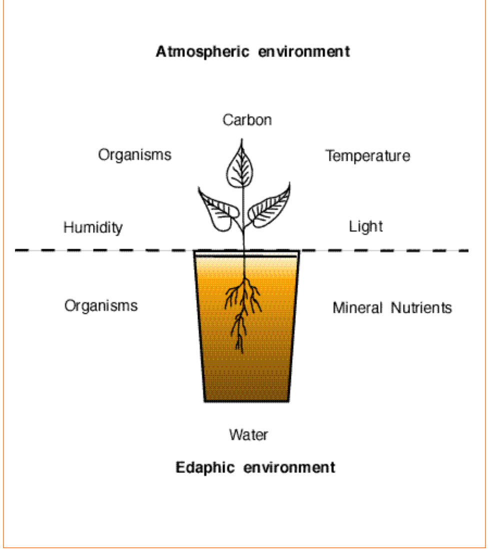
Section 6: Nursery environment and facilities

In this section, we discuss equipping an agroforestry tree nursery with enclosed structures, irrigation systems and shading. Not every nursery needs glasshouses or an automated irrigation system, but it is important that you know about their existence, their benefits to plant production, and their requirements in installation and maintenance.

Seedling growth is affected by conditions both above-ground — humidity, carbon dioxide, temperature and light — and below-ground — water and mineral nutrients. Other organisms, either beneficial or harmful, can influence plant growth. The below-ground factors have been discussed in the preceding sections. Depending on the needs of the project, more or less sophisticated equipment can be installed into the nursery in order to optimize the atmospheric factors. Almost anything is possible — but what is really necessary? Improving the nursery standards by providing a reliable water supply, uniform shading, and protected propagation and weaning areas can help greatly to produce uniform and healthy stock. Increased investment in nursery production is almost always recovered in increased plant survival and productivity. Controlling the atmospheric environment, on the other hand, may be necessary only in specific cases.



The whole nursery area needs to be well-drained. Avoid water-logging at all costs.

Nursery layout

Firstly, draw up a 'material flow chart': list all materials coming in (substrate, seed, containers etc.), where they will be stored, where they will be used, how they will be moved. List also what is going out of the nursery (seedlings) and from where. Incoming materials should be divided into toxic and non-toxic and into wet and dry. Keep the different types apart and keep toxic materials some distance from any plant growing area.

For seedling production, there are two distinct areas needed in a nursery: one in which close monitoring of temperature, light and humidity can be guaranteed for seed germination and for rooting cuttings; and one for hardening plants and preparing them for field planting. A germination area will be relatively small and can contain a number of enclosures, depending on the size of the operation and the species worked with: propagation boxes, polytunnels or glasshouses. The hardening area usually consists of areas under various degrees of shade, and an open area where plants are grown under full sunlight.

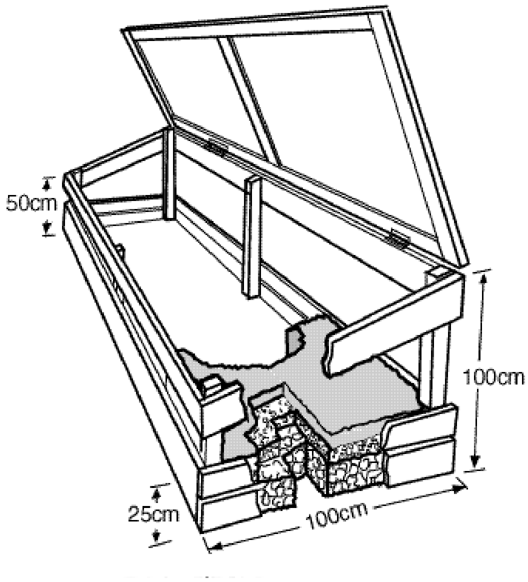
The whole nursery area needs to be well-drained. Avoid waterlogging at all costs. Put a 5-cm layer of medium gravel on the ground for good drainage and to control weed growth. Install benches to facilitate the operations. When using root trainers, frames need to be constructed at a convenient height for working, but at least 30 cm off the ground.

Enclosed structures

The need for enclosed structures varies greatly with the climate. In humid locations, structures may be needed only to provide shade or to keep pests out, whereas under arid conditions enclosures are needed to maintain a higher humidity for germinating seed, rooting cuttings and successful grafting. Although automated misting systems may be desirable for many projects, simple structures enclosed in polyethylene, such as a polypropagator or a polytunnel, are sufficient in most cases where small numbers of plants are produced. These low-cost techniques consider the restrictions of rural communities, which often do not have easy access to water, electricity and other materials. Their drawbacks are a large fluctuation in air humidity and a lack of air circulation which benefits pathogen development.

In Andra Pradesh, India, a modified polypropagator has been perfected. Holes 1.5 m x 1.5 m x 1 m deep are lined with polythene and filled with a 20 cm layer of gravel which acts as a reservoir. The gravel is covered with 10 cm of washed sand for rooting. A tube into the gravel is used to top up the reservoir as required. The whole propagator is covered by a polythene-covered hooped 'roof'. A small flap in the polythene permits misting by hand with a pressure backpack.

For small operations (less than 5000 plants a year) a few propagator boxes (polypropagators) are sufficient. These boxes can be made to varying specifications. A recommended size is 2 m long, 1 m wide and 0.5–1.5 m high, with a slanting lid. Note the layers of stones, gravel and rooting substrate. Whether or not the box is completely enclosed in polyethylene, i.e. including the bottom, depends on the conditions and the main use. For propagating cuttings, a complete enclosure is recommended to guarantee a very high air humidity; for seed germination or grafts, an open bottom with better drainage is acceptable. Boxes should be arranged with the long axis aligned east–west to allow for even illumination, and the lid sloping from south to north in the southern hemisphere (north to south in the northern hemisphere) to gather maximum light.



A polypropagator. Note the layers of stones, gravel and rooting substrate.

For larger operations or larger plants, walk-in structures like tunnels made from semi-circular steel rods can easily be put up, using locally available materials.

Both propagation boxes and walk-in tunnels are usually covered with polyethylene sheeting. Polyethylene transmits about 85% of the sun's light and allows through all

Sheeting with UV stabilizer can last up to 3–5 years under tropical conditions, whereas untreated material may need to be replaced after a few months.

wavelengths necessary for healthy plant growth. It is slightly permeable to CO_2 and oxygen, but it reduces the passage of water considerably. Polyethylene breaks down in sunlight, therefore the use of UV-stabilized material is recommended. Sheeting with UV stabilizer can last up to 3–5 years under tropical conditions, whereas untreated material may need to be replaced after a few months. This needs to be taken into account when calculating costs.

Although polyethylene is more permeable than glass to infra-red radiation, heat builds up inside a propagator or tunnel. Large temperature fluctuations between day and night are common. Use opaque polyethylene and/or shade the structure to avoid this problem.

Other materials for covering greenhouse structures are glass, which has excellent properties but is fragile, and various plastic materials. These materials are usually much more expensive than polyethylene film.

The high air humidity, high temperatures and generally stagnant air inside closed structures are extremely conducive to fungal growth. Extra care

Cover materials and their properties	
glass	good light transmittance, fragile, heavy
polyvinyl chloride (PVC)	strong, low light transmittance, degrades under UV
polyethylene	relatively cheap, comes in many sizes, degrades under UV unless stabilized
acrylic	excellent light transmittance, scratches easily, highly flammable
fibreglass-reinforced polyester	low cost, strong, yellows with age, highly flammable

is therefore needed to monitor for pests inside enclosed propagation structures. Provide sufficient ventilation, for example by opening the ends or by constructing the sides so that they can be rolled up.

Water

Water is the single most important factor in plant production. Seedlings contain over 95% water. The production calendar in tropical countries is determined by the rainy season, rather than by rising temperatures as it is in temperate regions. Proper irrigation and the maintenance of high humidity in the propagation environment are prime responsibilities of a nursery manager.

For controlled irrigation a reliable water source supplying piped water year-round is absolutely necessary.

Various irrigation systems have been developed locally. **Gravity-fed systems** are preferred by many small local nurseries in remote locations. However, for controlled irrigation a reliable water source supplying piped water year-round is absolutely necessary. Watering should be done with a hose pipe that has a nozzle with fine holes so that young seedlings do not get damaged. Regulating water output with a thumb on the hose pipe is not acceptable because the distribution of water is too variable. The addition of a 60 cm metal rod to the hose makes targeted watering of containers easier and saves water. If water pressure and water quality allow it, consider installing an **automated irrigation**

Mist propagation has major benefits in tropical climates: water is sprayed in very fine droplets in short intervals onto the plants, where it evaporates. A surface from which water evaporates is cooled because vaporization of liquid water to water vapour is energy consuming. This is also the principle behind mist propagation: the water vapour helps to cool the leaf surface so that stomata stay open even in a warmer environment and assimilation can proceed unhindered — allowing increased plant growth. It is important to note that the mist does not irrigate the plants but prevents excessive transpiration by the green shoots, thereby preventing desiccation.

The amount of water which air can hold depends on the temperature of the air. Once the air is saturated, water condenses, i.e. accumulates in drops. Cold air can hold less water before it condenses than warm air. This is why condensation occurs first on colder surfaces. The relative humidity inside a non-mist propagator can fluctuate between 100% during the night and below 50% at midday if the structure is kept closed and no additional moisture is provided during the day. This effect may be reduced by avoiding large temperature fluctuations, for example by providing bottom heat during the night and extra shading during the day. The condensing water inside the lid can reduce the light reaching the plants considerable and needs to be wiped off frequently.

Use good-quality shade cloth to provide durable and uniform shade to the seedlings.

system for even application of water. Especially in arid areas, **drip irrigation** is advisable to reduce evaporative losses. This system distributes water directly to the roots and therefore saves considerable amounts of water. Automated irrigation needs clean water so filters are necessary. High amounts of calcium or magnesium can clog the nozzles and make frequent washing, or the addition of low concentrations of acid (for example vinegar), necessary. The necessary information about irrigation systems should be obtained from qualified suppliers (See Annex 1 for examples).

Water quality is important for healthy plant development although often there is no way of changing it. Saline water should be avoided unless salinity-tolerant crops, such as *Casuarina* or *Prosopis*, are produced. Treating water with low concentrations of chlorine (1 ppm) helps control water moulds (see page 60).

Light

The right amount of light is critical for healthy plant development of seedlings. Too much shade, for example in high plant densities, leads to etiolated and elongated growth of the seedlings and makes them weak and prone to fungal diseases. Too much light leads to sun scorching and drying out of the tender tissue. Use good-quality shade cloth to provide durable and uniform shade to the seedlings. Avoid using grass, reed or bamboo mats as they are not

Effect of shade on air and leaf temperature

	Light intensity (μmol/m²/s)	Air temperature (°C)	Leaf temperature (°C)
unshaded	1370	36	40
50% shade	525	32	32

durable, do not provide uniform shade, and can harbour pests and diseases. Nursery managers must decide whether shade should be permanently installed and plants moved from one shade level to another, or whether the plants should remain in position and the shade be moved.

Shade cloth is usually woven from nylon (polypropylene) thread, but cheaper cloth made from saran (polyvinylchloride) is also available. Saran shrinks about 3% and needs to be installed with a slight sag. Shade cloth is available in various densities from 30 to 95% shade. It is usually black, but also comes in green or red; these colours change the wavelength of the transmitted light and thus influence plant development (see below). Aluminium-covered thread is used to make cloth that reflects the infra-red wavelength from the sunlight and keeps the shaded area cooler. Shade cloth made from nylon can last over 10 years under tropical conditions.

Use the higher densities of shade cloth (80–60%) for young seedlings, and lower densities (40–30 %) for older ones. You can either arrange two or three areas with different shade densities and move seedlings as required, or have several layers of shade cloth which can be removed as needed.

Light quality (red:far-red ratio) can affect plant growth and can be used to manipulate stock plant management, seed germination and shoot development. Vegetative growth is enhanced when the light quality is changed towards the red spectrum with green netting. When it is changed towards the blue/green using red netting, flowering can be induced. Coloured netting is not used on a routine basis in agroforestry tree nurseries but an easy way to change the light quality favourably for vegetative growth, for example in stock plant management for cuttings, is to grow plants under a light shade of small-leaved species, such as ***Calliandra*** or ***Leucaena***.

Day length is not critical for the production of tropical species, but an artificial change of photoperiod can influence root initiation in cuttings, and carbohydrate reserves in some species. The installation of lamps over part of the propagation area may be justified in experimental settings.

Note that three layers of 20% shade cloth do not necessarily provide a 60% shade, because they usually do not exactly overlap. Use a PAR meter[1] to ensure the correct amount of shade. The netting should be fixed above head height (ca 2 m) and run down the east and west sides to provide even shading and yet allow easy access to seedlings. If necessary, you can install additional layers of low shade at plant height. The netting should be supported on wooden beams or strong wires spread between poles at distances of 4–5 m or as convenient for the nursery. Wires are better than wooden beams because they shed less shade on the plants.

Temperature

The temperature range for optimal plant development is 25–35°C . Depending on the species and the prevailing humidity, it can be slightly higher, but avoid air temperatures above 40°C. When using any type of black container, the substrate can heat up to temperatures above 50°C in direct sun. This is undesirable and can be prevented by shielding the containers, for example with wooden planks.

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In some locations where temperatures can drop below 20°C, you might need to provide additional heating of propagation beds during the cold months. Heating cables or mats which provide bottom heat can easily be installed. If these do not have a thermostat, they need to be switched on and off according to a well-monitored schedule.

Temperatures need to be most carefully monitored and held inside the recommended range during seed germination, rooting of cuttings and graft union formation.

Gas exchange

Rooting cuttings and germinating seedlings have high respiration rates. This means that oxygen is consumed and carbon dioxide released. The proper exchange of these gases is very important for good root development. In heavy soils and under waterlogged conditions, root development is hindered, resulting in the accumulation of toxic amounts of carbon dioxide in the root zone. On the other hand, plants need to take up CO_2 for assimilation through the stomata on the leaves. Plants stressed by drought or nutrient deficiency have their stomata

[1] PAR = photosynthetic active radiation. Suppliers see Annex 1.

closed and cannot assimilate CO_2 properly, and this results in retarded development. Atmospheric air contains about 0.03% CO_2 and 21% O_2. For specialist purposes, plants can be grown under elevated CO_2 levels of up to 3% to increase production.

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In enclosed structures, the ambient level of CO_2 can drop so much that its assimilation through the stomates is slowed down. Opening the doors briefly for ventilation at set intervals can avoid this.

Electricity

Electricity should be available in the nursery so that equipment such as ventilators, heating cables, electrical balances, and data loggers can be installed. If it is not possible to connect the nursery to the main power line, consider using solar panels instead.

Further reading

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