evropský sociální fond v ČR
EVROPSKÁ UNIE
MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY
OP Vzdělávání pro konkurenceschopnost
INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

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Silviculture #5
Seed production & Nursery practice

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Dr. Radek Pokorný

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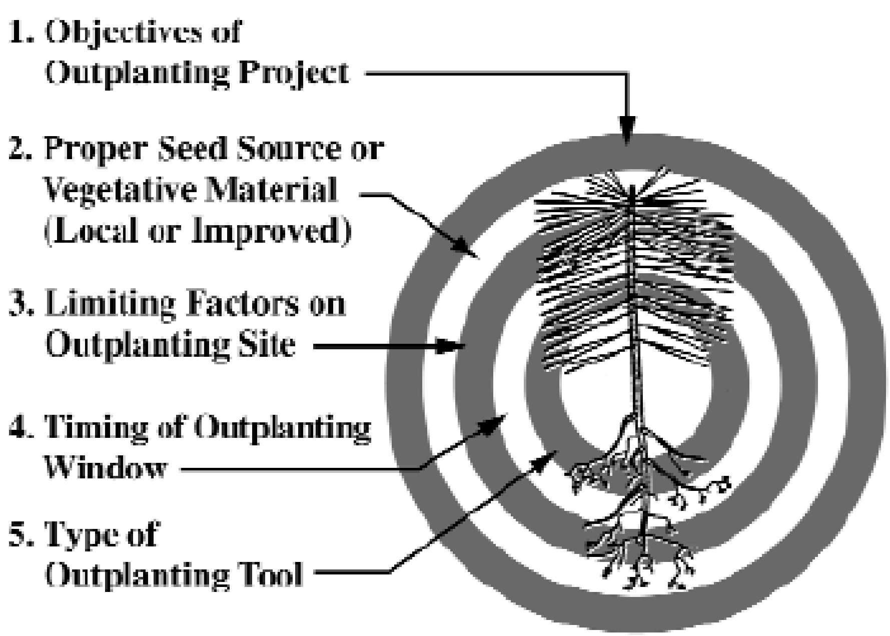
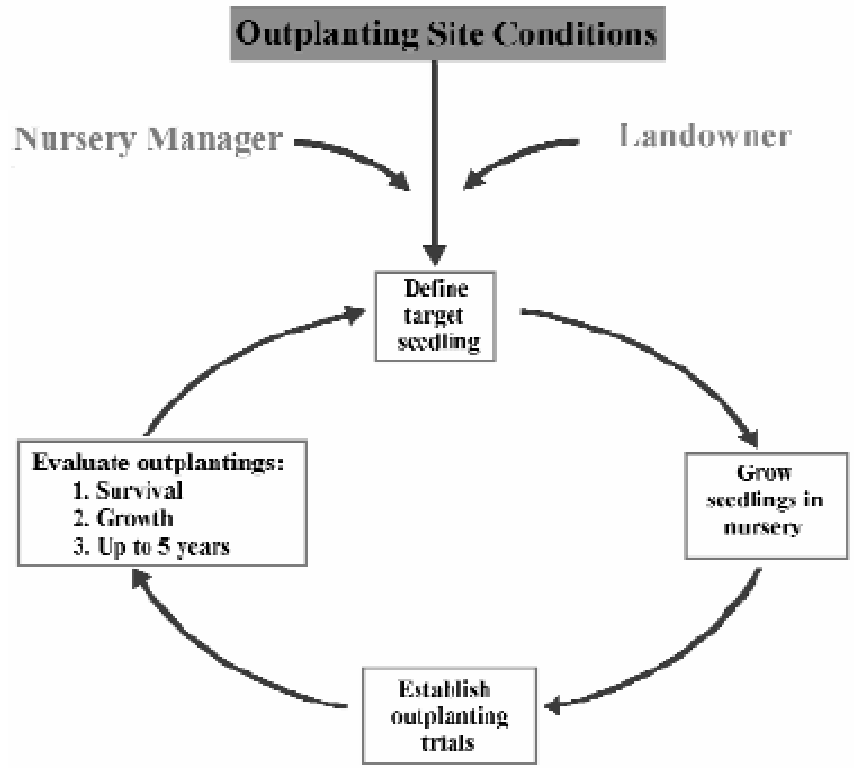




The best species and stock type of seedling depends on customer objectives and especially conditions on the outplanting site

This ideal plant is known as the "target seedling" and has traditionally been described by morphological characteristics

Seedling quality

- Here, we discuss targeting seedlings to the conditions you expect at the site where you will plant them. We give ways to monitor plant development and describe simple routines that help to handle planting stock or to reduce variation amongst seedlings. Feedback provided by experimenters and farmers is important in improving a nursery's standards.
- 'Targeting' seedling production to the anticipated field site is an important step in producing strong healthy seedlings.

- After they are planted, the seedlings have to survive without irrigation or fertilizer. Many studies have shown that field survival and productivity are related to the quality of the seedlings used.

Seedling quality depends on:

- the ability to produce new roots quickly
- the speed with which seedlings get anchored in the ground, and start assimilating and growing after planting out
- a well-developed root system
- sun-adapted foliage
- a large root collar diameter
- a balanced shoot:root ratio *
- good carbohydrate reserves
- an optimum mineral nutrition content
- the establishment of adequate mycorrhizal or *Rhizobium* infection

- * *A less rigorous, but non-destructive, index is the 'sturdiness quotient',which compares height (in cm) over root collar diameter (in mm).* A sturdiness quotient higher than 6 is undesirable.

Seedling quality

- For each nursery population, measure the root and shoot dry weight of a few plants at random to get an idea of the general population quality. Of course the data you get will be meaningless unless you correlate it with field survival at a later stage to see for each species and site how well these simple measurements relate to the survival and growth of the seedlings.

Quality seed

- Seedling quality also depends on the seed used. The quality of seed planted in the nursery is of crucial importance, since seeds are the most basic input into any planting programme.

Getting your seed

- You can collect it directly from local stands of a species (such sources include native or naturalized stands and stands established specifically for seed production).
- Alternatively, you can order it from a commercial or noncommercial seed supplier.

* When ordering seed from a supplier, always pay attention to the genetic quality of seed which relates to the origin (provenance) of seed and its genetic diversity.

- **Origin** is important because most trees exhibit considerable intraspecific genetic variation, so the performance of different provenances (origins) of the same species may vary widely. It is important, wherever you can, to get the best provenance for your particular planting purpose.
- **Genetic base** (the diversity of genes) is especially important when seed is collected, for two reasons. First, a wide genetic base (such as a large number of varieties) gives flexibility to changing user requirements and environmental conditions. Second, since most trees are predominantly outbreeding (they produce seed by cross-fertilization, rather than selfpollination),a wide base provides protection against a future loss in performance through inbreeding depression (a decrease in vigour common to outbreeding species when their genetic base is too narrow).

When ordering seed from a supplier

- Choose a supplier who provides good documentation on his or her seed (this can be judged by asking suppliers for their seed catalogues). The more information a supplier can provide about the seed, including provenance, source (natural, naturalized or planted stand), collection method and collector, the better your selection of material will be and the higher your chances of getting quality planting material.
- Specify the environment in which, and purpose for which, seed will be planted, and ask the supplier to provide the best possible material.
- Remember, it is important for the supplier to specify the origin of seed, so that you can get more seed of the same provenance in the future (from the same or other suppliers), if it performs well.

After collection

- For most species, **extract** seed from fruit as soon as possible. The method used will depend on the species. For many legumes, pods can be dried in the sun for two days and then rubbed across a coarse wire mesh through which seed falls. The extraction method used should not damage seed so that a significant loss in viability occurs. During extraction, remove impurities (for xample, diseased or partly eaten seed, contaminating seed, soil, chaff and insects) by winnowing or hand-sorting.

After collection

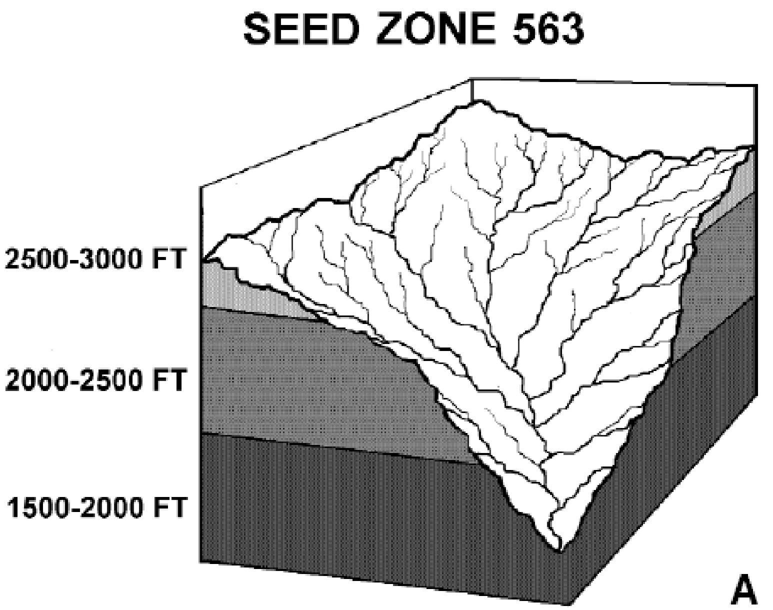
- After extraction, most seed should be **dried** further before storage. Generally, the lower the moisture of seed, the longer it can be stored. Normally, seed with amoisture content of 10% or less will maintain high viability for several years, if stored correctly. Sun drying seed for two to three days generally reduces moisture to an acceptable level, although more time is needed for large seed. Spread seed on raised beds to help air circulate, and shade the beds from strong sunlight (move seed into the shade for around two hours at midday).

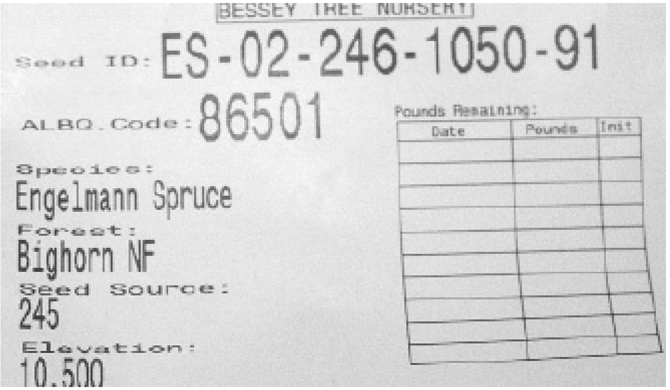
After collection

- During processing, the viability and purity of seed is normally **tested**. *Viability* is the percentage of germinating seed in a seedlot and is measured by germinating seed under conditions (including any pre-treatments such as nicking or soaking in hot-water) that would normally be applied during germination. This provides a reference level of germination for users. *Purity* is the percentage by weight of pure seed in a sample and is estimated by weighing a sample of seed before and after the removal of impurities. Record particular impurities, such as contaminating seed. The International Seed Testing Association (ISTA) has published guidelines for seed testing that qualified seed suppliers should adhere to.

After collection

- **Label** seed properly during processing and storage. An unidentified seedlot is almost worthless. As a minimum, seed should be labelled with the species name, original collection source, production location, collection date, producer and viability.





Seed storage

- After you obtain your seed, you need to store it in the correct conditions in the interval before planting, to maintain its physiological quality. This will ensure that maximum viability is maintained. The supplier should specify the proper conditions for storage of seed. Normally, orthodox seed, which can be stored without losing viability for a long time, should be kept cool, dry and dark in airtight containers (such as plastic or glass bottles with screw-tight lids, or hermetically-sealed foil sachets). If possible, orthodox seed should be stored in a refrigerator. For recalcitrant seed, storage is more problematic. Seed is viable for only a short time and, whenever possible, should be planted out immediately. If this is not possible, storage at 10 to 15ºC in humid conditions, for example in moist sawdust, may extend longevity.

Seedling development

There are three phases in seedling development:

- establishment
- production
- hardening

Establishment

- Various pre-treatments can be used to accelerate the start of germination and/or to shorten the germination period for all seeds so that germination is uniform rather than scattered over a long period of time. Which method to use depends on the species and the seed: large, hard seeds might require mechanical nicking and soaking, small seeds might only need to be soaked. If information is not available, carry out a few simple tests.

- **Most common seed pre-treatment methods**
  - soaking in cold water for 12, 24 or 48 hours
  - immersion in hot (70°C) water, letting cool and soaking for 12, 24 or 48 hours
  - nicking/partial or complete removal of seed coat

- Inoculation with mycorrhizal fungi or *Rhizobium* bacteria is necessary for good plant development of most agroforestry tree species. It can increase plant disease resistance and help alleviate plant stress by enhancing the plant’s water and nutrient uptake. Early infection with mycorrhiza can also increase the propagation success of cuttings and seedlings. It is especially important that mycorrhizal and *Rhizobium* associations are well-established when you are producing seedlings for acid or degraded soils.
- Ideally, get the inoculum from a reputable supplier. If this is not possible you can take advantage of the fact that spores and mycelia of mycorrhizal fungi are abundant in the soil around established trees. Inoculation is easy when some of this soil can be mixed into the propagation substrate. Usually, a small amount (5–10% of the total mixture) of topsoil is sufficient.

Inoculation

Type of mycorrhizal inoculation	Timing in the nursery crop cycle	Objectives of inoculation *	
		Nursery	Outplanting
Coating seeds with spores	Before sowing	1) Increased growth 2) Disease prevention	None
Incorporating mycelia into the growing medium	Before sowing	1) Increased growth 2) Disease prevention	None
Liquid drench with spores	Establishment or rapid growth phases	1) Increased growth 2) Disease prevention	None
Liquid drench with spores	Hardening phase	1) Disease prevention 2) Increased growth	1) Increased survival
Root dip with spores	During packing or before outplanting	None	1) Increased survival 2) Increased growth

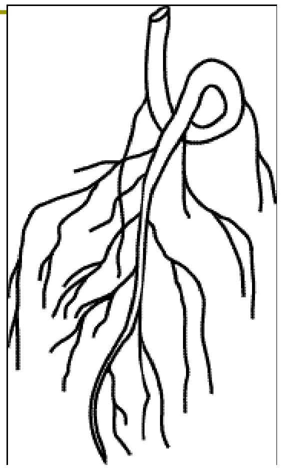
* Regardless of the biological objectives, mycorrhizal inoculation may have marketing advantages.

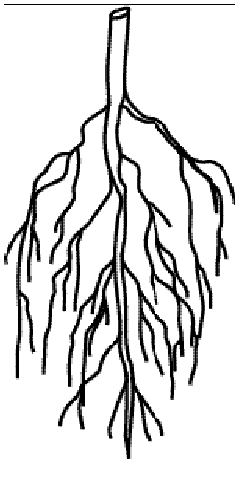
Steps in pricking out— these apply for both container and bare-root beds

1. Fill the containers well in advance with a good potting substrate and water the day before pricking out.
2. Water the germination tray well the day before pricking out.
3. Lift the seedlings carefully, holding them by the cotyledons, after loosening the substrate, so that the soft stem does not get damaged.
4. Prepare only as many seedlings as you can pot within 30 minutes; put the seedlings into a container with water or cover them with wet paper or cloth and keep them in the shade until needed.
5. Make a hole in the substrate using a small stick. Ensure that the hole is in the centre of the container — or that holes are equally spaced in the case of bare-root beds — and that it is longer than the roots of the seedling to be potted. This can be done in advance of pricking out to speed up the operation.
6. If the roots have already grown longer than the container's depth, cut tap root using a sharp and clean knife.
7. Put the seedling into the hole, ensuring the roots are not curled;insert the seedling a bit deeper than necessary, then lift it up again to straighten the roots.
8. Press substrate firmly around the seedling and water thoroughly to avoid air pockets in the substrate.
9. Keep filled containers under shade for at least two weeks.

Production

- As soon as a seedling is established, either a few days after germination or after pricking out, both roots and shoots begin growing rapidly. This phase is as important as the establishment phase. Root development is important for good inoculation with symbionts, for efficient nutrient uptake and for outplanting success. The number of fine roots with growing points largely determines the ability of the seedling to recover and start growing after planting out. If the root system is small and/or distorted, the tree cannot anchor itself sufficiently in the ground and is prone to wind-throw or lodging when waterlogged.
- You might be surprised how often unsuccessful tree development canbe attributed to root deformities.





Hardening and planting out

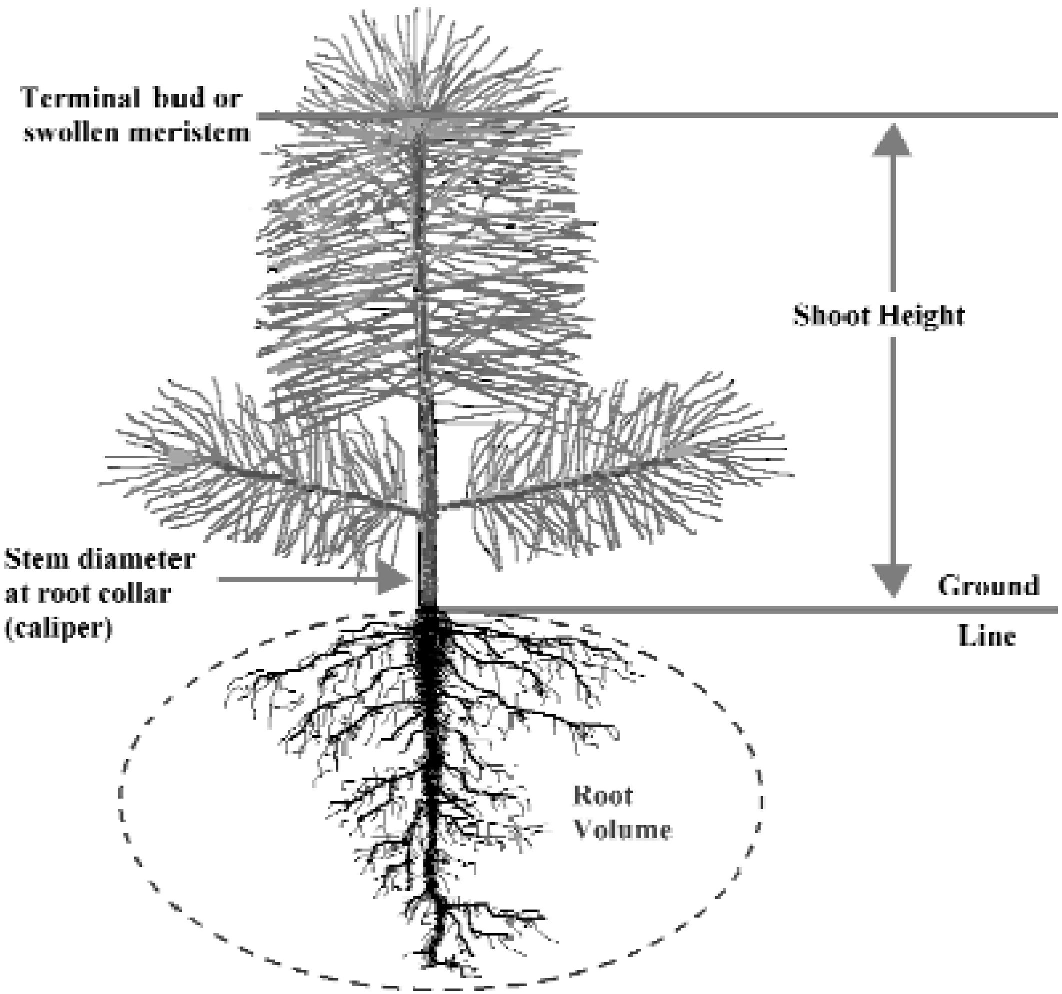
- Seedlings need to get accustomed to the conditions at a planting site. Therefore, about 4–6 weeks before planting out, start hardening them by reducing watering gradually to once a week and by gradually removing the shading.
- Plant seedlings out as soon as they have reached their optimum size.This varies with the species and the site, but it will usually be a height of 15– 30 cm. It can be much larger for some slow- rowing species, or when there is strong weed competition at the planting site. Do not leave seedlings in the nursery into the next season.
- If this is anticipated you can try to slow down plant development (e.g. delay pottingon into bigger containers, or stop fertilizing).
- If you know that planting will be delayed for a whole season, consider re-sowing.

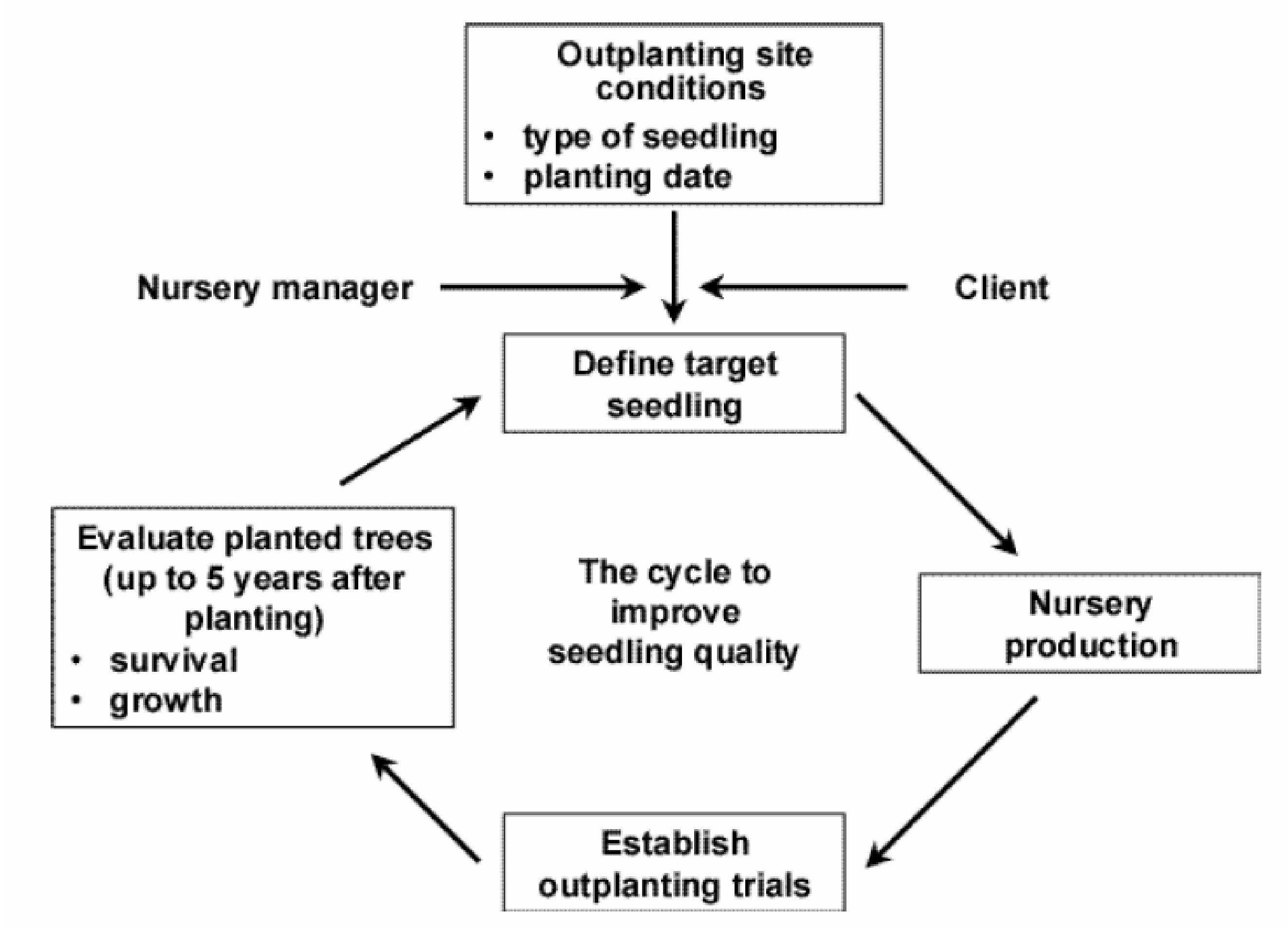
- *Handling seedling variability*

feedback

- When you are in the field make the following observations for each tree: is the tree healthy, dead, unhealthy or missing? If so, what are the reasons: drought, cattle, rodents, insects, loosely planted (soil not compacted), shallow planted (holes not deep enough), spiral roots, planted too deep, ‘J’ root (bent root), small seedling, fire, vandalism? Observe the site conditions, too: is there shallow soil, is it rocky, nutrient deficient or acid?

Seedling characteristics





Outplanting site conditions
• type of seedling
• planting date
Nursery manager
Client
Define target seedling
Evaluate planted trees (up to 5 years after planting)
• survival
• growth
The cycle to improve seedling quality
Nursery production
Establish outplanting trials

- **1. Cost.** Container seedlings traditionally have been more expensive than bareroot stock, although, in recent years, the costs are becoming more comparable. Container nurseries also are more cost-effective at low seedling production levels.
- **2. Species characteristics.** Most forest and conservation species can be grown as bareroot seedlings, although some do better in containers.
- **3. Production time**. Because container seedlings can be produced more quickly than bareroot seedlings, they are often used to reforest burns and other sites that need to be planted quickly.
- **4. Outplanting site condition.** Bareroot seedlings are used on typical reforestation sites, but container seedlings often are preferred for the more severe, hardto- plant sites. Container stock has a wider outplanting window than bareroot stock.
- **5. Personal preference.** Some customers tend to prefer one stock type over the other.

Containers

	bare-root nursery	container nursery
water	requires frequent watering	has moderate water requirements
soil conditions	needs excellent soil	soil quality is not critical
land requirements	needs large area of land because plants are grown at lower densities	can occupy a smaller area because of higher densities and lower culling rates
plant hygiene	soil-borne pests and diseases may become a problem	spread of disease can be better contained and controlled
symbionts	mycorrhiza and other symbionts may be present	specific mycorrhiza and other symbionts may need to be added to substrate
seedling handling	bare-root seedlings are relatively intolerant to physical abuse and mishandling	container seedlings are relatively tolerant to physical abuse and mishandling
root pruning	necessary and labour intensive	unnecessary if root trainers provide air pruning
outplanting	seedlings suffer outplanting stress; they are more suitable for better sites	seedlings are more tolerant to outplanting stress and are suitable for poorer sites

Types of containers

type	description	cost per unit	comments
polybag	black or clear polyethylene; 0.3–45 L volume	US$ 0.002–0.003 for the commonly used 0.5–1.5 L sizes	often made locally; usually used only once; can cause spiralled roots; root system can be crushed during handling.
polysleeve	black or clear polyethylene; 0.3–1.5 L volume,cut from an endless roll; open at both ends	as for polybag	allow air root pruning through the open bottom; substrate can fall out, therefore of limited usefulness when transporting seedlings to the field; usually used only once; root system can be crushed during handling.
jiffy pots and pellets	pots made from compressed peat	US$ 0.03–0.06	roots penetrate the container easily; can only be used once as the containers are planted with the seedling; easy planting but danger of root system drying out if planted too shallowly (wick effect).
root trainer	rigid containers with internal vertical ribs	US$ 0.04–0.10	big holes in bottom allow air root pruning; can be used 4–6 times; vertical ribs force roots to grow straight; some types open like a book to allow easy extraction of seedlings; require raised nursery frames; root damage during handling is negligible.

If you choose the root trainer system, you may need to adapt other nursery practices to the special requirements of the system. It is important to choose a potting substrate that is fibrous so that it does not fall through the bottom holes of the containers. Sand and soil or mixtures that contain a lot of sand or soil are not suitable. You need to construct raised frames so that the base of the root trainers is at least 30 cm above the ground to allow for air pruning. Because the root trainer cells often have a smaller volume than polybags, you may need to increase the watering schedule.

Changes in management also include the outplanting step. The ‘plugs’ from root trainers can be transported into the field like bare-rooted seedlings, provided there is a strong fibrous root system binding the plug. This reduces transport costs. Of course you will need to take the same precautions concerning desiccation of the plants as you do for bare-rooted seedlings:

- the seedlings have to planted on the same day you take them out of their containers
- never let the root system dry out
- keep the seedlings in the shade at all times
- special care has to be taken to avoid crushing the root system.

Substrates

- Most nurseries use mixtures of topsoil with organic and inorganic additions. However, these don't always allow the development of a good fibrous root system.

- ***A substrate should:***
  - be light in weight to ease transport to the planting site
  - hold cuttings or seedlings firmly in place
  - retain enough moisture to avoid need for frequent watering
  - be porous enough for excess water to drain easily
  - allow sufficient aeration of the roots
  - be free from seeds, nematodes and diseases
  - be able to be sterilized without changing its properties
  - have enough nutrients for a healthy initial development of plants
  - not have a high salinity level
  - have a suitable pH
  - be stable and not swell or shrink excessively or crust over in the sun.

Physical properties

- **water-holding capacity**
  - A substrate that allows a large amount of water to be held without waterlogging does not need frequent irrigation. The water-holding capacity is also a function of the container used. In shallow containers the substrate has a higher water-holding capacity than in deep containers

Physical properties

- Porosity
  - A substrate that allows a large amount of water to be held without waterlogging does not need frequent irrigation. The water-holding capacity is also a function of the container used. In shallow containers the substrate has a higher water-holding capacity than in deep containers
- Plasticity
  - A substrate that shrinks and cracks when drying, such as a clayey soil, damages the plants by shearing off roots.

Calculating water-holding capacity and porosity

You can calculate the water-holding capacity and porosity of a substrate by the following steps:

1. With drainage holes sealed in an empty container, fill the container with water and record the volume required to fill the top of the container. This is the **container volume.**

2. Empty and dry the sealed container and fill it with dry substrate.

3. Using a measured volume of water, irrigate the substrate in the container slowly until it is saturated with water. This might take several hours. The saturation point is reached when water stays visible on the surface. Note how much water you have used. The volume of water needed to reach this point is called the **total pore volume.**

Calculating water-holding capacity and porosity

4. Remove the seal from the drainage holes and catch the water as it runs out. Wait several hours until all water has dripped out. Record the volume collected — this is the **aeration pore volume.**

5. Calculate total porosity, aeration porosity and waterholding porosity using the following equations:

Total porosity = total pore volume / container volume

Aeration porosity = aeration pore volume / container volume

Water-holding porosity = total porosity – aeration porosity.

A good growing medium for most agroforestry trees has a total porosity of above 50% of which 30–50% is aeration porosity.

Chemical properties

- **fertility**

  As soon as a seedling has used up the nutrients provided by its cotyledons (about two weeks after germination), it needs nutrients from the growth medium.The basic nutrients, of which plants require relatively large amounts, are nitrogen (N), phosphorus (P) and potassium (K). Plants also need very small amounts of other nutrients (‘micronutrients’) and deficiencies in micronutrients can occur in the nursery. The micronutrients that agroforestry trees are most often lacking are iron (yellow, ‘chlorotic’ leaves), especially in soils with a high pH or those derived from limestone, and boron (shoot tip dries out), especially in soils from igneous rocks.

Chemical properties

- **Acidity**

  The right substrate pH is very important for healthy plant development. The reason for this is that nutrients become available for plants at different pH levels. The optimum is around 5.5 for organic soils and around 6.5 for mineral soils. Most plants grow best in a medium with near-neutral pH (5.5–6.5), although some plants are particularly tolerant of acidity or alkalinity.

Chemical properties

- **Cation exchange capacity**

  The cation exchange capacity (CEC) is the ability of a material to adsorb positively charged ions ('cations'). It is one of the most important factors affecting the fertility of a growth substrate. The main cations involved in plant nutrition are calcium, magnesium, potassium and ammonium, listed in order of decreasing retention in the substrate. Many micronutrients are also adsorbed, such as iron, manganese, zinc and copper. These nutrients are stored on growth medium particles until they are taken up by the root system.

  In practical terms, the CEC indicates the fertilizer storage capacity of the substrate and indicates how frequently fertilizer needs to be applied. Some soils contain high amounts of clays which absorb cations so strongly that they become unavailable for plant nutrition (mineral 'fixation'). These soils are unsuitable for nursery purposes. Although the CEC of some soil-less substrates is very high, anions get washed out easily and need to be replenished frequently. This is particularly important for phosphorus and for nitrogen in the form of nitrate. Mixing a slow-release Pfertilizer, such as rock phosphate, into the substrate before planting can help alleviate this problem.

Bulk densities and CEC for various growth substrates

- CEC is traditionally measured on a weight basis for field soils, but CEC per volume is more meaningful for container growth media, because of the relatively low bulk density of most media and the small volumes of the containers. CEC values for some typical growth medium components are compared below. Vermiculite and peat moss have the highest CEC values, whereas materials such as perlite and sand have very low CEC values.

substrate	approximate dry bulk density (g/L)	CEC meq/L
perlite	ca 100	1.5–3.5
sand	1400–1700	45–105
pine/fir bark	200–300	ca 100
vermiculite	ca 120	110–198
peat	ca 110	

As a rule of thumb when soil is to be part of the growing medium, use the following mixtures (topsoil : fine gravel : well- decomposed organic matter such as manure or compost):

- for heavy (clayey) soils 1 : 2 : 2
- for medium (loamy) soils 1 : 1 : 1
- for light (sandy) soils 1 : 0 : 1

The two major groups and components of soil-less media are:

- **inorganic**: for example, gravel, sand, vermiculite, perlite, tuff and pumice, polystyrene.
- **organic**: for example, peat, charcoal, softwood and hardwood barks, compost, rice hulls, sawdust and other organic waste products.

The choice for substrate components will depend on the location of the nursery, the resources available and plant requirements.

Calculating the amount of substrate needed

Before mixing, you need to know roughly how much substrate you will need. Start with the container volume and the number of containers to fill. To calculate volume you can seal the drainage holes of the container and fill it with water from a measuring cylinder, noting how much water you filled. Or you can calculate it by measuring the height and diameter of the container, assuming it is cylindrical:

volume = $hr^2 \pi$
(height x 1/2 diameter squared x 3.1416).

Once you know the volume of the container, multiply this by the number of containers needed. For example: volume = 500 ml; 10 000 seedlings needed. Total volume needed is 500 x 10 000 = 5 000 000 ml or 5000 litres or 5 m3. Then calculate the amount of each component needed.

Fertilizers

- When using soil or soil-based media, you might not need to fertilize the seedlings immediately because the substrate has residual fertility. However, with most soil-less substrates and during the production phase, seedlings need the addition of balanced nutrients.
- Fertilizers provide plants with the nutrients necessary for healthy growth. Apart from the macronutrients N, P, K, Ca, Mg, and S there is a known suite of micronutrients (Fe, Mn, B, Cu, Cl, Zn and Mo) that play important roles in the plant's metabolism.
- However, it is advisable to analyse the substrate for available plant nutrients regularly (in a laboratory), monitoring the plants themselves for symptoms of deficiency is common.
- Seedlings need nutrients from the growth substrate after the nutrients provided in the cotyledons become depleted. This is usually within the first couple of weeks after emergence — from then on, plants grown in a soil-less substrate need to be fertilized regularly and frequently.

Macronutrients

name (symbol)	**function**	**deficiency symptoms** (very general)
nitrogen (N)	Important component of amino acids and proteins.	Old leaves turn yellow, plant growth retarded, small leaves. Be careful: too much nitrogen leads to overgrown plants which are highly susceptible to diseases.
phosphorus (P)	Provides energy (ATP). Helps in transport of assimilates during photosynthesis. Important functions in fruit ripening.	Small plants with erect growth habit; thin stems, slow growth. Leaves appear dirty grey-green, sometimes red.
potassium (K)	Important in maintaining cell turgor, phloem transport, cell growth and cell wall development (K deficiency leads to susceptibility to pests because cell walls are weakened).	Older leaves show first chlorotic, later necrotic borders. Younger leaves remain small.
calcium (Ca)	Stabilizes cell membranes and cell walls, interacts with plant hormones. Ca is extremely immobile and can only be taken up through young, unlignified roots.	Deficiency is often only visible in retarded growth.
magnesium (Mg)	Component of chlorophyll–photosynthesis is hindered when deficient. Binds ATP to enzymes. Important for protein synthesis.	Old leaves chlorotic from middle or between veins, rarely necrotic. Leaves orange-yellow, drop prematurely.
sulphur (S)	Component of etheric oils, vitamin B, vitamin H, amino acids, and has important functions in protein synthesis.	Similar to N-deficiency but symptoms show first on young leaves.

Micronutrients

name (symbol)	function	deficiency symptoms (very general)
iron (Fe)	Component of chloroplasts. Part of the redox system in the electron transport during assimilation, and important for RNA synthesis.	Young leaves turn yellow to white.
manganese (Mn)	Important for enzyme activation, photolysis. When deficient, protein synthesis and carbohydrate formation are hindered.	Youngest leaves show chlorotic spots, later they grow into necrotic areas parallel to the veins.
copper (Cu)	Found in chloroplasts. Important for carbohydrate synthesis and protein synthesis.	Youngest leaves are chlorotic or necrotic, fruit set is insufficient.
zinc (Zn)	Has enzyme activating function, e.g. starch synthetase; is found in chloroplasts.	Small leaves and short internodes; thin shoots.
molybdenum (Mo)	Important component of enzymes, specifically nitrate reductase and nitrogenase. Essential element for all nitrogen-fixing plants.	Old leaves develop necrotic borders,often the symptoms are caused by secondary N-deficiency.
boron (B)	Found in cell walls, important for transport of assimilates and cell growth. If deficient, shoot tip dries.	Youngest leaves are deformed, thick, dark green to greyish. Root system development is hindered.
chlorine (Cl)	Important in maintaining cell tugor, increases sugar content in fruits.	Deficiency symptoms occur only in halophytes (salt-loving plants), mainly as loss in turgor.

Organic fertilizers

Animal manure
Composted green matter
Animal waste

Approximate nutrient contents of fresh manure of various farm animals			
	nitrogen (%)	phosphoric acid (%)	potassium (%)
cow	0.35	0.2	0.1–0.5
goat/sheep	0.5–0.8	0.2–0.6	0.3–0.7
pig	0.55	0.4–0.75	0.1–0.5
chicken	1.7	1.6	0.6–1
horse	0.3–0.6	0.3	0.5

Inorganic fertilizers

- Inorganic fertilizers are divided into single fertilizers, compound fertilizers and full fertilizers. They can be applied by broadcasting or by mixing with the irrigation water (‘fertigation’). Fertilizers are commonly known by the contents of the main nutrients N, P and K. The numbers on the bags show the content of these components. For example 20–10–20 fertilizer contains 20% N, 10% P, usually in the form of P_2O_5 [2] , and 20% K, usually in the form of K_2O[3] . Urea, a single fertilizer containing only nitrogen is labelled 46–0–0, indicating that it has 46% nitrogen, but neither phosphorus nor potassium. The remaining parts are made up of the non-N (P_2 O_5, K_2O) parts of the molecules and inert carrier materials.

Types and examples of granular fertilizers	
single fertilizers	contain only one nutrient: urea (N) superphosphate (P) rock phosphate (P)
compound fertilizers	contain two nutrients: DAP (N,P) CAN (N,Ca)
full fertilizers	Contain all three main nutrients: NPK 20-20-20 (N,P,K) NPK 17-17-10 (N,P,K) Also available with some or all necessary micronutrients: NPK 12-12-17-2 (N,P,K + Mn) Bayfolan (N,P,K + micronutrients)

How to calculate the right fertilizer concentration

Usually, fertilizer requirements are given in ppm (parts per million), or mg/kg or L. If you use a 19–19–19 fertilizer, a 50–80 ppm solution is recommended for frequent use. Calculate the correct amount like this:

- In a 19% N (or P2O5, or K2O) fertilizer, 100 g fertilizer contains 19 g or 19 000 mg N (or P2 O5, or K2 O)
- a solution of 50 ppm is wanted (50 mg N in 1 L)
- 100g x 50 mg/ 19 000 mg = 0.263 g or 263 mg.

For each litre of fertilizer solution, dissolve 263 mg of granular 19–19–19 fertilizer.

Controlled-release fertilizers

Controlled-release fertilizers provide an attractive alternative to granular fertilizers. These are fertilizer 'cocktails' that slowly release nutrients to the substrate. The release depends on water availability or soil temperature.

Controlled-release fertilizers are more expensive than the more common water soluble fertilizers, but they have several advantages:

- the danger of over-fertilizing is reduced as the release of fertilizers occurs gradually
- fertilizing is necessary only occasionally, sometimes only once in a season
- a balanced fertilizer mixture is provided at all times as the plants get what they need at different growth stages
- nutrients do not leach from the substrate so the plants receive all the nutrients applied.

Experimenting with controlled-release fertilizers will help you determine the best application rates and times.

Examples of controlled-release fertilizers

fertilizer	analysis (N-P-K)	release mechanism	length of time it lasts at 21℃	N source
Lesco	20-6-12	temperature	4–6 months	sulphur coated urea and amononium nitrate
MagAmp	7-40-6 + 12Mg	moisture	4–12 months	magnesium ammonium phosphate
Osmocote	18-6-12 14-14-14 13-13-13 19-6-12 17-7-12	temperature, coating thickness; no change with media moisture	8–9 months 3–4 months 8–9 months 3–4 months 12–14 months	ammonium nitrate and ammonium phosphate
Sulphur coated urea	36-0-0 + 17S	temperature, media moisture, coating thickness	up to 6 months, approx. 1% per day	sulphur coated urea
Ureaform	38-0-0	increases with temperature, maximum at pH 6.1 and 50% water saturation; bacterial action	60% in 6 months	urea-formaldehyde

Nursery and plant hygiene

Factors that influence plant health	
abiotic ('non-biological')	- drought or waterlogging - excessively high or low - injury due to chemicals - physical damage, for example shearing off roots
biotic (biological)	all biological organisms (bacteria viruses, viroids, phytoplasms, fungi, insects, mites, nematodes, weeds, parasitic plants, birds and mammals) that interfere with plant production

Basic approaches to nursery health:

- **preventive actions**, which include balanced fertilizers, use of resistant species or cultivars, timely hardening of plants, cleanliness in the whole nursery, and training of staff
- **curative actions**, which include the use of pesticides, heat, biological control or physical measures (e.g. cutting out of diseased parts).

Actions to prevent nursery contamination

- propagation facilities: containers, flats, knives, secateurs, working surface, boxes etc.
- propagation substrates
- irrigation water
- planting stock: seeds, cuttings, scions and rootstocks
- shoes and clothing of nursery staff and visitors.