

Choice of species :

Possibilities offered by the site ?

Jacques Becquey, CNPF-IDF

The choice of species determines the success of the plantation. They must be well adapted to the site where they will be located. If not, they may grow at best for a few years before withering.

Growers must begin by identifying the site potential (with professional advice if necessary), as the site determines the choice of the species, the establishment methods and even the nature of postplanting care for the plants. Once the appropriate species are listed, growers can then classify them according to their expectations and objectives. Their final choice of species will then best correspond to the desired mature stand type.

Identifying and listing species

All species have specific requirements for becoming established and growing properly, corresponding to the characteristics of the environment where they occur naturally. Foresters need to know these requirements, summarised in various documents or sheets¹ describing the autecology of the species. These are based on the results of studies conducted on their behaviour, observations and various measurements of their growth and qualities.

Introducing a species in the field requires careful site assessment to ensure that its characteristics are appropriate for the species.

¹ See the tree species autecology sheets (Wild cherry, wild service tree, walnut, etc.) on www.pirinoble.eu and also disseminated in Forêt-entreprise.



To produce big quality timber with valuable broadleaves, the site must be well adapted

This is particularly important in an agricultural environment without existing trees that could provide guidance.

Site diagnosis

This involves collecting and analysing the climatic, topographic, geological and soil characteristics of the planting site.

The table on the next page shows a list summarising these factors and how they can affect the outcome. Numerous other reference publications are available on this topic for further details.

The species that appear best adapted to a future plantation can be listed by analysis followed by comparison of the site characteristics with the species requirements.

Site catalogues, available in most regions, are useful tools for determining usable species.

Predicted changes should, however, be taken into account when drawing conclusions.

Recommendation : After checking that the planned site is comparable, it is helpful to observe the woods or hedges near the future plantation: the quality and growth of the species growing there can provide a good indication of the potential of the site and of appropriate associations for a possible speciesmix.

Classifying species according to their role

Among the species considered suitable for the site, several groups can be identified on the basis of the grower's objectives, the importance of various factors (climate, health, etc.) or the role they might play.

Timber production²

The main species, sometimes referred to as noble species, are generally valuable economically and the main objective of production from the stand is based on them.

These include :

- Scattered species in their natural (asocial) state, i.e. mixed with other species. These frequently have a high economic value due to their highly prized timber and are thus referred to as valuable or precious species.

2) Most of the definitions are from Bastien Y. and Gauberville C. 2011. *Forestry vocabulary*. 554 p + appendices.

Table 1 stand diagnosis			
	Main characteristics to be studied	Use	Effect on the trees
climate	<ul style="list-style-type: none"> - Average and extreme temperatures - Average rainfall and monthly distribution - Early frost (autumn) and late frost (spring) - Prevailing winds and exceptional winds 	<ul style="list-style-type: none"> - Study of annual and interannual variations - Characteristic or index (R-PET...) calculations - Risk assessment 	<ul style="list-style-type: none"> - Threshold of resistance to temperature extremes and water deficit. Varies between species - Effect of rainfall distribution on water supply and growth - Mortality, sun scald, fire, frost crack, deformities and damage to the timber, snapping, uprooting, etc.
Topography	<ul style="list-style-type: none"> - Altitude - Location, aspect, gradient 	<ul style="list-style-type: none"> - Adjusting climate data that do not always take into account the aspect or the precise altitude (due to the distribution of weather stations); - Drainage 	<ul style="list-style-type: none"> - Limits of vegetation - Influence on tree phenology and growth.
Geology	<ul style="list-style-type: none"> - Bedrock 	<ul style="list-style-type: none"> - Richness of the soil - Behaviour to water 	<ul style="list-style-type: none"> - Nutrition - Water supply
Soil (different horizons)	<ul style="list-style-type: none"> - Thickness - Texture (fine and coarse grained components) - Structure (arrangement of particles or aggregates) - Presence of limiting factors : waterlogging due to excess water, lime, etc. - pH (acidity) and chemical richness 	<ul style="list-style-type: none"> - Water reserves, - Porosity (water and air circulation), risk of compaction - Temporary or permanent soil waterlogging - Evaluation of richness (possible analysis to clarify the observations) 	<ul style="list-style-type: none"> - Potential for root development - Biological functioning of the soil - Risk of root asphyxiation ; - Anchoring, wind resistance ; - Tree nutrition and water supply

Examples include the wild cherry, wild service tree and pear tree.

- Social species that can naturally form extensive single-species populations.

Examples include oak, beech and pine.

Accompanying species, sometimes referred to as accessory or secondary species, are associated with the main species. These essentially play a cultural role. Examples include birch, hornbeam, lime, alder and willow.

Occasionally, when they locally replace a missing or poorly formed main species tree, these can have a production role and be treated as main species.

Sensitivity to various hazards

Growers wishing to plant one or more high-risk species with regard to particular factors may find it beneficial to mix them with other species that are insensitive to the same factors.

Table 2 : Examples of choices or possible associations for single-species or mixed stands (for sites assumed to be appropriate)

Desired final population	Plantation		
	Type of plantation	Composition examples	Comment
Pure	- single-species	Walnut, wild cherry, oak	Each single species covering at least ½ ha (cluster) or preferably 1 ha.
	- temporary mix (main species)	Walnut and poplar Sessile oak and birch and/or hornbeam	Poplars in rows harvested at 15-20 years (= intermediate production). Wild cherry scattered among oak, harvested at 50-70 years (= intermediate production).
	- temporary mix (main species + accompanying species)	Walnut and alder Sessile oak and birch (and/or hornbeam)	All alders are harvested once or several times, when walnut logs are acquired and as soon as they get in the way. Birches (or hornbeams) are gradually extracted to benefit the oak trees (it may however be beneficial to keep some hornbeams in the understorey).
Mixed	- sustainable mix (main species only)	Walnut and wild cherry Oak and wild service tree Oak and wild cherry	Pairs of species that can be grown together over one cycle: walnut and wild cherry in equal proportions Wild service trees scattered among oak. To keep the mix, the wild cherry trees (harvested before the oak) must be planted in clusters to ensure that they can regenerate naturally. They can also be dealt with irregularly (possibly adding another fruit-bearing species).
	- sustainable mix (main species + accompanying species)	Oak, service tree, (wild cherry), etc. and birch (or hornbeam, willow, etc.)	Several main species and one or more temporary accompanying species removed according to priority (but not necessarily entirely, to allow later regeneration) once the main species timber has been harvested. The mix can contain species harvested at different ages, planted in clusters or irregularly.

These “security” species can then ensure the success of the plantation and guarantee at least a minimum result. This can also reduce planting and maintenance costs.

This is frequently an issue due to excessive deer populations or local climatic conditions, or even their foreseeable development in coming decades. Using species resistant to deer damage can reduce the cost of protection by limiting it to the species that are the most palatable. Similarly, the success of a plantation with species sensitive to early frost (autumn) or summer drought can be secured by associating it with hardier species.

Special considerations

Some accompanying species can have beneficial properties for the growth of the entire plantation or the proper functioning of the stand.

This is the case for the alder and locust tree, which fix nitrogen from the air and partially return it to the soil. This benefits the growth of other species in the stand. Other species such as hornbeam, lime and birch produce beneficial humus.

Associating some hardwoods (oak, birch, etc.) with conifers (pine, spruce, etc.) can improve the function of water in the stand and reduce parasite infestations.

Beekeepers can benefit from lime and locust trees and some maple species, while growers may benefit from the locust tree or chestnut tree for the production of fencing stakes.

This type of classification thus helps growers to identify the choice they can or should make in order to meet their objectives.

Choosing the composition of the plantation

Growers can choose to plant one or more species depending on their objectives.

This choice is mainly determined by the desired composition of the mature stand.

To obtain a single-species stand, the easiest way is to plant a single main species. Another possibility is to plant two main species, one of which will be harvested for timber well before the other. A third solution is to plant the main species with one or more temporary accompanying species.

These can have various roles :

- providing lateral shelter and shading to improve main species tree shape and growth;
- providing ground cover and ensuring rapid canopy closure;
- nitrogen fixation, intermediate biomass production;
- reduced planting cost if protection is not needed or by reducing the number of expensive main species seedlings.

However, temporary species are harvested in all cases after their role has been fulfilled, except in the case of local replacement of a main species. The stand then quickly becomes monospecific.

To obtain a mixed population, at least two main species must be planted and kept throughout the course of operations. Here again, one or more accompanying species can be added for the same reasons as those mentioned previously. Even if the intention is to phase them out, a few individuals may be kept, either for their cultural interest or because it is advantageous to replace some poorly-developed individual trees from the main species.

Whether chosen to be temporary or long-term, the mix is made up by using associations that meet the objectives.

The main species must be able to grow together over time or even to regenerate in a mix. In some cases, fast-growing species can be associated with slow-growing species in order to phase the timber harvests and possibly to make it easier to obtain irregular populations. Table 2 shows some examples to illustrate this.

Different arrangements and spacings are possible for each type of plantation (see «Composition of the plantation» at the end of this file).

The site is the main factor determining the possible choices of species. These occasionally may not correspond to the species the grower may wish to plant. In the current context of climate change, particular attention must be paid to site diagnosis, avoiding at all costs planting species that are already borderline.

One way to reduce the risk of failure is to combine several possible species, which some refer to as «security» species. These are selected from the hardiest species, providing a form of insurance for the success of the plantation. In the long term, the mixture can also be a way anticipating the future regeneration of the stand by introducing species that may be better suited in the future. ■

Autecology of valuable hardwood trees

■ Larrieu L., Gonin P., Coello J., 2012 - Autecology of hardwoods: a reading guide. Forêt-entreprise n° 203, 2012, p. 5-8

■ Larrieu L., Gonin P., Coello J., 2012 - Autecology of the Wild cherry tree (*Prunus avium* (L.) L.). Forêt-entreprise n° 203, 2012, p. 9-12

■ Marty P., Larrieu L., Claessens H., Gonin P., Coello J., 2012 - Autecology of the Common ash (*Fraxinus excelsior* L.) and the Narrow-leaved ash (*Fraxinus angustifolia* Vahl). Forêt-entreprise n° 204, 2012, p. 9-12

■ Larrieu L., Gonin P., Coello J., 2012 - Autecology of the Wild service tree (*Sorbus torminalis* (L.) Crantz), the Service tree (*Sorbus domestica* L.) and the other *Sorbus* species. Forêt-entreprise n° 205, 2012, p. 5-11

■ Larrieu L., Gonin P., Coello J., 2012 - Autecology of the Common pear tree (*Pyrus pyraster* (L.) Du Roi) and the European wild apple tree (Crab apple) (*Malus sylvestris* Mill.). Forêt-entreprise n° 206, 2012, p. 5-10

■ Lestrade M., Becquey J., Coello J., Gonin P., 2012 - Autecology of the Common Walnut (*Juglans regia* L.), Black Walnut (*Juglans nigra* L.) and Hybrid Walnut (*Juglans x intermedia*). Forêt-entreprise n° 207, 2012, p. 5-12

■ Lestrade M., Gonin P., Coello J., 2013 - Autecology of the Small Leaved Lime (*Tilia cordata* Mill.) and the Large Leaved Lime (*Tilia platyphyllos* Scop.). Forêt-entreprise n° 211, 2013, p. 6-11

■ Lestrade M., Gonin P., Coello J., 2013 - Autecology of the Sycamore (*Acer pseudoplatanus* L.), Norway maple (*Acer platanoides* L.), Field maple (*Acer campestre* L.) and other maple species. Forêt-entreprise n° 212, 2013, p. 54-62

References available on www.foretprivee-francaise.com and www.pirinoble.eu, with complete bibliography



Density and plantation scenario: What means are provided for post-planting care in the plantation?

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Post-planting care is crucial for the success of plantations. Growers must assess their maintenance capabilities and possibilities, possibly trimming, pruning or thinning, before selecting a particular scenario and hence a planting density.



Examples of a timeline of operations over the years (highlighted) on a plantation, dependent on post-planting care modes

Plantation 2013			
Years	Maintenance		
2014			
2015			
2016			
2017			
2018			
2019			
2020			
2021			
2022			
2023			
2024			
2025			
2026			
2027			
2028			
2029			
...			

Before embarking on a planting project, prospective growers must determine the type of post-planting care to be practised during the first 15 years and the means to be allocated. A choice of three profiles is proposed for this purpose:

1. regular, intensive post-planting care including:

- at least one intervention per year for at least 15 years,
- several interventions are often needed during the first 3 to 5 years.

→ This arboricultural type of post-planting care profile corresponds to a « timber orchard » scenario.

2. intermediate post-planting care including:

- one or more interventions per year for 3 to 5 years,
- followed by three to six interventions at 2 to 3 year intervals.

→ This active forest management type of post-planting care profile corresponds to an assisted forest plantation scenario.

3. flexible post-planting care including:

- one or more interventions per year for 3 to 5 years,
- followed by two to three interventions at 3 to 5 year intervals.

→ This classic forestry type of post-planting care profile corresponds to a forest plantation scenario.

1 2 3

There are various implications for establishing the plantation depending on the profile of the grower, particularly with regard to the choice of density of the seedlings and the species composition.

The establishment and post-planting care scenarios corresponding to each profile are detailed in the following sheets.



Attention: if no intervention is planned after the first 4 or 5 years, the production of high-quality timber is very unpredictable and it is better not to plant at all!

« Timber orchard » scenario: regular intensive post-planting care

« Timber orchard » scenario allows very low planting densities, on average 100-200 seedlings/ha for plants of good quality in terms of their performance and of known origin and makes it possible to care for the trees individually. Establishment costs are relatively low, but post-planting care is time consuming (and hence expensive if finance is needed).

→ *The Arborist*

« **Portrait** » : *arborists in this case have plenty of free time or devote their leisure time to the forest. They are passionate about trees and cannot stand the presence of “weeds”. They usually live on site or nearby and spend their time in the plantations on a tractor or with pruning shears. Alternatively, they rely on a person on site with a similar profile.*

Why?

- To reduce the cost of establishment or of individual tree protection against animals.
- Because the time or the means are available for regular interventions over at least 12 to 15 years.

Type of production

- At these densities, good quality logs (3 m to 4 m on average) are generally short due to the difficulty in pruning trees that produce large branches.
- With regular treatment, timber harvests are spread out over a few felling stages: 1 or 2 thinnings followed by final felling of 40 to 70 trees at 40 and 60 years for precious hardwoods (the diameter varies with the species).
- Growth has little impact on timber quality, provided that it is regular. There is a risk of green vein on wild cherry grown in windy locations

How?

- Planting densities are very low, varying between 80 and 300 seedlings/ha. Rectangular spacing is recommended in order to minimise the distance moved in caring for the trees.
Choose a single main species or several in a mix. It is advisable to mix Rosaceae family species (service tree, wild cherry, pear and apple) with others (walnut, ash, maple, oak, etc.). The wild service tree is difficult to grow at these densities and is not recommended.
- Plant material must be of good quality, with a registered designation of origin (blue or pink label if available), stocky, sturdy and well-balanced seedlings.
- Regular annual maintenance, trimming and pruning over 10 to 15 years. Establishing the seedlings is a very meticulous process and protection is required if animals are likely to damage them.
- Individual mulching is recommended to facilitate establishment and improve the early growth of the seedlings.
- At these densities, weak or poorly formed seedlings can be replaced over several years.

Possible variants

- For the lowest densities (80-100/ha), the choice can be improved by establishing 2 or 3 seedlings at each planting location and subsequently selecting the best-formed stem after 3 to 5 years.



The expense of establishing an accompanying tree species can hardly be justified if maintenance, trimming and pruning are planned every year. However, it is possible (and sometimes desirable) to let natural regeneration become established.

« Timber orchard » scenario or very low density planting

Types of operations

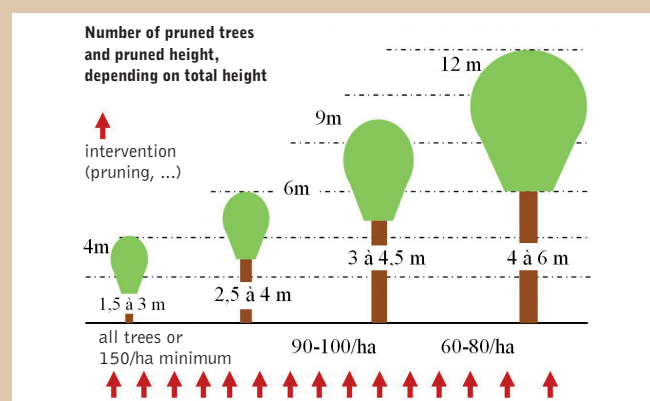
All trees in the plantation are cared for individually every year until they reach 7-8 m in height, applying operations to facilitate their growth and form good quality logs:

- maintenance to eliminate or reduce herbaceous competition and occasionally woody or semi-woody competition (brambles, etc.);
- removing climbing plants (clematis, honeysuckle, etc.);
- checking, then removing animal damage protection put in place at the time of planting;
- pruning to correct stem defects (forks, upright branches, etc.), thus forming a sufficiently long stem (at least 3 m) to obtain a straight log in time;
- pruning to eliminate gradually the lower branches to a height of 3 to 4 m in order to obtain defect-free timber of maximum diameter;
- in some cases, fertilisation or temporary irrigation during the first few years to facilitate the establishment and early growth of the plantation.

Subsequently, if possible, pruning of a limited number of trees continues (maximum 80/ha) up to a height of between 4 and 6 m. In many cases, trees have large branches or stem defects due to the spacing, preventing pruning above 4 m. In these cases, it is preferable to settle for 4 m without defects rather than risk diminishing the quality by trying to gain a few decimetres.



*Hybrid walnut «Timber orchard», 20 years old.
Big crowns and short pruned boles (3,5 to 4,5 m).*



Post planting care can be facilitated when the plantation is surrounded by a lateral shelter as edges, forest stand, ...



Mixed plantation : poplar and walnut ; 8m x 7m ; 3rd year.

All these operations usually require at least one intervention each year for 12 to 15 years. It is therefore essential to ensure the active presence of the grower, the grower's employees or subcontractors throughout this period.

This scenario can be very appropriate for growers who are available and do not take their own time into account.

Plots should be easily accessible. In association with crops or livestock, the scenario can be combined with agroforestry.

Interruptions or delays in management are incompatible with this scenario.

Forest plantation scenario: easy, flexible post-planting care

The forest plantation scenario involves planting densities sufficient to compensate for the loss of a proportion of the seedlings, which will at least temporarily protect and train the best formed plants.

These densities are on average around 1 100 seedlings per hectare.

This scenario combines costly establishment with relatively cheap post-planting care.

The traditional forest owner

« **Portrait** »: *traditional forest owner spend limited time at the plantation due to other professional activities or because they have a large area to manage. They are not only interested in trees and in many cases do not live on the site. In other case the work is subcontracted to a company.*

Why?

- As most of forest owners are less available for post-planting care, the number of interventions must be reduced; they are concentrated at the start, then spaced out in time.
- The duration of maintenance is reduced through rapid canopy closure, which also makes it possible to create a forest environment quickly.
- Stem formation and high pruning operations are reduced and facilitated by a high-density phase in a forest environment.

Type of production

- In the forest environment it is possible to obtain sufficiently long (x 6 m) quality logs.
- The timber can be harvested over several felling stages, taking care not to open up the stand too quickly (this, however, reduces the growth rate and increases the age of maturity).
- Coloured timber with a small proportion of sapwood can be obtained.
- For precious hardwoods under regular treatment, 40 to 60 trees are felled for the final harvest at 50 and 70 years of age (the diameter varies between species).

How?

- Planting densities can be between 900 and 1300 seedlings/ha or even higher (up to 1800). Lines are spaced to fit the width of mechanical maintenance equipment. Future extraction rides should be planned.
- It is possible to establish a single main species or several in a mix*. One or more accompanying species* can be used to reduce costs (partial substitution of the main species by cheaper ones), improving the growth and shape of the main species (through lateral shading and nitrogen fixation) and with less susceptibility to deer damage (unprotected).
- Seedlings should be stocky, sturdy and well balanced and the seed origins must comply with regulations* (all possible labels for the main species). Selected material (wild cherry cultivars, seed nurseries for hybrid walnut, wild cherry and service tree seeds, etc.) can be chosen for a limited amount of precious tree seedlings to be favoured later.
- The most sensitive main species are individually protected against animal damage. If this is insufficient, we recommend fencing off the plot.
- Maintenance, trimming and pruning are performed every year for 3-5 years, then in the course of 1-3 interventions at 3 to 6 year intervals to complete the pruning of designated stems.

Possible variants

- Biomass (short-rotation fuel wood) production can be combined with timber production by alternating lines or strips of species intended for each form of production. For example a line of noble hardwood trees (maple, wild cherry, walnut, etc.) can be alternated with one or more lines of fast-growing species to accompany them (alders, willow, etc.). The latter are harvested after their role of protecting and training the main species has been fulfilled (at around 10-12 m in height).



- Do not establish pure single-species stands of expensive species and/or trees sensitive to game damage (excessive establishment and protection costs!)
- Do not trim and prune too early, too often or too many stems (it is not necessary and this would nullify the benefit of dense spacing).
- Do not open the stand too soon in order to maintain the effect of density ("compression") in forming the future trees.

* see sheet «Composition of the plantation»

Forest Plantation scenario: medium or high density planting

Types of intervention

In the plantation, **trees are firstly cared for overall to ensure that they are properly established, then left a few years to look after themselves.**

When they begin to differentiate, special care is applied 2 or 3 times only to a decreasing number of stems identified in advance (see diagram) among which are those of the future mature crop **

The sequence of operations is as follows:

- **at least one intervention per year during the first 3 to 5 years** (up to a height of ± 2 m) with:

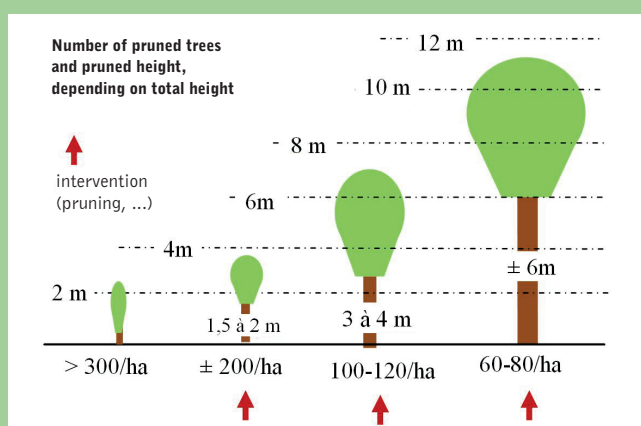
- maintenance to ensure that the seedlings have a good start by eliminating or reducing competition from herbaceous or possibly semi woody plants (bramble, broom, etc.). Climbing plants are eliminated (clematis, honeysuckle, etc.).

- checking animal damage protection that may have been put in place when planting.

- in the course of this intervention, also check that there are at least 300 sturdy stems/ha*** of the main species with no major defects in form. These should be chosen from rows other than those to be felled for future harvesting rides. If there are not enough well-formed plants, existing ones must be pruned to shape to obtain the required number.

- Subsequently, when the height of the most sturdy trees*** has reached 6-8 m, **about 120 sturdy, well-formed stems per hectare are pruned to about 3-4 m high.** Among the stems selected, up to 6 m of the defective ones are pruned if necessary. Some competing neighbouring trees can be felled at the same time and left on the spot.

- **when the height of the strongest trees reaches 11-12 m, 60-80 stems per hectare are pruned up to 6 m.**



Two prunings may be sufficient after the first maintenance interventions: about 6 - 8 m high, then up to 12 m .

**** Future stem:** saplings must be well formed (straight, with slender, well-distributed branches, no forks or upright branches, or easily eliminated if they occur) and sturdy (above average growth rate, dominant terminal shoot) that can produce a log of marketable quality timber in this location.

***** Sturdy stem (tree):** individual height (and girth) at least equal to the average height (average circumference) of trees in the plantation (on an identical site).

Post-planting interventions initially concentrate on the first ± 4 years (maintenance), then spread over 2 or 3 interventions (trimming and pruning) every 4 to 6 years until 6 m long pruned logs can be obtained. This scenario can withstand interruptions or management delays.

Assisted forest plantation scenario: semi-intensive, intermediate post-planting care

The assisted forest plantation scenario involves a sufficient planting density to compensate for the loss of some of the seedlings which temporarily serve to protect and train the best-formed plants, but not too many, as interventions are frequent enough to eliminate defects and favour the greatest number of well-formed stems. This density is on average around 400 to 600 seedlings per hectare. In the long term, taking into account the cost of all works, this is often the most expensive solution as high planting and protection costs are combined with considerable post-planting costs.

The active forest manager

« **Portrait** »: *active forest managers combine the qualities of the previous two; sometimes an « traditionnal forest owner » seeking to reduce the number of interventions (large area, unstable plant health) and a forester, intervening at frequent intervals. An active forest manager can also be someone with significant funds who makes them available to ensure and obtain the best possible results.*

Why?

- A compromise is sought between security in terms of the choice of the future stems, moderate establishment costs and sufficiently quick establishment of a stand.
- Time and means are available for frequent interventions for at least 12 to 15 years.

Type of production?

- The density to some extent facilitates pruning up to 3 m to obtain quality logs around 5-6 m long if the stand is not opened up too quickly.
- These densities, often linked to dynamic forestry practices, produce timber with considerable growth increments that can be maintained through regular, fairly drastic thinning (once the logs are formed).
- For precious hardwood trees under regular treatment, the final harvest comprises 40 to 60 trees aged 50-60 years (with diameter varying between species).

How?

- The planting density is between 300 and 900 seedlings/ha. Rectangular spacings are preferable to reduce distances moved in the course of post-planting care.
- A single main species or several in a mix* can be established (recommended for the service tree, wild service tree, wild cherry, pear and apple).
- Seedlings should be stocky, sturdy and well balanced and the seed origins must comply with regulations (all labels possible for the main species). For a limited amount of seedlings of subsequently favoured precious tree species, selected material can be chosen (wild cherry cultivars, seed nurseries for hybrid walnut, wild cherry, rowan , etc.)
- If necessary, the most sensitive main species can be individually protected against animal damage. If this is insufficient, the plot should be fenced off.
- Maintenance, trimming and pruning are performed every year for 3-5 years, then in 3-5 interventions at 2-3 year intervals, possibly coupled with cleaning, concluding the pruning of designated stems.

Possible variants?

- For the lower overall density range (3-400/ha) on ground suitable for poplar cultivation, a mixture* of precious hardwood trees (especially walnut and ash) can be considered along with poplar to improve the financial return on the first thinning.
- For the higher overall density range (6-800/ha), the mixture of primarily precious main species can be combined with one or more accompanying species* (e.g. walnut, ash or wild cherry with alder, willow or locust tree...), or even to add poplar on suitable ground.



- Establishing an accompanying tree species can be justified if it is kept long enough to reduce the work involved in high pruning; if not, it should be avoided.
- Take care not to trim and prune too many trees! Less than 120 stems/ha will be harvested for timber. Above all, do not try to recover trees with major defects.

* see sheet «Composition of the plantation»

Assisted forest plantation or low density plantation scenario

Types of intervention

In the plantation, overall post-planting care is initially carried out. Then in the course of 4 to 5 interventions at 2 to 3 year intervals, a number of pre-designated stems (see the diagram) are formed and pruned, including the intended final crop trees**.

During the first 3 to 5 years (up to a height of 2 - 3 m), the following is carried out at least once a year:

- maintenance to give seedlings a good start by eliminating or reducing competition from herbaceous (mainly grass) or potential semi woody (bramble, broom, etc.) species. Climbing plants should be eliminated (clematis, honeysuckle, etc.).
- checking animal damage protection that may have been put in place when planting.

During this intervention, ensure that at least 300 sturdy stems/ha*** have no major defects in form. If such plants are insufficient, other plants must be formed by pruning to obtain the required number.

When the most sturdy trees*** reach 4 m in height, 200 well-formed stems among them are selected, trimmed if necessary and pruned up to a height of 1.5 to 2 m.

At 6 m, this operation is performed on approximately 150 stems per hectare, which are pruned up to a height of 2.5 - 3 m.

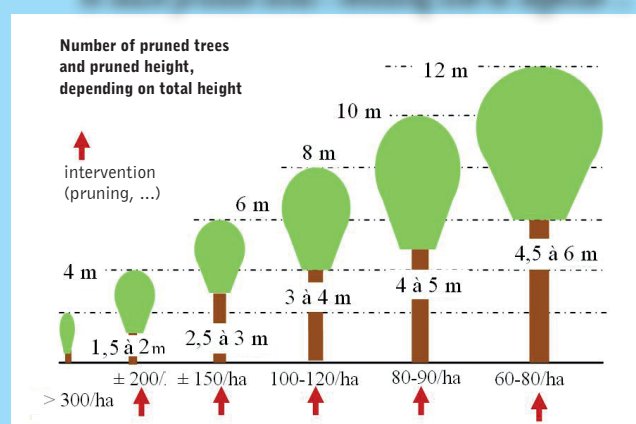
At 8 m, this operation is performed on approximately 110 stems per hectare, which are pruned up to a height of 3 - 4 m.

At about 10 m, 80-90 stems per hectare are pruned up to a height of 4-5 m and at 12 m, pruning concludes at ± 6 m on 60-80 stems per hectare. The pruned height can be less than 6 m on some sturdy trees with strong branches.

Post-planting interventions (maintenance, trimming and pruning) are initially concentrated in the first ± 4 years, then over 4 or 5 interventions until a 6 m pruned log is obtained.

This scenario can withstand very brief interruptions or minor management delays and may be suitable for growers who can intervene periodically and do not take account of their own time.

** et ***: see definitions in the Forest plantation scenario sheet.



If the number of well-formed stems allows (sufficient density), it is possible to intervene only 4 times at tree heights of 4, 6, 9 and 12 m. Then ± 100 stems/ha are selected and pruned up to a height of ± 4.5 m for the 9 m intervention.

Several examples of plantations



Hybrid walnut «timber orchard»

10 m x 10 m (100 /ha) - 15 years old

« Intensive» management

Intensive post-planting care : 1 to 3 interventions per year for 15 years.

All trees pruned. Average pruned height : 3,50 m

Consequences

Limited choice if accidents or badly shaped trees.

Plant material : good quality indispensable.

Very few thinnings (generally one)

Production : mostly furniture timber, few energy or industrial roundwood

Costs : quite cheap establishment - expensive and very binding post-planting care.

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Common ash «assisted forest plantation»

5 m x 4 m (500 /ha) - 20 years old

«Active» management

Active post-planting care : 1 to 2 interventions per year for 15 years. Numerous (too much) pruned trees. Average pruned height : 4,5 m

Consequences

Choice of the best trees, generally possible.

Plant material : good quality recommended.

Several thinnings (2 to 3)

Production : furniture timber and energy or industrial roundwood

Costs : quite expensive establishment and post-planting care.



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Sycamore «forest plantation «

3 m x 3 m (1100 /ha) - 24 years old, after 2 thinnings.

«Flexible» management

1 to 2 interventions per year for 5 years, then 2 pruning at 8 and 13 years.

Only the best trees pruned . Average pruned height : 6 m

Consequences

Good choice to select the best trees.

Identified plant material can suit.

Some thinnings (2 to 4)

Production : furniture timber and lot of energy or industrial roundwood

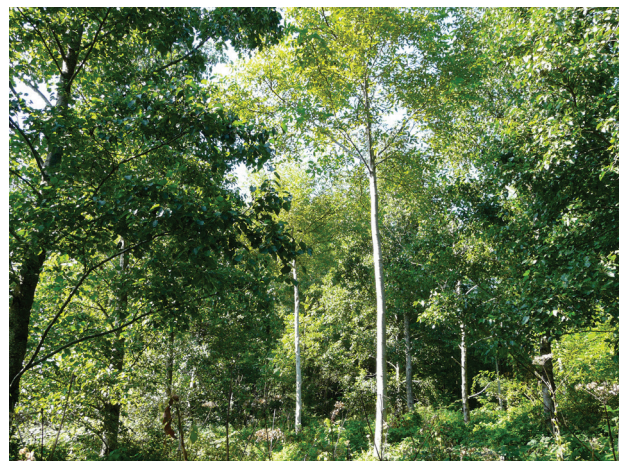
Costs : expensive establishment and quite cheap post-planting care.

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Composition of the plantation : For what mature stand ?

Jacques Becquey, CNPF-IDF

Once the species and plantation scenario are chosen, the way the seedlings will be established on the ground should be considered. The species distribution and spacing between seedlings will affect the operations to be carried out during the life of the stand.



*Hybrid walnuts mixed with italian alder (alternating rows) ;
14 years.*

Layout of seedlings: general principles

Both in single-species and mixed plantations, a few simple principles can assist in post-planting care and improve the chances of success.

The cost of works can be reduced in several ways:

- simplifying planting by avoiding complex planting schemes. This is not incompatible with the use of several species or anticipating future interventions (maintenance, thinning, etc.), but the schemes should be set out as simply as possible in planting instructions, e.g. planting accompanying species in odd-numbered rows and main species in even-numbered rows, etc.
- mechanising and rationalising maintenance by providing enough space between rows for equipment to pass through. For high-density planting, plants should be spaced at no less than 3 m apart. For low densities, a multiple of the width of the equipment can optimise the number of interventions.
- diminishing the time required to pass through the plantation for a gi-

ven planting density by reducing the number of rows per hectare, with the spacing between rows greater than between plants in a row. The distance, and hence the time required to move around the plot for trimming and pruning operations can then be significantly reduced. The impact on costs is particularly significant for low planting densities. For example, a density of 200 seedlings/ha spaced at 10 m x 5 m saves about 30% of the distance to be travelled as compared with square 7 m x 7 m spacing. Rectangular spacings also facilitate marking for the first thinnings.

Facilitating the timber harvest

Marking, felling and skidding the timber are facilitated by tracks or extraction rides: conspicuous, sufficiently straight and regularly laid out. Rides also restrict the extent of damage caused by machines to the ground and to the trees and preserve the rest of the stand. Spacings of about 18 to 25 m between rides are sufficient. When the spacing between rows is less than 4 m, rides should be cut at the time of the first thinning by felling

a complete row. In this situation, it is advisable to plan the ride layout at the time of planting, so as to avoid placing species intended for the mature stand in the rows to be removed and to save investment on individual protection, trimming and pruning.

Anticipate the development of the stand

If you wish to keep a mixture of species with different ages of maturity, such as oak and wild cherry, the latter should be planted in clusters of a few hundred square metres. Thus, after harvesting, it can regenerate naturally among the oak trees. If established as isolated plants, the oak canopy will close above the location vacated by the felled tree, preventing natural regeneration. Poplar trees must be spaced widely enough to allow their development up to the timber stage and to ensure that the associated species can withstand their lateral shelter or their instantaneous cover. In all cases, planting in clusters or rows must allow easy felling and extraction with a minimum of damage to the rest of the stand.

Composition of the plantation and layout of the seedlings

Two main criteria determine the way the plantation is organised:

- **The composition of the mature stand:** is the aim a single-species stand or a mixed stand?
- **The type of post-planting care considered.** This determines the density of the plantation and the possibility of using accompanying species.

Types of post-planting care are divided into the following groups

(see sheet about «density and scenario») :

- **Intensive** (arboricultural profile) or **inter-mediate** (active forest management profile): regular post-planting care must be ensured **for 12 to 15 years, with interventions every year or nearly every year** to perform various operations (initial maintenance followed by trimming and pruning).

- **Light** (classic forestry profile): after the first few years of maintenance, **more sporadic post-planting care** is possible with operations at greater or lesser intervals to ensure trimming and pruning if necessary.

Other criteria, such as the cost of the seedlings or their vulnerability to animal damage (and hence the cost of protection) can also influence the choice of composition.



18 year old plantation of wild cherry temporarily accompanied by white alder. 1 row out of 3 will serve as a ride

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The table below summarises the main options detailed in the following pages.

Which plantation for what mature stand ?			
Desired mature stand	Type of post-planting care	Possible types of plantation	Other selection criteria
single-species	intensive or intermediate	Low-density single-species plantation	Ease of establishment
		Temporarily mixed plantation with quick-growing species (intermediate production)	Reducing establishment costs
	light	Single-species plantation, medium to high density	Use of cheap seedlings Ease of establishment
mixed	intensive or intermediate	Medium or high density plantation with temporary accompanying species	Use of cheap seedlings and/or species not vulnerable to animal damage.
		Mixed low density plantation (at least 2 main species); variable details.	Reducing establishment costs Reducing the health risk for certain species and adequacy of the species to the local soil/ground conditions.
	light	mixed high density plantation (at least 2 main species); variable details.	Use of cheap seedlings Reducing risks related to parasites and soil/ground variations.
		mixed high density plantation (at least 2 main species), with accompanying species.	Cheap seedlings Use of social species, not sensitive to health risks and animal damage.

NB: this only concerns tree species. Although shrubs may be beneficial in the early years, they often become troublesome and costly to eliminate at the time of the last pruning and during subsequent operations. For these reasons, they have not been dealt with here.

Objective: single-species noble or precious timber stand

→ The final stand will consist of only one precious or noble species.

Why?

- To facilitate establishment and post-planting care.
- To obtain homogeneous products

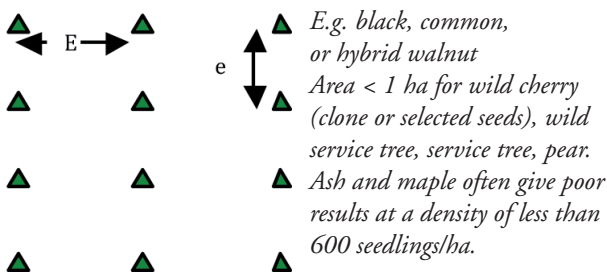
How?

- The easiest option is a single-species plantation
- All planting densities are possible

Low or very low planting densities are best suited to intensive (arboricultural) **or intermediate** (active forest management) post-planting care.

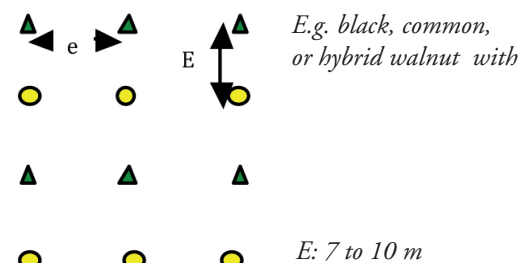
On adequate sites, a temporary mix with poplar as a source of production can also be a solution.

Single-species «timber orchard»-type plantation, (very) low density (100 to 600 stems/ha)



E: 4 to 15 m - e: 4 to 10 m - regular post-planting care over +/-15 years required (hence more appropriate for smaller areas). For rows at least 12 m apart, this could be appropriate for agroforestry plantations

Very low density plantation (150-250 stems/ha) in a temporary mix with a short-rotation species

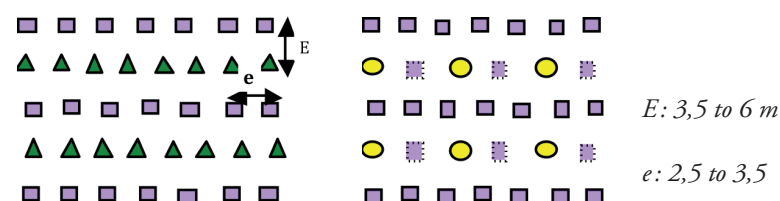


e: 6 to 8 m for poplar & 4 to 6 m for walnut. Regular post-planting care +/-8-10 years required + several years after cutting the poplar. Can be appropriate for agroforestry plantations

For lighter post-planting care (classic forestry), it is preferable to establish one or more quick-growing accompanying species temporarily. Protection costs can be reduced if these species are not sensitive to animal damage.

Planting the target species at a high density is a possible option for cheap seedlings.

Plantation temporarily mixed with an accompanying tree species



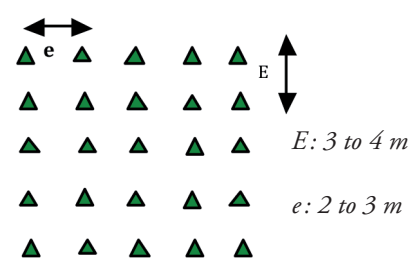
Method A
▲ = social species, e.g. walnut, ash, maple

■ = accompanying species
e.g. alder, birch, locust tree.

Method B
● = scattered or expensive species, e.g. wild cherry, service tree, wild service tree, pear, etc.

■ = optional

Single-species high-density plantation (cheap seedlings)



E.g. black walnut, ash, maple, oak, etc. Wild cherry (ordinary seeds) over small areas.

For temporary mixing, the rows of main species can be spaced 10 - 15 m apart with several rows (strip) of the accompanying species planted between them. Once their role of protecting and training the main species is accomplished, the latter can be harvested for fuel wood and industrial timber.

Important...

The target species must be well suited to the site, which must be sufficiently homogeneous. There may be health risks for fruit trees (scattered among natural stands) in a single-species plantation. It is therefore best to plant on small areas of less than 1 ha or even 0.5 ha. If the site is average or at the limit of suitability for a strongly-desired species, a mixture should be used with at least one other species better suited to the site (see below).

Objective: a mixed stand of noble or precious species

→ The final stand will be composed of at least two main species

Why ?

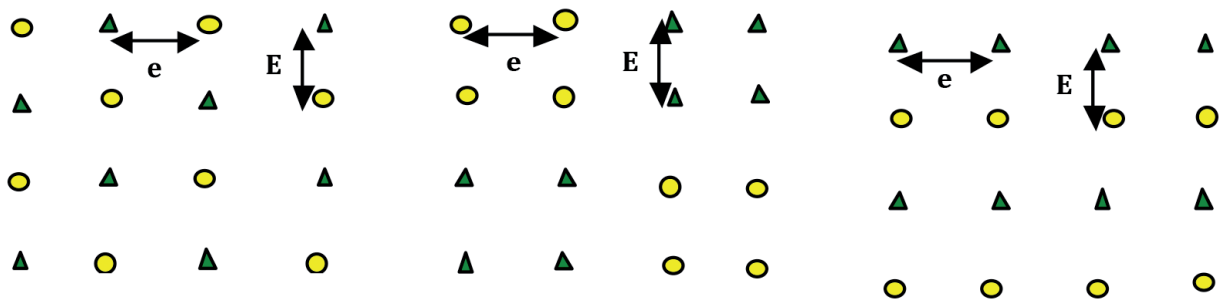
- To diversify the products, «not putting all one's eggs in one basket». Possibly to adapt felling stages to the market.
- Except in some cases, to reduce health risks.
- To improve flexibility in terms of recovery and growth of the plants on heterogeneous sites.
- To reduce the cost of protection against animal damage; some less vulnerable species can be left unprotected.

How?

- Several main species are established at the beginning of the plantation, with or without accompanying species. The plantation is managed to maintain the mixture over time.
- Various plantation densities can be used.

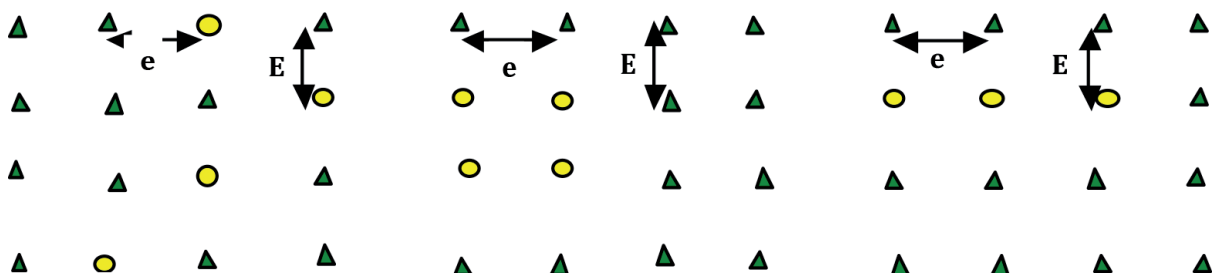
Under intensive (arboricultural) **or intermediate** (active forest management) post-planting care, low or very low densities are best suited. Only the target species are established in the mix.

«Timber orchard» plantation type, (very) low density (100 to 500 stems/ha) and mixed. Different mixing patterns laid out regularly: plant by plant, clusters, rows (2 species)



Examples of mixtures: over small areas, some fruit trees together (wild service tree, rowan or wild cherry, etc. with walnut) or larger areas with more social species (maple, ash, oak, beech, etc.).

«Timber orchard» plantation type, (very) low density (250 to 500 stems/ha) and mixed. Different mix patterns laid out irregularly and not balanced (one dominant species and one scattered species), plant by plant, clusters, rows (possibly sequenced) according to type



Examples of mixtures: scattered fruit trees (service tree, rowan, wild cherry, pear, apple) mixed with a more social dominant species (maple, ash, oak, etc.).

For the two diagrams, E: 5 to 14 m and e: 2.5 to 4.5 m

Regular post-planting care over +/- 15 years is required (hence preferably over relatively small areas).

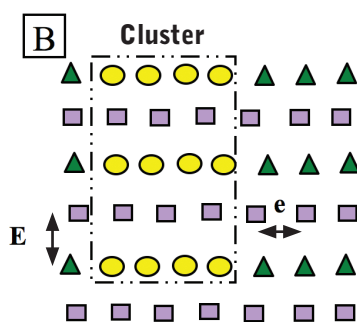
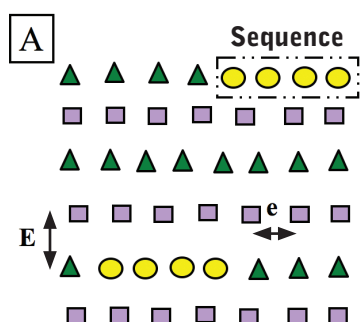
With rows spaced 12 m or more apart, this could be appropriate in agroforestry plantations

Clusters: the example shows squares of 4 seedlings, but the number of seedlings may be higher and the cluster can be rectangular in shape.

For lighter post-planting care (classic forestry), a high density including only the target species is possible. However, this method often causes technical problems at the time of the first thinnings (occasionally difficult choices, rides) and financial problems due to the need for protection against animals damage (for all seedlings). Possible methods are the same as for low densities (see figures 5 and 6, taking $E = 3$ to 4 m and $e = 2$ to 3 m (preferably choosing an overall density of between 900 and 1 300 seedlings/ha).

However, it is often preferable to establish a mixture with the target main species and one or several temporary species to accompany the former.

Mixed high density plantations comprising two main species, (one dominant and one scattered) and an accompanying species. The scattered species is laid out in sequences in method A and in clusters in method B.



Alternating rows of fast growing \blacksquare accompanying species with rows of noble species \blacktriangle , including fruit trees \bullet established in sequences or clusters.

Planting isolated seedlings is not recommended for slow-starting species.

For the two diagrams, E : 3 to 4 m and e : 2 to 3 m

Clusters: the example shows a rectangle of 12 fruit tree seedlings, but the number of seedlings can be higher. The shape of the clusters can also be square.

The rows of the main species can be widely spaced (10 - 15 m) with several rows (strips) of the accompanying species planted between them. One of the rows in each of some of these strips must be felled in the first thinning to form rides.

Important...

Establishment and post-planting care are more delicate than for a single-species plantation.

Heterogeneous growth can lead to an irregular stand. This may be the desired result, but the heterogeneous nature of the future products can sometimes complicate marketing.

Future extraction rides should be planned along rows of secondary species that will be felled during the first thinning.



To summarise the above:

Summary of possible options depending on the grower

Although the choice of species depends mainly on the site, the choice of density, composition and layout of the plantation are linked to the grower's objectives and the post-planting care method that the grower can apply. Firstly, rules for post-planting care and for the objectives of the stand's final composition are fixed in order to determine the initial density, composition and layout, not the other way round. For this reason **there is no ideal planting density but planting densities appropriate for particular growers**. The choice of plant material and the planting and ground preparation method also derive from this.

The table below summarises the main options described in the previous pages.

Profile	Seedling density	Target stand	
		Single-species: only 1 main species	mixed: at least 2 main species
«Arboriculture» Intensive post-planting care	very low, 80 to 300/ha	Single-species «timber orchard» Unrestricted layout of the selected main species seedlings.	Mixed species tree nursery Various possible establishment methods for the main species
		<p>Very low plantation density: all trees are cared for individually each year for at least 15 years.</p> <p>Accompanying tree species option: limited benefit due to the need for annual interventions. Special case: temporary mix with poplar (associated with walnut or ash, etc.).</p>	
Active forest management Intermediate level of post-planting care	low, 300 to 900/ha	Assisted single-species forest plantation Unrestricted seedling layout for the selected species.	“Assisted mixed forest plantation” Various possible methods to establish the main species.
		<p>Low density plantation where all or some of the trees are cared for individually, with frequent interventions over at least 15 years.</p> <p>Accompanying tree species option: limited benefit due to the need for frequent interventions, but may be beneficial in facilitating high pruning. Special case: temporary mix with poplar (associated with walnut or ash, etc.).</p>	
Classic forestry «extensive» post-planting care	medium to high: 900 to 1300, even 1800/ha	Single-species forest plantation Unrestricted seedling layout for the selected main species chosen.	Mixed forest plantation Various possible methods to establish the main species
		<p>Medium to high density plantation: after initial maintenance, some trees are cared for periodically in a few interventions spaced out over the first 15 years.</p> <p>Accompanying tree species option: highly beneficial due to less frequent need for intervention. Special case: temporary mix with poplar and an accompanying species (associated with walnut or ash, etc.).</p>	