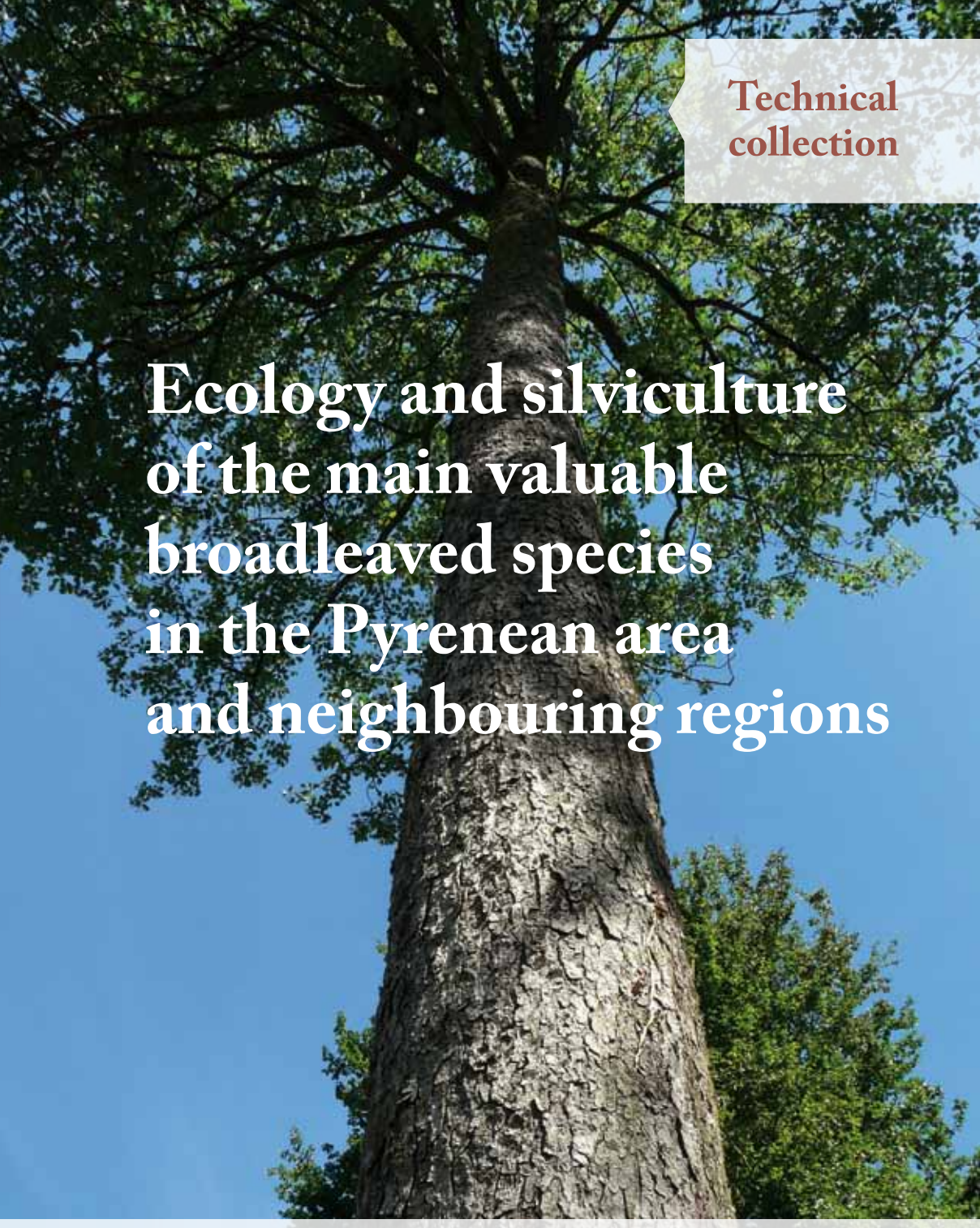
Technical collection

Ecology and silviculture of the main valuable broadleaved species in the Pyrenean area and neighbouring regions



Generalitat de Catalunya
Departament d'Agricultura, Ramaderia, Pesca, Alimentació i Medi Natural

Centre de la Propietat Forestal

Technical collection

Species and Silviculture

Ecology and silviculture of the main valuable broadleaved species in the Pyrenean area and neighbouring regions

Santa Perpètua de Mogoda (Spain), 2013

Generalitat de Catalunya
Departament d'Agricultura, Ramaderia, Pesca, Alimentació i Medi Natural

Centre de la Propietat Forestal

This document has been prepared in the framework of the European cooperation project PIRINOBLE (www.pirinoble.eu) as a support tool for diversification of rural areas through indicators on the requirements of each species, plantation techniques and management schemes for valuable timber production.

Technical collection
Species and Silviculture
Ecology and silviculture of the main valuable broadleaved species in the Pyrenean area and neighbouring regions

Edited by

Authors:
Jaime Coello, Forest Sciences Centre of Catalonia (CTFC, Spain).
Jacques Becquey, Institute of Forest Development (IDF, France).
Pierre Gonin (IDF).
Jean-Pierre Ortisset, Regional Forest Ownership Centre (CRPF, France).
Violette Desombre (CTFC).
Teresa Baiges, Catalan Forest Ownership Centre (CPF, Spain).
Míriam Piqué (CTFC).

Author of each species booklet:
Hybrid walnut and common walnut: Jaime Coello (CTFC), Jacques Becquey (IDF), Pierre Gonin (IDF), Jean-Pierre Ortisset (CRPF), Teresa Baiges (CPF), Míriam Piqué (CTFC).
Wild cherry and Service and Wild service trees: Jaime Coello (CTFC), Violette Desombre (CTFC), Jacques Becquey (IDF), Pierre Gonin (IDF), Jean-Pierre Ortisset (CRPF), Teresa Baiges (CPF), Míriam Piqué (CTFC).
European ash and Narrow-leaved ash: Jaime Coello (CTFC), Jacques Becquey (IDF), Pierre Gonin (IDF), Jean-Pierre Ortisset (CRPF), Violette Desombre (CTFC), Teresa Baiges (CPF), Míriam Piqué (CTFC).
Sycamore, Norway maple and Field maple, Pear and Apple trees and Limes: Jaime Coello (CTFC), Jacques Becquey (IDF), Jean-Pierre Ortisset (CRPF), Pierre Gonin (IDF), Teresa Baiges (CPF), Míriam Piqué (CTFC).

First edition: June 2013.
Design and layout: Elizabeth Fernández (CPF).

Photographs: If not otherwise stated, the photos have been taken by the Sustainable Forest Management Unit of CTFC.

Copyright: B. 18578-2013

Index

Presentation and objective

Ecology and silviculture of the main valuable broadleaved species in the Pyrenean area and neighbouring regions.

The production of valuable broadleaved species is an interesting alternative of great economic and environmental potential for many types of areas. The Catalan Forest Ownership Centre (CPF) and the Forest Sciences Centre of Catalonia (CTFC) began in 2001 a line of research to study the potential of Catalonia for the production of quality wood, specially walnut and cherry. During this collaboration, 20 experimental plantations of these and other additional species were performed, in order to evaluate species adaptation, the adequation of innovative plantation techniques (i.e. biodegradable mulching) and modern experimental designs (mixed plantations, double rotation systems, etc), aiming at increasing the available knowledge about the potential of the use of these species and the optimization of low intensity management.

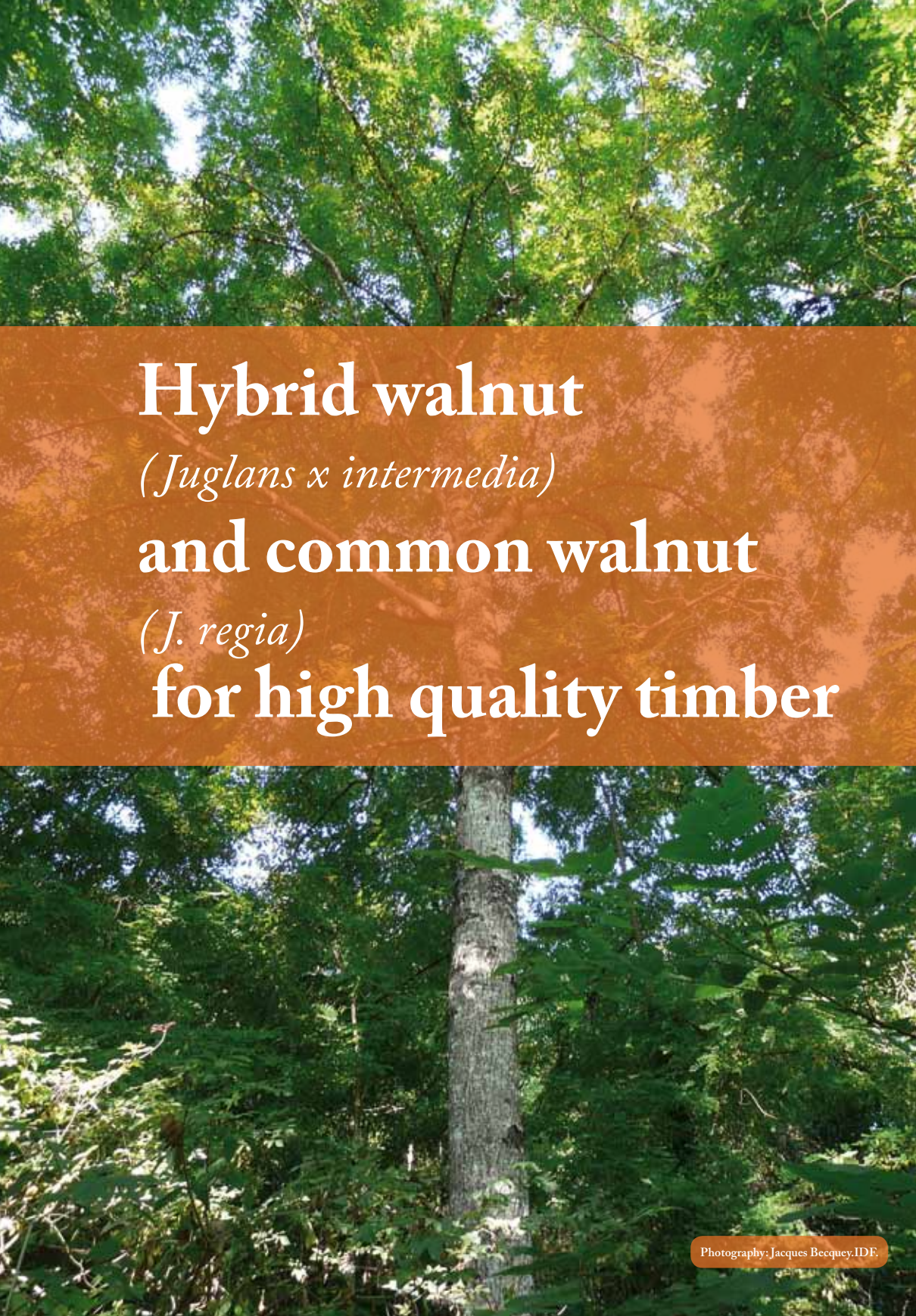
In 2009 CTFC and CPF launched the cross-bordering EFA 93/08 project *Valuable broadleaves for restoring and enhancing economic development of rural areas: innovation and technology transfer on sustainable plantation techniques* (Pirinoble), together with the French institutions *Institut pour le Développement Forestier* (IDF) and the *Centre Régional de la Propriété Forestière* (CRPF) of Midi-Pyrénées region. One of the outcomes of this project is the present book "Ecology and silviculture of the main valuable broadleaved species in the Pyrenean area and neighbouring regions": **Hybrid and common walnut, Wild cherry, Ash, Sycamore, Norway maple and Field maple, Service and Wild service trees, Pear and Apple trees and Limes**.

This work aims at introducing, in an applied manner, the main ecological requirements of these species, as well as to provide indications on the most adequate plantation techniques and designs in order to produce valuable timber. Likewise, it is intended to ease species choice as well as the design and management of plantations to a wide variety of managers.

This publication is available at the PIRINOBLE project website (http://pirinoble.eu); CPF (http://gencat.cat/cpf) and Sustainable Forest Management Unit of the CTFC (http://ags.ctfc.cat).

We hope that this publication will be interesting to help promoting this production of high strategic interest for Europe.

Juan Luís Abián
Managing Director
Centre de la Propietat Forestal



Hybrid walnut *(Juglans x intermedia)* and common walnut *(J. regia)* for high quality timber

Photography: Jacques Becquey.IDF.

1 Hybrid walnut

(*Juglans x intermedia*)

Photography: Jacques Becquey.IDF.

There are different walnut species utilized for valuable timber production. The most popular is Common walnut (*Juglans regia*), original from Central Asia and utilized in Europe for nut production for millennia. Other species with remarkable commercial interest are the black American walnuts (*Juglans nigra, J. major, J. hindsii*).

In the last decades, hybrid walnuts have appeared in the market, achieved by crossing common walnut with high performance clones of black American walnut. These materials have been selected based on their attitude to produce vigorous hybrids in natural conditions, with timber showing remarkable properties. The progenies of hybrid walnut most commonly utilized in plantations for valuable timber production are Mj-209xRa and Ng-23xRa.

Hybrid walnut plantations.

Why planting walnut to produce timber ?

Walnut has been widely utilized for valuable timber production for decades, both in Europe and in North America. The reasons include the superb technical and aesthetic features of its timber. The pieces with highest quality are destined to veneer industry (top class furniture), where they reach their highest price. Hybrid walnut timber has similar properties to the one from its parents. In comparison with common and black American walnut, the hybrids tend to be more vigorous since the first years of plantation, showing a marked apical dominance as well. Therefore, this vegetative material show excellent attitude for valuable timber production. Moreover, hybrids are more resistant to diseases and less sensitive to phototropism than common walnut, while being more tolerant to drought and less sensitive to spring frosts than black American walnut.

Hybrid walnut is an excellent compromise between growth rate, resistance to damaging agents and climatic uncertainties, while easing the management for valuable timber production.

Photography: Jacques Becquey. IDF.

Photography: Jacques Becquey. IDF.

What are the main walnut requirements ?

Hybrid walnut is exigent regarding soil and climate conditions, likewise common and black American walnuts: it needs a rather humid climate, preferably with a moderate or absent dry period, not too cold, as well as a deep soil, with balanced texture and well drained. The figure below summarizes the main ecological requirements of hybrid walnuts Mj-209xRa and Ng-23xRa for valuable timber production. Mj-209xRa progenies shows a higher tolerance to warm climates (Mediterranean areas), while Ng-23xRa is more suitable at cold sites. The last page shows specific ecological requirements of common and black American walnuts.

Optimal conditions / Conditions tolerated / Conditions not tolerated	**Comments**
Soil depth (cm) 10- 20 30 40 50 60 70 80 90 100 110 120+	Hybrid walnut has a well developed root system, with a strong tap root that allows it reaching deep soil water.
Texture Clayish / Clayish-silty / Loami-silty / Silty-sandy / Sandy	It is very sensitive to water stagnation, which may limit its utilization in heavy textures (clayish). Soils that are excessively light (sandy) should also be avoided, because of their low water and nutrient holding capacity.
pH 3,5- 4 4,5 5 5,5 6 6,5 7 7,5 8 8,5 9+	The optimal pH is neutral or slightly basic, although it can grow in a wide variety of soil types. Hybrid walnut tolerates active limestone.
Altitude (m) 150- 300 450 600 750 900 1050 1200 1350 1500 1650 1800+ **Mean annual temperature (°C)** 6- 6,5 7 7,5 8 8,5 9 9,5 10 10,5 11 11,5+	Hybrid walnut is favoured by warm mean annual temperatures, always that water provision is sufficient. It can also tolerate low winter temperatures relatively well.
Mean annual precipitation (mm) 400- 450 500 550 600 650 700 750 800 850 900 950+	Despite tolerating moderate summer droughts, high rainfall regimes considerably enhance growth, especially in areas without access to water table.

	Water need	Sensitivity to temporary stagnation	Need for Ca, Mg, K	N and P need	Active limestone sensitivity	Wind sensitivity	Drought sensitivity	Competition for light sensitivity
Hybrid walnut	High	Medium	Medium	Medium	Low	Medium	Low - media	Medium
Black American walnut	High	Low - medium	Medium	Medium	Medium	High	Medium - high	Low - medium
Common walnut	High	High	Mediun - high	Mediun	Low - media	Medium	low - medium	High

Hybrid walnut shows a capacity for adapting to different site features higher than its parent species. This material joins the drought and wind tolerance of common walnut with the "forest character" (limited phototropism) and tolerance to temporary stagnation of black American walnut.

Hybrid walnut plantation.

Pests and diseases of walnuts

The diseases affecting hybrid walnut are the same described for common walnut, despite they are considerably less frequent. Most of these pests and diseases have been described on plantations for fruit production, and are favoured by excessive soil moisture and air humidity, high soil clay content and for high rates of irrigation and nitrogen application. The main diseases are fungi penetrating through the root system: *Armillaria* and *Phytophthora*: they are favoured by wounds and high plantation densities. *Armillaria* causes the withering of leaves and branches, while *Phytophthora* produce trunk rots, starting at the root collar, where it leads to a black suppuration. The bacterium *Brenneria* (*Erwinia*) *nigrifluens* causes dark spots, 5 cm wide, on the bark, which can devaluate timber if reaching the inner trunk. Antracnosis (fungus *Gnomonia*), causes brown spots on leaves, leading to a loss of tree vigour. Regarding pests, the most remarkable one is *Zeuzera* (photo), a moth excavating galleries in branches and young stems during larval stadium. These galleries increases the wind-related breaking risk of these branches, as well as the risk of occurrence of other pathogens.

First steps of plantation

The first steps of a hybrid walnut plantation are similar to those of other valuable broadleaved species.

Choosing the plant

Hybrid walnut is an artificial species, and thus it is not possible to find native populations. The general recommendation is therefore to guarantee that the plantation area meets all the ecological requirements mentioned previously. It is also recommended to inquire about the performance of hybrid walnut in neighbouring areas, in order to find out the most suitable progenies. The plants are generally sold bare rooted, and must show a robust aspect, with a unique, lignified stem and a well developed root system, with abundant secondary roots. The most adequate size is 60 cm height for 1 year-old plants (1+0), with at least 30 cm of tap root. In high quality areas it is also possible to utilize 2 year-old plants (1+1), reaching 100 cm.

Soil preparation

The first step in every plantation is clearing the vegetation that could hamper plantation operations. Secondly, and especially at agricultural land, it is necessary to apply a sub-soiling, preferably crossed (in 2 perpendicular directions) at the maximum depth possible (40-60 cm) in order to allow the development of the vigorous walnut root system and promote soil water retention. Plantation is done manually in pits opened either manually or with backhoe excavator, with dimensions adequate to plant size.

Planting

Planting is performed during dormancy period, between November and April, on days without risk of frost, rain or strong winds. It is fundamental to prevent that roots remain bended or compressed at the plantation pit, so that it is important to hold the plant in upright position and progressively fill up the pit. The tip of the taproot can be cut if damaged during its uprooting in the nursery, but at least 30 cm should be respected. The root collar (a thickening at the stem base) must remain at floor level, not buried. The plantation can be completed with a watering amounting 30-40 l/tree in order to ease plant establishment and early growth.

Protect

Hybrid walnut is very sensitive to weed competition for water and light, which can reduce considerably both growth and survival during the first 5-10 years. It is recommended to cover the ground around the tree with a 1 m2 mulch. This technique allows reducing considerably weed competition, while mitigating soil water loss by evaporation. Browsing damages (rabbit, hare, roe deer, red deer) must be avoided with individual or collective (fencing) protection.




Photography: Jacques Becquey. IDF.

Management of a walnut plantation

Because of its vigorous growth, hybrid walnut plantations must be managed following a dynamic silviculture. The plantation can be either pure (composed only by hybrid walnut) or mixed (hybrid walnut and some other species). The density chosen defines the initial investment and the cost of tending operations (weeding, pruning, thinning).

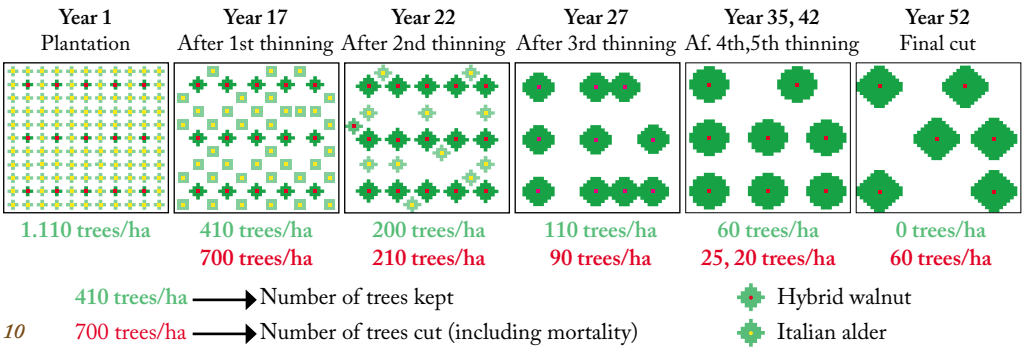
Pruning

Pruning of hybrid walnut for valuable timber production established at open areas is normally applied annually. In highly productive sites it might be necessary to apply two pruning interventions yearly, while in areas with limiting conditions pruning could be applied every two years. Pruning is performed around July, in order to avoid the sprout of epicormic shoots. Pruning is done in two simultaneous interventions: **formative pruning**, consisting on promoting the main stem axis or apical shoot, clearing or blunting those high branches that could compete with it; and **quality pruning**, during which the thickest branches (2.5–3 cm diameter at their base), are cut, in order to avoid creating large knots in the timber. Pruning is applied progressively, respecting at least 50% of leaves at each intervention, although in very productive sites it is possible to apply higher intensities during the first 4 years, for preventing thick branches. The target clean bole length is 3–6 m, depending on tree potential and site quality. Pruning is simpler at high density plantations, as well as on mixed plantations with fast-growing species, because of lateral shading, which reduces branch development.

Scheme of application of pruning in walnut, during the first 6 years. Red lines indicate where to apply pruning.

Thinnings

Thinnings consist on promoting the best trees (future trees), which are those with potential to produce timber valid for veneer industry: vigorous trees, with a straight bole, free of defects. With this aim, all trees that compete with future trees are progressively cut. This intervention allows keeping a high and regular diameter growth rate. The intensity and frequency of thinnings depend on the initial density and site productivity. Below it is shown a thinning scheme for a hybrid walnut plantation (12x6 cm, 140 trees/ha) accompanied by Italian alder (*Alnus cordata*, 3x3 m, 970 trees/ha), in a good quality site. Target diameter of hybrid walnut: 60 cm at breast height (60 trees/ha).



A more classic silvicultural scheme

Example of 1 ha pure hybrid walnut plantation, 9x6 m (185 trees/ha) at a site well adapted to species requirements.

Summary of the plantation stages and economic assessment.

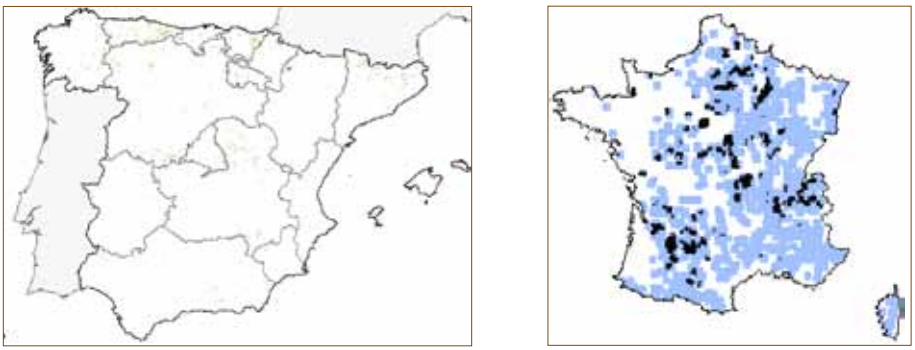
Age (years)	Mean diameter (cm)	Operations	Quality timber obtained (m^3)	Expense/ revenue (€2013)
-1		Soil analysis. Pre-existent vegetation clearing. Soil preparation		-850
0-1		Plantation marking and pit opening. Vegetative material (185 hybrid walnuts) purchase and plantation. Mulching (1 m^2) purchase and install individual shelters purchase, install. Initial watering.		-2,220
1-6		Annual pruning. 1 annual weeding between tree rows. 1 emergency watering.		-1,200
7-12		Annual pruning, up to 4-6 m on 100 best trees. 1 weeding between tree rows every 2 years. 1 emergency watering.		-500
18	20	Thinning of 45 walnuts, promoting the best 100.	15 steres	+90
25	28	Thinning of 35 walnuts.	20 steres + 2 m^3 quality wood	+220
35	41	Thinning of 25 walnuts.	30 steres + 8 m^3 quality wood	+980
43	50	Thinning of 20 walnuts.	35 steres + 12 m^3 quality wood	+3,210
50	60	Final cut: 55 walnuts.	100 steres + 60 m^3 quality wood	+36,600
IRR (Internal Rate of Return)				**4.7%**

Note: it is considered that 5 walnuts are not harvested because of low vigour. The income resulting from possible crops between rows during the first years are not considered.

The 100 walnuts pruned up to 4-6 m and promoted at the first thinning are cut during the last thinnings and the final cut.

Common walnut (*Juglans regia*)

Common walnut is an emblematic species in Europe, with a remarkable interest regarding fruit and timber production. Despite its use for the latter has been set aside in favour of hybrid walnut, this species still suppose a considerable share of the walnut timber utilized at veneer industry.



*Distribution of common walnut (*Juglans regia*) in Spain (Source: Genfored Inia-CIFOR, 2009) and France (Source: IFN; Black: occurrence ≥ 5% of sampling points; Blue: occurrence < 5%; White: occurrence = 0%).*

The ecological requirements of common walnut are relatively similar to those from hybrid walnut. The main differences are its higher sensitivity to water stagnation, even when temporary, and to bacterial and fungal diseases in wet areas. The varieties of common walnut with early flushing are especially sensitive to damages by spring frosts.

Common walnut plantations.
Photographs: Jacques Becquey. IDF.

Photography: Jacques Becquey. IDF.

At forest conditions common walnut tends to show leaning shapes, because of its strong phototropism. In general, its needs for light and warmth are higher than those of hybrid walnut, as well as its tolerance to drought. This species is very well adapted to low density plantations in open areas, such as agricultural fields, as well as on agroforestry systems.

Because of the strategic interest of this species, and of the presence of individuals with superb features for valuable timber production and disease resistance, common walnut has been devoted improvement programmes for developing local materials to be utilized in plantations. It is possible to find in the market some different clones and other high performance materials selected for their timber production potential and their tolerance to the limiting conditions that hamper the use of this species.

Wild cherry *(Prunus avium)* for high quality timber

2 Wild cherry (*Prunus avium*)

The European wild cherry (*Prunus avium*), belongs to the family *Rosaceae*, which includes the pear tree, apple tree and other fruit trees.

This species is widespread in Europe, West Asia and North East Africa, especially in areas with humid and warm conditions.

In areas with Mediterranean climate, wild cherry appears in shady, mountainous conditions, near water streams. In the Iberian Peninsula, they are located mainly in the North.

Distribution of wild cherry (Prunus avium). *Source: EUFORGEN 2009.*

Why planting wild cherry to produce timber ?

Wild cherry timber is one of the most valued in Europe. The top-quality pieces are used in the veneer industry, where they reach the highest price. In this industry, wood is cut into thin sheets that are used to cover top quality furniture. Wild cherry timber is also very appreciated as high-quality sawnwood.

Wild cherry shows a fast growth rate, that enables short rotations, between 40-50 years, always that they are well adapted to the site and adequately managed.

This species is a precious component of European forests, with a spectacular early flowering period that provides them a very high aesthetic value.



What are the main wild cherry requirements ?

In natural conditions wild cherry can adapt to a great variety of climates and edaphic conditions. Nevertheless, for achieving a successful plantation for high quality timber production it is necessary to utilize it at the most favourable conditions for this species. If these conditions are not adequately met, the plantation can lose its productive and economic interest, due to slow development and a higher risk of diseases.

The main ecological needs of wild cherry are summarized in the following graph:

Appropriate conditions / Slightly restricting conditions / Very restricting conditions / Non-appropriate conditions	**Comments**
Soil depth (cm) 10- 20 30 40 50 60 70 80 90 100 110 120+	A shallow soil hampers root development, leading to increased sensitivity to drought and wind-thrown (uprooting).
Texture Clayish Clayish-silly Loamy-silly Silly-sandy Sandy	Loamy textures are ideal for wild cherry. Because of their tendency to stagnate, clayish and compact soils must be avoided. On the other hand, sandy soils are not adequate because of their low capacity to hold water and nutrients.
pH 3,5- 4 4,5 5 5,5 6 6,5 7 7,5 8 8,5 9+	Wild cherry appears in a wide range of pH, being especially suitable in sites rich in nutrients. It is thus recommended to avoid poor soils.
Altitude (m) 150- 300 450 600 750 900 1050 1200 1350 1500 1650 1800+	Cold (and thus altitude) reduces annual tree growth. Late frosts or severe winters are not a problem for the production of valuable timber of wild cherry. However, this species is sensitive to intense snowfalls.
Mean annual precipitation (mm) 400- 450 500 550 600 650 700 750 800 850 900 950+ **Mean summer precipitation (mm)** 0 15 30 45 60 75 90 105 120 135 150 165+	Wild cherry is very sensitive to drought, so those areas with persistently hot and dry summers must be avoided if artificial watering cannot be applied. A well distributed precipitation rate is preferable to a high annual rate unevenly distributed.

Water need	Sensitivity to temporary stagnation	Need for Ca, Mg, K	N and P need	Active limestone sensitivity	Wind sensitivity	Drought sensitivity	Competition for light sensitivity
High	High	Medium	High	Negligible or low	Medium to high	High	High

The best sites for wild cherry production are those well supplied with water but without risk of stagnation, protected from wind and drought. Some of the most convenient areas in Mediterranean conditions are valley floors and gentle slopes with a north or west aspect.

Wild cherry plantation in a mountain area.

Stagnation must be avoided.

Pest and diseases of wild cherry

Cherry trees are sensitive to attacks from insects, fungi and bacteria, although most of them can be avoided by keeping an adequate vigour: this is achieved through a correct choice of the vegetative material (species and provenance) to the site features. The following table shows the most common problems in plantations and the factors linked to their occurrence.

Pest	Diseases		Symptom	Timber defects	
Aphid (1)	**Cilindrosporiosis (2)**	**Bacterial canker**	**Gummosis (3)**	**Core rotting (4)**	**Green vein (5)**
Large, pure continuous plantations	Sensitive vegetative material	Excess of humidity or nitrogen	Mechanical damage on the tree	Too long rotation (60-70+years)	Genetic predisposition, areas with steep slopes and strong winds

Photographs 1, 2 and 3: Óscar Cisneros.

First steps of plantation

The first steps of wild cherry plantations are similar to those of other valuable broadleaved species.

Choosing the plant

It is recommended to use a plant material from an area similar to the plantation site, considering the soil features and the severity of summer drought. When using clones it is recommended to include at least 4 – 6 different ones to avoid health problems. Bare rooted plants are appropriate in high-quality soils. The plant must have a vigorous and healthy apical bud and a unique stem without branches. The root system must be well developed, with numerous secondary roots. One year-old plants (1+0) should be 50 - 70 cm high and have a base diameter of at least 1 cm, while two year-old plants (1+1) should be 125 - 150 cm high with at least 2 cm of base diameter.

Soil preparation

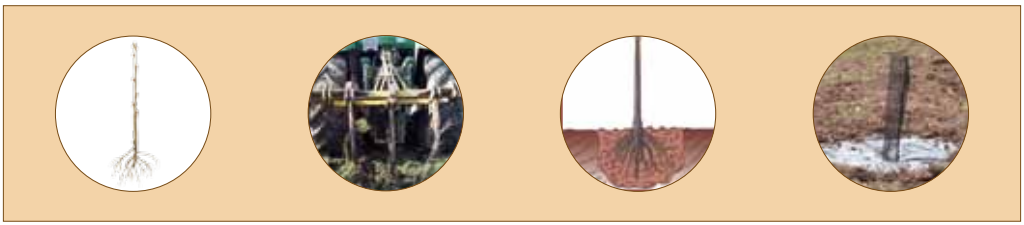
After clearing the vegetation that could impede or difficult plantation operations, it is recommended to apply a sub-soiling, preferably crossed (in two perpendicular directions) to the maximum depth possible (at least 50 cm), in order to enhance soil water retention. The plantation pits can be opened with backhoe excavator or with manual tools, with dimensions appropriate to the root system size.

Planting

The plantation is done during plant dormancy, normally between November and March. Days with frosts, precipitation or strong winds should be avoided. When planting, the root system must be displayed in a stretched manner, and should not be compressed. After filling the pit (keeping the tree vertical) it is recommended to apply an initial watering of 30-40 l/tree, if rainfall is not forecasted for the weeks following the plantation.

Protecting

Wild cherry is very sensitive to weed competition during the first 5-10 years of plantation. This negative effect can be avoided by mulching, preferably as individual pieces of 1 m^2. This technique impedes weed establishment in the soil near the tree. Browsing damage due to wildlife can be avoided with individual shelters (preferably with mesh wall, rather than solid wall), that can be complemented with an electric fence. Damages due to drought can be avoided or mitigated by emergency watering.

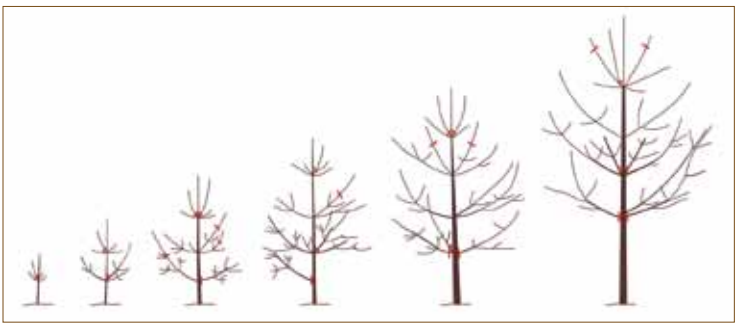


Plantation management

Wild cherry requires a dynamic and well planned silviculture. In order to limit management costs pruning will be applied to selected trees (vigorous, straight, vertical and free of defects) with potential to be promoted during the thinnings and to reach the final cutting. These trees should be selected and marked as soon as possible. The following scheme describes pruning and thinnings planning.

Pruning

During the **formative pruning** the forks and the high or vertical branches that can shade the terminal shoot are eliminated. **Quality pruning** consists on eliminating those branches that have a diameter larger than 3 cm in their base, in order to avoid big knots. Both operations are applied simultaneously, during June or July, for preventing epicormic shoots development. The severity of the intervention must be adapted to tree vigour, and should not lead to the removal of more than 30% of leaves in a single intervention. It is recommendable to clean frequently the pruning tools, for reducing the risk of transmitting diseases.

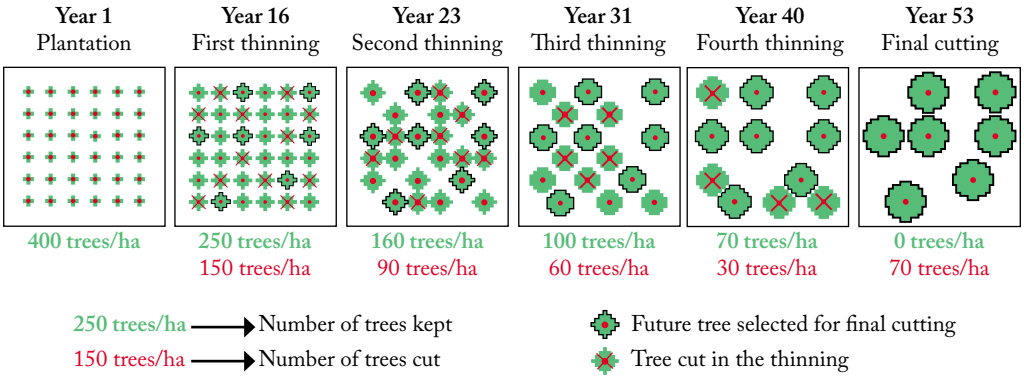


Pruning of a wild cherry during 6 years. Red marks indicate where to cut the branch.

Thinnings

Thinning consists on eliminating those trees that can compete with the best ones during the following years. Hence, top quality (selected) trees grow freely, at the maximum growth rate that the site quality provides. Thinnings should be moderate (eliminating around 33% of the trees in each thinning) and regular (every 7-10 years). The last thinning can be applied 10-12 years before the final cutting.

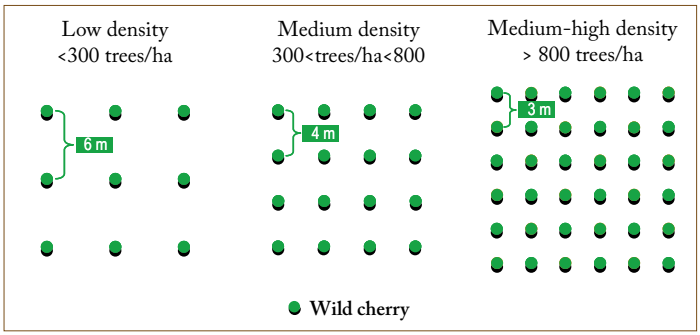
Thinnings planning on a plantation of 400 cherries/ha, in an appropriate soil (average target diameter at breast height: 50 cm).



Plantation scenarios

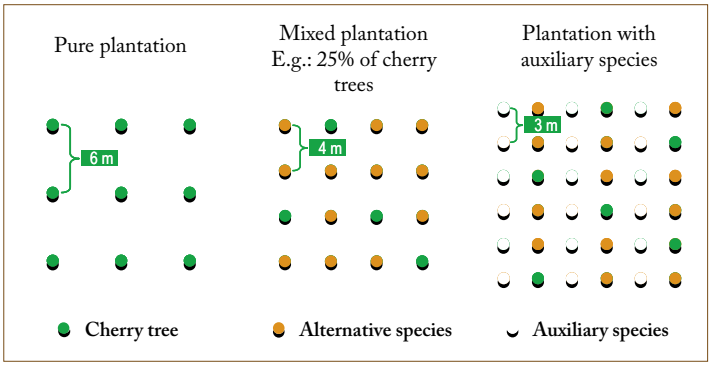
There are many options for designing and managing wild cherry plantations. Each manager may adapt the density and composition of the plantation to the available management capacities (time and funds that are planned to invest) and objectives. Some possible scenarios are shown below.

Plantation density



In a plantation the initial investment depends largely on the initial density: low densities minimize initial expenses. On the other hand, the notable costs of high density plantations are partially compensated by an increased revenue from thinnings, and a reduced pruning effort as a result of lateral shading, that encourages the straight and vertical growth of the trees and limits the size and number of branches.

Plantation composition



Because of the sensitivity of wild cherry to pests and diseases, pure plantations are only recommended for small areas, with less than 1 ha. In the case of larger areas, if is recommended to mix it with other species.

The most adequate species to utilize in mixed plantations with wild cherry are other valuable broadleaves, preferably from families other than *Rosaceae*, in order to avoid possible transmission of pathogens. Plantations with "auxiliary" species consist on using fast growing trees near the valuable broadleaves for providing a lateral shading that "educates" them during the first years. The modality promotes an adequate shape of the bole, with a reduced emission of branches, providing a protection against wildlife, wind and sun.

Example of silviculture model for wild cherry

There are many possible silvicultural schemes for wild cherry plantations. The frequency and intensity of pruning and thinning operations depend on site quality, plantation density and the technical capacity of the manager. The silvicultural model shown below refers to a 1ha pure plantation in appropriate soil, meeting all the species requirements. The figures of diameter and height growth come from different growth models; expenses and revenue are estimated based on real costs of plantations and market prizes. Profitability is expressed as the Internal Rate of Return (IRR).

Age (years)	Height (m)	Diameter (cm)	Intervention	Quality volume cut (m^3)	Expenses/ revenue (€)
-1			Soil analysis. Vegetation clearing. Soil preparation.		-830
0-1			Plantation marking and pit opening. Vegetative material purchase. Plantation of 400 wild cherries (5x5 m frame). Mulching ($1m^2$) purchase and installation. Mesh shelters (60 cm) purchase and installation. Initial or emergency watering.		-3,000
2-6	1,5-2,5	2-5	Annual formative pruning (all trees). Possible emergency watering.		
4-9	3-5,5	6-13	Pre-selection of 150 trees/ha with potential to reach final cutting. Annual formative and quality pruning of pre-selected trees. Possible emergency watering.		-1,690
10-14	6-8	15-20	Final selection of 70 trees/ha to reach final cutting. Annual quality pruning of selected cherries, up to 4,5-6 m.		
16	9	18	Thinning, keeping 250 trees/ha, including those selected.	7.6	0
23	12	25	Thinning, keeping 160 trees/ha, including those selected.	15.5	+77
31	16	33	Thinning, keeping 100 trees/ha, including those selected.	36.5	+2,043
40	19	41	Thinning, keeping the selected 70 trees/ha.	33.6	+4,412
53	22	50	Final cutting of the selected 70 trees/ha.	116.0	+30,224
IRR					**4.10%**

Ash

(*Fraxinus excelsior* and *F. angustifolia*)

for high quality timber

Photography: Jaime Coello.

3 European ash

(Fraxinus excelsior)

Photography: Agroof.

The European ash (*Fraxinus excelsior*) belongs to the family *Oleaceae*, which also includes the olive tree.

Its area of distribution includes Europe, Asia Minor and North Africa, particulary in mild and wet climates.

In areas with Mediterranean climate, they are located in mountainous areas, along shady areas besides water streams. In the Iberian Peninsula they are located especially in the northern area.

Distribution of European ash (Fraxinus excelsior).
Source: EUFORGEN 2009.

Why planting ash to produce timber ?

Ash timber is highly valued. Those pieces of highest quality are used in the veneer industry, where they reach the highest price. Ash timber is also valuable for top-quality sawnwood and cabinet-making.

Ash grows very rapidly, which allows moderately short rotations, between 40-50 years for reaching a diameter at breast height of 45-50 cm (the minimum for veneer industry), provided that they are grown in high-quality and well managed conditions.

Ash has a very important ecologic role, since it provides a habitat for birds and mammals. Its fruits are sought by granivorous birds and squirrels. Ash leaves are used to feed cattle and they have plenty of medicinal properties.



Photography: Agroof.

What are the main ash requirements ?

European Ash is among the most water demanding valuable broadleaved species. This species only grows in good pattern in those areas where climate and soil conditions provide a high water supply during the whole year. In plantations, this species must be only used in those soils that have a good water provision, with no risk of drought. Their productivity and even survival could be notably reduced if these requisites are not met.

The ecological needs of European ash are summarized in the following graph:

Appropriate conditions / Slightly restricting conditions / Very restricting conditions / Non-appropriate conditions	**Comments**
Soil depth (cm) 10- 20 30 40 50 60 70 80 90 100 110 120+	Due to their high water demand, ashes need a deep soil with a considerable water reserve, being favoured by the access to the water table. However, they do not tolerate waterlogging.
Texture Clayish / Clayish-silly / Loamy-silly / Silly-Sandy / Sandy	Ash prefers silty or loamy well-aired soils. Very clayish or sandy textures are unfavourable, unless the provision of water is very high without risk of waterlogging.
pH 3,5- 4 4,5 5 5,5 6 6,5 7 7,5 8 8,5 9+	Ash prefers rich and neutral-pH soils, so it is recommended to avoid very calcareous or acidic soils. It is not particularly sensitive to the presence of active limestone.
Altitude (m) 150- 300 450 600 750 900 1050 1200 1350 1500 1650 1800+ **Mean annual temperature (°C)** 6- 6,5 7 7,5 8 8,5 9 9,5 10 10,5 11 11,5+	Cold (and therefore altitude) can hamper its growth. Ash tolerates extremely cold winters (when they have no leaves), but they are sensitive to spring frosts, which can damage the terminal bud and cause the formation of forks, which must be corrected during formative pruning.
Mean annual precipitation (mm) 400- 450 500 550 600 650 700 750 800 850 900 950+	Ash does not tolerate severe droughts. It can tolerate water scarcity if accessing the water table, such as in riparian zones.

Water need	Sensitivity to temporary stagnation	Need for Ca, Mg and K	N and P need	Active limestone sensitivity	Wind sensitivity	Drought sensitivity	Competition for light sensitivity
Very high	Medium	Medium	High	Negligible or very low	High	High or very high	High

In areas with influence of Mediterranean climate, ash must have access to the water table during summer or else grow in shady areas with an important water reserve. It is an appropriate species for riparian conditions. They can tolerate the effect of wind, although it may have a negative effect on productivity, because of its drying effect.

The rapid growth of ash makes it suitable for being a main species in plantations. Their ecological needs are similar to those of wild cherry, therefore they can be planted together in mixed plantations. They are commonly planted in forest conditions and in silvo-pastoral systems.

Ash in forest environment.

Plantation in former pasture land in mountainous Mediterranean area.

Pests and liseases of ash

The most common disease of ash is *Chalara fraxinea*, a fungus that spreads rapidly, killing ash trees of any age. Pure plantations should be avoided in order to prevent its proliferation. In the event of an attack, the affected trees must be cut and burnt. Another important disease is canker, caused by *Pseudomonas syringae* bacteria or by *Nectria galligena* fungus (1). These diseases appear when the tree is not adapted to site conditions, or when planted in excessive density; the only treatment is to remove the affected trees as soon as possible. *Abraxas pantaria* is a lepidopter whose larvae feed on ash leaves. The wasp *Vespa crabro* (2) can cause severe damage to the branches. A defect which decreases timber price is the blackening of heart wood, which can be avoived by utilizing rotations shorter than 60-70 years.

1

Photography: A. Abrahami.

2

Photography: R. Altenkamp.

First steps of plantation

The first steps of an ash plantation are similar to those of other valuable broadleaved species.

Choosing the plant

The vegetative material must be chosen from a region with ecological conditions similar to the area of plantation. It is possible to find in the market an important variety of ash vegetative materials and provenances. It is recommended to choose bare-rooted plants with robust aspect, a healthy terminal bud and a developed root system with an important volume of secondary roots. Plants of 1 year (1+0) or 2 years (1+1) are recommended.

Soil preparation

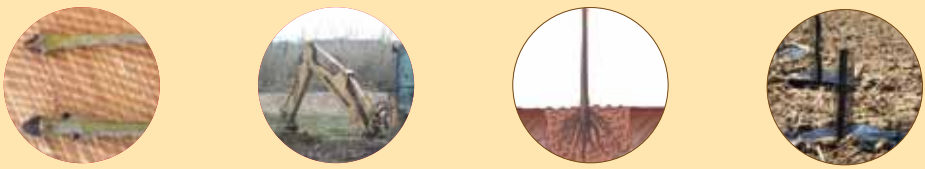
After clearing the vegetation that can interfere with the execution of plantation, it is recommended to apply a sub-soiling, preferably crossed (in 2 perpendicular directions) and to the maximum depth possible (50 cm or more), in order to foster plant early growth and soil water retention. After that, it is recommended to let 1-2 months for soil consolidation. The plantation pits are made with backhoe excavator or manually, depending on the number of trees and the accessibility. The size of the pit is decided in accordance with plant dimensions.

Planting

Plantation is done out of the vegetative period, between November and March, trying to avoid days with frosts, rainfall or snowfall. When planting, the root system must not be compressed and the base of the trunk has to be levelled with the ground. It is recommended to apply an initial watering of 30-40 l/tree, if no rainfall is foreseen during the first weeks following the plantation.

Protect

During the first 5 - 10 years it is necessary to protect the plants from weeds, browsing damage and drought. The negative impact of weeds can be avoided by using an individual ground cover (mulch) of 1m2 that allows water infiltration into the soil, while being opaque and thus impeding light accessing the soil. Other common techniques are localized herbicide application and mechanical weeding. The damage caused by browsing mammals can be avoided with individual mesh shelters resistant to the wildlife present in the plantation area. Electric fencing can also be added if required. In the case of severe drought, especially if the plantation is young, an emergency watering may be necessary.



Photography: Jean-Pierre Ortisset. CRPF.

Plantation management

Ash requires an active and well planned silviculture, because of its high light demand and vigorous growth. In order to limit the maintenance costs it is important to identify and promote as soon as possible the trees with highest potential for producing valuable timber (future trees). Pruning, especially when applied over 2-3 m, will be applied only on future trees. The pruning and clearing planning over time is detailed in the following silvicultural scheme.

Pruning

Formative pruning implies eliminating (or cutting the tip) of high or rather vertical branches that can compete with the terminal shoot. The appearance of forks (especially after a late frost) is relatively frequent in Ash, and must be corrected as soon as possible, keeping only the strongest shoot as the new bud. **Quality pruning** consists on eliminating the lower branches with a diameter larger than 2.5-3 cm at their insertion, in order to avoid big knots. It may be also necessary to cut shoots sprouting from pruning wounds (epicormic shoots). It is recommended to prune in a progressive manner, clearing less than 50% of the trunk and eliminating less than 30% of the leaves in each intervention, until obtaining clean boles 3–4 m long (5-6 m in good quality sites and with high densities). Pruning is undertaken between June and July every 1-3 years, depending on the density and site quality.

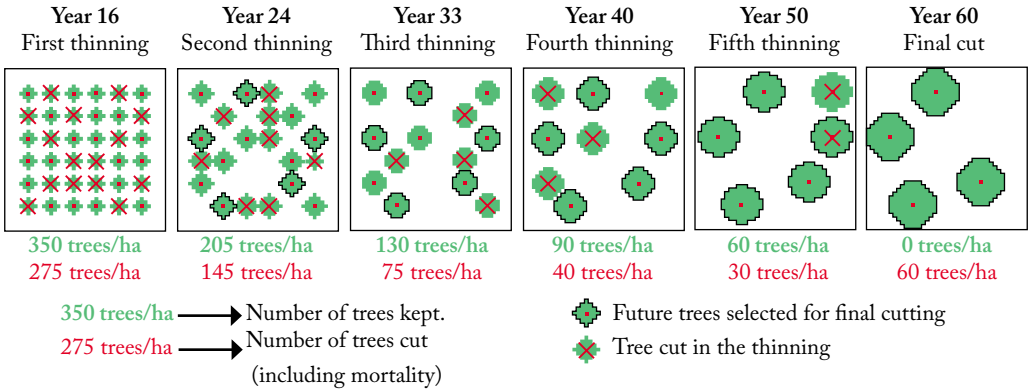
Formative pruning on ash.

Quality pruning on ash.

Thinnings

Thinnings consist on eliminating those trees that can compete for light and nutrients with the best ones (selected trees) in the short term. With this operation it is possible to maintain an adequate growth rate on the best trees, while avoiding the shading and potential rotting of the crown base. It is recommended to apply moderate (eliminating each time 30% - 40% of trees) and recurrent thinnings (every 8-10 years). During a thinning, those trees showing a disease of low vigour are eliminated first.

Thinnings planning on a pure plantation of 625 ashes/ha, in an appropriate site.



Some silvicultural options for ash

Ash is a very versatile species that can be used either in pure stations or mixed with other species. Moreover, it has a great potential for high quality timber production in forest conditions.

Pure and mixed plantations

Unlike many other valuable broadleaved species, which usually appear scattered in the forest, ash can locally occur as a dominant species in relatively continuous areas. This feature allows the use of ash in pure or mixed plantations with many possible designs.

Silvopastoral Systems

Ash is a very interesting species with regard to livestock feeding, which has been traditionally the most common use of ash in mountainous areas. It can be used in silvo-pastoral systems, where livestock and timber are produced at the same space and time. In these systems, trees are favoured by the fertilization effect caused by animals, which can in turn benefit from the shelter effect of trees against sun, wind and hail. It is possible to perform a plantation of ash in an area devoted to grazing, and identify progressively those that can produce high-quality timber (that are pruned) and those devoted to be used as a source of tender shoots and leaves for feeding the cattle, thus diversifying the nutrient provision.

Photography: Agroof.

Management of natural regeration of ash

Ash is a relatively common species in mountain forests, and can be locally abundant. The abandonment of many agricultural and grazing activities in these areas has led to their colonization by forest species, among others ash and other valuable broadleaved species. This natural regeneration consists on trees that are well adapted to the environment, among which it is possible to find some especially interesting individuals for high quality timber production (valuable broadleaved species, straight trees with few, thin branches) that can be selected and promoted through pruning and thinnings. With this scheme, and with a minimal investment, some forest areas may lead to considerable economic and environmental benefits, especially in areas where valuable broadleaved species are naturally under-represented.

Photography: Jaime Coello.

Narrow-leafed ash (*Fraxinus angustifolia*)

Location of the Narrow-leafed ashes in Spain. Source: DGMNPF-INIA.

Narrow-leafed ash (*Fraxinus angustifolia*) is the species equivalent to European ash (*Fraxinus excelsior*) in areas with marked Mediterranean climate. It occurs over the whole Iberian Peninsula, except in cold mountainous sites in the north, where it is replaced by European ash or by hybrids of both species.

This species can tolerate low rainfall regimes, starting at 450 mm per year, as well as summer drought, always that the soil has a sufficient water reserve. Nevertheless, they are very sensitive to waterlogging and its use must be avoided in very clayish and compact soils.

Narrow-leafed ash is sensitive to the same pests and diseases as the European ash.

Narrow-leafed ash plantations are not very common in Europe yet, leading to a lack of silvicultural guidelines specific for this species. Thus, its seems appropriate to use it in combination with other species, and to consider a silviculture similar to the one of European ash, regarding plantation density, pruning, thinning and rotation, provided that the site features are adequate for this species. The quality of the timber of narrow-leafed ash is generally not as good as in the case of European ash, because of its tendency to generate a large amount of branches and show a wavy growth pattern.

Narrow-leaved ash plantation.

Tree shape and branchiness of an unmanaged tree.

Sycamore *(Acer pseudoplatanus)*, Norway maple *(A. platanoides)* and Field maple *(A. campestre)* for high quality timber

Photography: Jaime Coello.

4 The genus *Acer*

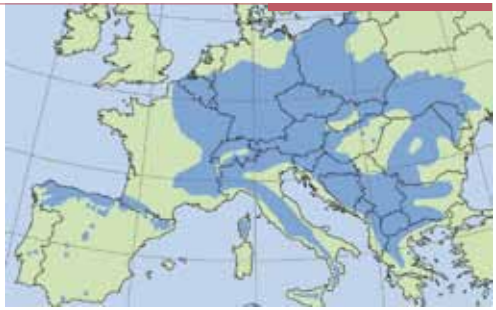
Photography: Pierre Gonin. IDF.

The species from genus Acer with highest productive potential in Europe are Sycamore (*Acer pseudoplatanus*), Norway maple (*Acer platanoides*) and, to a lesser extent, Field maple (*Acer campestre*).

Sycamore and Norway maple occur in a similar distribution area, mainly in Central Europe and, less frequently, Southern Europe.

Both species appear scattered in broadleaved forests, preferably in fresh, humid and nutrient rich sites, including riparian areas.

In this document both species will be considered together, as the main difference between them is a slightly higher tolerance to drought and lower growth rate in the case of Norway Maple.



Distribution of sycamore (Acer pseudoplatanus).
Source: EUFORGEN 2009.

Why planting maples to produce timber ?

Maple timber is quite valuable, reaching exceptional prices when fibres show a wavy aspect. Additional to its excellent aesthetic properties, this timber is easily worked. The most common industries for this timber are sawnwood and, for the best logs, veneer, when they reach highest price. This species is very appreciated for cabinetmaking, woodturning and furniture making.

Sycamore is among the valuable broadleaved species with highest growth rate under adequate conditions. In a high quality site it is possible to achieve rotations of about 40 years, with a target diameter of 50 cm.

Sycamore (A. pseudoplatanus).
Photo: Philippe Van Lerberghe. IDF

Norway maple (A. platanoides).
Photography: Pierre Gonin. IDF.

Photography: Philipp Zinger.

What are the main requirements of maple ?

Sycamore and Norway maple have rather similar requirements with regard to climate and soil features. They occur preferably on deep fresh soils, well drained and without stagnation. Young seedlings are favoured by shading, but from years 4-7 onwards they grow optimally when exposed to direct light. The following figure summarizes the main ecological features required by maples for optimal growth and valuable timber production.

Appropriate conditions / Very restricting conditions / Slightly restricting conditions / Non-appropriate conditions	**Comments**
Soil depth (cm) 10- 20 30 40 50 60 70 80 90 100 110 120+	Maples require deep and fresh soils, preferably thicker than 70-80 cm.
Texture Clayish Clayish-silty Loamy-silty Silty-sandy Sandy	Optimal texture is loamy - silty, always that there are no stagnation problems. Soils with deficient drainage, as well as those with low water and nutrient retention capacity, are to be avoided.
pH 3,5- 4 4,5 5 5,5 6 6,5 7 7,5 8 8,5 9+	Maples are favoured by neutral pH, despite tolerating active limestone and gypsum. They are also demanding species regarding nutrient richness. These species tolerate moderate salinity levels.
Altitude (m) 150- 300 450 600 750 900 1050 1200 1350 1500 1650 1800+ **Mean annual temperature (ºC)** 5- 5,5 6 6,5 7 7,5 8 8,5 9 9,5 10 10,5+	These species lie in altitudes ranging between 600 and 1000 m, although they can reach 1800 m altitude in areas with Mediterranean influence. Maples are not affected by severely low temperatures or late Spring frosts, thank to their late flushing. However, early Autumn frosts and extreme summer heat can affect them negatively.
Annual precipitation (mm) 400- 450 500 550 600 650 700 750 800 850 900 950+	Optimal annual precipitation is over 800 mm, although it can tolerate summer droughts of around 2 months, always that they are compensated by high air humidity.

Water need	Sensitivity to temporary stagnation	Need for Ca, Mg and K	N and P need	Active limestone sensitivity	Wind sensitivity	Drought sensitivity	Sensitivity to competition for light
High	High	Medium	Medium	Low	low	Medium - high	Low (young) - high (adult)

Under adequate conditions, especially regarding sufficient nutrient and water availability and without stagnation problems, maples show a fast growth rate. These species are especially interesting for areas with high air humidity, as well as in areas protected by prevailing winds and evaporative stresses. In open areas maples tend to lose or fork the terminal shoot, which needs to be corrected by formative pruning.

Sycamore (Acer pseudoplatanus). Photography: Jean-Pierre Ortisset. CRPF.

Norway maple (Acer platanoides). Photography: Jean-Pierre Ortisset. CRPF.

Sycamore. Photography: Philippe Van Lerberghe. IDF.

Norway maple. Photography: Pierre Gonin. IDF.

Pests and diseases of maples

There are few severe health problems affecting maples that represent a significant restriction to their commercial use. It is very common to observe attacks from fungus *Rhytisma acerinum* (1), with conspicuous dark round spots but with negligible impact on tree growth. Other negative agents affecting maples include aphids as well as defoliating (*Lymantria, Operophtera* (2)) and drilling (*Cossus, Xyleborus*) insects. A fungus deserving attention is *Cryptostroma corticale*, which attacks especially after periods with high temperatures drying the bark and potentially resulting in the death of the tree. Moreover, the spores of this fungus can cause severe allergies to human beings.

First steps of plantation

The first steps of a maple plantation are similar to those of other valuable broadleaved species.

Choosing the plant

It is recommendable to utilize vegetative material from provenances with features similar to those in the plantation area, especially with regard to soil characteristics and severity of summer drought. The plant must show a healthy terminal bud and a unique, robust, branchless stem. The root system must be well developed, with abundant secondary roots. It is recommended to utilize 1 year old plants (1+0), 40-50 cm high.

Soil preparation

After clearing the pre-existent vegetation that could interfere with the execution of plantation works, it is recommendable to perform a sub-soiling, preferably crossed (in 2 perpendicular directions), to the maximum depth possible, in order to promote soil water retention. The opening of plantation pits can be done by either backhoe excavator or manually. In any case, pits size should be defined according to plant dimensions.

Planting

Plantation is executed during dormancy period, normally between November and March, avoiding days with risk with frosts, precipitation or strong winds. When planting, the root system must be well stretched, with the stem base over ground level. It is recommendable to apply an initial watering of 30-40 l/tree, if no precipitation is foreseen during the first weeks after planting.

Protecting

During first years it is recommendable to utilize a ground cover (mulch) in order to avoid negative weed effects. This technique prevents light from reaching the soil, thus keeping the soil over the root system free of vegetation that could compete for water and nutrients. Browsing damage must be avoided with the use of tree shelters, preferably with mesh wall, that can be complemented by electric fencing in the perimeter of the plantation.

Damage caused by severe drought could be prevented by emergency watering. When existent, it is possible to plant 50 cm away from brushes, which can be respected in order to reduce weed competence and browsing damage. These brushes, with an accompanying auxiliary function, must be controlled if shading the upper part of the tree.




Photography:
Philippe Van Lerberghe. IDF.

Plantation management

Because of their vigorous and fast growth maples require an active and dynamic silviculture (pruning and thinning). Thinnings are applied for favouring the best trees: those showing the best morphology and growth rate. These trees will reach the final cutting to be utilized in the highest quality industrial destinations.

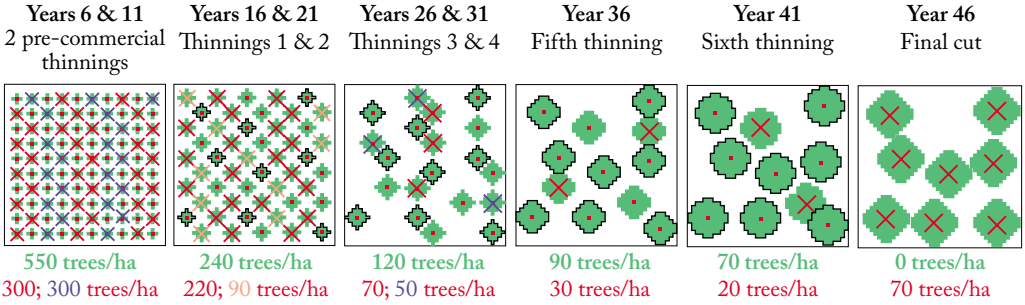
Pruning

Maple often form forks in the terminal shoot, as well as sprouts at the stem base. These situations must be solved promptly. During **formative pruning** the branches that appear in the upper part of the crown that could compete with the main shoot are cut or blunted, as well as the forks. During **quality pruning** the branches thicker than 3 cm at their base are cut, to prevent the existence of big knots. The aim of pruning is to form a clean bole without branches 3 - 6 m long in 100-120 trees/ha, by eliminating progressively the crown base, and always respecting, at least, the upper half of the tree with branches. With this balanced and progressive intervention the stress caused to the tree is mitigated and the risk of emergence of epicormic shoots is reduced. Optimal pruning period ranges from mid June to early August.

Pruning of a young maple.

Thinnings

Thinnings consist on eliminating those trees with least commercial potential, when they can compete with the best ones for light and nutrients. With this intervention, the growth rate of the best trees remains high, as growing without competence. Despite tolerating shading during early years, maple reaches its highest growth rate when exposed to direct light. On the other hand, a moderate, lateral shading, can be beneficial for maple, as maintaining a "forest climate" conditions with mitigated evaporation and wind effect. First thinning is applied generally when trees reach 10 – 12 m height, with further thinnings every 5 – 10 years. Despite it is possible to keep higher densities than in other valuable broadleaved species, it is recommended to apply frequent and moderate thinnings in order to avoid a sudden exposition to sunlight. Example of thinning plan on a pure sycamore plantation: 3x3 m - 1.150 trees/ha).



Other silvicultural schemes with maples

Besides the example of thinning plan analyzed (1,150 maples/ha), there are many alternative schemes for the utilization of maple for valuable timber production in our conditions, as shown below.

Mixed plantation

Maples can be combined with one or more valuable broadleaved species. Because of the fast growth rate of maple, an interesting combination could include species with longer rotation, such as *Sorbus* or walnut. Because of the high demand of air humidity and its need for partial shading, it would also be interesting to combine maple with alternative productions that provide a lateral shading during first years: in this sense, a mixed plantation with poplar (for either biomass or veneer production) would be a wise choice, as poplar would provide micro-climate conditions optimal for maple development during the first years, and would lead to a short-term (12-14 years) income, that would allow covering plantation costs

Mixed plantation with maple.
Photography: Grégory Sajdak. IDF.

Plantation for forest diversification

This productive scheme consists on performing small-sized maple plantations, which can also include other valuable broadleaves, in forest spots with remarkably high site quality for these species: fresh areas such as valley bottoms, flat areas (abandoned terraces), etc. The management of these new stands would focus on promoting those planted trees with best shape and vigour, which will be pruned during the first years. In this scheme it is fundamental to apply measures for preventing potential negative impacts by weeds (e.g. by mulching), browsing damages (shelters) and by excessive shading by surrounding trees (selective thinnings). With such a minimal intensity management, focused only on small areas, it is possible to increase considerably the economic value of the forest, produce interesting revenue and promote its environmental and landscape values, especially if these plantations are implemented within pure stands dominated by conifers.

Plantation for forest diversification.

Silvo-pastoral systems

Maple is an interesting species for its use in silvo-pastoral systems, where timber production and grazing are combined at the same space. These systems lead to revenue in the short term (grazing) and in the medium term (valuable timber), being especially interesting for low mountainous areas. The global productivity of these systems is superior to timber and grazing production separately, thank to the positive interaction between trees and animals: the trees benefit from the organic matter release (fertilization), while the animals find shelter (sun, wind, hail) under the tree crowns. These systems should be established in areas without risk of soil compaction, as the continuous presence of animals may lead to root suffocation. It is also compulsory to protect trees with shelters adapted to the animals utilized.

Maple in silvo-pastoral system with cows.

Field maple (*Acer campestre*)

Distribution of field maple (Acer campestre).
Source: EUFORGEN 2009.

Field maple (*Acer campestre*) occurs in a large proportion of European forests located on neutral or basic soils, from lowlands to middle mountain conditions. Despite it frequently appears as a small tree, it can reach 20 m height under adequate site conditions.

This species is especially adapted to areas that are transition between Mediterranean and Euro-Siberian. As field maple can tolerate both conditions, it occurs in very diverse forests. Field maple tolerates poor soils and especially drought much better than sycamore and Norway maple. Early growth rate is similar to other maple species, but it slows down afterwards. It grows optimally with full sun, although it can also tolerate moderate shadowing and competence.

This species represent an interesting alternative to other maples for plantation in open areas with significant Mediterranean influence and sun-facing conditions. Despite its higher tolerance to drought, annual precipitation should be at least 600 mm to allow a growth rate justifying the choice of this species. As it has difficulties reaching large dimensions, it is recommended to use it in combination with other valuable broadleaved species with higher potential for premium timber production.

Alike other maples, it is necessary to apply formative pruning for promoting a unique straight stem and a vertical growth of the tree, that must be free of forks. This pruning should be applied every 2-3 years. Quality pruning is applied until reaching a branchless clean bole at least 3 m long.

With regard to pests and diseases, this species is affected by the same agents as other maples.

Photography: Frank Vincentz.

Photography: Óscar Cisneros.

Photography: Mireille Mouas. IDF.

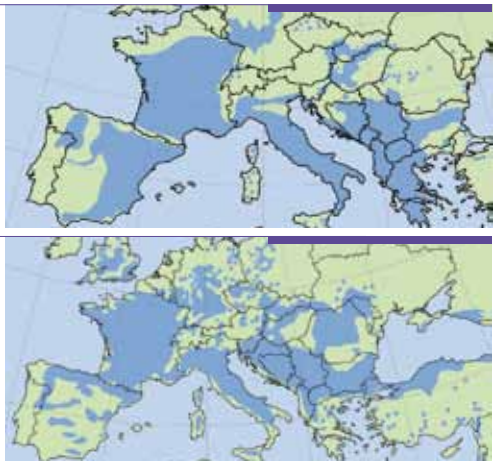
Service tree *(Sorbus domestica)* and Wild Service tree *(Sorbus torminalis)* for high quality timber

Photography: Jacques Becquey. IDF.

5 The *Sorbus* genus

In Europe the main *Sorbus* species are Service tree *(Sorbus domestica)*, and Wild service tree (*S. torminalis*), to both which we will refer as *Sorbus*. Other species from the same genus are Rowan (*S. aucuparia*) and Whitebeam (*S. aria*).

Although these species have a very wide range of occurrence, they are normally found in forests dominated by other species. In our conditions, Service and Wild Service trees are well adapted to Mediterranean and sub-Mediterranean climates, while Rowan and Whitebeam prefer mountainous areas, with more humid and colder conditions.



Distribution of Service (Sorbus domestica), *up and Wild Service trees,* (Sorbus torminalis), *down. Source: EUFORGEN 2009.*

Why planting *Sorbus* species to produce timber ?

Due to the relative scarcity of large trees of these species, their timber market is not widespread. Nevertheless, wild service trees reach the highest price of all European timbers, while service tree timber is also quite appreciated in veneer and luxury furniture industry. The timber of both species have excellent aesthetic and technical characteristics. The top quality pieces are used in veneer industry, where they reach their highest price. In this industry, timber is cut into thin slices that are used to cover or top-quality furniture. Rowan and Whitebeam timber could also produce high quality products, but these species hardly form as big boles, which limits their potential for this industry.

Photography: Jacques Becquey. IDF.

Service tree.
(Jean-Pierre Ortisset)

Wild Service tree.
(José Carlos Santana)

What are the main wild service and service trees requirements ?

Service and wild service trees have a great tolerance of harsh sites (drought, compact soils, etc), in comparison with the majority of other valuable broadleaves. In natural conditions they occur in a wide variety of conditions, although they tend to disappear in high quality sites, dominated by other, faster growing species. In any case, their use in plantations is recommended especially at high quality sites, in order to achieve an adequate rotation. Their growth rate depends especially on water availability and soil quality. The following graph summarizes the main requirements of service and wild service trees.

Appropriate conditions for Service tree *(Sorbus domestica)* Appropriate conditions for Wild service tree *(Sorbus torminalis)*	**Comments**
Soil depth (cm) 10- 20 30 40 50 60 70 80 90 100 110 120+	*Sorbus* are very resistant to drought and wind, even in shallow soils. Therefore they can be used in areas that are too limiting for other valuable broadleaved species with regard to soil depth and moisture.
Texture Clayish Clayish-silty Loamy-silty Silty-sandy Sandy	Both species, especially Service trees, can tolerate heavy soils, with moderate stagnation. Sandy soils are normally too poor in nutrients for supporting *Sorbus* species development.
pH 3,5- 4 4,5 5 5,5 6 6,5 7 7,5 8 8,5 9+	*Sorbus* can grow in a great variety of soils and pH, being recommendable to ensure an adequate provision of nutrients. They tolerate the presence of active limestone.
Altitude (m) 150- 300 450 600 750 900 1050 1200 1350 1500 1650 1800+ **Mean annual temperature (°C)** 6- 6,5 7 7,5 8 8,5 9 9,5 10 10,5 11 11,5+	Both species, especially Service trees, need warmth during the growing season, although they both tolerate extremely cold winters. Generally, late frosts do not limit valuable timber production of these species.
Mean annual precipitation (mm) 400- 450 500 550 600 650 700 750 800 850 900 950+	These species, especially Service tree, can grow under low rainfall regimes, and can tolerate up to two months of severe drought.

	Water need	Sensitivity to temporary stagnation	Need for Ca, Mg and K	N and P need	Active limestone sensitivity	Wind sensitivity	Drought sensitivity	Competition for light sensitivity
Service tree	Low	Medium	Medium	Medium	Negligible - very low	Low	Low	High
Wild Service tree	Medium	Medium	Low	Medium	Negligible - very low	Low	Low	Medium

These species have a relatively slow growth rate, therefore they are usually planted together with other valuable broadleaved species that are more productive. Thank to their ecological plasticity, service and wild service trees are particularly interesting in those parts of the plantation that are the most limiting: perimeter, areas with risk of temporary stagnation, areas exposed to wind, etc. They can also be used on agroforestry systems, always that the herbicide application is not excessive.

Service tree **(Sorbus domestica). Photo: Jean-Pierre Ortisset.CRPF.**

Wild Service tree **(Sorbus torminalis).**

Pests and diseases of *Sorbus*

There are few harmful agents reported as affecting service and wild service trees. Leaf-mottle fungi and aphids (1) normally attack the leaves but are not a serious menace for tree growth and vigour. The insect *Janus compressus* causes the withering of shoots (2), although the tree tends to correct the defect without leading to major shape defects (3). The most serious problems are caused by canker (4), especially in Service tree, which may cause deformities, as well as the Honey fungus (*Armillaria*) in Wild Service tree. These diseases can rot the root system and even kill the tree. In order to prevent health problems it is recommended to use these species in areas where they are adequately adapted, as well as disinfecting the pruning tools. It is especially important to pay regular attention to the health status of the trees if they are planted close to areas with fruit trees or other *Rosaceae* species.

Photographs: Antoni Vilanova-IRTA (photo 2) and Jacques Becquey, IDF (photo 4).

First steps of plantation

The first steps of plantation with service and wild service trees are similar to those of other valuable broadleaved species.

Choosing the plant

It is recommended to use a vegetative material from an area similar to the plantation zone, especially with regard to soil characteristics and intensity of drought. Bare rooted plants is the most adequate format for high quality soils. The apical bud must be well developed and healthy, with a unique, branchless stem. The root system must be consistent and well developed, with an important volume of secondary roots. One year-old plants (1+0) should be between 20-30 cm high, while two year-old plants (1+1), should be around 50 cm high.

Soil preparation

After clearing the vegetation that could affect negatively the plantation operations it is recommended to apply a crossed sub-soiling (in 2 perpendicular directions) to the maximum depth possible (at least 50 cm), for enhancing soil water retention. The plantation pits can be made either manually or by backhoe excavator, with dimensions adequate for the plant size.

Planting

Trees are planted during their dormancy period, preferably between November and March, trying to avoid days of frost, precipitation or strong winds. When planting, root system must be well stretched, keeping the plant vertical and the base of the trunk at soil level. An initial watering of 30-40 l/tree can be beneficial if rain is not forecasted during the first weeks immediately after planting.

Protecting

Sorbus trees are very sensitive to weed competition during the first 5-10 years of plantation. The negative effect of weeds can be avoided by mulching (ground covers of $1m^2$ installed at each tree). This system impedes weed establishment and development near the tree, while reducing soil water evaporation. These species are very sensitive to herbicides, so their careful application is mandatory. Browsing damage can be avoided by individual shelters (preferably with mesh walls), which can be complemented with electric fencing. Drought negative effects could be avoided or mitigated by emergency watering.

Plantation management

Sorbus species can be utilized with a large variety of plantation schemes, regarding species composition, densities, etc. The planning of pruning and thinning interventions is similar to other valuable broadleaved species, although it should be considered that Service and Wild Service trees have generally a slower growth rate.

Pruning

In the **formative pruning**, the highest or most vertical branches that could shade the apical shoot are blunt or cut. In the case of Wild Service tree, it is especially important to eliminate the forks that the terminal shoot may create. Service trees have normally a strong apical dominance and thus their formative pruning is easier.

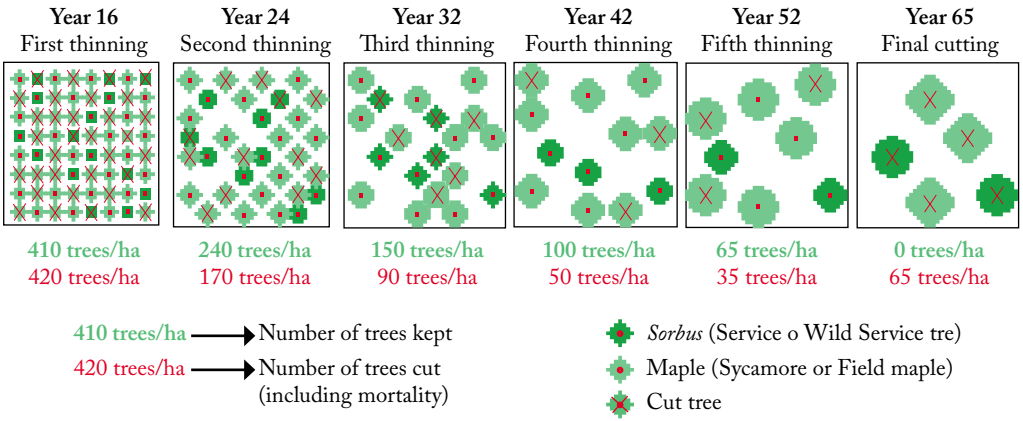
Quality pruning consists on eliminating the thickest branches before they reach 3 cm of diameter at their base, in order to avoid big knots. It is recommended to prune progressively (less than 50% of the total height of the tree each time) until obtaining a clean bole of 3-4 m (medium quality sites) or 4-6 m (high quality sites). Formative pruning and quality pruning are applied during summer, every 1-4 years. In both species, it is important to form a symmetric and well-balanced tree crown in order to avoid internal tensions in the timber.

Fork of a wild service tree, requiring an urgent formative pruning.

Thinnings

Thinning consists on cutting those trees that could compete with the best ones of the plantation in the upcoming years. By this intervention, the best trees are promoted and their free growth is maintained. The first thinning is generally made when trees are 10-12 m high. The following thinnings are made approximately every 10 years, with intensities of 30-40% of trees. The final cutting is applied when the trees are 60-80 years old, when their diameter should be larger than 45 cm.

The following scheme shows the thinning plan of a mixed *Sorbus* (25% of trees) and maple (75% of trees) plantation, with an initial density of 830 trees/ha, in an area suitable for both species.



Some technical itineraries for *Sorbus*

Besides the example of plantation shown before (mixed Sorbus and maple plantation), there are many other schemes for using *Sorbus* in our conditions.

Other mixed plantations

There are several options for combining *Sorbus* with other valuable broadleaved species. Pure plantations of *Sorbus* should be used if the available area is small (< 0,25 ha). When designing a mixed plantation, it is recommended not to use exclusively Rosaceae species (pear tree, wild cherry, *Sorbus*), in order to avoid possible health problems. An interesting design would be to consider including species with different growth rates, in order to perform progressive final cuttings, with an improved use of resources. For example, it is possible to combine short rotation productions (biomass or ornamental species), medium rotation (fast growing valuable broadleaved species) and long rotation (service or wild service trees) ones.

Underplanting forests

This proposal consists on installing small plantations of *Sorbus* (alone or mixed with other valuable broadleaved species) in high quality forest sites (old terraces, valley floors, gentle slope conditions, etc). The management of the resulting system will focus on enhancing the vigour and growth of valuable broadleaved species (including pruning and selective thinnings), while keeping a forest cover that does not compete with them: thinnings will allow achieving an adequate shading and sheltering of the valuable broadleaved trees. With this system, a small-scale management (focused on planted trees) will increase considerably the economic value of the forest areas, while diversifying them.

Agroforestry plantations

Sorbus are interesting species for agroforestry systems (combination of agricultural and timber production in the same area), due to their resistance to strong winds and their positive effect on filtering and increasing the quality of water that is lixiviated from the agricultural field. The deep root system filters and absorbs the water that may carry high loads of fertilizer, thus avoiding the pollution of groundwater while enhancing tree growth. Other advantages include the reduction of the drying effect of wind and the presence of pests in agricultural areas (the trees may host auxiliary species that would tend to balance the ecosystem), as well as the recirculation of nutrients from deep soil layers. Service trees have been successfully combined with soya, wheat, rape and vineyards in Greece, Italy and France.

Service tree in pine forest.

Wild service tree in an agro-forestry system. ©agroof.

Other *Sorbus* species

Whitebeam (*Sorbus aria*) and Rowan (*Sorbus aucuparia*) are very resistant species, that can tolerate many soil and climate conditions. They both require direct light exposition from the very first years and have little capacity to compete with other tree species. They tolerate strong winds and stony and dry soils. Their production potential is lower than in the case of service and wild service trees, because the harsh conditions where they usually grow, which hampers the possibility for constituting large boles. Their use could increase the economic interest of micro-sites on mountainous areas with high quality timber production, as well as restoration plantations. They are sensitive to the same pests and diseases as the other *Sorbus* species.

Whitebeam (Sorbus aria)

Whitebeam has the widest ecological range among all *Sorbus* analyzed; it tolerates severe droughts and poor quality soils, including those with very low pH or with active limestone. However, this species does not tolerate stagnation, even if temporary, so it is recommended to avoid their use in very clayish and heavy soils. They usually appear in mountainous areas, between 600 m - 1700 m, thank to their tolerance to cold.

Although they tend to form several stems, it is possible to shape a unique straight bole by pruning. Its wood quality is slightly lower than that of service trees and wild service trees, and thus its economic interest is limited due to its difficulty to achieve pieces with the appropriate size required by the veneer industry.

Photography: Óscar Cisneros.

Photography: Jacques Becquey. IDF.

Rowan (Sorbus aucuparia)

Rowan needs high humidity and precipitation distributed over the year. It is a mountain species that can grow in areas up to 2000 m in altitude, in different type of soils. At lower altitudes, they prefer neutral or slightly acidic soils, free of active limestone. They have a low tolerance to stagnation or air pollution.

Alike whitebeam, rowan tends to generate multiple stems and branches, which makes necessary to apply formative pruning in order to achieve a straight clean bole in order to produce commercial pieces.

Photography: Mireille Mouas. IDF.

Photography: Jacques Becquey. IDF.

The Pear tree (*Pyrus communis*) and the Apple tree *(Malus sylvestris)* for high quality timber

Photography: Mireille Mouas. IDF.

6
Pear tree
(Pyrus communis)
and Apple tree
(Malus sylvestris)

These species are especially used for fruit production, in spite of which it is possible to find them as forest species, with a significant and potential for valuable timber production. Pear tree (*Pyrus communis*) and apple tree (*Malus sylvestris*) belong to *Rosaceae* family, alike wild cherry and service trees.

Despite their large distribution area, its occurrence pattern is scattered, embedded in forests dominated by other tree species, as beech, oak and chestnut. Both species are favoured by fresh conditions, influenced by water streams. They are also common in hedges close to agricultural fields.

Distribution of pear (Pyrus communis pyraster), *up, and apple trees* (Malus sylvestris), *down. Source: Euforgen, 2008.*

Why planting pear and apple trees for timber production ?

Because of their scattered pattern of occurrence, and to the difficulty for finding trees of these species with adequate features for valuable timber production (excellent shape, large dimensions), it is not possible to find a market specialized in the industrial use of their timber, and no silvicultural models have been proposed for them. In this moment a large proportion of the timber from these species utilized commercially comes from large fruit trees, although their value is considerably reduced by their short clean bole. However, good quality logs are very appreciated for top-quality cabinetmaking, musical instruments construction and fine sculpture, being a dense, homogeneous and easily worked timber. The pieces with adequate shape and dimensions can be utilized in veneer industry.

Pyrus communis.
(Grégory Sajdak. IDF.)

Malus sylvestris.
(Mireille Mouas. IDF.)

Photography: Óscar Cisneros.

Photography: Óscar Cisneros.

What are the main requirements of pear and apple trees ?

Both species have a good tolerance to a wide variety of soil conditions, regarding texture (silty to sandy) and pH (acid to basic). However, both species are exigent regarding soil freshness, not being suitable for neither dry soils nor those stagnation-prone. Pear and apple trees tolerate moderate to severe dry periods while being close to water streams. These species achieve an optimal growth rate in deep fresh soils, with a high availability of water and nutrients. They are also favoured in sunny areas, not tolerating the shadowing. The following figure summarizes the main ecological needs of both species.

Appropriate conditions for pear tree *(Pyrus communis)* Appropriate conditions for apple tree *(Malus sylvestris)*	**Comments**
Soil depth (cm) 10- 20 30 40 50 60 70 80 90 100 110 120+	Deep soils allow a larger water reserve, being the optimal for the adequate development of these species.
Texture Clayish Clayish-silty Loamy-silty Silty-sandy Sandy	The range of tolerance to different soil textures is wide for both species, although they prefer clayish-silty soils (always that there is no risk of stagnation), because of their higher nutrient availability.
pH 3,5- 4 4,5 5 5,5 6 6,5 7 7,5 8 8,5 9+	Pear and apple trees can grow in soils with very diverse pHs, with an optimal performance on neutral soils. Both species tolerate active limestone.
Altitude (m) 150- 300 450 600 750 900 1050 1200 1350 1500 1650 1800+ **Mean annual temperature (ºC)** 6- 6,5 7 7,5 8 8,5 9 9,5 10 10,5 11 11,5+	Both pear and apple trees have a good tolerance to low temperatures. In fact, summer high temperatures are limiting for them, especially when leading to low water availability.
Mean precipitation (mm) 400- 450 500 550 600 650 700 750 800 850 900 950+	Both species require an adequate water supply to achieve a sound growth rate; thus, dry conditions should be avoided.

	Water need	Sensitivity to temporary stagnation	Need for Ca, Mg and K	N and P need	Active limestone sensitivity	Wind sensitivity	Drought sensitivity	Competition for light sensitivity
Pear tree	Medium	Medium	Medium	High	Very low	Very low	Low	High
Apple tree	Medium	Medium	Low	High	Very low	Low	Low	High

Pear tree (Pyrus communis pyraster).
Photography: Doris Anthony.

Apple tree (Malus sylvestris).
Photography: Mireille Mouas. IDF.

Up: Leaf of Pear tree.
Photography: Grégory Sajdak. IDF.
Down: Leaf of Apple tree.
Photography: Mireille Mouas. IDF.

Both pear and apple trees tolerate a wide variety of climates and soils, in spite of which it is fundamental to guarantee an adequate provision of water and nutrients. These species are especially suitable for open areas, exposed to sun. Additionally to their productive interest (valuable timber production), these species have extraordinary value from the landscape and environmental point of view, being scarce, producing fruits esteemed by wildlife and flowers with melliferous interest.

Pets and diseases of pear and apple trees

The most relevant disease affecting both species, as well as many other Rosaceae trees, is "fire blight", caused by *Erwinia amylovora* bacterium, leading to the withering of young shoots, branches and stems, occasionally being lethal for the tree. Affected tissues show a blackish aspect. There is no effective healing treatment for this disease, so prevention (through the use of vegetative material selected for its insusceptibility) is the only current option. In the event of detection of this disease the affected trees must be cut and burnt. These species can be also attacked by aphids.

First steps of plantation

The first steps of a plantation including pear or apple trees for high quality timber production are similar to those from other valuable broadleaved species.

Choosing the plant

It is recommendable to utilize vegetative material original from an area with characteristics similar to those at the plantation site, especially with regard to soil features and severity of summer drought. The plant must show a healthy, well developed terminal bud and a unique, robust branchless stem. The root system must be well developed, with abundant secondary roots. It is recommended to utilize 1 year-old plants (1+0), 30-40 cm high or 2 year-old plants (1+1), root-pruned, taller than 50 cm. It is also recommended to avoid very spiny vegetative materials, for easing handling, planting and pruning operations.

Soil preparation

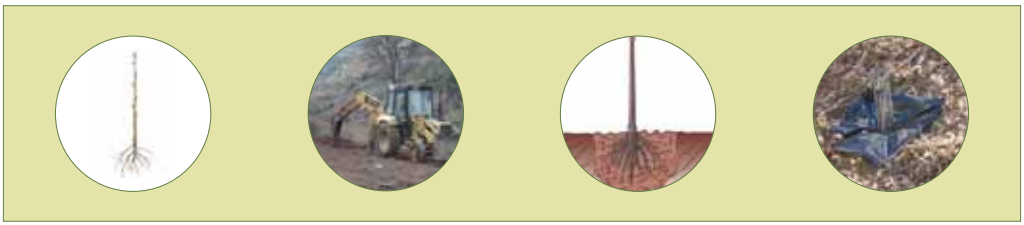
A fundamental intervention, especially when afforesting arable land, is the sub-soiling, that must be applied in two perpendicular directions, to the maximum depth possible, in order to break compact soil layers and enhance water infiltration and retention. Plantation pits can be opened manually or with machines, depending on the plantation size and accessibility.

Planting

The plantation must not be done on days with frosts, strong wind or precipitations. Moreover, the soil should not be too wet. The plant is installed during the dormancy period (between November and March), in such a manner that it remains vertical, with the root system not bended and keeping the trunk base levelled with the ground, for avoiding shape problems.

Protecting

During the first years of the plantation it is convenient to utilize a ground cover (mulch) for avoiding weed competence for water, nutrients and light. Browsing damages can be prevented by either individual shelters (preferably with mesh wall) and / or by collective fencing. In this sense, a light electric fencing can be a cheap solution for protecting a dense plantation. Damages caused by severe droughts can be avoided or mitigated with the application of emergency irrigation.



Pear tree plantation management

Pear tree is more widely used for timber production than apple tree, so that the below proposed management and silvicultural model refers to pear tree. Considering the high demand for light of this species, it is necessary to apply a dynamic and well planned silviculture, which will be partially defined by the initial plantation design: species composition, density, etc. The program of pruning and thinning, linked to growth rate, could be considered as intermediate between those of ash/cherry and of *Sorbus* species.

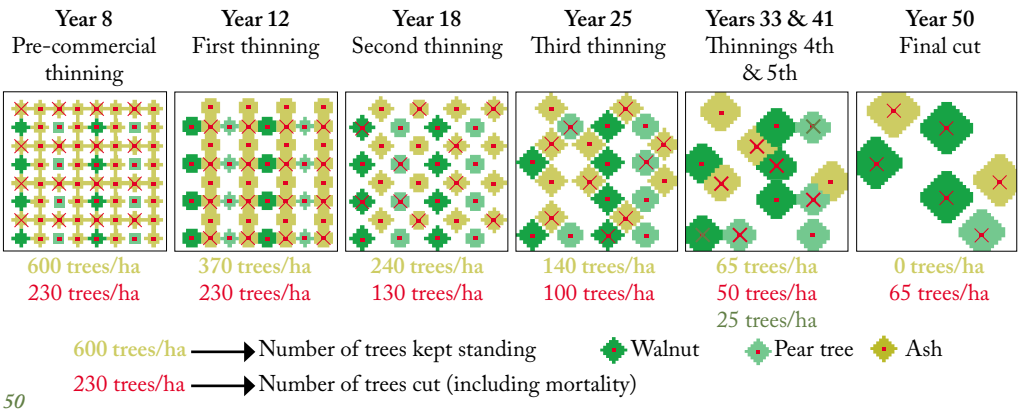
Pruning

Pear tree pruning criteria are similar to other valuable broadleaved species. The main peculiarity is linked to its horizontal branching pattern, which reduces the risk of forking occurrence and branches competing with the terminal shoot. However, the risk of wavy-shaped stems is higher. To avoid this problem, as well as the emergence of epicormic shoots it is recommended to apply frequent (annual or bi-annual) prunings of moderate intensity, eliminating all branches with a diameter larger than 2.5-3 cm at their insertion point. It is also recommended not to remove all branches in more than a third of total tree height. This species tend to generate root sprouts, which should be eliminated promptly.

Quality pruning on a pear tree.

Thinnings

During thinnings, the trees that could shade the ones with highest potential value (those with best shape and vigour) in the next years are removed. As a result, the best trees keep a fast growth rate. Because of the high potential of pear tree timber for industries not requiring large diameters it is possible to generate revenue from intermediate trees, provided that they have an adequate shape: first commercial thinnings (15-25 cm dbh diameter) lead to timber adequate for musical instruments and sculpture; intermediate thinnings (20-40 cm) may lead to pieces suitable for fine cabinetmaking; final cut (40-50 cm) could result in pieces usable in veneer industry. Final cut could be expected around 50-65 years. Because of the general lack of vegetative material from pear tree selected for valuable timber production it is recommended to design a plantation with medium or high initial density, preferably mixed with other valuable species suitable for veneer production. Thinning plan: mixed plantation with pear tree (12,5%), walnut (12,5%) and ash (75%), 830 trees/ha (3x4 m):



Other silvicultural schemes with pear tree

Additionally from the thinning plan shown above (620 ashes, 105 pear trees and 105 walnuts per hectare), there are different modalities of use of pear tree in our conditions.

Mixed plantation of poplar and valuable broadleaves

This plantation scheme consists on mixing poplar rows and rows planted with valuable broadleaves (e.g. pear tree). This plantation is performed in areas devoted to populiculture, where it is intended to diversify poplar production with other species whose timber has higher added value. This scheme allows covering the plantation costs and producing a first significant revenue in the short term, during poplar final cut, at 12-15 years. Pear tree and other valuable broadleaves thinnings, leading to trees with intermediate dimensions, and especially the final cut, result in the highest part of the revenue. An adequate design for this plantation scheme would be leaving 7-10 m between rows of poplar and valuable broadleaves, with 6–8 m between two consecutive poplars in a row and 4-5 m between two consecutive valuable broadleaves.

Plantation with accompanying species

This scheme consists on utilizing auxiliary species whose function is to enhance the shape and/or the productivity of the main species (pear tree or other valuable broadleaved species). These accompanying species can improve the shape of the main species through a lateral shading, forcing the main species to grow straight and with few branches. Moreover, a higher growth rate of the main species can be also achieved with accompanying species able to fix atmospheric nitrogen on the soil (e.g. alder) or producing a high quality humus (e.g. birch). The distance between accompanying and main species has to be carefully chosen, and proportional to their growth rate.

Valuable broadleaved accompanied by birch.

Agroforestry system

Pear tree is an interesting species for its use in agroforestry systems, where tree rows (valuable broadleaves) are placed in a field devoted to agricultural production. Each of the two productions (timber and agriculture) is managed independently. The distance between two consecutive tree rows is defined by the machines utilized in agricultural management. These systems imply an enhanced productivity, thank to the positive effects of trees on crops: lower wind speed and thus reduced evaporation, re-circulation and input of nutrients through dead leaves), deep water and nutrients pumping…Reversely, crop management favours tree growth, through fertilization and weed control. Moreover, these systems count for a high environmental interest, with a considerable reduction of many negative impacts of current agriculture: less erosion and lixiviates release (in terms of both volume and concentration), avoided application of agrochemicals, etc.

Agroforestry system.
Photography: Philippe Van Lerberghe. IDF.

Apple tree *(Malus sylvestris)*

As mentioned before, apple tree (*Malus sylvestris*) has, in general terms, similar requirements and ecology than pear tree.

Photography: Agroof.

This species has a somewhat lower potential for valuable timber production, because of its slower growth rate and wavy shape pattern. As a result, the use of this species in plantations for timber production should respond to a diversification principle, and should not be utilized in pure plantations, but always mixed with other valuable broadleaved species.

Among the main ecological differences between pear and apple trees, the latter show a higher tolerance to high altitude, sand content and soils with high pH.

Regarding management, apple tree has a lower apical dominance, and tends to generate branchy shapes. As a consequence, pruning of apple trees for valuable timber production is more complex and exigent technically.

Photography: Óscar Cisneros.

Limes
(*Tilia platyphyllos* and *T. cordata*)
for high quality timber

Photography: Vicent Tourret.IDF.

7 Limes

(Tilia platyphyllos)

(T. cordata)

The most remarkable lime species in our conditions are large-leaved lime (*Tilia platyphyllos*) and small-leaved lime (*Tilia cordata*). Both species grow in fresh and humid areas, especially valley bottoms and canyons in low and middle mountains.

Both limes appear scattered and discontinuously in forests dominated by other species, frequently beech or oak, and can be also associated with ash, yew, maple, *Sorbus* trees, etc.

Distribution of limes (T. platyphyllos), *up and* (T. cordata), *down. Source: EUFORGEN 2008.*

Why planting limes for timber production ?

Because of their scattered and scarce occurrence pattern, frequently in areas with limited accessibility, these species are generally not managed based on silvicultural schemes aiming at producing valuable timber (through pruning and selective thinnings, promoting trees with highest commercial potential). Moreover, there are no production models for these species in our conditions yet. However, lime timber has excellent technical and aesthetical values: it is soft, easily worked and extraordinarily homogeneous in all directions. It can be utilized in veneer industry and is especially esteemed for sculpture making.

Photography: Vicent Tourret.IDF.




Tilia platyphyllos.
Photographies: Mireille Mouas. IDF.

Tilia cordata.

What are the main requirements of limes ?

Both species have similar ecological requirements: they have a low tolerance to drought, which restricts their occurrence in Mediterranean areas to humid sites. Moreover, they require fresh soils, very rich in nutrients. They are thus frequent in areas influenced by water streams (floodplains, canyons, gorges). They prefer neutral or basic soils, although they can also grow in acid soils well provided with water and nutrients. The following figure summarizes the main ecological requirements of limes.

Appropriate conditions for large-leaved lime *(Tilia platyphyllos)* Appropriate conditions for small-leaved lime *(Tilia cordata)*	**Comments**
Soil depth (cm) 10- 20 30 40 50 60 70 80 90 100 110 120+	These species, with a well developed root system, require a deep soil in order to satisfy their important needs for water and nutrients.
Texture Clayish Clayish-silty Loamy-silty Silty-sandy Sandy	Both species are favoured by balanced textures, although large-leaved lime tends to occupy well-aerated soils while small-leaved lime has a notable tolerance to compact and temporarily stagnated soils.
pH 3,5- 4 4,5 5 5,5 6 6,5 7 7,5 8 8,5 9+	Limes tolerate different types of soils, provided that they are rich in nutrients. As a result, basic soils tend to be more adequate for these species.
Altitude (m) 150- 300 450 600 750 900 1050 1200 1350 1500 1650 1800+ **Mean annual temperature (°C)** 6- 6,5 7 7,5 8 8,5 9 9,5 10 10,5 11 11,5+	Limes have a considerable tolerance to low temperatures, especially small-leaved lime. However, they tend to avoid high altitudes, where their performance is limited because of the steep slopes that limit soil depth and nutrient availability. High summer temperatures are not a problem while water provision is ensured. Limes are sensitive to late frosts (Spring).
Annual precipitation (mm) 400- 450 500 550 600 650 700 750 800 850 900 950+	These species are exigent regarding precipitation and air humidity, especially small-leaved lime. An insufficient precipitation can be compensated by the water table from a nearby water stream.

	Water need	Sensitivity to temporary stagnation	Need for Ca, Mg and K	N and P needs	Active limestone sensitivity	Wind sensitivity	Drought sensitivity	Competition for light sensitivity
Large-leaved lime	Medium	High	Medium	Medium	Low	Low	Medium	Low (young)-meidum (adult)
Small-leaved lime	Medium	Low	Medium	Low - medium	Low	Low	Medium	Low (young)-medium (adult)

Always that the availability of water and nutrients is high, limes can grow in very diverse site conditions. These species are especially suitable for confined, shaded areas, with limited exposition to sun, close to water streams. They are also interesting as diversifying species, because of their capacity to grow shadowed by other tree species.

Large-leaved lime.

Small-leaved lime.
Photography: Mireille Mouas. IDF

Large-leaved lime.
Photography: Mireille Mouas. IDF.

Small-leaved lime.
Photography: Mireille Mouas. IDF.

Pests and diseases of limes

Being species relatively scarce and currently with limited economic interest, there are few pests and diseases with noticeable effects at commercial level. The main agents reducing lime vigour result in damages on leaves, caused by fungi (*Cercospora microsora, Apiognomonia tiliae*) or by insects (*Caliroa annulipes* and aphids). Fungal attacks causing serious rots in stems and roots (e.g. *Phytophthora*) have been also reported.

First steps of plantation

The first steps of a lime plantation for high quality timber production are similar to those from other valuable broadleaved species.

Choosing the plant

It is advised choosing plants from a provenance the most similar possible to the plantation area, both regarding climate (annual and summer precipitation, incidence of drought) and soil (pH, etc). Plants that are too slender, with an undeveloped root system as well as those forked or without a healthy, unique stem, are to be discarded. It is recommended to utilize 1 year-old plants, 80 cm high.

Soil preparation

Firstly, the vegetation that could imply difficulties for the execution of the plantation must be removed, if existent. Then, a deep, crossed sub-soiling (40-50 cm deep) should be applied, few months before planting. The planting pits can be opened either manually or with an excavator, depending on the plantation size, density, accessibility and soil type.

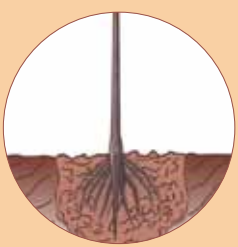
Planting

The plant must be installed during its dormancy period (without leaves), during days free of risk of frost, rain, snow or strong wind. Until the plantation is performed, the plant must be protected from direct sun and wind exposition, especially if bare rooted. The plantation can be complemented by a support watering, to ease the adaptation to new conditions.

Protecting

In order to avoid the negative impact (competence for water and nutrients) due to weeds it is recommended to install 1 m2 ground covers or mulch, that have a further beneficial effect reducing soil water evaporation. Mulching materials are variable, including plastic, bioplastic, chips, straw, stones…In areas where grazing animals (both wild and domestic) are a threat to the young trees, they must be protected with the use of individual shelters or impeding the access of the potentially harmful animals to the plantation, preferably with electric fence.

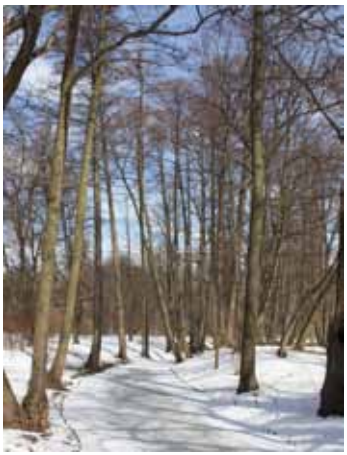





Photography:
J. Engel-Whiteoaknursery.biz

Lime tree plantation management

There is a limited number of references regarding well-monitored experiences of lime plantations for valuable timber production, which makes difficult to propose a silvicultural scheme adapted to these species. Because of their growth rate, relatively slow, and the need for protecting from direct sun exposition during the first years, limes should not be utilized in pure plantations in open areas, but rather as species aiming at diversifying forest stands or plantations dominated by other species. Under these circumstances, limes have both a productive and an environmental role: they have a remarkable longevity, with a notable aesthetic value (it is frequently utilized in parks and gardens) and with a great interest for soil improvement (generating an excellent humus), and a extremely developed root system. Finally, these species are known for the interest of the limeflower tea and their melliferous value.



Lime plantation along a trail. Photography: Jaime Coello.

Pruning

The growth rate of limes is lower than the major part of valuable broadleaved species. As a result, pruning interventions can be applied with less frequency, every 2 – 3 years. Pruning limes for high quality timber production is similar to other valuable broadleaved species: the aim is to achieve a straight, homogeneous, long (minimum 3 m) clean bole, with the smallest knots possible. With this aim, it is necessary to apply:

Formative pruning: it consists on promoting the straight growth of the main shoot by eliminating forks and high lateral branches that can compete with it.

Quality pruning: elimination of all branches with a diameter thicker than 3 cm at their insertion point, in order to prevent large knots.

Young lime plantation. Photography: Florent Gallois. IDF.

Silvicultural schemes with limes (I)

Some options of utilization of limes for high quality timber production are shown below.

Lime in mixed plantations with other valuable broadleaves

Limes are not recommended to be utilized in pure plantations, in spite of which they can represent a very interesting element for diversification when mixed with species with faster growth rate and a clearer vocation towards valuable timber production. Moreover, limes can be also considered for beating up operations (replacing dead plants by new ones) in plantations consisting in other species, especially if this intervention could not be done during the first years and the shadowing starts to be excessive for other species. Also in the case that mortality has been caused at certain areas of the plantation with temporary stagnation (or presenting high clay content), dead trees can be substituted by small-leaved lime, with a high tolerance to these conditions.

Mixed plantation of valuable broadleaves species.

In the case of plantations at open areas (e.g. afforestation on former agricultural land) limes must represent a minor component, in favour of species growing faster. The mixture can be done either as individual trees or by patches. In any case, it is recommended to utilize high initial densities (900-1,600 trees/ha), in order to protect limes from direct sun exposition. Moreover, the "forest effect" leads to a fast canopy closure which reduces branch and weed proliferation and thus simplifies tending operations. However, high densities make necessary the application of multiple thinnings, during which the best trees of the plantation are promoted, and the proportion of species is kept.

Mixed plantation of valuable broadleaves species.

Silvicultural schemes with limes (II)

Forest diversification plantation

The aim of these plantations is to diversify forest ecosystems by underplanting species that are scarcely represented but have an interesting potential because of their economic and / or environmental value. For example, pure pine or beech stands can be diversified, in the freshest and most shadowed spots, with limes. This intervention would lead to an increased and diversified revenue while enhancing biodiversity. These plantations are implemented with low densities, aiming at small-sized sites especially suitable for limes. This type of plantation represent a minimal investment, considering the low number of trees utilized, but can contribute significantly to the economic and environmental value of the forest.

Pine forest underplanted with limes.

Limes are species especially suitable for these types of plantations, as they need shadowing during the first years and they are benefited by the high air humidity within the forest. During the thinnings and cuttings of the pre-existent tree species, limes will get progressively more light and space for growing vigorously. Limes must be protected against wildlife browsing.

This type of plantation is especially interesting for forest spaces with significant value for leisure and landscape, as well as in areas where productivity and accessibility allows the application of adequate management (pruning, selective thinnings) aiming at producing valuable timber.

Forest diversification plantation.

Centre de la Propietat Forestal
Torreferrussa
Carretera de Sabadell a Santa Perpètua, Km 4,5
Apartat de correus 240
08130 Santa Perpètua de Mogoda

T. +34 93 574 70 39
F. +34 93 574 38 53
cpf@gencat.cat
http://www.gencat.cat/cpf

This publication has been prepared in the framework of the European cooperation project PIRINOBLE

Generalitat de Catalunya
Departament d'Agricultura, Ramaderia, Pesca, Alimentació i Medi Natural

Centre de la Propietat Forestal

CENTRE TECNOLÒGIC FORESTAL DE CATALUNYA

CRPF MIDI-PYRENEES

Forêt Privée Française CNPF IDF

PIRINOBLE

Unión Europea
Fondo Europeo de Desarrollo Regional

COOPERACIÓN TERRITORIAL COOPÉRATION TERRITORIALE TERRITORIALE
ESPAÑA-FRANCE-ANDORRA
2007-2013

2007-2013 *Invirtiendo en nuestro futuro*
Investir dans notre avenir