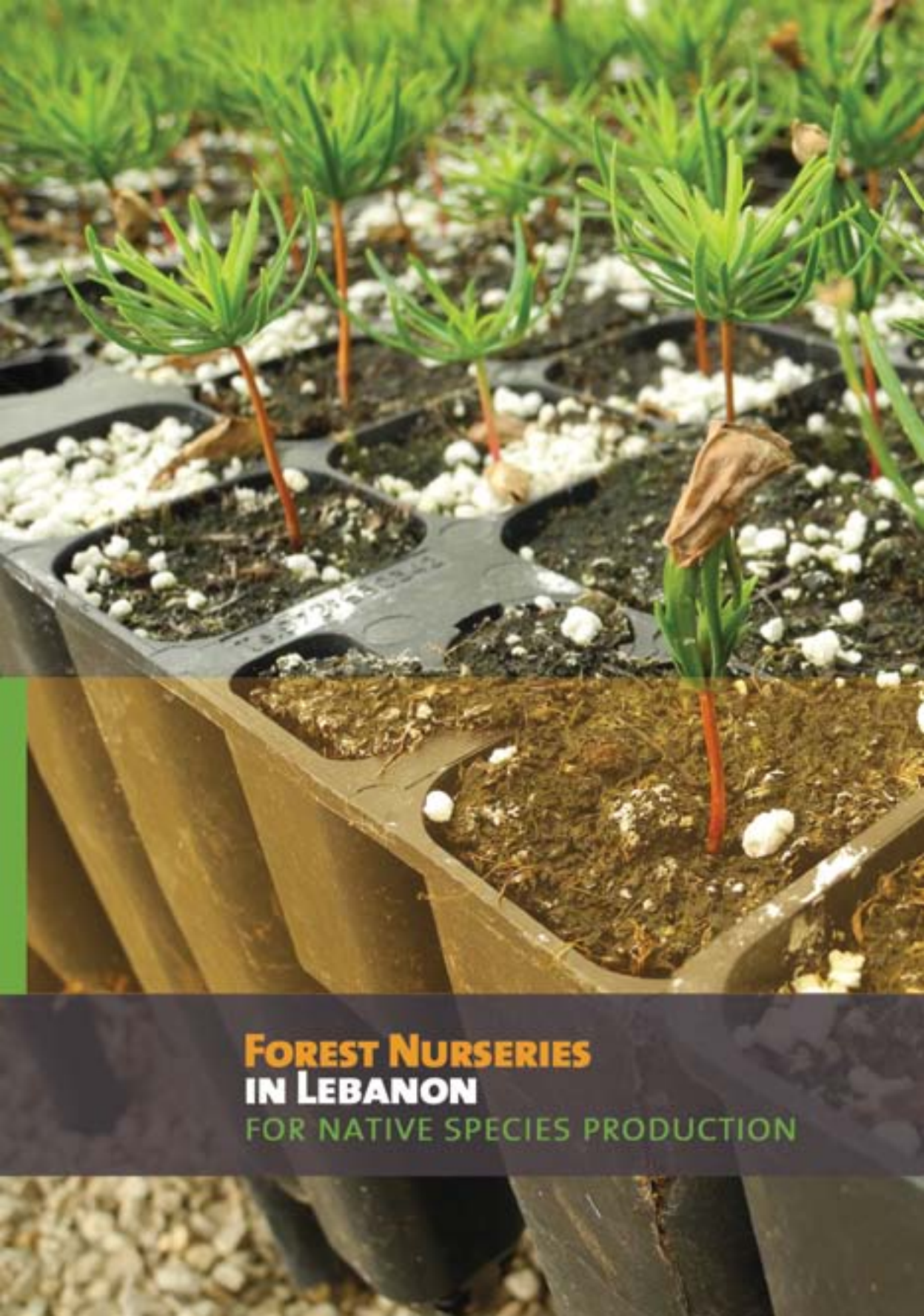

Forest Nurseries in Lebanon

For Native Species Production

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Contents

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Preface

During recent years there has been increasing interest in restoring the forest landscapes of Lebanon. A number of initiatives supporting different reforestation activities are being developed in the country. Most initiatives, however, have been focusing on no more than three tree species, partly because of the lack of technical references for native species production.

The vision behind this publication is to provide a handbook that covers all the technical aspects of restoration, from seed collection, through seedling production in the nursery, to planting out in the field. This will hopefully help in the process of planning and design, which is essential for supporting the restoration of forest landscapes. The handbook is divided into four main sections: Chapter one describes the procedure for seed collection, processing and storage. The principles of nursery management are then examined, from bare-root production of forest species (chapter two) to production of seedlings in containers (chapter three). Finally, the principles of planting and sowing in the field are described in chapter four.

The second part of the manual (annexes) includes nearly 30 protocols for propagating native plants that are important for restoration purposes, including trees and shrubs. Together they should provide a solid foundation for Lebanon's foresters and others interested in producing native plants. The selection of species described here is not exhaustive, but they have been chosen for their ability to support ecological restoration and provide goods and services in the long term. In time this list will need to be expanded to include other species and practices of interest.

Introduction

Forests everywhere provide a wide range of environmental services and are believed to harbor more than half of the world's biodiversity. They frequently protect fragile soils from erosion, and play a role in conserving and recycling fresh water. They also soak up large quantities of carbon dioxide, one of the main gases contributing to climate change.

Yet, despite their significance, forests around the world are disappearing and being degraded at an alarming rate. Every year over 14 million hectares of forest—an area the size of Greece—is destroyed. Agriculture, urban development, mining and plantation forestry are the main causes of forest loss, and destructive logging leads to degradation of even greater areas of forested land.

Around 8 per cent of the world's forests are protected in national parks and nature reserves, and the area of commercially exploited, well-managed forest is steadily increasing. However, protection and good management alone are not enough.

In response, IUCN (International Union for Conservation of Nature), the World Wide Fund for Nature (WWF International) and various governmental and non-governmental partners have developed an approach called Forest Landscape Restoration (FLR) and a Global Partnership on Forest Landscape Restoration[1].

Photos By: M. Navarrete, IDAF

[1] The Global Partnership on Forest Landscape Restoration is a proactive network that unites governments, organizations, communities and individuals with a common goal. The partnership was initiated with the purpose of catalyzing and reinforcing a network of diverse examples of restoration of forests and degraded lands that deliver benefits to local communities and to nature, and fulfil international commitments on forests. http://www.ideastransformlandscapes.org/

Forest Landscape Restoration

FLR focuses on restoring the goods, services and ecological processes that forests can provide at the broader landscape level. It differs from more conventional approaches to afforestation and reforestation, which tend to be limited to increasing tree cover, usually for a very narrow range of goods and services.

FLR brings people together to identify and put in place a variety of land use practices that will help restore the functions of forests across a whole landscape, such as a water catchment. It thereby seeks to strengthen the relationship between rural development, forestry and other natural resource management and conservation approaches. It shifts the emphasis away from simply maximizing tree cover on individual sites to optimizing the supply of forest benefits, such as clean water, timber production and nature conservation, within the broader landscape.

The concept of Forest Landscape Restoration (FLR) is an ideal basis for the maintenance and enhancement of biological and social values in Mediterranean forests and other terrestrial ecosystems, for the following reasons:

- FLR concerns the restoration of the functionality of landscapes and respects their dynamic nature, as well as their complexity.
- FLR considers landscapes at the broader level, including biological and social values and parameters.
- FLR fills the gap between the sustainable management of productive forests and the protection of specific habitats and species; the FLR approach complements the protection and enhancement of ecosystem integrity, especially in degraded forests.
- FLR involves stakeholders and encourages participation while also securing long-term benefits for society.
- FLR is the most appropriate tool for combating desertification in the Mediterranean, due to its holistic approach and the integration of social, economic and ecological parameters in planning procedures.

What makes FLR work?

While FLR in practice raises many site-specific technical issues, most of the common challenges are more political and social in nature. It is clear from the experience gathered by IUCN and WWF that local support is a key element in the success of any forest landscape restoration activity. Stakeholders need to feel empowered to act and be sure that what they put in place will not be taken away from them. This means being prepared to address perennial land-use governance issues, such as decentralized decision making and the transfer of access and usage rights. Traditional practices and institutions also play a significant role, while the importance of long-term government commitment cannot be discounted.

Finally, there is no single blueprint for FLR. Success is inevitably built on adaptive management and driven by people who are willing to learn.

Mediterranean forests: A mosaic of interactions with society

Forests have always played, and still play, an important role in the daily life of Mediterranean communities. People have been harvesting forest animal and plant products on a large scale in the region for thousands of years, developing numerous uses and management systems and acquiring sophisticated knowledge of their environment. In the past, forests and trees were attributed long-standing cultural values that have defined the Mediterranean landscapes. Many endangered ecosystems and rare, endemic species in the Mediterranean still coexist in close relationship with human beings.

Although Mediterranean forests provide low direct economic returns on timber products in comparison to northern European forests, they play a crucial role in maintaining key components for securing human welfare and life in the region. For instance, forests of the northern Mediterranean region support tourism in a major way by providing recreation opportunities and scenic value. Given the significant differences in economic and social development across the region, the role of forests in society varies greatly between the northern Mediterranean on one hand and the eastern and southern parts of the Mediterranean on the other.

Forest Landscape Restoration: a concept for the Mediterranean

The classical reforestation approach does not apply in the Mediterranean and cannot guarantee the long-term production of goods and services for society. A new approach is needed, which in combination with sustainable forest management, and forest protection, can become a promising conservation strategy for the region.

It is worth noting that FLR should not be regarded as a completely new concept in the complicated Mediterranean context. It should rather be introduced as a framework within which existing tools and mechanisms can be organized and become more effective. Restoring forest functions is beneficial for most of the related policies and sectors.

Considerable forest landscape restoration work has been undertaken in EU countries of the Mediterranean region, with a range of outcomes. The following recent FLR efforts, for example, have attempted to balance socio-economic and ecological concerns:

Principles of landscape restoration in the Mediterranean region

- Prioritize soil conservation and water regulation: loss of fertile soil remains the main reason for land degradation.
- Use native species: non-native species often lack natural control mechanisms like pests or competition, and can become invasive thereby threatening local biodiversity.
- Conserve and support biodiversity: restoration must safeguard the biological diversity of species at all scales.
- Promote diversity and heterogeneity at landscape scale: varied patches of vegetation at landscape level reduce vulnerability to perturbations and increase resilience.
- Design reforestation activities according to forest-fire prevention principles: although restoration techniques very often imitate the successional stages of the vegetation, intermediate stages with highly flammable components must be avoided.
- Promote forest multifunctionality and productivity: strike a balance between traditional goods and services, such as timber products, and new values demanded by society, including recreation and carbon sequestration.

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Chapter 1.
COLLECTING, PROCESSING AND STORING SEEDS

1.1. Introduction

Reforestation and ecosystem restoration are becoming more and more important, with the number of techniques and plant species used steadily increasing. Unfortunately some of the species in demand today are not sufficiently well known or they are not widely produced in forest nurseries, so there are many questions about how they should be cultivated.

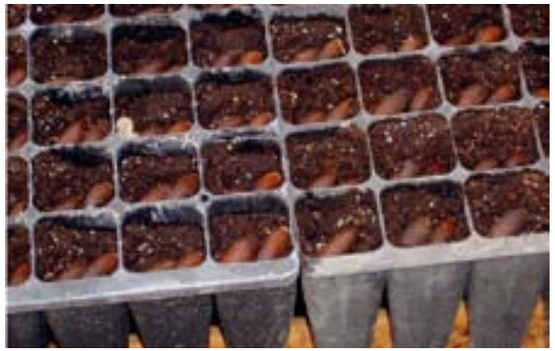
Habitat loss, unsustainable harvesting, climate change and anthropogenic disturbance threaten the diversity and abundance of native plants. In the case of commercial species, overharvesting often reduces the proportion of plants with desirable characteristics and, in effect, artificially selects for inferior phenotypes. Nurseries play an important role in combating this genetic degradation by collecting, maintaining and propagating a wide variety of genetically diverse native plants.

Detail of tree nursery
Photo by: Nuneza25. Creative commons

Knowing which seeds and vegetative propagation material to use in seedling production is an essential first step, without which it is impossible to expect satisfactory results either from the production process or in the characteristics of the future forests. Propagation material means the structures, organs or tissues by which a forest species ensures the production of new plants. The reproductive strategies generally applied in forestry (Landis et al., 1998) are:

1. **Seed propagation**, for which there are several options (Table 1),

2. **Vegetative propagation**, the option which involves different forms of asexual reproduction (Table 2).



Propagation system - cuttings
Photos by: R. Navarro, UCO

Table 1. Types of seed propagation techniques used in nursery production

Options	DESCRIPTION
Direct sowing	Placing seeds directly into the growth container and allowing them to germinate and grow in place.
Container and plug transplants	Transplanting seedlings from growth containers into larger containers (container transplants) or soil beds (plug transplants) to obtain larger plant sizes.
Planting germinants	Sowing seeds into shallow trays and then transplanting germinating seeds ('germinants') into growth containers.
Transplanting emergents	Sowing seeds into shallow trays and allowing them to germinate and the seedlings to emerge. The young 'emergents' are then transplanted into the growth container to finish their development

Table 2. Types of vegetative propagation techniques used in nursery production

Propagation technique	DESCRIPTION
Cuttings	Stem, root or leaf sections are separated from the mother plant, appropriately treated and kept in conditions that promote the formation of new roots and stems. The new plant grows and develops all its organs independently.
Layering	A propagation technique that induces the formation of adventitious roots on a stem still attached to the mother plant. The new plant is separated when it is capable of supplying its own nutritional demands and growing on independently.
Grafting	Shoots or buds from one plant are surgically implanted into another so that they become functionally joined and continue their growth and development as one plant.
Micropropagation	A method consisting of cultivating small sections of plant tissue in a nutritional medium under totally aseptic conditions (for the production of disease-free plants, multiplication *in vitro* and elimination of the seasonal effect) to form multiple shoots, which are then rooted.

1.2. Collecting and processing seeds

1.2.1. Collecting seeds or fruits

Fruits of forest species - cone
Photos by: N. Hani, AFDC

Fruit of forest species - strawberry tree
Photos by: N. Hani, AFDC

Seeds or fruits must be collected during the period between seed or fruit maturation (which do not necessarily coincide) and their disappearance as a result of dispersal or the action of harmful agents. It is also possible to collect immature fruits and store them under relatively cool, well-ventilated conditions, which allow the seeds to continue ripening inside the fruit.

A general idea of the collecting period for some species is given in Table 3. As a rule, seeds should not be collected from isolated, overripe, diseased or stunted plants or those in sites with poor fruit production. The problem of endogamy is common in isolated trees or small stands.

Table 3. Seed collecting period for some relevant species in Lebanon

	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
Cedrus libani					■			
Abies cilicica					■			
Pinus pinea						■	■	■
Pinus brutia						■	■	■
Ceratonia siliqua					■	■		
Quercus infectoria					■	■		
Quercus callipronos					■	■		
Celtis australis					■	■		
Populus alba (winter cuttings)								■
Quercus cerris pseudocerris					■	■		
Platanus orientalis						■	■	
Salix alba (winter cuttings)						■	■	■
Alnus orientalis					■	■		
Acer syriacum				■	■			
Arbutus unedo						■		
Arbutus andrachine						■		
Crataegus monogyna			■	■				
Juniperus oxycedrus					■	■		

Table 3, continued

	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
Juniperus excelsa								
Nerium oleander								
Myrtus communis								
Laurus nobilis								
Rosmarinus officinalis								
Rosa canina								
Spartium junceum								
Pistacia palaestina								
Thymbra spicata								

Three main methods for collecting fruit or seeds from forest species have been described (Willan, 1985):

1. **Collecting fruits from felled trees:** advantage is taken of felling, where the felling period is scheduled to coincide with seed ripeness. Collecting is usually done by hand with the aid of rakes or hooks.

2. **Collecting fruits from standing trees:** this is the most advisable method from the viewpoint of seed quality and causes the least damage to the trees. In this case, the collecting method can be directly from the ground (from trees and bushes with low branches), or by climbing the tree (using the appropriate safety measures); this is the only method applicable in the case of forests not exploited for timber or when trees are felled outside the seed maturation season.

Seed collection
Photo by: Consejería de Medio Ambiente-Junta de Andalucía

3. **Collecting fallen fruits:** the fruit or seed fall can be *natural* or the result of *manual or mechanical vibration*. This is the method used to collect large seeds, as in the case of leafy species of *Castanea*, *Quercus*, *Juglans*, etc. When they are harvested after naturally falling, care must be taken to discard those that have fallen first because they may be damaged or immature.

1.2.2. Seed extraction and processing

After collection and once their genetic quality has been confirmed, seeds must be subjected to a series of operations until they are used or stored. Great care must be taken in each of these operations to avoid any loss of seed viability. The greatest risks to the seed occur during temporary storage immediately after collection, during shipping to the processing facilities and once again during shipping from seed storage to the nursery. In these periods good ventilation is essential and high temperatures must be avoided.

Pre-processing:

- **Cleaning of fruits:** this is normally done by sieving to eliminate impurities. In some cases it is the only operation carried out in those species whose seeds and fruits are used in almost the same state as that in which they are collected (*Quercus*, *Castanea*, *Acer*, *Ulmus*, *Fraxinus*, etc.).

- **Temporary storage of the fruit:** this may be necessary if it is impossible to extract seed from all the fruits collected or in order to complete maturation. The temporary storage site must be dry, cool and well ventilated to prevent high temperatures or the development of mould.

Seed extraction: the different methods used depend on the type of fruit and can be grouped in four categories:

- **Cleaning of cones:** the drying processes normally used are: i) *air drying* (useful for species like *Abies* and *Cedrus*), in which the fruits are spread in thin layers on the ground or on trays in very well-ventilated storehouses and turned frequently; a simple drying rack can be constructed from a simple wooden frame with multiple mesh screens; ii) *sun drying* (used for those species which open their fruits when exposed to the joint action of sun and wind for some time); its drawback is its slowness.

- **Cleaning of recalcitrant seeds**: seeds of species such as *Quercus* or *Castanea* are generally collected quite cleanly and are stored temporarily. Before being used, they need additional cleaning by flotation in water, so that viable seeds sink whereas non-viable seeds, trash, and debris float. This method keeps the seeds hydrated until they are sown.

Seed cleaning
Photo by: E. Chnais, AFDC

- **Cleaning of dry fruits:** this consists of shelling the fruits mainly by mechanical means. It is useful in the case of those species whose pods or fruit capsules are easily opened by hitting them or to separate fruits when they grow in clusters or bunches (*Ceratonia*, *Genista*, etc.). This can be done by machines, such as hammer or blade mills, or by spreading the fruit in a heap on the ground and then trampling or beating them. Once the seed is threshed one of the cleaning methods is used to separate the seeds from the shells.

- **Cleaning of fleshy fruits:** this method is applied to species with fleshy fruits whose seeds must be separated from the pulp (*Arbutus*, *Prunus*, *Crataegus*, etc.). Fruits should be processed soon after collection to avoid damaging the seeds. The process consists of the following stages: mechanical milling or maceration of the fruit in water to soften the pulp; seed separation (a jet of enough water to prevent the seed and pulp from forming a paste, which is difficult to handle); cleaning and drying of the seeds until optimum moisture content for conservation is obtained.

Seed cleaning: once the seed has been extracted from the fruit and allowed to dry until reaching the appropriate moisture content, it must be subjected to different cleaning operations to separate viable seeds from empty, non-viable ones and from fruit debris. The most commonly used methods are:

• **Dewinging:** some species (*Pinus*, *Picea*, etc.) require the removal of wings in order to reduce the volume occupied by the seeds and avoid the drawbacks involved in using winged seeds in sowing machines. Dewinging can be done manually or by machine. There are species, such as maples, whose seed wings are not normally removed as the seed could be damaged during the process.

• **Blowing:** this operation separates good seeds from heavy impurities and from empty seeds and lightweight impurities. It can be done manually in the wind or by blowing machines.

• **Screening or sieving:** this consists of passing the seeds through sieves of different mesh sizes, with a rotating movement. When machines are used for cleaning seeds, they usually include a blowing and a sieving device.

• **Liquid flotation**: this is based on densitometric methods and consists of separating the seeds by density or specific gravity. Good seeds go to the bottom while empty ones and impurities remain on the surface. If the liquid is water, full seeds absorb it, become heavier and sink. It must be used carefully to avoid subsequent problems (such as fungal attacks or softening).

• **Centrifugal or separation:** like the above method, these are based on the specific gravity of the seeds. When the seeds are centrifuged in an open cylinder, the heavier particles are the first to rise out of the cylinder. Variation in the rotation speed allows particles of different weights to be separated.

Cleaning of *Arbutus andrache* seeds
Photo by: R.Colomer

Seeds of *Rhododendron*
Photo by: R. Colomer

As result of this process, a seedlot will be obtained. A seedlot is usually defined as a quantity of seeds from the same species that was collected from a specific seed zone or source and that is of reasonably uniform quality (Landis et al., 1998).

1.2.3. Seed storage

Once the clean seeds have been obtained, they can be used for sowing right away. However, when collecting frequency makes it necessary, or when production does not cover needs prior to sowing, seed storage and preservation must be as efficacious as possible. Seeds may be classed in two main types according to their storage requirements and longevity:

1. **Orthodox seeds** are those that can be dried to a very low moisture content, around 2–6% depending on the species, and stored at very low temperatures, even below -20°C, for long periods of time. Many Mediterranean genera, such as *Pinus*, *Cupressus*, etc., are in this group.

2. **Recalcitrant seeds** are those that cannot survive severe drying, generally not being able to withstand a moisture content below 20–50%, and cannot tolerate storage for long periods of time. Genera such as *Quercus*, *Castanea*, *Juglans* and *Fagus* are in this group.

The most important factors to be controlled for seed storage are *temperature*, *humidity and oxygen content in the environment*, so that the seeds can conserve their viability or germinative potential. A series of methods normally used for storage have been proposed taking into account the main factors involved in seed preservation:

• **Dry cold storage:** temperature of 1–4°C and humidity generally below 10%. The recommended seed moisture content for this type of storage varies according to the species. In order to maintain this degree of moisture, the seed must be stored in airtight containers in refrigerated chambers. This is most commonly used for seed from *Abies*, *Acer*, *Pinus*, etc.

• **Storage at ambient temperature:** in a cool environment without any sudden changes in temperature. The seed can be stored in bags, though preferably in airtight containers. This type of storage is only advisable for periods of one or two years. It is used for species which, due to their hard or impermeable coats or for other reasons, maintain their viability for several years if stored under these conditions (*Pinus*, *Ceratonia*, *Juniperus*, etc.).

• **Moist cold storage:** temperature of 2–3°C and minimum humidity of 40%. To obtain these conditions the seeds are usually mixed with a quantity (2 or 3 times their volume) of previously moistened sand, peat or any other porous substance. As a guideline, when sand is used, 15–18 litres of water are usually added to 100 kg of dry sand. If the storage period is short and the local climate is humid, storage can be outside in well-drained and ventilated places covered by straw or leaves, or in pits. Refrigerated chambers are required in hot climates. This is the storage system for *Quercus*, *Castanea*, *Juglans*, etc. It is advisable to store the seeds in normal refrigerators with freezers that can be kept at -4 to -5°C, for small quantities of seeds, or in large refrigerated chambers.

• **Partial vacuum storage:** temperature slightly above 0°C and 1 mm pressure. The seeds are stored in airtight containers. This is used for species with very delicate, short-lived seeds, such as *Populus*, *Salix*, etc. species. This type of storage is only used for laboratory research, as propagation of these species for commercial purposes is by cuttings.

• **Storage inside the fruit:** this is used for short periods of time and for species easily stored at ambient temperature inside the fruit. Its greatest drawback is the large space required to store all the fruits. It is used for *Platanus* and some *Pinus* species, among others.

The container to be used must protect the seeds against animals and pests and, if necessary, prevent moisture and gas exchange with the outside environment. The different types used for storing forest seeds can be classified according to their permeability to moisture and the gases produced by the different materials:

• **Materials completely permeable to moisture and gases:** within this group are *sackcloth bags, cotton bags and paper or soft or rigid cardboard containers*. None of these materials offers full protection against attacks by insects and rodents and they are completely permeable to water vapour and other gases. They are only to be used for orthodox seeds for quite short periods of time or in storage areas with controlled temperature and relative humidity. In the case of moist storage of recalcitrant seeds, periodically dampened sackcloth can be used to prevent the seeds from drying.

• **Completely impermeable materials:** within this group are *aluminium, tin, glass, rigid plastic and laminated aluminium foil containers.* The degree of protection against humidity is provided by the material and the type of container closure (screw tops, clamps, heat-sealing, etc.). This is a basic aspect of long-term storage. The type most often recommended is airtight, metal tins. They are not recommended for recalcitrant seeds or orthodox ones with a high moisture content, which deteriorate more rapidly under airtight conditions than in the open air.

Storing dried seeds
Photo by: E. Chnais AFDC

• **Resistant but not completely impermeable materials:** within this group are *polyethylene and other plastic-material bags and aluminium foil.* These materials are resistant to moisture but allow an exchange of water vapour, which tends to balance outer and inner atmospheres when used for long periods of time. Polyethylene bags can be heat-sealed. They are not recommended for long-term storage of orthodox seeds.

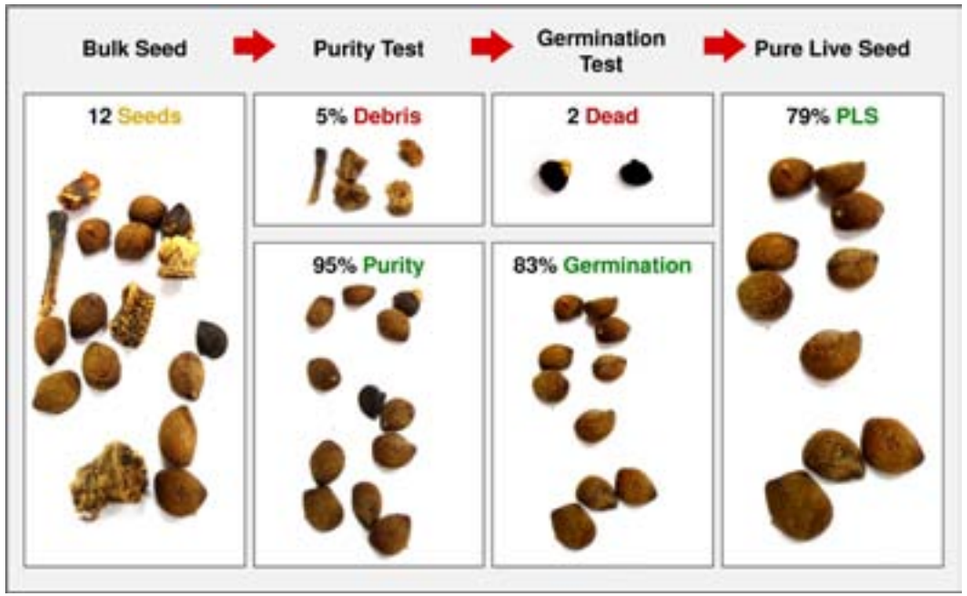
1.3. Seed testing

Nurseries routinely conduct seed germination tests to improve methods of seed sowing. The first step is to determine whether the seed has dormancy. If it does, a study should be conducted to determine the most effective treatment to overcome dormancy. The next step is to assess the germination percentage—the proportion of seeds that germinate—to determine the number of seeds that should be sown per container to achieve the desired number of seedlings. Finally, the germination rate must be investigated to determine the length of time over which seeds both start and stop germinating. Growers should understand that germination in the nursery can vary due to the variability in germination inherent in most native species and to environmental conditions such as humidity and temperature.

1.4. Seed pretreatments

A survival mechanism of some plant species is seed dormancy. This refers to the physiological or morphological adaptations by which seeds can retain their viability for long periods of time, even when temperature and moisture conditions are favourable for germination. This avoids the risk of, for example, a later drought destroying all the seedlings and endangering the survival of the species in the region. In this way the species naturally possesses a permanent soil seed bank which guarantees its persistence under viable conditions. Seed dormancy can be expressed in two ways: one is *imposed dormancy*, where the seeds do not germinate because the environmental conditions are not favourable; this phenomenon is called *quiescence*. The other is intrinsic to the seed itself: this is *organic or innate dormancy*, due to which the seed does not germinate even though the environmental conditions are suitable for optimum germination; the term used is *seed dormancy* or *lethargy*.

Seed maturation includes the development of internal mechanisms that control germination so that it coincides with the season when environmental conditions favourable to plant survival are more likely to occur. There are three types of dormancy:



Seed testing. Pure Live Seeds (PLS) is the percentage of the bulk seed weight that is composed of viable seeds. In this example, results of a purity test show 95% of the bulk weight is composed of seeds. The subsequent germination test indicates that 83% of the seeds germinated. Multiplying percentage purity by percentage germination yields 79% PLS (adapted from Steinfeld *et al.*, 2007). Photo by: IDAF

1. **External dormancy:** this is due to the physical-chemical characteristics of the seedcoat. It can be *physical*, due to the impermeability of the seedcoat to water and gases (frequent in legumes, e.g. *Ceratonia*); *mechanical*, due to the resistance of the seedcoat to embryo growth (less frequent, e.g. *Olea*); or *chemical*, due to the presence of inhibitory substances in the pericarp (e.g. *Abies*).

2. **Internal dormancy:** this may be due to physiological causes, germination inhibition mechanisms, embryo immaturity, or morphological and physiological factors (e.g. *Acer*).

3. **Double or combined dormancy:** this occurs in both the seedcoat (external dormancy) and the embryo (internal dormancy), and the necessary treatments must be given in sequence (e.g. *Crataegus*).

Types of treatment vary according to the types of dormancy described (Table 4):

1. **Physical external dormancy** is overcome by:

• **Acid soaking:** this consists of scarifying the seedcoat with acid, normally sulphuric acid at a commercially approved concentration, and varying exposure between 15 and 120 minutes at a temperature of 15 –25°C. Each batch requires careful handling and partial testing, as excess acid can destroy the seed and any defect makes treatment useless. It is a dangerous treatment and not recommended when other methods are available.

• **Hot water soaking: Immersion** consists of submerging seeds in water at a temperature of 65–70°C, and allowing them to cool for 12–24 hours (e.g. *Ceratonia*).

Scalding consists of boiling the seeds at approximately 100°C for a short period of time (between 10 seconds and 1 minute depending on the species), and leaving them to cool down completely (e.g. *Genista*).

• **Immersion in cold water**: the seeds are submerged in water at ambient temperature for 24–48 hours to overcome germination dormancy; this is common practice above all for dried seeds (e.g. *Pinus*). Seeds which float, generally empty ones, are discarded during this process.

• **Mechanical scarification:** seedcoats are weakened by abrasion in suitable machines (scarifiers); the abrasiveness and the treatment time may be varied.

Carob seeds scarification 1
Photo by:E. Chnais, AFDC

Carob seeds scarification 2
Photo by: E. Chnais, AFDC

2. **Chemical external dormancy** is overcome by:

• **Removal of the pericarp**: the pericarp is normally removed by maceration during the seed extraction and cleaning process. In some cases (e.g. *Olea*) a cleaning substance (such as caustic soda) must be used to remove it completely.

• **Intense washing or leaching:** the inhibitors are removed by soaking the seeds in running water or changing the water frequently. The process lasts for 12–24 hours.

3. **Internal dormancy** is overcome by:

• **Cold stratification:** this method consists of mixing the seed with a moistened inert material (sand or peat) and storing it in refrigerated chambers at 2–4°C for 30–90 days. The combination of high humidity and low temperature triggers a series of biochemical changes that transform complex nutritive substances into simpler ones which can be assimilated by the embryo. It is recommended for breaking physiological latency. Similar results to those of stratification can be obtained in many species (e.g. *Juniperus* species) by storing damp seeds in polyethylene bags.

• **Hot stratification followed by cold stratification:** this procedure is similar to the previous one and consists of keeping the seeds for 1–3 months at 30°C during the day and 20°C at night, and then for a similar period of time at 2–4°C (e.g. *Fraxinus* species).

Table 4. Advantages and drawbacks of pre-germination treatments

PRE-GERMINATION TREATMENT	ADVANTAGES	DRAWBACKS
Soaking in acid	• Highly effective for many species • No special equipment required • Reasonable cost • Most of the acid can be recovered • Facilitates temporary storage • Eliminates any pathogens in the testa.	• Difficult to determine treatment time and control variables • Dangerous
Hot water soaking	• Highly effective for many species • No special equipment required • Reasonable cost • Simple and safe	• Some seed species are softened and form clumps • Very varied results • Difficulties when sowing
Mechanical scarification	• Highly effective for many species • No danger of damaging the seeds due to excess heat. • Not dangerous • Equipment is costly but treatment is cheap • The seed remains dry after treatment	• Special equipment required for large seed batches • Seeds must be resin free • Seeds become more sensitive to pathogens

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Chapter 2.
PRODUCTION OF BARE-ROOT SEEDLINGS

2.1. Introduction

Every nursery has a unique environmental, economic and social context that planners must take into account when defining the objectives, design and methods of their operation. Establishing a nursery requires careful strategic planning to address questions about its purpose, location and startup time and the products and services that the nursery will offer. Ideally, the methods used to grow plants, share knowledge and serve the community should be oriented to meet local needs.

Sprouting seeds
Photo by: M. Navarrete, IDAF

Cedrus Libani with cones
Photo by: C. Abi Faraj

The aim of this chapter and chapter 3 is to provide information to help nursery managers with propagation and management of seedlings. The first step is to select the seedling stock for cultivation. Seedlings can be produced either in containers or with bare roots by means of different procedures depending on the goal. This chapter discusses procedures for bare-root seedling production such as bed preparation, seed sowing, and growing practices to ensure a vigorous nursery crop.

The following terms are used in referring to seedling cultivation (Landis et al., 1994):

Seedling: a plant that has been grown from seed. However, the term is often used loosely to refer to many types of nursery stock, including transplants, rooted cuttings, and emblings (which are produced through micropropagation).

Stock type: forest and conservation seedlings are traditionally divided into two basic stock types:

- *Bare-root stocks* are typically grown in native soil in open fields and the seedlings are removed from the soil at the moment of harvesting.
- *Container stocks* are grown in artificial growing media in a controlled environment, such as a greenhouse, where growth-limiting factors can be manipulated.

2.2. Establishing the nursery crop

2.2.1. Seedbed preparation

The area where plants will be produced should be selected according to the objectives outlined for the nursery. Once the site has been selected, cleared and prepared for cultivation, it should be levelled so that the maximum slope is 2–3% and it has some form of drainage at the bottom.

The soil should be treated in the dry season. In this early stage of preparation, the following tasks should be completed according to the nursery design:

- Plant distribution and bed orientation,
- Design and installation of irrigation systems and roads,
- Optimization of field efficiency (the area containing growing trees divided by the area under cultivation in a given field) according to the irrigation design.

In new nurseries established on sites that have not previously been used for tree cultivation, the next step is to modify soil conditions to promote root development. Methods include:

- Subsoiling or deep ploughing (>40 cm),
- Harrowing,
- Disinfection and addition of organic matter,
- Light harrowing.

Seed bed preparation
Photo by: R. Hierro

If the basic work is to be *ploughing*, the ideal season for preparation is autumn, when the soil is in good condition. After preparation, the soil should be left over winter. In spring, when it is dry enough to be worked, the seedbeds can be prepared for sowing. If the basic work is to be *subsoiling*, the ideal season for this is at the end of summer, when the soil is dry, prior to the first autumn rains. Additional harrowing should be done when the soil is in good condition in autumn, with irrigation if necessary. In spring, as above, the site is given its final preparation, generally light harrowing or one pass of a rotavator.

Beds should be laid straight and at the proper intervals between irrigation lines. Work starts with rotavating or lightly harrowing and then staking out to mark the bed width and length, or ridgers with small bars on a frame can be used for checking distances. The soil must remain soft to a depth of 7–15 cm to facilitate drainage and sowing.

2.2.2. Seed sowing

Once the bed preparation and layout have been finished, the nursery is ready for sowing. Successful sowing depends on several factors which must be taken into account:

Sowing of *Juniperus excelsa* seeds
Photo by: R. Colomer

1. **Sowing date:** sowing must be done as soon as temperatures allow good germination and while the risk of disease is low. Sowing of Mediterranean species is normally done in spring (March/April) (e.g. *Pinus* species). However, it can be done in autumn (e.g. *Juniperus* species) to avoid stratifying or storage, or in winter (e.g. *Quercus* species), but this involves a series of additional precautions, such as protection against predators, frosts, etc.

2. **Sowing depth** is crucial to uniform plant germination. As a general rule, sowing depth should be 1.5–2 times the maximum diameter of the seed.

3. **Seedbed density:** the density at which a nursery chooses to sow depends on the seedling characteristics desired at harvest and the economics of seedbed use. Seedling spacing within a row should be as uniform as possible for optimum growth. On the basis of percentage yield, a density is chosen which will give the maximum number of shippable seedlings per square metre at the lowest cost. Reduced density results in better seedling quality by providing better growth conditions per unit area. However, the larger area required for production may make this economically unfeasible.

Juniperus excelsa seeds
Photo by: M. Navarrete, IDAF

4. **Sowing formula:** Once seed density has been decided, a formula must be used to calculate the amount of seed necessary to produce the desired number and size of seedlings. Sowing is usually done in rows in bare-root cultivation to allow for mechanized weeding. The sowing rows are 10–15 cm apart for conifers and 15–20 cm apart for broadleaved species, and sowing is done on a completely flat seedbed (Table 5).

Table 5. Bare-root sowing densities for some forest species

Species	Seeds/m2	Species	Seeds/m2
Acer spp.	200 / 300	*Fraxinus* spp.	120 / 150
Alnus spp.	350	*Malus* spp.	150 / 200
Cedrus spp.	250	*Pinus brutia*, *Pinus pinea*	200 / 300
Cornus spp.	300 / 400	*Prunus* spp.	150 / 200
Crataegus momogyna	200 / 250	*Pyrus* spp.	150 / 200
Abies spp.	250	*Sorbus aria*	200 / 250

The period from sowing until the plants develop true leaves is a critical time, as both the seed and the recently emerged seedling are very vulnerable to environmental factors. Certain precautions must be taken:

- Irrigation during germination must keep the soil moist but avoid swamping.
- The nursery must be protected from animal predators. In some cases the only solution is to use plastic or metal mesh covers.
- Suitable cultivation conditions (low pH, good drainage, low soil organic matter content, etc.) must be maintained to reduce vulnerability to pests and diseases.
- Weed control in the seedbeds is essential.

2.3. Seedling growth

The growth phase covers the time from plant germination to the start of the hardening process prior to transfer to the planting site. The following factors must be controlled during this phase:

2.3.1. Shading and predation

Germination and early seedling growth are critical times in the nursery, because seeds and seedlings are vulnerable to the environment and predators. Predators such as birds and rodents

are a serious problem during germination. Shade systems comprising a metal or wooden frame the width of a bed and 2–5 m in length covered with a fixed or movable fibreglass screen can be placed over the bed until seedcoats are shed. These shade systems can be easily removed, thus adapting to the production needs of the nurseries, and allowing other forms of plant protection (against hailstorms, for example) to be used during cultivation.

Some species also have different light needs during the germination and growth phase (e.g. *Fraxinus* and *Sorbus*). Shade-loving species must be protected throughout these periods by shade covers. Other species (e.g. *Cedrus* and *Pinus*) need to grow in full light to prevent poor or abnormal growth.

Seedbed in nursery
Photo by: M. Navarrete, IDAF

2.3.2. Soil fertility in bare-root nurseries

One important goal of nurseries is to maintain an adequate level of soil fertility to produce high-quality seedlings. There is no fertilization formula to cover all possible nursery situations and species, or even a prior fertilization programme that can be extrapolated to all soil types, as they vary in their physical and chemical characteristics. In the case of bare-root nurseries, the most commonly used fertility management methods are: 1. controlling soil pH, 2. organic matter, and 3. fertilization.

1. **Controlling soil pH:** soil pH in bare-root nurseries must be adapted to suit the species cultivated. Soils which are too acidic can be corrected by adding calcium sulphate (gypsum), calcium carbonate or slaked lime to obtain an optimum pH of 5.5–6.

2. **Organic matter (OM):** OM increases the cation exchange complex, soil buffer capacity, and water retention, and supplies some nutrients and micronutrients needed to produce high-quality seedlings. In nurseries, organic fertilizers aim to restore the OM content, which plant cultivation and extraction tend to decrease. Maintaining a value of between 2 and 4% is recommended. This must not be excessive because of the risk of encouraging plant diseases. This replacement fertilization can be done every 3 or 4 years at a rate of 20–30 tonnes of OM ha^{-1}.

3. **Fertilization:** Fertilizers can be *organic* (such as compost or manure) or *inorganic* (salts of nutrient elements), and they are incorporated during cultivation to compensate soil nutrient extraction. Nutrient elements must be balanced so that plant growth is appropriate and the morphological and physiological condition enables greater outplanting survival and growth. The macronutrients required must be determined in each case according to the species cultivated, soil analysis and commercial fertilizer features (Table 6). Fertilization tends to modify the pH, either causing acidification (nitrogenated and phosphoric fertilizers) or increasing soil alkalinity. Mineral fertilizer must not modify the soil reaction value, so it is advisable to use the following substances:

Seedlings of *Quercus cerris*
Photo by: M. Navarrete, IDAF

Basic soils: *Ammonium sulphate* is recommended for use as a nitrogenated fertilizer as it eliminates salinity.

The soil must contain organic material or, failing that, such material must be added to enable the release of Nitrogen sulphate

Superphosphate is indicated for use as a phosphorus fertilizer because of its low pH, which is easily neutralized.

Potassium chloride is recommended as a potassium fertilizer for the same reason.

Acid soils: Phosphorus (dicalcium phosphate or Thomas slag), potassium (potassium sulphate or plant ash) or calcium fertilizers can be applied.

Table 6. Some fertilizers commonly used in nurseries, with their analyses and factors for calculating application values (van den Driessche, 1984)

Fertilizer	Analysis	Nutrient	%	Factor[1]	Nutrient	%	Factor	Nutrient	%	Factor
Ammonium sulphate $_{(NH4t)2SO4}$	21–0–0	N	21	4.76	S	24	4.17			
Ammonium nitrate $_{NH4NO3}$	33–0–0	N	33	3.03						
Urea $_{CO(NH2)2}$	45–0–0	N	45	2.22						
Sulphated urea	32–0–0	N	32	3.13	S	22	4.55			
Calcium nitrate $_{Ca(NO3)2}$	16–0–0	N	16	6.25	Ca	24	4.17			
Ammonium phosphate $_{NH4H2PO4}$	11–55–0	N	11	9.09	P	24	4.17			
Diammonium phosphate $_{(NH4)2PO4}$	21–55 – 0	N	21	4.76	P	24	4.17			
Calcium superphosphate $_{CaH4(PO4)}$ + $2CaS_{P4}$ $2H_{2O}$	0–20–0	P	8.7	11.5	Ca	20	5	S	11	9.09
Triple superphosphate $_{Ca(H2PO4)2}$	0–45–0	P	19.6	5.1	Ca	14	7.15			
Phosphoric acid $_{H3PO4}$	0–52–0	P	22.7	4.4						
Potassium sulphate $_{K2SO4}$	0–0–50	K	41	2.44	S	17	5.89			
Potassium chloride KCl	0–0–62	K	51	1.96	Cl	46	2.17			

[1]The factor is used to determine the weight of a nutrient in a fertilizer. For example, to provide 50 kg of N as ammonium sulphate (21–0–0), it must be multiplied by the factor N: 50 x 4.76 = 238 kg ammonium sulphate

The equipment and method most appropriate for fertilizer application depends on the nutrient(s) used as well as the timing of the application during the rotation. For example, broadcast spreaders with rotary flingers that spread fertilizer over 8–10 m swaths can be used for P or a application prior to seedbed formation. These pre-sowing fertilizers are normally disked into the soil. Broadcast spreaders can also be used to apply N, K or other nutrients to the soil surface, covering four or

five beds of 1–2 m width each in a single swath. Fertilizer loss can be reduced with a worm gear drive bar, which meters out fertilizer and allows it to fall via gravity on individual beds (van den Driessche, 1984).

Nursery with irrigation system
Photo by: M. Navarrete, IDAF

Fertilization method
Photo by: R. Colomer

Species respond in different ways to different types of fertilization; some general rules are as follows:

1. **Fertilization with N:** Many conifers respond rapidly to fertilization with N. The sooner the application, the better the response; fertilizer is best applied little and often. In general, it should not be applied after July so as to prevent loss of frost and drought resistance in the plant and to begin the hardening process.

2. **Fertilization with P:** The response to P is slower, but P fertilization may be very necessary when establishing a new nursery. The fertilizer used must ensure that the plants absorb the nutrient adequately, so it must be placed close to the roots and under suitable pH conditions. Fertilizer applied as a top dressing is usually quite ineffective, except on loose-textured soils or when highly soluble fertilizers, like ammonium sulphate, are used. Calcium superphosphate (0–20–0) is a fertilizer for sandy acid soils, because it supplies Ca and S as well as P and tends to reduce soil acidity. Triple superphosphate (0–45–0) can be used if soil pH or Ca level is very high. Finally, ammonium phosphate (11–55–0) must be used if the superphosphate does not provide enough P.

3. **Fertilization with K**: Potassium does not show a rapid response either. Fertilization must be done before sowing and must be supplemented with a top dressing in July and during the second year.

4. **Fertilization with Ca**: Ca content must be checked to avoid an increase in pH, which benefits the proliferation of pests. Modifications are made for pH values below or equal to 5. Fertilization with dolomite is preferable in forest nurseries when adding Mg.

Fertilizer should be applied early in the morning and irrigational washing done afterwards to prevent any leaf burn or damage. Monthly fertilization programming must be adapted to production, so the first application of fertilizer is usually delayed until the seeds have germinated and are completely established (4–6 weeks after sowing). Table 7 provides general guidelines on the supply of nutrients in a typical cultivation cycle.

Monitoring of N values is the most important factor in controlling seedling growth, as they vary considerably from one cultivation phase to the next. The general rules are:

- Moderate N levels during the establishment phase
- High levels during the growth phase,
- Low levels during the hardening phase.

Table 7. Nutrients applied during a typical cultivation cycle (adapted from van den Driessche, 1984)

Nutrient (range kg ha^{-1})	N	P	K	Ca	Mg	S
Pre-sowing treatment	22–56	5–87	18–148	750–2240	22–50	14–185
Top dressing in the first year	36–152	10–139	23–62			9–130
Top dressing in the second year	53–306	20–140	23–208		28–33	33–248

Irrigation system in a bare-root nursery
Photo by: R. Hierro

In general nurseries tend to homogenize fertilization with a standard dose for all species, which is clearly not ideal, but is the only practical thing to do when organizing production: for example, by using a 3–6–6 N-P-K fertilizer, which means 3% N, 6% P and 6% K. In any case fertilizers must never be dosed empirically. They must always be applied on the basis of signs of deficiency or after a specific problem (such as frosts), when the seedling plants require a stimulus to recover.

2.3.3. Irrigation

A water supply of sufficient quality and quantity is the most important factor in choosing a forest nursery location and for all potential water-management purposes. Requirements can be found either by consulting tables of average water requirements in various regions or by obtaining climatic data from a station at or near the nursery site and calculating seasonal and annual water requirements. Irrigation techniques must follow the current trend towards mechanized systems, given the area and frequency of irrigation, which makes a manual system unfeasible or very costly. The main irrigation systems used in bare-root nurseries are:

- **Flood irrigation:** this is done by completely flooding cultivation beds, which are separated by border ridges. It is the less advisable irrigation system and is less efficient than sprinklers.
- **Sprinkler irrigation:** this is the most common irrigation system used in forestry nurseries, either alone or combined with other systems. Varieties include rotating and micro sprinklers.

As with fertilization, a suitable programme of irrigation intensity and frequency needs to be drawn up for the different plant growth phases:

1. **Irrigation during the germination phase:** this starts immediately after sowing, for which the beds must be kept well irrigated with frequent, light watering. The quantity must be gradually increased in order to maintain moisture levels in the root zone. During this phase droplet size must be carefully checked to prevent the seed being uncovered or the covering layer being removed.

2. **Irrigation during the growth phase:** the plants' irrigation needs increase. Soil moisture levels must be kept as close to field capacity as is practicable.

3. **Irrigation during the hardening phase:** the irrigation dose is controlled in order to start subjecting the plants to water stress analogous to that which they will encounter when established. This does not mean, in general, suppressing irrigation but rather spacing it out and reducing the quantity.

2.3.4. Root culturing

Bare root extraction for Shipping
Photo by: R. Hierro

Root culturing is the broad term for describing the various nursery practices implemented in the seedbed to improve seedling root growth and morphology. Two practices, undercutting and wrenching, involve the mechanical cutting of the root system with a blade drawn horizontally under the seedbed. Undercutting is the drawing of a thin, sharp blade under the seedbed parallel to the surface. The blade severs the taproot and all other roots extending beyond the regulated depth of the undercut. Wrenching, which usually follows undercutting, is done with a thicker, broader blade titled at an angle (20–30°) when drawn under the seedbed. Wrenching cuts off any newly penetrating roots and lifts seedlings. Both practices reduce height growth and promote lateral root growth, which ultimately produces a better seedling root to survive when planted. Determining undercutting depth is very important, and it ranges from 10 to 30 cm. Early root pruning (in late autumn or early winter) is recommended for broadleaved species and late root pruning (in late winter or early spring) for conifers.

The most commonly used undercutting method is mechanical, using a horizontal blade. However, manual undercutting can be done using a straight gardener's shovel dug into one side of the line of plants at an angle of 45º and at an equal distance from the plant to the depth at which pruning is required. This procedure is less efficient and less precise than the mechanized method, and many plants are left unpruned. It is only advisable for small nurseries. In all cases, it is advisable to irrigate the seedbeds to ensure root contact with the soil after pruning, thus preventing plant death.

Salix alba planted seedlings
Photo by: R. Colomer

2.3.5. Weed management

By competing with nursery plants for water, nutrients, light, and space, weeds can have a negative impact on yield and seedling quality. Uncontrolled growth of weeds is one of the main problems in nurseries, especially for bare- root seedlings. In general, it is more efficient to anticipate and prevent weed problems than to react to them once they occur.

The best approach to weed control draws on integrated pest management, which combines prevention, sanitation and control by chemical, physical or biological means. The most effective measures prevent weeds from becoming established in the first place. For example, efforts should be made to avoid transporting weed seeds to seedbeds via clothing, equipment, irrigation water, and soil amendments. Preventative measures tend to be safer and sustained over longer time periods than direct weed control and removal.

Nevertheless, some weeds inevitably become established in the nursery and direct control will become necessary. Important factors to consider when designing weed control strategies include effective methods to control certain species, the level of control that is satisfactory, costs, measures that can serve multiple purposes, and environmental impacts.

Control methods useful in nursery seedbeds may be physical, chemical or biological. Physical control includes mechanical cultivation, hand weeding, and mulching. Biological control includes crop rotation and reliance on biological enemies, and chemical control includes the use of inorganic or organic herbicides.

2.3.6. Hardening

Seedlings cultivated in nurseries grow under suitable environmental conditions for good growth: a constant water supply and a good supply of nutrients. When they are transplanted to their final destination of establishment, they are going to be met with completely different

Hardening
Photo by: R. Colomer

environmental conditions and subjected to great water stress, and to development in an edaphic environment with limitations to root formation and growth. Hardiness is the ability of plant cells to withstand outplanting conditions without suffering irreversible physical damage. In order to improve seedling adaptation to field conditions, the hardening process basically consists of controlling fertilization and gradually reducing irrigation to doses close to wilting in the last few weeks, though never compromising the survival or good physiological condition of the plants.

Seed bed during growth period
Photo by: R. Hierro

2.3.7. Lifting and shipping

Transplanting is lifting seedlings from their original seedbed to plant into the field, and therefore occurs once they have attained the morphological and physiological condition for planting out. Transplanting steps vary slightly with the time of the year seedlings are transplanted and with nursery location and conditions. Generally, seedlings should be watered well, lifted using the means available in the nursery, graded, root-pruned, packed and sometimes stored, and finally shipped. The steps to be taken are:

1. **Irrigation and lifting:** This consists of extracting seedlings from the seedbeds. Seedlings should be well irrigated before lifting. The most appropriate time is early morning or when it is damp, to reduce drying to a minimum. If possible, it should be done mechanically using undercutting or extraction blades. The soil is loosened when the blade passes and the plant is extracted by hand.

2. **Selection:** Selection is a continuous process which starts long before the seedling plants are delivered. Any seedling plant showing signs of any disease during the growth phase must be immediately destroyed, and all defective plants are periodically removed from the beds.

3. **Counting and packaging:** The plants are counted as they are packaged; counting known quantities makes it easier to check numbers for shipping and planting. The plants are packed in special boxes without being pressed together excessively, thus preventing deformation or physical damage.

4. **Storage and shipping:** The transport time between the nursery and the planting area must be kept to a minimum and it is advisable to dispatch the plants directly to the site without any intermediate storage. If storage is unavoidable because of time lags between extraction and dispatch, plants must be kept in refrigerated chambers at temperatures close to 0°C; otherwise, there may be a significant loss of viability. The plants must not be exposed to strong draughts during transport, so vehicles must preferably have a closed box body, or be hermetically sealed with canvas. Shipping must be conducted as rapidly as possible, and the loading and unloading operations must be performed carefully and without piling up the packages if they are flexible.

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Chapter 3.
PRODUCTION OF CONTAINER SEEDLINGS

3.1. Introduction

Quercus calliprinos containers
Photo by: R. Colomer

Compared to bare-root seedlings, production of container seedlings is more recent and provides several advantages, such as more efficient use of space, ease of handling, greater time available for outplanting and lower costs. Container seedlings are optimal for diverse plant production. The distinguishing feature of container seedlings is the formation of a 'plug', which results from the fusion of roots with the growing medium within a restricted space. A range of container types have emerged to meet different demands. 'Single-cell' containers tend to be more popular than 'block' containers due to the ease of separating and handling individual seedlings. In contrast to the production of bare-root seedlings, container seedling production requires less land and initial cost. Container stock is hardier during handling, shipping and storage, and offers a greater outplanting window because seedlings can be harvested almost all year round. The compact root systems facilitate outplanting, especially on difficult sites, and the cylindrical shape of the plugs provides a greater surface area to facilitate root egress.

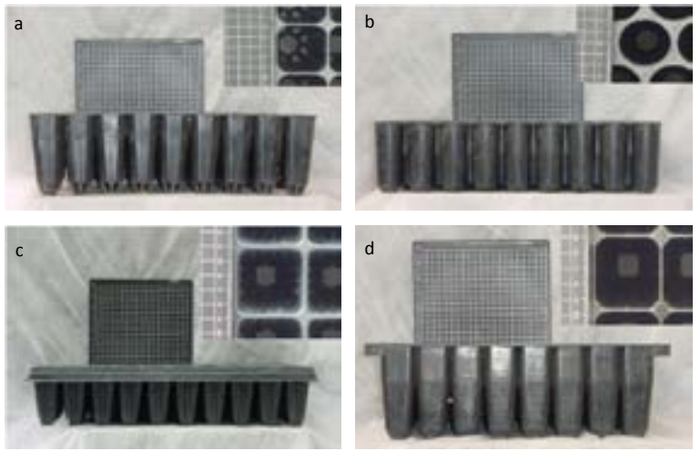
Table 8. Advantages and disadvantages of container seedling production

ADVANTAGES	DRAWBACKS
Nursery installations	
Requires smaller area and has fewer infrastructure requirements.	Cost of infrastructure, in particular if seedlings are grown in greenhouses. Requires better design and appropriate management.
Seedling cultivation	
Better control of cultivation variables: i.e. they can be adapted to the required type of plant. More uniform seedling quality. Better regulated and more precise application of irrigation and fertilization. More mechanization and reduced labour. Suitable for species which cannot withstand conventional bare-root production.	Limited volume for root growth, which can cause morphological defects in seedling roots. Difficulty with certain cultivation practices, such as growing media or fertilization. More complex planning of crop cultivation. Difficulty in cultivating species that need large root volumes or areas. High production cost—5–10 times that of bare-root cultivation for the same species and age. Greater problems with plant mycorrhization due to frequent use of sterile substrates.

Table 8. continued

ADVANTAGES	DRAWBACKS
Lifting and handling	
Reduces problems of drying and damage during shipping. Facilitates mechanization of the process.	Possible problems in recovering containers. Container weight and volume can increase operating costs.
Outplanting	
Greater plant resistance to outplanting stress, particularly under adverse conditions. Facilitates the planting process. Greater chances of root forming as the root system is not mutilated. Planting seasons can be extended in climates with long winters or early dry periods.	Problems with seedling reaction to growing outside the root plug.

3.2. Types of container



Types of containers a) 300 cc block b) 250 cc block c) 250 cc d) 300 cc block single use,
Photo by: R. Hierro

Selecting the type of container to be used is one of the most important decisions during the establishment phase of a new nursery or production of a new species. The type and dimensions of the container not only determine the amount of water and nutrients available to plants, but also bear on operational aspects of the nursery like bench size and type of filling and harvesting equipment. Changing the type of container used once production has started can be costly in terms of time and money.

Before continuing it is important to clarify some of the terminology related to nursery containers, which is broad and to some degree interchangeable. 'Plugs' refer to seedlings for landscape restoration that tend to be grown in small, individual containers called 'cavities' or 'cells'. Individual cavities are permanently aggregated into 'blocks', while cells are independent and can be inserted in or removed from 'trays' or 'racks'.

Choice of container depends on the plant species, root system morphology, target plant criteria and cost. In general, the following container dimensions are recommended for plants with these root systems:

- **Tall** containers for long taproots (e.g. oaks and some pines);
- **Short** containers for shallow, fibrous root systems (e.g. most forbs);
- **Wide** containers for numerous, thick, fleshy roots and rhizomes.

Because choosing the type of container is such a critical step, Landis et al. (1990) is a recommended reading for a more complete discussion of the biological and operational aspects of container seedling production.

Many types of container are available and each has its advantages and disadvantages. The main types of container used in forest plant nurseries are as follows:

Single-use containers


Nerium oleander seedling
Photo by: M. Navarrete, IDAF

- **Polyethylene bags:** these were the most commonly used containers for forest plant production until the appearance of the new types of container, and are still used today. They are transparent or opaque plastic bags with holes in the lower part to facilitate drainage and are defined by the gauge of the plastic (100–200 µm), the diameter (7–15 cm ø) and the total length (15–25 cm). These containers have certain advantages which have meant they are in widespread use, such as their low cost, availability everywhere and ease of adaptation to different species and volumes. However, in the case of forest species they cause problems of root spiralling as well as rooting in the nursery bed when placed directly in the soil. At present their use is not generally advisable. Some species with fasciculated root systems which do not penetrate deeply and require a large volume (for example wild olive and carob) have responded well to production in this type of container, so they may be of interest in certain circumstances.

The low initial cost of polyethylene bags is a very questionable criterion for choosing them, as filling the bags and moving and shipping them in the nursery, from the nursery to the site and on the outplanting site itself place great demands on labour and make mechanization difficult, thus increasing the real cost and providing an inferior plant quality to other containers.

Multiple-use containers


Sowing in seed trays
Photo by: E. Chnais, AFDC

- **Single, free-standing containers**

A variety of single-cell, free-standing containers have been developed to grow native plants under different conditions, particularly trees and woody shrubs. These containers come in a range of sizes and shapes and are generally made from hard flexible plastic. Square containers are recommended over round ones because of more efficient irrigation and use of space.

- **Exchangeable cell containers on a tray or in a rack**

These are individual cell containers arranged at a particular density on a tray or in a rack. Although there are many types, the best known is the 'Leach' type container (Table 9), such as:

* *Conifer Super-Leach™ (CSL)*, 25–47 mm in diameter and 165–220 mm in length, with a capacity of 123–205 cm^3. This model has smooth container walls with ridges inside.

* *Broadleaf Super-Leach™ (LSL)* 52–56 cm in diameter and 165–175 mm in length, with a capacity of 235–305 cm^3 and undulating walls.

Although their capacities are somewhat limited, moderate-growth species can remain there for two growing seasons if the substrate is correctly fertilized.

Table 9. Characteristics, volumes and dimensions of Leach container models

Model	Cells/tray	Cells/m^2	Depth (cm)	Capacity (cm^3)	Recommendations
M – 32	48	320	16.5	205	Slow growth conifers
M – 20	35	265	16.5	235	Common conifers
M – 30	35	265	17.5	305	*Quercus* spp.

- **Block containers made up of many cavities or cells**

These consist of a block, generally rectangular, which contains a certain number of regularly distributed cells. These blocks are usually quite light and easy to handle, but do not have individual cells. The cells have auto-pruning and anti-spiralling systems. High cultivation densities are possible. Table 10 shows the characteristics of one type of tray (Forest-pot, Spanish manufacturer).

Table 10. Characteristics, volumes and dimensions of block containers

Model	Cells/tray	Cells/m2	Depth (cm)	Capacity (cm3)	Recommendations
FP 200	50	390	15	200	Slow growth conifers
FP 250	44	340	-	250	Common conifers
FP 300	50	390	18	300	*Quercus* spp.

After seedlings have been transplanted, the containers should be disinfected with hot water or water mixed with 10% bleach to prevent infection by fungi or other diseases during the next crop.

3.3. Growing media

Growing components a) vermiculite perlite b) Peat
Photo by: R. Navarro, UCO

After selecting the type and size of container, the next important decision is choosing the most appropriate growing medium. The substance through which roots absorb nutrients and water, the growing medium consists of either natural or artificial soil (the latter is more commonly used). Generally composed of peat moss and compost, artificial media have a texture based on the size of individual particles but lack structure because the particles are only loosely bound. Texture is an important factor to consider when choosing a growing medium to ensure optimal porosity for plant growth.

Three broad types of growing media are used in container seedling production:

1. **Seed propagation media** are used for germinating seeds and growing germinants. These media must be sterile to prevent fungal infection and have fine texture to retain moisture around seeds and germinants.

2. **Root cutting media** are used for cuttings subject to frequent misting. These media must be highly porous to prevent moisture saturation and allow sufficient aeration for root growth.

3. **Transplant media** are used for small seedlings and rooted cuttings that are transplanted into larger containers. These media are usually coarser and contain compost rather than *Sphagnum* peat moss.

To facilitate growth of mycorrhizal fungi and other beneficial organisms, 10–20% of natural soil or 'duff' (forest litter) can be added to the growing medium. See Landis et al. (1990) for further details.

3.3.1. Components of artificial media


Filled seed trays
Photo by: R. Colomer

A typical artificial growing medium consists of two or three components chosen according to their physical, chemical or biological characteristics. Here the term 'component' refers to a substance comprising a large percentage (> 10%) of the medium. An 'amendment' is additional material making up less than 10%. Organic and inorganic components are usually combined in proportions that maximize their complementarity and generate physical and chemical benefits. Amendments such as wetting agents and fertilizers are also sometimes added during the mixing process.

- **Organic components:** common organic components include compost, peat moss, sawdust, coconut coir and rice chaff. These substances are light and provide suitable substrate structure (micropores), increase water retention, raise cation-exchange capacity, improve resistance to compaction and have a high nutrient content. The quantity of organic components varies between 25 and 70%. The most commonly used are:

  Peat moss: there are various types, although the most commonly used is *Sphagnum*. Thick structure peat is used for long cycles and medium peat for short cycles. The ideal base mix would consist of 70–80% *Sphagnum* and 20–30% black peat.

  Pine bark: this is suitable for growing most forest species. Nevertheless, it is advisable to use bark at least two years old rather than fresh bark. As regards its fertility, some studies seem to indicate that Ca, Mg and P do not need to be added, but N and K do.

- **Inorganic components:** These components, which include sand, vermiculite, gravel, perlite, pumice and polystyrene beads, improve growing media by providing macropores, which improve aeration and drainage. They are also sterile. The three most important inorganic components are:

  o *Vermiculite* is an expanded aluminium silicate with characteristic weight and volume properties. It has high water-retention and cation-exchange capacities. Its pH is approximately 7. Its proportion in the mix varies between 20 and 40%.

o *Perlite* is a natural aluminium silicate which provides the substrate with suitable drainage, weight and porosity. Its pH is relatively neutral and it is added to mixes at a rate of 10–30%.

o *Sand* is one of the components most often used in the past because it is relatively cheap and easy to find. It provides the substrate with good porosity, but it must be uncontaminated and its proportion in the mix must be checked.

3.3.2. Growing media formulation

Juniperus excelsa sowing
Photo by: R. Colomer

Growing media preparation is one of the most important decisions in the production process. **Natural growing media** have many limitations given their heterogeneity, ease of infection, difficulty in programming fertilization and irrigation, etc.; all this means that they are currently being abandoned. In contrast, **artificial growing media** are simple to formulate, have stable and homogeneous characteristics, are easy to use and facilitate crop planning, all of which favours their general use. Finally, **semi-natural media**, which are mixes of natural and artificial components, are half-way between the previous two as regards their characteristics, and have some limitations (e.g. component heterogeneity) but also some advantages (e.g. mix stability at the planting site, mycorrhization, etc.), which make them an interesting alternative to be considered in nurseries.

The mixes tend to be either for general use in the nursery or specifically for conifers or broadleaf species. Some examples of media are given as a guideline (Table 11), bearing in mind that the final formulations must be carefully considered for each specific nursery.

Table 11. Different growing media formulation types according to components

Semi-natural media	Peat (50%): Loamy sand (50%) Peat (75%) : Loamy sand (25%) Peat (30%) : Loamy sand (35%) : Bark (35%). Peat (50%) : Loamy-clayey earth (50%)
Artificial media	Peat (50%) : Perlite (50%) Peat (75%) : Perlite (25%) Peat (80%) : Perlite (20%) Peat (75%) : Vermiculite (25%)

Fertilizers, surfactants, superabsorbents, lime, mycorrhizal inoculums and other materials are routinely added to growing media during the mixing process. Incorporation of these substances should be as homogeneous as possible due to the fact that plant roots have limited access to the growing medium in the small container volume normally used in nurseries. Growers should be fully aware of the exact contents and amounts of these amendments when purchasing commercial growing media. The following are perhaps the most common amendments:

- **Limestone** (referred to as 'lime' in horticulture) has traditionally been added to growing media when increased pH and Ca availability is necessary for plant growth. However, more modern methods of supplying Ca are widely practised and it is not recommended to add limestone unless the target plants require a neutral or alkaline pH.
- **Starter fertilizers** provide a small 'starter dose' of soluble granular fertilizer and are found in some commercial growing media. Use of starter fertilizers is suitable when fertigation (irrigation with water containing liquid fertilizer) is unavailable, to improve seedlings' access to mineral nutrients. However, care must be taken not to apply excessive soluble fertilizer, which can result in salt production.
- **Controlled-release fertilizers** emit nutrients at a specific rate over a specific time period rather than all at once.
- **Mycorrhizal inoculum** is a small amount of mycorrhizal fungi added to the growing medium. Native plants can be inoculated with mycorrhizal fungi by incorporating the inoculum into the growing medium at the time of mixing. As with the above amendments, it is recommended to test this method before adopting it on a large scale.

3.4. Sowing

Laurus nobilis direct sowing
Photo by: R. Colomer

Choosing the best method for sowing seeds in containers depends on the species, type of seed and seed quality. Here the discussion focuses on direct sowing, but nursery growers should be aware that several options exist beyond standard methods for improving the efficiency and effectiveness of seed sowing, which should be explored when growing unfamiliar species.

Direct sowing is relatively fast, easy and cost-effective due to minimal seed handling and labour requirements. Mechanization of this method is an option for large-scale operations. To optimize the efficiency of direct sowing, seeds should be abundant, easy to handle, uniform in shape and size, and have simple dormancy treatments as well as a high germination rate. The better the requirements for germination of a species are understood, the more successful the sowing process will be. Because rates of seedling emergence in the nursery will likely vary from those measured in the laboratory, it is recommended that growers test germination outcomes in containers to determine the number of seeds needed to obtain the desired number of seedlings. The following measures will improve the success of direct sowing:

- Determine the number of seeds necessary to achieve the production target.
- Determine a method of treating seeds to break dormancy.
- Sow seeds in the centre of containers or according to the spatial orientation that optimizes seedling growth and development.

Spartium sowing
Photo by: R. Colomer

- Avoid damaging the emergent root of pre-germinated seeds, which can be used under certain circumstances.

Control of sowing depth follows the same criterion as previously mentioned, leaving the seed buried at a depth 1–1.5 times its smallest diameter. Seed can be covered with the same growing medium but it is more advisable to cover it with perlite, vermiculite or pure sand, which prevent the formation of layers of moss on the container surface.

In some cases seeds may have to be germinated in special containers and then transplanted. This is usually done with species that are difficult to germinate (e.g. *Arbutus unedo*) and guarantees a homogeneous crop. The main drawback is that it is very labour intensive, but it may turn out to be more economical in the general cost analysis as it considerably reduces losses caused by a high number of failures in cells.

Cultural operations include:

- **Replacement of failed plants:** empty cells represent a significant loss of resources. In general, if the shortfall is over 15%, it is advisable to replace. This must be done as soon as possible, normally 10–15 days after germination to avoid problems with transplanting.
- **Thinning:** having more than one plant per cell results in a loss of quality and compromises the plants' survival when planted out. Conventional practice is to eliminate all double bases once plant development has been ensured.

Seeds sowing
Photo by: R. Colomer

3.5. Seedling growth

3.5.1. Irrigation

As the single most important element determining plant health and growth, water is essential for photosynthesis, nutrient transport and cell expansion and development. Irrigation is therefore the most important activity of day-to-day nursery operations, and requires careful planning and execution to insure that timing, methods, and quantities of water are optimal for plant growth. Adequate watering is especially critical for plants grown in containers, because their confined roots are entirely dependent on irrigation for water. On the other hand, excessive water can cause root disease and impede seedling growth. Careful design and operation of the irrigation system is fundamental to successful nursery management.

The most frequently used irrigation system in nurseries for producing plants in containers is by sprinklers, either on stands or suspended when operating in a greenhouse or under a shelter. The following considerations should be borne in mind:

- The cells have a small exposed area in comparison with their volume, so sufficient irrigation doses must be provided to wet the growing medium.
- Some species, above all broadleaf ones, can intercept a large amount of irrigation water, even managing to stop it reaching the medium.
- Water losses can be very high, especially in the case of suspension systems, with only a small amount of water reaching the roots (13–26% in suspended systems), which makes the irrigation system expensive and complicated.

Water requirements vary with the crop phase:

1. **Sowing phase:** the containers must be completely saturated to ensure sufficient moisture for seed germination.
2. **Growth phase:** once the plant has started to grow actively, the medium must be kept at its field capacity to create optimum conditions for growth.
3. **Hardening phase:** irrigation is reduced until the plant shows signs of wilting.

3.5.2. Fertilization

Fertilization is another important aspect of successful plant production in nurseries. Because seedlings rapidly deplete resources stored within seeds, and cuttings have limited reserves, nursery plants depend on nutrient uptake from the growing medium. Proper fertilization provides an adequate supply of micro- and macronutrients that can stimulate plant growth at rates three to five times greater than normal. The following section describes some proven fertilization practices to grow native plants in small nurseries.

Soil testing kit
Photo by: M. Navarrete, IDAF

Two fertilization methods are commonly used in container seedling production in low-tech nurseries: **granular fertilizers** and **controlled slow-release fertilizers** (CSRF).

Direct application of dry granular fertilizers to the surface of containers, a process known as 'top dressing', should be avoided due to the risk of 'burning' succulent plant tissue. In contrast, controlled-release fertilizers can be top dressed as long as each container or cell receives an equal number of prills. In the case of larger containers (> 4 L), a special drop-type application wand can be used for top dressing. This tool regulates the fertilizer dose applied to the base of plants and prevents fertilizer granules from coming into contact with foliage, which would raise the probability of burning the plant when it was watered.

However, incorporating dry granular fertilizers or controlled-release prills into the growing medium avoids these risks. Dry granular fertilizers are often incorporated as a 'starter dose' by the manufacturer, as mentioned earlier. Controlled-release fertilizers are recommended to growers who wish to mix their own growing medium, although measures should be taken to ensure uniform distribution in the medium without damaging the prill coating. Rupturing this coating releases the soluble fertilizer and potentially leads to severe salt injury to the plant. In view of these risks, it is recommended that nurseries purchase growing media already mixed with controlled-release fertilizers.

Table 12. CSRFs used in producing plants in containers

Commercial name	Type of fertilizer	Nutrient analysis	Release period	Recommended dose (kg/m3)
Macronutrients				
OSCOMOTE® 13–9–13	Pelletized granules	17% N 9% P_2O_5 13% K_2O	70–90 days at 21°C	3–5
OSCOMOTE® 18–6–12	Pelletized granules	18% N 6% P_2O_5 12% K_2O	8–9 months at 21°C	4–6
Triple superphosphate	Granules	46% P_2O_5 14% Ca 2% S	-	0.6–1.2
Dolomite	Granules	17% Ca 12% Mg	-	3–5

When the fertilization methods and doses have been defined, the required programming can be done. The following considerations must be borne in mind:

1. **Sowing phase**: the first fertilizer application is normally delayed until germination is complete and the first true leaves have formed (4–8 weeks after sowing) to avoid any damping-off problems or direct damage to the plant caused by fertilizer action.

2. **Growth phase:** this is the phase when most fertilization takes place. It can be done *constantly*, maintaining a fixed nutrient concentration, or *periodically*, injecting higher concentrations at regular intervals (e.g. on alternate days or weekly). The first method reduces the risk of salinization and distributes the nutrients more homogeneously, although periodical fertilization tends to be used for reasons of simplicity and cost.

3.5.3. Weed management

Weeding within the containers is usually unnecessary, as the medium does not have any weed seeds initially, provided it is artificial and is irrigated by sprinkling. If aerial dispersal of weed seeds occurs, weeding should be done by hand. In order to prevent weed growth in the soil below the containers, it is covered with a sheet of black plastic which impedes germination of the seeds underneath.

Growth phase of *Pinus pinea* seedlings
Photo by: R. Navarro, UCO

A problem analogous to that of weeds is the growth of *cryptogams*, which tend to cover the soil surface in the container in a continuous layer. This reduces water and nutrient infiltration. The most common cryptogams are mosses (bryophytes). The simplest method for preventing their appearance is to cover the surface with sand or perlite (0.5–1 cm in depth) to discourage their development and to control irrigation.

3.5.4. Hardening

Before outplanting, nursery stock should be subjected to horticultural practices that promote hardening, which improves plant survival and growth by increasing durability and stress resistance. Although the result of internal processes, hardening manifests itself externally in thickened stems, tough leaves, and leaf abscission in the case of deciduous species. Without hardening, plant growth suffers and the likelihood of winter mortality increases after outplanting. Growers should dedicate substantial time and effort to learning effective hardening techniques to ensure their plants endure upon leaving the nursery.

The way to induce hardening has already been described in the chapter on bare-root plant production (section 2.3.6). The following points should be borne in mind:

- Once the plant reaches the desired size, growing medium moisture content must be reduced, subjecting the plant to variable degrees of stress according to the species and required characteristics.
- Once the plant has reached 80% of the desired height, the nitrogen concentration in the fertilizing solution must be decreased to reduce height growth prior to planting, and thus enhance lignification. The P and K concentrations can be maintained, which allows growth of the root and of the root collar diameter.
- It is advisable to take the plant out of the shade (if any) one month before shipping it to the outplanting site.

3.5.5. Lifting and shipping

Once plants reach target specifications and have been sufficiently hardened they can be harvested and delivered to clients. In the traditional method of growing nursery stock in fields, nursery managers would 'lift' plants out of the soil at the time of harvest. The term 'lifting window' is still used today to refer to the time when plants have reached maximum hardiness and stress tolerance (usually between late autumn and early spring in temperate climates) and are therefore in optimal condition for harvesting.

Shipping phase
Photo by: R. Navarro, UCO

Most containers are designed to make the extraction and shipping phase easier. In some cases a pallet system is available, which facilitates handling; in others, the structure of the trays makes transport simple. Other containers, like plastic bags, are complicated to handle, given their weight and flexibility, which increases shipping costs considerably. The considerations to be taken into account in this phase have already been described in the section on bare-root plant production.

Mediterrean forest ©
Photo by: C. Danelutti

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Chapter 4.
PLANTING OUT

4.1. Introduction

There are a number of ways in which trees may be grown on forest and agricultural land, including as conventional woodland (high forest), coppice, widely spaced tree systems (agroforestry), short rotation coppice to produce firewood or charcoal, or even as isolated trees, and this chapter describes these systems in more detail. Woodland will normally be planted with the intention of growing either timber or non-timber products for sale or for protection purposes, and it can usefully be used on public and private land or in a diversified landscape. Forest managers will also want to consider the important implications for landscape and conservation which are offered by forestry.

Another essential factor to be considered before the establishment operations is the objectives. Failure to make these clear from the outset will lead to difficulties and mistakes in all the subsequent operations. Some major objectives of reforestation in Lebanon are landscape restoration, wildlife conservation and recreation. The main steps in establishing new plantations are:

- Choice of species
- Establishment
- Maintenance
- Protection

4.2. Choice of species

The right choice of species is essential for meeting the selected objectives of forest plantations. In Lebanon climatic conditions are generally restrictive for tree growth, although a wide range of species can be grown. Before considering establishment techniques, it is useful to examine the range of species available to foresters.

Nursery overview
Photo by:M. Navarrete, IDAF

4.2.1. Native and exotic species

Native species are those that have natural populations in a given country. In Lebanon, only a few native species are suitable for commercial and landscape restoration purposes, so those will be the main species cultivated in nurseries and used in reforestation programmes. The native tree category is helpful in the context of the conservation of semi-natural woodlands and in the improvement of plantation forestry to meet wildlife management and conservation objectives.

The introduction of exotic species into Lebanon has a long history. The main reason for it has been that several introduced species grow well in difficult site conditions. The main native species that are potentially useful in Lebanon are listed in Table 13.

Table 13. Main native species of potential use in Lebanon

Native species		
Gymnosperms	**Angiosperms**	
	Trees	**Shrubs**
Abies cilicica	*Acer syriacum*	*Arbutus andrachne*
Cedrus Libani	*Alnus orientalis*	*Arbutus unedo*
Juniperus excelsa	*Celtis australis*	*Crataegus monogyna*
Juniperus oxycedrus	*Ceratonia siliqua*	*Myrtus communis*
Pinus brutia	*Laurus nobilis*	*Nerium oleander*
Pinus pinea	*Platanus orientalis*	*Pistacia palaestina*
	Populus alba	*Rosa canina*
	Quercus calliprinos	*Rosmarinus officinalis*
	Quercus cerris pseudocerris	*Spartium junceum*
	Quercus infectoria	*Thymbra spicata*
	Salix alba	

4.2.2. Site factors used in species selection

A suitable choice of species is fundamental when growing forest trees and is possible only if the characteristics of the site and the species are properly understood. Factors which have a marked influence on tree establishment and subsequent growth are soil, local climate and topography. Different tree species are adapted to different conditions. Within species, differences in races or provenances are important. However, there is a risk of over-complicating the process of matching species to site and the use of a wide range of species is likely to introduce management and marketing problems.

Stock types of *Pinus pinea* seedlings
Photo by: R. Navarro, UCO

4.3. Stocking

4.3.1. Sowing vs planting

Depending on the forest propagation material to be used, two methods of implantation can be used: sowing and planting. Sowing means placing seeds in ground that may or may not have been previously prepared, while planting involves introducing nursery-produced plants of varying age and size, depending on the species, which are established in previously prepared ground.

The choice of planting or sowing is determined by various factors, which must be taken into account when deciding on the most suitable method for a specific reforestation site (Table 14).

Table 14. Advantages and disadvantages of the sowing and planting methods

SOWING	PLANTING
Seasonal factors	
1. Seasons must be appropriate for the species to be introduced. 2. Soil conditions must be favourable; soil must be permeable and not too stony. 3. Little risk of predation. 4. Sowing conditions on dunes and agricultural land must be good.	1. There are no limitations to season, except as regards the choice of species and type of reforestation. 2. It is the most suitable method for climatically difficult seasons, and the one that benefits most from correcting soil limitations.
Cultivation factors	
1. The species must have relatively large seeds. 2. Competition with shrubs in the early stages must be reduced. 3. Uncontrolled density levels. 4. In areas with no existing vegetation, the species to be introduced must be robust.	1. No limitations with regard to species. 2. Initial density is controlled. 3. The forest will be naturally pruned late or will require artificial pruning.
Social factors	
1. Little specialist labour is required. 2. Longer restricted grazing periods are required.	1. A lot of specialist labour is required. 2. Grazing restrictions are shorter than with sowing.
Financial factors	
1. Overall it is cheaper, though the results are more uncertain. 2. Extra seeds are needed, and they must be of suitable quality. 3. Initial cultural care will be greater than for planting, except for spot seeding.	1. It is more costly but the results are more reliable. 2. Fewer seeds are required so their quality and origin can be better controlled. 3. It requires a good network of forest nurseries. 4. The cost of cultural care is lower than for sowing, except for spot seeding.

Sowing is carried out with species whose seeds germinate easily, rapidly and at low cost, and that are abundant and easily harvested in the area to be reforested (e.g. *Pinus brutia)*. The site soil must be deep (rootable depth), with a certain degree of moisture; soil preparations must be able to penetrate the soil sufficiently and provide good conditions for root development. Sowing can be done in separate spots (the seeds are sown in open, square pits in the ground), in lines

Pinus brutia detail
Photo by: E. Chnais, AFDC

Quercus seedlings
Photo by: M. Navarrete, IDAF

(the seeds are distributed in open drills in the ground) or broadcast (the seeds are scattered randomly all over the area to be reforested). The seed should generally be buried no deeper than 1.5–2 times its maximum dimension. Sowing should preferably take place in autumn, depending on the species, climatic conditions in the area and risk of predation.

Planting is still the best alternative for establishing forest plantations in Mediterranean countries (Table 14). There are several planting stock possibilities. Planting stock received from the nursery must be healthy, well balanced (at least an even root/shoot ratio), undamaged and free from pests and diseases. Generally younger (smaller) plants are preferred for planting in exposed localities, while older (larger) ones are used on more fertile sites where regrowth is greater and competition reduces exposure. Plants raised in small containers, typically plastic bags or new seedling containers (Chapter 3), are more extensively used. Containers may be particularly useful for improving the establishment of sensitive species such as *Quercus* (Table 15).

Table 15. Specific quality recommendations for planting stock selection

BARE-ROOT PLANTS	CONTAINER-GROWN PLANTS
1. Bare-root plants should be pruned at least once or twice, depending on the number of growing seasons or age of the seedlings. 2. As little time as possible should elapse from when the bare root is extracted in the nursery until it arrives at the planting site, and transport and storage conditions must be carefully controlled.	1. Containers must be such that no spiralling or twisting of the roots occurs. 2. The minimum container volume will be determined by the requirements of each species. 3. The container material must be impenetrable to the root. 4. The height of the container must be at least 15 cm for resinous species and 18 cm for leafy ones, with a mouth area of at least 22 cm^2. 5. The containers must enable easy and complete extraction of the root ball. 6. Plants where the surface of the growing medium is covered with moss are not acceptable, as this means that the container has insufficient drainage or has been watered excessively. 7. No type of shade must be used for pine cultivation.

4.3.2. Time of planting

The right time for planting depends firstly on the general climate, rainy season, frost and the weather conditions at the time. In Lebanon the best time to plant forest species is between late October and mid-December, during mild weather. In years when the rains arrive late, planting can be successfully carried out until the end of February.

Planting in early autumn is recommended in areas with a warm climate and dry springs, as long as the plants have been shipped from the nursery when the sap has stopped flowing. It can be delayed until November in warm regions (broadleaf species generally benefit from being planted before the end of this month). **Planting in late winter** is recommended according to the risk of frost, but losses can be quite high if followed by a spring with low rainfall (as quite regularly occurs in Mediterranean climates). The following points should be taken into consideration:

- An adequate water regime is required for planting (a more limiting condition in the case of bare-root plants, but not so critical with container seedlings).
- Planting is not advisable when there is frost, or in strong winds or abnormally high temperatures.
- Planting on cloudy or showery days is preferable.

4.3.3. Plant handling and planting

There are many possible reasons for failure of planting stock, but the main cause of death is often poor plant handling. Many failures can be avoided if care is taken over the handling of plants at every stage from the nursery bed to where they are finally planted. Damage occurs in the following three main ways:

1. **Root drying:** During planting the seedlings should be kept protected from wind and sunlight, and lifted out individually.
2. **Overheating**: Seedlings should be kept in a cool place and out of direct sunlight until planting.
3. **Physical damage**: Seedlings should always be treated with great care and never thrown around. When planting, the plug should be used to firm gently into the ground.

Rosmarinus officinalis seedling
Photo by: M. Navarrete, IDAF

A suitable method for planting forest species as follows:

1. Use a a hoe or spade to make a hole in the ground large enough for the plant: at least 5 cm deeper than the length of the root plug or the bare roots.
2. If the plant is in a bag or container, remove it or any other material that may prevent the plant from growing.
3. Discard plants with physical damage, pests or defects.
4. Place the seedling in the hole, holding it by the root ball or collar.
5. The plant should be upright, with the roots well spread out and the root collar at ground level (if the root is left uncovered, it will dry out and the plant will die, and if planted too deep the root collar will rot).

6. Bury the plant 4–5 cm above the root collar so that when the surrounding soil settles it will be just below this level.

7. After the plant has been put in place, fill the hole and lightly tread the surrounding soil to compact it and remove any air pockets in contact with the root.

8. In dry soil with good drainage, the plant can be sunken slightly to enable rainwater to accumulate; this should not be done in heavy soil.

9.Finally, it is advisable to pull the plant slightly so that the roots take well and are well distributed in the soil.

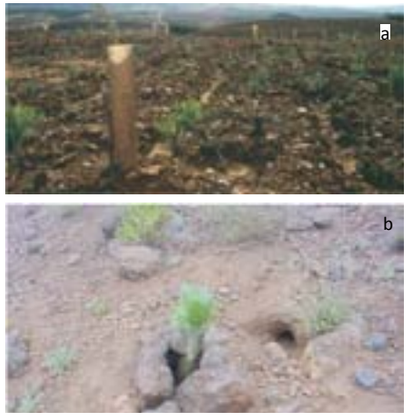
4.3.4. Stocking level

To achieve good survival and growth of forest species in Lebanon, it is essential to decide the initial plant density (stocking level). The stocking level is determined by the reforestation aim and by a series of factors: silvicultural (ecology, root system, growth, etc. of the species), financial (depending on the characteristics of the desired product) and social (multiple use of the forest). Table 16 gives recommendations on the minimum initial stocking level for the major forest species.

Table 16. Recommended minimum initial stocking level for forest species in Lebanon

SPECIES	TYPE OF PLANTATION	MINIMUM DENSITY (Trees ha^{-1})	PLANTING STOCK
Abies spp.	Conservation	1100	Container seedling
Olea spp.	Agroforestry/Protection	250–500	Container seedling
Populus spp.	Production/Protection	278–400	Bare root
Ceratonia spp.	Agroforestry/Protection	1100	Container seedling
Arbutus spp.	Agroforestry/Conservation	250	Container seedling
Cedrus spp.	Conservation	1100	Container seedling
Prunus spp.	Agroforestry/Conservation	250	Container seedling
Cupressus spp.	Agroforestry/Protection	500–1000	Container seedling
Juniperus spp.	Conservation	250	Container seedling
Fraxinus spp.	Conservation	250	Bare root
Ulmus spp.	Conservation	250	Bare root
Pinus pinea	Agroforestry/Protection	1100	Container seedling
Pinus spp.	Protection/Production	2000	Container seedling
Pistacia spp.	Conservation	250	Container seedling
Quercus spp.	Protection/Production	500–1100	Container seedling

Once the overall stocking level has been established it can be varied depending on the final design of the site, which basically depends on its purpose. Stocking can be homogenous throughout the plantation (typical of low-management reforestation), heterogeneous by stands or gradual depending on site topography. A practical technique is to estimate a final stocking level 5–10% higher than the minimum recommended to allow for mortality in some plants and thus avoid having to fill gaps.



Cultural practices: a) tree shelter b) mulch
Photo by: R. Hierro

4.3.5. Planting design

The following aspects must be taken into account in the planting design:

1. Site topography, which defines the **layout of the planting pattern** on the site. When trees are planted in rows, these should generally follow the contours of the land.

2. Constraints due to **natural or artificial features** that call for the use of special planting designs. Linear structures such as power lines, roads, irrigation channels, etc. make it advisable to change planting density, minimum distances (for example, 10 m in the case of power lines) or even the selected species (for example, shrubs in areas close to irrigation channels).

3. **Discontinuities in the quality of the site** to be reforested—due, for example, to existing stands of vegetation, reforestation on agricultural land where part of the previous vegetation has been maintained, rocky outcrops, etc.—which could mean changes in stocking level or even areas being left unreforested. Whenever possible, and where planning objectives permit, good use should be made of discontinuities involving soil quality and the distribution of water courses, etc., to vary both the species and the design of reforestation to a maximum. Such variations bring about a significant improvement in the environmental quality of reforestation, as well as its resistance to fire and pests.

Pure plantations

Pure plantations have many disadvantages, and are not recommended when forest landscape restoration is one of the objectives of the plantation, especially in the Mediterranean. However, they have been used in the past for specific purposes.

There are three types of planting pattern: *square*, *rectangular* and *triangular*. In the first two systems the seedlings are planted on the vertices of squares or rectangles whose sides determine the spacing between plants. The following formula is used to calculate the number of plants required for a specific area of land:

$$N = 10{,}000 \frac{H}{D \cdot L}$$

N = number of plants
H = number of hectares
D = distance in metres between plants
L = distance in metres between rows

When the land is on a slope or erodes easily, the seedlings should be planted on the vertices of equilateral triangles (triangular pattern) so that the plants are staggered in alternate rows. To

$$N = 10{,}000 \frac{H}{D \cdot L \cdot 0.866}$$

N = number of plants
H = number of hectares
D = distance in metres between plants
L = distance in metres between rows

Cedrus libani
Photo by: C. Abi Faraj

calculate the number of plants required for such steep areas the following formula is used:

Mixed planting

As many broadleaf Mediterranean species grow slowly, mixing with a faster growing species can improve the growing conditions for other, more delicate ones, since they act as protection against too much sun or frost. Moreover, it has been demonstrated that the size and development of many broadleaf species improves when they grow under a protective canopy formed by other species.

Traditionally, mixtures have occurred naturally in reforestation, with an upper layer of planted conifers under which an underlayer later forms, which is generally a major leafy species and its accompanying bushes and shrubs. When forestry practices are adequate, this underlayer develops quite rapidly, resulting in good, mixed forest of high environmental quality in a relatively short period of time.

When the combination occurs as part of the planting design, the first aspect to be taken into account is that the species used should be ecologically compatible. The combinations tried so far have generally been **conifers with broadleaf species** (e.g. *Pinus*/*Quercus*, *Abies*/*Cedrus*, *Cedrus*/*Pinus*/*Quercus*, *Ceratonia*/*Olea*/*Pinus*), though more complex mixtures of only broadleaf species can also be considered (*Quercus*/*Olea*, *Ulmus*/*Populus*, *Quercus*/*Arbutus*).

4.4. Preparation for planting

4.4.1. Treatment of existing vegetation

Vegetation existing on the land prior to planting may affect the success of reforestation, as it competes with the recently installed plants for water, light and nutrients. It increases the risk of forest fires as well as the difficulty in extinguishing them. Thick vegetation should be removed before reforestation work begins. The main treatments for controlling vegetation are shown in Table 17.

Vegetation control prior to planting
Photo by: A. García

Table 17. Main vegetation treatments according to the type of existing vegetation

Weed vegetation	Woody vegetation
Tillage	Manual brush-cutting
Application of herbicides	Clearing
	Brush-cutting and stripping

1. **Treatment of weed vegetation:** the main problem with weeds is competition for water in the reforested area, especially in very dry areas. The extent of **tillage** to be undertaken (localized, in strips, or continuously over the whole area) depends on weed density and the species present and their aggressiveness when competing with planted trees. Should the weed be low density and consist of annual species (for example pasture species), it may be better not to take any action so as to protect the soil and avoid letting in more aggressive species, or only to carry out localized action around each planting spot. When weeds are at high densities or are aggressive (depending on the species), stripping or continuous work should be carried out when site conditions allow.

Another option is to apply **herbicides**, though, despite the advantage of their longer-lasting effects, expert advice will be required to prevent damage to the newly introduced plants.

2. **Treatment of woody species:** this consists of eliminating the aerial part of the shrub by cutting it to ground level with tools such as sickles, brush hooks or pruning hooks. The method is costly because of the labour required but more flexible as treatment is one-off and selective. These manual tools can be replaced by motorized brush cutters (light equipment consisting of a petrol engine that drives a vertical shaft which turns a rotary blade with varying cutting characteristics).

Another alternative is brush-cutting and stripping. This consists of eliminating woody vegetation in strips using the front blade of a crawler. **Brush-cutting** only involves pulling up vegetation with the blade when it does not touch the surface of the soil. If the blade penetrates the soil, **stripping** occurs, which consists of pulling up the vegetation and soil simultaneously, and at the same time the angle dozer blade deposits the top soil mixed with roots and the upper part of the shrub in ridges or lateral furrows.

4.4.2. Site preparation

Selective manipulation of the soil environment is a powerful tool that influences the outcome of forestation efforts. Well-designed site preparation strategies improve the soil's suitability for planting (in terms of drainage, root depth and water regime) and aid the mechanical penetration of the new plants' roots. The method chosen for ground preparation must be well thought out, as the wrong decision will lead to the complete failure of reforestation and have serious effects on the soil properties. It must be carried out in such a way that soil properties are altered as little as possible and any action leading to profile rejuvenation is avoided. The most common kinds of ground preparation are mechanical and manual. Ground preparation can be done continuously, over the entire area, in a line, in strips or in localized spots. Opting for one choice or another will depend mainly on the soil features, slope and reforestation method (sowing or planting) (Table 18).

Site preparation : a)manual b) an excavator,
Photos by: R. Hierro

Manual ground preparation

- **Manual digging:** holes approximately 50 x 50 x 50 cm in size are dug manually with a hoe or pick to enable the roots of plants with 1 or 2 growing seasons in warm areas to stand upright, that is, without any part being bent, especially the tip of the main root. This option is recommended on sites that are not easily accessible, such as rocky outcrops or slopes that are too steep for machinery, or in low-impact reforestation, woodland densification or conservation planting. In these cases, and given that areas are usually small, the hole must be dug properly to the minimum size required, otherwise reforestation will not be successful and money will be wasted.

Mechanical ground preparation

• **Augering** consists of the manual or mechanized drilling of cylindrical holes about 30 cm in diameter using a motor-driven auger. Hole depth varies between 0.4 and 1.0 m according to the type of plant and the soil conditions. At present, this practice is limited to easy access sites or low-density spot preparation work, and is not very widely used due to the limitations of forest soils (above all their stoniness). Its use is recommended in densification or conservation planting (e.g. riparian restoration) in those places where it is not desirable to alter existing vegetation. On agricultural sites it can be used on gentle slopes, the auger being attached to an agricultural tractor or crawler, and on soils with no stones, which considerably increases performance.

• **Excavator mounding:** this consists of moving the soil with an excavator backhoe, either without removing the earth (in protective reforestation on forest sites) or removing it and then replacing it in the hole at the time of planting (simultaneous planting in waterside areas). Backhoe digging is excellent ground preparation because of both its depth and the volume of soil which is moved. The minimum recommended hole size is 0.6 x 0.5 x 0.5 m, which is achieved by using a 40–50 cm bucket. At present it can replace other procedures to advantage, above all on 35–60% slopes and when attempting to reduce the impact of ground preparation. It can be supplemented on sloping sites by making microbasins (with small lateral furrows to collect run off and direct it towards the hole). This practice is expensive as it is done manually but very effective in hydrological terms. It can be done at the same time as planting.

• **Bulldozer digging :** this mechanized technique consists of making holes by forcing a crawler ripper into the ground. A tractor crawler moves down the maximum slope line (<60 %) of the hillside with two, generally modified, ripper tines. It is stopped at a point and the ripper is hammered down to a depth of 0.5 m. Depending on the characteristics of the site and the type of bucket, this operation is repeated once or twice more for each hole.

• **Linear ripping:** this consists of breaking up the deep layers of soil with a subsoiler (one, two or three ripper tines with a variable depth of 40–60 cm). This allows useful soil depth to be increased, water infiltration and retention capacity to be improved and readily fragmentable stone to be broken up. It has been shown to be extremely effective at improving plant growth and survival. However, its general use must be avoided for reforestation in chalky moorland without a prior detailed study of the environment. In sloping areas, when it is possible and is done following the contours, it also has a very favourable effect on the control of surface run-off (this effect is improved by using rippers with flanges which form small furrows). Powerful agricultural ripper tractors (over 75 hp(M) or 55 kW) or forestry tractors (over 140–170 hp(M) or 103–125 kW) are needed, depending on the slope, type of site, and number and shape of the tines.

Plantation after site preparation: a)manual b)excavator
Photos by: M. Navarrete, IDAF

• **Deep furrowing:** this consists of forming ridges of earth or furrows following the contour, varying in width and height according to the size of the implement. Ridging ploughs leave a furrow or channel uphill of the ridge formed from the soil extracted from the furrow. This preparation procedure is of very limited use due to the characteristics of most forest sites (steep slopes and high level of stoniness), although it has been shown to be quite effective in terms of water regime and seedling survival. Its use is therefore highly recommended so long as conditions allow.

• **Surface furrowing:** this is a combination of stripping and linear ripping, in which a ridge is formed from the accumulated stripped surface soil and then the stripped layer is subsoiled. A 120–180 hp(M) (88–132 kW) crawler tractor with an angle dozer blade is required which can operate with the blade at an angle of 25% to the front position, together with a ripper with 2 or 3 tines. This type of ground preparation is fairly widely used on steeply sloping sites with run-off problems, above all in semi-arid areas. Although it has been criticized for its labour intensity, it allows excellent control of erosive processes when done carefully, ensuring a good water supply to the plant and excellent survival rates. It can be used with good results in areas covered by low-lying shrubs.

• **Large-scale methods of ground preparation:** this type of work can only be performed when the site slope is less than 15%, because of the erosion problems which can be caused. These ground preparation methods are not very commonly used for restocking forest land, due to gradient constraints, except in the case of moorland reforestation. However, they can be very useful for foresting agricultural lands. The methods include *full tillage*, *full deep furrowing* and *full ripping,* with the same characteristics as those previously described but applied to extensive areas.

Cedrus Libani in El Chouf cedar natural reserve, Photo by: C. Abi Faraj

4.4.3. Maintenance operations

Winter cuttings.
Photo by: R. Colomer

Depending on the case, reforestation projects must include various procedures for the maintenance of young seedlings. These maintenance operations continue during the years immediately after reforestation. It can never be said that a forest plantation is successful simply because seedlings have been planted at the site, since a series of aftercare procedures are also needed. The type of care, its quality and frequency will depend on the aim of the reforestation, labour costs, quality of planting and the species used (according to their tolerance to drought, competition with weeds, etc.). The most important maintenance operations are:

- ***Beating up (replacing dead seedlings):*** some losses after planting are almost inevitable due to wildlife or pest damage. Summer drought can take its toll in Mediterranean countries or in very dry years, but much so-called drought damage may be the result of poor root response after planting, occasioned by inadequate planting, stock quality and poor plant-handling practices. It is not worth replacing failures unless the gaps are substantial, and it should be done as soon as the failures become apparent.
- ***Protection***: fencing or protection tubes/cloches (to prevent predators); protection against pests and diseases.
- ***Weed and woody vegetation control:*** competition is most detrimental if the seedlings have already been stressed, for example by poor planting or desiccation during transport from the nursery. Mechanical weeding with a tractor-mounted swipe or with a clearing saw can be effective in breaking down woody vegetation. In herbaceous vegetation, a weed-free area of about 1 m diameter has been shown to give cost-effective relief from competition.
- ***Tree shelters:*** tree shelters are translucent plastic tubes placed around a tree at planting in order to assist establishment by providing a warm microclimate and offering considerable protection against animal damage. Most Mediterranean species benefit from tree shelters, and some can be expected to increase survival and growth. Although specific research should be carried out in Lebanon on the effectiveness of such an application, results in other Mediterranean countries seem promising.
- ***Irrigation****:* establishment and maintenance irrigation may be provided depending on species' needs, climate, type of reforestation and cost.
- ***Pruning****:* branches are removed to improve the quality of tree growth. The work should be done in stages while the stem is still small in diameter.

Table 18. Main ground preparation methods according to site features

Ground method	Weather	Lithology	Soil depth	Slope	Stoniness	Shrubs	Hydrologic effects	Reforestation type
Manual digging	Dry weather only	Any	> 40 cm Selective in irregular depth soils	Low yield above 60%	Low	With or without	Negligible	Protective and specific
Augering			> 50 cm	<20%	Low	Without shrubs	Negligible	Productive and specific
Excavator mounding	Dry and intermediate weather	Any	> 50 cm	< 60%	Medium–high	Light	Good (increases infiltration)	Protective and productive
Bulldozer digging	Dry and intermediate weather	Any	> 50 cm	< 60%	Medium–high	Light	Good (increases infiltration)	Protective
Linear ripping		Any	>80 cm	<35% 3555%-	Medium–high	Light	Good (may require runoff control)	Protective and productive
Deep furrowing	Dry and intermediate weather		> 50 cm	< 30 %	Medium	Without shrubs	Very good (excellent retention and infiltration)	Protective and productive
Surface furrowing	Dry weather	Acid and fragmented soils	>80 cm	< 30 %	Medium–high	Light	Very good (excellent retention and infiltration)	Protective
Full tillage		Acid soils	> 40 cm	< 510-%	Low	Without shrubs	Medium (increases infiltration)	Productive
Full ripping	Dry and intermediate weather	Any	> 80 cm	Cross < 8% Parallel < 15%	Medium–high	Light	Good	Productive
Full deep furrowing	Dry weather	Acid soils	> 50 cm	< 30%	Low	Without shrubs	Good	Productive

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Appendix:
NATIVE SPECIES OF POTENTIAL USE IN LEBANON: DESCRIPTIONS AND CULTIVATION NOTES

Cilician fir Sapin de Cilicie شوح كيليكيا	*Abies cilicica* (Ant. & Kotschy) Carr.
Description of species and habitat	Cilician fir is a pyramidal tree which reaches 25–35 m in maximum height and a trunk diameter of up to 210 cm. Smooth, ash-grey bark initially, becoming fissured into scaly plates. Branchlets reddish-yellow to grey-olive-brown with scattered pubescence. Needles dark green on the upper side and whitish green on the underside, 20–40 mm long by 1.5–3 mm wide, apex entire or slightly bifid. It grows spontaneously in the mountains of Lebanon, Syria and Turkey, at 1,000–2,200 m elevation. Pure or mixed stands with Lebanon cedars in Taurus mountains (Turkey) and in northern Lebanon. The species grows slowly.
Description of fruit and seeds	Cylindrical cone, erect, reddish-brown, 15–30 cm long by 4–6 cm wide, apex bluntly pointed and scales fan-shaped. Seeds reddish-brown, obovoid with wings, 2–5 cm long.
Harvesting	Harvesting is at the beginning of autumn (October–November) when cones are ripe. Harvesting must be done before cones disintegrate and yield decreases considerably. Cones can be harvested with poles before they fall off the tree (in the case of not very tall trees) or by climbing the tree using the appropriate safety measures (harness, safety line, helmet).
Storage	Storage in a cold, dry environment at 1–3°C, in plastic bags or glass jars. Seeds stored under these conditions for over one year lose most of their viability. If stored at more than 15% humidity they lose their viability entirely.

Seed extraction efficiency (%)	Purity test (%)	Germination test (%)	Seeds kg^{-1}
	87		11,700

Pre-germination treatments	The general treatment for *Abies* spp. is soaking in water for 24 hours, followed by cold stratification in the fridge at 1–3°C in damp sand, peat or a mix of both (1 part of seeds to 3 parts of substrate) for 2 months before sowing.
Nursery production	Sowing must be done in late winter or early spring (February or March) at a depth of 10–12 mm. Transplanting is possible by sowing in a seed box and then transplanting into containers. After sowing, water the trays generously and place them outside on seedbeds. This species requires 2–3 years in the nursery for later transplanting into the field; relatively large growing containers (400–500 cm^3 or larger) must be used. Different types of growth media are acceptable, consisting of 20% natural soil, 10–15% fine sand and the rest of peat or coconut fibre. A simple fertilization programme based on NPK (12-8-14) using CSRF (controlled slow release fertilizers) , 2.5 Kg m^{-3} during 8-9 months is recommended.

Abies seeds. Photo by: S. Hatoum, AFDC

Abies cone on tree top. Photo by: E. Chnais, AFDC

Abies tree. Photo by: M. Navarrete, IDAF

Establishment	• Sowing and planting The most common establishment method is planting by hand; sowing is not recommended. Two- to three-year seedlings can be used. Planting should be carried out during autumn–winter (October to February) if the seedlings are large enough. Remove the nursery shade from over the seedlings in Septembetr, at least 1 month before transplanting. • Density and distribution The Cilician fir is mainly used in conservation programmes, although density is highly variable and ranges between 600 and 1,100 trees ha^{-1}. Low or very low density planting is recommended for ecological restoration purposes (<200 trees ha^{-1}). • Treatment of existing vegetation The method usually recommended for eliminating existing vegetation is manual weeding or clearing of woody vegetation, given the site characteristics where this species grows (slopes and rocky terrain); motorized brush-cutters may be used in more accessible places. • Site preparation In steep, rocky areas (common in the species' habitat) and in ecological restoration programmes, manual hole digging is the best alternative.

Lebanon cedar Cèdre du Liban الارز اللبناني	*Cedrus libani* A. Rich.
Description of species and habitat	Lebanon cedar is a large tree which grows to 20–40 m tall under favourable conditions. Blackish-grey bark which cracks open with age. Conical crown becoming broadly tabular with age with more asymmetrical branches. Thick, straight, sometimes horizontal branches. Dark green acicular leaves, 1.5–3.5 cm, sharp, broad rather than thick. Often present in the Taurus and Anti-Taurus, with residual stands remaining in Lebanon and part of Syria. Altitude distribution: 900–2,100 m in Mediterranean, temperate or cold continental climate zones, avoiding areas of extreme atmospheric humidity. Slow growth species requiring medium light. Any type of soil. It flowers in autumn (generally October), requiring less than two growing seasons to mature.
Description of fruit and seeds	Seed cones occur in isolation on the terminal branches, erect, oblong, ovoid and pedunculate, globular becoming barrel-shaped, 7–10 cm long by 4–6 cm in diameter, flattened at the top, brown when mature. Very numerous, dense scales up to 5 cm wide, purplish on maturity then turning greyish, pubescent on the outside. Seeds 15–18 mm long, with 9–10 cotyledons and wings up to 25 mm. The cones are harvested on turning brown and are opened on an air drying rack followed by threshing or rubbing.
Harvesting	When the cones mature (on turning brown), they can be harvested with poles before they fall off the tree (in the case of not very tall trees) or by climbing the tree using the appropriate safety measures (harness, safety line, helmet).
Storage	Sowing immediately after seed extraction is preferable. However, whole cones should be placed in a cold, dry environment in the case of storage.

Seed extraction efficiency (%)	Purity test (%)	Germination test (%)	Seeds kg^{-1}
	87		11,700

Pre-germination treatments	This species does not require any pre-germination treatment (for direct sowing in autumn), although prior immersion of the seed in water at ambient temperature for 2 or 3 hours is recommended. For the *Cedrus* genus, cold stratification at 0.5–1°C can be carried out for a few weeks to separate the covering from the seed if desired.
Nursery production	Nursery sowing can be done in autumn (following seed extraction) or in spring using previously stratified seeds (6–12 weeks in a cold environment at 4°C) if correctly stored. Sowing in a light, well-drained substrate. Ideally, seedling can be produced in 400 cm^3 forest tray containers. Slow-release fertilizer may be added to the mix to enhance seedling vigour.

Cedar seeds. Photo by: S. Hatoum, AFDC

Mature cedar tree. Photo by: N. Hani, AFDC

Cedar seedlings. Photo by: E. Chnais, AFDC

Establishment	• Sowing and planting The usual establishment method is planting . Manual planting of 1–2 year-old seedlings must be done in autumn and the plant should not be given too much shade. • Density and distribution Cedar is mainly used in conservation programmes, although density is highly variable and ranges between 600 and 1,100 trees ha^{-1}. Low to very low density planting is recommended for ecological restoration purposes (<200 trees ha^{-1}). • Treatment of existing vegetation The method usually recommended for eliminating existing vegetation is manual weeding or clearing of woody vegetation, given the site characteristics where this species grows (slopes and rocky terrain); motorized brush-cutters may be used in more accessible places. • Site preparation Simple or double subsoiling in places and soils allowing this. In steep, rocky areas (common in the species' habitat) and in ecological restoration programmes, manual hole digging is the best alternative.

Crimean juniper Genévrier élevé لزاب	# *Juniperus excelsa* Bieb.
Description of species and habitat	The Crimean juniper is a large shrub or tree growing to 6–20 m (in rare cases 25 m) in height and 2 m in trunk diameter, with a broadly conical to irregular crown. Young leaves in needle form, 8–10 mm long, and adult scale leaves, 0.6–3.5 mm long, on older plants. Smooth bark (on young trees and branches), becoming reddish brown and scaly over time, and finally reddish-purple and fibrous in old trees, furrowed in longitudinal strips. Found in the eastern basin of the Mediterranean. It does not occur in regions with a mean annual precipitation of under 500 mm. It is considered a high-altitude species, and is one of the few trees species that can survive above 2,000 m, but it also grows readily at lower altitudes. It is resistant to drought and heat, mainly growing on rocky slopes and even on rock formations (limestone and others). It can form pure, open stands or mix with other *Juniperus* or other conifers such as *Cedrus libani*, *Cupressus sempervirens* or *Pinus* spp., or as part of *Quercus* spp. heathland communities.
Description of fruit and seeds	Short cones in the form of berries, 6–11 mm in diameter, bluish-black, with 3–6 seeds, which mature about 18 months after appearance of the fruit. Seed extraction is by pulp removal, washing, drying and sieving. A densitometric method to separate empty seed is recommended, giving an approximate yield of 10.5%. The berry impedes seed germination. Fruits are fleshy but they have a very hard stone inside with 2 well-protected seeds, so the fruits take a long time to break open and allow the embryo to germinate. In addition, the seeds have internal dormancy.
Harvesting	Cones must be collected manually between late summer and autumn depending on the elevation of the collecting site.
Storage	It is essential to remove the external fleshy seed coat and not to store the whole fruits. It can be removed by macerating the fruits in water (with 1% of bleach to eliminate resins), for 1–2 days after collecting. After that, the seeds are extracted by sieving under a jet of water. The floating pulp is removed. Dried seeds with or without the external seed coat can be stored in a dry and well-ventilated room or in the fridge at 1–3°C, in plastic bags or glass jars.

Seed extraction efficiency (%)	Purity test (%)	Germination test (%)	Seeds kg^{-1}
	85–90	20–40	

Pre-germination treatments	Treatments recommended for this species: Pre-refrigeration for 90 days at 3–5°C Seed collection in October and then empty seeds separated by densitometry.
Nursery production	The juniper is grown as a forest species in 200–300 cm^3 forestry pots, sown in early autumn to winter, or in spring with stratified seed. Sowing must always be done as early as possible, Germination starts within the first few weeks after sowing and may continue all summer long, and seedlings may even sprout the following season. It is a slow-growing species and germinated seedlings will reach a height of 10–15 cm within the first season.

J. excelsa seeds. Photo by: S. Hatoum, AFDC

J excelsa tree. Photo by: N. Hani, AFDC

J. excelsa seedling. Photo by: E. Chnais, AFDC

Establishment	• Sowing and planting The establishment method is planting by hand; sowing is not recommended. One- or two-year-old seedlings can be used. Planting should be carried out in autumn or winter (October to February) if the seedlings are large enough. • Density and distribution The recommended planting density for the species must be low. In ecological restoration higher densities (about 500 trees ha^{-1}) can be used, but they will decrease progressively towards less favourable zones that would best be left for other, less demanding species at variable densities (200–300 trees ha^{-1}). •The most commonly recommended method for eliminating existing vegetation is manual control, given the site characteristics where this species grows (slopes, rocky terrain); motorized brush-cutters may be used in more accessible places. • Site preparation In ecological restoration programmes manual hole digging will be the best alternative, or occasionally mechanized digging using an excavator.

Prickly juniper Genévrier Oxycèdre عرعر كادي	*Juniperus oxycedrus* L.
Description of species and habitat	Prostrate or erect shrub growing up to 3 m or sometimes becoming a small tree up to 10 m in height. It is heavily branched, with a broad crown. Acicular-lanceolate leaves, up to 2.5 mm wide, attenuated from the base to a pointed apex. It flowers in spring; the berries mature at the end of their second summer. The flowers are dioecious; female ones produce fruits. Berries, 12–15 mm, coriaceous, covered with a waxy layer, globose, light green when young and reddish-dark grey when ripe. The fruits take 2 years to mature.
Description of fruit and seeds	The fruit has up to three seeds, long and angular, yellowish-dark grey and 5–7 mm in length, covered with a thick, slightly ribbed testa. Seed extraction is by pulp removal, washing, drying and sieving. A densitometric method to separate empty seed is recommended, giving an approximate yield of 10.5%. The berry impedes seed germination. Fruits are fleshy but they have a very hard stone inside with 2 well-protected seeds, so the fruits take a long time to break open and allow the embryo to germinate. In addition, the seeds have internal dormancy.
Harvesting	Berries must be collected manually between September and November.
Storage	It is essential to remove the external fleshy seed coat and not to store the whole fruits. It can be removed by macerating the fruits in water (with 1% of bleach to eliminate resins), for 1–2 days after collecting. After that, the seeds are extracted by sieving under a jet of water. The floating pulp is removed. Dried seeds with or without the external seed coat can be stored in a dry and well-ventilated room or in the fridge at 1–3°C, in plastic bags or glass jars.

Seed extraction efficiency (%)	Purity test (%)	Germination test (%)	Seeds kg^{-1}
	95–99	60–70	11,200–78,000

Pre-germination treatments	Treatments recommended for this species: • Pre-refrigeration for 90 days at 3–5°C • Seed collection in October and then empty seeds separated by densitometry.
Nursery production	Sowing has to be done after pre-treatment in autumn, in containers (200–300 cm^3) with a peat:perlite mix (3:1 vol.), 1 cm deep. Germination can take many months or even one year. The first seedlings may appear during summer, but most likely will take longer and appear the following spring, depending on seed quality. During this time the seeds and seedlings must be protected: in the winter inside a greenhouse and in the summer in a shaded place. Weeds should be removed and animal predation prevented when necessary.

Fruit of *J. oxicedrus.* Photo by: R. Navarro-C. Gálvez, UCO

Landscape with *J. oxicedrus*. Photo by: R. Navarro-C. Gálvez, UCO

J. oxicedrus seeds. Photo by: X. Goñi, UdL

Establishment	• Sowing and planting The establishment method is planting by hand; sowing is not recommended. One-year-old seedlings can be used. Planting should be carried out in autumn or winter (October to February) if the seedlings are large enough. • Density and distribution The recommended planting density for the species is low. In ecological restoration higher densities (about 500 trees ha^{-1}) can be used, but they will decrease progressively towards less favourable areas that would best be left for other, less demanding species at variable densities (200–300 trees ha^{-1}). • Treatment of existing vegetation The most commonly recommended method for eliminating existing vegetation is manual control, given the site characteristics where this species grows (slopes, rocky terrain); motorized brush-cutters may be used in more accessible places. • Site preparation In ecological restoration programmes manual hole digging will be the best alternative, or occasionally mechanized digging using an excavator.

Calabrian pine
Pin de Calabre
الصنوبر البري

Pinus brutia Ten.

Description of species and habitat

Calabrian pine grows to about 20 m, with light green needles in fascicles of two, 10–16 cm long by 1–1.5 mm wide. Open crown and generally crooked, powdery-whitish trunk with reddish-brown fissures.

It grows on hills and sunny, dry slopes from sea level to about 1,200 m, higher in mountain areas. It prefers lime-rich soils and is very resistant to drought and more sensitive to frosts. It adapts well to extremely poor, shallow soils. It is found in eastern Mediterranean countries.

It flowers from February to April and bears fruit in late summer in the second year, which can be harvested in the spring of the third year.

Description of fruit and seeds

Long oval-conic cones, erect and generally in groups.

Seed 6.5–9 mm long, scaly reddish rhytidome at first, becoming darker and fissured with a triangular wing. The cones remain on the tree for several years (serotinous cones).

Seed extraction is simple, by drying in the sun, mechanical or water dewinging, sieving, blowing and separating empty seeds by flotation.

Harvesting

In spring, by collecting cones on the ground or harvesting in the crown using ladders.

Storage

Keep in a cold (0–2°C) dry (humidity <10%) environment, which allows for prolonged storage.

Seed extraction efficiency (%)	Purity test (%)	Germination test (%)	Seeds kg^{-1}
20–30	90–98	90–95	45,000–60,000

Pre-germination treatments

The limiting factor for seed germination is temperature. The optimum germination temperature is 15–20°C. Values above 25°C impede germination and induce seed lethargy, which remains until favourable conditions are re-established. Temperatures of 10–15°C delay germination, but do not affect it completely.

Nursery production

Nursery sowing is usually done in spring (February–March), after harvesting or with cold stratified seeds (4–8 weeks, this being particularly effective for seeds collected in areas with hard winters). Germination occurs in the three weeks following sowing if the seed is placed in water for two days beforehand. Plants are grown in 200 cm^3 containers for one growing season, reaching a final size of 10–15 cm Medium levels of fertilization, with balanced ratios of N/P/K, such as 120–50–100 ppm in the growth phase and 40–30–120 ppm during hardening..

Mature *Pinus brutia* tree. Photo by: N. Hani, AFDC

Pinus brutia flowers. Photo by: M. Navarrete, IDAF

Pinus brutia branches with cones. Photo by: E. Chnais, AFDC

Establishment

- Sowing and planting

The usual establishment method is planting. Planting can be done using container seedlings or bare root seedlings (less recommended).

- Density and distribution

High densities of 1,100–1,600 trees ha^{-1} are recommended for protection in favourable places. For restoring semiarid land, density is lower (< 600 trees ha^{-1}), using more favourable shady spots or gullies, or very low densities are used for ecological restoration.

- Treatment of existing vegetation

Treatment of woody species may be required with tools such as a sickles, and manual or motor brush-cutters.

- Site preparation

Simple or double subsoiling or excavator mounding are the most common site preparation methods in steep areas. Deep ridge ploughing can be used in particular on sandy ground.

Stone pine
Pin pignon
الصنوبر المثمر

Pinus pinea L.

Description of species and habitat

This tree grows up to 30 m, with an umbrella-like dense crown and straight, robust trunk with branches only in the upper part. Greyish-brown bark, with reddish fissures and large plates. Light brown, thin branchlets. Intensely green needles in bundles of two, 10–20 cm long and 1.5–2 mm thick, slightly curved with a convex inner side. Male flowers occur in oblong-cylindrical spikes.

The stone pine grows in deep soils, mainly sandy ones, even prospering on seashore sandy soils and permanent dunes. It prefers siliceous soils, but grows well on lime if not very heavy and clayey. It requires abundant light and a rather warm climate, and cannot survive heavy, continued frosts. Altitude distribution from sea level to 1,500 m, rarely above this. It flowers from March to May. Fruit setting requires three years, dehiscence of the scales occurs and the cones fall in the autumn of the third or in the spring of the fourth year.

Description of fruit and seeds

Large pine cones, 8–15 cm long by 7–12 cm wide, oval becoming globular, thick scales, with apophyses of octagonal appearance. Sessile, globular appearance, slightly asymmetrical, green at first, becoming reddish brown and shiny.

Oval, oblong, dark brown to powdery black seed, 15–20 mm long and 7–11 mm wide with very narrow, rudimentary wings, deciduous and with a woody seed cover.

Seed extraction is simple, by sun drying, mechanical or water dewinging, sieving, winnowing and a densitometric method for separating empty seeds.

Harvesting

From November to March (harvest of closed co nes to avoid seed loss).

Storage

Keep in a cold (0–2°C), dry (humidity <10%) environment, which allows for prolonged storage.

Seed extraction efficiency (%)	Purity test (%)	Germination test (%)	Seeds kg^{-1}
15–22	90–100	70–90	1,200–2,100

Pre-germination treatments

Seeds do not require any pre-germination treatments, although more homogeneous germination as well as elimination of empty seeds can be favoured by soaking for 12 to 24 hours.

Nursery production

Nursery sowing is usually done in spring (February–March). Germination occurs during the three weeks following sowing if the seed has previously been soaked in water. Plants are grown in forest containers with a relatively wide range of volumes, from 150 to 400 cm^3 (recommended volumes are about 300–400 cm^3), to a final seedling height of 10–15 cm and diameter of 3–5 mm.

Growing media are formulated from peat or fertilized peat with different components such as perlite, pine bark and occasionally others. Growing media should be well aerated (10–15% aeration porosity), since heavy growing media do not encourage root development.

Medium levels of fertilization, with balanced ratios of N/P/K, such as 120–50–100 ppm in the growth phase and 40–30–120 ppm during hardening.

Pinus mature tree. Photo by: R. Navarro y C. Gálvez, UCO

Pinus Pinea seeds. Photo by: X. Goñi, UdL

Pinus fruit and leaves. Photo by: R. Navarro y C. Gálvez, UCO

Establishment

- Sowing and planting

The most common establishment method is planting, sowing being infrequent. Planting can be done using container seedlings or bare root seedlings (less recommended).

- Density and distribution

500–1,200 trees ha^{-1} according to plantation purpose, less in cone production (approximately 500–600 trees ha^{-1}, with a final optimum density of about 80–120 trees ha^{-1}), and more in protection programmes such as dune restoration (approximately 1,000–1,500 trees ha^{-1}).

- Treatment of existing vegetation

Treatment of woody species may be required with tools such as sickles and manual or motor brush-cutters.

- Site preparation

Simple or double subsoiling or deep ridge ploughing (in particular on sandy ground) are the most common site preparation methods.

Syrian maple Erable de Syrie قيقب سوري	# *Acer syriacum* Boin and Gaill
Description of species and habitat	The Syrian maple is a small tree, up to 8 metres high. It has truncated leaves, 3–8 cm in size with characteristic 3 lobes. Hermaphroditic flowers are clustered in a white-yellowish corymb. The tree is native to the eastern Mediterranean and is found in middle-altitude oak and pine forests.
Description of fruit and seeds	The fruit is a winged samara which bears 2 attached seeds. The samara wings are reddish in colour, which helps in the identification of the tree. The medium-sized seed is round to rectangular in shape.
Harvesting	In September–November, when the fruits are brown and before they fly from the trees. The fruits should be placed on paper to dry. The wings must not be removed.
Storage	Dried fruits with wings can be stored for some years in the fridge at 3–4°C, in plastic bags or glass jars.

Seed extraction efficiency (%)	Purity test (%)	Germination test (%)	Seeds kg^{-1}
90–100	90–95	5–15	

Pre-germination treatments	Cold stratification in moist sand, peat or a mix of both (mix 1 part of seeds to 3 parts of substrate), for 3 months before sowing (December to February), in the fridge at 1–3°C.
Nursery production	Seeds are sown after pre-treatment in March, in seed trays with peat, 1 cm deep. The trays should be kept inside a greenhouse. When the seedlings appear and are large enough to be handled, they should be transplanted into forest containers (400 cm^3) using growing medium t (peat–perlite, 3:1 vol.) The forest containers can be placed in seedbeds outside.

Photo by: M. Navarrete, IDAF

A. syriacum seeds , Photo by: S. Hatoum

A. syriacum tree , Photo by: M. Navarrete, IDAF

A. syriacum mature tree with fruits , Photo by: N. Hani, AFDC

Establishment	• Sowing and planting The establishment method is planting by hand; sowing is not recommended. One- to two-year-old seedlings can be used. Planting should be carried out during autumn or winter (October to February) if the seedlings are large enough. • Density and distribution The Syrian maple is mainly used in conservation programmes. The low planting density reflects the situation in the wild, where *Acer syriacum* never forms pure stands but is usually found scattered throughout Mediterranean-type forests. Depending on the site requirements and the objectives of the reforestation, the density might vary from 20 to 100 trees per ha. • Treatment of existing vegetation The most commonly recommended method for eliminating existing vegetation is manual control, given the site characteristics where this species grows (slopes and rocky terrain); motorized brush-cutters may be used in more accessible places. • Site preparation In ecological restoration programmes manual hole digging will be the best alternative.

Oriental alder
Aulne oriental
نغث

Alnus orientalis Decne.

Description of species and habitat

Oriental alder grows to a height of 8–10 m and has a medium thick bark. It has petiolate, entire or dentate deciduous leaves. The flowers are catkins, with elongate male catkins about 12 cm long and shorter female catkins of an ovate-oblong shape. Both are on the same tree and often appear before leaves; they are mainly wind pollinated, but also visited by bees to a small extent.

Their roots harbour nitrogen-fixing bacteria that help fertilize the soil.

They are native to western Asia and are fou nd in wet areas and on river banks.

Description of fruit and seeds

Female catkins turn into a dark green, oblong, cone-like structure. Fruits mature within one year. The catkin is composed of many interlocking, thick, woody scales. Each scale covers one or two winged seeds at its base. As the fruit ripens it opens up, releasing the small seeds.

Harvesting

In November–December, when the little cones are very brown and before they open and shed their seeds.

Storage

Fruits should be dried on paper. They will open and the seeds will appear. The seeds can be separated from the fruits by means of a suitable sieve. Dried seeds can be stored for some years without losing their viability. They should be kept in the fridge at 3–4°C, in plastic bags or glass jars.

Seed extraction efficiency (%)	Purity test (%)	Germination test (%)	Seeds kg^{-1}
8–10	60–70	40–70	

Pre-germination treatments

No pre-treatment is needed.

Nursery production

Sowing must be done in February–March before spring temperatures increase (the seeds need less than 25°C to germinate), in seed trays with peat. Seeds should be sown on the surface, less than 5 mm deep, and kept inside a greenhouse.

When the seedlings appear and are large enough to be handled, they should be transplanted into small forest containers with peat and kept in the greenhouse. After about 1 month the root system will have filled the small forest cells and they will be ready to be transplanted into larger forest containers (400 cm^3) and moved to outside seedbeds. Alternatively, seedlings can be directly transplanted into large forest containers without requiring the second transplant.

A. orientalis fruits. Photo by: N. Hani, AFDC

A. orientalis seedlings. Photo by: E. Chnais, AFDC

A. orientalis detail of branch. Photo by: E. Chnais, AFDC

Establishment

- Sowing and planting

The common method is to plant one-year-old seedlings directly on river banks.

- Density and distribution

High densities of 900–1,100 trees ha^{-1} are recommended for protection in favourable places. For riverside restoration, density is lower (300–600 trees ha^{-1}), used together with other species.

- Treatment of existing vegetation

Treatment of woody species may be required, with tools such as sickles and manual or motorized brush-cutters.

- Site preparation

Manual digging or excavator mounding are the most common site preparation methods for riverside restoration.

European nettle tree
Micocoluier austral
ميس

Celtis australis L.

Description of species and habitat

This species grows to 10–20 m and has a slender trunk with smooth, greyish bark, a broad crown and straight branches. Leaves are 7–11 cm long by 3–4.5 cm wide, lanceolate to oval-lanceolate, strongly acuminate, asymmetrically rounded at the base, slightly hairy on the upper side and pubescent on the underside. Hermaphrodite flowers, single, axillary.

The European nettle tree grows in mild, warm or temperate regions, mainly on deep and fertile soils. It sometimes grows among rocks in gullies and on rocky slopes, in which case it does not usually get any larger than a small tree.

It is found in southern Europe, western Asia and North Africa. It flowers from April to June, bearing fruit from September to October.

Description of fruit and seeds

Fleshy drupe fruit, 8.5–12 mm in length with a 2–2.5 cm peduncle, rounded, smooth, with a ring of hairs at the base, green at first, then reddish-yellowish and finally violet, almost black when mature. Fruit-bearing peduncle 2–3 cm long.

Round seed with a reticulated surface, rough, light grey, somewhat whitish and 5–8 mm in diameter.

Seeds are extracted by removing the pulp, washing, drying, sieving and winnowing, with a yield of 13–15%.

Harvesting

From September to October by knocking the fruits down with poles. The fleshy fruit pulp is removed after soaking in water for 1–2 days, and then the seeds are sieved under a jet of water. The seeds may be dried for storage or sown after pre-treatment.

Storage

The seed is orthodox, so must be stored in dry, cold conditions at a temperature of 4–5°C (moisture content 4–8%). Seeds can be stored in airtight containers for 5 years without any significant loss of viability.

Seed extraction efficiency (%)	Purity test (%)	Germination test (%)	Seeds kg^{-1}
30–40	95–100	60–90	5,000–9,000

Pre-germination treatments

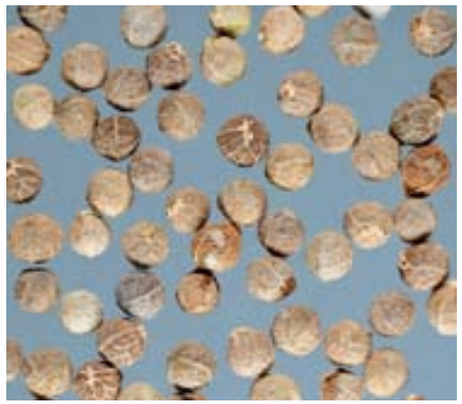
Treatments recommended for this species:

- Cold stratification, 2–4°C, 2 months (December–January).
- Stratification in moist sand at 4°C for 3–4 months.
- Sowing immediately after pulp removal

The condition of the seeds must be observed frequently during stratification and the treatment stopped when the first signs of germination are observed.

Nursery production

Celtis sp. seedlings have traditionally been cultivated as bare-root plants, as they are used in riverside restoration work. In this case sowing is in autumn or spring if the seed has been stratified previously. Plants are usually grown for 2 years in seedbeds, to a final size of 50–75 cm. Seedlings can also be grown in production containers of 300–400 cm^3 in peat–perlite growing media (volume 2:1). After pre-treatment, seeds are sown in germination trays at 1 cm depth and the trays put inside a greenhouse. When the seedlings appear and they are large enough to be handled, they are transplanted into containers (400 cm^3) using potting growing media, taking care not to damage the roots.



Celtis australis seeds .
Photo by: X. Goñi, UdL

Celtis australis fruits.
Photo by: R. Navarro-C. Gálvez, UCO

Celtis australis seedlings.
Photo by: R. Navarro-C. Gálvez, UCO

Establishment

- Sowing and planting

The only establishment method for this species is planting because of seedling requirements and the type of reforestation. If planting aims to restore riparian ecosystems, larger trees can be used, even as bare root plants (height > 1.5 m, diameter > 3 cm); the roots must be protected from physical damage. The planting season is autumn except in areas where winter frosts occur, where planting should be delayed until winter ends.

- Density and distribution

High densities of 1,100–1,200 trees ha^{-1} are recommended for protection in favourable places. For riverside restoration, density is lower (200–300 trees ha^{-1}), used together with other species.

- Treatment of existing vegetation

Treatment of woody species may be required, with tools such as sickles and manual or motorized brush-cutters.

- Site preparation

Simple or double subsoiling or excavator mounding are the most common site preparation methods for agricultural land and riverside restoration.

Carob tree
Caroubier
الخروب

Ceratonia siliqua L.

Description of species and habitat

This tree grows up to 10 m in height and has brown bark and a rounded crown. Perennial leaves with 3–6 pairs of leaflets up to 40–65 mm, elliptic oval or obovate, obtuse, frequently emarginate, petiolate, coriaceous and with an undulating margin. Flowers in racemes borne on the branches and trunk, almost always single sex, small, inconspicuous, with a calyx formed of 5 greenish or reddish sepals, without corolla.

The carob tree grows in warm, gentle climates, not penetrating far into the interior because of its sensitivity to frosts. It lives on dry, rocky, mainly limestone soils, in gullies and on sunny hillsides; it does not tolerate badly drained or clayey soils. It is found at low elevations in almost all the warm parts of the Mediterranean basin, especially in North Africa and the Near East. It grows larger than other fruit trees though very slowly, starting to bear fruit about 7–10 years after planting and reaching full production after 15–20 years. With its evergreen leaves, it is quite drought tolerant.

It flowers from May to December, bearing fruit in the summer.

Description of fruit and seeds

The fruit is a polyspermous legume, elongated and compressed, 4.5–25 cm long, 0.9–2.5 cm wide and 3–6 mm thick, indehiscent, frequently curved, with a sweet, fleshy-fibrous pericarp, which is green at first, becoming reddish-brown to black.

Flat-oval seeds, measuring 8–10 x 6–7.5 mm, shiny reddish-brown, with a thick impermeable testa. Seed extraction is not easy without damage: the carob has to be threshed, sieved and separated by densitometric/ flotation methods.

Harvesting

From mid-August to October depending on the area, by knocking down with poles or directly from the ground.

Storage

Seed can be stored in a cold, dry environment for quite prolonged periods (only seeds from the current year's harvest are recommended for sowing). It can also be stored outside.

Seed extraction efficiency (%)	Purity test (%)	Germination test (%)	Seeds kg^{-1}
8–16	95–98	70–90	4,500–5,500

Pre-germination treatments

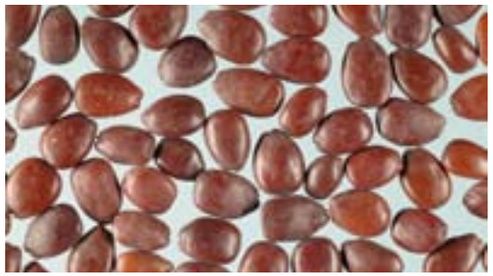
Treatments recommended for this species:

- Immersion in water for 10–15 days, removing the swollen seeds every third day.
- Scalding in boiling water for 1–10 minutes and resting in cold water for 24 hours.
- Mechanical scarifying and soaking for 24 hours.

Nursery production

Seedlings are grown in 300–400 cm^3 forest containers for 1 or 2 growing seasons. Growing medium formulated with peat with low percentages of inert material (perlite). Nitrogenated and phosphoric fertilization (if this is not possible, the addition of forest and mineral soil to the growing media is recommended). Some recommended doses of CSRF (controlled slow release fertilizers) are 16–8–9 to 3.5 kg/m3 or 9–13–18 to 5 kg/m^3.

Ceratonia fruit. Photo by: R. Navarro y C. Gálvez, UCO



Ceratonia seeds. Photo by: X. Goñi, UdL

Ceratonia seedlings. Photo by: R. Navarro y C. Gálvez, UCO

Establishment

- Sowing and planting

The usual establishment method is planting with 1–2–year-old container seedlings, generally after winter in areas susceptible to frosts. If there is no risk of frost, earlier planting can be carried out in winter.

- Density and distribution

The usual pattern is in a rectangular grid (9x9 m or 7x8 m), with final densities of 100–175 trees ha^{-1}, to optimize fruit production. Density should be higher in forest restoration, about 500–1,100 trees ha^{-1}.

- Treatment of existing vegetation

Weeding or treatment of woody species may be required, with ploughing or brush-cutting.

- Site preparation

Simple or double subsoiling or deep ridge ploughing (in particular on sandy ground) are the most common site preparation methods.

Laurel Laurier غار	*Laurus nobilis* L.
Description of species and habitat	The laurel tree grows up to 10 m in height, with a dense crown and a straight trunk with smooth bark and erect branches. Leaves shortly petiolate with limb measuring 9–12 x 2.5–4 cm, narrowly oblong-elliptic, acute or acuminate, with an undulating margin, glabrous, dark green on the upper side and somewhat lighter on the underside. Clusters of 4–6 flowers, axillary, single. Flowers are yellowish green or whitish. The laurel grows in moist, shady gullies in coastal zones. It is pyrophytic and grows in any soil. It flowers from the second half of January to April, the fruit maturing in late summer, becoming blackish when ripe.
Description of fruit and seeds	Berry fruit with thin pericarpium, black, smooth, shiny skin. It is somewhat elliptical, slightly acuminate, 15–20 x 10–15 mm wide. Elliptical seed, 9 x 6.5 mm, brown with ochre markings. The fruit is normally used as a commercial seed due to the seed's fragility, so it is not separated from the pulp.
Harvesting	Seeds: collection is usually in September and October, the fruits being harvested manually directly from the plant. The fleshy seed coat is removed by macerating the fruits in water for 1–2 days and then sieving under a jet of water. The rest of the floating pulp and bad seeds can be removed from the water. Cuttings: these are taken in March–April from new branches of the current year, or in September–October from these same branches (they will be woodier than in spring). Very straight, thick, soft growing shoots are cut, preferably from the bottom of the shrub. A basal cut is made about 10–15 cm from the top of the cutting and below a node. Any leaves should be removed from the bottom half (to two-thirds) of the cutting. Remaining large leaves should be trimmed so that they do not overlap.
Storage	Seeds: care must be taken with these seeds because they are recalcitrant and their storage period is limited, so any short-term storage must be in the cold and damp (moisture content of 10–15%). Cuttings: these can be stored for only a few days while they are being planted. They should be put into sand, potting substrate or water in the fridge at 2–4°C.

Seed extraction efficiency (%)	Purity test (%)	Germination test (%)	Seeds kg^{-1}
	95–98	70–95	500–1,100

Pre-germination treatments	Treatments recommended for this species: • Untreated laurel seeds germinate very slowly, so stratification for 1–2 months at a temperature of 2–4°C is recommended. • Soaking in water for about 10 days to eliminate the fleshy pericarp which encloses the seed and causes its latency.
Nursery production	The laurel has traditionally been produced as a species for riverside and ecological restoration, using one- or two-year-old seedlings with a final height of 50–80 cm. Seeds: Seeds are sown in March in seed trays, with peat, at a depth of 0.5–1 cm. They should be kept in a greenhouse, on tables. Care should be taken to water them enough by spraying until germination begins. When the seedlings appear and are large enough to be handled, they should be transplanted into small forest containers with peat and kept in the greenhouse. After about 1 month, the root system will have filled the small forest tray cells and they will be ready to be transplanted into larger containers (300–400 cm^3) and moved to outside seedbeds. Cuttings: cuttings are inserted in the cutting medium up to the level of their leaves in perforated containers to ensure proper drainage. The cutting growing medium could be 50% sand + 50% peat or perlite, or 50% perlite + 50% peat. They should be watered with a fungicidal solution to prevent root rotting. The growing medium should always be kept moist. The cuttings will root in 1–2 months. When the roots are 2–3 cm long the seedlings can be transplanted into forest containers (400 cm^3) and placed outside on the ground. In the case of autumn cuttings it will be better to keep the forest container inside the greenhouse until April–May. During the summer the seedlings should be protected with a shade mesh in hot weather.

Tree of *Laurus Nobilis*. Photo by: R. Navarro-C. Gálvez, UCO

Laurus nobilis seedlings.
Photo by: R. Navarro-C. Gálvez, UCO

Laurus nobilis seeds.
Photo by: X. Goñi, UdL

Establishment

- Sowing and planting

The establishment method is planting by hand. One- or two–year-old seedlings can be used. Planting should be carried out during autumn or winter (October to February).

Cuttings can be planted out the following autumn or winter (October to February). The shade should be removed from over the plants in September, at least 1 month before transplanting.

- Density and distribution

The recommended planting density for the species is low. In riverside restoration higher densities (about 300 trees ha^{-1}) can be used on moister sites with deeper soil.

- Treatment of existing vegetation

The most commonly recommended method for eliminating existing vegetation is manual control, given the site characteristics where this species grows (slopes, rocky terrain); motorized brush-cutters may be used in more accessible places.

- Site Preparation

Low- to medium-intensity work (depending on the type of restoration) involving manual hole digging, or occasionally mechanized digging with an excavator.

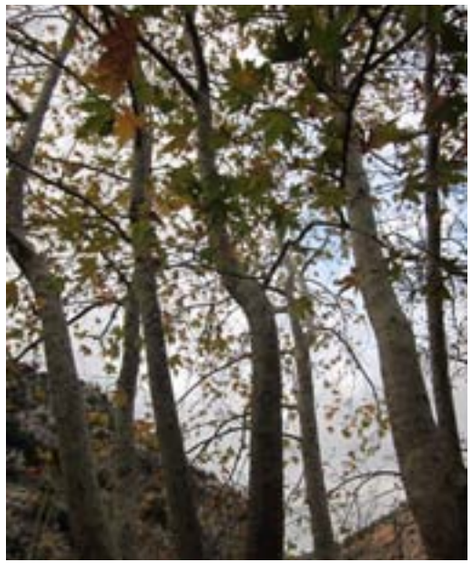
Photo by: N. Trung, Creative Commons

Oriental plane tree Platane d'orient دلب	*Platanus orientalis* L.
Description of species and habitat	The Oriental plane is a robust tree which can exceed 30 m in height. Oval crown, more rounded over time, which can become very wide. Sinuous, twisted branches with shoots that can be vertical, above all on upper branches. Straight, thick trunk with scaly bark in patches on the oldest branches and generally rough and fissured. Deciduous leaves, palmate, large, with 5–7 lobes clearly longer than wide, medium green and lighter on the underside. It has a powerful root system which requires deep soil to develop properly. It is native to south-eastern Europe and south-western Asia to Iran, and even occurs in central Asia (Uzbekistan, Tajikistan). It flowers from April to May.
Description of fruit and seeds	Male and female flowers on the same tree, each sex grouped in spherical inflorescences which hang from long peduncles. The fruits are tightly grouped in spherical glomerules, about 3–5 cm in diameter, in the form of an inverted pyramid, which gives the glomerule the appearance of a spiny cover, downy to facilitate its dispersal by wind. The seeds are extracted by sun drying and gentely rubbing.
Harvesting	When the fruits mature in mid-winter (January–February), they should be put to dry on paper. Then, the seeds are separated from the fruits and the hairs removed by using a fine sieve.
Storage	The seeds can be kept for several years if placed in airtight containers at a low temperature (3–4°C), after their moisture content has been reduced to 7–10% by air drying.

Seed extraction efficiency (%)	Purity test (%)	Germination test (%)	Seeds kg-1
55–66	90–95	30–50	178,600–357,200

Pre-germination treatments	The species does not require any pre-germination treatments. Average germination is generally low (30–40%). Nevertheless, soaking the seeds in water for 1–2 days before sowing can improve the germination.
Nursery production	Seeds are sown immediately after harvesting without any prior treatment or in spring after cold stratification for 6–8 weeks. They can be sown directly into forest containers (400 cm^3), 0.5 cm deep. Three to four seeds can be placed in each container. It is advisable to cover the seeds with a very thin layer of growing medium. When seedlings appear, if more than one has germinated in some cells they can be removed and transplanted into empty cells to complete the trays.

This species can also be multiplied by cuttings from the current year's shoots, collected when the tree is at rest in winter, or from an area felled the same year; in the latter case the best tree stumps are chosen, and from these the best stalks (stock shoots) are taken for cuttings. The stalks may be given some type of treatment to encourage rooting, like an application of hormones or immersion in water and moist sand, before planting in the nursery plots.



Mature *P. orientalis* trees during autumn. Photo by: E. Chnais, AFDC

P. orientalis seedlings. Photo by: E. Chnais, AFDC

P. orientalis seeds. Photo by: E. Chnais, AFDC

Establishment	• Sowing and planting The most common method is to plant a one-season-old bare-root plant or to plant collected, treated cuttings directly beside rivers. They should be set deeply and firmly in the soil. Remove the shade from over the plants at least 1 month before transplanting. • Density and distribution Low densities of 200–400 trees ha^{-1} are recommended for production in favourable places. For riverside restoration, density can be increased (> 600 trees ha^{-1}), used together with other species. • Treatment of existing vegetation Treatment of woody species may be required, with tools such as sickles and manual or motorized brush-cutters. • Site preparation Excavator mounding is the most common site preparation methods for production plantations and riverside restoration.

White poplar
Peuplier blanc
حور ابيض

Populus alba L.

Description of species and habitat	A deciduous tree which can exceed a height of 30 m. Greyish-white, smooth trunk at first, fissuring longitudinally with age, showing a darker inside. Whitish downy shoots becoming reddish and hairless. Variable leaves, those on vigorous branches with 3–5 roughly dentate lobes, 6–12 cm long, with a round base. Dark green upper side with white down on the underside. The leaves on short branches are smaller, 4–9 cm long and 3–7 cm wide, oval or oblong, sinuate–dentate, with a truncated base and greyish underside. Almost cylindrical, downy petiole much longer on leaves from long branches than on those from short branches. Species originating in Europe, Western Asia and North Africa. Its habitat is the banks of rivers and streams, sometimes forming dense woods which can form closed canopy. It grows on neutral or basic soils, although it can tolerate heavy ones with a certain degree of salinity, standing up well to warm climates if the water supply is sufficient. Rapid growth. It flowers from February to April before forming new leaves. Anemophilous pollination.
Description of fruit and seeds	Male catkins 8 cm long, generally with 8-stamen flowers. Female catkins 5 cm long with 2-stamen flowers. Oblong–conical capsule, 4 mm long with two valves, green to dark grey, on short pedicle. Small seeds 2–2.5 mm long, with a hairy, white 8 mm tuft. They mature from March to June. Vegetative reproduction is used for seedling production.
Harvesting	• Seeds: from April to June, before maturity. Directly from the branches by accessing the crown, or from the ground by collecting seeds which have fallen. It is an advantage to collect from felled trees. • Winter cuttings: these should be taken in late winter, about February, when the buds are ready to open. Very straight branches, 1–2 years old, should be cut and cuttings 20–30 cm long and 0.6–0.12 cm wide prepared by making a cut just above the proposed top bud and another just below a bud 15–20 cm below the top cut .
Storage	• Seeds: In airtight containers in a cold, dry environment. For long-term storage (over 2 years), store at a temperature between 0 and -18°C and a moisture content of 4–8%. They can be conserved at 4–5°C for a couple of years with the same characteristics. • Cuttings of *Populus alba* need to be well irrigated to produce roots, so they are soaked in water (for example in boxes inside a plastic pool) for 10–15 days, before planting in the soil.
Pre-germination treatments	The seeds of the *Populus* genus do not present lethargy of any type and germinate rapidly without needing any prior treatment.

Nursery production	• Cuttings: Set cuttings in the ground in February–March after soaking in water. Dig the soil very well. Plant the cuttings vertically, leaving about 2.5 cm (at least 2 buds) exposed. Cuttings should be planted at about 15 cm intervals in rows at least 0.5–1 m apart. If the soil is very heavy or poor, adding sand and/or compost will be useful. The root growth from the cuttings will need a well-drained soil. Water very well after planting and when the soil becomes dry. Remove weeds as necessary. Cuttings can also be placed in forest trays (400 cm^3) with growing media instead of using the method above.

Populus alba tree.
Photo by: E. Chnais, AFDC

Populus alba flowers.
Photo by: R. Navarro-C. Gálvez, UCO

Populus alba leaf.
Photo by: R. Navarro-C. Gálvez, UCO

Establishment	• Sowing and planting The only establishment method for this species is planting because of seedling requirements and the type of reforestation. If planting aims to restore riparian ecosystems, larger trees can be used, even as bare root plants (height > 2 m, diameter > 2–3 cm); the roots must be protected from physical damage. The planting season is autumn except in areas where winter frosts occur, where planting should be delayed until winter ends. • Density and distribution Low densities of 200–400 trees ha^{-1} are recommended for production in favourable places. For riverside restoration, density can be increased (> 600 trees ha^{-1}), used together with other species. • Treatment of existing vegetation Treatment of woody species may be required, with tools such as sickles and manual or motorized brush-cutters. • Site preparation Excavator mounding is the most common site preparation method for production plantations and riverside restoration.

Kermes oak
Chêne vert
سنديان

Quercus calliprinos Webb.

Description of species and habitat

Medium-sized tree , 5-1 8 m tall (often only 1-3 m tall in frequent grazing areas) and a trunk up to 1 m in diameter, this being tortuous with a smooth grayish bark and heavily branched. Evergreen leaf, 3-5 cm long and 1.5-3 cm wide, with short petiole, coriaceous, oblong to oval-lanceolate, ondulated edge with spiny-serrated teeth, totally hairless when adult, green on the upper side and grayish on the underside side, which lasts for at least two years.

It appears on dry, sunny slopes with Mediterranean heath land formations and semi-steppe zones. Kermes oak lives on all type of soils and prefers warm climates. Well adapted to summer droughts. Mainly eastern Mediterranean region.

It flowers from March to May, bearing fruit in the summer-autumn of the second year.

Description of fruit and seeds

Fruit in acorn, 3-4 cm long and 2-3 cm in diameter, chestnut-brown when mature, with a shiny or coriaceous cover surrounded at the base by a corneal husk covered in scales with a curved apex, patent and rigid.

Seed covered by a dark grey film which separates longitudinally into two halves (cotyledons). The seed is cleaned by eliminating the husks via sieving, and floatation.

Harvesting

Acorns are collected in early autumn when it turns chestnut brown. The most appropriate method is by knocking down with poles. It is better to collect from the branches rather than from the soil; in this last case take care to collect good fruits not attacked by insects or fungi.

Storage

Seeds are recalcitrant, so conservation must never be prolonged, and always in a cold, moist environment (water content of hygroscopic medium 90%). For longer conservation the acorn humidity content must be between 40-42% to impede germination. They must always be kept in humid sand or peat, in the fridge at 1-3 °C in plastic bags or glass bottles.

Seed extraction efficiency (%)	Purity test (%)	Germination test (%)	Seeds kg-1
60 - 85	95 - 100	80 - 90	

Pre-germination treatments

The species does not require pre-germinative treatments although soaking the seeds for 24-48 hours is recommended for homogenous sprouting.

Nursery production

Nursery sowing is usually done in autumn with recently collected seeds or in spring with seeds stratified in moist sand or moist peat for 30-60 days at 0-2 °C. If sowing is in spring with stratified seeds, they may have germinated during storage and have a root 2-5 cm long. If this happens, the roots are pruned and the acorns are sown immediately. The long-standing percentage is much smaller with pre-germinated seeds. Germination occurs in the 4-6 weeks following sowing.

Growth is done in a 300-400 cm3 and 15 cm deep forest containers during a growing period, with a final height of 15-20 cm. Using two-year-seedlings, plants will demand a larger volume container. In winter sowing it would be better to cover the trays with a piece of mesh or mulch, until germination begins, to avoid damages from frost or mice.

Growing media is formulated with peat and another component like vermiculite, perlite or pine bark. A fertilization regime can be applied from July, with average contributions of N-P-K of the order of 100-40-120 ppm in growth and 50-40-150 ppm in hardening. With slow release fertilizers quantities of 1.8-2 kg m-3 of growing media, Osmocote type fertilizer 15-9-11+2.5 mg are used.

Mature tree of *Q. calliprinos* acorn.
Photo by: N. Hani, AFDC

Seedling of *Q. calliprinos*.
Photo by:
E. Chnais, AFDC

Seeds of *Q. calliprinos*.
Photo by:
S. Hatoum, AFDC

Establishment

- Sowing and planting

The most widely used establishment method is planting (one-year-seedling), although sowing has lately regained importance and it must be consider as an alternative. Planting and sowing are manual, placing the seedling or 2-3 acorns in each pit. The planting season is autumn-winter except in zones where winter frosts advise delaying until winter ends.

- Density and distribution

This will depend on the plantation target, although high densities of around 600-1000 trees ha-1 or more are recommended on ecological restoration.

- Treatment of existing vegetation

Weeding or treatment of woody species may be require with ploughing or brush-cutting

- Site preparation

Simple or double subsoiling or ploughing deep ridges (in particular on sandy terrain) are the most frequent soil preparation methods.

Turkey oak Chêne chevelu العزر	*Quercus cerris* L.
Description of species and habitat	A medium-sized tree growing up to 20–25 m, sometimes 35 m; straight trunk, grey bark when young, then forming a non-corky, deeply fissured bark, reddish on the inside and dark grey on the outside. Simple, alternate leaves, falling in late autumn, subcoriaceous or slightly coriaceous, 7–14 x 3–5 cm. It occurs naturally over the centre and south of Europe and south-east Asia, requiring a mean annual precipitation of over 500 mm. It prefers siliceous soils, although it tolerates lime well if rain washes the excess away from its base. Relatively rapid growth to approximately 50 years. Medium light requirements. It flowers from April to May and the fruit matures in autumn of the following year.
Description of fruit and seeds	Acorn, 3–4 cm, sometimes very long up to 5 cm, by 18–20 mm in diameter, reddish-dark grey, oblong, flattened at the apex. Cup 20–30 mm, covered in soft, long, bristly scales, pubescent, flattened or rolled up. The seeds are cleaned by removing the husks by sieving and flotation.
Harvesting	Seeds are collected in early autumn, when they turn chestnut-brown. The most appropriate method is to knock them down with poles. It is better to collect from the branches rather than from the soil; in the latter case care should be taken to collect good fruits not attacked by insects or fungi.
Storage	Seeds are recalcitrant, so storage must never be prolonged, and always in a cold, moist environment (water content of the hygroscopic medium 90%). For longer storage the acorn moisture content must be 40–42% to impede germination.

Seed extraction efficiency (%)	Purity test (%)	Germination test (%)	Seeds kg^{-1}
60–80	95–100	60–90	

Pre-germination treatments	The species does not require pre-germination treatments, although soaking the seeds for 24–48 hours is recommended for homogenous sprouting. They must always be kept in damp sand or peat in the fridge at 1–3°C in plastic bags or glass jars.
Nursery production	Nursery sowing is usually done in autumn with recently collected seeds or in spring with seeds stratified in moist sand or moist peat for 30–60 days at 0–2°C. If stratified seeds are sown in spring, they may have germinated during storage and have a root 2–5 cm long. If this happens, the roots must be pruned and the acorns sown immediately. The survival percentage is much smaller with pre-germinated seeds. Germination occurs in the 4–6 weeks following sowing. Plants are grown in 300–400 cm^3 and 15 cm deep forest containers for one growing season, to a final height of 15–20 cm. Two-year-old seedlings will require larger containers. In winter sowing it is best to cover the trays with a piece of mesh or mulch until germination begins, to avoid damage by frost or mice.

The growing medium is formulated with peat and another component such as vermiculite, perlite or pine bark. A fertilization regime can be applied from July, with average N–P–K in the order of 100–40–120 ppm during growth and 50–40–150 ppm during hardening. Slow-release , Osmocote®-type fertilizers, 15–9–11 +2.5 Mg, are used at a rate of 1.8–2 kg m^{-3} of growing medium.

Q. cerris trees. Photo by: S. Hatoum, AFDC

Q. cerris seeds. Photo by: S. Hatoum, AFDC

Q. cerris seedlings, Photo by:E. Chnais, AFDC

Establishment	• Sowing and planting The most widely used establishment method is planting (of one-year-old seedlings), although sowing has lately regained importance and must be considered an alternative. The planting season is autumn–winter except in areas where winter frosts advise delaying until winter ends. • Density and distribution This will depend on the plantation purpose, although high densities of around 600–1,000 trees ha^{-1} or more are recommended for ecological restoration. For silvicultural objectives, density should be lowered to 200–300 trees ha^{-1}. • Treatment of existing vegetation Weeding or treatment of woody species may be required, with ploughing or brush-cutting • Site preparation Simple or double subsoiling or deep ridge ploughing (in particular on sandy ground) are the most common site preparation methods.

Cyprus oak
Chêne tinctorial
ملول

Quercus infectoria Oliv.

Description of species and habitat

Small, semideciduous tree or shrub, 2–5 (even 10) m tall, straight trunk, spherical or ellipsoidal crown, rather thin, very rough bark. Leaves very varied in size and colour, 40–70 (100) x 10–45 mm, coriaceous, oval to narrowly oblong, long, rounded or wedge-shaped at the base, often undulating with 4–8 crenate-dentate to entire lobes.

It grows in areas with a continental Mediterranean climate, neither extreme nor sub-Mediterranean. The nature of the soil is unimportant though it prefers limy or clayey-limy soils. Altitude range usually 500–1,600 m.

It flowers from April to May and bears fruit from September to October.

Description of fruit and seeds

Fruit inside acorn, cylindrical, two or three times longer than the husks.

The seed is cleaned by husk elimination via sieving, and flotation.

Harvesting

Acorns are harvested in early autumn when they turn chestnut-brown. The most appropriate method is by knocking down with poles. It is better to collect from the branches rather than from the ground; in the latter case care should be taken to collect good fruits not attacked by insects or fungi.

Storage

Seeds are recalcitrant, so storage must never be prolonged, and always in a cold, moist environment (water content in hygroscopic medium 90%). Acorn humidity content must be 40–42% for longer storage in order to impede germination. They must always be kept in moist sand or peat, in the fridge at 1–3°C in plastic bags or glass jars.

Seed extraction efficiency (%)	Purity test (%)	Germination test (%)	Seeds kg^{-1}
51–80	95–100	80–95	

Pre-germination treatments

This species does not require pre-germination treatments, although soaking the seeds for 24–48 hours is recommended to homogenize sprouting.

Nursery production

Nursery sowing is usually done in autumn with recently collected seeds or in spring with seeds stratified in moist sand or moist peat for 30–60 days at 0–2°C. If sowing is in spring with stratified seeds, they may have germinated during storage and have a root 2–5 cm long. If this happens, the roots are pruned and the acorns are sown immediately. The survival percentage is much smaller with pre-germinated seeds. Germination occurs in the 4–6 weeks following sowing. Plants are grown in 300–400 cm^3 and 15 cm deep forest containers for one growing season, attaining a final height of 15–20 cm. Two-year-seedlings will require larger containers. In winter sowing it is best to cover the trays with a piece of mesh or mulch until germination begins, to avoid damage by frost or mice.

The growing medium is formulated with peat and another component such as vermiculite, perlite or pine bark. A fertilization regime can be applied from July, with average N–P–K in the order of 100–40–120 ppm during growth and 50–40–150 ppm during hardening. Slow-release, Osmocote®-type fertilizers, 15–9–11+ 2.5 Mg, are used at a rate of 1.8–2 kg m^{-3} of growing medium.

Seeds of *Q. infectoria*. Photo by: S. Hatoum, AFDC

Q. infectoria seedlings. Photo by: E. Chnais, AFDC

Q. infectoria tree. Photo by: N. Hani, AFDC

Establishment

- Sowing and planting

The most widely used establishment method is planting (of one-year-old seedlings), although sowing has lately regained importance and must be considered an alternative. Planting and sowing are carried out manually, placing the seedling or 2–3 acorns in each pit. The planting season is autumn–winter except in areas where winter frosts advise delaying until winter ends.

- Density and distribution

This will depend on the plantation purpose, although high densities of around 600–1,000 trees ha^{-1} or more are recommended for ecological restoration. For silvicultural objectives, density should be lowered to 200–300 trees ha^{-1}.

- Treatment of existing vegetation

Weeding or treatment of woody species may be required, with ploughing or brush-cutting.

- Site preparation

Simple or double subsoiling or deep ridge ploughing (in particular on sandy ground) are the most common site preparation methods.

White willow Saule blanc صفصاف ابيض	*Salix alba* L.
Description of species and habitat	White willow grows to a height of 15–25 m, with a straight trunk up to 1 m in diameter. Bark is greenish grey at first becoming greyish brown, with longitudinal striations in longer-living specimens. Irregular crown with numerous erect branches, long, flexible, with smooth bark. Large leaves, lanceolate or oblong-lanceolate, acuminate, slightly serrate-glandular, inserted alternately in patent position, with a short petiole measuring less than 5 mm. It is found over almost all of Europe, northern and central Asia and North Africa. It occurs in groves, on river banks and in moist places. The type of soil is unimportant, and it tolerates some degree of salinity. Very rapid growth species. Flowers grouped in catkins. It flowers from April to May.
Description of fruit and seeds	Fruit in 2–4 mm capsule, ovoid, obtuse, hairless. Numerous small seeds with tufts of silky hairs. The seed matures from April to June, one or two months after flowering. Vegetative reproduction is used for seedling production.
Harvesting	• Seeds: from March to June, depending on the site. When the capsules mature they turn dark yellowish grey and the tufts of fruit hairs begin to appear. Once collected, they are allowed to dry for 1 or 2 days at ambient temperature for opening. Normally the seeds are not separated from the open capsules. They are harvested manually from the ground or with poles. • Winter cuttings: collected during January when the buds on the branches are still dormant. Very straight branches, 1–2 years old, are cut. Cuttings 15–20 cm long and 0.6–0.12 cm wide are prepared by making a cut just above the proposed top bud and another just below a bud 15–20 cm below the top cut.
Storage	• Seeds: may be kept for one month in airtight containers (moisture content 6–8%) at 4°C. For longer periods (3–5 years), the seeds are kept under the same conditions but at a temperature below 0°C. • Cuttings: if the weather is too cold, the prepared cuttings can be stored for 1–3 weeks before planting, in plastic boxes, top down. They should be watered a little to maintain moisture. The boxes have to be stored in a dark, cool, damp area. If roots appear the cuttings should be planted out immediately
Pre-germination treatments	The species does not require pre-germination treatment.

Nursery production	Cuttings: Plant the cutting in the ground in January. Dig the soil very well. Plant the cuttings vertically, leaving about 2.5 cm (at least 2 buds) exposed. Cuttings should be planted at about 15 cm intervals in rows at least 0.5–1 m apart. If the soil is very heavy or poor, adding sand and/or compost will be useful. The root growth from the cuttings will need a very well-drained soil. Water very well after planting and when the soil becomes dry. Remove weeds as necessary. Cuttings can also be planted in forest containers (300 cm^3) instead of using the method above.

Mature *Salix alba* mature tree. Photo by: N. Hani, AFDC

Salix alba leaves and flower buds. Photo by: N. Hani, AFDC

Salix alba tree. Photo by: M. Navarrete, IDAF

Establishment	• Sowing and planting The most common method is to plant a one- or two-season-old bare-root plant or to plant 0.8–1.5 m cuttings directly on river banks. They should be set deeply and firmly into the soil during winter after the leaves have fallen. • Density and distribution High densities of 1,100–3,000 trees (cuttings) ha^{-1} are recommended for protection in favourable places. For riverside restoration, density is lower (300–500 trees ha^{-1}), used together with other species. • Treatment of existing vegetation Treatment of woody species may be required, with tools such as sickles and manual or motorized brush-cutters. • Site preparation Manual digging or excavator mounding are the most common site preparation methods for riverside restoration.

Oriental strawberry tree
Arbousier d'Orient
قطلب

Arbutus andrachne L.

Description of species and habitat

Shrub or small tree growing up to 12 m in height; its trunk has striking reddish bark which splits into scales. Young branches are downy and reddish. Abundantly leafy branches. Oval or oblong leaves, usually with entire margins or, less commonly, slightly serrate, coriaceous, 5–10 cm long, dark green on the upper side, matt on the underside and with a short petiole. Inflorescence in a multifloral terminal panicle. White corolla, yellowish on desiccation and hairy inside.

It flowers generally from December till March.

Description of fruit and seeds

Red or orangey, globe-shaped berry when ripe, 25 mm in diameter, knobbly, tuberculate. Small seeds, 2–3 mm long, angular with a dark grey fissured seed coat.

Harvesting

The fruits are harvested in autumn and ripen gradually. Collection is not very complicated, although the fruits vary in consistency, so branch cutting is recommended. Seed extraction is complicated both because the pulp has to be removed and because the seeds are small. It is done by removing the pulp and then washing, drying and sieving the seed, producing a very low yield of about 2–3%.

Storage

Seeds may be stored in a cold, dry environment, in plastic bags or glass jars, in the fridge (3–4°C). They should be stored for no more than 3 months

Seed extraction efficiency (%)	Purity test (%)	Germination test (%)	Seeds kg^{-1}
2–3	30–40	20–40	

Pre-germination treatments

The strawberry tree seed germinates, though slowly, without the need for any prior treatment. Better and more rapid germination is obtained if the seed is first stratified in moist sand at 2–4°C for 60 days. Seeds should be placed in warm water for 5–6 days to soften before sowing.

Nursery production

As a general rule seeds must be sown in autumn, without the need for any prior treatment, or in spring if previously stratified seed is used. If sown before spring temperatures increase (the seeds need less than 20°C to germinate), they should be sown in seed trays, with peat, very shallowly, only 1–2 mm deep. They must be kept inside a greenhouse on raised tables. Care should be taken to water them enough by spraying until germination begins. If the surface of the seedbed dries out, the seeds can go into secondary dormancy and germinate later, during the following autumn. Fungal attacks in the seedbed must be prevented by spraying with fungicides after the seedbed is made and every 10–15 days thereafter. When the seedlings appear and are large enough to be handled, they should be transplanted into forest containers with peat and kept in the greenhouse.

After about 1 month, the root system will have filled the small forest tray cells and they will be ready to be transplanted into larger forest containers (300–400 cm^3) and moved to outside seedbeds to produce one-season plants up to 20–25 cm in height.

As it is a species which can be used in ecological restoration, in particular in riverbank or enrichment planting, production of large seedlings is also recommended. In this case, growing bare-root seedlings could be more appropriate.

Seedlings of *A. andrachne*, Photo by:E. Chnais, AFDC

A. andrachne mature tree with fruits. Photo by: N. Hani, AFDC

Seeds of *A. andrachne* Photo by: S. Hatoum, AFDC

Planting in soil

- Sowing and planting

The establishment method is planting by hand; sowing is not recommended. One- to two-year-old seedlings can be used. Planting should be carried out during autumn or winter (October to February) if the seedlings are large enough.

- Density and distribution

The recommended planting density for the species is low, seeking maximum vitality, protection and shade with minimum interspecies competition. Higher densities (about 500 trees ha^{-1}) can be used on moister sites with deeper soil, but densities decrease progressively towards less favourable areas that would best be left for other, less demanding species at variable densities (200–300 trees ha^{-1}).

- Treatment of existing vegetation

The most commonly recommended method for eliminating existing vegetation is manual control, given the site characteristics where this species grows (slopes, rocky terrain); motorized brush-cutters may be used in more accessible places.

- Site preparation

In ecological restoration programmes manual hole digging will be the best alternative.

Strawberry tree Arbre aux fraises طعمة حمراء	*Arbutus unedo* L.
Description of species and habitat	The strawberry tree is a tree or shrub growing to 4.5–7 m in height; its trunk has reddish, scaly bark. Young branches are downy and reddish. Abundantly leafy branches. Leaves 8–10.5 x 3–4 cm, lanceolate, lauroid, serrate, bright green on the upper side, matt on the underside and with a short petiole. Inflorescence in a reddish, multifloral, terminal panicle. White corolla, yellowish when desiccated and downy on the inside. The strawberry tree normally occurs in the successional stages of stands of Quercus spp., frequently mixed with other shrubs on all types of limy or acid soils, up to 1,000–1,200 m. It prefers quite cool, deep soil and requires a gentle climate, without heavy frosts. It is found in southern Europe, western Asia and north Africa. It flowers from the second half of October until the first half of December, bearing fruit from November to February.
Description of fruit and seeds	Red or orangey globe-shaped berry when ripe, 25 mm in diameter, knobbly. Small seeds, 2–3 mm, long, angular with a dark grey fissured seed coat.
Harvesting	The fruits are harvested in autumn and ripen gradually. Collection is not very complicated, although the fruits vary in consistency, so fruit cutting is recommended. Seed extraction is complicated both because the pulp has to be removed and because the seeds are small. It is done by removing the pulp and then washing, drying and sieving the seed, producing a very low yield of about 1–2%. To separate the fleshy pulp from the seeds, the fruits have to be macerated in water for 2–3 days after collecting. Then the seeds are extracted by crushing the fruits in sieves (with holes smaller than the seeds) under a jet of water. Finally, the seeds will still be mixed with some fruit pulp, but they can be stored or sown like that. This mixture should be dried for storage or for immediate sowing, if there is no danger of frost.
Storage	Seeds may be stored in a cold, dry environment, in plastic bags or glass jars, in the fridge (3–4°C). They should be stored for no more than 3 months.

Seed extraction efficiency (%)	Purity test (%)	Germination test (%)	Seeds kg^{-1}
1–2	30–50	50–70	290,000–500,000

Pre-germination treatments	The strawberry tree seed germinates, though slowly, without the need for any prior treatment. Better and more rapid germination is obtained if seeds are first stratified in moist sand at 2–4°C for 60 days. Seeds should be placed in warm water for 5–6 days to soften before sowing.
Nursery production	As a general rule seeds must be sown in autumn, without the need for any prior treatment, or in spring if previously stratified seed is used. If sown before spring temperatures increase (the seeds need less than 20°C to germinate), they should be sown in seed trays, with peat, very shallowly, only 1–2 mm deep. They must be kept inside a greenhouse on raised tables. Care should be taken to water them enough by spraying until germination begins. If the surface of the seedbed dries out, the seeds can go into secondary dormancy and germinate later, during the following autumn. Fungal attacks in the seedbed must be prevented by spraying with fungicides after the seedbed is made and every 10–15 days thereafter. When the seedlings appear and are large enough to be handled, they should be transplanted into forest containers with peat and kept in the greenhouse. After about 1 month, the root system will have filled the small forest tray cells and they will be ready to be transplanted into larger forest containers (300–400 cm^3) and moved to outside seedbeds to produce one-season plants up to 20–25 cm in height. As it is a species which can be used in ecological restoration, in particular in riverbank or enrichment planting, production of large seedlings is also recommended. In this case, growing bare- root seedlings could be more appropriate.

A. unedo fruit. Photo by: R. Navarro-C. Gálvez, UCO

A. unedo seedlings. Photo by: R. Navarro-C. Gálvez, UCO

A. unedo seeds. Photo by: X. Goñi, UdL

Establishment	• Sowing and planting The establishment method is planting by hand; sowing is not recommended. One- to two–year-old seedlings can be used. Planting should be carried out during autumn or winter (October to February) if the seedlings are large enough. • Density and distribution The recommended planting density for the species is low, seeking maximum vitality, protection and shade with minimum interspecies competition. Higher densities (about 500 trees ha^{-1}) can be used on moister sites with deeper soil, but densities decrease progressively towards less favourable areas that would best be left for other, less demanding species at variable densities (200–300 trees ha^{-1}). • Treatment of existing vegetation The most commonly recommended method for eliminating existing vegetation is manual control, given the site characteristics where this species grows (slopes, rocky terrain); motorized brush-cutters may be used in more accessible places. • Site preparation In ecological restoration programmes manual hole digging will be the best alternative.

Photo by: Lucarelli, Creative Commons

Hawthorn Aubépine زعرور أحمر	*Crataegus monogyna* Jacq.
Description of species and habitat	Hawthorn is a shrub or small tree growing up to 10 m in height, with glabrous stalks that are only pubescent on young branches. It loses its leaves in winter and branches profusely; the trunk is greyish-brown or ash-grey. The leaves are rhombic or obovate-cuneate, petiolate, more or less coriaceous, discoloured, with 3–5 lobes, oblong, entire or somewhat dentate in the apical part. In general they are pubescent on the upper side, especially on the nerves, and glabrous or weakly pubescent on the underside. Large leafy stipules, frequently with a dentate edge. Inflorescence is cymose, terminal or axillary, forming scented corymbs. They have 5 round petals in a star shape. The flowers are white or pink-white. The hawthorn grows on all soil types in strips of woods, clearings, hedges, bramble patches, thickets, etc., between 0 and 1,500 m. It flowers from March to April–May and bears fruit from October to December.
Description of fruit and seeds	Subglobal or ovoid pomes, 6–10 x 4.4–10 mm, red, with a single seed protected by a whitish testa. Yellowish-dark grey ovoid seed, between 5 and 8 mm, with a hard testa and lethargy in the embryo. The seeds must be extracted immediately after collection to avoid inducing latency. Extraction is by pulp removal, washing, drying, and sieving, with an approximate yield of 12%.
Harvesting	The fruits must be collected by direct harvesting from the plant between August and October, before they mature completely. The fruits have a fleshy pulp that has to be removed immediately after collecting because it contains chemical inhibitors in the seed coat that obstruct germination: the fruits are macerated in water for 1–2 days after collecting, and the seeds extracted by sieving under a jet of water. The floating pulp and empty seeds are removed. The seeds can be dried for storage or for sowing after pretreatment.
Storage	Cold, dry storage in plastic bags or glass jars in the fridge (1–3°C).

Seed extraction efficiency (%)	Purity test (%)	Germination test (%)	Seeds kg^{-1}
12–22	92–100	60–90	11,000–18,000

Pre-germination treatments	Treatments recommended for this species: Scarifying with sulphuric acid and then stratification in moist sand for 4–5 months (or longer, depending on seed hardness); Hot stratification at 25°C in moist sand for 1–2 months; Mechanical scarification followed by stratification in moist sand for 4–5 months; Hot stratification at 25°C for 3 months, then cold stratification at 3–5°C for 9 months; Scarification with sand (3–5 months at 25°C; then 3 months cold); Pour hot water on the seeds; soak for 1–3 days; Pre- Refrigeration for 12 months at 3–5°C.

Nursery production	The hawthorn is a very difficult species to germinate, so nursery cultivation is always complicated. Some of the best results are achieved by collecting the fruit in summer, a little before they it is ripe, extracting the seed immediately and sowing it. Germination occurs 7–9 months after the first sowing. Sowing done in spring with previously treated seeds has rather low initial germination in that spring, so growth must be prolonged to two growing seasons. Seedlings can be transplanted to 300–400 cm^3 containers to produce one- or two-year-old seedlings 20–60 cm in height. For use on riverbanks, it can be grown as bare-root seedlings, producing plants with a final height of 60–120 cm in long rotations.

C. monogyna fruit.Photo by: R. Navarro-C. Gálvez, UCO

C. monogyna seedling.Photo by: R. Navarro-C. Gálvez, UCO

C. monogyna seeds.Photo by: X. Goñi, UdL

Establishment	• Sowing and planting The establishment method is planting by hand; sowing is not recommended. One- to two-year-old seedlings can be used. Also larger (more than one metre in height) bare-root seedlings can be planted out. Planting should be carried out during autumn or winter (October to February) if the seedlings are large enough. • Density and distribution The recommended planting density for the species is low. In riverside restoration, higher densities (about 500 trees ha^{-1}) can be used on moister sites with deeper soil. • Treatment of existing vegetation The most commonly recommended method for eliminating existing vegetation is manual control, given the site characteristics where this species grows (slopes, rocky terrain); motorized brush-cutters may be used in more accessible places. • Site preparation In ecological restoration programmes manual hole digging will be the best alternative, or occasionally mechanized digging using an excavator.

Myrtle
Myrte commun
آس شائع

Myrtus communis L.

Description of species and habitat

An aromatic shrub which can grow up to 5 m, although its normal height is 1 or 2 m. Heavily branched. The branches have two coriaceous, shiny, opposite leaves in the nodes, almost without a petiole, dark green on the upper side and somewhat lighter on the underside. Flowers are up to 3 cm in diameter, aromatic and white.

The myrtle usually mixes with other heathland plants as a result of felling, burning or degradation of *Quercus* spp. and other Mediterranean-type evergreen woods. It requires a gentle climate where the summer drought is not especially marked and prefers cool, somewhat moist soils. It is found in southern Europe, North Africa, south-western and central Asia and Macaronesia.

It flowers from May to August, bearing fruit from autumn to winter.

Description of fruit and seeds

Fleshy berry fruit, pea-sized, bluish black when mature, 7–10 mm long by 6–8 mm wide, broadly elliptic with five teeth at the end and crowned by the persistent calyx.

Kidney-shaped seed, cream and shiny.

Seed extraction is by pulp removal, washing, drying, sieving and eliminating the empty seeds by flotation, with an approximate yield of 6%.

Harvesting

Fruit is collected from October to December, when the fruits become dark blue or white. They can have two different colours when ripe. The fleshy seed coat is removed by macerating the fruits in water for 1–2 days. They are then mixed in a liquidizer (very slowly) and sieved under a jet of water. Floating pulp and bad seeds can be removed from the water.

Storage

Seeds should be kept in a cold, dry environment. Dried seeds (fruits without pulp) can be stored for some years in the fridge at 3–4°C, in plastic bags or glass jars.

Seed extraction efficiency (%)	Purity test (%)	Germination test (%)	Seeds kg^{-1}
9–16	90–95	80–90	140,000–250,000

Pre-germination treatments

No pre-germination treatment is required, although seeds can be soaked in water at ambient temperature for 12–24 hours before sowing, which accelerates germination. Treatment with hot water is not recommended: at first it accelerates germination but it is also harmful to the seed as it favours the fermentation and destruction of other seeds.

Nursery production

Seeds are generally sown in late autumn immediately after collection, without any prior seed treatment. Alternatively it can be done in spring, using cold-stratified seeds.

Sowing in spring with previously treated seeds results in high initial germination the same spring, so culturing takes one growing season. Seedlings can be transplanted to 300 cm^3 containers for one-year-old seedlings, reaching a final height of 10–15 cm. In some nurseries the species is still grown as bare-root plants for use as two-year-old seedlings, producing plants with a final height of 60–80 cm in long rotations.

Myrtus communis seeds. Photo by: X. Goñi, UdL

Myrtus communis fruit. Photo by: R. Navarro-C. Gálvez, UCO

Myrtus communis seedlings, Photo by: R. Navarro-C. Gálvez, UCO

Establishment

- Sowing and planting

The establishment method is planting by hand. One-year-old seedlings can be used. Also larger bare-root seedlings can be planted out. Planting should be carried out during autumn or winter (October to February) if the seedlings are large enough.

- Density and distribution

The recommended planting density for the species is low. In riverside restoration higher densities (about 500 trees ha^{-1}) can be used.

- Treatment of existing vegetation

The most commonly recommended method for eliminating existing vegetation is manual control, given the site characteristics where this species grows (slopes, rocky terrain); motorized brush-cutters may be used in more accessible places.

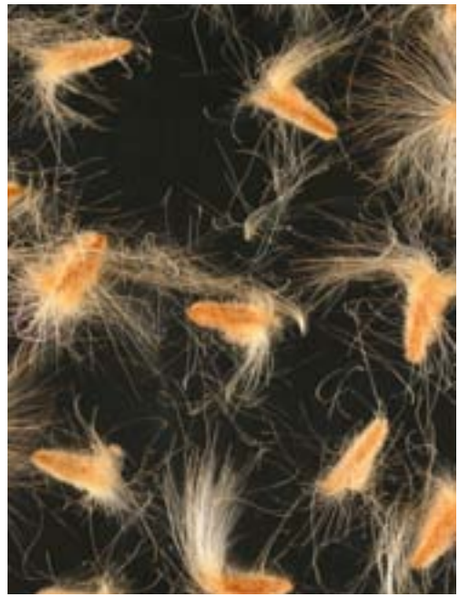
- Site preparation

Low- to medium-intensity work (depending on the type of restoration) involving manual hole digging, or occasionally mechanized digging with an excavator.

Oleander Laurier-rose دفلی	*Nerium oleander* L.
Description of species and habitat	This shrub grows up to 4 m in height. Smooth-barked trunk, ash-dark grey, and the branches are greenish or stained reddish or dark grey. Leaves in pairs or whorls of 3, thick, coriaceous, linear-lanceolate, pointed. The flowers form corymbiform clusters at the ends of the branches. They are pink, 3–5 cm in diameter. The oleander occurs on river and stream banks as well as in watercourses and gullies. It requires a gentle climate without intense frosts, although when cultivated it does well in quite cold conditions. Mediterranean region and Macaronesia. It flowers from April to October, bearing fruit in a rather staggered way from late spring to autumn.
Description of fruit and seeds	The fruit is a double coriaceous follicle or pod, dry, about 8–16 cm long, dark grey, with a rounded section which splits open laterally to release numerous downy seeds, with a pappus. Downy seeds with a fascicle of hair at the apex. Seed extraction is by sieving to separate the seed from the pod.
Harvesting	Manual harvesting of the seed after the first episodes of intense winter cold, when the fruit opens allowing seed dispersal. The numerous villous seeds are collected from the fusiform fruits.
Storage	Seed should be stored in a cold, dry environment. Dried seeds can be stored for some years in the fridge at 3–4°C, in plastic bags or glass jars.

Seed extraction efficiency (%)	Purity test (%)	Germination test (%)	Seeds kg^{-1}
8–15	90–95	80–90	250,000–330,000

Pre-germination treatments	If seeds are sown on a well-drained substrate in environments with a temperature of about 20°C, germination is not usually a particular problem and starts after 7–10 days. Cold, short-term stratification (7–10 days) can aid simultaneous germination.
Nursery production	The oleander is a species frequently used in gardening and for roadside restoration work. Plants can be grown in 200–300 cm^3 containers for one-year seedlings, to final size of 20–60 cm. Like other riverbank species, it can be grown as bare-root plants for planting out as two-year-old seedlings, producing plants with a final height of 60–100 cm in long rotations.



N. oleander seeds.
Photo by: X. Goñi, UdL

Nerum oleander plant. Photo by: R. Navarro-C. Gálvez, UCO

N. oleander seedlings ,
Photo by:R. Navarro-C. Gálvez, UCO

Establishment	• Sowing and planting The establishment method is planting by hand; sowing is not recommended. One-year-old seedlings can be used. Also larger bare-root seedlings can be planted out. Planting should be carried out during autumn or winter (October to February) if the seedlings are large enough. • Density and distribution The recommended planting density for the species is low. In riverside restoration higher densities (about 500 trees ha^{-1}) can be used on moister sites with deeper soil. For linear planting (roadside restoration), planting at 1–2 m intervals is recommended. • Treatment of existing vegetation The most commonly recommended method for eliminating existing vegetation is manual control, given the site characteristics where this species grows (slopes, rocky terrain); motorized brush-cutters may be used in more accessible places. • Site preparation Low- to medium-intensity work (depending on the type of restoration) involving manual hole digging, or occasionally mechanized digging with an excavator. For roadside restoration and linear planting, more thorough preparation by means of mechanized hole digging can be used if the ground permits.

Palestine pistachio
Pistachier de Palestine
بطم

Pistacia palaestina Boiss.

Description of species and habitat

The Palestine pistachio is a shrub or small tree which grows up to 5 m in height. Compound and deciduous leaves, imparipinnate with 7–8 ovoid folioles, with slightly hairy margins. Paniculate inflorescence, with long peduncles. Reddish or dark grey flowers.

It occurs on heathland and in open groves of *Quercus* spp. Frequently on rocky slopes or between large blocks of stone, almost always without forming large groves. It is found throughout southern Europe, North Africa and south-west Asia.

It flowers from April to May and bears fruit in July, which falls in July–August.

Description of fruit and seeds

Small drupe, barely fleshy, pedicellate, ovoid, 5–8 x 4–6 mm, somewhat compressed, reddish at first, becoming dark grey. Fruit arranged in panicles. Oval seed, slightly pointed, with a smooth seed coat, dark brown.

Seed extraction is by pulp removal in water to separate the empty seeds and then drying, with an approximate yield of 10%.

Harvesting

Fruit must be manually collected in August, when well ripened and before it falls to the ground. The fruits turn red and finally, when they are fully ripe, they are green to black. The fleshy seed coat is removed by macerating the fruits in water for 1–2 days. Then they are crushed on a sieve under a jet of water. Floating pulp and bad seeds can be removed from the water. After cleaning the seeds may be sown.

Storage

Storage in a cold, dry environment. Dried seeds (fruits without pulp) cannot be stored for many months with any guarantee of success because their oil content affects their viability. They should be kept in the fridge at 3–4°C, in plastic bags or glass jars.

Seed extraction efficiency (%)	Purity test (%)	Germination test (%)	Seeds kg^{-1}
	80–90	55–90	

Pre-germination treatments

Treatments recommended for this species:

- Immerse in water about to boil and leave the seeds in while it cools.
- Cold stratification at 3–6°C for 15 days, with or without the epicarp.
- Mechanical scarification and soaking in water at ambient temperature for 24 hours.

Nursery production

This species is of great value in forestry, for reforestation, ecological restoration and pistachio production. Sowing in spring with previously treated seeds results in medium to low germination, so early sowing is advisable to achieve viable seedlings in one growing season. The species can be grown in 300 cm^3 containers to produce one-year-old seedlings with a final height of 20–40 cm. Two-year-old bare-root seedlings can also be grown, with a final height of 60–80 cm.

P. palaestina seeds. Photo by: S. Hatoum, AFDC

mature *P. palaestina* tree with red fruits.
Photo by: E. Chnais, AFDC

P. palaestina seedlings.
Photo by: E. Chnais, AFDC

Establishment

- Sowing and planting

The most widely used establishment method is planting (of one- or two-year-old seedlings). Planting and sowing are carried out manually, placing the seedling or 2–3 seeds in each pit. The planting season is autumn to winter.

- Density and distribution

This will depend on the plantation purpose, although high densities of around 600–1,000 trees ha^{-1} or more are recommended for ecological restoration. For production objectives, the density should be lowered to 200–300 trees ha^{-1}.

- Treatment of existing vegetation

Weeding or treatment of woody species may be required, involving ploughing or brush-cutting.

- Site preparation

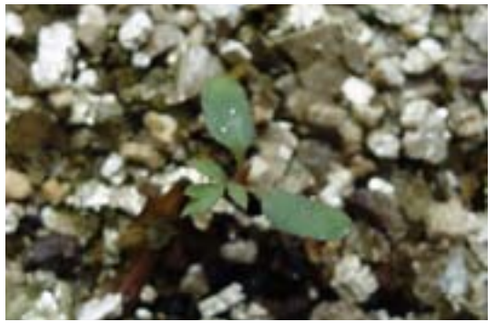
Simple or double subsoiling or deep ridge ploughing are the most common site preparation methods, occasionally mechanized with an excavator. Silvopastoral systems can be created at low density (< 300 trees ha^{-1}) by means of manual or mechanized hole digging.

Dog rose Eglantier نسرين	*Rosa canina* L.
Description of species and habitat	The dog rose is a shrub growing up to 3 m, with erect, glabrous stems with prickles hooked backwards. Deciduous compound leaves made up of 5–7 folioles, oval-rounded to oval-lanceolate, acute, with a round base, serrate, and rachis with dispersed glands. Flowers single or in corymbiform groups of 2–5 flowers, normally white or pink, with 5 petals incised at the apex. The dog rose grows in thickets and hedges, on steep banks and at the edge of woods, on all soil types and is ecologically widespread. Altitude range 0–2,000 m. It is found in Europe, western Asia and North Africa. It flowers from April to June with fruit maturing in late summer or early autumn.
Description of fruit and seeds	Fruit (hip), 10–18 x 10–14 mm, spherical, urceolate or ellipsoid, glabrous, smooth, in rare cases with stipitate glands and aculei, at times very fleshy, dark red. Triangular, angular seed, smooth surface, light, at times chestnut brown. Seed extraction is by pulp removal, washing, drying, sieving and winnowing, with an approximate yield of 11%.
Harvesting	Manual collection from late summer, when the fruits turn red and soft The fruits have a fleshy pulp that has to be removed immediately after collecting because it contains chemical inhibitors in the seed coat that prevent germination: the fruits should be macerated in water for 1–2 days after collecting. The seeds are extracted by sieving under a jet of water. The floating pulp and empty seeds are removed. The seeds are then dried for storage or for sowing after pre-treatment.
Storage	Storage in a dry, cold environment. Dried seeds may be stored in plastic bags or glass jars in the fridge (3–4°C).

Seed extraction efficiency (%)	Purity test (%)	Germination test (%)	Seeds kg^{-1}
11	95–98	30–50	49,000–75,000

Pre-germination treatments	Most *Rosa* seeds have internal lethargy, so stratification of seeds in sand or in moist vermiculite for 3 months or more at 5°C is recommended as a pre-germination treatment.
Nursery production	*Rosa canina* is a species of interest for restoring riversides and other forest ecosystems. Sowing can be done in autumn (preferably) or in spring, as the seeds germinate unevenly. The seedlings are transplanted to 300–400 cm3 forestry containers to obtain one-year-old seedlings, with a final height of 15–30 cm. Like other riverside species it can be grown as two-year-old bare-root seedlings, producing plants with a final height of 40–80 cm in long rotations.

Rosa canina seeds.
Photo by: X. Goñi, UdL



Rosa canina seedling. Photo by: R. Navarro-C. Gálvez, UCO

Flower of *Rosa canina*.
Photo by: R. Navarro-C. Gálvez, UCO

Establishment	• Sowing and planting The establishment method is planting by hand. One-year-old seedlings can be used. Larger two-year-old bare-root seedlings can also be planted. Planting should be carried out during autumn or winter (October to February) if the seedlings are large enough. • Density and distribution The recommended planting density for the species is low with no distribution pattern. In riverside restoration higher densities (about 300 plant ha^{-1}) can be used on moister sites with deeper soil. For linear planting a spacing of 1–2 m between plants is recommended. • Treatment of existing vegetation The most commonly recommended method for eliminating existing vegetation is manual control, given the site characteristics where this species grows (slopes, rocky terrain); motorized brush-cutters may be used in more accessible places. • Site preparation Low- to medium-intensity work (depending on the type of restoration) involving manual hole digging.

Rosemary
Romarin
أكليل الجبل

Rosmarinus officinalis L.

Description of species and habitat

This shrub grows up to 2 m in height, erect or trailing, abundantly branched, pubescent at least in the youngest parts. Leaves 10–36 x 1–4.3 (9) mm, linear or linear-lanceolate, green upper side, glabrous or puberulent, more or less rough, and underside with thick down. Puberulent floral pedicels. Light blue, pink or whitish flowers.

Rosemary grows on all types of soil, although it prefers lime, forming part of the heathlands that develop in dry, sunny places, mainly in *Quercus* spp. environments or as stages degraded by felling or burning, or on rocky or eroded slopes. Altitude range 0–1,500 m.

It flowers in two periods, from March to May and from September to October, with the seed maturing for harvest from May to June.

Description of fruit and seeds

Fruit in the form of a calyx (nucule), 2–2.8 mm, glabrous, formed of four tiny obovate nuts, dark grey.

Seed, 2–2.8 mm, globose, with a smooth dark brown seed coat.

Seed extraction is by threshing, winnowing and densitometric methods, with an approximate yield of 2.5%.

Harvesting

From May to June, the fruits are harvested one by one.

Storage

Storage in a cold, dry environment. Dried seeds (fruits without pulp) can be stored for some years in the fridge at 3–4°C, in plastic bags or glass jars.

Seed extraction efficiency (%)	Purity test (%)	Germination test (%)	Seeds kg^{-1}
	85–90	30–50	450,000–550,000

Pre-germination treatments

Rosemary does not require any pre-germination treatment. Results improve if it is stratified for 30–60 days in moist sand at 2–3°C before sowing.

Nursery production

Rosemary is a species whose forestry applications are oriented to erosion control, non-wood forest production and gardening. Seedling production can be in 200–300 cm^3 forestry containers for early sowing in autumn or winter. Sowing must always be carried out as early as possible to produce one- or two-year-old seedlings with a final height of 15–20 cm.

Plant of *R. officinalis* with flower. Photo by: R. Navarro-C. Gálvez, UCO

Rosmarinus officinalis seedlings. Photo by: R. Navarro-C. Gálvez, UCO

Rosmarinus officinalis seeds. Photo by: X. Goñi, UdL

Establishment

- Sowing and planting

The establishment method is planting by hand. One- or two-year-old seedlings can be used. Planting should be carried out during autumn or winter (October to February).

- Density and distribution

The recommended planting density for the species is low. No distribution pattern is followed for the same reason. For production planting, however, high-density linear planting (10,000–15,000 shrubs ha^{-1}) is recommended.

- Treatment of existing vegetation

The most commonly recommended method for eliminating existing vegetation is manual control, given the site characteristics where this species grows (slopes, rocky terrain); motorized brush-cutters may be used in more accessible places.

- Site preparation

Low to medium-intensity work (depending on the type of restoration) involving manual hole digging.

Spanish broom
Genêt de l'Espagne
وزال

Spartium junceum L.

Description of species and habitat

This shrub grows up to 3.5 m in height, with green, cylindrical, junciform branches. Unifoliate leaves, deciduous, linear or lanceolate, glabrous on the upper side and sericeous on the underside. Flowers in long racemes, yellow, large, very fragrant, with a butterfly-shaped corolla.

The Spanish broom grows in hedges and on heath land, in forest clearings, on gradients, by small streams and on the lower part of steep banks, climbing up to more than 1,000 m in some areas. It prefers shallow, rather cool soils. It is found in the Mediterranean and Macaronesian regions. Rapid growth. It sprouts from the stump and stands up to grazing very well. It lives on all soil types except for saline or chalky ones.

It flowers from May to June.

Description of fruit and seeds

Long, straight legume, 60–120 x 6.5–8 mm, with almost parallel flattened edges, hairless, lustrous and dark grey when mature. Polyspermous, 10–18 seeds, brusquely dehiscent on the driest days in summer.

Seed 3.2–4.5 x 2.4–3.5 mm, lentiform, somewhat flattened, with a smooth seedcoat, shiny, chestnut brown to reddish, with a clear strophiole.

Seed extraction is by threshing, sieving, and winnowing and densitometric methods.

Harvesting

Fruits are harvested one by one before maturity. Once collected they are sun-dried and covered by a net until final ripening and dehiscence, when the seeds are extracted.

Storage

Storage in a cold, dry environment; the seed tolerates prolonged storage and temporary storage in the open air.

Seed extraction efficiency (%)	Purity test (%)	Germination test (%)	Seeds kg^{-1}
	95–100	80–95	68,000–71,000

Pre-germination treatments

Treatments recommended for this species:

- Immerse in water about to boil (80°C) and leave the seeds in while it cools.
- Soak in water for 24 hours (germination = 64–89%).

Nursery production

Nursery cultivation of the species for forestry purposes is frequent for gardening and roadside planting work. Nursery cultivation is simple, given the ease of obtaining homogeneous germination, this being done in 200–300 cm^3 containers. Sowing is usually carried out in spring with treated seed and germination occurs in the following 2–4 weeks, producing one-year-old-seedlings with a final height of 15–20 cm.

Spartium junceum fruit. Photo by: R. Navarro-C. Gálvez, UCO

seedlings. Photo by: R. Navarro-C. Gálvez, UCO

Spartium junceum seeds.
Photo by: X. Goñi, UdL

Establishment

- Sowing and planting

The establishment method is planting by hand. One-year-old seedlings can be used. Planting should be carried out during autumn or winter (October to February).

- Density and distribution

The recommended planting density for the species is low. No distribution pattern is followed for the same reason. . If planted linearly (in roadside restoration), a spacing of 1–1.5 m between plants is recommended.

- Treatment of existing vegetation

The most commonly recommended method for eliminating existing vegetation is manual control, given the site characteristics where this species grows (slopes, rocky terrain); motorized brush-cutters may be used in more accessible places.

- Site preparation

Low to medium-intensity work (depending on the type of restoration) involving manual hole digging. For roadside restoration and linear planting, more thorough preparation by means of mechanized hole digging can be used if the ground permits.

Spiked thymbra Thymbre en épi زعتر دق	*Thymbra spicata* (L.) Cav.
Description of species and habitat	A tall, medium or short shrub, stems up to 0.5 m, downy white branchlets, trigonal linear leaves, flat on the upper side and with an axial convex angle on the underside. Flowers with bright pink or carmine, sometimes lilac, corolla. It grows in areas close to the sea or open to its influence, doing well in long summer substrate droughts if air humidity is relatively high. It usually forms small groups mixed with other shrubs or plants in areas dominated by *Olea* and *Ceratonia* and on the warmer, drier edges of *Quercus* spp. stands. Its oil is rich in carvacrol, which gives it a spicy flavour and makes it ideal for cooking. It flowers in late spring and early summer.
Description of fruit and seeds	The fruit appears split into ovoid or oblong nucules, enclosed in the calyx, all this forming the propagule. Small, round seed, pointed, with smooth seed coat, brown to black. Seed extraction is by threshing, winnowing and densitometric methods.
Harvesting	Propagules are harvested one by one or by reaping in late summer. If the aim is to obtain essential oils, it can be done by mechanical cutting prior to flowering, from May to November.
Storage	Storage in a cold, dry environment.
Pre-germination treatments	No treatment is considered necessary, not even shelling the nucules, which is very costly.
Nursery production	Thymbra is a species whose forestry applications are very limited but is of interest in non-timber forest production. It can be grown in 200 cm^3 containers for early sowing in autumn to winter, the seed being sown very shallowly or placed in the growing medium and covered with a fine layer of soil. Sowing must always be carried out as early as possible to produce one- or two–year-old seedlings with a final height of 10–15 cm. Sowing can also be done in spring, with planting out recommended in the vegetative rest period when the plants reach 6–8 cm. A simple fertilization programme based on NPK (143-2.5 ,5-8- kg/m^3) by CSRF (controlled slow-release fertilizers) is recommended. This species can also be propagated by cuttings.

Thymbra spicata capitata flower. Photo by: N. Ofir, Creative Commons

Thymbra spicata plant. Photo by: G. Pisanty, Creative Commons

Thymbra spicata seedlings. Photo by: E. Chnais AFDC

Planting in soil	• Sowing and planting Both direct sowing (the small stems or flowers can be sown if not separated from the seed) and planting of one-year-old seedlings are widely used establishment methods. Planting and sowing are carried out manually, and the planting season is autumn or winter. • Density and distribution This will depend on the plantation purpose. For production, high densities are used (50,000 plants ha^{-1}), the plants being grown at 20–30 cm intervals in rows 75–100 cm apart. Variable lower densities are used for densification or restoration. • Treatment of existing vegetation Weeding or treatment of woody species may be required, involving ploughing or brush-cutting. • Soil preparation Simple or double subsoiling or deep ridge ploughing are the most common site preparation methods, occasionally mechanized with an excavator.

Glossary:

Acicules	Needle-like leaves
Acorn	A nut with a persistent cup-like structure at the base, as in the case of Oak species
Aculei	Plural of aculeus, a prickle or spine
Acuminate	Gradually tapering to a sharp point, forming concave sides along the tip
Anemophilous	Refers to wind pollination of flowers
Appendiculate	Having an appendage or outgrowth of some sort
Apex	The portion of a plant structure (bud, leaf, stem, etc.) farthest from its point of attachment, the tip (plural: apices)
Caducous	Petals, sepals and stipules that fall off early
Calyx	The collective term for all of the sepals of a flower, the outer perianth whorl
Capsule	A dry fruit that opens in any of various ways at maturity to release few to many seeds
Catkin	A pendent, more or less flexible, spike-like inflorescence with numerous small flowers, typically of only one sex
Cymose (inflorescence)	Of, pertaining to, or resembling a broad, flat-topped inflorescence in which each floral axis terminates in a single flower (cyme)
Coriaceous	Plant parts, especially leaves, that have a leathery texture
Corolla	The collective term for all of the petals of a flower, the inner perianth whorl
Corymb	A racemose inflorescence with the individual flower stalks progressively shorter towards the apex so the flowers are all about the same level
Corymbiform	Having the shape of a corymb
Crenate	Leaf, petal and sepal margins that have the shape of rounded teeth
Culm	The above-ground or aerial stems of grasses and sedges
Down	In botany, short, hair-like structures
Drupe	A fleshy fruit that does not split open at maturity, with a softer outer wall and one or more hard inner stones usually containing one seed, such as apricots and cherries
Emarginate	Leaves or petals that have a notch towards their apices
Enrichment and densification	In reforestation, an activity which aims to increase the number of species at a site or increase their density
Entomophily	Plant pollination by insects
Erecto-patent	Having a position intermediate between erect and spreading
Foliole	A leaflet, part of a compound leaf
Fusiform	Elongate, broadest at the middle, evenly tapering to either end, and rounded in cross-section
Glabrous	Lacking plant hair

Glomerule	A dense cluster of flowers
Heathland	In the Mediterranean, it refers to open lands with small bushes and shrubs
Heliophilous	Sun-loving
Hermaphrodite flower	Flower having both male and female structures
Husk	The outer shell or coating of a seed
Imparipinnate	Compound leaf with a single leaflet at the tip
Indehiscent	Not splitting or forming an opening at maturity, the contents being released for dispersal only after decay, digestion or erosion of the structure, as certain fruits, such as achenes or berries, that retain their seeds when ripe
Junciform	Rush-like in appearance
Lanceolate	Several times longer than broad, widest near the base and tapering to a point at the apex
Lethargy	Showing signs of dormancy
Nucule	A small nut with a hard shell
Oblong	Shaped like a compressed oval, with the sides approximately parallel for most of their length
Obovate	Egg-shaped in outline, with the point of attachment at the narrower end, inversely ovate
Obovoid	Egg-shaped with the base at the narrower end, inversely ovoid
Ornithochorous dissemination	Bird-assisted dispersal of seeds
Outplanting	The planting of seedlings raised in a greenhouse or nursery planting bed into the field
Ovoid	Rounded in cross section, broadest near a bluntly rounded base and convexly tapering to a narrower rounded tip, egg-shaped
Panicle	A branched raceme, the main axis either determinate or indeterminate, and the lateral branches racemose; more loosely, a much-branched inflorescence of various types
Patent	In a spreading position
Pedicellate	Having a pedicel, which is the stalk of an individual flower, either that of a solitary flower or of a single flower in a multi-flower inflorescence
Pedunculate	Having a peduncle, which is the main stalk of a multi-flower inflorescence or of a cluster of flowers within an inflorescence
Pericarp	The ripened and variously modified plant ovary. In stone fruits, such as peaches, it forms the edible part
Petal	A unit or segment of the inner floral envelope or corolla of a flower, often coloured and more or less showy
Petiolate	With a leaf stalk known as a petiole
Polyspermous	Containing many seeds
Propagule	Any plant material used for the purpose of plant propagation

Puberulent	Covered with minute hairs
Pubescence	The broad term for any type of plant hairiness
Pyrophytic	Adapted to fire events within the ecosystem
Raceme	An elongate, indeterminate inflorescence with stalked flowers borne singly along an unbranched main axis or rachis
Recalcitrant seeds	Unorthodox seeds that cannot survive drying or freezing during storage
Rhytidome	Outer part of the bark that covers the trunks of trees
Sclerophyllous	Having hard leaves placed a short distance apart on the stem
Sepal	A unit or segment of the outermost floral envelope or calyx of a flower, usually green and leaf-like
Sericeous	Referring to buds, leaves (lower or upper surface) or sepals that have long silky, usually appressed hairs
Serrate	Margins that are toothed, with the sharp teeth pointing forward
Sessile and subsessile	Flowers, leaves, and seed cones that do not have a stalk
Silvopastoral	Combining forestry and grazing of domesticated animals in a mutually beneficial way
Stipitate	Having a stipe, which is a supporting structure or stalk
Testa	The seed coat that develops from the integument, the tissue originally surrounding the ovule
Trailing plants	Plants that do not grow upright
Transplant	Uproot and replant (a growing plant) from one location to another
Truncate leaves	With the base cut more or less straight across, ending abruptly, almost at right angles to the midrib
Undulating	Wavy, serpentine, gently rising and falling
Unifoliate	A structurally compound leaf with a single leaflet, making it appear simple, the compound nature of the leaf evident by a distinct articulation in the leaf stalk
Urceolate	Having the shape of an urn
Winnowing	The process of removing seeds from other plant debris with the help of wind

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