is to water in the early morning or late afternoon, when the sun is cooler. It may be necessary to change the schedule of workers to accommodate the needs of plants. For example, workers may come very early in the morning or in the evenings, and have a long break during mid-day. When plants are watered in the hot sun, they lose more water by evaporation or transpiration than they gain from watering. This heavy water loss stresses the plants. Water drops on the leaves can also magnify the sunlight causing the leaves to burn.

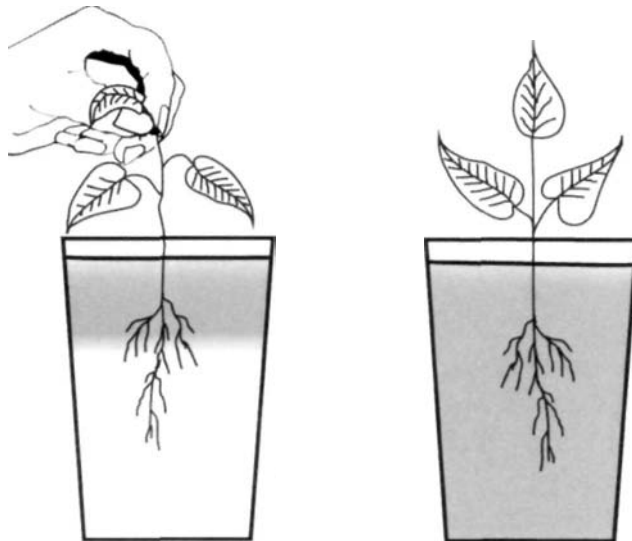
A sandy soil loses water faster than a soil with a high clay content, so watering is needed more frequently. However, when a soil high in clay content dries out, it often becomes very hard and will crack. This can tear the plant's roots and slow its growth or even kill it.

If the area is very sunny, more water is needed. If the area is very shady, less water should be applied. A **poor, but unfortunately common nursery practice** is to keep an area shady too long in order to reduce water use. As we discuss in chapter 6, shade should be regulated as the plants grow and not simply to save water.

Check the leaves
and the soil to determine
if the plant needs water.

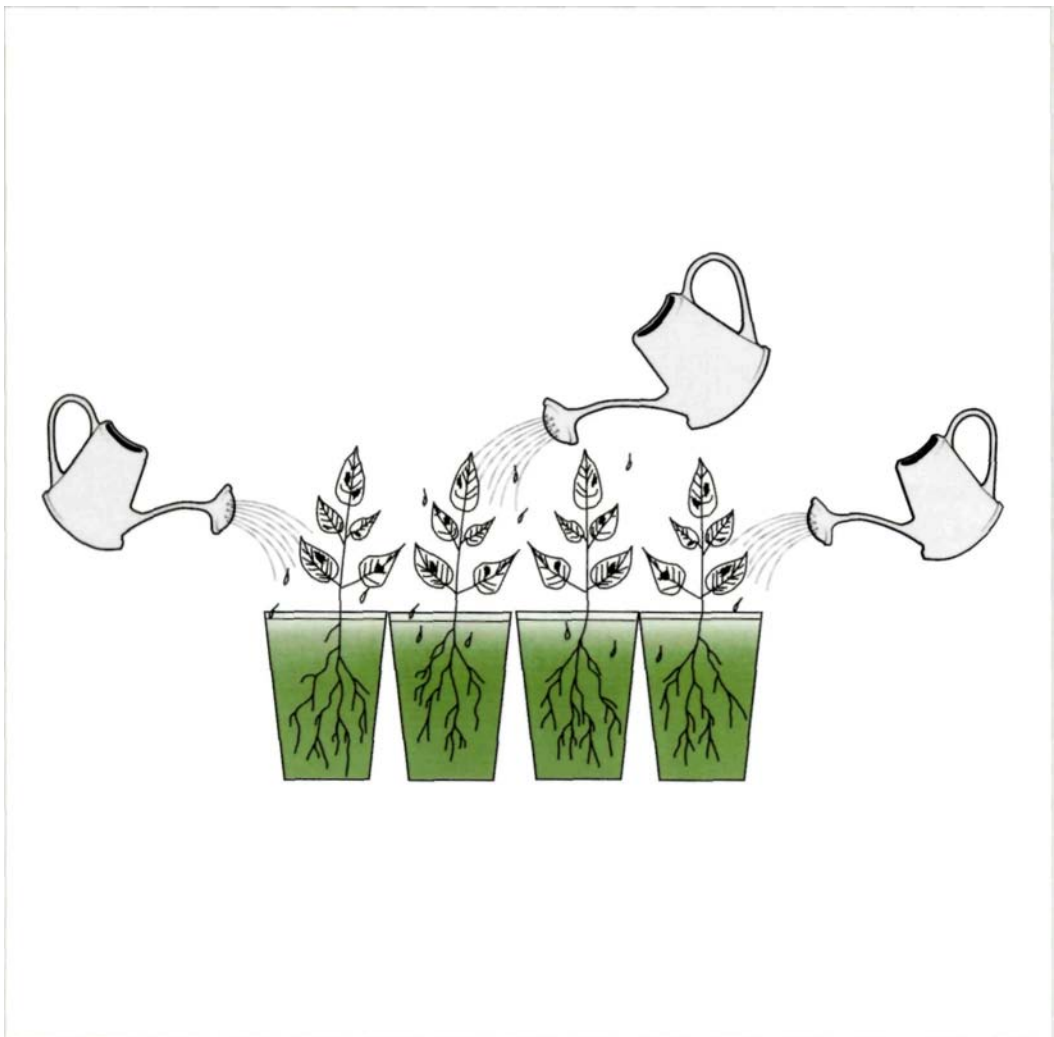
**Regularly check
the water status
(turgidity) of
the leaves to
determine when
to water.**

**Water in
the early
morning or
late afternoon,
when the sun
is cooler.**



Too much water can damage the plants just as much as not enough water. The root system needs a balance of water and oxygen for optimal development. If bags **do** not have sufficient and large enough holes for drainage, the substrate will become waterlogged and the roots cannot breathe. When the area is too wet, the plants are also more susceptible to fungus attack. If you can see brown patches or loose bark at the soil level, this is a sign that the stem is rotting, probably due to over-watering. Also, **if** the substrate is too wet, the seedlings are more susceptible to the attack of soil dwelling insect larvae such as those of sciarid flies.

Overwatering weakens plants and causes many diseases.



If the soil is covered with green moss or algae, you are watering too often.

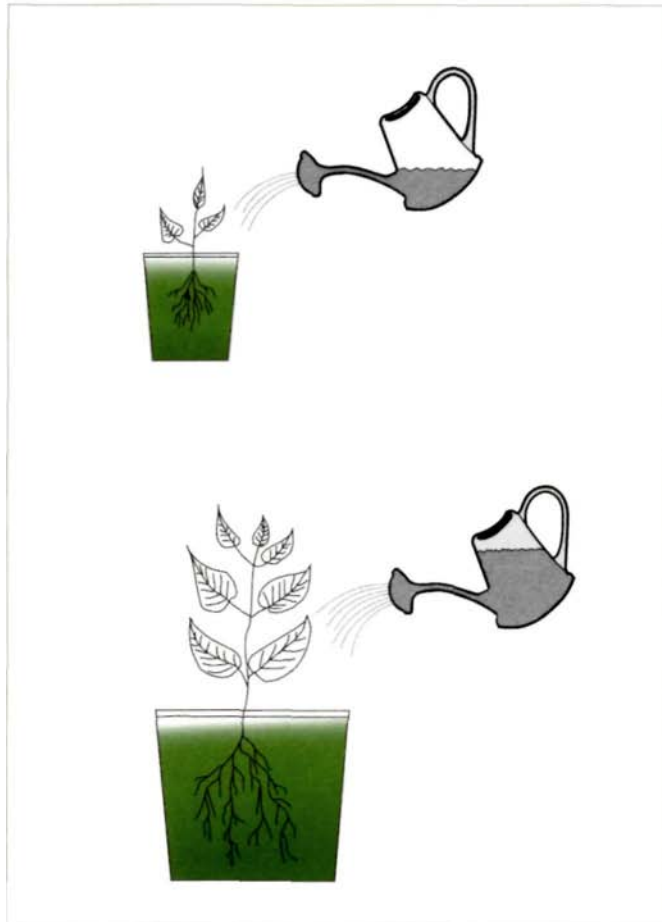


Water small seedlings with small amounts of water. Water large plants with large amounts of water. Direct the water to the substrate, not the leaves!

How to water

A good nursery practice is to water the substrate thoroughly. **A poor, but unfortunately common nursery practice** is to direct the water to the leaves and not the soil. Although it is good to occasionally wash the leaves in a dusty environment, roots absorb the water, not the leaves.

Most nurseries water plants manually with a hose or a watering can. This system is more affordable and easier to maintain than an automatic



Water slowly and check that the water penetrates to the bottom of the container.

irrigation system. However, plants are generally not watered evenly when watered manually. Some plants receive too much water, while other plants do not receive enough. Frequently, the plants on the ends of rows, or along the sides do not receive adequate water, while those in the middle receive too much. You can often see from growth patterns within a bed that some plants thrive or are stunted as a result of uneven watering.

Low water pressure is better for watering than high pressure. When the water pressure is too high, the soil and/or seeds can be washed out from the bag or bed. Similarly, if the plants are in a bed that is not level, always stand at the bottom of the slope when watering to minimize the loss of soil by erosion. A *good nursery practice* is to water slowly and check that the water penetrates to the bottom of the container. *Apoor, but unfortunately common nursery practice* is to water quickly whereby only the surface of the soil is wetted.

Provide the workers with the best equipment and working conditions for maximum labour efficiency.

If at all possible, buy a sprayer nozzle for the hose with an on/off valve. This reduces water loss, an adjustable sprayer allows better distribution and control of the water, and it is easier for the person who is watering. An even better buy is a watering lance (like a wand with a shower nozzle). Water can be directed accurately into the tops of the bags from a standing position. It isn't a good idea to control water flow by holding your finger or thumb over the hose: this results in uneven water distribution and quickly leads to tired and uncomfortably hands. A *good nursery practice* is to provide the workers with the best equipment and working conditions for maximum labour efficiency.

Hardening off and transport

Reduce the amount of water four weeks before the seedlings are planted out. At this stage it is advisable to allow the soil to completely dry out and the plants to wilt for a day. This process should be repeated several times. This hardening-off helps prepare the plants for the new conditions in the field where water might be limiting. Water plants well the day or night before they are taken from the nursery. This will reduce water stress during transport to the planting site, from high temperatures, wind and mechanical damage. If trees are transported in a truck, cover the seedlings with a plastic sheet to provide protection from the wind and sun.

Summary of watering

It is essential to supply seedlings regularly with clean water. The amount of water needed by the plants changes with plant age.

Good nursery practices

- regularly check the water status of the leaves to determine when to water
- water in the early morning or late afternoon
- water the substrate — not the leaves — thoroughly
- water slowly and check that the water penetrates to the bottom of the container
- use a spray nozzle
- reduce the amount of water the seedlings receive four weeks before planting out
- water well the day before transporting and planting out
- cover the seedlings with a plastic sheet to avoid drying out on transport

Poor, but unfortunately common nursery practices

- watering according to a fixed schedule
- directing the water to the leaves and not the soil
- watering during midday
- watering quickly and only wetting the soil surface
- using your thumb to regulate water flow

Shade cools

Nursery plants need to be protected from extreme environmental influences until they are strong enough to withstand them. Shade reduces water loss in the soil (evaporation) and water loss through the leaves (transpiration). It also reduces the temperature of the plants and of the substrate. The amount of shade needed changes during the development of the plant. A *good nursery practice* is to reduce the shade as the plants grow.

Regulate the amount of shade and water together. When plants are in heavy shade, they require less water. When plants are in full sun, they require more water.

Regulating shade

During germination, most plants require 40-50% shade, though some species may require more or less than this. With increasing plant age, the shade should be reduced and for the last two months before the plants go to the field, they should be exposed to full sun. As described above for water, this hardening-off process helps the plants become accustomed to field conditions. Transplanting stress is minimized when plants are accustomed in the nursery to the sun's full intensity.

Kgood nursery practice is to regulate the amount of shade and water together. When plants are in heavy shade, they require less water. When plants are in full sun, they require more water. *A poor, but unfortunately common nursery practice* is to maintain plants in the shade during the entire nursery production.

Plants grown in too much shade often have the following characteristics:

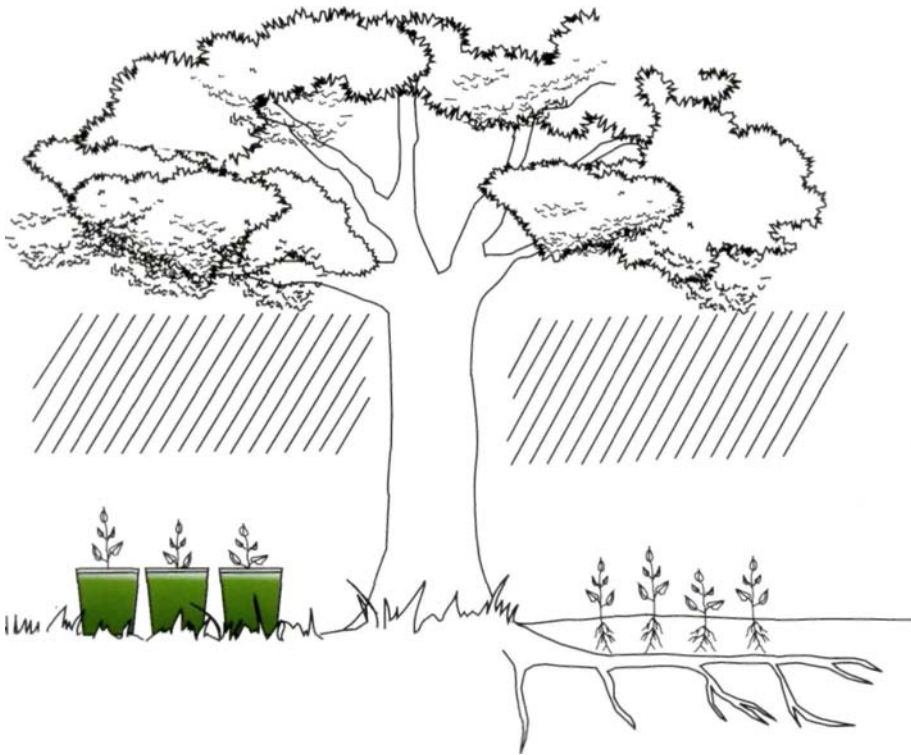
- they are stunted and grow slowly, or they are tall and skinny with a soft stem which does not become woody
- their leaves are either dark green or, in very dark conditions, yellow
- they are susceptible to disease or insect attack
- they are easily sunburnt when taken to the field.

Types of shade

Natural shade from trees is often preferred by nursery managers because it appears the cheapest and easiest to manage. While it provides comfortable working conditions in the nursery, frequently it provides too much shade. Shade trees should not cover the area totally; sun must also penetrate throughout the day. *Kgood nursery practice* is to cut the branches

of natural shade trees back (pollard) to allow light to enter. Madero negro (*Gliricidia sepium*) or poro (*Erythrina poeppigiana*), which are used as living fences, are examples of trees that pollard well because the branches grow back quickly. An ideal natural shade tree would retain its leaves in the dry season and then lose its leaves during the rainy season. This would allow protection during the hot, dry months, but would allow sunlight to penetrate during the cooler, wetter months. Unfortunately, this is usually the reverse of the normal growth cycle for most trees.

Cut the branches of natural shade trees back (pollard) to allow light to enter.



Natural shade trees make the nursery a cool and comfortable place to work. However, they usually provide too much shade and compete for water. Plants often grow slowly in the dark conditions.

A big disadvantage of natural shade trees near bare-root or germination beds is that their roots can compete with the seedlings for water and nutrients, especially when growing close to or in the beds. Established trees have larger and more efficient root systems and will take water and nutrients away from the seedlings which means that additional water and fertilizer need to be applied to nursery plants.

Repair, adjust,
and replace
shade material
in time to
prevent
damage to
plants.

Materials that can be used to provide shade include palm leaves, bamboo, shade cloth, and grass that can be woven into mats. Mats must allow rainwater and light to flow through evenly. If mats are not flat, rainwater can concentrate in some spots and drip excessively onto seedlings, causing considerable damage. If mats overlap, some areas may be too dark. A **good nursery practice** is to repair, adjust, and replace shade material in time to prevent damage to plants.

Plastic shade cloth is available in different grades that cut out from 30 to 95% of the sunlight. The most commonly used shade cloth filters out 50% of the sunlight. Experiment with different strengths for each species. While seedlings are germinating, the shade cloth can be doubled. As the plants grow, remove one layer of the shade cloth. Make sure the shade cloth has UV chemical protection in the fabric so that

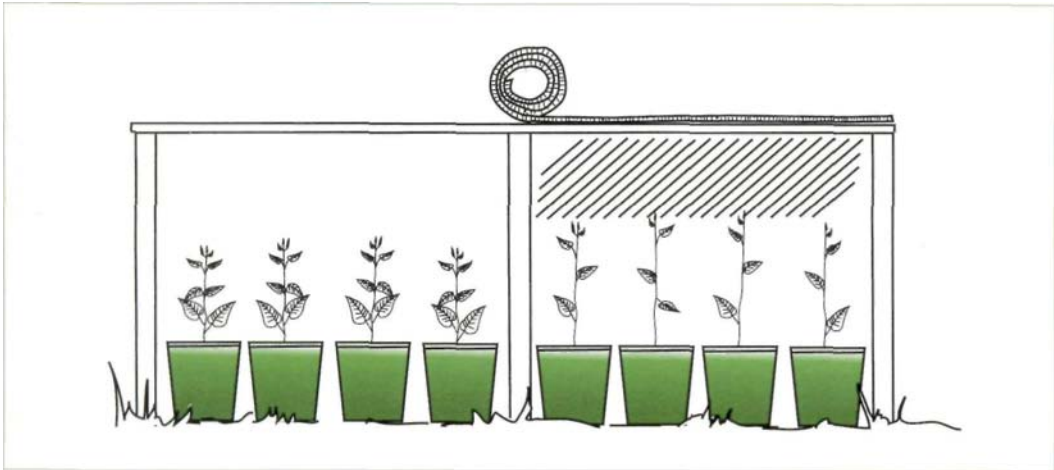
Adjust the
height of the
shade with
the sun's
movement
throughout
the day.

it does not deteriorate quickly. Enforced metal rivets, an optional but more expensive feature, are useful for fastening the cloth to a support. If stored in a dry place and kept free of dirt and rodents, shade cloth should last many years.

Accustom
the plants
gradually to
full sun.

The height of the shade above the plants influences the shade's effectiveness. When placed 2 m above the plants, it is easier for the workers to water or weed, but it might allow too much sunlight in from the sides. A **good nursery practice**, if you can, is to adjust the height of the shade to the sun's movement throughout the day. If the bed length runs from east to west (which we recommend), then the shade can be fairly high. If the beds run north-south, the shade should be fairly low and should cover the sides of the beds so that plants on the sides of the bed are protected from full sunlight throughout the day.

Shade should be removed as the plants grow. A *goodnursery practice* is to accustom the plants gradually to full sun. During the course of 10 days, remove the shade for first two, then three, then four hours in the day, and so on, until the last day you remove the shade



Artificial shade should be removed as plants grow. Too much shade, as seen on the right, may cause the plants to grow tall and spindly. Accustom the plants gradually to full sunlight.

Removing the shade

A nursery manager constructed artificial shade for the seedlings. The seedlings grew well, and had a dark green colour. But he never took the shade down, even though the plants were five months old, and almost 30 cm tall. One day, a forestry technician advised him to remove the shade. So the nursery manager removed it that same day. One week later, he returned to find that the trees were very yellow and many had dark brown, dry patches. He began to wonder if a malicious person had entered the nursery and poisoned the plants or if they were stricken with some disease. What happened? The plants were burnt because the shade was not removed gradually. The leaves were adapted to the dark conditions, and were dark in colour. When they were suddenly exposed to the sun, the chemical processes in the leaves could not adapt fast enough, and the leaves turned yellow. To demonstrate that it was not a disease or poisoning, a few plants from a shady area were put in direct sun. By observing them daily, the manager could watch them burn.

completely. Start on a rainy, overcast day, or remove the shade during the early morning or late afternoon. ***Apoor, but unfortunately common nursery practice*** is to remove the shade at once on a hot, sunny day, burning the plants.

Summary of shade

Grow seedlings under protected conditions during their early growth. As they age, reduce the shade they get. There are different types of shade material available, such as living shade trees, bamboo mats or shade cloth. It is important that the seedlings are shaded uniformly.

Good nursery practices

- cut back the branches of natural shade trees
- repair and replace shade material in time to prevent damage to seedlings
- regulate the amounts of shade and water together
- align beds or rows of plants with the sun's path
- add shade to the sides of the bed, or let shade cloth overhang, if sun is directly on plants most of the day
- gradually remove the shade as the plants grow
- observe how the plants react to shade removal and adjust your treatment as necessary

Poor, but common nursery practices

- maintaining the seedlings in shade during the entire nursery production
- applying too much shade, as plants will grow more slowly and are more susceptible to diseases
- aligning plants opposite the sun's path
- removing the shade too quickly and burning the plants

Plant nutrients

All plants require nutrients to survive and grow. Plants take nutrients from the air, the soil, and the water. Because you cannot see nutrients — they are colourless gases or are like dust dissolved in water or stuck onto each piece of soil — it is sometimes hard to understand how they work.

The quantity of nutrients available to the plants is affected by:

- substrate quality
- water quality
- plant type.

Nutrients are taken up by the fine root hairs, not by the big roots. Even the very largest of trees have many small, fine root hairs to absorb the nutrients and water they need. The larger roots are used for supporting the tree and for storage of water and other plant food. The root hairs can also excrete liquids that affect the acidity of the soil (pH). When the pH changes, the amount of nutrients available may also change.

There are two sorts of nutrients: macronutrients, required in large quantities, and micronutrients, required in small quantities. The big three, nitrogen, phosphorus and potassium, together comprise over 75% of the mineral nutrients found in the plant. All nutrients are abbreviated by one or two letters, their chemical symbols that are based on their Latin names. The symbols are the same in all languages.

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

The only way to know if one nutrient is missing is to analyse the leaves, stems and roots in the laboratory and compare this to published values for that species. If values are not known, fertilizer trials might show what is lacking. This would involve adding different types of nutrients and at different levels during the growing season. Soil analyses can show what is in the soil, but might not indicate what is available for the plants to use, and you might need a soil scientist to help interpret these results.

Nutrient balance and nutrient deficiencies

Plants (like people) need a 'balanced diet'. They need all 13 nutrients to remain healthy. If one is missing, the plant will not grow well. Poor plant nutrition causes plants to grow slowly in the nursery and in the field, and to be more susceptible to diseases.

Many people confuse the symptoms of nutrient deficiencies with those of too much or not enough shade or water. In fact, all three factors, shade, water and nutrients affect plant growth, and interact to produce healthy plants. A plant that grows in full light with abundant moisture and receives all the 13 nutrients will grow fast and have a dark green colour in its leaves. A plant that grows slowly in the shade may also have dark green leaves, but when exposed gradually to the sun, the leaves may turn yellow. This does not mean that plants do not like full sun — it might indicate a nutrient deficiency which did not show up in the shade because the plant did not have enough light to stimulate fast growth.

**Carefully
monitor the
leaves of your
plants for signs
of nutrient
deficiency.**

Together, water, shade and nutrients must be monitored and adjusted to produce quality seedlings.

It takes practice to learn the signs identifying a missing nutrient or nutrients, but you can learn to do so, and some of the signs are common to many plants. *A good nursery practice* is to carefully monitor the leaves of your plants for signs of nutrient deficiency, and correct them with a better substrate or with fertilizer. The symptoms can vary for each species — the lists on the next pages are only a general guide.

Inorganic fertilizers

Inorganic fertilizers are mined from the soil, or produced during complicated chemical reactions. *A good nursery practice* is to read the fertilizer labels. This allows you to apply what the plants need without wasting nursery resources. Fertilizers contain only plant nutrients; they are not used to combat plant diseases or insects. Inorganic fertilizers do not improve the

Common nutrient deficiency symptoms

Macronutrients

Nitrogen: This is a mobile nutrient, which means that when nitrogen is deficient, plants move it from the older foliage to the younger, actively growing leaves. The older leaves (the ones lower on the stem of the tree) become yellow first, while the new leaves remain green.

Phosphorus: The entire seedling is stunted, especially during early growth. Depending on the species, the leaves may become dull green, yellow or purple-tinged. The purpling of leaves is a classic symptom, but sometimes there are no colour differences in leaves, so visual diagnosis is not always reliable. The purple colour should not be confused with new leaves that often appear purple or red when they first flush out.

Potassium: Symptoms appear in older leaves first. These start to yellow at the edges, and have some green at the base. Later, leaf edges turn brown and may crinkle or curl and small necrotic (dead) spots may appear. Plants may wilt, even though sufficient water is available in the substrate. When deficiencies are severe, leaves will die.

Calcium: This is difficult to detect because signs include slow growth, and die-back of bud or root tips. Seedlings will have stubby little roots with brownish discoloration. The problem is most common in very acidic soils. A well-developed root system with many fine root hairs is important for calcium uptake.

Magnesium: This nutrient is commonly deficient in coarse-structured soils and in acidic soils. Uptake may be blocked if there is too much potassium in the soil. Like nitrogen, magnesium is a mobile nutrient, so deficiency symptoms show up in the older leaves first. These leaves show a very characteristic yellowing between the veins or ribs, and they appear streaked.

Sulphur: Plants will be slightly stunted. This is not a mobile nutrient, so the symptoms show up on younger leaves which are initially light green, but eventually develop scorched and curled margins. Dry areas can form along the margins and then spread inward to the leaf midrib.

Common nutrient deficiency symptoms

Micronutrients

Micronutrient deficiencies are difficult to diagnose because often more than one nutrient is missing. Only the most common symptoms are listed below.

Iron: Deficiency is common on alkaline or calcareous soil (pH above 7). Younger leaves become yellow to white and dry up.

Manganese: The tissue between the veins mottles, while the veins remain green and are surrounded by a band of green tissue.

Copper: New leaves are yellow at the tips and often become twisted.

Boron: The deficiency affects the terminal bud which yellows, dries out and dies. Plants grow slowly.

substrate physical properties, whereas organic material such as compost does. Inorganic fertilizers are also expensive and not always available in the stores. Nursery managers should carefully consider the cost and benefit of buying these products.

Granular fertilizers are commonly given names like "17-17-17", or "10-30-10". What do the numbers mean? They represent the percentages of nitrogen (N), phosphorus (P), and potassium (K) in the fertilizer — 17% N, 17% P, 17% K. In this case, 51% of the mixture is made up of N-P-K, and the rest is inactive material used to help spread the fertilizer evenly. Urea contains only N, and is labelled as 46-0-0. Urea is very strong and can easily burn the plants if too much is applied.

Granular fertilizers can be mixed into the substrate or into the irrigation water, or be applied to older plants on the soil surface. It is better to mix the fertilizer directly into the substrate before planting the seed because the roots can avoid or seek the fertilizer as they need it. Use only small quantities such as 2 or 4 grams (*Qli* teaspoon) per 1 kg of soil. It is better to add too little than too much. You need to experiment with different levels. Plants should respond within two weeks.

When dissolving fertilizer in warm water, carefully note whether it is thoroughly dissolved. If not, it is probably the phosphorus that remains. It may be better to apply fertilizer in granular form if it does not dissolve thoroughly. Apply liquid fertilizer to the soil, not to the leaves which are easily burnt if fertilizer remains on them. Be extremely cautious when applying fertilizer to young plants.

Foliar fertilizers are used in order to get the nutrients to the plants quickly. They are specially formulated to apply directly on the leaves. Foliar fertilizers are absorbed by the leaves, not by the roots. When plants are acutely deficient in nutrients, foliar fertilizers often help 'green them up'. Frequently, foliar fertilizers only contain the micronutrients, since it is assumed that the macronutrients are available in the substrate. However, some such as 'GroGreen'® contain both micronutrients and 20-30-10 of N-P-K. Often an adhering agent such as 'Da-Plus' is used to help the fertilizer stay on the leaves so that it is not washed off in the rain. Because foliar fertilizers are expensive, and they may not encourage strong root growth, they should not be used as a long-term solution for plant nutrients.

Calculating fertilizer quantities

The following technique can be used for calculating the amount of fertilizer or any pesticide that is mixed with water. Atypical foliar fertilizer recommends using one bag of fertilizer (1 kilo) per 200 litres of water. How much is needed then in one 15 litre back pack sprayer? You can simply approximate by dividing in half both amounts:

1 kilo (1000 grams) is for 200 litres

500 grams is for 100 litres

250 grams is for 50 litres

125 grams is for 25 litres

62.5 grams is for 12.5 litres

You would need a little more than 62 grams, because the sprayer contains a bit more than 12 litres, or 75 grams, to fill the sprayer. If you divided the fertilizer in the bag into 10 equal parts each would weigh 100 grams. So in this case you would need a bit less than one-tenth of the bag.

Summary of plant nutrients

Plants require 13 nutrients in different quantities to grow well. Common deficiency symptoms help identify which nutrients are missing. Nutrient deficiencies should not be confused with the effects of too much or too little shade and water.

Good nursery practices

- carefully monitor the leaves for signs of nutrient deficiencies, and correct them with compost or fertilizer
- understand fertilizer labels so that the right nutrients are applied
- thoroughly dissolve and dilute the granular fertilizer in warm water and apply it only to the soil, not the leaves

1

Safe pesticide use

Chemical use has become common in many tree nurseries, I just as in agriculture. Unfortunately, the safe use of chemicals is not equally common. This will not change until the people who use the chemicals demand that proper protection be taken. The person most responsible for your safety is you. Your family depends on you to take good care of yourself! *A good nursery practice* is to make safe chemical use part of your everyday routine. Teach others to use them correctly as well. Some people may laugh at you, or complain that safety is too much bother. They are wrong, you are right!

Make safe chemical use part of your everyday routine.

Teach others to use them correctly as well.

If you are using chemicals at your work, or if you are told to do so by your boss, then you must insist that you be provided with the proper protection. More than likely, it is the law in your country that your boss provides these materials, but the only one to enforce these laws is you. It is not acceptable to provide chemicals without providing gloves, protective glasses, soap, etc. for your protection as described below. Ask for safety information about the specific chemical that you are applying. Remember that natural chemicals are often just as toxic to people, animals and fish as synthetic ones.

You do not have to risk your health unnecessarily.

Classification of pesticides

Chemicals are commonly called pesticides because they fight organisms which harm plants. They are not all the same — they are not simply 'medicine'. If you understand the differences between these groups of chemicals, you can use the most appropriate one for a specific plant problem. By knowing more about pesticides you can also ensure that you only buy the chemicals that you need, when you need them. Keep an inventory of the chemicals already in the nursery and buy chemicals only in the quantities you need. Try to exchange your surplus chemicals with other nurseries. This avoids problems with safe chemical disposal.

Chemicals are classified by their use:

- fungicides kill fungi
- insecticides kill insects
- herbicides kill weeds
- bactericides kill bacteria
- nematicides kill nematodes (soil-dwelling worms).

Some pesticides act only upon direct **contact** with the pathogen, usually one living on the outside of the plant. Therefore it is important to spray all parts of the plant including the underside of the leaves. Others act **systemically** — they are absorbed by the plant, and only after a plant part is ingested by the pathogen (usually one living inside the leaf, stem or root) does the pesticide take effect. Some act to kill a **broad spectrum** of pathogens (and often the

beneficial organisms), while others work against **specific agents**.

Some are **curative** (stop the damage once started) others are **preventative** (stop the damage before it starts). Plant pathogens are very effective at damaging plants because they have a short life span and because they easily become resistant to the active ingredients in pesticides. Rotating between different types of active ingredients may be the most effective way to reduce pest problems.

Take several samples of the affected seedling to the agrochemical dealer and ask for expert diagnosis of the problem.

Agood nursery practice is to take several samples of the affected seedling to the agrochemical dealer and ask for expert diagnosis of the problem. Tell the dealer what chemicals, if any, you have already tried. In many countries, like Mexico, by national law the store must have a trained parasitologist (person who studies plant diseases) at the store, or who visits the store on a regular

(weekly) basis, can accurately name the cause of the plant problem, and knows the most effective pesticide and the correct dose to apply.

In Latin America chemicals are rated and labelled based on their toxicity, or how much of the chemical it would take to kill a person.

Green label — lightly toxic
Blue label — very toxic

Yellow label — moderately toxic
Red label — extremely toxic



Post, read, and explain the pesticide labels at the nursery. Teach others how to use them correctly. Ask for help if you do not understand how to use them.

The effects of pesticides on people

Pesticides can enter our bodies in many ways:

- through the skin
- through the nose, when breathing
- through the eyes
- through the mouth, when eating, drinking, breathing, smoking or chewing gum.

The effects can be felt immediately, after one hour or sometimes much later. They include pain, coughing, vision problems, weakness, stomach problems, headaches, vomiting, trembling, diarrhoea, sweating, fever, coma, death.

Sometimes, it takes many years for the symptoms to occur. This long-term exposure is just as serious as an immediate poisoning. It may even be worse, because a person may not notice anything at the time, but only years later, when it is too late. This may also affect your unborn children. They may be sick or have deformities because of the pesticides stored in your body. It may or may not be difficult to prove this. However, isn't it better to know that you did everything you could to protect them?

Maybe you have experienced the bad effects of pesticides on your body. Most people know of someone who has become sick. These experiences are unnecessary and hazardous to your health and your family's. Once is already too much!

A pesticide mishap

A man had to spray fungicide in his nursery. He thought he was well protected because he was wearing gloves. Later in the day, he was thirsty and wanted a drink. The lid of his coke bottle was very tight, so he used his shirt to open the bottle. He forgot that pesticides often stay on your clothing. The shirt had been contaminated with the fungicide and by drinking from the bottle the man poisoned himself. Within one hour he became very sick — and he was taken to a hospital. **The man is okay now, but no one knows what the long-term effects of this poisoning will be.**

Precautions with pesticides

Most people do not take the right precautions because it is too hot, uncomfortable, or they do not have the right equipment handy. However, one hour of discomfort is better than years of sickness. Keep extra clothes, gloves, boots, and soap handy at the nursery. If you do not have them, more than likely you can wait one day to apply the chemicals when you have the correct safety materials.

- Wear a long-sleeved shirt and full length pants.
- Wear rubber gloves.
- Wear a nylon or plastic apron over your clothes.
- Wear rubber boots.
- Your pants should go on the outside of the boots.
- Your sleeves should be on the inside of the gloves.
- Wear a hat.
- Wear a mask, preferably with a filter; if not available, use a bandanna.
- Wear protective glasses.

Keep extra clothes, gloves, boots, and soap handy at the nursery.

Precautions when mixing chemicals

The most dangerous time to work with pesticides is during the mixing process. The poison in a powder or liquid form is very concentrated and very dangerous. Therefore, always mix the chemicals and water outside (not in a closed storage area), but sheltered from the wind so that it does not blow away or onto your body.

If possible, use different sprayers for the different pesticides. For example, use one only for herbicides, one only for fungicides, and one only for insecticides. If you do not have several sprayers, ensure that your equipment is meticulously clean after each use because left over herbicide will kill your seedlings when you spray them with an insecticide or fungicide a while later. Check the sprayer with clean water before filling with the chemicals to make sure it is working well, and that it does not leak. Have everything handy before you start to mix: some scissors to open bags or bottles, measuring cup, clean water and a stick for stirring.

Read the label, or ask someone else to explain it to you. Make easy-to-follow instructions and post them on the doors of the storage shed, so that the right amount is used every time. Do not use more pesticide in the mixture than the amount recommended on the label. Making the pesticide too strong will not make it work better. Also, never use less than what is



Always wear protective clothing when applying pesticides. The man in the top figure is properly prepared, the man in the bottom figure is not protected; he is risking his health.

recommended on the label. Using pesticide solutions which are too weak allows some of the insects or fungi to survive. The next generation will be resistant to the pesticide and will be very difficult to control in the future.

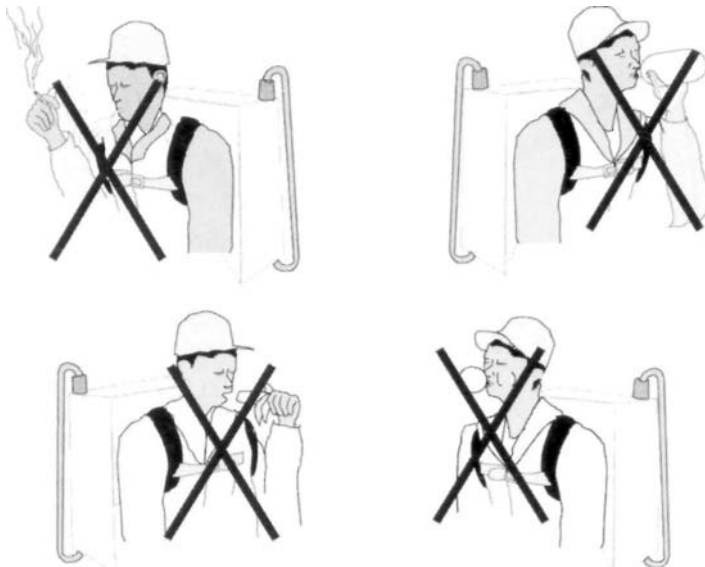
Mix only what you will use that day. If you do not use it all, but think you might use it within a few days, clearly label a container with the name and concentration of the chemical inside it. ***Never leave pesticides without proper labelling in the storeroom.***

Precautions when spraying pesticides

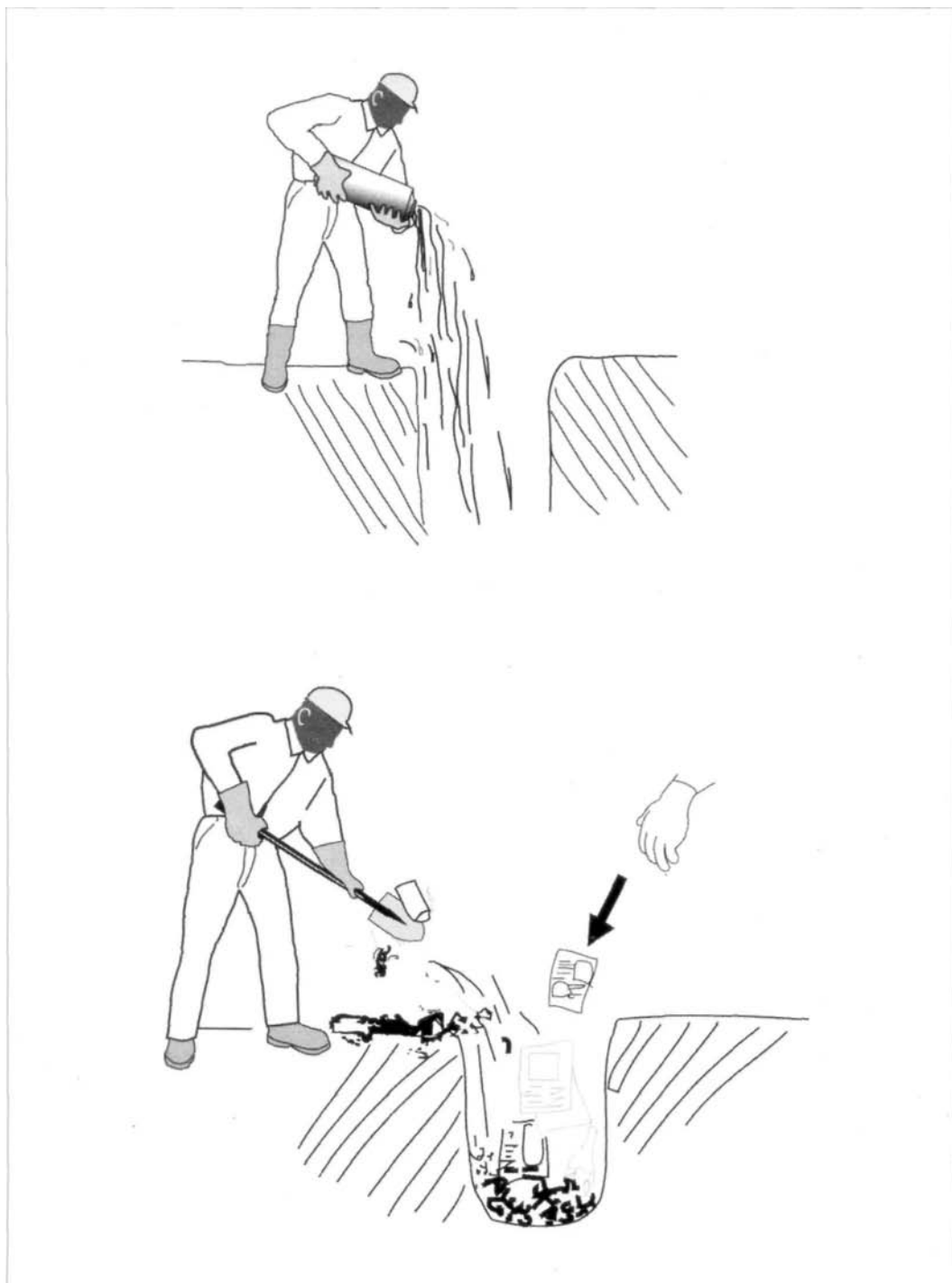
Spray early in the morning before the strong winds, or late in the afternoon when the wind has died down. Never apply pesticides on windy days. Do not spray when it is raining.

Never eat, drink or smoke when you are spraying. Make sure other people are not near the area where you are spraying, especially children. Do not let anybody touch the plants until the leaves have dried completely.

If chemicals were used to disinfect the substrate, wear gloves when filling it into containers. If no gloves are available, then let the soil sit at least five days with some, but not too much, water so that the chemicals can start to break down.



Pesticides commonly enter through the mouth if you smoke, drink or chew gum.



Proper pesticide disposal in a deep hole, far from a water source. Cover it well with soil

Pesticide disposal

A good nursery practice is to discard leftover chemicals. Try to exchange chemicals with other nurseries to limit disposal problems. Expired chemicals should be discarded because they are no longer effective. First, ask in the chemical store where you bought the pesticides if they will take back unused portions or expired chemicals. It may be the law that they accept these chemicals.

Burning chemicals or their containers is not safe disposal. Never reuse chemical containers. Frequently, the only way to dispose of chemicals is to dig a hole and put the chemicals and their full or empty containers in it. The hole should be at least 3 m deep; it must be far away—at least 800 m from where people live and at least 1 km from any water sources. It should always be on the slope **below** the well, pond or river. You may have to leave the nursery to find an ideal spot, but you must make sure nobody will dig up the hole to plant food crops for the next 10 years, if possible! ***It is your responsibility to dispose of pesticides in a responsible manner, avoiding harm to people, especially children.***

Burning chemicals or their containers is not safe disposal.

Never reuse chemical containers.

Cleaning up

After applying chemicals you must immediately clean yourself with soap and lots of water. Do not work all day and then wash only when you get home. The nursery should provide soap and water for washing. If there is no soap, bring it from home, and bring clean clothes unless you live close by so that you can go home to wash and change clothes.

- Clean your safety equipment each time. Dirty clothes and gloves do not protect you!
- Clean the sprayer with soap and lots of water at least 3 times. Always clean the sprayer after use, regardless of how late it is. Do not leave it until you need it again.
- Dry all equipment thoroughly in a windy place and store in a safe place.
- Wash your whole body with soap.
- Wash your hair and clean under your finger and toe nails.
- Do not mix the clothes you wore while working with pesticides with other clothes for washing. Wash these clothes separately.

Summary of safe pesticide use

The safe use of pesticides is YOUR responsibility, and so is your health. By adhering to a few simple rules, the dangers of using chemicals can be greatly reduced. Safety clothes should always be used.

Good nursery practices

- make safety part of your normal work routine, and make your safety your responsibility
- insist that you be provided with safety materials
- prepare and plan ahead of time — you can always delay application if necessary
- read instructions and ask for help if necessary
- mix chemicals in a well-ventilated area
- wear long sleeves, pants, gloves and a mask when applying pesticides
- keep extra clothes in the nursery and change clothes immediately after spraying
- wash immediately, keep soap handy
- dispose of leftover chemicals in a responsible manner

Poor but unfortunately common nursery practices

- joking about safety
- risking your health
- accepting chemicals without safety equipment
- rushing, and forgetting your safety equipment
- mixing the chemicals in too high or too low concentrations
- working in a closed room
- eating, smoking, chewing gum or drinking while applying pesticides
- continuing to work in the same clothes after spraying

After your plants leave the nursery

Agoodnursery practice is to maintain close communication with the nursery customers: the farmers and foresters who plant your trees. Their feedback allows you to make adjustments in your nursery practices. The nursery should use these comments to better meet the needs of its customers. Nursery success is not just a matter of producing healthy and vigorous trees **in the nursery**. Overall success must include how those trees grow and survive **in the field**. The number of trees planted really means nothing unless they grow well in the field.

Many reforestation programs evaluate the outplanting success. If they do not, they should, and the information should be passed on to the nursery. Evaluations need to include real data — not just casual observations — which can be used to improve the reforestation program, starting with the seedlings you produce in the nursery. While it is beyond the capacity of the nursery staff to make such detailed studies, it is very important that you visit as many different planting sites as possible.

Visit planting sites, mi»'	• >stions, and make suggestions:
How long after delivery did it take until the trees were planted?	They should be planted immediately.
How were they stored until they were planted?	They should be stored in the shade.
Was the substrate in the container dry before planting?	Trees should be well-watered when they leave the nursery and if stored at the outplanting site, they should be watered again before planting
How many trees did not survive the transport or were damaged?	The nursery should ensure that trees are carefully loaded for transport.
Were damaged trees planted?	It is better to throw damaged trees away, than waste the effort to maintain them.
Were bags removed and plants checked for root deformities at the bottom of the bag?	NEVER plant the trees with their bags. Remove coiled roots with a machete.
How were they planted? Are roots exposed above the soil line?	Holes should be deep
Was the site rocky, difficult to dig large enough holes?	Smaller bags may be more appropriate.
Are weeds or cattle a problem?	Larger plants may be more appropriate.
What time of year were the trees planted?	Plant at the beginning of the rainy season whenever possible.

9 AFTER YOUR PLANTS LEAVE THE NURSERY

Maintain close communication with the nursery customers: the farmers at, foresters*, who plant your trees.

] Nursery managers should return to the outplanting sites ^{aft^{er}} 3, 6, and 12 months, and even for up to five years to observe the growth and condition of the trees. The effects of nursery practices can still be seen after many years.

^{Fo^r trees matⁿave} already been established:

Are many trees leaning?

Many people think the cause is a strange new disease, but in ^{fact^r mⁱs} often indicates root deformities that started in the nursery. Remove dead trees carefully from the ground with their roots. Are root deformities present?

How many trees have survived?

If less than half of those planted have survived, the tree planting program needs to be evaluated. This will include other factors such as the reforestation policies. However, tree quality in the nursery and at the time of planting will ALWAYS play a major role in the survival and growth of trees in the field.

Consider what you can change in the nursery. This book is dedicated to enabling you to decide what needs to be changed and how. Defining the target seedling, or best seedling for each situation, requires input from the nursery and the client, producing the seedling under different nursery conditions, and evaluating growth in the field. This process takes several nursery seasons and most importantly requires that the nursery has close contact with the people who plant the trees and that the nursery manager visits the outplanting sites.

Good nursery practices depend on you

The nursery is the foundation for tree planting success, whether for reforestation or for agroforestry. The quality of the trees you produce will greatly influence the livelihood of the people who plant them. Trees improve our soil, clean our water and air, provide us with fruit, fire wood and timber, and are home to many animals. Your trees are important!

Just as you give your children a good start in life by nurturing them and responding to their needs by feeding them healthy foods, you must give your trees special early care. Proper shade and water, fertilizer amendments, and strict quality guidelines do not mean that the plants are being pampered in 'luxurious conditions'. On the contrary, when given proper light, water and nutrients, vigorous, healthy plants will result. They will be better prepared to grow and survive in the harsh conditions of the 'real world'. Your work is important!

By using these good nursery practices, your trees and your customers will appreciate it:

- make plant quality, not plant quantity, your most important objective
- collect seed from several of the best trees in the region
- assess your stock regularly and cull poor quality plants
- sow the seed directly whenever possible
- make sure the roots are straight down when pricking out
- prepare and use compost from different organic materials
- use small volume containers
- regulate the amount of water and light as the plants develop
- water slowly with a low pressure hose, and ensure the substrate is well wetted
- water all the trees, especially along the edges and at the ends of rows
- look for nutrient deficiencies and correct them with fertilizer or a better substrate
- weed frequently
- always use safety precautions when applying chemicals
- visit other nurseries and outplanting sites, exchange ideas, and experiment with different techniques.

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Nursery experiments for improving plant quality

Why try nursery experiments?

Often the common production techniques are used without experimenting with other procedures. Even if growth has been adequate in the past, and especially if it has not been, it is worth trying other techniques to see if growth can be enhanced.

Speeding up production time is important to get trees out of the nursery within one season. Species that produce seed during the middle of the rainy season are often not ready for planting out during the same season. Thus, the trees often remain in the nursery into the next **year**, often eight months or more. By this time, plants are often overgrown and exhibit root coiling.

Improving plant growth not only improves plant quality, but also means more efficient use of time, labour and resources for the nursery.

An experiment with a big result

In Costa Rica, a common tree used to shade coffee, *Cordia alliodora*, is normally grown as *pseudo-estacas*. These are bare-root plants that are grown for 18 months, then drastically cut back to 15 cm root and 3-5 cm shoot. When grown in bags of soil, seedling growth is very slow, thus *pseudo-estacas* are preferred. However, *pseudo-estacas* grow slowly in the field and have a low survival rate. When *Cordia* seedlings were tested in bags filled with compost or soil plus fertilizer, growth improved dramatically. Average plant height was 50 cm with the improved substrates, versus only 15 cm in unfertilized soil substrate. The plants were ready within three months for planting out, a great saving for the nursery.

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Everyone is a researcher

Experimentation is always a good idea. Planning an experiment, applying different treatments and analysing the results means that you are curious and interested in solving problems or trying out new ideas in the nursery. You don't have to be a fancy engineer or technician to do experiments. Everyone is a researcher!

Research is about making observations and about paying close attention to the exact causes and effects of something. Research is about solving a big puzzle, by collecting little pieces of information and seeing how they fit together. You will not always know the outcome of the puzzle and you will make some mistakes. Don't be discouraged; use your imagination and initiative to try again. The only danger lies in thinking you already know everything and not being open to new possibilities!

How to conduct experiments

You may have observed that the soil from one area produces better plants than the soil from another area. This is an important casual observation. When we do experiments, we want to verify or prove without a doubt that one soil is better than another. In order to prove something is better we need to design a test with several plants and with several repetitions. We apply the treatments to groups or blocks of plants, called a repetition. Repeating the treatments three to six times ensures that the result we obtain was not just by coincidence.

The treatments are the different materials or methods we are comparing, for example, two levels of fertilizer, or two different seed pre-treatments. Always include the control, which is the current nursery practice, for example the soil you regularly use. Do not test more than five treatments at one time. With many treatments, it becomes too difficult to manage and interpret the results. Always plant the seedlings on the same day, or apply the treatments to seedling of the same age.

The key to any testing is to know for sure that only one factor (or group of factors) is the cause for the results you see. You do not want to confound the results. For example, if some plants were grown in a substrate with rice hulls and fertilizer added, and others only in soil, you do not know if the rice hulls or the fertilizer caused the changes. Similarly, make sure that not all of the trees in one of the experimental treatments are at the shadier end of the nursery or at the end of the beds without a good shelter belt. If possible have blocks of each treatment in different parts of the nursery.

All the plants in an experiment must be treated equally. For example, if some trees receive more water because they are closer to the irrigation sprinkler, and they are all the trees that were treated with fertilizer, you will not know whether the plants responded to the fertilizer or the water.

Correct data collection

Generally, the size of the plants at the time of (ideal) planting out is of most interest. Intermediate data, for example, taken at months one, two and three after germination, are useful only if growth rates are being followed.

- Measure height to the tip of the growing point, not to the tip of the last leaf.
- It is easier to measure diameter at the soil line, than at a specified height above the soil line.
- Fresh weights of leaves, stems and roots are not useful — they depend on the water content of the plant at the time of harvesting.
- Dry weights (dried for three days at 65°C) are used after you carefully remove any soil from roots.

Substrate experiments

Probably the most important factor influencing seedling growth is the correct substrate. Both the physical and chemical properties of the substrates play a role. Therefore, substrate tests should include a range of levels, for example, in nutrient content and porosity. Again, these tests should not be limited to new tree species.

Treatments should be carefully chosen to exhaust the most important comparisons. Tests could include for example:

- soil only
- soil with 25% and 50% compost, and 100% compost (no soil)
- soil with low, medium and high levels of fertilizer.

If you tested all these conditions, you would then have seven treatments. If you wanted to reduce the number of treatments because it is difficult to manage seven, use those which you suspect will give the best results. In this case, you could use only the medium level of fertilizer or 50% mixture of compost.

Test any treatments separately for their effects on the physical and chemical properties of the substrate. For example, to test the effects of porosity on the substrate, add sand, rice

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hulls or some other light material such as perlite. To test the effect of increased nutrient levels, add fertilizer. Then, test the effect of the addition of both. The following will allow the comparison of each element as well as their combination:

- soil only
- soil with sand (or rice hulls)
- soil with fertilizer
- soil with sand (or rice hulls) and fertilizer.

Plant density experiments

Plant density studies are easy to establish for both bare-root beds and containers. The objective is to find the optimum density that allows the plants to develop with minimal competition for light, water, and nutrients. As plant density increases, plant growth usually decreases. Plants should be evenly spaced in the nursery to allow for best development.

To find the best spacing, first check the current plant density per square metre. Try to choose areas that are typical — not very high or very low densities. Count several areas and take an average. Optimal plant density will vary with the species and/or the bag size used. A general guideline for choosing treatments would be three densities. For example, for bare-root beds:

- high density — 600 seedlings per square metre
- medium density — 400 seedlings per square metre
- low density — 200 seedlings per square metre.

Choose three one-metre square areas with similar shade conditions, water and soil types. If the beds are wider than one metre, for example 1 m 40 cm, then you will have to multiply all suggested planting densities by 1.4. If the beds are less than 1 m wide, say 80 cm, then you must multiply the planting densities by 0.8.

If you are going to use the current plants in production, start the experiment when the plants are still small, about 10 cm or less. The larger the plants, the harder it will be to see any plant density effects. If the current density used is 550 seeds per square metre, then this should be considered the high density treatment. For the medium density treatment, remove every third seedling to reach a final density of 369. For the low density treatment, leave only every third seedlings to reach a final density of 187. Try to maintain even spacing between plants.

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You will have more flexibility in determining plant density if you plan the experiment in advance and plant the different seedling densities to start with. Remember to plant extra seedlings because some may not germinate.

For plants grown in bags, the size of the bags will greatly determine the final plant density. For example, for 7 cm diameter bags, there are 13 rows of 13 plants or 169 bags per square metre. For larger bags, there are fewer plants per square metre. Pick an area of bagged plants, and try the following arrangements to understand the effects of different plant densities:

- for high density, leave the bags side by side
- for medium density, remove every third row
- for low density, remove every other row.

Interpreting the results

Measure the height and diameter of the plants when they are to be taken to the field. For some of the plants, examine the root systems and make a visual estimate of the root volume or mass. Check to see that there are many white root tips which indicate that the plant is vigorously growing.

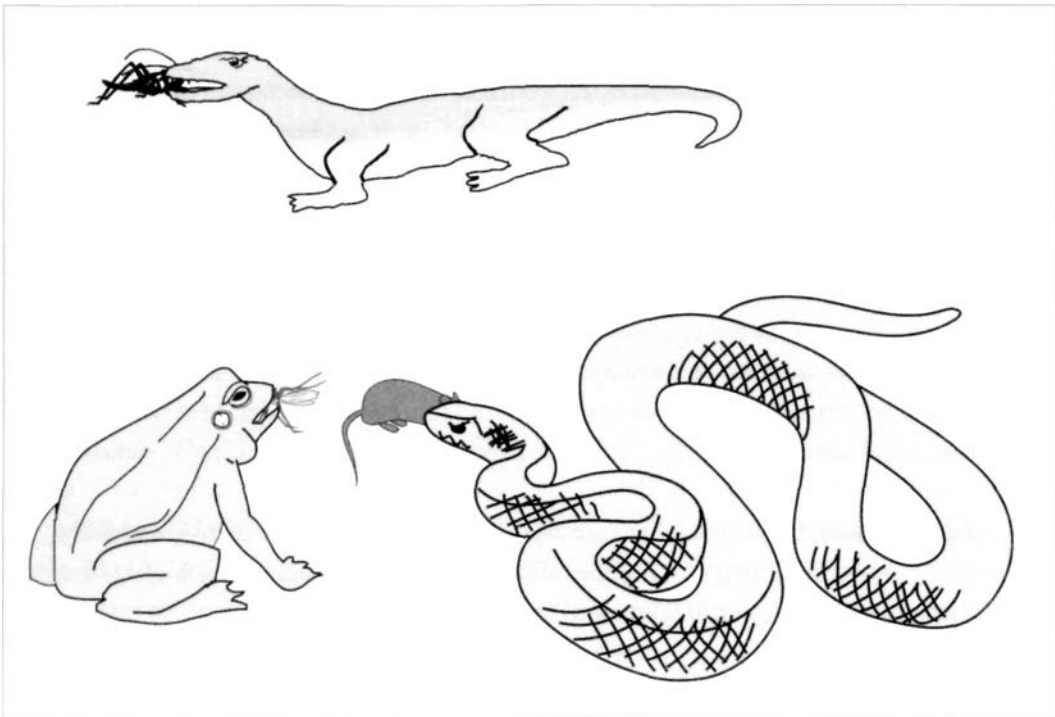
You will probably find that the low density plants are shorter than the high density plants, and that they have larger diameter stems and more root mass. Diameter and root mass are often positively correlated. That means, generally, the larger the diameter of the stem, the more roots it produces. This is because plants in the high densities are competing for light, so they grow tall. Because the plants are investing in shoot growth, they do not invest in root growth. In the case of bare-root beds, plants compete for limited water and nutrients, and this competition also reduces root growth. Remember that the root system is more important for early growth and survival in the field than the shoots and leaves.

Planting the experiments in the field should be an important part of any nursery research. A demonstration area can be established near the nursery to show the importance of nursery work. Chose a site that has homogenous soil conditions throughout the site. The growth during the first year is most important because this is when plants need to compete most strongly with weeds and when mortality is highest.

Natural pesticide recipes

Natural pesticides are a cheap and safer alternative to products bought in a store. Unfortunately, these recipes are being lost as advertising to use modern chemicals increases. It is not old fashioned to use natural pesticides - rather it is a smart use of the natural resources that are readily available!

Leaves, bark, seeds and wood can have toxic effects on different plant pests. Natural pesticides usually take longer to work than synthetic pesticides. Thus, it is important to apply them as soon as the plants show evidence of pests. When preparing a pesticide from plants, always let them dry in the shade, because direct sunlight could break down the active ingredients. Strain or filter any liquid with a cloth to remove any loose material. Adding a little soap will help the liquid adhere to the plants. When applying, wet both sides of the leaves. Some substances can burn young plant tissue unless they are diluted. Try first on a small patch before applying broadcast.



Lizards, snakes, and frogs are among the many natural helpers which can control pest problems.

Many natural predators in the nursery help control pests. Insects such as spiders, dragonflies and ladybugs specialize in eating other insects. Before killing any insect or animal, first consider what it eats!

CAUTION: Although these natural products are generally not toxic to humans, they can cause serious injury if inhaled, ingested, or rubbed on the skin or in the eyes. Use the same safe practices as described for commercial pesticides.

Insecticides. Insects are killed either by contact or by ingestion of the insecticides. Some insecticides only repel the insects by a strong odour.

Neem (*Azadirachta indica*). A tree native to India and Pakistan, but planted widely around the world for its use as a natural pesticide. In addition to being an insecticide, it has been used as a fungicide, nematicide and bactericide. Commercial products made with neem include Bioneem, Margoan-O, Biotrol and Nimex. The active ingredient in neem mimics an insect hormone and repels insects, as well as inhibiting their digestion, metamorphosis and reproduction. It has been used effectively on over 100 leaf-eating insects. To use neem, collect mature seeds, wash and remove the husk, and allow to dry completely. Take twelve handfuls of dry seeds (or use 500 grams per 10 litres water) and grind them into a fine powder. Mix the powder in 12 litres of water and soak overnight. Strain the liquid and apply.

Anona y guanabana, custard apple and soursop (*Annona squamosa*, *A. muricata*). Collect two handfuls of seeds and dry. Grind into a fine powder. Mix with 4 litres of water and soak overnight.

Chile, pepper (*Capsicum frutescens*). Collect two handfuls of chillies and dry. Grind into a fine powder, taking care not to inhale too much of the highly irritating dust, mix with 2 litres of water and soak overnight.

Tabaco, tobacco (*Nicotiana tabacum*). Only real tobacco contains nicotine, the substance acting as an insecticide. Collect healthy, fresh leaves which are free of spots. Mix 80 grams of dry leaves and stems per litre of water and soak for two

days. Best if applied in the early morning because the solution is very volatile — it escapes as a gas. CAUTION: Tobacco is toxic to people, do not breath the vapours, or allow to touch the skin.

Piretro, pyrethrum (*Chrysanthemum cinerariifolium*). A widely cultivated annual flower. The active ingredient is found in the flowers. Collect only fully opened flowers. Mix 100 grams of dried flowers in 1 litre of water and soak for one day. Can be stored for up to two months, but strain it first.

Ricino, castor bean (*Ricinus communis*). Leaves and stems can be used, but the seeds are the most effective part. Mix 300 grams of dry plant material for every 1 litre of water and soak for one day. The active ingredients rapidly disintegrate, therefore the insecticide must be applied frequently and with fresh solution each time. Also works as a nematicide and fungicide.

Mata raton, cacaute, gliricidia (*Gliricidia sepium*). Roots, seeds and leaves are poisonous to rats and other small animals. Also an insecticide against aphids.

Ajo, garlic (*Allium savitum*). Finely chop 3 bulbs of garlic and mix with 10 litres of water. You can store this for up to two weeks unstrained, although its effect on the plant lasts only for one to three days after applying it.

The following mixtures are said to relieve the symptoms of some virus diseases:

Bougainvillea (*Bougainvillea spectabilis*). Mix 200 grams of fresh leaves per litre of water. Mix at least 5 minutes in a blender. Used against several virus diseases in tomatoes and beans.

Dahlia (*Dahlia pinnata*). Mix 150 grams of fruit per litre of water.

Ginkgo (*Ginkgo biloba*). A tree native to China, widely planted as an ornamental in cities because it is highly resistant to pollution. Mix 1 kg of dry leaves and roots in 1 litre of alcohol. Soak for 24–36 hours. Filter and dilute with 15 litres of water.

Espinaca, spinach (*Spinacea oleracea*). Mix 200 grams of fresh plant leaves per litre of water and soak for one day.

Non-plant substances used as insecticides

Chalk. Mix 3-5 grams of chalk per litre of water. Soak for 12 hours if construction grade chalk is used, 3- 4 days if natural chalk is used. Stir frequently and apply directly. Dehydrates the insect when in contact. It can burn young plant tissue and should therefore only be used on mature leaves.

Mineral oil. Use a high grade oil such as ultra fine spray oil or M-Pede. Mix 10-30 ml of mineral oil in a small amount of water, then add one litre of water, stir constantly. Cooking oil can be used instead of mineral oil, if soap is added. Dehydrates or suffocates the insects or their eggs when in contact.

Animal urine. Collect cow or goat urine and mix with a small amount of soil. Allow to ferment for two weeks. Dilute with 2-4 litres of water per litre of urine. Urine is very high in nitrogen and thus can burn tender leaves. Do not apply in full sun, and dilute further if necessary. Human urine can also be used.

Cow's milk. Mix *U2* cup of fresh, unpasteurized milk with 4 cups of flour and 20 litres of water. It kills insect eggs and acts against some insects which carry viruses.

Fungicides. Fungi prosper in conditions of high humidity and shade. Reducing these two factors helps control them. Fungi often appear first on the lower leaves of the plant because the spores are released from the soil. Always apply fungicides to the soil and the bottom leaves.

Papaya (*Carica papaya*). Finely chop 1 kg of dry leaves and mix with one litre of water; stand overnight. Dilute with four litres of water.

Ajo y cebolla, garlic and onion. (*Allium sativum*, *A. cepa*). Mix 500 grams finely chopped material in 10 litres of water. Allow to ferment for one week. Dilute with another 10 litres of water. Incorporate into the soil.

Canavalia (*Canavalia* sp.). *Canavalia* has been shown to kill the nests of leaf-cutter ants. The ants do not eat the leaves they cut, but use the leaves to grow a fungus which the ants eat. *Canavalia* leaves prevent the fungus from growing, and this starves the ants. It can be planted around the border of the nursery.

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Suppliers' addresses

Even if the nursery does not have funds to pay for the materials offered by these companies, it is worth ordering their catalogues. One can often use the pictures to create similar devices at much less cost.

Brazil		
supplier	contact	products
MECPREC Mecânica de Preciso Industrial e Comercio LTDA Estrada Rodrigues cldas 2191 A- CEP227 13-370 Jacarepagua, Rio De Janeiro, RJ Brazil	Tel +55 21 446 5644 fax +55 21 446 5768	Makers of tubette containers, individual cylindrical containers with grooves along the inside walls.

Peru		
supplier	contact	products
AGRO COSTA S.A. Av. Javier Prado Este # 2965 San Borja. Lima 41	Tel+51 1 346 1649 +51 1 346 1916 fax+51 1 346 2210	general nursery articles
AGROSUNI S.A. Calle Jose Diaz # 140 Lima, Lima 1	Tel +51 1 474 0156	general nursery articles
CARLESSI Av. Nicolas Arriola # 2400 San Luis, Lima 30	Tel +51 1 474 0156	general nursery articles

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Canada and the United States		
supplier	contact	products
Spencer-Lemaire Industries 11413-120th Street Edmonton, Alta T6G 2Y3 Canada	Tel +1 403 451 4318 fax +1 403 452 0920	Makers of the original Rootainers, a 'book style' container (one that opens and closes at a hinge) with four or five cavities per book. Also can provide an extensive manual in English or Spanish on the use of Rootainers.
BBC Sylviculture Systems Inc. Canada 190 Bronson Ave Ottawa Canada K1R6H4	Tel +1 613 237 1567 fax+1 613 237 8920	Containers and other nursery equipment. They have representatives based in several Latin American countries.
Jiffy Products PB Box 360 Shippegan, N.B. Fredericton Canada EOB 2P0	Tel +1 506 336 2284 fax+1 506 336 1844	Makers of Jiffy Pellets, substrate and container in one. The seedlings can be planted directly in the ground without removing the pot. Can provide information in Spanish on their use.
Forestry Suppliers International Sales 205 West Rankin St PO Box 8397 Jackson, MI 39284-8397 USA	Fax+1 601 355 5126	Largest supplier of forestry equipment and other related fields.
Stuwe and Sons, Inc. 2290 SE Kiger Island Drive Corvallis, OR 9733-9461 USA	Tel +1 800 553 5331 fax+1 541 754 6617 e-mail: info@stuewe.com Internet: www.stuewe.com	Supplies variety of containers and planting devices.
Griffin Corporation PO Box 1847, 2509 Rocky Ford Road Valdosta, GA 31603 USA	Fax+1 912 249 5977	Makers of Spinout, a copper hydroxide solution for coating the inside of containers to reduce root spiralling.

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Mexico		
supplier	contact	products
Polietilenos del Sur, S.A. de C.V. Av. Centenario No. 1, CIVAC Jiutepec, Cuernavaca, Morelos Codigo Postal 62500	Tel +52 173 19 25 00 fax+52 173 27 22	Large supplier of all types of plastic bags, fertilizers, pots, irrigation systems etc.
Desarrollo Forestal, S.A. de C.V. Calle Sindicato Agricultura No. 701 Col. Lopez Mateos 86040 Villahermosa, Tabasco	Tel+52 93 14 3672 fax+52 93 14 3667	Supplies the same tubette container from the company MECPREC in Brazil