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Nursery manual - a guide to healthy seedlings

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Nursery Manual -

A Guide to Healthy Seedlings

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1. Introduction

The chance of survival and good growth of seedlings in the field is influenced by their health and vigour, when they are planted. Healthy, well-proportioned and good growing seedlings have higher chance of survival than weak and stressed seedlings.

We normally raise plants of forest trees in the nursery, because we have experienced that they usually have a better chance of survival when we plant them out, than if we sow a seed directly in the field. The better survival has 4 main causes: 1. In the field seeds often fail to complete germination because of adverse environment (drought, flooding) or attack by pathogens; 2. Destruction by seed predators can be extremely high in the field; 3. Newly germinated seeds and small seedlings are often suppressed by other vegetation, e.g. herbal weed, against which they may have poor competition. 4; In the nursery we can control the germination and growth environment, so seedlings have optimal chances to survive the critical stages and predation problems are usually small compared to in the field. The head start in the nursery will provide seedlings with a head start in the field.

However, a nursery is also an artificial environment, where: 1. Species specific pest and diseases may spread more quickly than in the field; 2. Roots are often enclosed in a limited space in a polypot or tube, which prevents root expansion, may restrict root respiration and hence make seedlings sensitive to over or under watering. A seedling in a nursery is completely dependent on the caretaking.

The better we care for the seedlings in the nursery, the better they grow, and the less time do we need to keep them before they are ready to plant out. When we have raised a plant in the nursery, it should be healthy and strong, so it can compete with other plants once it is planted out. Attention to details can make the difference between failure and success. This is what this guide is about.

2. Propagating plants from seeds and cuttings

There are two main methods for propagation *viz.* propagation from seeds and propagation from rooted cuttings. There are also some other ways e.g. micro propagation (tissue culture), but that is not part of this manual. Propagation by seed is called sexual propagation because seeds are usually a result of an ovule (female) in a flower being fertilised by pollen (male) of usually a different flower. In that way is produced an offspring (seed) that is a mixture of a male and a female and each seed is genetically different. Plants produced from seed have genetic variation, but if they have the same mother and father, they are siblings. Seeds collected from one tree are always siblings on the mother's side, but if they are pollinated by different trees, they are only half siblings. Whether they are full siblings or only half siblings depends on how many other trees are within pollination distance. However, in practice many seeds from a single mother tree will be full siblings. The more trees seeds are collected from and the more pollination trees (fathers) are involved, the smaller is the chance that seeds share the same genes. For environmental plantings we usually prefer large variation, because then adaptability to different environments can then be high.

Rooting of cuttings is called asexual or vegetative propagation because it is independent from flowering. When a shoot produces roots it is genetically an exact copy of the mother plant. Rooted cuttings from the same plant are thus genetically exactly the same. Such groups are called clones, - there is no genetic variation within a clone. Hence, variation in rooted cuttings can only be present, if cuttings are taken from different mother trees.

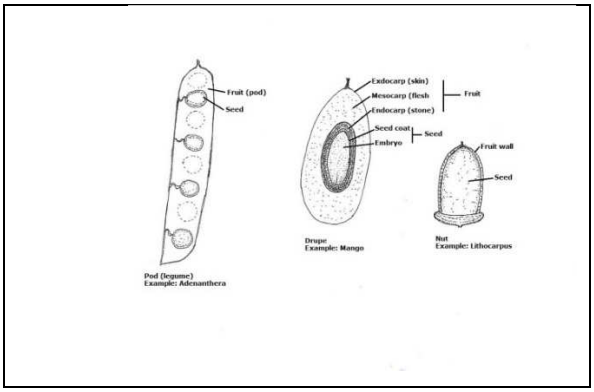
3. Propagation from seeds

Propagation from seeds presupposes germination. Seeds are temporary 'sleeping' (dormant) offspring. Seeds are designed to be dispersed into new growing sites. Therefore they are usually 'small' (sometimes tiny, each a fraction of a gram, sometimes larger up to a few hundred grams, - only exceptionally cases exists where individual seeds weigh more than 300 grams). In botany fruits are the structures that contain the seed and used to be part of the mother (flower). Seeds are the embryos of new plants that have developed from fertilisation. Fleshy soft parts are usually parts of the fruits, e.g. mangoes. However, sometimes they are outgrowth of the seed. Sometimes seeds and (part of) fruits are inseparable e.g. nuts (like *Lithocarpus*). In practice, we call the part we sow a seed and the part we remove the fruit (figure 1).

<u>Seed dormancy</u>

Seeds often have a mechanism that prevents them from germinating until they have been dispersed. Firstly they must become fully mature. Secondly they must be activated ('woken up'). Seeds that do not have dormancy ('deep sleep') can be activated just by providing them with good germination conditions such as optimal temperature, moisture and a suitable substrate. Seeds that are dormant need a special treatment before they can germinate. For example, seeds contained in fleshy soft fruits (for example mango) need to be extracted from the soft cover and sometimes washed carefully to remove inhibitors contained in the fruits that inhibit germination. Sometimes seeds need to undergo a prolonged after-maturation period before they can germinate. Another group of seed have very hard seed or fruit coat that must be scarified (penetrated) in order for the seed to be able to absorb water and initiate germination. Dormancy can sometimes be an advantage because it prevents seed from germinating during an un-wanted period. Some examples of seed dormancy are listed in table 1.

Figure 1. Fruit and seed. The seed is a minute plant-to-be (embryo) within a seed coat. Sometimes there is nutrient tissue (endosperm) around the embryo, but often this is absorbed by the embryo. The fruit encloses the seed, sometimes fleshy like in most animal dispersed fruits, or dry like in most wind dispersed fruits. The biological role of the fruits is to help dispersing the seed into new environments via wind or animals. We usually collect the fruits and extract the seed, which we sow in the nursery. For legumes it is easy to separate the fruit (here the pods) from the seed. In drupes the hard stone is part of the fruit, but we only remove the fleshy outer part. In nuts we sow the whole fruit.



Dormancy type	Fruit types	Pre-treatment	Species examples
Chemical inhibitors	Fleshy fruits e.g. berries, drupes, compound fleshy fruits, seeds with arils	Storing seeds in containers until the fruit flesh gets naturally soft, then thoroughly washing in water, e.g. using high pressure water	*Artocarpus, Durio, Horsfieldia, Knema, Mangifera*
Hard fruit and seed coat (physical dormancy).	Prevailing in legumes, also in e.g. *Lithocarpus* and *Canarium*	Fresh seed may be sown w/o pretreatment, dried seed need scarification e.g. dipping in hot water or manual scarification	*Archidendron, Koompassia, Adenanthera, Dialium, Intsia, Ormosia*
No dormancy	Most wind dispersed seeds and fruits	None. Occasional soaking in water speed up germination rate.	Dipterocarp species, *Macaranga*,

Table 1. The most common seed dormancy types and methods to break seed dormancy (pretreatment)

Seed viability

Seeds of many tropical rain forest species are intolerant to desiccation and have short viability. Such seeds must be sown immediately after collection as viability is sometimes lost in a matter of days. These are called recalcitrant seed. Another term is desiccation sensitive emphasizing their inability to maintain viability at low moisture content. Germination rate may be delayed or slowed down by moderate cooling e.g. in an air-conditioned room at about 20˚C. Another group of seed, the orthodox, are found mainly among pioneers like *Macaranga*, and most of the legumes (*Fabaceae*). These seeds can be dried and stored, preferably cool (5-10˚C, refrigerator temperature) and sown at a convenient time; viability for cool dry orthodox seed can usually be maintained for more than one year depending on storage conditions. Infection by insects or infestation by fungi may quickly cause loss of viability. Cool and dry conditions are the best prevention for orthodox seed. Moderate cooling and drying to the physiological tolerance limit may also slow down attack for recalcitrant seed. However, fast sowing and germination will bring seeds beyond the critical point of insect predation.

Germination conditions

These are rather similar for most seed of the humid tropics. Most seed will germinate if they have adequate moisture and germinate in a substrate conducive for germination, e.g. lose forest topsoil, sand or a mixture of the two. Seeds of some species, primarily small seeds of pioneers and seeds of *Ficus* species need light for germination. Such seed should be broadcast on top of the soil in a seedbed, watered and covered with plastic cover to maintain high humidity during germination. Large seed should preferably be sown fully or

half covered by soil to maximize soil contact and hence water absorption. Sometimes large seeds are sown directly in the poly-tubes. This is preferred if germination percentage is high since any re-planting from seed bed to poly-tubes will inevitably impose some stress. However, if germination rate is low, it is preferable to sow the seeds in seed beds. Seeds prone to predation by e.g. rodents or birds are normally also easier to protect in seedbeds.

4. Propagating plants from rooting of cuttings

Where seed procurement and/or propagation is very difficult or where rooting of cuttings is exceedingly easy, vegetative propagation is used as an alternative. As a rule of thumb species that coppice prolifically are often rather easy to root. Some species will root from cut-off branches or stem sections when these are placed in moist soil, other species can be rather difficult. Most species will benefit from pre-treatment with rooting hormones. Sections of shoots are dipped in rooting powder or soaked in a rooting solution after which they are placed in the rooting medium in a high humidity rooting 'tunnel'. High humidity must be maintained since cuttings cannot absorb water until roots have been formed.

Sometimes there is seasonal variation in ability to form roots. Best root setting is normally at the beginning of the active growth period. Leaves will usually need to be removed to avoid too high water loss through transpiration while the plants produce roots.

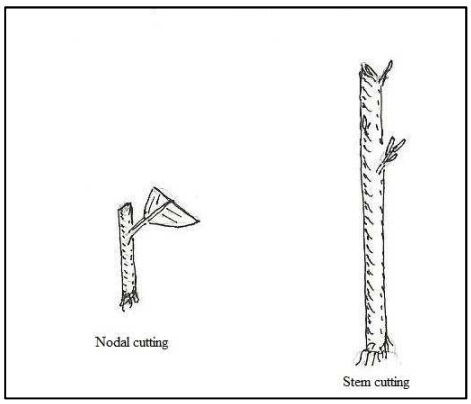


Figure 2. Different types of cuttings. Nodal cuttings are small sections of seedlings that. are rooted in high humid conditions (e.g. mist tents). Hardwood cuttings are long sections of stems or coppice shoots, sometimes up to 2 meters long (stake cuttings), that are rooted in soil under field conditions

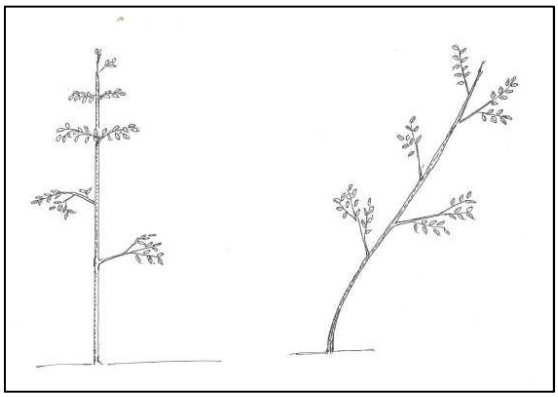


Figure 3. Orthotropic (left) and plagiotropic (right) growth habit of rooted cuttings. Some species tend to easily revert to upright growth while others tend to remain their original differentiation through their life.

The innate growth habit of species can sometimes cause obstacles. Differentiation into upright (stem-like, - orthotropic) growth and horizontal (branch-like, - plagiotropic) tend to occur very early in some species with the practical result that it is difficult to produce upright trees from cuttings of these species. A number of methods have been developed to produce shoots with orthotropic growth habit. Reference is made to specialised literature.

5. What does a plant need?

A plant must have light, optimal temperature, adequate water, nutrients and air in order to grow well.

Leaves need light, because that's from where plants get the energy for growth. Some species need a lot, some species need less. Some species suffer from too strong light exposure while others are very tolerant. In Indonesia low temperature is rarely a limiting factor, unless we are in the highlands. Critical high temperatures can be reached, if plants are exposed to direct sunlight without shade. In this instance it may be difficult to distinguish between high temperature and light damage. If plants have adequate water, the evaporation will help keeping cooling down leaves.

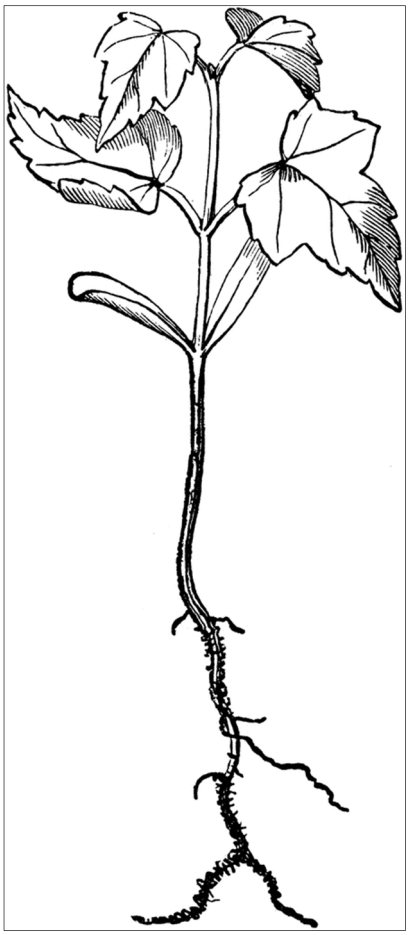


Figure 4. Schematic seedling.

Water is needed for all processes taking place in the plant. Water is part of growth (photosynthesis); water is used for transport within the plant and to keep the plant cells turgid. Eventually water is important for cooling down leaves. With insufficient water plants cannot absorb nutrients by their roots. Water is primarily absorbed by the roots. Therefore the water balance around the root is important.
Nutrients are necessary for plant growth. There are many types of nutrients. Nitrogen is necessary for making proteins, phosphorus is necessary for energy processes, and potassium is necessary for plant cell transport. Each nutrient has its roles and one nutrient cannot compensate for the lack of others. They must all be there in the right quantity. Nutrients are absorbed by the plant roots. Sometimes nutrients are there but not accessible to the plant, for example if the soil is acid.

All parts of a plant respire. If a plant or part of a plant cannot respire it will suffocate and die. Leaves and stem are in the air. They rarely have respiration problems. Roots are in the ground. If there is no air around the roots they cannot respire and therefore they will die. Roots cannot respire if there are too much water, or if the soil is very compact.

6. Above ground environment, light and humidity

Leaves and stem of seedlings are above the ground. The environment here includes humidity and light. Species that normally grow in shade in nature must also be raised under shade in the nursery. However, most seedlings, even those of light demanding pioneers like *Macaranga* and *Acacia* are grown under some shade. Shade reduces evaporation and protects the plants from desiccation. However, too much shade prevents photosynthesis and plant growth. Hence, shade effect must be adjusted to the demand and tolerances of individual species or species groups. Shade may be established by roofing material such as grass mats or synthetic nets. The density of roofing material can be adjusted to seedling requirement and tolerance.

Humidity refers to moisture content of the air around the seedlings. Humidity is created by water supply, evaporation from the soil and the plants' own respiration. High humidity prevents desiccation, for example if the root absorption capacity is small. However, too high humidity may also cause problems because fungi and bacteria thrive under high humidity. Such organisms may spread if humidity is very high.

7. Below ground environment, the root zone

In potted seedlings root development is restricted and water and air cannot exchange freely. Therefore the pot environment is the most important concern when raising seedlings in the nursery. What can you do to create a good root environment for potted seedlings? Firstly, you can make a good potting mix that balances the properties of different elements of the soil. The soil should have a good structure:

1. Not too hard and not too soft, - both extremes restrict root development
2. Be able to hold water so seedlings do not dry out easily, yet allow sufficient drainage to allow air for respiration

In addition, the soil must have sufficient nutrients to feed the seedling during growth. Compost is nutritious and has a good structure. It may also be possible to add fertiliser later. Potting mix usually consists of topsoil, humus, sand and compost:

Soil that is very coarse grained (small stones, gravel and sand) has a good drainage, but it doesn't hold water well and contains no accessible nutrients. A potting mixture consisting entirely of such material is not good, because the soil will dry out easily and plants will suffer from lack of nutrients.

Soil with very small grains (e.g. clay or silt) can be rich in nutrients and can hold a lot of water, but water replaces air space, and when clay dries out it gets very hard, so plant roots cannot grow. If soil tends to be very fine-grained, it is advisable to mix it with some coarse grained or organic material.

Organic material (sawdust, rice husk, peat) can hold a lot of water. Drainage is usually not good, but if the soil is allowed to dry out regularly, air will enter. However, it can be difficult to regulate the water. Some organic matters like cow manure contain a lot of nutrients; others like sawdust contain virtually none. Some organic matter may contain unwanted compounds; sawdust contains for example tannin and lignin, which restricts root development. Manure can contain harmful organisms and too high nutrient content to be used directly as the only medium. Most deleterious compounds disappear during decomposition. Rice or coconut husk are often used as components of potting soil. A compost medium mixed from different kinds of organic matter is often a good root environment.

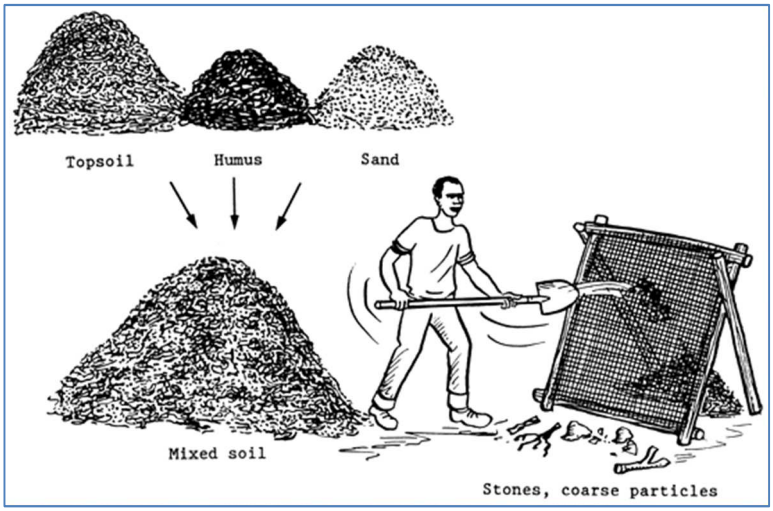


Figure 5. Mixture of different components of soil. The mixture is sieved to remove large material such as branches, stones and leaves

Forest top soils sometimes have good properties of all the required factors: drainage, porosity, water holding capacity and nutrients. Further they may contain important soil microbes that will make the plants grow better. Unfortunately forest soil may also contain something that is not wanted in the nursery for example pathogens or allelopathic (harmful) compounds. Most nurseries use a mixture of different components.

Material	Properties
Coarse grained material, e.g. river sand	Good water drainage, poor water holding capacity, low nutrients, good air space. Beach sand should be washed as it can contain high level of toxic salt
Fine grained material, e.g. forest top soil	Large water holding capacity, poor drainage, rich in nutrients, and microorganisms. Tends to get sticky when wet and hard when dry.
Compost, e.g. cow manure	Poor drainage, large water holding capacity. High nutrient content (low C:N ratio) and gradual nutrient release, see Box 2 on p. 17 for more information.
Structured organic matters, e.g. bark, rice husk, sawdust, coconut husk, peat.	Combines good drainage with good water holding capacity. Some wood material may contain growth inhibitors (tannin); partial decomposition may reduce damaging compounds

Table 2. Summary of some properties of different soil components.

Figure 6. Potting components. Left: compost, centre: rice husk and right: saw dust

8. Some nursery operations

Nursery operations include major tasks such as sowing seed, pot filling, re-planting of seedlings into pots and tending seedlings (watering, weeding).

Sowing seeds in seedbeds

Pre-sowing into seedbeds or trays is used for small seed or where germination is slow or over a prolonged period of time. The former is often connected to pioneer growth habit. Many of these seed also requires light for germination. Germination medium in seed beds or trays is sand or a mixture of sand and soil. The coarse grained material makes it easier to remove seedlings later for transplanting. Small seeds are often sown directly on top of the germination medium; sometimes they are covered with a thin layer of soil to improve soil contact. Larger seeds may be sown in rills or pushed into the soil to increase soil contact and hence allow absorption of water. Germinating seeds are always sensitive to desiccation until they have developed a root that can absorb water. To prevent desiccation it is customary to cover seed beds or trays with plastic foil that prevents to rapid evaporation of soil moisture. On the other hand, trays and seedbeds should have good drainage because the germination medium does not hold water well.

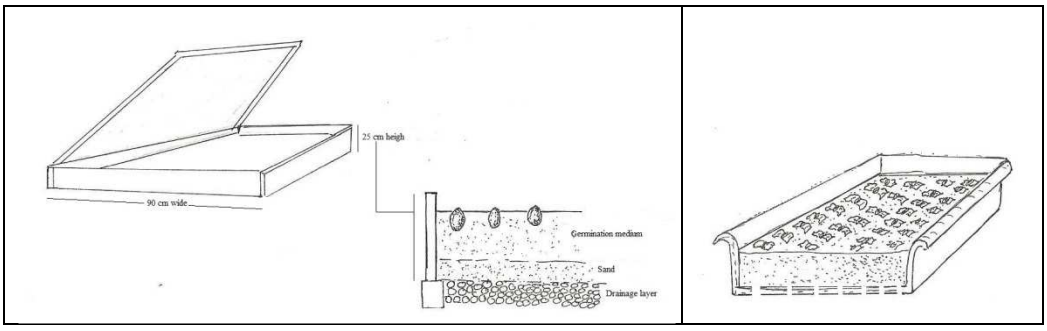


Figure 7. Germination trays and seed beds. Small seeds are sown on top of the germination medium (right), large seeds are inserted into the medium, fully or ¾ covered with soil (left)

Filling poly-tubes and pots

One of the most time-consuming operations in the nursery is filling tubes and pots, since each container must be handled individually. Some simple techniques ease the procedure: A simple funnel with outlet opening fitting the tube opening; a filling container with standard volume fitting the pot volume. Usually pots are filled prior to planting or sowing, but sowing can also be done as a part of the filling process. The soils should be sufficiently dry to flow freely (not sticky). The pots can be filled almost to the edge; the soil will sink later when water is added

Figure 8. Simple funnel for filling soil into poly-tubes. The funnel is made from a plastic cup or bottle where the bottom is cut off. A simple 'shovel' is made from a piece of PVC pipe.

Sowing seeds and planting seedlings into poly-pots

Large seeds are often sown directly into poly-pots without pre-sowing in seedbeds. Each seed is here inserted/bushed into the soil, usually just covering the seed with soil, - sometimes leaving about ¼ of the seed above soil level.

Planting seedlings into poly-pots are done when seedlings are transplanted from seedbeds, when seedlings are transplanted into larger pots, or if the root environment changes dramatically because of decomposition of organic matters. The main concern during planting is to assure that roots are well distributed in the pot, and that the planting depth is so that soil level of the pots is the level of the root collar i.e. the transition between root and stem. Small seedlings from seedbeds can be planted into prefilled pots in a small hole made by a planting stick. After insertion of the plant the soil is gently pushed down around the roots. Larger plants are difficult to transplant into prefilled pots without disturbing the roots. Easiest is to fill up pots only half, then insert the seedling and after-fill the pots with nursery soil, again gently pushing soil around the roots.

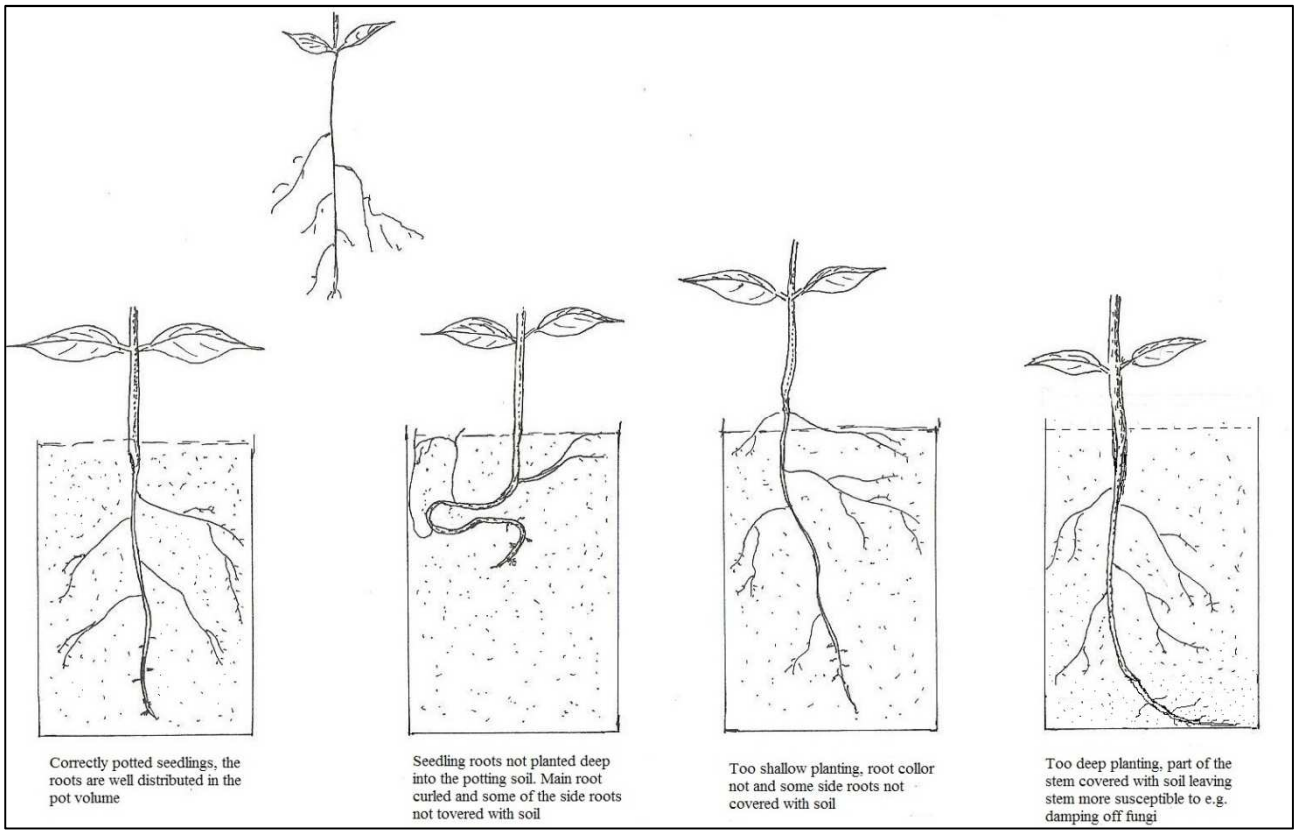


Figure 9. Correct planting of seedlings (a) and three examples of carelessly transplanting of seedlings. In b) the roots are inadequately covered with soil and the taproot is coiled, that gives poor soil contact. In c) the position of the plant is very shallow exposing the upper roots to desiccating air and without soil contact. In d) the plant is planted too deep and some of the stem is covered with soil. That increases the risk of fungal attack (damping off).

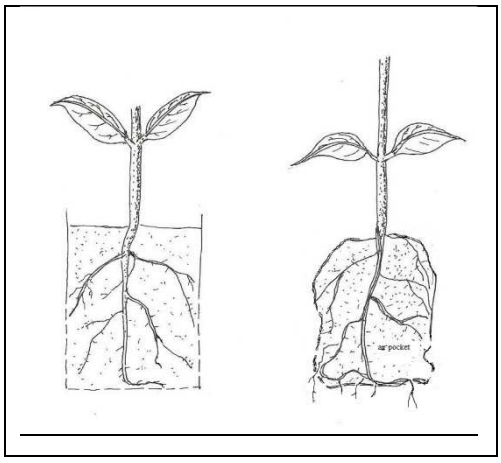


Figure 10. Problem of nursery soil decomposition. If seedlings are kept for a long time in the nursery and the nursery soil has a large component of decomposable organic matter (compost), the organic matter may disappear and leave a small pot soil volume of mineral soil. Since the soil volume decreases, edges of pots sometimes falls in, and make a barrier to water. To prevent rapid degradation of organic matter and consequent reduction of potting soil volume, slowly degrading organic matter such as husk or sawdust may be used. Otherwise seedlings need to be re-planted into a new potting mixture.

Weeding

Nursery soil usually contains weed seeds that will germinate and compete with woody seedlings for space and nutrients. Most weed species are herbs and grasses. Weed is easiest to remove, when it is small with

only short roots and can be pulled up without damaging the potted seedlings. Weeding of potted seedlings should be performed every 2-3 weeks. In addition, nursery workers should be instructed to remove large weeds whenever they handle or inspect seedlings.

Watering

As seedlings are completely dependent on the pot volume, too little or too much water is damaging. Watering should be adjusted to consumption. 1. Small plants use less water than large plants; watering small plants should accordingly be moderate. 2. Seedlings consume more water during hot dry periods than during cooler cloudy or rainy periods. 3. Shaded seedlings use less water than plants exposed to full sunlight. 4. Some species are more water-demanding than others; experience will show how much water is needed and tolerated by different species.

If watering is done manually by watering cans, individual sections can be watered according to their demand. If watering is done by spraying systems, it is advisable to arrange seedlings according to their water demand, e.g. small seedlings separated from large seedlings. In addition it is advisable to establish some closing vents on pipe sections so water supply can be regulated for individual sections.

9. The size of nursery plants

A standard size of nursery plants of forest trees is about 35-50 cm tall. That size has proven most suitable for most plantation species planted out on barren, weeded land, e.g. after clear-cutting. For a 35-50 cm tall seedling a small root volume is sufficient, e.g. a 8 cm diameter and 15 cm tall poly-pot (contains about ¾ litre of soil, see table 1). The size is convenient for transport and planting. However, 35-50 cm is not a universal rule. If plants are planted out among strongly competing weeds, larger size will help their competition and survival. At least a part of the top should be above the height of ground weed like grasses, ferns and herbs. Fruits trees for grafting must have a relatively large size to fit scions, and many farmers like larger size fruit trees because they want quick return in terms of fruits. Fruit trees are often kept until they are > 1-1½ meters tall.

Root – top ratio

The size of the roots must be balanced with the size of the top. Seedlings that have a very vigorous top and small root volume can have problems surviving in the field. Why? Because water that is lost from the leaves and stems must be replaced by water absorbed by and transported from the roots. In the nursery, plant roots have restricted growth, especially those grown in polybags. But in the nursery we can compensate evaporation by watering. In the field water must be absorbed from the soil. When planted out, the polybag is removed and roots start to colonize the soil around the planting hole. After some time there will be a balance between root development and top development. But it takes some time before roots have penetrated into the soil around them. Plants that have a large top and a small root tend to lose water from the top faster than the roots can replace it by absorption. The problem is aggravated if the planting site is temporarily dry.

The problem of top-root ratio also pertains to 'carry over' seedlings, i.e. seedlings that for various reasons are not planted in the current season. In practice the planting season finishes in March in Harapan, and planting may start in November. Hence, seedlings that fail being planted must be kept, maintained and preferably with minimum growth for about 7 months. There are basically two things that can be done:

1. Cut back (prune) the top. Tolerance to pruning varies. If there is no experience from the particular species, a rule of thumb say max ½ of the top should be pruned.
2. Re-plant the seedling into a larger poly-pot which allows the seedling to develop a more extensive root system.

Figure 11. Pruning of overgrown seedlings

Pot sizes: A 10 cm tall, 6 cm diameter poly-pot is a good 'standard' for standard size seedlings. Larger seedlings also need larger root support and thus larger poly-pots. The following guideline on poly-pot (root volume size) can be used.

Poly-pot size, diameter x height	**Soil / root volume diameter equivalent**	**Seedling size (height) recommendations**	**Remarks**
8 cm x 14 cm	700 cm^3(0.7 l)	30-40 cm	Most commonly used pot size for 'standard' seedlings
6 cm x 10 cm	275 cm^3 (0.28 l)	15-25 cm	Often used for small seedlings or for direct sowing in poly-pots
12 cm x 18 cm	2250 cm^3(2,25 l)	40-70 cm	Used for large seedlings to be planted out under strong weed competition or for fruit trees

Table 3. Poly pot size and volume and recommended seedling size

Overgrown seedlings

Seedlings in poly-tubes or poly-pots have restricted root development, limited by the barrier of the tubes. As the roots grow in restricted volume, they tend to curl and wherever there are openings they will try to grow out e.g. through drainage opening in poly-pots or open bottoms of poly-tubes. If they are allowed these roots will anchor themselves into the nursery soil, become the dominant roots. When removing them from the seedling bed, they must be cut or dug up which will inevitably stress the plants. Root development outside the pots or tubes should therefore be avoided. Regular moving of plants and pruning of roots restrict their development.

Figure 12: Seedling with very large top :root ratio

Species variation

Some species are light demanding; other species will die under the same conditions. Some species need regular drying out while others are highly water demanding. Rain-forest plants are often divided into pioneer plants and climax plants. Pioneer plants are typically those that colonise open areas; they have small seeds and long distance dispersal and are light demanding when young. Climax species are species that grow under a canopy of shading trees; they have large seeds, are shade tolerant and sometimes shade demanding. Some characteristics of their behaviour as pertain to nursery practices are listed below.

	Pioneer species	**Climax species**
Light	Light demanding in all stages	Shade tolerant and often shade demanding when young.
Growth rate	Fast and continuous growth if provided with adequate water and nutrients	Often fast initial growth followed by a period of restricted growth
Soil	Often adaptive to stressed soil condition	Often demanding nutrient rich soil
Species examples from Harapan	*Macaranga* spp*., Syzygium* spp,	*Artocarpus* spp., *Lithocarpus* spp., *Dipterocarpus* (*Shorea, Hopea, Anisoptera, Vatica, Dipterocarpus*), *Horsfieldia*.

Table 3. Some characteristics of pioneer and climax forest species.

10. Water demand for nursery seedlings

Watering of nursery seedlings should replace water lost through evaporation from and growth of the plants. Large plants consume more water than small plants, fast growing plants consume more water than slow growing or dormant[1] plants, and plants growing in the sun consumes more than plants grown in shade. Leaf volume can also influence the demand for watering because water is usually applied by spraying, and water typically only reaches the soil after the leaves have been wetted. Hence, large leaves tend to hold more water than small leaves. Over-watering is not necessarily fatal as long as excess water can be effectively drained off (figure 13, cf. also the section on potting mixture). However, if drainage is impeded, over-watering tends to kill the roots because of restricted respiration. Permanent wetting of soil with a large part of clay also tends to cause some changes of the soil. If plants suffer from excess water, poly-pots should be allowed to partly dry out, as this will re-establish the water-air balance in the soil.

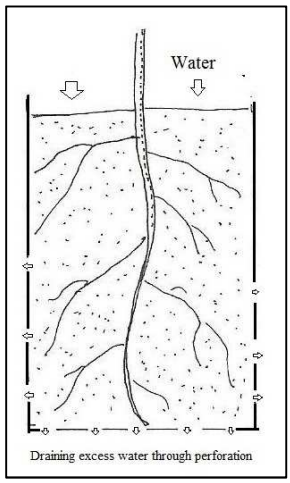


Figure 13. Drainage of poly-pots. Excess water should be able to drain through holes or perforations in the pots

Box 1: Plant containers

Poly-pot is an abbreviation of a pot/container made of polyethylene (type of plastic material) sheet, same material as usually used as 'plastic bags'. Some 'pots' are open at the bottom and are sometimes called poly-tubes or sleeves. Poly-tubes are sometimes available in un-cut roles, which allows for adjustment of the length (height) of the pot, i.e. to allow a larger vertical root development. This is sometimes practical for species that tend to form a very long striking root.

Some authors reserve the word 'container' to pots with firm / hard material. Plants raised in pots or containers are referred to as container plants. So-called bare-root plants are grown in seedling beds, where plants have more free root development, but are more prone to desiccation when transferred from nursery to the field planting.

11. Hardening off and preparing plants for out-planting

In the nursery we nurse plants to give them a good start. We provide them with water, nutrients and optimal shade that give them optimal growth conditions. In the field they will face the hazard of an often 'hostile'/stressed environment - sometimes exposed to high temperature, water stress and competition

[1] Some species tend to have a dormant period after the seedlings have grown to full size.

from other vegetation. Hardening off is a 'weaning' process in which plants are gradually exposed to a more stressed environment.

The need for and way of hardening depends on species and planting environment. A frequent practice is to harden plants by reducing shade and reducing watering. This practice has been adopted from plantation forestry where plants are normally raised under shade and planted into an open environment. However, where plants are to be planted under shaded conditions, a hardening process under open exposure may be more damaging than beneficial. Reduction of watering would be imposing an unnecessary stress to plants that are to be planted in very moist environments. Hence, only plants of pioneers or other species that are to be transferred to an open environment should be hardened under exposed (non-shaded) conditions.

12. Labelling seedlings and maintaining identity

For almost all purposes of planting, proper identity is crucial. Whenever research aspects are involved, proper identity and usually reference of seed origin are required. Labelling starts during collection in the field (seeds or plantlets); if it is not possible to identify the species properly, specimens should be collected to be identified by botanists later. A proper reference is then given to the seeds and specimen. In the nursery, labelling will follow seeds from seed bed to poly-tubes. It is practical to write species name and a reference number, so more detailed information (e.g. site of collection, date collected and sown etc.) can be found from the nursery protocol (ledger). One of each group of 100 seedlings is conveniently provided with a written, waterproof label. A larger label is posted on a stick with each seedling group.

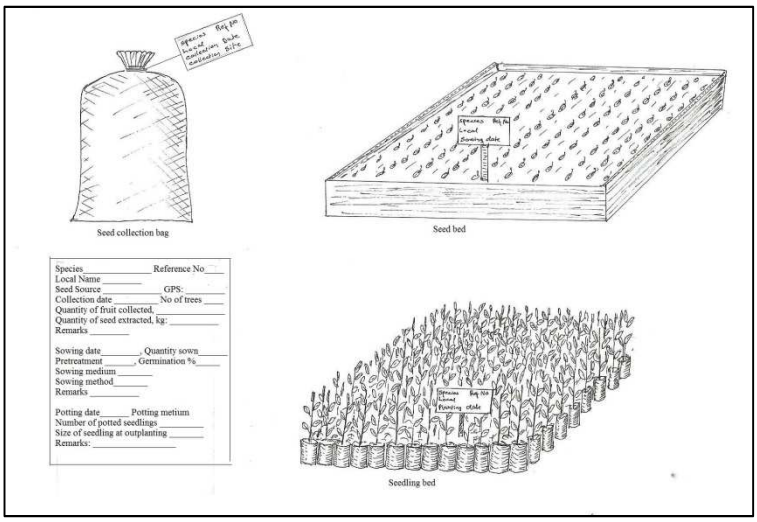


Figure 14. Labelling and documentation of seedlings from seed collection to planting. Each seed lot is given a reference number which is used on all labelling and documentation. A complete documentation of plants and seed are maintained in a seed and plant record ledger. Local and scientific names of individual species should be indicated on all labels. Sowing and planting dates are conveniently also written on labels whereas all other information, e.g. on seed or plant collection can be found in the ledger.

Box 2: Compost

Compost is partly decomposed plant material or animal debris, e,g, manure. Compost has lost the structure of its original material such as leaves or straws. That makes it easier to handle for example filling in planting pots and mixing with other material. Potentially damaging infectious bacteria or nematodes are also often eliminated during decomposition. Unwanted chemicals, such as lignin from woody material, tend to disappear or are greatly reduced during decomposition. Nutrients are released and become available to plants during decomposition and composting. Eventually, compost tends to have a very suitable structure for root development with a good balance between water holding capacity and drainage (and hence air space).

Any organic material can be made into compost. The quality compost varies with the material used for composting and the length of composting. Decomposition takes place when microbes consume organic material. Microbes can be bacteria or fungi. Decomposition requires that micro-organisms have sufficient moisture (but not wet!), sufficient 'free' food for bacteria (for example nitrogen containing manure), and air (to avoid fermentation).

Decomposition is also a product of time. In the tropics like Indonesia, decomposition is fast. About 6-8 months composting will be sufficient time to decompose most organic material, unless the material contains a lot of woody material such as sawdust. Decomposition is faster if the micro-organisms can attack the material from all sides. That means that small fractioned pieces will be decomposed quicker than large ones. For example, sawdust decomposes quicker than a tree trunk.

Composting can take place in a compost heap, which is a pile of organic material to be decomposed. It is most convenient to make composting in a 'compost cage', especially if material that can attract rats, wild boars or other unwanted visitors are included. Large material should be chopped into smaller units, either manually with a machete of with the use of a compost grinder. Material is then thoroughly mixed. If the material does not contain sufficient nitrogen, it is advisable to add manure, e.g. cow or chicken manure. Forest soil should be added to the material because it contains necessary microbes for decomposition. In practice the different kinds of material (leaves, sawdust, grass, manure, forest soil etc.) are piled in layers. The material is wetted and, if it is an open pile, a layer of soil is put on top. Decomposition will now proceed by itself. Once every two weeks the pile may be sprayed with a water hose to make sure there is adequate water for decomposition to take place. After 2½ months the pile is 'turned' i.e. material is dug out into another pile. This is done to assure adequate aeration. The process may be repeated after another 2½ month

The composting process is finished when the material has a porous soil-like structure without any rotten smell. This can easily be checked by taking out a sample. Now the material can be used as a potting material. Compost is rarely used as a sole material but rather together with mixture of sand and soil. Compost typically contains about 3.2% nitrogen and 6% phosphoric acid.

13. Some nursery structures

Seed bed

Small seeds are usually broadcasted into seed beds rather than sown individually in pots. Seedbeds are also convenient if seeds tend to take long time to germinate; it is easier to weed seed beds than pots and the problem of decomposition of potting mixture can be postponed. Seed beds are often constructed with a wooden frame (beware, wood of some species deteriorate very fast). The bottom of the seed bed is gravel or other well-draining material and the germination medium often consists of relatively loose material, e.g. sand which makes it easier to remove seedlings later for pricking out without damaging the root system. For humid forest species, seed beds are usually covered by polythene sheets that will keep temperature and humidity high inside the seed bed. Polythene sheets are conveniently placed on wooden frames and can be opened and removed, e.g. to prevent overheating and when seed beds need to be watered, weeded, germinated seed planted into poly-tubes, new seeds sown etc.

When seeds have germinated, seed beds may be covered by frames with wire mesh to prevent wild animals (rodents, birds, monkeys, wild boars) damaging seeds and seedlings.

Seedling beds, drainage, frames and elevated beds

Seedling beds should have good drainage to prevent waterlogging of pots. If seedlings are placed directly on the soil, the bottom should preferably have a layer of gravel or sand to assure good drainage. In addition, a drainage ditch on either side of the seedling bed should be in place to drain off water during heavy rain to. Seedlings must be kept in place by some frame construction. Iron-bar frames as wide as the seed bed (about 1 meter) and 1-2 meters long are suitable. Seed beds are usually about 1 meter wide since to allow for manual weeding. Alternatively, some nurseries use elevated seedling beds. These are constructed with a wooden frame, a wire mesh bottom and placed on poles. The elevated beds are usually better protected from destruction by for example rodents and wild pigs. In addition it allows for a more comfortable working position for nursery staff.

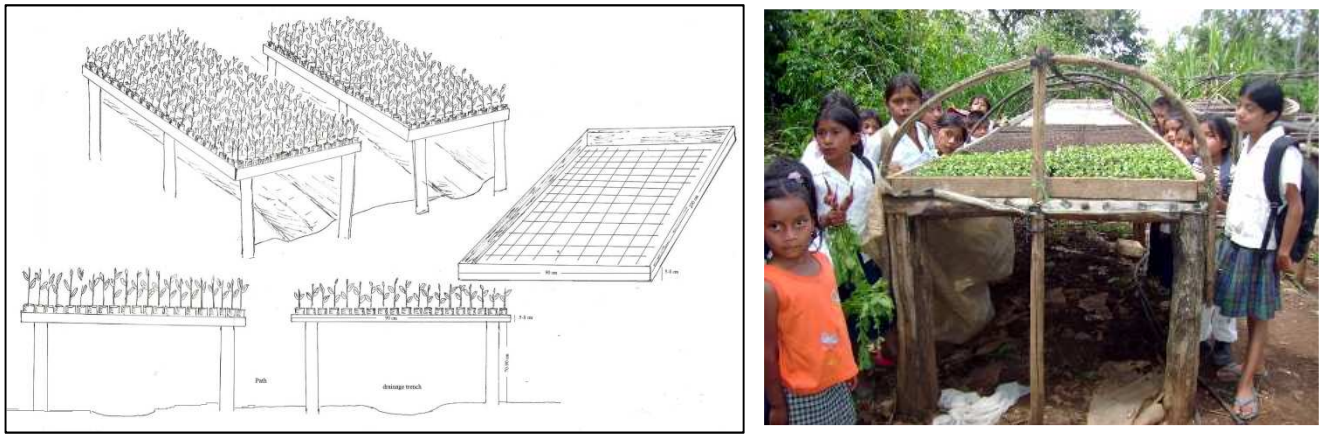


Figure 15. Elevated seedling beds consist of a wooden frame with wire mesh bottom, strong enough to carry the weight of seedlings and substrate. The seedling trays rest on poles. Drainage trenches are established under the seedling beds. The trenches allow drainage of excess rain or irrigation water. Since ground level of walking paths between seedling beds is higher than the trenches, the walking paths will not get muddy. Left is a schematic drawing of the construction. Right is a photo of the system in a community nursery in India.

Shade

The main function of shade constructions is to protect seedlings from direct sunlight. Especially in open nurseries without shading from trees, it is necessary to construct a shade cover. Shade constructions consist of roofing material carried by some ground structures. In wind prone areas, the structures must be rather strong. Shade can be provided by grass mats of shelter nets. Some light penetration must be allowed, and it should be possible to remove the shade material during hardening of the seedlings. Alternatively, seedlings may be moved out of the shade area during the hardening process. Commercial nursery shading nets are usually black and made of synthetic material with about 50% light penetration.

Natural shading trees can also provide good shade. In Harapan the exotic *Paraserianthes falcataria* is an exceptionally good shading tree because of its fast growth, spreading and relatively open crown, which provides a uniform and not very deep shade.

Figure 16. Shaded nursery area with shade material of synthetic nursery net. Inserted: Detail of material

Box 3: Protection of wood constructions in nurseries

- All wood is subject to rot and decay. The rate of decay varies with species. Soft wood like *Paraserianthes* keeps very short time, while *Eusideroxylon swageri* may last for a very long time. Wood is attacked by various decomposing organisms e.g. fungi, termites and insects. Humidity in nurseries is often high and whenever wood constructions are exposed to moist soil contact, the rate of decay accelerates. We often use wood constructions for seed beds, seedling trays, poles for fences and for supporting shade nets.

The rate of decomposition can be slowed down by applying antifungal and anti-insect pesticides, which are applied to wood by painting. In seed beds, the inside, which is exposed to moist soil, may be covered with plastic sheet to keep it dry.

Fresh wood has a certain temporary resistance to decay. Permanent structures such as fences and support to shade can be stabilised and made durable by placing them concrete blocks. Holes should be about three times the diameter of the poles and concrete should cover the entire length of the pole in the ground. Hence, a 4 inch (10cm) diameter pole should be placed in a concrete block with a diameter of about 30 cm. With about 50 cm in the ground, the concrete should be about 60 cm deep. This would require about $\pi \times 15^2 \times 60 - (\pi \times 5^2 \times 50) = 40 - 4 = 36$ litres of concrete.

Watering / irrigation system

A reliable watering system is crucial for plant production in nurseries. Water sources are typically permanent rivers and ponds, more rarely ground water. Electric or fuel based pumps extract the water from the source to a central pipe system through which sprinkle systems spray water over the plants. For a sprinkler system to work properly, the pump should have the capacity to provide adequate pressure. Different sections of the nursery are watered in turns by closing vents to some sections while watering others.

Water-backup systems should be available in case the irrigation system breaks down, which inevitably happens every now and then. Large water tanks of 2,5 m diameter and 3,5 meter tall holds $1.25^2 \times \pi \times 3.5$ = about 17 m^3 or about 17,000 litres. Water from water tanks must be brought to the seedling beds. A drum of about 70 cm diameter and 1 meter long, mounted on a wheel cart can be pulled around by hand. It holds about $3.5^2 \times \pi \times 10 = 385$ litre, enough to fill about 30 standard 12 litre watering cans.

Figure 17. A water tank is used as a backup system in case the ordinary water supply from the river is not working

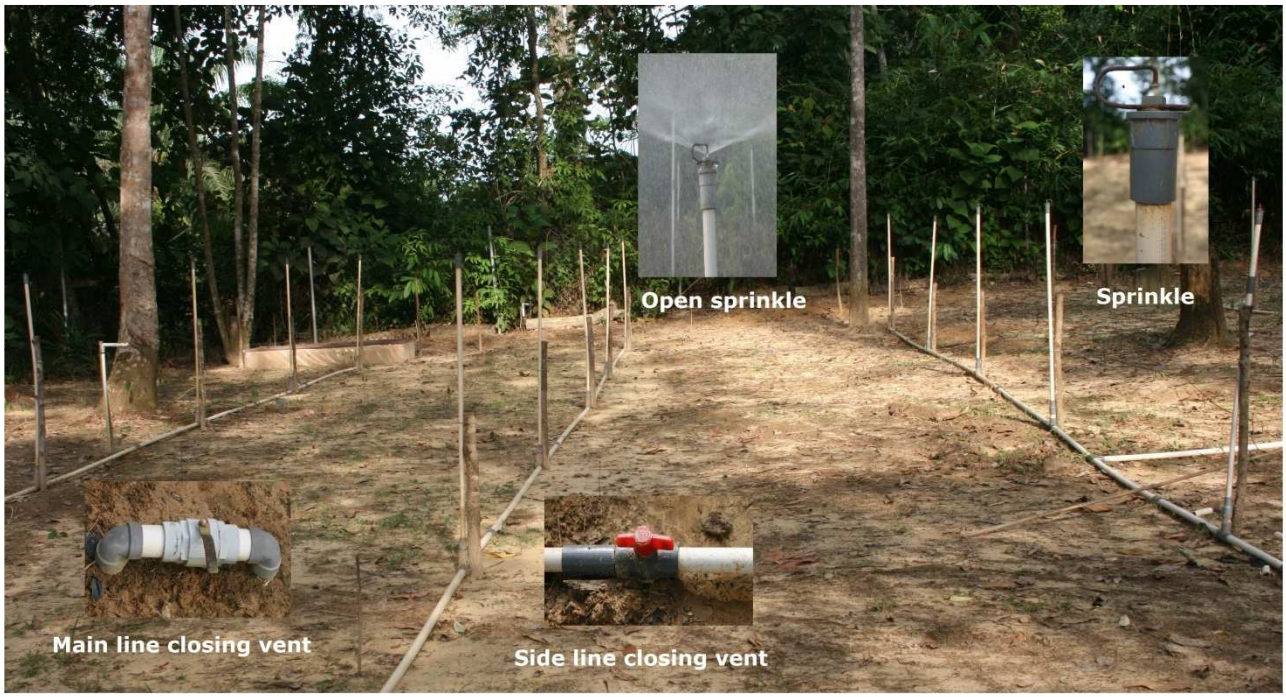


Figure 18. Network of PVC pipes connected to a sprinkler system for watering plants. Individual sections of the pipe network can be opened and closed in order to regulate water supply and maintain a sufficient pressure in the system.

Recommended readings

Forest Restoration Research Unit 2005. How to plant a forest: The principles and practice of restoring tropical forests. Biology Department, Science Faculty, Chiang Mai University, Thailand.

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