Agrodok 19

Propagating and planting trees

Ed Verheij

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Foreword

This Agrodok is a companion to Agrodok 16: Agroforestry. Trees and shrubs play important roles on the farm and in the environment. Unfortunately too many trees are lost because of overgrazing, excessive fuelwood collection and deforestation. Agroforestry supports the efforts of people in rural areas to plant more trees and to use them to greater advantage, also because of their favourable interaction with crops and livestock.

It is fairly common for farm households to propagate a few trees and shrubs in tins, bowls or other containers under a tree or on the veranda. Where larger numbers of planting material are to be produced, it would be helpful do have a better understanding of: different propagation techniques, how to run a proper farm nursery, and planting out and aftercare of young trees. That is why this Agrodok was written. The emphasis is on propagation from seed or cuttings. The more complicated propagation methods used for horticultural crops, such as budding and grafting, are not dealt with. The Agrodok is written using simple language so that the information can easily be used for extension material.

Acknowledgements
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Wageningen, October 2004, Ed Verheij

Contents

1 Introduction

Trees are vitally important to people. They provide many products, including food for humans and animals, timber, fuel and medicines. In the tropical zone trees are much more important as food crops and cash crops than in temperate zones, where palms and large herbaceous perennials such as banana are absent because of the cold winters.

Trees not only provide products, they also protect the environment and improve the living conditions around a farm. For example, they provide shade and shelter and play a vital role in preventing soil erosion and in sustaining soil fertility. All over the world forests as well as scattered trees are being cut down by people in their search for timber, fuelwood or land for other uses. Uncontrolled fires also destroy many trees.

Proper management of trees and forests is necessary to make resources sustainable. Trees – or rather: woody plants in general – play an important part in traditional farming systems in the tropics, not just as food and cash crops but also as suppliers of fuelwood and fodder. Farmers are also aware of the environmental benefits and use trees as fallow vegetation, hedges, windbreaks, erosion barriers, etc. Where these traditional roles of trees are diminishing due to increasing population pressure and/or changing land use, it is necessary to encourage and support local initiatives to plant trees. That is the subjectmatter of Agrodok 16: Agroforestry.

This Agrodok describes techniques used to propagate and plant agroforestry trees. It has been written primarily for farmers and extension workers. Simple, low-cost and low-input methods are emphasized.

In Chapter 2 the different roles that trees play in various parts of the farm are briefly discussed and the importance of choosing the right tree species for each role is emphasized. Chapter 3 deals with the collection and handling of propagules, i.e. the parts of a plant used in

propagation: seeds, wildings, cuttings and layers. Chapter 4 presents propagation methods: from stimulating natural regeneration – which interferes the least in the natural course of events – and sowing tree seeds directly in areas where you want these trees to grow, to raising plants in a nursery for field planting later on.

Chapters 5 to 8 all deal with raising and field planting of nursery stock. The techniques are suitable for simple on-farm nurseries to raise small numbers of trees to be planted from year to year, as well as for village nurseries, producing trees for reforestation of communal land.

In Chapter 5 the major elements of nursery work are presented in some detail: raising seedlings, using pots, and rooting cuttings. This is followed in Chapter 6 by how to set up a permanent nursery that comprises all these elements: different types of beds for seedlings and cuttings as well as for pots. The chapters on nursery work conclude with Chapter 7 dealing with how to care for the plants in the nursery till they are ready for field planting. Field preparation, planting out and the aftercare for the young trees is the subject of Chapter 8.

At the end of this Agrodok there is a list of publications for Further Reading, a list of Useful Addresses where seeds and/or information can be obtained and a Glossary explaining terms used in the text.

There are two Appendices. Examples of measurements and calculations are given in Appendix 1. Common names are used for well-known crop plants, such as cassava and mango. Many agroforestry species have no generally accepted common names. That is why botanical names are used in this Agrodok for all lesser-known woody plants. Appendix 2 lists these botanical names and gives the common names as far as known, along with some other characteristics of the species.

Growing conditions differ greatly within the tropics. It is therefore impossible to give detailed information which applies to all local conditions. To develop local methods of propagating and planting trees it

is essential to collaborate and exchange knowledge. Readers are strongly advised to gather local knowledge on trees and combine it with the information in this Agrodok, in order to make the right choice for their specific situation.

You may contact Agromisa if you have specific questions. In your letter always include information on local climate (in particular seasonal pattern and quantity of rainfall), tree species, soil types and other important factors. Agromisa's address is on the cover of this book.

2 Choosing the right tree species and planting location

Trees can be used in a variety of ways; they can be planted in various locations and for many purposes. They are extremely valuable in shaping the landscape and in sustaining the capacity of the land to support a growing population. However, trees have a long lifespan and grow to a large size, so the grower has to be able to wait till the tree yields its product(s). Moreover, as land is getting scarce it is becoming more difficult to give trees the space they need. Because of these limitations it is very important to choose the right tree and to plant it in the right place. These aspects are briefly outlined in this chapter. They are discussed much more extensively in Agrodok 16: Agroforestry.

2.1 Trees play multiple roles

Trees protect and produce. They cast their shade over man and beast and provide shelter against strong winds, hot sun and lashing rain. Not only man and beast, but also companion crops, the soil and the entire environment benefit from these protective functions. Trees protect the soil against erosion. Moreover they pump up nutrients from deep down which end up in the topsoil when the tree litter decays, thus replenishing fertility of the topsoil to some extent. Trees shape the landscape and have a moderating influence on the climate: they reduce the wind and the maximum temperature, raise the minimum temperature and humidity, and also act as a barrier against air pollution. Companion crops benefit from soil conservation (erosion control, nutrient recycling) and the ameliorated climate. Garden crops are physically protected against cattle and trespassers by a hedge of woody plants.

Trees also yield a wide variety of products as shown in Table 1. And species that do not yield any of these products for the market or home use usually provide forage for the farm animals and/or fuelwood for the household. In fact forage and fuelwood are *the two most important tree products* in many rural areas.

Table 1: Products provided by trees, with examples

Examples	Product
Papaya, guava, cashew	Fruits and nuts
Nutmeg, clove, cinnamon	Spices
Coffee, cocoa	Stimulants
Annatto, wattle, black mangrove	Dyes and tannins
Pine trees, rubber, gum arabic tree	Resin and gum
Ylang ylang, camphor tree, citrus species	Perfume
Neem, derris	Pesticides
Quinine, snakewood	Medicine
Oil	Oilpalm, candlenut tree
Vegetables	Young shoots of many trees
Timber or other wood products	Nearly all trees

Obviously a single tree may serve several distinct purposes. An excellent example is the coconut: in southern India more than 200 uses have been described for different parts of the palm! Such trees are called multi-purpose trees. On the other hand, using the tree for a particular purpose tends to affect the other uses. For instance, if a farmer regularly lops branches off a tree for fodder he cannot expect that tree to yield much fruit or provide much shade for cattle. Also there will be less fuelwood left when the tree is cut down. Thus it is important to treat each tree in accordance with the main purpose for which it is grown and to accept that as a consequence the other benefits are reduced.

It is useful to distinguish trees that are primarily grown for the product they yield, the true TREE CROPS (e.g. fruit trees, plantation tree crops, timber trees), from the so-called AUXILIARY WOODY PLANTS which are primarily grown for their supportive role on the farm, their environmental benefits, and for forage and fuelwood. These roles, e.g. a hedge around a garden, contour hedges to stabilize a slope, live posts to support a cattle fence, a windbreak along a banana plantation, or trees planted to improve fallow vegetation, can often be combined very well with the use of prunings for fodder and/or fuelwood.

Agroforestry is mainly concerned with auxiliary woody plants and their interactions with field crops and animals on the farm. Tree crops are mainly found as scattered trees in home gardens and as commercial crops in orchards (fruit trees) or plantations (e.g. rubber, oil palm, coffee).

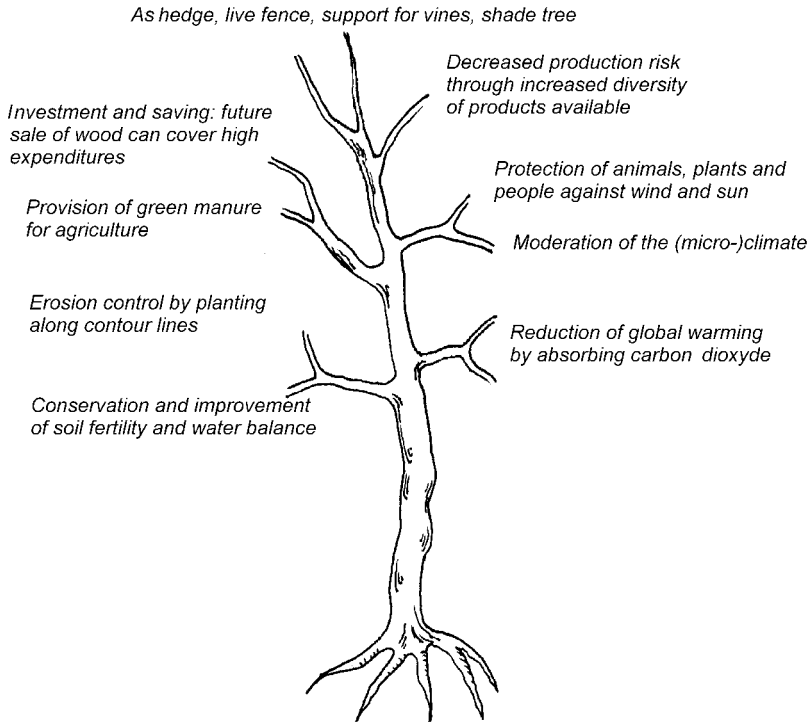
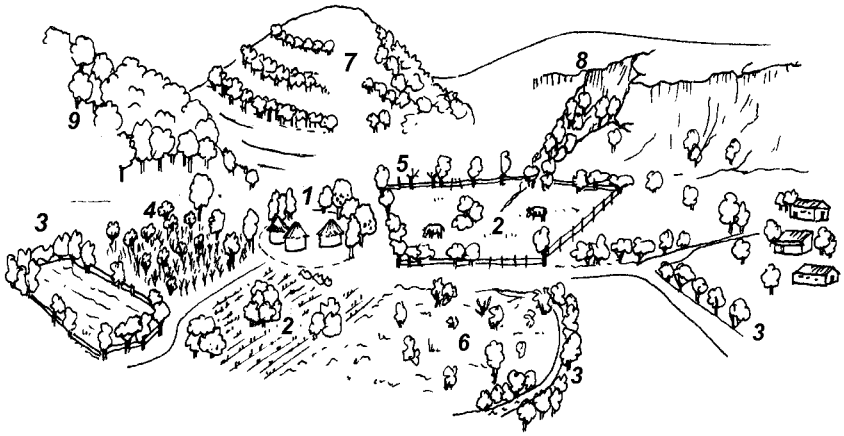


Figure 1: Trees protect the environment, including man, animals and crops.

The distinction between *tree crops* and *auxiliary trees* extends to the propagation methods. Forestry and agroforestry generally employ simple methods suited to mass propagation, the large majority of the plants being raised from seed. Most tree crops, on the other hand, are cloned using more complicated methods such as rooting of cuttings or (air) layers, or budding or grafting on a rootstock.

2.2 Where trees fit on the farm

Figure 2 illustrates the many locations on a farm where trees can be planted. Fruit trees are best planted near the house; trees for livestock feed are best planted near grazing fields and trees for fuelwood can be located further away from the farm.



1) in the farmyard or home garden
2) scattered in fields and pastures
3) on field borders or along paths, ditches, streams
4) as shade trees (e.g. for cocoa) or live support for climbers (e.g. yams)
5) as hedges or live fences around fields and pastures
6) on fallow land
7) along the contours on sloping land
8) in erosion gulleys
9) in areas of natural woodland

Figure 2: Planting locations for trees (adapted from Weber & Stoney, 1986)

Bear in mind that much effort is needed to grow trees successfully on poor soils. However, once trees have gained a footing they will improve the fertility and structure of the soil. They add organic material

and nutrients to the topsoil from their decaying litter of leaves and branches, and their roots break up compacted soil. (See also Agrodok 2: Soil fertility) If you intend to plant trees in an area where trees have disappeared due to felling, animal grazing or fire, you need to be sure that you can prevent this from happening again.

Finally, try to choose a place where a tree will not cause problems for others, for example from the shadow it casts or by decreasing crop yields through competition for water. It may be necessary to consult neighbours in order to avoid conflicts.

2.3 Which trees meet your requirements?

When you have decided where you want to plant trees and for what purpose, you can select the appropriate tree species. Start by considering trees growing locally, because you then know what to expect in respect of growth, yield, disease and pest problems, etc. Trees in your surroundings are adapted to the prevailing growing conditions and it should be easy to get seed or planting material.

The choice of species is limited by the site: species that thrive on a dry hillside are different from those suited to a well-watered valley. And as farmers know well, desirable tree characteristics generally come at a price: there are no miracle trees! Fast growth, for instance, leads to quick closure of a hedge, but it also means that the hedge has to be trimmed more frequently to keep it in good shape. Moreover trees that grow fast usually require better growing conditions than slow-growing species. They also tend to be fierce competitors, leading to poor growth of a nearby field crop. Most fruit trees prefer sheltered conditions so if they have to be planted on an exposed site, a windbreak may be needed.

If local species cannot quite meet your requirements, or if knowledgeable people convince you that a certain species growing elsewhere would be better, it may be worthwhile to first try out alternative species alongside local species.

2.4 Limitations for tree planting

Although growing trees can have many benefits, you must also take the limiting factors and possible negative results into account:

- Some trees are poisonous, like the flowers of the ornamental tree frangipani, for instance. A tree may increase the risk of diseases or pests affecting other plants or animals. The ornamental hedge plant *Lantana camara* can become a noxious weed. Other shrubs, e.g. *Prosopis juliflora* in dry areas, may also spread rampantly and become a nuisance. *Dovyalis caffra* makes an excellent hedge in the highlands, but if allowed to fruit it harbours fruit flies that are much feared by citrus growers. Falling branches and heavy fruit can also cause damage, for instance where sausage trees are planted on the roadside.
- A considerable drawback is that trees *take a number of years* to provide the desired products or protection. During these years, tree cultivation takes up land and costs time and money; inputs which might have been used to grow field crops, for instance.
- *Growing trees entails risks* that are related to their long life-span. These risks lie on the marketing side (is there still a good market for the product(s) by the time the trees come into production?), as well as on the production side ('new' diseases or pests may attack them; a fire may ruin years of hard work in a plantation, etc.). The risks involved must be weighed and found acceptable. Generally speaking it is a good idea to plant a variety of trees using several methods (see Chapter 3) in order to decrease the risks.
- Before planting trees the *ownership rights* for the planned location must be clear. It is important to know who has authority over the tree for the whole period from planting to harvest. Where land is not owned privately, it must be ensured that the benefits go to the planter/caretaker. National and local laws concerning trees on the land must also be respected. For example, felling may be prohibited or reforestation may be obligatory where erosion is a problem or where certain tree species are becoming rare.

3 Collection and treatment of seeds, wildings and cutting

3.1 Mother trees and the properties of their offspring

Trees that are used for propagation material are called mother trees. Of course it is important to select outstanding mother trees. For instance, choose the seed from a jackfruit which is liked by one and all in the village, or take root cuttings from a breadfruit tree which produces fruit that is particularly suited to making chips. Mark the outstanding mother trees so that you can recognize them in years to come.

Selection makes sense because the young trees will be expected to inherit the favourable characteristics from the mother tree, such as fast growth, upright or spreading shape of the tree crown, good flowering and fruiting and tolerance of diseases or pests. However, here we must distinguish between propagation by seed and propagation using other parts of the tree.

The seed is the result of sexual reproduction. This implies recombination of the genes when the flower is pollinated. Each pollen grain (the male component) gets a unique set of genes and likewise every ovule (the female component) in the ovary of the flower. Successful pollination is the fusion of the genes of a pollen grain with those of an ovule. As a result each fertilised ovule has a unique set of gene pairs. The ovary becomes the fruit, and the ovules develop into seeds.

Because of the recombination of the genes, the genetic make-up of the seeds differs, resulting in seedling variation. Hence, although all the seedlings resemble the mother tree in some respects, no two seedlings are the same. Seedling variation occurs even if the pollen comes from the same mother tree. In that case, while the seeds inherit all their characteristics from the mother tree, the rearrangement of the genes in

the flower ensures that each individual seed receives a unique mix of genes, so that its characteristics are not the same as those of the mother tree. The differences between the seedlings will become even greater if they are grown under different conditions.

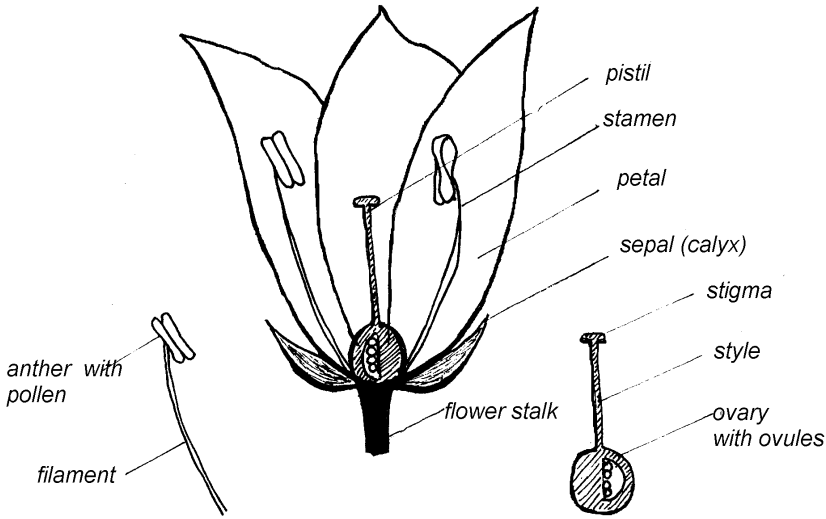


Figure 3: Diagram of a flower with names of parts

In contrast, if a part of the mother tree – other than the seed – becomes a new plant, e.g. a layer or a cutting, the genetic make-up of that plant is exactly the same as that of the mother tree. Consequently all cuttings from one mother tree have the same set of gene pairs and therefore the same characteristics; they form a so-called clone. Differences between plants of a clone can only be caused by different growing conditions.

So, in the above examples of jackfruit and breadfruit, the jackfruit seedlings may not produce the same delicious fruit as the selected mother tree. However, because seedlings inherit characteristics, there

is a better chance that some seedling(s) will produce delicious fruit, than seedlings from an indifferent jackfruit tree. On the other hand, all the root cuttings of the breadfruit tree should produce fruit equally suitable for making chips as that of the mother tree, provided the growing conditions are similar to the conditions in which the mother tree is growing.

Conclusion: Selection of a superior mother trees is always desirable, but the characteristics for which it was selected will only be reproduced straightforwardly if it is cloned. Cloning implies that within each crop named varieties or cultivars are distinguished. Seedling populations that are better adapted to specific growing conditions can be obtained using seed from carefully selected mother trees grown in so-called seed gardens.

Seedling variation is a drawback if you want to reproduce one specific characteristic. A fruit grower, for instance, wants to grow a specific variety of guava, not just any guava, and devotes much time to caring for each tree. A forester, on the other hand, wants vigorous vegetation on an area of land which does not demand much attention. In the latter situation seedling variation is an advantage because it leads to 'the survival of the fittest': the fastest growing trees, the ones that are most tolerant to diseases or pests, and so forth.

Another advantage of seedlings is that they have a much stronger root system, typically with a long taproot, than cloned plants. This leads to increased vigour and delays the onset of flowering and fruiting. This advantage – for the forester – becomes a drawback when the trees are grown for their fruit. That is one reason why fruit growers prefer clonal material. Because of the weaker root system cloned trees need far more care: they may have to be tied to a stake and are more likely to require irrigation during a dry season.

Finally, propagation by seed has the advantage that few diseases are transmitted through seeds, so that seedlings usually have a healthy start. If other parts of the mother tree are used, they may be infected

by viruses, bacteria, fungi, eggs of insects, etc., giving the clonal material a bad start (and making selection for health of the mother tree all the more important!).

In the case of wildings – whether seedlings or suckers on a stump – the characteristics of the mother trees are generally not known, so that selection for superior characteristics is not feasible.

3.2 Seed

Seed collection

You can collect seed yourself or buy it from traders, forestry services or 'seed banks' usually located in research institutes (see: Useful Addresses). If you plan to collect seeds from local trees choose ripe fruit with seeds that are large and healthy. Seeds that have recently fallen are generally good, but very often the first and the last seeds to fall are either infertile, infected or damaged. Ripeness is indicated in different ways: fleshy fruits often change colour, or the flesh becomes softer. Dry fruits often burst open causing the seed to be released.

Methods of collecting seeds and fruit:

- Gather from under the tree (clear the ground under the tree before fruit/seed falls).
- Hit the tree with a stick or shake branches using a long hook or by throwing a rope (Figure 4), catch the seeds in containers or sheets under and around the tree.
- Use long-handled cutters or a saw.
- Climb the tree and pick the fruit.
- Pick fruit from bearing trees that have been cut down.

Ripe fruit and seed must be collected without delay, otherwise they will be eaten by animals, including bats and birds. Many types of seeds lose their germination strength rapidly (especially large seeds, e.g. mango, avocado, durian, jackfruit). Germination of these so-called recalcitrant seeds is even reduced if they are stored for just one week after extraction from the fruit. Moreover the growth of the seedlings

lags behind that of freshly sown seed. If recalcitrant seeds cannot be sown immediately, it is best to leave them in the fruit till they are sown.

Figure 4: Seed collection with a throwing rope

Fruits must be brought quickly to a dry, well-ventilated place. Never leave them in a plastic bag where they may suffocate and rot.

Methods for removing seed from the fruit vary. Dry fruits such as cones and pods often need special treatment (e.g. exposure to the sun to open them) to extract the seeds. Sometimes this occurs naturally: the seed pods of some *Acacia* species disintegrate when they have dried out, and by shaking them gently the seeds will fall out. Advice on suitable methods for extracting seed is best obtained locally.

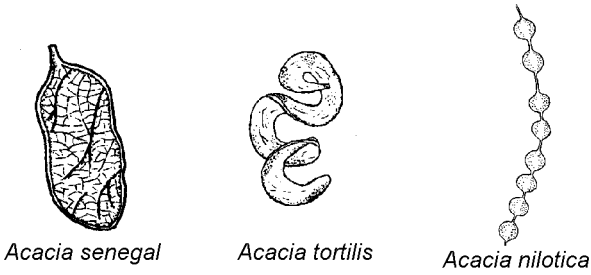


Figure 5: Different Acacia pods

Seed cleaning

Once the seeds have been removed they need to be cleaned thoroughly to remove all bits of fruit flesh, pod or husk, especially if the seed is to be stored. The flesh of soft fruit (e.g. mango) has to be brushed/rinsed off before the seed is planted; many fleshy fruits contain substances that inhibit germination. You can clean seeds by hand or – for dry seeds – by winnowing in the wind, as is done with most *Acacia* species and *Senna siamea*.

Seeds may be sieved to remove dirt and low quality seeds. The best quality seeds are nearly always the biggest. Another way of separating seeds is to immerse them in water. The bad seeds and most dirt will float, while the good seeds sink. Remove the good seeds and dry them carefully.

Seed storage

If seeds cannot be planted immediately after collection, they must be stored. Some seeds (e.g. legumes) can be stored at normal temperatures for many years as long as they are kept dry. Most seeds, however, can only be kept for a limited period of time; recalcitrant seeds should be sown as soon as possible after extraction from the fruit.

Well-stored seeds are kept dry and at a constant cool temperature. Dry the seed before storage to prevent infection by fungi and bacteria. However, extreme heat must be avoided as this destroys the seeds' ability to germinate. Do not dry seeds in direct sunlight, but in a shaded, well-ventilated place.

Seeds that have been properly dried can be stored in containers such as pots, tins, boxes or bags. For insulation, seeds can be doubly sealed by first putting them in a thick plastic bag. Close the bag tightly and put it in a container with a lid. By burying the containers under a layer of dry soil in a shaded place you can keep them at a constant cool temperature.

Make sure insects or rodents cannot get into the containers. Label each container and insert a note of treatment given and the date of storage. Check the contents regularly and at the same time turn the seeds or shake the container.

Pre-germination treatment of seed

Germination of seed of some trees may take many months, the seed awaiting the low temperatures of winter or the heat of a forest fire to break seed dormancy. Germination may also be delayed by a hard or tough seed coat or by certain substances in the seed. Such seeds can be treated to speed up germination and – even more important – to ensure more simultaneous germination. If little time lapses between emergence of the first and last seedlings of a sowing, the uniformity of the seedlings greatly facilitates proper timing of all propagation work.

A range of treatments is used to accelerate germination:

➢ Soaking in water or acid

This is a simple method involving soaking the seeds for 2 days in cold water prior to sowing. This makes the seed swell, breaking the coat and leaching the substances that delay germination. This method works for seeds from many tree species. In some cases acid is added to make the liquid more abrasive.

➢ Hot water treatment

This removes the hard outer cover of some seeds, leaving a softer covering that the sprout can break through more easily. Bring water to the boil (about 4 litres for 1 kg of seeds), take it off the fire and immerse the seeds in it. Allow the water with seeds to cool overnight. Rinse them with clean water the next day. This method is the right one for leguminous species such as *Acacia, Senna,* and *Prosopis* species and also for *Faidherbia albida*. Some seeds must be boiled briefly, e.g. baobab seeds.

➢ Scarification:

To facilitate germination a shallow incision is made in the hard seed coat using a file, or the tip of the seed is cut off. A simple way of scarifying legume seeds is to rub them over a rough surface, e.g. sandpaper. This scratches the seed coat, but the scratches should not go right through the coat. You must also be careful not to let the seeds get too hot, as this will destroy the sprout. This method works for instance for *Leucaena* species and *Faidherbia albida*.

➢ Stratification:

Many seeds of trees from the temperate and subtropical zones require winter chilling to break seed dormancy, e.g. pecan nut, persimmon, peach. Where these trees are grown in tropical highlands it may be necessary to put the seed in a pot with moist sand in the refrigerator for about 2 months. This is not a common method. For more information write to Agromisa or ask your local forestry service (see Useful Addresses).

3.3 Wildings

Wildings are planting material collected from natural vegetation, e.g. seedlings or cuttings. Wildings should have at least 2 to 4 fully formed leaves when you dig them up. Larger wildings have a stem about the diameter of a pencil. They can be collected when rain has moistened the soil, either with or without a root ball.

Wildings with a root ball are dug up by making a cut on both sides of the plant at an angle of 45^{o} using a spade or machete. The plant is then lifted on the spade, holding the stem with the other hand and removed with the root ball intact. It is difficult to dig up small wildings with a root ball, because the root system is too small to hold the soil.

Bare-rooted wildings are uprooted by loosening the soil around the roots with a pointed stick. The plants are pulled up carefully and the soil is shaken off the roots.

In order to facilitate planting out, and avoid planting with crooked roots, the taproot and large side roots are often trimmed. Leaves except for the top ones can be removed to reduce transpiration.

It is not a good idea to store wildings. It is better to plant them out as quickly as possible. The roots of bare-rooted wildings should be protected during transport by covering them with damp material (earth, jute sacking, banana leaves, etc.). Alternatively you can give the roots a mud dip in a mixture of clay and water.

3.4 Cuttings

Different parts of the plant – leaf, stem or root – may be cut for rooting. Propagation by leaf cuttings is virtually limited to some ornamental plants. Stem cuttings are most common; they are classified as softwood or hardwood cuttings. Softwood cuttings are taken from a growing shoot, not far below the shoot tip, e.g. tea. Such tender, leafy cuttings require intensive nursing. In this Agrodok we shall only consider trees and shrubs which root well on hardwood. Hardwood refers to the

wood of resting shoots, after the termination of a flush. It includes older twigs and branches, formed in earlier flushes.

Stem cuttings

The preferred time to take hardwood cuttings is generally during the dry or cool season, when shoot growth is minimal. In deciduous trees the cuttings are best taken when the trees are leafless. Most woody plants are evergreen and the leaves have to be stripped from the part of the cutting that is inserted in the soil: about two/third of the length of the cutting. Usually a few leaves – sometimes halved – are left at the tip of the cutting, the number depending on growing conditions (shade, humidity, etc.). Leaves generally stimulate root growth, but cuttings are likely to dry out if the leaf area is large.

The tip of the shoot or twig is usually discarded, but a vigorous shoot can still yield several cuttings of 15 - 50 cm, the recommended length. Commonly, the diameter of cuttings ranges from pencil-thick to about 3 cm. The upper cut is oblique so rainwater runs off (see Figure 6). The lower cut is usually made just below a node, because rooting generally occurs mainly at the node.

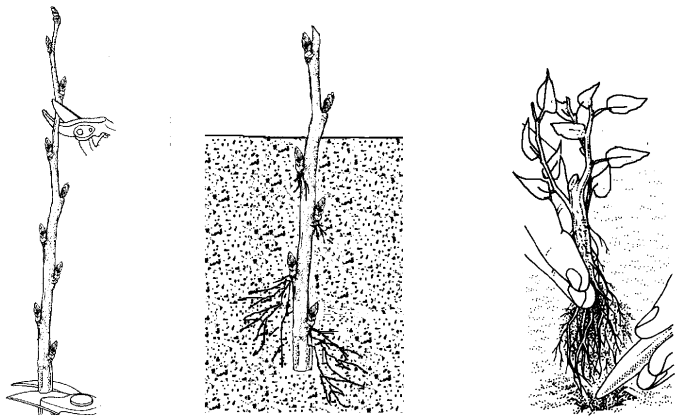


Figure 6: The cuts, the rooting and the rooted cutting

Always use clean tools: disinfect your cutting tool in boiling water before use. Never use a blunt knife or machete for taking cuttings. If a cut is not smooth and clean, rot may lead to failure of the cutting; it can also infect the wound on the mother tree. Upright branches and twigs are preferred for cuttings, because they grow upright after rooting, forming a tree with a proper trunk. Cuttings taken from horizontal or drooping branches often do not grow upright.

If cuttings cannot be planted straight away they may be stored in a cool shaded place under damp jute bags, grass or leaves. Leafy cuttings should be planted without delay.

Ringing and pruning of the mother tree

Stem cuttings of some woody plants strike root more easily if the branches have been ringed beforehand. Two weeks to two months before taking a cutting, a ring of bark about 2.5 cm wide is cut away down to the wood (the shoot will be cut near the underside of the ring). The leaves near the ring are cut off. In a ringed branch the sugars formed by the leaves can no longer travel further down the branch. It results in food reserves being built up in the part that will serve as the cutting. However, this only works if the ringed shoots are growing vigorously; otherwise the accumulating sugars may enhance flowering of the branch. Flower formation and root growth are antagonistic: a part of a plant which is inclined to flower is much less likely to form new roots!

Several pruning techniques – cutting back, pollarding, coppicing – are used to stimulate trees to form additional shoots from which to take cuttings. Hard pruning helps to suppress flowering (that is why a frequently pruned hedge fails to flower), enhancing the ability to form roots.

➢ Cutting back

Cutting back branches or twigs stimulates buds to break and grow into new shoots. These shoots can be used as cuttings. The advantage is that a larger number of uniform (same age, similar size) cuttings be-

comes available. If many branches are cut back the mother tree requires adequate vigour to support sturdy growth of all the new shoots. Make sure that there is enough moisture in the soil. It may be advisable to fertilize the mother tree in the season before it is cut back.

➢ Pollarding

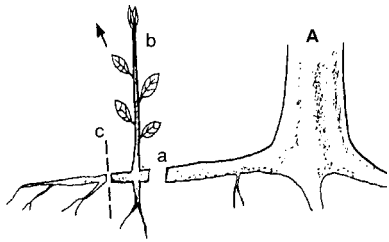
Pollarding is more drastic pruning: the tree trunk is cut at a height of about 2 m. Below the cut a number of watershoots emerge, which after about a year can be cut to be used as large cuttings, so-called live stakes. *Gliricidia sepium* or *Erythrina* species are examples of trees that produce good live stakes, because they strike root easily when planted during the wet season. They may be used to support a fence or climbing plants (e.g. pepper, vanilla) or a trellis (e.g. for gourds or chayote).

➢ Coppicing

Coppicing is cutting the tree trunk off close to the ground in order to stimulate the growth of new shoots on the stump. These shoots can then be cut off and used for planting.

Root cuttings

Tree roots can also be used to take cuttings, e.g. *Casuarina* species. Some trees (e.g. breadfruit) even produce root suckers spontaneously. If these suckers form their own roots, they can start life on their own. To encourage the emergence of root suckers, roots are cut using a spade or small axe. The piece of root cut off may form a rooted sucker (see Figure 7A). In the seedless breadfruit in this example, roots a few centimetres in diameter and about 20 cm long are cut off. These cuttings are planted in a shaded spot in the nursery. If a high humidity is maintained rooted suckers will be ready after a couple of months (see Figure 7B).



a: Cut off piece of root;
b: Development of shoot and new roots on root cutting;
c: Cut off shoot at dotted line and dig up new shoot.

Remove section of root and transfer to nursery

Figure 7: Root cuttings

3.5 Layering

Tree species that cannot be propagated by cuttings because they do not readily form roots, may in some cases be induced to form roots on shoots before the shoots are detached from the mother tree. This propagation method is called layering after its simplest form: tips of drooping shoots of shrubs bend till they lay on the ground where they may root spontaneously, as in the case of some *Rubus* species (e.g. blackberry).

Although in some countries layers are propagated in large numbers, the techniques are particularly suited to home gardeners who have an outstanding tree and want to make relatives or friends happy with one or two plants with the same excellent characteristics.

Simple layering

In simple layering long flexible twigs of certain shrubs and vines are bent down and part of the twig behind the tip is covered with soil (see Figure 8). Obstructing the sap flow from the tip of the twig by twisting the part that is to be buried, helps to induce root formation. Instead of twisting the twig it may be wounded by cutting a notch in it or by removing a ring of bark. Rooting will take place near the wound on the side of the tip. Once the roots are sufficiently developed the layer can be cut free from the mother tree.

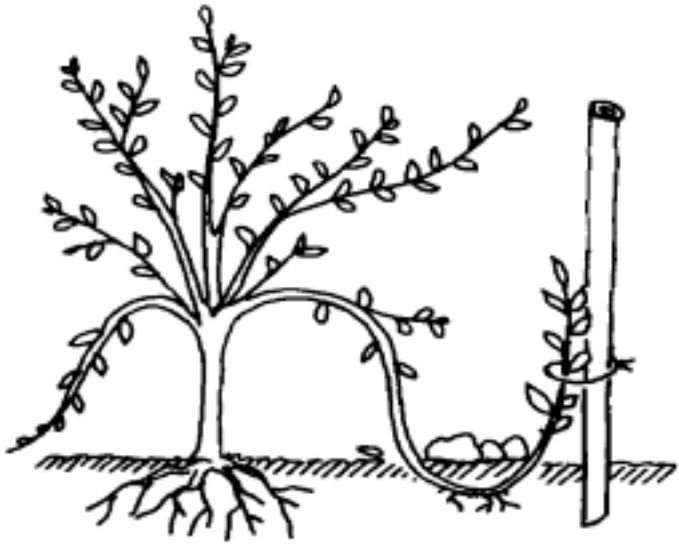


Figure 8: Layering (From: Geilfus, 1989)

Air-layering

It is difficult to bend upright branches down to the ground to be layered. The alternative is to bring the soil up to the branch: air layering (also called marcotting). A ring of bark is removed from the twig or branch that is to be air-layered, as described above, and the soft cambium layer is scratched off, so that the wound cannot heal. A ball of moist friable soil, shredded coconut fibre or other rooting medium is

fixed around the ring by wrapping it in polythene so that it does not dry out (see Figure 9). Roots are formed just above the ring and after 2 - 6 months (depending on the tree species) the rooted air layers can be cut. Do not cut layers if the shoots on the mother tree are expected to flush during the next few weeks. The layers will flush at the same time and the young roots may not be able to cope with the sudden burden of all these new leaves. In home gardens fruit trees such as guava and litchi are often propagated by air layering.

Figure 9: Air layering. From left to right: ringing the branch; polythene with moist rooting medium is wrapped around the wound; tie firmly so that the medium does not dry out; the rooted cutting, 2- 6 months later.

4 Propagation methods

The number of trees can be increased through natural regeneration of existing trees or through man's propagation activities, as shown in the schedule below.

WAYS OF REGENERATION:

NATURAL:
- spontaneous growth of seedlings, suckers, layers

PROPAGATION BY MAN:
- direct field planting, using e.g. seeds, wildings, cuttings
- in a nursery, raising trees from e.g. seeds, cuttings

Natural regeneration is often facilitated and stimulated by foresters or farmers. The methods have much in common with those employed in direct field planting. These two approaches are both discussed below; propagation of plants in a nursery is only outlined in this chapter, because the details of nursery work are dealt with in Chapters 5 – 8.

4.1 Natural regeneration

Spontaneous growth of new plants, without the interference of man, is called natural regeneration. Seeds are the main source of new plants, in natural vegetation as well as in farming. Some plants – including several shrubs – also spread through suckering: the growth of side shoots (suckers) that form roots and become independent of the mother plant. Others – in particular vines – may form new plants through layering: a long trailing shoot striking root where it touches the ground. Regrowth from the stump after cutting down (coppicing) certain trees – e.g. many *Eucalyptus* species – is also a way of natural regeneration.

Natural regeneration can be encouraged by improving conditions for growth of young trees and by protecting them against hazards such as fire and browsing animals. This applies for instance to fallow fields

where the vegetation traditionally results from natural regeneration. Scarcity of land forces farmers to shorten the fallow period; in this situation measures to hasten natural regeneration and to encourage the growth of desirable trees and shrubs are most welcome.

Clearing litter from strips of land (the litter may be moved to the adjacent strips) makes it easier for seeds to germinate. The strips are commonly 50 - 100 cm wide. Always align the strips along the contour to reduce the risk of erosion; strips running down the slope aggravate erosion. On steep slopes or fragile soils it is best not to disturb the existing vegetation more than is absolutely necessary. In these conditions.stimulating natural regeneration is the preferred approach. The seeds of some species, e.g. *Prosopis juliflora*, can be fed to animals that graze the area. In this way the seeds will be distributed with the dung, and germinate in the fertile environment provided by the dung. Once the seedlings are growing they can be helped along by weeding around them and later by slashing vegetation that competes with the sapling, leaving the cuttings as mulch under the sapling to conserve moisture and suppress weed growth.

Fire is a hazard where the dry season is long, especially if fires are part of the farming routine (e.g. shifting cultivators burning fallow fields, or pastoralists burning parklands to speed up regrowth of grasses). In that case firebreaks – strips of cleared land wide enough to stop a fire – are needed, particularly where litter has accumulated under the trees.

In areas in Africa used by pastoralists, planting trees failed because the trees were not protected against browsing animals. This happened in a project in Senegal, where an area of 1,700 hectares was afforested. It is now common practice to protect a selected area from livestock so that natural regeneration can take place till tree cover is restored. Thorny branches can also be used to protect young trees against browsing and trampling by animals.

In a community project in the hill country of Nepal, aimed at forest regeneration in combination with fodder grass production, protection goes even further. A plot of degraded land is fenced off and a guard is employed. In this way the natural regeneration (e.g. *Alnus nepalensis*, *Castanopsis* species, *Sekinia* species) is protected against disturbance during the first year. Thereafter, the plot is weeded, undesirable trees are removed and regular grass cutting is allowed. After 5 years branches of the regenerated trees may be cut – for firewood or fodder – as well. Eventually the trees are harvested and the cycle is repeated.

Natural regeneration is often not recognized as a form of land-use, which means that other people may occupy the land for their own use. This played a role in Papua New Guinea, where natural regeneration was not successful due to lack of clarity concerning ownership rights and lack of supervision. Areas where regeneration has taken place have been lost through fire or illegal land-use by farmers. This shows that for natural regeneration to succeed, it is necessary to have the co-operation of all people involved in the exploitation of an area.

Natural regeneration is of course limited to trees that are already growing in the area. On the other hand these trees have the advantage that they are well adapted to the climate and are tolerant to native pests and diseases. Moreover the local people are familiar with the trees and their uses.

4.2 Direct field planting

Direct planting out of seeds

It is only a small step from encouraging natural regeneration to direct field planting: foresters or farmers gather the seed and sow it where they want these trees or shrubs to grow. When a farmer takes this trouble it makes sense to work the soil where the seed is to be sown to facilitate germination and early growth of the trees. To minimize the work the soil is not ploughed or hoed but scarified (scarification is just loosening the uppermost soil layer). This improves the uptake of water and reduces the competition by grasses.

An elegant way of direct sowing is practiced by Laela Agricultural College in southern Tanzania. The nutritious pods of *Faidherbia albida* are fed to cattle – a few handfuls per day. The manure is collected and a shovel-full is mixed in the soil at each plant position. This is a very successful and simple method to establish the trees, provided the young seedlings are protected against grazing and competition by weeds.

Where the rainy season is short or severe droughts occur direct seeding is often not successful. On sloping land with a soil that stores much moisture, this problem can be solved by guiding the rainwater to shallow pits. A tree can be grown at the edge of each pit. (See Agrodok No.13: 'Water harvesting and soil moisture retention' for detailed information on this so-called 'run-off farming'.) In dry areas of Africa good results have been achieved by direct seeding with *Borassus aethiopum, Acacia* species and cashew. The seedlings first form a long taproot and grow quickly above the height of surrounding weeds.

Fast-growing trees are most suited to direct sowing because they are better able to compete with weeds. Moreover, ample quantities of seed should be available, because only a small percentage of the seed will produce successful seedlings: they face the same hazards as in natural regeneration. The calculation of the amount of seed needed for direct seeding is shown in Appendix 1.

In areas with clumps of thorny shrubs it is possible to sow seeds between thorny branches to reduce the chance of seedlings being eaten. Using hardy tree species to establish a shelterbelt in a windswept area will improve growing conditions for more delicate species

Direct planting out of wildings

Instead of collecting and sowing seed, young seedlings or rooted suckers may also be gathered from where they are growing spontaneously for direct field planting. Field establishment of these wildings needs care and favourable growing conditions, because these plants

were not raised to be transplanted and often most roots are lost when the plants are lifted.

Figure 10: Wildings growing in a clearing in the woods

The soil must be moist; the number of leaves is usually reduced by stripping or by cutting the shoot back. Moreover, if there is still a risk of the wildings drying out, each wilding may need to be shaded during

the first season, for instance by one or two palm fronds. A high percentage of survival of the trees can only be expected when species that establish easily are transplanted during the most favourable time of the year, i.e. generally early in the wet season.

Direct planting out of cuttings

Farmers often plant cuttings directly on the spot required, for instance to establish a hedge round a garden or field. Examples: *Gliricidia sepium, Euphorbia* species, *Lantana camara*. Very large cuttings, so-called live stakes, are up to 2 m long with a diameter of up to 10 cm. They are planted directly along a field boundary: to support a fence (e.g. *Albizia procera, Erythrina* species); around a cattle pen where livestock will be kept during the night (e.g. *Commiphora* species); in a field as shade trees for cocoa or coffee (e.g. *Gliricidia sepium, Erythrina* species); to support climbing crop plants such as pepper or chayote (e.g. *Moringa oleifera*).

In forestry direct field planting of cuttings includes *Casuarina* species and *Eucalyptus* species in dry lands and *Calliandra calothyrsus* and *Dactyladenia barteri* in humid climates. Only species that strike root easily can be propagated by cuttings. And even fewer species can be propagated by live stakes, partly because live stakes generally receive no aftercare whatsoever.

If trees have to be established quickly – as is often the case when the protective function (e.g. erosion control) is most important – direct planting out of wildings or cuttings may be best. This planting material is in principle available throughout the year, although cuttings should not be taken when the tree is flushing. If trees shed their leaves, the best time to take cuttings is when they are leafless.

The scale on which planting is to take place also determines the choice of planting material. Wildings and cuttings are often only available in limited numbers. Seed is usually available in larger quantities.

4.3 Raising planting material in a nursery

If natural regeneration or direct field planting are not successful for the tree species you wish to grow, the trees must be propagated in a nursery. A nursery is a plot of land where young trees can be raised under more or less controlled conditions. These include:

- protection against cattle, goats, chickens, etc.
- a guaranteed water supply
- shade against the hot sun and shelter against strong wind
- improved soil conditions, if necessary by preparing your own potting soil.

Consequently 100 seeds or cuttings raised in the nursery will generally yield many more plants, which will be more uniform than following direct sowing/planting in the field. These advantages of a nursery are greater if field conditions are harsh, e.g. free roaming animals, unpredictable rainfall, degraded land. It takes from about two months to a year to raise different agroforestry species in the nursery, depending on how fast the plants grow and on the preferred size for field planting.

There is of course a danger that the advantages of better germination and uniformity of plants raised in the nursery are lost following transplanting in the field. To prevent this the nurseryman must stick to two principles:

(1) planting material must be ready in time
(2) in nursery work the roots come first.

(1) Plants should be ready for transplanting in the most favourable season – usually shortly after the beginning of the rains.

> The entire planning and timing of all activities from ordering seed to hardening off before field planting, should be geared to ensuring that the plants are ready on time, neither early nor late. Even in a climate without a clear dry season there is still a most favourable time of the year for field planting.

Farmers in eastern Zambia raise seedlings of *Sesbania sesban* in a nursery and plant these in fallow fields to improve the fallow vegetation. They have found that it is worthwhile to sow seed twice with an interval of 2 weeks. If the rains come early, the first-sown batch of seedlings is planted; if the rains arrive late, the second batch is used. In other words: farmers are prepared to throw away half the seedlings, just to improve the chances of the plants being ready for planting at the right moment!

(2) The survival and uniformity of the plants in the field depends on their roots rather than the shoots. Unfortunately the roots grow in the dark, the shoots in the light and it is very common in nursery work to pay more attention to the shoots than to the roots. A small plant with relatively many roots is much better equipped to survive field planting than a large plant with a small proportion of roots. (see Figure 11).

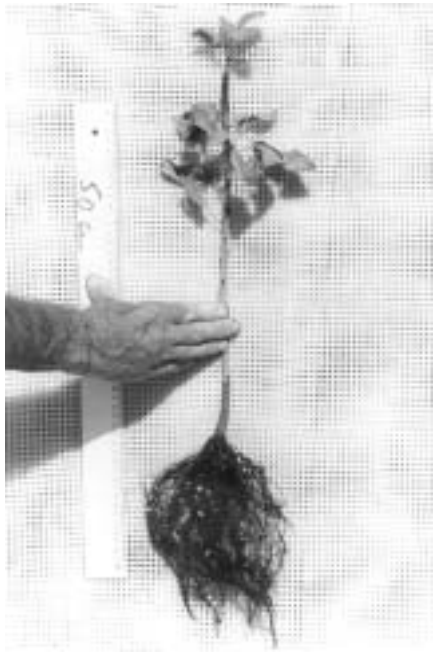


Figure 11: Pistachio plant with well-branched fibrous root system.

A well-branched root system, even at the expense of shoot growth, is the secret of success in nursery work. In other words: the root:shoot ratio should be high – much root growth in relation to the size of the shoot. If this is not the case the root:shoot ratio must be increased when the plants leave the nursery, by cutting back the shoot or stripping off most of the leaves.

Let us assume that you are already doing some nursery work, for instance in a corner of the home garden, and that you want to improve and expand the nursery. Step-by-step we will consider the following topics:

- propagation of bare-rooted seedlings and wildings
- the use of pots
- propagation of cuttings
- setting up a farm nursery
- care for the plants in the nursery
- planting out and aftercare in the field.

While reading these topics, keep the two points in the boxes above in mind. Proper timing of nursery work is further discussed in Section 6.4, fostering root growth comes to the fore in Sections 5.1 and 5.2 as well as Section 7.1; the root:shoot ratio is one of the subjects of Section 7.3.

5 Raising plants in a nursery

Chapter 3 dealt with the collection and treatment of seedlings, wildings and cuttings. In this chapter we discuss how to raise these propagules in the nursery.

5.1 Raising bare-rooted seedlings and wildings

Direct sowing in beds in the nursery

Growing bare-rooted seedlings is the simplest form of tree propagation in a nursery. This method is used if the species is 'easy to plant out', meaning. not prone to heavy losses after field planting. Ample quantities of (cheap) seed and a high germination percentage are also favourable for direct sowing. Sow the seed in a well-prepared bed and let the seedlings grow till they are ready for field planting. You may have experience with raising vegetable seedlings, such as tomato and eggplant, in this way. However, vegetable seedlings are ready for planting out in a matter of weeks, whereas seedlings of trees have to stay in the nursery bed for two months to one year. Therefore more care is needed in the preparation and maintenance of the beds, as explained in Section 6.2.

Sowing in seedbeds or trays; further growth in plantbeds

The above method is not used much for tree nursery work. It is only suited to seedlings which will be ready within a few months and will survive easily after field planting. A more common method is to sow the seed closely in seedbeds and to prick out the young seedlings into plantbeds at the right spacing for their further growth in the nursery. Pricking out is the term used for transplanting young delicate seedlings by lifting them gently, using a pointed bamboo stick for instance.

There are good reasons to separate the germination stage and further growth in the nursery:

- The seed of many trees germinates slowly and unevenly. Seed of *Cordia alliodora*, for instance, starts to germinate two weeks after

sowing, but you may have to wait for 8 months to see the last seeds germinate! As discussed in Section 3.2 pregermination treatments are needed for many species to stimulate germination of the bulk of the seeds within a reasonably short period of time. By pricking out the seedlings that have reached the right stage every few days, a uniform stand is achieved in the plantbed. And if plants grow uniformly they can be given the right treatment (e.g. topdressing with fertilizer, root pruning) at the right time!

- The requirements for germination are not the same as those for seedling growth. A seedbed needs careful levelling to prevent washing down of seeds to a lower edge during watering. Rake the bed to obtain a fine tilth so that the seeds can be sown at the proper depth and break through the soil surface easily. On the other hand the soil in a seedbed does not need to be rich. River sand is fine, because it is well drained and relatively free from moulds which attack germinating seeds. The soil does not need to be fertile because the seedlings are pricked out before the food reserves in the seed have been exhausted. A plantbed does not require such a perfect surface, but friable, rich soil to encourage growth and branching of the roots.

- A germinating seed first produces a taproot and then the sprout. Usually the taproot grows much faster than the sprout and the growth of side roots lags behind. During pricking out the tip of the taproot breaks off and this stimulates branching of the root system. This is extremely important: remember – in nursery work the roots come first!

Instead of seedbeds you can use seed trays, wooden or plastic boxes of, say, 40 × 30 cm and about 5 cm deep, filled with coarse sand. These can be put on the veranda or under a lean-to roof to protect the germinating seeds against heavy rain or the hot sun. Place the trays on a bench or table, so that you do not have to bend down to sow the seed and to facilitate pricking out seedlings that have reached the right stage. As the trays contain little soil, it will be no problem to fill them with clean sand for each batch of seed. This prevents diseases such as

damping off. Placing the trays on a bench also puts them out of reach of cutworms.

Air-pruning of roots in seed trays

A final improvement in the germination stage is the use of seed trays with an open-mesh bottom. You could make your own wooden trays with a wire mesh bottom (like a sieve) or cut and fold heavy netted plastic sheets that are used as windscreens (see Figure 12). You may even find cheap plastic trays with mesh sides and bottom in the market.

Sand would fall through, so you have to fill the trays with friable soil or – better still – with a good rooting medium such as shredded coconut fibre. Place the tray(s) on a bench with an open top, e.g. made of wire netting or slats, so that the underside of the trays is exposed to the air.

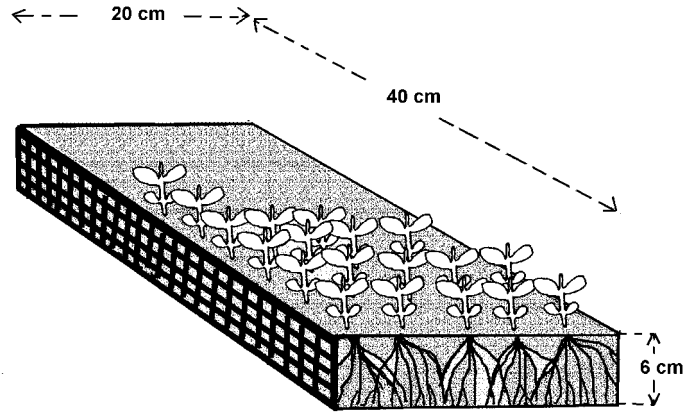


Figure 12: Air-pruning of roots in an open-mesh seed tray.

What happens when you sow the seed in such a tray? Within a few days from germination the taproot reaches the underside of the tray and its growth is stopped by exposure to the air. In response to this air-pruning numerous side roots grow out near the root collar. When the

seedlings are pricked out one can see the dramatic effect: instead of a long, sparsely branched taproot, the root system looks more like that of an onion with its full skirt of side roots. Prick the plants out 5 to 10 days later than usual to give the side roots time to grow and the seedlings will arrive in the plantbed with a perfectly branched root system in the making!

Air-pruning the taproot by germinating seeds in open-bottom trays is recommended where pricking out is not a serious bottleneck. (Pricking out requires much labour and for seedlings with well-developed side roots the work is even more time-consuming.) The fruit, nut and agroforestry species, on which air-pruning has been tested in different parts of the tropics, all responded very well. Where seed trays are already used, it is quite simple to change over to open-bottom trays.

Some species of the arid zone need a taproot to reach the groundwater table in the shortest possible time. However, in the Negev desert in Israel it was shown that one or two side roots of trees of which the roots had been air-pruned took over the task of the taproot in racing down towards the water table. For an extensive discussion of the pros and cons of air pruning of roots see AgroSpecial 1: A nurseryman and his trees.

Preparation of seedbeds and seed trays; sowing

The soil in seedbeds must be compacted to ensure good contact between the top layer in which the seeds are sown and the deeper layers. In loose soil the topsoil may dry out quickly because moisture cannot move upwards between the soil particles. Firm the soil, for instance using a board over which you can walk. The soil is sufficiently compacted if only a slight imprint is left when you press it with the knuckles of a fist. Light watering after sowing also helps to settle the soil around the seed. Do not compact the soil in a bed when it is too wet as this can ruin the soil structure.

Sow seeds at a density that will produce sufficient seedlings to fill the area. Never sow too densely, as crowding will result in weak, lanky

seedlings; it also increases losses due to damping off. Leave a space of about 8 cm around the edge of raised seedbeds without seeds, as the edge often crumbles away. Water seedbeds or trays one day before sowing.

If seeds are sown in seedbeds or trays and will be pricked out later, they are broadcast or dibbled in rows. Small seeds (e.g. *Eucalyptus* species) are mixed with fine sand in a sand-seed ratio of 2:1. This makes even sowing at the right density much easier.

Broadcasting is scattering the seed by hand; it requires practice to achieve a fairly even distribution. If you lack experience, it is better to sow thinly, for overcrowding means that the seedlings have to be thinned, which is a waste of planting material. Broadcasting is limited to small seeds, because large seeds cannot be placed at the right depth by broadcasting. Broadcast seed is either raked in or covered immediately with loose material, such as coarse sand or very fine gravel. Light watering of the covered seeds helps to settle the soil, ensuring good contact between seeds and soil.

Row-seeding makes it easier to ensure an even distribution, although dibbling also requires practice and some thinning out may be needed. Sowing in rows also facilitates weeding and pricking out. The rows can be made by pressing a slat across the bed to make small V-shaped furrows in which the seed is sown (see Figure 13).

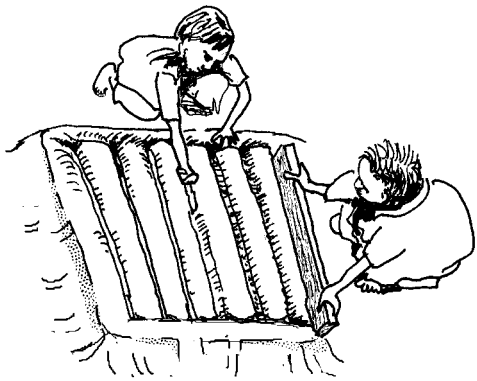


Figure 13: Row-seeding

If seeds are sown directly in their final position in the nursery (no pricking out) they are sown in pits at the proper spacing in a regular pattern. The spacing depends on the tree species and the required seedling size for planting out. A drilling board, fitted with pegs at the desired spacing is a very useful tool to make holes the correct distance apart and in the correct pattern (see Figure 14). Both large and small seeds can be sown in this way.

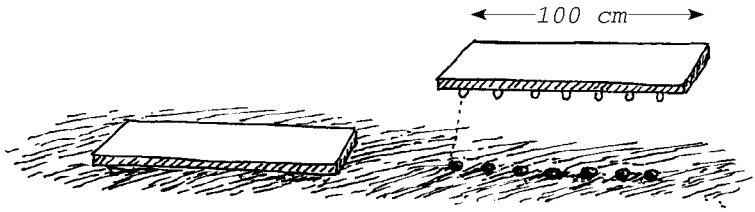


Figure 14: Drilling board, with pegs at regular intervals

Depending on the germination percentage a single seed or several seeds (usually 3 to 6) are sown in each position. The spacing ranges from 7 x 7 cm (ending up with 200 seedlings per m^2) for slender conifers to 14 x 14 or 20 x 20 cm for species with large leaves such as teak (resulting in 50 or 25 seedlings per m^2). After emergence of the seedlings they are thinned leaving only a single seedling in each grid position. If thinning is inadequate, the seedlings are crowded; they grow spindly and may not survive after planting out.

Sowing depth is generally twice the diameter of the seed. For example, seed with a diameter of 3 cm is sown at a depth of 6 cm (see Figure 15). If seed is sown too deep the food reserves in the seed may be depleted before the seedling has formed green leaves for its nourishment.

Cover seeds immediately after sowing. Seed in seed trays is often covered with loose material, such as coarse sand or very fine gravel, which are easier for the seedlings to break through. The soil in seedbeds must be firmed to ensure good contact between seeds and soil; contact is further improved by light watering of the covered seeds. If

germination takes several weeks it is worthwhile to mulch seedbeds and seed trays. The mulch softens the impact of watering and keeps the topsoil moist. However, remove the mulch as soon as the first signs of germination are observed, otherwise sprouts growing through the mulch will be blanched, spindly and prone to disease.

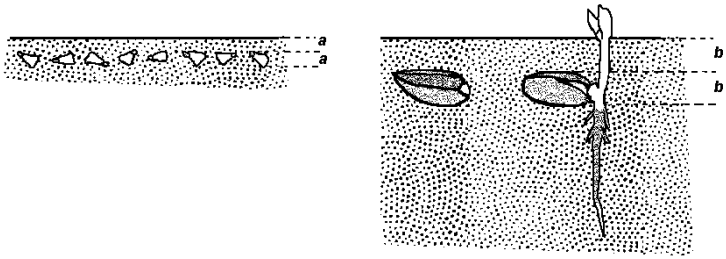


Figure 15: Correct sowing depth (a, b) and positioning of large seed so that taproot and sprout can grow straight

Pricking out

Seedlings in seedbeds or seed trays have to be transferred to the plantbeds. Pricking out is usually done when the seedlings have one or two normal leaves. Within the seed are preformed leaves, the so-called cotyledons: one for palms and two for nearly all other woody plants. A germinating seed first issues the cotyledon(s); thereafter the sprout forms normal leaves. The shape of the cotyledons is often quite different from that of the normal leaves (see Figure 16). In some cases the cotyledons remain underground.

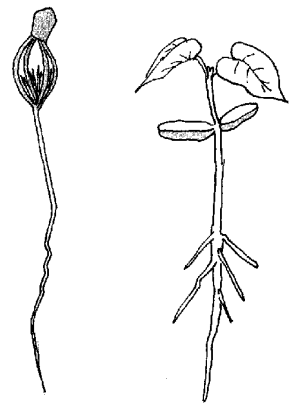


Figure 16: Seedlings of a conifer (left) and a broad-leaved tree (right) with cotyledons and normal leaves, ready to be pricked out

If seeds are sown at the right spacing, the seedlings fill the bed or tray by the

time they have reached the stage for pricking out. For most species this is within a few weeks from emergence of the sprout. Simultaneous germination makes it possible to prick out all the seedlings at the same time, but even with proper pre-germination treatments it is often necessary to prick out repeatedly at an interval of several days. In that case the spacing of the seeds in the tray or bed needs to be wide enough to prick out seedlings without damaging the others.

For larger seeds, e.g. of nut crops, the problem is sometimes circumvented by germinating the seeds on a moist gunny sack, putting another gunny sack on top. Every few days the seeds that start to germinate can be sown in a seedbed or tray, resulting in uniform batches of seedlings when it comes to pricking out.

The way in which seedlings are pricked out is shown step by step in Figures 17 and 18. Figure 18 shows pricking out in pots, but the process is the same for plantbeds. Note that the seedlings are held by a leaf, not by the stem. This is to avoid damaging the tender stem or transmitting damping-off.

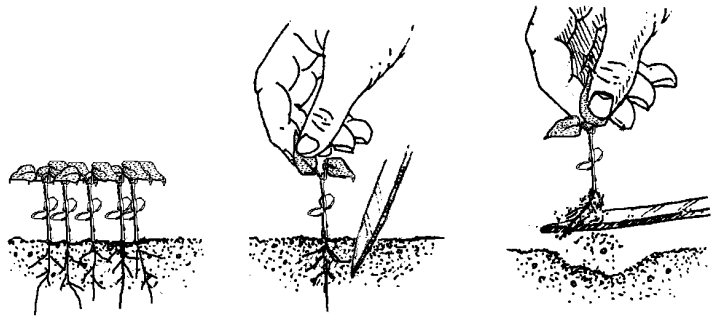


Figure 17: Pricking out, lifting the seedling

When pricking out, the following points are important:

- Seedling size: most species are large enough for pricking out about 10 – 20 days after germination, but conifers are often pricked out sooner, even 2 – 4 days after emergence. If the seedlings are too

young they will be very delicate and likely to be damaged. However, if you wait too long the seedlings become overcrowded and separating the roots becomes difficult.

- Drying out: only prick out a few seedlings at a time (as many as you can plant in an hour). As far as possible work in the shade and in a sheltered place out of the wind.
- Planning: the work is time-consuming and should not be delayed (increased risk of damping off, spindly plants, many casualties). Moreover, it must be completed within a few hours per day, avoiding work during the hot hours. Plan successive sowings so that batches reach the pricking-out stage one after the other, not simultaneously.

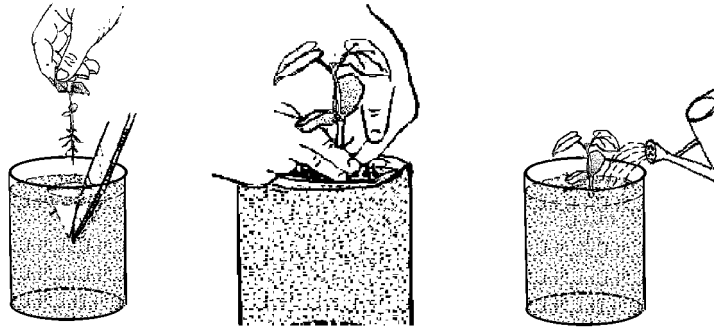


Figure 18: Pricking out, transplanting the seedling

Make sure the seedlings will have enough room when pricked out to attain the size desired for planting out in the field. The planting distances may be the same as mentioned above for direct seeding, ranging from 7 x 7 cm to 20 x 20 cm. But to facilitate weeding and root pruning, rows are often spaced about 20 to 25 cm apart, and the seedlings are set closer together in the rows, for instance 5 - 10 cm apart.

If wildings have to be nursed before field planting, they are set in plantbeds at the proper spacing. They can be graded according to size, paying particular attention to the amount of roots, to improve uniformity of the planting material.

5.2 Raising plants in pots

Raising bare-rooted or potted planting material?

Sowing or planting in pots is an alternative to sowing or planting in beds. This requires extra work in the nursery and greatly increases the cost of transport if the seedlings are to be planted in a remote site. Making pots from local materials is time-consuming and earthenware pots are expensive, but with the introduction of cheap plastic pots ('polypots') potting up has become a lot more popular. Polypots are polythene sleeves that are supplied flat; filling with soil gives them their pot shape.

The extra work and expense involved in using pots has to be made good by better quality of the planting material, resulting in a high percentage of survival and a uniform stand in the field. The main advantage is of course that the roots are left undisturbed in the potting soil when pot plants are planted out. Seedlings raised in the ground are dug up, and after transport little, if any, soil is held by the roots. Hence, they are planted bare-rooted.

The advantages and drawbacks to both types of planting material are listed in Table 2.

Table 2: Characteristics of bare-rooted and container-raised planting material (or wildings with a root ball).

Characteristics	Bare-rooted	With pot or soil ball
labour requirements	low	high (filling/handling pots)
space utilization	extensive	intensive
soil loss from nursery	minimal	substantial
transport	light and cheap; risk of drying out	cumbersome, but safe if watered
planting out	severe growth shock	mild growth shock

Potted plants have to be used when bare-rooted material would lead to many casualties, e.g. because of time-consuming transport from the nursery to the field, or unfavourable growing conditions in the field at

the time of planting. Commercial nurseries usually raise many plants in pots, because they can be sold and planted over a much longer period than bare-rooted plants.

It is not worth spending time and money on raising seedlings in pots if bare-rooted plants produce equally good results. If the roots are air-pruned to obtain a sturdy well-branched root system, and if the trees can be planted at the right time of the year, it is unlikely that better results would be achieved with pot plants, even in case of long-distance transport. Often bare-rooted and potted plants are found side by side in the nursery, the choice depending on the hardiness of the tree species and the conditions mentioned above.

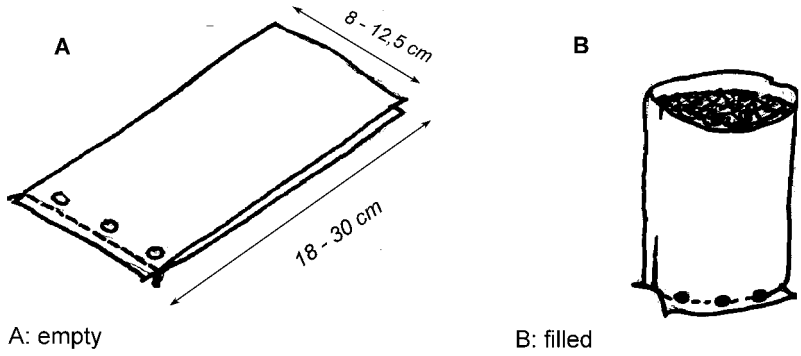


Figure 19: Soft plastic pot ('polypot'), made from a plastic bag.

The simplest and cheapest pots are made by cutting a polythene sleeve into sections of the required length. With one or two staples the sleeves can be converted into pots with a draining bottom. Ready-made polythene bags, so-called polypots, are the main alternative (Figure 19). The size of these bags varies, but use ones that measure at least 18 × 8 cm when laid out flat. Hard plastic pots are more expensive. Pots must always have a hole in the bottom so that excess water can drain away. Pots can also be homemade from various materials such as paper, tin, clay, plastic (shopping bags) or plant material such as bamboo, banana stems or leaves.

Optimum pot size

If plants stay in the pot longer than intended the roots either get 'pot-bound' or escape from the pot. In the case of pot-bound roots, active root growth in search of moisture and nutrients is largely limited to the bottom of the pot where the roots grow in circles. Elsewhere in the pot one finds few whitish root tips indicating active growth. As a result shoot growth slows down too. And during field planting the circling roots have to be cut off to prevent stunted growth, leaving only the inactive roots in the rest of the pot. In other words: instead of starting with an intact root system, the pot-bound plant has to make do with a mutilated and defective root system.

Similarly, if roots grow through the drainage holes and find a better supply of water and nutrients in the soil underneath, they will grow vigorously at the expense of the roots inside the pot. The escaped roots are disrupted when the pot is lifted or when the pot is removed during planting out. So, in this case too, the purpose of raising plants in pots is thwarted.

A small pot shortens the period during which the plant can be kept in the nursery. And if pots are larger than necessary, their use becomes more cumbersome and expensive. Appendix 1 gives examples of the increasing quantity of potting soil and bed area required if larger pots are used.

Conclusion: to reap the advantages of raising plants in pots, it pays to find the optimum combination of pot size, period of growth in the pot, and size of planting material.

Handling pots

Filling pots

Soil for filling the pots should be light and loose-textured for good aeration and drainage, so that root development is not impeded. But a ball of moist potting soil should not fall apart when picked up.

It is difficult to give a standard mixture for potting soil, because what is used depends on what is available locally. However, a commonly used mixture is 3 parts topsoil, 1 part compost and 1 part sand. Sieve the soil to get rid of lumps and stones. Make a large screen from wire mesh (with 5 – 10 mm square holes) stretched over and fastened to a wooden frame. Lean the sieve against a support so that it is at an angle and shovel the potting soil over it so that it falls through the sieve.

Pots should be well filled. Tap the pot on the ground to settle the soil, leaving no air pockets Use a funnel to fill narrow pots, e.g. made by cutting the top half of a plastic bottle with a wide top. This works well if the soil is sufficiently loose and dry to flow down the funnel. Water the filled pots and leave them to stand for a few days till the pot soil has settled.

Beds for pots

Pots are placed close together in blocks of similar length and width as the plant beds in the nursery. It is very important that the ground has been properly levelled and firmed, so that the pots do not fall over and water does not erode the ground. A frame of wood, bricks or earth can be set up along the sides of the bed to keep the pots upright and to prevent overheating of the outer row of pots. (Black pots can get very hot in the sun.) On a slope the pots can be placed in trenches – again with carefully levelled bottom – to be inundated periodically by surface irrigation. The water cascades from the upper trench to the lower trenches, similar to the practice in wet rice fields. If water is scarce the trenches can be lined with polythene.

Place the pots together in straight lines of equal length; this makes counting and transplanting easier. Always place the pots upright even though it is often easier to lean them against each other. If the pots lean to one side, even only slightly, water sprinkled over the pots tends to run off the lower edge instead of penetrating into the pots. It also results in a one-sided root system.

Sowing or planting in pots

Pots can be seeded directly, or they can be planted with seedlings pricked out from seedbeds or seed trays. Wildings or cuttings can also be planted in pots.

Following direct seeding it is not possible to stimulate branching of the roots by (air)-pruning. So this method is only suitable for species that naturally form a root system branching sufficiently to hold the potting soil together during field planting. Choose a large enough pot to enable the seedling to grow to the desired size.

Also, the germination percentage of the seed lot should be known, because this determines how much seed can be sown in each pot (see Table 3). How to calculate the germination percentage is explained in Appendix 1. If nearly every seed produces a good seedling, as is the case for *Acacia* species, one seed per pot is enough and there will be no need to thin out.

Table 3: The number of seeds per pot depends on the germination percentage.

Germination percentage	Number of seeds per pot
> 80	1
50 - 80	2
40 - 50	3
20 - 40	4
<20	5

For very small seeds use a sand-seed mixture (2:1). Dip a small (paint) brush in water, then in the sand-seed mixture and spread the mixture carefully over five pots that are filled with soil. For *Eucalyptus* seeds this will produce a maximum of 4 or 5 seedlings per pot. In case several seeds are sown per pot, only the strongest one is left after emergence. Thinned seedlings can be pricked out into pots in which none of the seeds germinated.

For most tree species pricking out seedlings into pots is much preferred to direct seeding in the pots, for two reasons:

- Pricking out stimulates branching of the root system, so that the pots are better filled with roots to hold the soil during field planting;
- Because the pricked out seedlings are uniform, each batch of pot plants is uniform; problems with delayed germination are avoided.

5.3 Rooting cuttings

Cuttings rooted in a nursery are commonly set in raised, well-drained beds of friable soil. Before planting cuttings the lower end may be cut again to ensure that the cut surface is clean. This cut at the base is made just below a node, i.e. the point where a leaf was attached, because generally root formation is best at the nodes. If the bark is thick, it may be sliced or scraped off the base of the cutting to make it easier for new roots to break through.

Push the cuttings into the soil until about 2/3 of the length of the cutting is covered. For cuttings of trees two buds are allowed aboveground. If they both grow out the weaker one is removed, so that the most vigorous one will form the tree trunk. In the case of shrubs 3 - 5 buds may be left aboveground and all emerging shoots are allowed to grow. The cuttings may be set at an angle. A vertically placed cutting tends to produce one dominant shoot, whereas a more horizontally inclined cutting is likely to produce several more or less equivalent shoots. Hence a vertical position is generally preferred for trees, and a slanted position for shrubs. Do not plant the cuttings upside down!

Plant the cuttings in rows about 25 cm apart with a spacing of about 20 cm in the row. After planting, water the bed again.

Cuttings can also be set in pots, but this requires close attention to watering. The soil must be kept moist all the time, but if it becomes too wet the young roots quickly die because of lack of oxygen. In a bed it is easier to keep the soil moisture between these limits. Shade helps to reduce moisture loss and is essential for cuttings that retain some

leaves, also because shade reduces air temperature. Shelter is also important because it protects the cuttings against drying wind and tends to raise the humidity of the air.

Whereas seedlings have a dominant taproot, cuttings form so-called adventitious roots, which are basically all equal. In due course some adventitious roots may become much stronger than the others, but the root system does not become as strong as that of a seedling with a taproot. As mentioned in Section 3.1 this has far-reaching consequences for tree vigour and the onset of flowering and fruiting.

6 Setting up a farm nursery

Farm nurseries are used successfully in many areas: in West Kenya about a third of households traditionally raise their own seedlings. They are usually grown in the homestead. A nursery should be simple to lay out, requiring very little in the way of materials and maintenance. In the previous chapter we have seen that seedbeds and plantbeds and a collection of pots are possible features of a farm nursery. They may be used to raise seedlings or cuttings and – in some cases – wildings. Indeed, in its simplest form a nursery may be limited to one or two beds with seedlings, or some seedlings or cuttings growing in makeshift containers such as old tins, pots or bowls placed in the shade of a tree.

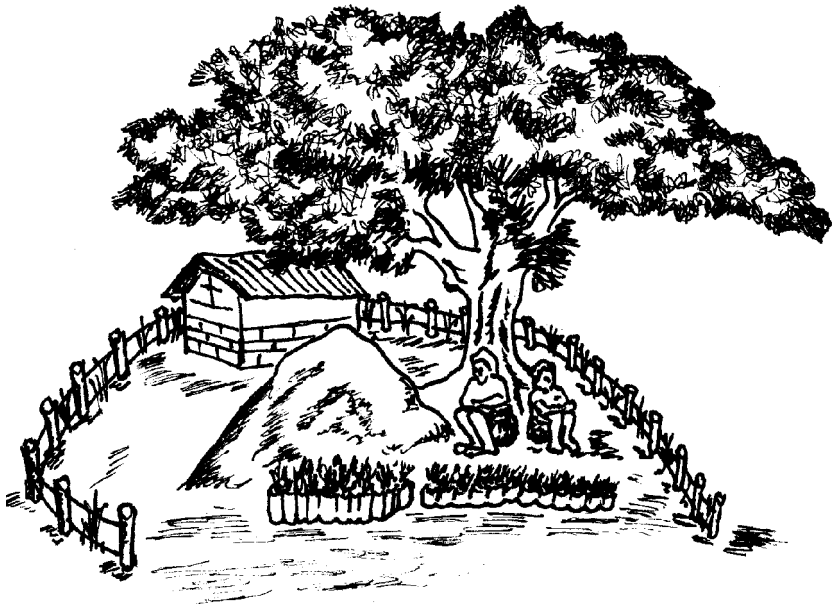


Figure 20: A simple farm nursery

In this chapter we shall discuss where and how a farm nursery can best be set up, be it a simple or a more ambitious one. Because, if you plan to propagate trees and shrubs year after year, a permanent location can be chosen and the layout can be perfected.

6.1 Location

A nursery should be established as close to the house as possible – for instance in the home garden – to facilitate management and supervision. Below is a list of the most important factors that have to be taken into account when choosing the location for a nursery.

Fence or hedge

The nursery must be protected against intruders, in particular animals such as goats and chickens. Usually the home garden is surrounded by a hedge, so if the nursery is in the garden protection against intruders is fairly simple.

Water

The nursery requires between 10 and 20 litres of water per square metre bed per day, depending on the temperature and the size of the plants. If rainfall is not sufficient there must be enough water available from another source, preferably throughout the year.

Establish the nursery as close as possible to the water supply. A tank may be bought or built to store water in order to balance supply and demand. For instance, if there is shortage of water in the daytime when everybody draws water, the tank can be filled during the night so that you are not dependent on the daytime flow.

Land, soil

A nursery is best laid out on fairly level ground, preferably with a gentle slope so that water runs off, avoiding problems of water stagnation and erosion. If the slope of the area is more than 2% (a height difference of about 2 cm over a distance of 1 m) terraces must be made.

The nursery soil should be friable, deep and well drained. A thin layer of soil on top of stony subsoil is not suitable. If pots are to be used the quality of the soil is less important: pots can be filled with soil from elsewhere.

Shade

A nursery must be shaded, because most tree seedlings are adapted to starting life shaded and sheltered by mature trees. Shade prevents overheating during the hot season and raises the humidity in the beds by impeding air movement. A home garden is generally a favourable location because the garden trees can provide the necessary shade. In South-East Asia more even shade is often provided by rows of fast-growing *Sesbania grandiflora* (a small tree with large flowers which serve as a vegetable). This tree is sown in the nursery; the fine feathery leaves give a dappled shade, which can be regulated to some extent by pruning.

The possibility to regulate the intensity of the shade is welcome, because older seedlings tolerate stronger light than young ones. Moreover, before planting in the field the seedlings have to be 'hardened off' to get used to the growing conditions in the field, where they may not be shaded at all. Instead of shade trees, simple shade structures as shown in Figures 21 and 22 are often used, because these allow a much better control over the degree of shading.

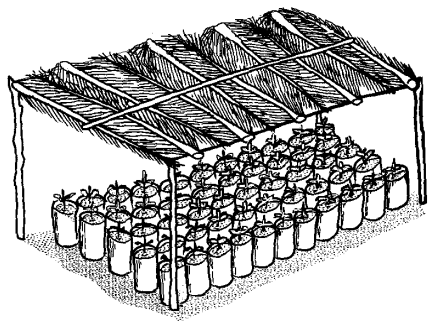


Figure 21: Simple leaning shade cover of palm fronds or grass stalks

In Figure 21 palm fronds provide the shade; the shade can be reduced by removing some fronds. Mats made from sorghum or millet stems, split bamboo or grass can be laid on frames made of posts and bamboo or wire, about 50 cm above the beds (see Figure 22).

Figure 22: Roll-up mats (From: Nieuwenhuis, 1990)

These mats can be rolled out when it gets hot in the morning and rolled up again in the afternoon or when they interfere with work in the bed. Shade mats should allow about half the total amount of sunlight to penetrate so that the seedlings can grow well.

Shelter

Young plants should not be exposed to strong winds, as this greatly increases water requirements and reduces the rate of growth. Again the home garden environment is generally favourable, because the house, the garden trees and the hedge surrounding the garden all contribute to protecting the young plants against wind and dust.

If the nursery is in an exposed position, a windbreak must be planted to break the prevailing wind. (See also Agrodok No. 16: Agroforestry and Agrodok No. 13: Water harvesting and soil moisture retention.)

6.2 Making nursery beds

Although the beds in the nursery have been mentioned a number of times, we have not yet looked at the way in which they are prepared. In fact the beds are the most important part of the nursery and we shall now pay due attention to their preparation.

Begin by preparing the area you want to use: level the ground and if possible make a slope with a gradient of 1 - 2%. Dig drainage channels if necessary. Mark out beds and paths before shaping them.

Beds are about 1 metre wide so that you can easily reach the plants in the middle from both sides. You should be able to do all the work – pricking out, weeding, watering, etc. – without stepping on the bed. The length of the beds is of little importance; choose whatever length is convenient for the numbers of plants you intend to raise. The paths between the beds should be at least 60 cm wide.

Beds are generally raised, although one sometimes sees level or sunken beds. Beds for pots are on level ground, occasionally they may be sunken to facilitate watering, as explained in Section 5.2. Raising seedbeds and plantbeds improves drainage, good drainage being the first requirement. Moreover, working with raised beds is easier, because there is far less bending down to do. (Seedbeds require much attention and this is another reason why seed trays are often used instead of seedbeds. The trays can be placed at a convenient height on a workbench, so that you do not have to bend down at all.)

Topsoil can be scraped off the paths to raise the beds; the height usually ranges between 8 and 15 cm. Generous amounts of compost or manure (both old, well-decayed!) are added to make the soil more crumbly (friable) and to supply nutrients for the plants. If the soil is sandy this will also improve water retention. If it is a heavy clay soil, sand should be mixed in too, even up to 50 % (1 cm sand for every cm clay, making the bed twice as high). Heavy soil has poor drainage, is difficult to work, and the roots are easily damaged when the plants are lifted. Mixing it with sand will improve these conditions and make it easier for the germinating seed to break through.

If the beds are to be used for a number of years it may be worthwhile preparing them more thoroughly, starting with solid edges and filling with material largely brought from elsewhere, as follows (see also Figure 23):

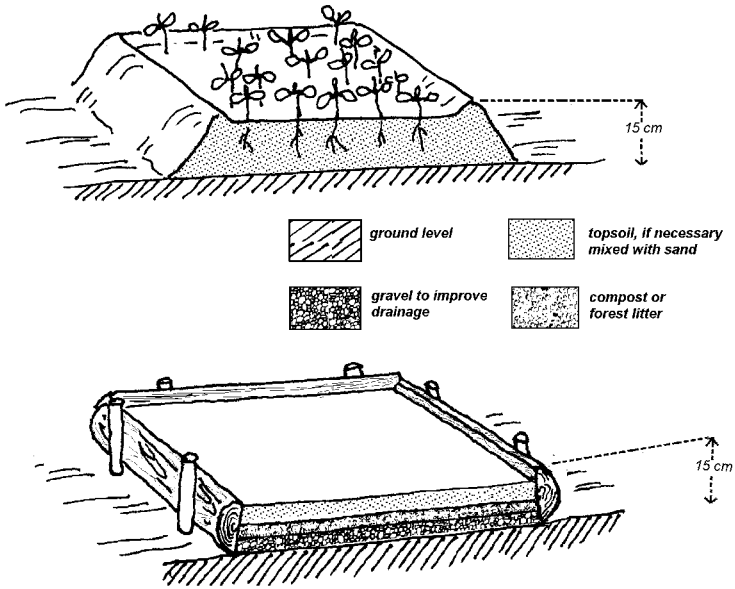


Figure 23: Temporary bed (top) and more permanent bed (bottom).

- Construct an edge around the bed, about 15 cm high, using wood, bricks or woven twigs.
- Cover the bottom of the beds with a layer of gravel or broken bricks 5 cm thick to ensure good drainage.
- Cover this layer with 2 - 3 cm of compost or a mixture of soil and forest litter.
- For the top layer of the bed use fine textured, fertile soil. This is the layer in which the young trees will root. Use sieved soil, or a mix (1:1) of soil and sand.
- Trample the beds so that the soil is well settled.

If this bed construction is too ambitious you may still adopt some of the recommendations, particularly for the seedbeds and beds for cut-

tings, because these should meet the highest standards of drainage and tilth of the soil (e.g. the topsoil should certainly not form a crust).

6.3 Features of a permanent nursery

Figure 24 shows a model nursery with all the features that have been discussed before, such as water source, windbreak, hedge and beds of various kinds. The model also includes areas for storage and activities such as filling pots, which are described below. These areas, including the paths, access road and headlands, usually require a larger area than the beds. A nursery as depicted in Figure 24, if used intensively, could raise all the trees and shrubs for an entire village year after year.

Work area

An area of a few square metres is needed for activities such as seed extraction, treating cuttings, filling pots and for potting up plants. Seeds which have been collected may have to be spread on the ground to dry after extraction from fruits, pods, cones, etc. The same space can also be used for treating cuttings. Potting up usually takes up the most space and hence determines the size of the work area. This area should be shaded, keeping you and the plants out of the sun.

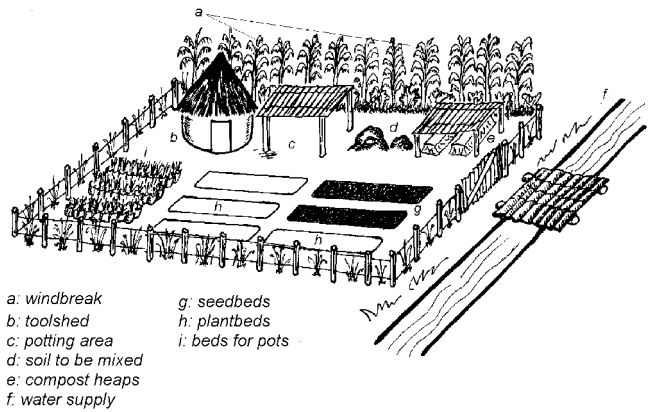


Figure 24: Layout of a fairly large permanent nursery.

Materials

If pots are used the ingredients for the potting soil, e.g. sand, clay, compost or manure, should be at hand, ready to be mixed whenever pots need to be filled. These materials may also be used to improve the soil in the beds. There should also be room to mix or sieve the potting soil. Poles and stakes are needed for fencing and the construction of shade.

Compost heap

Discarded plants, removed mulching materials, prunings from hedges, shade trees and the like can be composted. This reduces the quantity of manure that has to be brought in from elsewhere. Add some manure to the compost heap to enrich the mixture and to speed up decomposition. And when you water the plants check whether the compost heap also requires watering (dry material decomposes very slowly). There must also be enough space to turn the heap over while it is decomposing (see Agrodok No. 8: Preparation and use of compost). If no compost is available, forest litter can be collected.

Maintenance

It is important to maintain your nursery well: check drainage channels, paths and terraces regularly for damage or wear. Carry out any repairs immediately, especially during the rainy season. Check fences regularly for gaps. Fill pots each time with fresh, uncontaminated soil to prevent spread of diseases and pests.

6.4 Planning

As emphasized in Section 4.3 the first rule in nursery work is that the plants should be ready on time. This requires planning. Organise the nursery in such a way that good quality seedlings are ready for planting out at the beginning of the rainy season. The mistake often made is to start nursery activities once the rains have set in. This may save the work of watering, but the consequence is that seedlings grow too small and – once planted out in the field – they are overtaken by the

dry season. As a result losses in the field are high and stunted growth of the survivors during the first year gives the trees a bad start.

To be able to plant out just as the rains begin, seeds should be sown two to twelve months earlier. The exact amount of time needed depends on the tree species you wish to raise and the preferred size for planting out. Pregermination treatments also affect the period of time needed to raise the plants. It is best to obtain this kind of specific information locally, e.g. from the agricultural extension service or the forestry service.

Make a calendar showing when collection of seeds, sowing, pricking out, field planting, etc. are expected to take place. (see Figure 25).

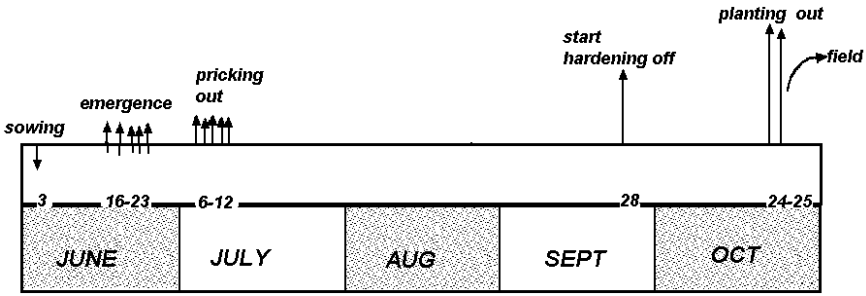


Figure 25: Time schedule of nursery operations for a single tree species. In this example the wet season starts in October.

This schedule also determines the need for watering, the timing of bed preparation or pot filling (preceded by buying pots and gathering the ingredients for the potting soil), etc. Compare the actual dates with your schedule, so that your planning improves as you gain experience year by year.

Recalcitrant seeds cannot be stored for any length of time, so the seed must be sown as soon as possible after the fruit ripens. Quite a few fruit crops that are at home in monsoon climates, flower during the dry season, the fruit ripening during the wet season. Hence, if the seed

is recalcitrant, as in the case of mango, the plants have to stay in the nursery for nearly a year, if they are to be planted at the beginning of the next rainy season.

Labour requirements should be taken into account too. Hand watering is hard work that recurs every day during the dry season. Preparing potting soil and filling pots cause a peak in labour requirement and so does pricking out. In the dry season it may not be too difficult to fit in the work in the nursery, but the beginning of the wet season is the busiest period on the farm, and the help of all members of the household may be needed.

6.5 Keeping records

If you intend producing planting material in your nursery – whether small or large – for a number of years, you should consider keeping records. You may not like the idea. You may prefer handling the hoe to handling a pen, but as the years go by you will rely more and more on what you wrote down and wish you had recorded more rather than less!

Records are a powerful tool to make nursery work more rewarding. One forgets a lot within a year and as the years go by it becomes very difficult to remember what happened when and why. Even for a nursery of a single species – e.g. to raise planting material for improved fallows – records do help. Moreover, for a single species you do not have to write down a lot!

As this Agrodok is not about bookkeeping we will limit the discussion to three types of records: seed stock inventory, production records and labels.

Seed stock inventory

Keeping track of the kinds, quantities and age of stored seeds is only important if you store seed of several tree species, especially if some seeds are stored for several years. The inventory consists of two parts:

- Particulars of each lot of seeds written down when the seed is acquired.
- A running account of the quantities taken out of storage periodically.

Both parts can be entered on a single page in your record book, for instance as shown in Table 4.

Table 4: Page in the record book showing details of seed lot 05/1 and the way it has been used.

SEED STOCK INVENTORY		**Seed lot no. 05/1**	
Species		papaw	
Collected:		10 Feb. 2005	
Source:		tree in front of house Mr. Nanyaro	
Quantity:		50 g	
Treatment:		rubbed skin off and dried	
Seed weight:		10 g = 170 seeds	
Germination rate:		not tested	
STOCK RECORD:			
Date	Out to:	Qty out	Balance
10/2/05	-	-	50 g
2/3/05	Sown	10 g	40 g
10/3/05	Mr. Ngowi	10 g	30 g
5/3/06	Sown	15 g	15 g
20/1/07	Test	2 g	13 g
20/3/07	Discarded*	13 g	0 g
* germination only 24%; replaced by fresh seed, lot no. 2/07			

Any seed lot obtained from traders, forestry services or other professional sources should be supplied together with the following information:

- species
- date of collection
- origin of seeds (where collected, from which mother trees or seed garden)
- germination percentage
- quantity and price (both shown on the bill)

Copy this information in your own record book and if you collect seed yourself, also write down the species, date and source of seed in that book.

You may wish to record further particulars. For instance, seed is usually sold by weight, but you want to raise a certain number of plants. Suppose a batch of seeds weighs 50 gram. By measuring how many seeds weigh 1 g (or 10 or 50 g, depending on seed size) you can calculate how many seeds there are in 50 gram. The number of plants that can be raised from this batch depends on:

- The germination percentage, which gives the expected number of seedlings.
- The success of your nursery work, i.e. the percentage of the seedlings that grows into a good plant.

So seed weight is a very useful measure to plan your nursery work and weighing scales are an indispensable instrument for the nurseryman. Appendix 1 shows how to calculate the amount of seed needed to produce the required number of seedlings. It also describes how you can test the germination percentage yourself. If you do this do not forget to write the date and the result in your record book!

Give each batch of seed an identification number: the seed lot number, for instance according to the sequence of collection in that year, e.g. 05/1 indicating the first batch of seeds collected (or bought) in 2005.

The second part of Table 4 needs no explanation. It contains the record of quantities of seed taken out and the purpose for which it was used. If the seed lot contains less than a few hundred seeds, it may be more convenient to record the number of seeds instead of seed weight.

Production records

A production record follows what happens to the seed from the moment it is taken out of the store, until the planting material leaves the nursery. The most important elements of the record are the dates and the numbers of seeds/seedlings. By writing down the dates of sowing,

germination, pricking out and planting out, you can calculate how long each stage of growth takes and this is a great help in improving your planning for next year.

By keeping track of the number of seeds sown, germinated, pricked out and delivered, you see how many good seedlings have grown out of, say, 100 seeds. Also you can see where the main losses occurred: was it poor germination, were many sprouting seeds weak or emerging so late that you did not prick them out, or did something go wrong in the plantbeds or pots? In this way you can learn from your mistakes and within a few years you will be thoroughly familiar with the behaviour of different species in your nursery.

Production records can take various forms; an example is given in Table 5.

Table 5: Example of a production record sheet

Seed lot no. Name		**Sown**	**Germination**	**Pricked out**	**Field planting**
05/1 Paraserianthes falcataria	when	8 June 05	16-23 June	1-7 July	24-25 Oct
	where	2 trays		small pots	Mpaka 1
	qty	10 g	>400 plants	410	340
	remarks	soaked in boiling-hot water, 2 min.	fast, vigorous		
05/6 Azadirachta indica	when	12 June 05	end of June?	16 & 20 July	12 Oct
	where	seedbed 1		large pots	Front lane
	qty	60 seeds	32	28	18
	remarks		uneven, weak		
04/3 Senna siamea	when	9/7/05	20/7 – 15/8	7 – 28 Aug	5 – 15 Oct
	where	3 mesh trays		plantbeds 1-3	Dodo fallow
	qty	20 g	approx. 800	700	680
	remarks	soaked in boiling-hot water, 2 min.	high and fast		

Labels

Labels are extremely useful. They link what goes on in the store and in the nursery with your record book. A record book may be big, but labels should be small and require a minimum of writing. The identification number is handy in this respect. If you store the seed in an airtight bottle, you need only to put a label with its lot number in that bottle. You can find the particulars of that batch of seed in your record book. Likewise, you can label the seed tray or the plantbed with the same lot number, adding the date of sowing, or pricking out.

A label may be a sticker fixed on the outside of the container, or – better still – a scrap of paper put inside the bottle or plastic bag containing the seed. In trays, beds or pots soft or hard plastic labels can be used, or you can make your own wooden labels. Use a waterproof laundry marker pen to write on labels made of plastic or wood.

7 Care for plants in the nursery

7.1 Day-to-day husbandry

Watering

The beds must be watered regularly. Always check soil moisture before watering. Lift potted plants in different parts of the bed to check how moist the soil is.

When watering seedbeds or containers that have just been sown, use a watering can with a fine rose, so that the seeds and the covering soil are not washed away. Until the seedlings emerge you should water sparingly and often. Alternatively, the seedbeds may be mulched during this period to save water and to keep the topsoil moist. Remove the mulch as soon as the first seedlings emerge. If this is done late, your first – and probably most vigorous – seedlings are spoilt, as they form long, thin, whitish stems trying to grow through the mulch towards the light.

Moisten the soil but do not soak it: lack of air impedes the germination process and encourages seed rot. As the plants get bigger they can be watered less frequently, giving more water each time to match the increasing depth of rooting. Larger seedlings can be watered quickly using a garden hose, but watering slowly with a rose can is better because it gives the water more time to penetrate the (pot) soil.

Shade

When seeds have been sown, seedlings have been pricked out or cuttings or wildings have been planted, shading is necessary to prevent drying out and scorching of the leaves (see Section 6.1 on shade constructions). Shade mats can be rolled back once the seedlings become established, gradually reducing shading intensity. Shade trees may be pruned to reduce shading when the plants in the nursery are hardened off before field planting.

Weeding

Beds and pots must be weeded regularly, before the seedling roots get tangled up with the roots of the weeds. Reduce weed problems by keeping paths and hedges free from weeds.

Fertilizer application

In the nursery liquid fertilizer is ideal. One part of animal dung in five parts of water is left for 10 days. Before spreading the liquid it should be diluted by adding more water until the colour is that of light tea. Seedbeds require no fertilizer, but plantbeds and pots should receive liquid manure once in two weeks to twice every week. If you water by hand it is easy to apply the liquid frequently, but if you depend on the rains or on watering with a hose pipe, larger dressings at longer intervals are more practical.

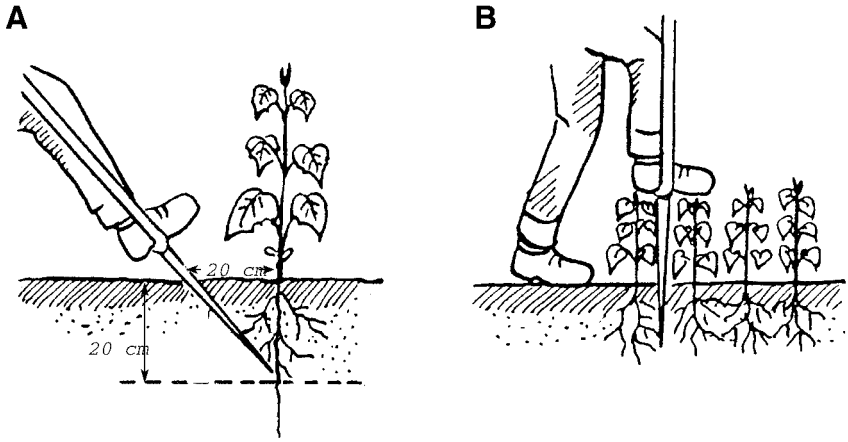
Factory-made fertilizer is usually not necessary. However, if you cannot find a lime-free soil for your nursery, sulphate of ammonia or urea may be applied to raise the acidity near the roots, for most trees grow best in a slightly acid soil.

Root pruning

Root pruning prevents the plant from developing a long taproot. It encourages the growth of side roots and prevents intertwined root systems of neighbouring plants. A well-developed root system improves the chance of survival after planting out. As explained in Chapter 5 pricking out is an early form of taproot pruning; air-root pruning by germination seeds in open-bottom trays is the ideal method to obtain a well-branched root system right from the start. Following air-root pruning there may be little need for further root pruning in later stages: slicing a machete or spade through the soil between neighbouring plants should suffice. In case of direct sowing in the plantbeds and also for seedlings that have been pricked out, further root pruning – as illustrated in Figure 26 – is usually needed.

First the taproot is pruned: push a spade down at an angle under the plants. Aim at cutting the taproot at a depth of 15 - 20 cm. Taproots of

some tree species grow extremely fast and if the seedlings have not been pricked out they may need to be pruned within one month of germination. Potted plants can be moved to break the taproot when it has started to penetrate into the soil under the pots. Alternatively, a wire can be pulled under a bed of potted plants to cut the taproots.



A: Pruning the taproot
B: Pruning side roots

Figure 26: Root pruning (From: ILO, 1989)

In many woody plants, one or two side roots resume the dominant downward growth of the taproot. Here, taproot pruning has to be repeated and it is done on both sides of each row of plants. This time long side roots are also cut, leading to further branching of the roots; the length of side roots should be limited to 20 cm or less (Figure 26). To separate the root systems of adjacent plants in a row they may be cut with a spade or machete. This is commonly done a few weeks before transplanting, allowing time for the growth of new roots in response to pruning.

Cuttings require little or no root pruning. They have no taproot; normally several adventitious roots emerge, ensuring a well-branched root system.

7.2 Special techniques

Damping off control

Damping off is a common and serious disease in seedbeds. Several moulds in the soil may infect germinating seeds and emerging seedlings. The stems rot at ground level and the little plant topples or shrivels up. Often you can see a slimy mass at the base of the stem. Sowing in clean soil, such as fresh river sand, is the best way to prevent damping off.

High humidity, heavy wet soil, too much shade, crowding of the plants in the seedbed, and a high organic matter content of the soil can all encourage fungus growth, wiping out virtually all the seedlings in a seedbed or seed tray. The risk of damping off is reduced if the soil is well drained and aerated and the air above it well ventilated (e.g. by timely removal of mulching material or thinning out plants) and by ensuring that conditions do not become too damp.

Inoculation

If you are planning to propagate conifers (e.g. pine trees), you should spread some soil from stands of established conifers over the beds. This soil contains micro-organisms which cooperate with the conifer roots, improving the uptake of nutrients by the tree. Legumes also grow better if you use soil in which older legumes of the same type are already growing. (This form of living together of 2 organisms to the benefit of both is called symbiosis. Legumes living in symbiosis with bacteria can be recognized by nodules on their roots, which contain the bacteria.)

7.3 Preparation for field planting

Hardening-off

Before planting out watering and shading of the planting material should gradually be reduced. This is known as hardening-off and is done to accustom the plants to conditions in the field. Five to six weeks before field planting watering should be cut down and eventu-

ally stopped. Reduction of the shade can start much earlier depending on the tree species. Water the plants copiously once more on the day before planting out.

Lifting the plants

Bare-rooted plants are usually dug up by carefully lifting the plants with a fork. The plants are shaken gently to remove excess soil from the roots and packed in sacks, polythene bags with holes, banana leaves, or crates for transport to the planting site.

The standard of nursery work can be judged by:
1 the health and uniformity of the plants in a bed
2 the sturdiness of the plants

To improve uniformity, diseased or unthrifty plants and plants that are not true to type (i.e. plants which look different) should be removed. For potted plants the uniformity can be further improved by grading them: separating the sturdy plants from the slender ones. Plants in beds can be graded when they are lifted for planting out.

Root:shoot ratio

Although everybody knows that the quality of the root system is the main factor for successful transplanting, root growth too often gets little attention. As stated in Section 4.3 planting material should have a large root mass in relation to the size of the shoot; the root:shoot ratio should be high. For planting material the root:shoot ratio is probably the best measure of sturdiness.

Pricking out, air-root pruning in open-bottom germination trays and root pruning in the plant beds have already been presented as methods to enhance branching of the root system. The immediate effect of root pruning is of course a lower root:shoot ratio, but the response – enhanced branching of the root system at the expense of shoot growth – increases the root:shoot ratio in due course.

Nursery stock with a well-branched fibrous root system suffers comparatively little damage when lifted from the nursery; such bare-rooted plants and potted plants can be planted out intact.

If the plants have not been nursed to encourage root growth they will have a low root:shoot ratio at the end of their stay in the nursery. And there is inevitably some damage to the roots, further lowering the proportion of roots, when they are lifted for transplanting. At this stage the only possibility to raise the root:shoot ratio is to prune the shoot, wasting part of the growth made in the nursery.

Balancing root and shoot mass by curtailing the shoot is fairly common for bare-rooted forestry species. If the plants have grown too large, either through bad planning or an unforeseen delay in the planting season, the shoot can be cut back. This is not uncommon for fast growers, such as *Eucalyptus* species. The shoots are usually cut back to 30 cm (twice pot height).

Two more drastic methods to curtail the shoot result in 'striplings' and 'stumps' (see Figure 27).

Striplings are seedlings of broad-leaved trees from which most of the leaves have been stripped, leaving only some leaves at the shoot tip; side shoots – if present – are cut out too. If the main shoot is cut back the seedling is likely to form several side shoots in response. To avoid this very severe pruning is the rule, leaving only a stump a few cm long. The roots can then safely be trimmed too (to 20 cm, to facilitate planting), still leaving a very high root:shoot ratio. Trees with a strong taproot, such as *Azadirachta indica*, teak and breadfruit are often planted as *stumps*.

Striplings and stumps can be more easily transported than intact seedlings and have better chances for survival under difficult growing conditions. Stumps may be used to stabilise unstable slopes, where unpruned seedlings would find it difficult to survive in the loose soil.

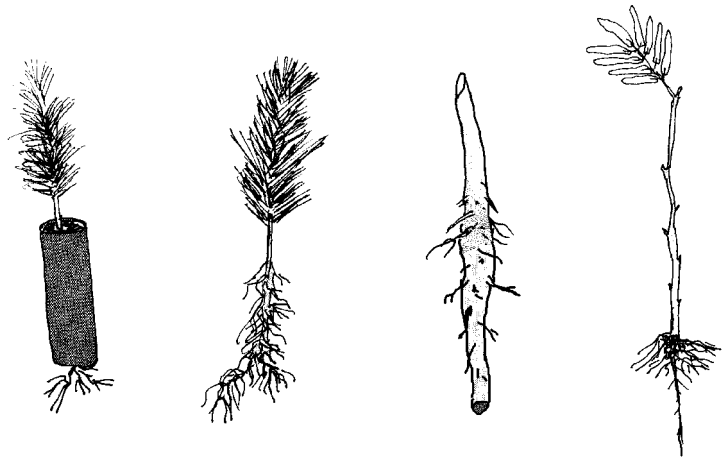


Figure 27: Four types of planting material, from left to right: pot plant, intact bare-rooted plant, stump and stripling.

8 Work at the planting site

The best period for both sowing and planting is after the first regular rains. This period is often the busiest time on the farm, therefore it is very important to be well prepared. If you have your labour and time schedule well worked out then digging up, transport and planting out can all be done in quick succession. You also need to think of activities such as fencing against livestock. This costs time and needs to be in place before planting out.

8.1 Site preparation

Where trees are to be planted the land should be weeded and the soil loosened to improve the uptake of water. If the weeds are tall they may be slashed, after which the land should be hoed or ploughed and clean-weeded. To plant a windbreak, a contour hedge or even a forest plot, only strips of land need to be cultivated. In some other cases, such as planting avenue trees, clearing and loosening a circle of about 1 m diameter suffices.

Planting distance

Tree spacing depends on species and environmental conditions. Hedge plants are spaced 0.3 - 0.5 m apart, sometimes in a double row. A barbed wire fence can be supported by heavy stakes, e.g. of *Erythrina, Commiphora, Jatropha*, or *Euphorbia* species, planted at distances of 1 to 4 m. Planting distances in plantations range from 1 × 1 m (e.g. improved fallow of *Sesbania sesban*) to 10 × 10 m (e.g. large fruit trees).

Trees in agroforestry parklands are usually planted far apart to minimise competition with crops or pasture. Where trees must be properly aligned, as when planting an orchard or an avenue of trees, this can be done by placing sticks marking the exact spots where the trees are to be planted. The sticks can be aligned by sight.

8.2 Transport and storage of planting material

Often a lot of planting material is lost because things go wrong during transportation and storage. To prevent this, pay due attention to the following points:

- Keep the period of time between digging up in the nursery and planting out as short as possible.
- Keep the plants moist and cool by covering them, especially if transported by lorry.
- Make sure that the roots of bare-rooted plants are kept covered throughout; they dry out quickly.
- Handle the planting material gently during loading, transport and unloading.

> If you move potted plants or plants with a root ball always hold them by the pot or the root ball, and not by the stem.

Transport seedlings in trays or boxes where possible, and keep pots upright. Planting material must be given water and kept in the shade the moment it arrives at the planting site.

A common cause of death among young trees is delay in planting after they have been dug up. In order to avoid these losses you can dig them in temporarily in the following way (see Figure 28):

Dig a trench (A: a=east, b=west). Lay the plants next to each other on the side of the trench, where they are the least exposed to the sun (B). Cover them with moist soil (C). Place a new layer of plants against the first layer and so on (D).

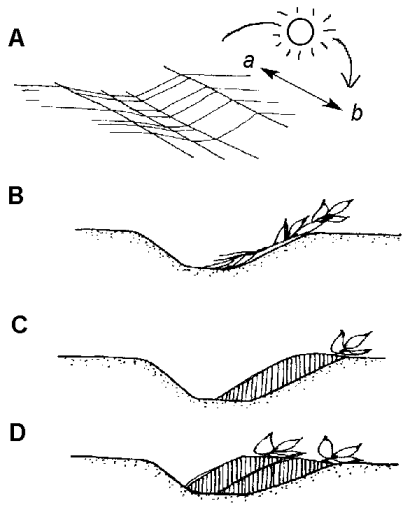


Figure 28: Temporary storage of bare-rooted planting material

8.3 Planting out

Making planting holes

Textbooks generally recommend digging large planting holes (e.g. 40 × 40 × 40 cm) well in advance of the planting season, keeping topsoil and subsoil separate, so that when the tree is planted the topsoil can be spread over the roots first. This may be all right if you have nothing else to do, but as a rule labour is scarce and the time can be better spent on raising stronger plants, or on mulching or watering the young trees.

The planting hole should be big enough to accommodate the root system or the contents of the pot. Place the plants carefully in the correct position in the planting hole. The root collar, that is the point where the root changes over into the stem, must end up level with the ground, after the soil in the hole has settled. Planting bare-rooted material at the right depth requires experience. Plants in polypots can be removed by carefully cutting the plastic without damaging the root ball (Figure 29).

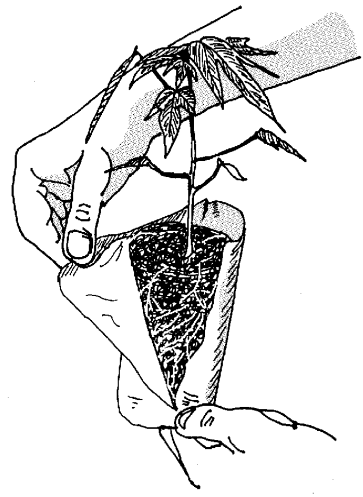


Figure 29: Removing the polypot before planting.

The top of the root ball must be at the same level as the ground. The earth around the plant needs treading down with the heel to get rid of pockets of air. Watering the trees is also an excellent way to settle the soil around the roots. Conditions for planting are best when the earth is fairly moist, the sky is cloudy and the air humid. If the soil is dry even a well-watered pot will quickly dry up, losing its moisture to the surrounding soil. The best time to plant is in the evening. Under such favourable conditions a mere slit in the ground, made with a spade, will suffice to plant bare-rooted plants.

Place the roots against one side of the slit at the correct depth (not difficult in this case) and press your foot down against the other side to complete the planting.

In places where rainfall is unreliable, a low ridge can be set up around the tree to capture water from rainfall or irrigation. Mulching around the trees is very worthwhile to conserve moisture and suppress weed growth. Use the dried weeds cleared from the site for this purpose or similar material from elsewhere. On stony ground you may even use stones as mulch.

Fertilizing the seedlings

You can provide the young tree with extra nutrients by mixing compost, manure or fertilizer in the topsoil before or during planting. Fertilizers are salts. If too much is applied or the water content of the soil is low, the moisture in the soil becomes saline and the roots cannot take up water. Therefore fertilizer should be used in small quantities and only in moist soil. Manure and compost have the advantage that they release nutrients slowly over a longer period of time and that they help to retain soil moisture.

8.4 Aftercare

Once planting or natural regeneration has taken place the work is certainly not finished. Care of the young trees in the field will improve establishment and growth. Maximum vigour during the first year(s) ensures a robust frame with well-spaced branches, a great asset for the tree during all its lifetime.

Protection

Fire

Fire is often a serious threat. Weeding and removing dead branches and dry leaves decreases the risk of fire. This, however, affects the layer of litter, and ultimately soil fertility declines. Firebreaks (strips of cleared land which stop a fire) can be constructed between or around tree stands.

Wind

Young plants can be protected against the wind by a hedge or a windbreak, e.g. made with palm leaves. Using stakes to support young trees also helps. If the tree is moving to and fro in the wind, young roots that should in due course anchor the tree, are ruptured; this may greatly delay establishment of the plantation. Place the stake on the windward side, so that the tree is not rubbing against the stake when the wind blows. Cross the tie between tree and post, making a figure 8 (∞).

Shade

Whereas auxiliary tree species are generally fairly hardy, tree crops tend to be more delicate. Many fruit and plantation crops benefit from shade during the first year(s) after field planting. If the trees are staked a palm frond can be tied to the stake to shade the tree.

Animals

Animals browsing leaves or bark cause much damage. Small wild animals, such as mice, rats and rabbits can be caught in traps. Other solutions include digging ditches, placing wire fences or planting small hedges of strong smelling herbs (e.g. rue). You can also surround individual trees with thorny branches. Young trees can be protected from birds by fine netting. Domestic animals, such as sheep, goats and cattle, not only browse trees, they also trample small trees down. The best solution, however, is to keep livestock away, if necessary by employing a guard.

Pests and diseases

Healthy plants are often able to outgrow pests and diseases. Using hardy species, healthy planting material and good maintenance techniques reduces the risk of damage. Planting strong-smelling plants around the young trees can ward off pests. A mulch containing insect repellent material such as neem (*Azadirachta indica*) or *Eucalyptus* leaves can sometimes prevent problems.

Maintenance practices

Watering

One of the greatest problems is early onset of the dry season. If you have only a small number of trees to care for you can water them for some time after planting. Clear the weeds around the trees before watering. A small basin around each tree or a trench running along a row of trees will help the water to flow towards the tree.

Water should be given in the late afternoon. The quantity needed will of course depend on the weather and the amount of rainfall. It is better to give a large amount of water just a couple of times a month than to give a small amount often.

Weeding

Keep a circle with a diameter of 50 cm to 1 m around the tree free of weeds; this prevents competition for water, light and nutrients. Climbing or winding weeds can quickly strangle young trees. Apart from weeding, weed growth can also be suppressed by mulching using organic material or stones around the tree.

Nutrition

For nutrition use domestic animal dung, compost, liquid manure or fertilizer. For liquid manure see Section 7.1. Spread the fertilizer in a circle around the tree and work it in superficially, taking care not to damage the roots. When you use fertilizer add only a small amount per tree (one handful at the most). Mulching with organic material around the tree will also provide extra nutrients (see also Agrodok 2: Soil Fertility).

Filling in

Replace young trees that die. This is known as filling in or gapping up. Retain some trees in the nursery for this purpose in seedling beds or large pots. These trees should be about the same size as the trees in the field and will require extra care when planting out.

Appendix 1: Measurements and calculations

1. Test percentage and rate of germination

If you buy seed from a reliable source it should be supplied with information about the seed, including the germination percentage. This germination percentage has been measured in a laboratory under controlled conditions. Unfortunately, this is not a good indication of the percentage that will germinate under the conditions in your nursery. A lab test of 92% means that more than 90 seeds out of 100 are viable. Of course it is reassuring that the seed you bought is viable, but still: in your seedbed or seed tray only 70 or 40 out of 100 seeds in this seed lot may germinate. Moreover, if you store seed, the viability will decline in the course of months or years, depending on the tree species and storage conditions. Therefore, if you want to know how much seed should be sown to raise 750 trees, you should test the germination in your own nursery.

Sow a sample of seeds in a tray to test the germination. For a species with small seed the sample may consist of 400 seeds, if the seed is large 50 seeds should do. (Large seed – such as palm seed – generally germinates well, because it contains much reserve food to sustain germination.) Treat the seed as you do usually (e.g. pre-germination treatment, depth of sowing, watering, mulching, etc.). When germination is complete simply count the number of seedlings and calculate the germination percentage. Run the test in good time to obtain the result before the start of the sowing season.

If you are a keen nurseryman you will realise that with a little effort you can get a lot more information out of these germination tests by recording the start and the progress of germination, as in the following example from a nursery in Costa Rica.

Table 6: Daily emergence of Pinus caribaea seedlings) in a sample of 400 seeds.*

Day	Qty*	Day	Qty	Day	Qty
0-7	0	12	16	19	4
8	20	13	14	20	4
9	24	14	12	21	2
10	34	15	10	22	2
11	26	16	12	23	0
		17	10	24	0
		18	6	25	2
				26	2
	___		__		__
Total:	104		80		16
*) Number of emerging seedlings, counted at the end of the day and pulled out to avoid confusion.					

Out of 400 seeds 200 seedlings emerged, so the germination percentage is 50. However, the daily counts of emerged seedlings also give valuable information about the germination rate. Germination started 8 days after sowing and was more or less complete 19 days later. Note that more than half of the seedlings emerged within 4 days of the start of germination. The next 7 days contributed 40% and the last 8 days only 8% of the number of seedlings. Such a drop in the rate of germination is quite common; you have to consider whether or not you will wait for the last seedling to emerge.

Pinus caribaea seedlings are pricked out 2 or 3 days after emergence. Thus – based on the figures in the table – 10 to 15 days from sowing the daily labour requirements will be about twice as high as during the next week; thereafter there will only be few seedlings needing to be pricked out.

Therefore, in a germination test it is very worthwhile to include counts of emerging seedlings at regular intervals (daily to weekly depending on the species). Whereas the germination percentage is the basis to determine how much seed needs to be sown, the germination rate is a great help to plan work in the nursery.

2. How much seed is needed to raise a given number of plants?

With the exception of large seed (particularly seed of recalcitrant species) seed is generally sold and handled by weight. To answer the above question you should therefore know how many seeds there are in a gram or kilogram. With scales and a set of weights you can measure how many seeds make up 1g (or, say, 10 or 100 g in the case of larger seeds). Repeat the measurement with another seed sample and take the average. If the difference between the samples is more than 10% repeat the procedure until the figures correspond better.

The number of grams to be sown must be increased on the basis of your estimate of:

- the germination percentage
- the percentage of seedlings that does not grow well
- the need to fill gaps occurring shortly after field planting.

The germination percentage can be estimated from the above test. In a well-managed nursery losses during nursing should be below 10%. They include mainly plants that are not "true to type", plants affected by a pest or disease, and plants that are growing too slowly to be ready in time. Slow-growing plants may still be suitable for filling in gaps that occur shortly after field planting. The need for filling in should be well below 10% of the plants if you, the nurseryman, make sure that sturdy planting material is ready at the right time!

The above safety margins of course cannot cover the risk of calamities, such as hailstorms, locust plagues, etc.

The simplest way to estimate the quantity of seed to be sown is to start with the number of trees to be planted and first estimate the number of seedlings needed,

- allowing for seedlings which do not grow into good plants and
- allowing for spare trees to fill in gaps following field planting.

The second step is to estimate the number of seeds needed to obtain the seedlings, based on the germination percentage. The third step is to convert the number of seeds into seed weight.

Example:

1 Number of trees to be planted: 100.
  Number of seedlings to be raised: 10 - 20% more;
  say 20%, that is 120 seedlings.
2 Result germination test: 58%.
  Assumed germination: 50%.
  Number of seeds to be sown: 100/50 × 120 = 240.
3 Number of seeds in 10 g: 80.
  Quantity of seed to be sown: 240/80 × 10 = 30 g.

3. Bed area and quantity of potting soil required for pots

The following table gives some quantitative aspects of the use of polythene pots of different sizes. The number of pots per kg plastic is given for 0.04 mm thick polythene.

The important point in the table is the sharp increase in bedding area and volume of potting soil required when pots with a larger diameter are used. Doubling pot diameter leads to a fourfold increase in area and volume. Compare, for instance, the requirements for 18 cm high pots with a diameter of 4.1 or 8.0 cm. It may not be difficult to find more potting soil and extra space; the main consideration is that so much more labour and effort is required to fill the larger pots and to move them, not only in the nursery but also to the planting site.

For cylindrical pots the volume is proportional to pot height. So, 30 cm high pots in Table 2 require just 50% more potting soil than 20 cm high pots of the same diameter. Even so, a 50% increase in load to be carried is sufficiently important to choose the appropriate pot size with great care, as emphasized in Section 5.2.

Table 7: Some common polythene pot sizes, and the bed area and volume of potting soil required.

Pot size (cm)			**Pots per kg (0.04 mm gauge}**	**Bed area for 1000 pots (m2)**	**Potting soil for 1000 pots (litre)**
Height	Width flat	Diameter filled			
18	6.5	4.1	1160	1.6	240
18	10.0	6.5	750	4.2	600
18	12.5	8.0	600	6.4	900
20	12.5	8.0	540	6.4	1000
30	12.5	8.0	360	6.4	1500

Appendix 2: List of tree species in this Agrodok

Explanatory notes

The information in the following list has been gleaned from several published sources. Sometimes the information is incomplete, resulting in blank spaces in the list; in a few instances the information from various sources is contradictory. A longer list can be found in Agrodok 16: Agroforestry.

Botanical name:

The species are listed alphabetically by their botanical name. The botanical name of a species may change because of new insights in its relations with similar species. If the name has changed in recent years and the species is still better known by its former name, that name is given between brackets. An asterisk (*) behind the botanical name indicates that the species is able to convert inert nitrogen from the air into a form that can be taken up by the plant. All these N-fixing plants are legumes, except *Alnus nepalensis* and *Casuarina equisetifolia*.

Common names:

Some species have no common English (E), French (F) or Spanish (S) name that is widely used; in that case the botanical name has to be used.

Common names are not unique; they may differ in different parts of the world. That is why for some species several common names in one language are given.

Origin:

The continent where the species is thought to have its origin is given, mainly because it may indicate that the chance that seed or planting material can be obtained is best in that continent. However, many species have found their way across the tropical world and are readily available outside the continent of origin.

Habit:
The general appearance of the plant is briefly described. The habit of species that occur over a wide range of ecological conditions may differ substantially at the extremes of the range.

Propagation:
Propagation methods that have found practical application are given. In case of several propagation methods the most common method is mentioned first; if one of the methods is recommended, this method is underlined.
Stakes are very large cuttings, such as used in the case of live posts.

Ecology:
Information about the growing conditions that the plant requires is often fragmentary; also it is given in very different terms in the sources. Moreover, within many species several types are distinguished which differ in their ecological requirements, e.g. one type being much better adapted to dry conditions than the other type.
In as far as it is available, information starts with the range of altitudes at which the plant is found within the tropics. The symbol < indicates "lower than", > indicates "higher than"; a plus sign (+) behind a figure means that the plant is generally found up to the altitude given, but in some instances in even higher locations.
Rainfall requirements are given in similar terms; however, if plants have access to ground water, e.g. along riverbanks or in depressions, they may thrive with less rainwater than indicated.
Information about soil requirements is available for only very few species.

Uses:
Both use of products yielded by the plant – e.g. fruit, fodder, fibre – and environmental uses of the tree – e.g. green manure, shade, shelter – have been listed. It has been attempted to give the principal use first, but this main use may differ in various regions, e.g. in relatively wet areas the plant may be mainly used for fodder, in dry areas for its fruit

and fuelwood. The limited space does not permit listing uses extensively; in a few cases the most important uses are followed by "etc."

Remarks:
In this column information is presented that does not fit into other categories, is of interest to the grower, and can be given in a few words.

	Botanical name	Common names	Origin	Habit
1	Acacia nilotica*	Egyptian thorn (E); acacia d'Arabie, gommier rouge, gonakié (F)	Africa	small thorny tree
2	Acacia senegal*	gum arabic tree (E); gommier blanc (F)	Africa	small thorny tree or shrub
3	Acacia tortilis*	umbrella thorn (E); faux gommier (F)	Africa	tree
4	Albizia procera*	white siris, tall albizia (E)	Asia	tall tree
5	Alnus nepalensis*	Indian alder, Nepalese alder (E)	Asia	deciduous tree
6	Azadirachta indica	neem (E,F)	Asia	tree
7	Borassus aethiopum	borassus palm, elephant palm, fan palm (E); rôtnier (F)	Africa	robust palm
8	Calliandra calothyrsus*	(red) calliandra (E)	America	shrub or small tree
9	Castanopsis indica	?	Asia	fairly large tree
10	Casuarina equisetifolia*	coast she-oak, ironwood, casuarina (E); filao (F)	Austr. Malesia	large tree
11	Commiphora africana	African bdellium (E); bdellium d'Afrique (F)	Africa	shrub or small tree stake
12	Cordia alliodora	cordia, salmwood, Spanish elm (E); bois soumis, chêne caparo (F)	America	large tree
13	Dactyladenia barteri	monkey fruit (E)	Africa	scandent small tree
14	Dovyalis caffra	kei apple (E)	Africa	small tree
15	Erythrina poeppigiana*	coral tree, mountain immortelle (E); bois immortelle (F); poró gigante (S)	America	tree
16	Eucalyptus camaldulensis	river red gum, Murray red gum (E)	Austr.	tree

	Propagation	Ecology	Uses	Remarks
1	seed	0 - 1300 m; river banks; 400 - 2300 mm rain	tannin (bark, pod), gum, fodder, wood (fuel, constr.)	reclaims alkaline soil
2	seed	dry savanna (< 700 mm rain) on sandy soils	gum (bark), fodder, cordage, wood, medicine	only stressed trees yield gum
3	seed	drought-tolerant; common in the Sahel	forage, sand-binder, shade tree, wood, fibre, medicine, etc.	deep-rooted
4	seed, stake cuttings	0 - 1500 m; 500 - 3000 mm rain	fuelwood, timber , windbreak, shade, land rehabilitation	
5	seed, tissue culture	moist, cool mountain monsoon climate	fuel wood, shade, posts, live support, erosion control	used to reclaim land
6	seed, layers, grafting	0 - 1500 m; 400 - 1400 mm rain	insecticide, oil, timber, fuel	protects and improves very poor soils
7	seed	savanna palm of tropical Africa	fruit, sprouting seed, palm sap, cordage, logs, etc.	fan-shaped leaves, to 4 m long
8	seed, cuttings	0 - 850 + m; >1000 mm, 2 - 6 dry months	fuelwood, forage, land rehabilitation, lac insect host	popular auxiliary shrub
9	seed, coppicing	(500-)1000 - 1500 m; < 2 - 4 dry months	timber, fuel, fodder	
10	seed, cuttings	coast - 1200m; semi-arid to subhumid	reclaim land, shelterbelts, fuel, charcoal	very fast early growth
11	Cuttings	dry areas, such as Sahel savanna woodland	live fence/hedge, fodder, resin/gum, food (root)	
12	seed, cuttings	0 - 1000 (2000) m; 750 - 2000 mm rain	timber, shade	pioneer plant; good regeneration
13	seed, stake cuttings	0 - 300 m; > 1200 mm rain	fallow crop, forage, poles	thrives on poor soils; popular in Nigeria
14	seed	highland monsoon climate	fruit, hedge	
15	seed, cuttings	500 - 1500+ m; >1200 mm rain	shade tree, live stake, forage, ornamental	
16	seed, cuttings	very adaptable; copes with 0 - 8 dry months	wood, timber, charcoal, shade honey	most common tree in dry tropical lands

	Botanical name	Common names	Origin	Habit
17	Euphorbia balsamifera	balsam spurge (E); euphorbe de Cayor, euphorbe candélabre (F)	Africa	erect shrub
18	Faidherbia albida* (Acacia albida)	African winterthorn (E)	Africa	deciduous tree
19	Gliricidia sepium*	gliricidia, mother of cocoa (E)	America	small tree
20	Jatropha curcas	physic nut, pig nut, fig nut (E)	America	tall shrub
21	Lantana camara	lantana, wild sage, curse of Barbados (E)	America	low shrub
22	Leucaena leucocephala*	leucaena (E), leucaene, faux mimosa (F)	America	small tree
23	Moringa oleifera	horseradish tree, drumstick tree (E); ben ailé (F)	Asia	small tree
24	Paraserianthes falcataria* (Albizia falcataria)	paraserianthes (E)	Asia	tree
25	Pinus caribaea	Caribean pine, pitch pine, Nicaragua pine (E)	America	large tree
26	Prosopis juliflora*	mesquite (E); bayahonde (F); algarrobo (S)	America	shrub/tree
27	Schima wallichii	needle wood, schima (E)	Asia	evergreen tree
28	Senna siamea* (Cassia siamea)	Siamese senna, kassod tree, Thailand shower (E)	Asia	spreading tree
29	Sesbania sesban*	Egyptian sesban (E)	Africa Asia	short-lived small tree

	Propagation	Ecology	Uses	Remarks
17	cuttings	southern edge of Sahara; deep sandy soil	(boundary) hedge, fodder (camels, goats), medicine	best hedge in dry (<900 mm rain) areas
18	seed	0 - 2500 m; dry climates	parkland tree, fodder, honey, fuelwood, timber, medicine	leafless in wet season; access to ground water
19	seed, cuttings	0 - 1500 m; > 900 mm rain; tolerates fire	multi-purpose auxiliary crop	2nd only to Leucaena
20	cuttings, seed	drought-tolerant	hedge, live support, oil, medicine	
21	cuttings, seed	0 - 1500 m; does not need much moisture	hedge, ornamental	may become noxious weed
22	seed	0 - 1000+ m; 650 - 1500+ mm	multi-purpose auxiliary crop, parts used as vegetable	most important agroforestry species
23	cuttings, seed	0 - 1300 m; wet to fairly dry climates	vegetable, condiment (bark), live support, medicine	excellent home garden plant
24	seed, tissue culture	0 - 2300 m; wet climate: < 2 - 4 dry months	land reclamation, shade, fuel, woodwork, forage, ornamental	fast growing pioneer species
25	seed	cool upland with marked dry season	light construction timber, paper, fibreboard; oleoresin	light-loving pioneer tree
26	seed, root cuttings	forage (pods), honey;0 - 1500 m; tolerates drought (50+ mm rain) and saline soil	land reclamation, hedges, food	colonizes dry, saline and alkaline lands
27	seed	lowland - 2400+ m; both wet and monsoon climates	timber, fuel wood, fodder	easy to grow
28	seed, tissue culture	0 - 1300 m; > 700 mm rain, 4 - 8 dry months	shade, windbreak, tanning, food/fodder, sandal wood host	much used in agroforestry systems
29	seed, cuttings	up to 2300 m; 500 - 2000 mm rain	fodder/food, green manure, live stake, shade, windbreak	other Sesbania spp. are used similarly

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Glossary

Agroforestry	Mutually beneficial combinations of woody plants and crops or livestock on the farm..
Broadcasting	Sowing by scattering seed freely over an area.
Clone	A group of plants originating from a single plant by vegetative propagation and therefore all having the same genetic make-up.
Coating	A layer of mud with additives used to cover a seed or root system for protection.
Coppicing	Cutting the tree trunk back close to the ground.
Damping off	Fungus diseases of seedlings that have just emerged, causing rot of the stem base, so that the plant topples and wilts.
Dormancy, of seed:	The inability to germinate, even under favourable growing conditions.
Drilling board	Board with pegs used to make holes in the soil according to a regular pattern, to ensure that seeds are sown evenly.
Etiolation	Keeping part of the stem in darkness, e.g. by hilling up, so that it turns a light colour; usually to improve the capacity to form roots.
Fallow	Period of one to many years during which a field is not cropped, to allow soil fertility to be restored.
Firebreak	Area of land at least 5 m wide with no trees, kept bare or planted with greenery so that fire cannot spread across the strip.
Genetic make-up	Information contained in every cell of a plant which determines its characteristics.
Germination percentage	Number of seeds which germinate out of a sample of 100 seeds.
Green manure	Manure made solely from plant material.

Hardening off	Measures taken to prepare plants raised in a nursery for planting out in the field.
Hardwood cuttings	Cuttings from woody stems: twigs or branches.
Layering	Method to stimulate growth of roots on shoots or twigs in order to propagate the layered plant true to type.
Litter	Layer of decomposing plant material (leaves, branches etc.) covering the ground, especially under trees.
Mother tree	Tree from which seeds or vegetative parts are collected to be propagated.
Mulch	A layer of loose material on the soil to reduce moisture loss, moderate soil temperature and inhibit weed growth.
Multi-purpose trees	Trees yielding one or more products and offering environmental benefits as well.
Nitrogen	Major plant nutrient, which in the soil is easily converted or leached, leading to rapid changes in availability.
Pollarding	Cutting the tree back drastically, leaving only the trunk and short sections of the major branches.
Polypot	Polythene bag used as a pot to raise young plants.
Prick out	Transplant seedlings from seed trays or seedbeds into nursery beds or pots.
Propagule	A part of a plant that can give rise to a new plant (e.g. seed, cutting).
Recalcitrant seed	Seed that has to be sown fresh because it loses its viability rapidly; e.g. that of many large-seeded tropical fruits.
Root collar	The point where stem and taproot of the seedling are joined.
Scarify	Stir the surface of the soil (e.g. with a wire rake), but without turning the soil over.

Seed bank	Large seed storage locations where the origin and quality of seeds is known.
Seed tree	Mother tree used to obtain good quality seeds.
Softwood cutting	Leafy cutting taken from a stem close to the tip of an actively growing shoot, the stem not yet being woody.
Stratification	Low-temperature treatment to break seed dormancy that prevents germination.
Stripling	Seedling of broad-leaved tree all leaves of which have been stripped off, except the leaves at the top.
Stump	What remains of a tree (or stem of a young plant) after it has been cut close to the ground.
Taproot	Main root of seedling, growing straight down.
Terrace	One of a series of level strips of land made by converting a gradual slope into a stepwise descent.
Water harvesting	Catching and storage of rainwater.
Wilding	Young tree growing spontaneously.