



Practice Guide

# Raising trees and shrubs from seed

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Peter Gosling

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# Raising trees and shrubs from seed

Growing a few trees from seed is a relatively easy and extremely rewarding hobby. But without previous plant production experience, it is unwise to expect to grow even a few hundred plants, for example, for a recently acquired piece of land. And considerable caution and detailed planning are needed before setting up a commercial tree nursery.

This Practice Guide is aimed principally at people interested in raising small numbers of trees – to plant in the garden, raise for bonsai, or perhaps just for the fun of finding out what it's like to grow a few trees from seed (Figure 1). Nevertheless, in describing some of the basic properties of tree seeds, principles of seed handling, plus explaining how to avoid or overcome common problems, this Guide will be a useful reference for all. It covers approximately 120 woody species (listed in Appendix 1) which are either native to, or commonly grown in, the British Isles.

**Figure 1** Mother and daughter collecting horse chestnut seeds.

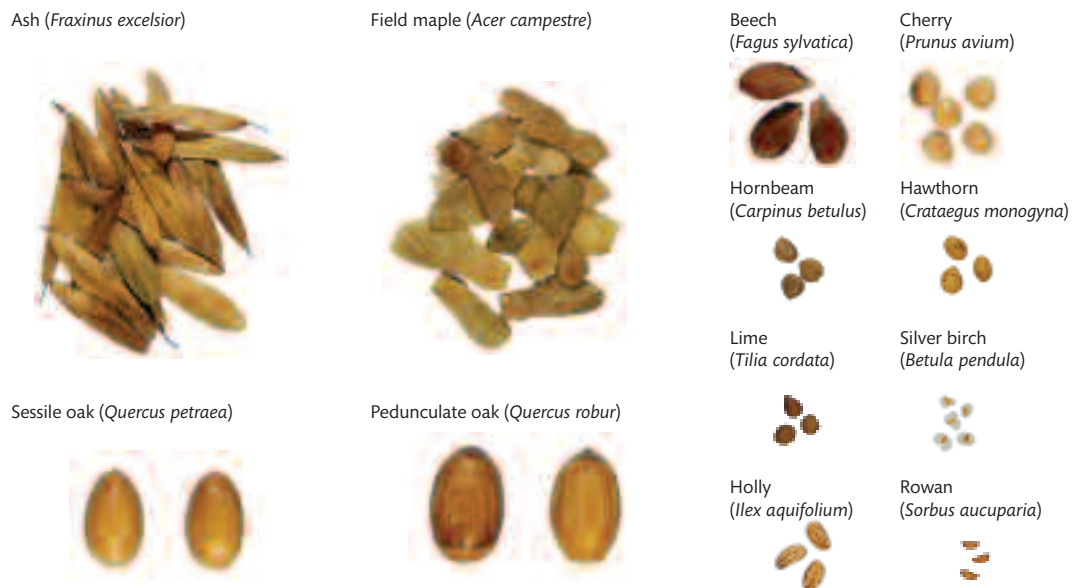


## Understanding tree seeds

Most seeds appear drab, dried, apparently lifeless objects (Figure 2). They are consequently often treated as though they are inert matter, but they are living organisms. Handled with care they will fulfil their potential to germinate, grow and develop into healthy plants, whereas mishandling will damage or kill them.

Tree seeds (in comparison to flower, vegetable and agricultural seeds) are some of the most fragile but also interesting of all seeds. Some of their characteristics are unique and they also have several quirks and idiosyncrasies that make them the eccentrics of the seed world, as described in this section.

**Figure 2** Examples of some fruits and seeds of tree species commonly grown in Britain.



## Erratic seeding

One oddity is the erratic and unpredictable fruiting of trees. In some years, trees produce very large quantities of cones, fruits or seeds and in other years almost none. There are some people who think that the intermittent production of large seed crops (so-called 'masting') is a distinct ecological advantage. They propose that 'barren' years cause predator populations to fall, and in mast years there are more seeds than all the surviving predators can possibly eat, so a larger proportion of seeds will escape predation and sprout the next spring. However, the less romantic explanation is that inconsistent seed production merely reflects annual variations in weather. And presumably, in the context of such a long-lived entity as a tree, erratic seed production is of little evolutionary consequence. But, whatever the explanation for masting, it is important to appreciate the phenomenon. Do not expect to be able to collect a guaranteed crop of tree seeds every year. Small crops are the norm, large crops the exception. The general rule is, when it looks like it is going to be a good seed year – plan to collect (Figure 3).

**Figure 3** Collecting acorns in a 'mast' year.



## Unproductive seeds

A second peculiarity of nearly all trees is that, in addition to live seed, they habitually produce a large proportion of empty and dead seeds (Figure 4). From the human perspective, this also seems very odd that an organism invests time, effort and resources into making something unproductive. As with masting, it has been suggested that this is a special survival strategy. For example, it is believed that, firstly, the tree benefits in that it produces empty, decoy seeds with minimal energy expenditure; and secondly, that potential predators will learn that they waste too much time and effort in sorting through empty and dead seeds which will act as a deterrent and encourage them to seek food elsewhere. Again however, it is more likely that in the context of a large and long-lived tree, a high proportion of empty and dead seed is simply not enough of an evolutionary disadvantage to have become selected out. Nevertheless, it is particularly important to bear this characteristic in mind with the previous point on erratic seeding, because there is often a much higher proportion of dead and empty seeds in a poor crop year than a good crop year – so it is doubly advantageous to collect tree seeds in mast years.

Figure 4

An x-ray of Douglas fir (*Pseudotsuga menziesii*) seeds, showing 'empty' (left), insect damaged (centre), and 'filled' (right) seed. The x-ray does not reveal whether filled seeds are 'dead' or 'alive'.



## 'Suicidal' seeds

Another curiosity is that some very small seeds, such as willow and poplar, and some very large fruits, such as oak, sycamore, sweet chestnut and horse chestnut, die quite soon after being shed from the tree – one of the last properties you would normally associate with seeds. The fruits are killed if they dry out and at present there is no known method of doing anything more than slowing down their rate of deterioration. It is therefore only worth collecting seeds of these species if you can sow them fairly quickly, or are prepared to suffer significant losses over, for example, one winter's storage. Seed longevity and associated storage characteristics are considered more fully under the headings 'orthodox', 'recalcitrant' and 'intermediate' on pages 8–10.

## 'Malingering' seeds

Finally, there is a phenomenon known as dormancy. There are many definitions of dormancy, but for anyone interested in raising trees from seed all you really need to know is that the seeds of some species have an absolute requirement to be 'pretreated' before they will germinate at all; and the seeds of other species are merely reluctant to germinate until they have been pretreated. Further information on 'dormancy', 'hard-seededness' and 'pretreatment' is given on page 11 onwards.

As these examples of a few unusual tree seed characteristics show, never expect every tree seed sown to produce a seedling. A three-hundred-year-old English adage sagely predicts 'One to sow, one to grow, one for the mouse and one for the crow', meaning that you are only likely to get one tree seedling for every four seeds sown. It is therefore a sobering thought that all the trees of the future are in just a few seeds of today. The rest of this Practice Guide will consider the process of raising trees and shrubs from seed.

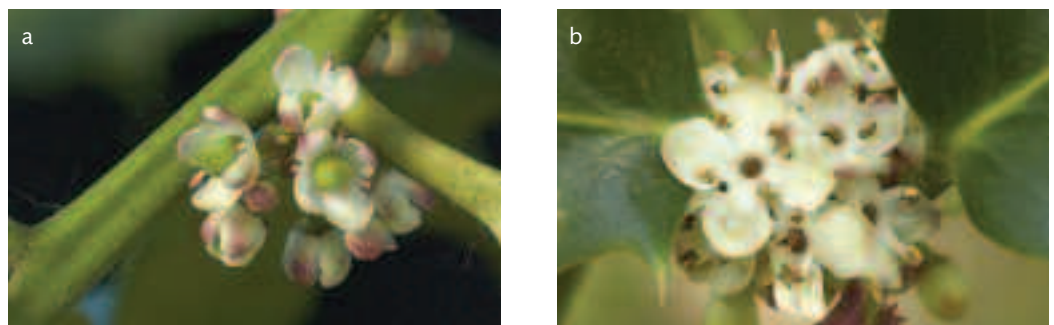


# Flowering and fruit development

Every potential plant propagator should know something about the reproduction of trees. In common with most higher organisms, it is generally believed that it is an advantage for trees to promote gene mixing through the transfer of pollen between different plants (so-called 'out-breeding'). A corollary of this is that there are mechanisms to prevent or at least reduce the chances of 'in-breeding'. A few trees achieve this by having separate sexes – they exist as male and female individuals (so-called 'dioecy' – see Figure 5). This makes self-pollination ('selfing') impossible. Other species produce male and female flowers on the same tree but on different branches, or at different times, or both. This again provides a physical and/or temporal obstacle to selfing. However, the flowers of the majority of trees are hermaphrodite – that is they contain both male and female structures. These flowers use several anatomical, temporal and biochemical mechanisms to reduce the chances of selfing. However, this means that some thought should be given to the different self-incompatibility systems of different species and the effect that collecting in different situations and for different purposes might have on the likely gene-pool of the seeds.

**Figure 5**

Holly is often dioecious – a) shows swollen, central carpel and four, reduced anthers of the female flower; b) shows reduced, central carpel and four more prominent anthers of the male flower.



As the most obvious example, do not expect to get fruits from the male individuals of species that are usually dioecious (e.g. ash, holly). It is also relevant to consider pollen source. For example, whether the pollen is mainly local or whether it has been blown in from a distance. This may be especially important if your aim is to collect seeds of native trees and shrubs, from a local source, undiluted by genes from afar. Another consideration is that self-incompatibility systems are not fool-proof, and their failure is frequently the explanation for why trees produce such large percentages of empty and dead seeds. Pollination, fertilisation and early fruit development occur, and it is only later that embryo abortion and possibly tissue resorption takes place. As a general rule, an identifiable group or defined population of at least 20–30 cross-pollinating individual trees will help to ensure that a reasonable amount of inter-breeding has taken place and that the gene pool of the seeds is not too narrow.

There is one other genetic consideration regarding the likelihood of climate change. A number of groups currently encourage the collection and propagation of native trees from local seed sources – their aim being to preserve locally adapted genotypes. However, if the UK climate is likely to significantly change in the next 50–100 years then perhaps seed sources adapted to the local environment may not be so appropriate.

Finally, to emphasise two points made in the previous section. Firstly, most trees do not produce a good fruit/seed/cone crop every year, and secondly, in a poor crop year, seed quality tends to be lower than in a good crop year. It is therefore wise to monitor flowering and the development of fruit quality and quantity and only collect in years when there appears to be a worthwhile crop.

# Collecting, handling and processing

One major practical difficulty about collecting tree seeds is how to collect from such tall plants. In the case of large fruits and seeds which fall directly to the ground (e.g. acorns, sweet chestnut and horse chestnut) the solution can be to gather the seeds from beneath the tree, or for larger collections, possibly clear any ground cover and spread out nets or tarpaulins. This way you can also be fairly sure that, since natural dispersal has taken place, the seeds are likely to be fully mature.

But, if animals or birds are likely to get to the fruits before you (e.g. cherries, rowan and hazel) or if seeds are wind-dispersed and either tiny (e.g. alders, birches, poplars, willows and most conifers) or medium sized (e.g. ash and sycamore) then the only safe option is to identify trees with accessible branches and pick the fruits just before maturity.

Two other things should be considered. If the trees are on private land it is essential to obtain permission from the owner(s) before collecting any seed. Secondly, always remember to leave some seeds behind – they are a vital food source for wildlife.

For collection, handling and processing purposes, tree fruits/seeds and cones can be split into the following groups with similar properties: legume pods, large 'dry' single fruits, medium sized 'dry' fruit clusters, medium size 'dry' fruits containing many seeds, fleshy fruits containing one or more seeds.

## Legume pods

Examples include acacia, broom, false acacia, gorse, laburnum (pictured) and tree lupin

Legume pods should be picked from the tree/shrub when they turn from green to brownish-black, and before they have fully opened and shed their seeds. The pods should be spread out to air dry and then placed in a bag and squeezed, beaten or threshed to release the seeds. The crushed, dried pods can then be separated from the seeds by sieving, fanning, or a combination of techniques. Note that the pods and seeds of laburnum are considered poisonous if eaten.



## Large 'dry' single fruits

Examples include beech (pictured), chestnuts, hazel, oaks and walnuts

Acorns and chestnuts are easiest to collect from the ground. Small quantities can be gathered by hand; larger quantities can be swept or raked up. Beech nuts are a little bit smaller and can either be collected from accessible branches when they have turned brown, or from the ground. However, with beech it is advisable to avoid the first nuts to fall, as these are prone to have a particularly high proportion that are empty. Hazel nuts and walnuts must be collected from the tree and the development and maturation of the crop will have to be monitored very closely or squirrels may get there first. The most processing that these large, dry fruits ever need is perhaps some cleaning to remove larger debris such as twigs, leaves and the 'pixie pipes' of acorns (the cupules plus fruit stalk). It is also important to take great care not to expose acorns and chestnuts to drying (see pages 16–17).



## Medium sized 'dry' fruit clusters

Examples include ash (pictured), maples, limes and hornbeam

Collect clusters of ash fruits (commonly called 'keys'), maple fruits (commonly called 'helicopters'), limes and hornbeams from the tree as they turn from green to brown. Strip individual fruits from bunches and remove the stalks to reduce bulk and facilitate subsequent handling.



## Medium sized 'dry' fruits containing many tiny seeds



Examples include alder and birch strobiles and conifer cones (pictured)

The botanical term for the structure containing the fruits of alders and birches is 'strobile', but in common with the seed-containing structures of many conifers they are often loosely referred to as 'cones'. The cones of birches and most cedars and firs are prone to disintegrate when fully mature so they must be collected from the tree before this happens or all the seeds will be lost. In comparison, the ripe 'cones' of alders, Lawson's cypress and most pines and spruces open and close in response to dry and wet weather as they are 'programmed' to shed their seeds over several days, weeks or even months. It is therefore possible to miss the first seed shed of these species, yet still collect seed. Place the cones of either 'disintegrating' or 'opening and closing' cones in a paper bag at room temperature and allow them to dry. The former group will disintegrate to leave a mixture of winged 'seeds' and 'bracts'. However, there is often so little difference between the sizes, shapes or weights of the different components that the mixture is usually too difficult to separate. The latter however, will open, release their seeds and the intact cones are either easily removed by hand, or the seeds can be separated by blowing.

## Fleshy fruits containing one or more seeds

Examples include apple, cherry, hawthorn (pictured), holly, juniper, mulberry, privet, rose, yew



Fleshy fruits are those that are soft, squidgy and frequently sticky. They are also often the most difficult to judge when to collect. They will either need to be carefully hand-picked, avoiding thorns where necessary, or possibly shaken from the branches. Apple seeds are an example of one of the difficulties of using the external appearance of a fleshy fruit to judge the internal development of the seeds. It is usually necessary to pick a few 'pomes' when they first turn from green to yellow/orange and cut open the centre. If the seeds are still white, or only partially brown then wait and re-sample weekly until the surface of the seeds is uniformly brown before progressing to the final collection. Cherries exhibit several difficulties. Firstly, you will generally need to collect them before they are fully ripe – to beat the birds! Secondly, it is important to remember that different cherry species ripen at different times of the year, and also that they ripen to different colours. For example, wild cherry (*Prunus avium*) ripens from green/yellow to red in June/July; whereas sloes (*Prunus spinosa*) turn blue/black in September/October (Figure 6).

Figure 6 Picking sloe fruit (*Prunus spinosa*).



Collecting yew berries has its own set of problems. It is vital to remember that, although the red flesh of the 'berry' surrounding the seed is regarded as safe to handle, all other parts of the tree, including the seeds, are toxic and may cause skin irritation. It is therefore necessary to exercise reasonable caution when collecting and handling these fruits, for example by wearing rubber gloves and washing hands thoroughly after processing.

Fleshy fruits are also some of the most awkward and certainly the messiest to process. Fruits such as apple, cherry, hawthorn, holly, juniper, mulberry, privet, rose and yew, usually need highly individual combinations of maceration (or controlled mashing), extraction, cleaning, soaking and washing procedures to separate and clean the seeds. The first step is generally very gentle maceration or even squeezing of the sticky fruits by hand to release the harder coated fruits or seeds within. Sometimes this may be assisted with a water soak and very occasionally a little fermentation can help. However, for seeds such as hawthorn, holly and rowan, fermentation can be significantly harmful or even fatal and is therefore to be avoided. Subsequently, most seeds will need repeated washing not only to remove the clinging remnants of sticky flesh, but also as a means of removing chemicals that have the potential to inhibit germination. A large sink plus draining board, rubber gloves, several buckets, bowls and assorted sieves are required when processing fleshy fruits.

Throughout seed collection and processing it is essential to keep a record of the identity of each seed lot. Minimum requirements to note are species, place and date of collection. Details of how and when the fruits/seeds were temporarily stored, transported and subjected to different processing and cleaning procedures will help improve next year's techniques.

Box 1 contains a checklist of things to consider before starting seed collection.

#### **Box 1 Questions to consider before starting seed collection**

- Is permission to collect necessary?
- Are you sure of tree identification?
- Does this species fruit regularly or intermittently?
- What is approximate date of fruit ripening?
- Are fruits prone to sudden dispersal or early predation?
- Is collection of fallen fruits from the ground possible?
- Is hand picking from branches possible?
- Is an extendable pole-pruner or pole-saw an option?
- What is best container for collection and possibly temporary storage, e.g. bucket, polythene bag, paper bag, sack, open tray, lunch box?
- What are best labelling materials, e.g. pencil and paper, plastic plant labels and indelible pen?
- What is minimum information to record, e.g. species, place and date of collection?
- What conditions are best for temporary storage (before cleaning or processing), e.g. airtight, well ventilated, cool, refrigerated?

At the end of fruit/seed processing a decision will have to be made on storage. This will depend partly on whether the seeds can be stored or not, partly on whether storage is necessary, and partly on how long they will need to be stored. The next section provides some guidance on the storage characteristics and likely longevity of the seeds of different species. (The widespread usage of the term ‘dry’, to describe fruits that are not ‘fleshy’ ‘squidgy’ or ‘sticky’, is rather unfortunate in relation to seed storage characteristics: for example, acorns have been described as large, ‘dry’ fruits, yet it will be seen in the next section that excess drying will kill them.)

## Seed storage

The seeds of most plants are easy to store (so-called ‘orthodox’). The seeds of a small minority of plants are currently impossible to store (termed ‘recalcitrant’). And in recent years it has become increasingly widely acknowledged that there are seeds between these two extremes (termed ‘intermediate’). In other words, there is a range of seed storage characteristics (see Table 1). The ease or otherwise of seed storage generally depends on whether the seeds of particular species can be dried or not. Seeds of recalcitrant species (e.g. Figure 7) at a low moisture content are likely to be dead. Orthodox seeds at a high moisture content will need drying before storage. It is therefore very useful to be able to measure the percentage moisture content of seeds (see Box 2).

**Table 1** Seed storage characteristics vary from ‘easily stored’ to ‘highly perishable’.

Orthodox (Easily stored)	Intermediate (Awkward)	Recalcitrant (Highly perishable)
90% of temperate woody species	Many species of fir ( <i>Abies</i> spp.) Norway maple ( <i>Acer platanoides</i> ) Incense cedar ( <i>Calocedrus decurrens</i> ) Cedar ( <i>Cedrus</i> spp.) Lawson’s cypress ( <i>Chamaecyparis lawsoniana</i> ) Beech ( <i>Fagus sylvatica</i> ) Bay laurel ( <i>Laurus nobilis</i> ) Western red cedar ( <i>Thuja plicata</i> )	Sycamore ( <i>Acer pseudoplatanus</i> ) Horse chestnut ( <i>Aesculus hippocastanum</i> ) Monkey puzzle ( <i>Araucaria araucana</i> ) Chestnut ( <i>Castanea sativa</i> ) Poplar ( <i>Populus</i> spp.) Oak ( <i>Quercus</i> spp.) Willow ( <i>Salix</i> spp.)

**Figure 7** The seeds of the sweet chestnut are ‘recalcitrant’ or highly perishable.





## Box 2 Determining seed moisture content

Most tree seeds can be stored for longer at lower moisture contents (6–8% moisture content for most pines and spruces, 10–15% moisture content for most firs, cedars, cypresses and broadleaves). Recalcitrant seeds, for example, oak, sweet chestnut, horse chestnut and sycamore, begin to die below 40% moisture content. Seed moisture content is generally reported as the weight of water, expressed as a percentage of the fresh weight of the seeds. This is called the moisture content on a fresh weight basis.

Note: moisture content can also be calculated on a dry weight basis, but this method is less common and is not used here.

Moisture content measurement is generally carried out on a minimum sample weight of 5 g. However, it has also been shown that the minimum number of seeds in a moisture content sample should never be below 30 seeds. Method A describes how to measure seed moisture content for small-seeded species – those containing more than 30 seeds per 5 g, and Method B for large-seeded species – those which would contain fewer than 30 seeds per 5 g.

### Method A – Smaller seeded species, where a 5 g sample exceeds 30 seeds

1. Accurately weigh a 5 g sample of seeds (this is the 'fresh weight').
2. Dry the sample (preferably at approximately +105°C for between 18–24 hours or until two consecutive weighings give a constant weight).
3. Take a final 'dry weight'.
4. See below for calculation.

### Method B – Larger seeded species e.g. acorns, chestnuts and sycamore

1. Take 30 clean, firm, healthy and apparently live fruits.
2. Cut the fruits into approximately 3 x 3 mm cubes and mix the sample as quickly as possible to minimise drying.
3. Accurately weigh a 10 g sub-sample of the cut fruits (this is the 'fresh weight').
4. Dry the sub-sample (preferably at approximately +105°C for between 18–24 hours or until two consecutive weighings give a constant weight).
5. Take a final 'dry weight'.
6. See below for calculation.

### Calculation for Method A and Method B

Assuming that any reduction in weight reflects moisture loss:

$$\text{Moisture content (as \% fresh weight)} = \frac{(\text{fresh weight [g]} - \text{dry weight [g]})}{\text{fresh weight [g]}} \times 100$$

Note: for fruits containing significant amounts of volatile substances such as resins, fat, and oils, this is slightly erroneous because these substances are also driven off by heating. However, even for these species the weight of volatile substances is usually relatively small, and does not significantly affect the moisture content calculated.

## Orthodox seeds

At one end of the range of storage conditions are the seeds which can be dried without harm. The cells of these seeds can not only be dried, but (once dry) they can then be frozen, stored and relatively easily revived. Fortunately, these seeds are in the majority and that is why they are called 'orthodox'. In general, most pine and spruce seeds are orthodox and can be safely dried to 6–8% moisture content (fresh weight basis). Whereas the seeds of most orthodox broadleaved species are best dried to only 10–15% moisture content. In Britain, when the freshly collected seeds of these two groups of species are left in a shaded, cool, well-ventilated room, they ultimately tend to equilibrate at approximately these moisture contents. Nevertheless, once dried it is preferable to avoid moisture content fluctuations by storing orthodox seeds in airtight, waterproof, sealed containers – a tightly tied, thick polythene freezer bag is ideal. At these moisture contents, and a storage temperature of +3°C to +5°C (the main compartment of a refrigerator) most 'orthodox' tree seeds will exhibit little deterioration over 5–15 years. In addition, because the cells of these dried seeds do not contain enough water to freeze solid, longevity is further increased by reducing the storage temperature to –10°C to –20°C (the icebox of a refrigerator or a deep freezer).

There are two important guidelines about the effects of storage conditions on the longevity of 'orthodox' seeds. Firstly, a 1% increase in moisture content will halve the storage life (at any given temperature). Secondly, a 5°C rise in storage temperature will halve the storage life (assuming no changes to moisture content). These dramatic effects emphasise why it is so important to avoid moisture content and temperature fluctuations during seed storage.

## Recalcitrant seeds

At the other end of the range of storage conditions, the seeds of a small minority of species cannot be dried, cannot be frozen and are therefore highly perishable. They have been named 'recalcitrant' seeds. The cells that make up the seeds of these species are like the cells of most other animal and vegetable tissues – if they are frozen or dried, they die. The species in this group are given in Table 1. Optimum storage conditions for freshly collected, temperate, recalcitrant seeds combine low (but not freezing) temperatures (+3°C to +5°C) to slow seed deterioration and minimise fungal growth, with high humidity to retard drying. But even under these conditions, the seeds of some poplar and willow species are extremely recalcitrant and all die within days of dispersal or collection. Acorns and chestnuts kept under similar conditions usually suffer 60–70% losses over a couple of years. Practical guidance on how best to handle recalcitrant seeds is given on pages 16–18, and in Forestry Commission Practice Note *Handling and storing acorns & chestnuts and sycamore fruits*.

## Intermediate seeds

In between the two extremes of seeds with either 'recalcitrant' or 'orthodox' storage characteristics are seeds with so-called 'intermediate' properties (see Table 1). These seeds can usually be dried to 10–15% moisture content without harm, but if further drying is possible, it must be done much more slowly and carefully. At the storage temperatures most commonly used for orthodox seeds (i.e. +3°C to +5°C) they also tend to deteriorate more quickly. Hence, for practical purposes all seeds with intermediate storage characteristics should be dried to 10–15% moisture content and then stored at –10°C to –20°C. Having used Table 1 to identify whether seeds of a particular species can be stored it must then be decided *if* it is necessary to store them or not. This will not only depend upon when it is intended to sow the seeds, but also the seeds dormancy characteristics and whether there is enough time available to dry and store them before a dormancy breakage 'pretreatment' should begin.

# Hard-seededness, seed dormancy and pretreatment

In many naturally reproducing plant populations a delay between seed shed and subsequent germination can be a significant ecological advantage. Postponing emergence clearly allows extra time for dispersal (whether by wind, water, birds or animals) to potentially greater distances (Figure 8). In any region with seasonal variations, it has the additional advantage that the germination of at least some seeds will coincide with the most favourable season for seedling growth and establishment. Natural selection has therefore favoured many species with seeds which do not germinate immediately after dispersal – even when the environmental conditions are ideal (e.g. ample water, a suitable temperature for growth and good aeration). When seeds are inactive because they are 'immature' or possess a layer of tissues that prevent water uptake or gaseous exchange, they are said to be 'quiescent'. But when seeds can be shown to be fully hydrated and alive yet still remain outwardly inactive – they are said to be 'dormant'.

**Figure 8** A blackbird eating a rowan berry. It is likely that passage through a bird gut removes germination inhibitors from the fruit skin and pulp, however, intact seeds still retain their innate 'deep-dormancy'.



A dormant seed is one that is known to be alive, but remains outwardly inactive and does not germinate when we expect it to. The seeds of some species remain dormant under all conditions, and the seeds of others are only dormant under some conditions. There are a number of natural processes, seasonal stimuli or combinations of the two which overcome dormancy and stimulate germination. And there are a number of artificial substitutes which humans can use to mimic such 'dormancy breakage'. These are called pre-(sowing) treatments or pretreatments for short. Nearly all tree seeds exhibit dormancy of one sort or another and therefore fast, uniform and complete germination is only possible after live, dormant seeds have been exposed to a natural or artificial dormancy breakage pretreatment. This section describes a few of the features of hard-seededness, seed dormancy and seed pretreatment and the properties of seeds with different types of dormancy are illustrated, see Figures 9a, b and c.

## Hard-seededness

Temperate legume tree seeds (e.g. broom, false acacia, gorse, laburnum, tree lupin) possess a seed coat which prevents or at least significantly retards the germination of otherwise live seeds. This is usually caused by a layer (or layers) of tissue that acts as an impermeable barrier to water uptake, respiratory gas exchange or both. Hence the embryo tissues are either unable to hydrate or respire or both. There is no fundamental, physiological block to embryo growth, merely a physical barrier which excludes one or more of the essentials for growth from the tissues. This condition is known as 'hard-seededness' and because it is an in-built physical barrier to germination, some people do not acknowledge that it is a form of dormancy – but the result is the same: poor or non-existent germination, until the seed coat is 'pretreated' (Figure 9a).

## Seed dormancy

In contrast to hard-seeded species (which do not germinate because the outer layers prevent water uptake or respiration) the seed coats of most tree species are permeable to water and respiratory gases. As a consequence, in favourable conditions for growth, the embryo tissues absorb water, metabolise and respire. Yet even when environmental conditions are ideal (e.g. ample water, a suitable temperature for growth and good aeration) most freshly collected (and even dry-stored) seeds still remain outwardly inactive and exhibit no signs of germination. Seeds with these characteristics exhibit true, physiological 'dormancy'.

The seeds of some species remain outwardly inactive under all conditions and are said to be 'deeply dormant' (Figure 9b). The seeds of other species only remain inactive under some conditions and are therefore described as 'shallowly dormant' (Figure 9c). All dormant seeds require some form of pretreatment before they acquire their full ability to germinate (Figures 9b and c).

## Pretreatment

In nature, the delayed germination of many 'hard-seed coated' species is overcome in several ways. For example, animal teeth can fracture the coat; bird or animal intestines can mechanically abrade, chemically digest and microbially breakdown the seed coat; and fire, repeated freezing and thawing, and wetting/drying cycles; and fungal and microbial breakdown in the soil can all 'scarify' a hard seed coat. Each of these processes will allow subsequent hydration of the embryo and thus stimulate germination, providing it does not harm the embryo within.

In comparison, physiologically dormant seeds tend to respond to other natural environmental stimuli. For example, they can perceive:

- transitions between one or more cold winters, followed by warmer springs;
- cycles of burial followed by re-exposure to light;
- sequences, or combinations of these changes.

These environmental changes act as natural dormancy breakage mechanisms and they can be reproduced in artificial dormancy breakage pretreatments. For example, various physical, chemical, biochemical and even biological methods can be used to pretreat hard-seeded species (see Appendix 2). Also deliberate exposure of seeds to seasonal temperature changes or thermostatically controlled equipment can be used to artificially pretreat deeply- and shallowly-dormant species (see Appendix 3).

Table 2 summarises which tree species exhibit the above forms of dormancy.

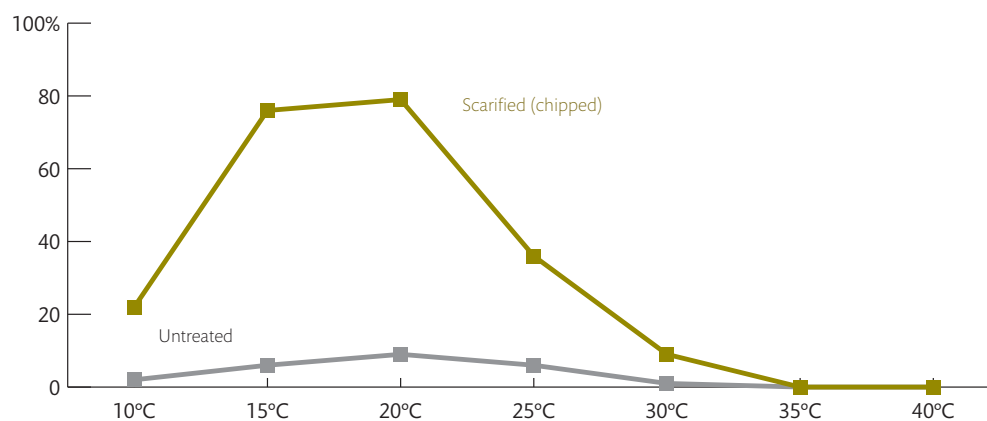


Figure 9a

Maximum percentage germination at different temperatures of a hard-seeded species (broom, *Cytisus scoparius*) with and without chipping.

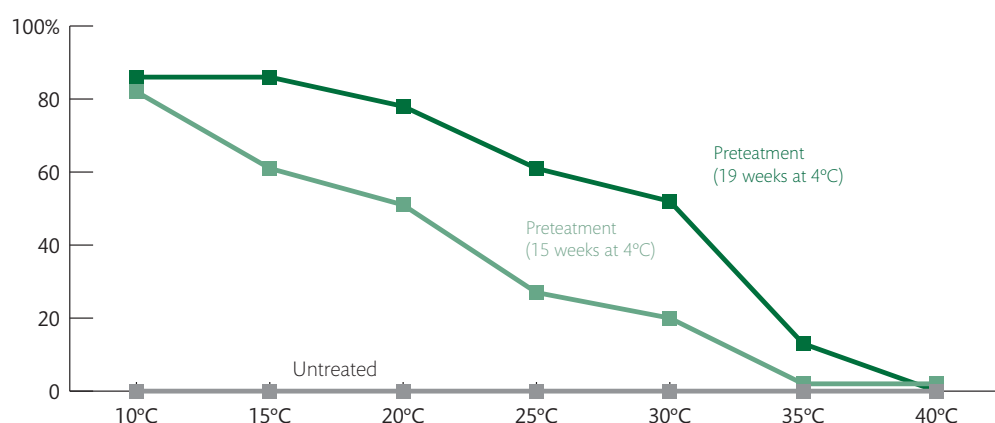


Figure 9b

Maximum percentage germination at different temperatures of a deeply dormant species (beech, *Fagus sylvatica*) following different durations of pre-chill.

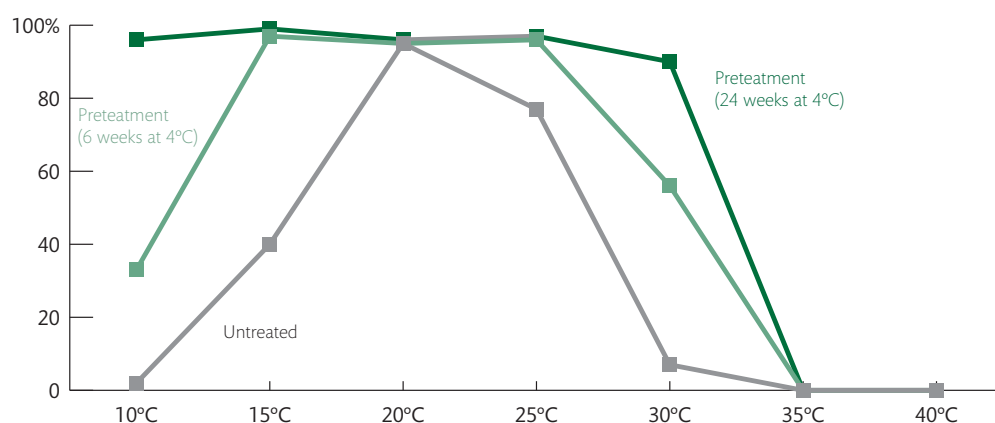


Figure 9c

Maximum percentage germination at different temperatures of a shallowly dormant species (Sitka spruce, *Picea sitchensis*) following different durations of pre-chill.

Table 2 Types of dormancy exhibited by different tree species.

Types of dormancy	Species
Hard-seededness	Broom ( <i>Cytisus scoparius</i> ) Scotch laburnum ( <i>Laburnum alpinum</i> ) Common laburnum ( <i>Laburnum anagyroides</i> ) Tree lupin ( <i>Lupinus arboreus</i> ) False acacia ( <i>Robinia pseudoacacia</i> ) Gorse ( <i>Ulex europeaus</i> )
Shallow	Most conifers Alder ( <i>Alnus</i> spp.) Birch ( <i>Betula</i> spp.)
Deep	Most broadleaves Juniper ( <i>Juniperus communis</i> ) Macedonian pine ( <i>Pinus peuce</i> ) Yew ( <i>Taxus baccata</i> )



# Interaction between storage properties and dormancy characteristics

The previous two sections of this Guide show that storage and dormancy characteristics are the two properties most likely to determine tree seed handling and propagation techniques. Table 3 combines Tables 1 and 2 and shows how the seeds of most species fall into seven (of a possible nine) different combinations of category. This section of the Guide uses the seven categories identified in Table 3 to highlight whether there are any handling, storage or pretreatment options for different species, and what those options might be. The numbered boxes in Table 3 can also be used as an approximate measure of how easy or difficult it is to handle, store, pretreat and ultimately propagate the different groups of species from seed. For example, in (approximately) ascending order of overall difficulty of germination:

1. Leguminous trees and shrubs like laburnum, broom and gorse are very easy to dry, handle and store. The only special consideration is that the seed coat must be 'scarified' (i.e. abraded, punctured or softened) to permit germination.
2. Alders, birches and most conifers are also easy to dry, handle and store, but their shallow dormancy characteristics can make them a little more challenging to germinate, especially to achieve the maximum germination possible.
3. Some firs, cedars, cypresses and a few other conifers are slightly more difficult again to germinate. They can be dried and stored but often die within weeks at room temperature and ideally require sub-zero storage temperatures. They also exhibit shallow dormancy and there is some evidence that some seed lots can suffer damage during water uptake.
4. Poplars, willows, oaks, sweet chestnut and horse chestnut are the least dormant and easiest to germinate of all tree species, but they are all very awkward to handle, and simply impossible to store because they cannot tolerate drying and are therefore highly perishable.

**Table 3** Species exhibiting different combinations of storage and dormancy characteristics. See numbered text for details.

	Orthodox	Intermediate	Recalcitrant
Hard	1. Broom ( <i>Cytisus scoparius</i> ) Scotch laburnum ( <i>Laburnum alpinum</i> ) Common laburnum ( <i>Laburnum anagyroides</i> ) Tree lupin ( <i>Lupinus arboreus</i> ) False acacia ( <i>Robinia pseudoacacia</i> ) Gorse ( <i>Ulex europeus</i> )		
Shallow	2. Most conifers Alder ( <i>Alnus</i> spp.) Birch ( <i>Betula</i> spp.)	3. Many species of fir ( <i>Abies</i> spp.) Incense cedar ( <i>Calocedrus decurrens</i> ) Cedar ( <i>Cedrus</i> spp.) Lawson's cypress ( <i>Chamaecyparis lawsoniana</i> ) Western red cedar ( <i>Thuja plicata</i> )	4. Horse chestnut ( <i>Aesculus hippocastanum</i> ) Monkey puzzle ( <i>Araucaria araucana</i> ) Chestnut ( <i>Castanea sativa</i> ) Poplar ( <i>Populus</i> spp.) Oak ( <i>Quercus</i> spp.) Willow ( <i>Salix</i> spp.)
Deep	5. Most broadleaves Juniper ( <i>Juniperus communis</i> ) Macedonian pine ( <i>Pinus peuce</i> ) Yew ( <i>Taxus baccata</i> )	6. Norway maple ( <i>Acer platanoides</i> ) Beech ( <i>Fagus sylvatica</i> ) Bay laurel ( <i>Laurus nobilis</i> )	7. Sycamore ( <i>Acer pseudoplatanus</i> )

Some poplars and willows will deteriorate within hours and die over a few days. As a general rule, 10–50% of oak and chestnut populations will deteriorate between autumn collection and spring sowing.

5. Most broadleaved trees (plus junipers and yews) are relatively easy to dry, handle and store, but their deep dormancy makes them significantly more difficult to germinate because pretreatments are not reliable and pretreatment times are so lengthy.
6. A few broadleaves (e.g. beech, laurel and Norway maple) combine the intermediate storage characteristics with deep dormancy. This means that they require careful drying, relatively precise storage conditions and also very lengthy pretreatment.
7. Sycamore would appear to have the potential to be the most difficult of all fruits because it not only deteriorates quite quickly, but also needs a long time to pretreat and germinate. However, in practice, since it must be stored at a high moisture content and a low temperature (to maximise longevity), and at the same time, this combination overcomes dormancy, then the optimum storage conditions and optimum pretreatment conditions automatically coincide.

## Details and advice on 7 storage/dormancy combinations

### 1. Orthodox/hard seeded species

Broom (*Cytisus scoparius*); Scotch laburnum (*Laburnum alpinum*); common laburnum (*Laburnum anagyroides*); tree lupin (*Lupinus arboreus*); false acacia (*Robinia pseudoacacia*); and gorse (*Ulex europeaus*).

All hard-seeded species have 'orthodox' storage characteristics, and all will require seed pretreatment to stimulate germination.

#### Storage and pretreatment and sowing

The freshly extracted, undried seeds are usually at a low enough moisture content to be treated in either of the following ways:

- Store in a loosely-tied polythene bag in the main compartment of a refrigerator (approximately +4°C) for no more than one winter; or
- Dry to 6–8% moisture content (fresh weight basis) which will allow sub-zero storage with little deterioration for up to 20 years.

Then: pretreat artificially according to Appendices 1 and 2 and sow the following spring.

### 2. Orthodox/shallowly dormant species

Most conifers, alder (*Alnus* spp.) and birch (*Betula* spp.).

Orthodox seeds all have the potential to be dried and stored, if required. It is important to note that some untreated seeds will germinate, but pretreatment will usually stimulate quicker germination of more seeds over a wider range of conditions.

Occasionally, pretreatment is harmful. For example, the germination capacity of up to 20% of commercial seed lots of Corsican pine, Scots pine and Norway spruce may be significantly

reduced by pretreatment. The reasons for this are unknown but the seeds of other species appear significantly less likely to suffer damage.

#### Storage and/or pretreatment and/or sowing

The freshly extracted, undried seeds are usually at a low enough moisture content to be treated in either of the following ways:

- Store in a loosely-tied polythene bag in the main compartment of a refrigerator (approximately +4°C) for no more than one winter; or
- Dry conifers to 6–8% moisture content (fresh weight basis) and alders and birches to 8–10% which will allow sub-zero storage with little deterioration for up to 10 years.

Then:

- Sow outdoors in January/February (to pretreat naturally); or
- Pretreat artificially (according to Appendices 1 and 3) and sow the following spring; or
- Sow the following spring without pretreatment.

### 3. Intermediate/shallowly dormant species

Fir (*Abies* spp.); incense cedar (*Calocedrus decurrens*); cedar (*Cedrus* spp.); Lawson's cypress (*Chamaecyparis lawsoniana*); and western red cedar (*Thuja plicata*).

On current evidence these seeds are less tolerant of drying and shorter-lived than the majority of seeds with orthodox storage characteristics. They are sensitive to desiccation, but not as much as recalcitrant seeds, or as highly perishable. The seeds exhibit the usual features of shallow dormancy in that some untreated seeds will germinate, but pretreatment will usually stimulate quicker germination of more seeds, over a wider range of conditions. Occasionally, pretreatment is harmful – especially to incense cedar.

#### Storage and/or pretreatment and sowing

The freshly extracted, undried seeds are usually at a low enough moisture content to be treated in either of the following ways:

- Store in a loosely-tied polythene bag in the main compartment of a refrigerator (approximately +4°C) for no more than one winter; or
- If storage is considered, careful drying to approximately 9–12% moisture content (fresh weight basis) will probably make sub-zero storage possible. Storage at approximately 9–12% moisture content (fresh weight basis) and –5°C to –20°C is more likely to achieve 2–5 years of storage than storage at +4°C.

Then:

- Sow outdoors in January/February (to pretreat naturally); or
- Pretreat artificially (according to Appendices 1 and 3) and sow the following spring; or
- Sow the following spring without pretreatment.

### 4. Recalcitrant/shallowly dormant species

Horse chestnut (*Aesculus hippocastanum*); monkey puzzle (*Araucaria araucana*); chestnut (*Castanea sativa*); poplar (*Populus* spp.); oak (*Quercus* spp.); and willow (*Salix* spp.).

The combination of recalcitrance and shallow dormancy means that at the high moisture contents necessary to keep these seeds alive, any exposure to cool temperatures (–3°C to +5°C)

will contribute towards dormancy breakage. But it is vital to appreciate that the seeds of many poplar and willow species are so 'recalcitrant' that even at these low temperatures they die within days. Oaks, sweet chestnut and horse chestnut will typically decline from 90% to 50% germination over the 10–24 weeks between collection in October/November to spring sowing in March/April. A combination of low temperature (–3°C to +5°C) to slow the rate of deterioration and minimise fungal growth plus high humidity to retard drying and adequate gaseous exchange to permit respiration are the main principles to follow (see Forestry Commission Practice Note *Handling and storing acorns & chestnuts and sycamore fruits*). The most likely explanation for the earlier death of poplar and willow seeds in comparison to oaks and chestnuts is the smaller size of the former leading to faster desiccation (drying out).

### Storage and/or pretreatment and sowing

The freshly collected fruits are usually at a high moisture content and should be sown as soon as possible. If short-term storage is unavoidable, the following guidelines apply to a few days storage for poplar and willow seeds and a maximum of 18–24 weeks for the fruits of larger, recalcitrant species:

- Low temperatures (–3°C to 5°C) will slow fungal growth and retard respiration.
- High humidity will retard drying.
- Avoid sealed containers as sufficient gaseous exchange to permit respiration is essential.
- It may be beneficial to spray or soak fruits intermittently during storage as this appears to have a rejuvenating effect.
- Do not aim to store poplar or willow seeds any longer than a few days.
- Do not aim to store acorns or chestnut fruits until any later than the following spring.

Then: sow outdoors as soon as possible.

## 5. Orthodox/deeply dormant species

**Most broadleaves; juniper (*Juniperus communis*); Macedonian pine (*Pinus peuce*); and yew (*Taxus baccata*).**

These orthodox seeds will all have the potential to be dried and stored, if required. It is also important to note that they all have an absolute requirement for pretreatment in order to bring about any germination. However, it should be assumed that freshly collected seeds will not contain sufficient moisture to respond to pretreatment – therefore they must be deliberately imbibed (soaked and fully hydrated) before pretreatment.

### Storage and/or pretreatment and sowing

The freshly extracted, undried seeds are usually at a low enough moisture content to be treated in any of the following four ways:

- Sow immediately outdoors to pretreat naturally (in line with pretreatment times recommended in Appendix 1); or
- Store in a loosely-tied polythene bag in the main compartment of a refrigerator (approximately +4°C) for no more than one winter, or until imbibed (soaked and fully hydrated) for natural or artificial pretreatment (according to Appendices 1 and 3); or
- Mix with moist (but not waterlogged) peat and sand and store in a loosely-tied polythene bag in the main compartment of a refrigerator (approximately +4°C) for no more than one winter; or until fully imbibed for natural or artificial pretreatment (according to Appendices 1 and 3); or

- Dry to 10–15% moisture content (fresh weight basis) allowing sub-zero storage with little deterioration for up to five years.

Then:

- Sow outdoors, to pretreat naturally (in line with Appendix 1); or
- Pretreat artificially (according to Appendices 1 and 3) and sow the following spring.

## 6. Intermediate/deeply dormant species

**Norway maple (*Acer platanoides*); beech (*Fagus sylvatica*); and bay laurel (*Laurus nobilis*).**

Seeds with intermediate storage characteristics are less tolerant of drying and are shorter-lived than the majority of seeds with orthodox storage characteristics, but not as sensitive to desiccation or as highly perishable as recalcitrant seeds. However, Norway maple (*Acer platanoides*) and beech (*Fagus sylvatica*) have two further characteristics. If Norway maple fruits are to be dried, they need very slow drying to start with and can only tolerate faster drying later. There is also some evidence that beech nuts may have an optimum storage moisture content of approximately 15%. It appears that they deteriorate more quickly as the moisture content is progressively reduced below 15%. Otherwise the seeds in this group exhibit the usual features of deep dormancy, i.e. they all have an absolute requirement for pretreatment in order to bring about any germination. However, it should be assumed that freshly collected seeds will not contain sufficient moisture to respond to pretreatment – therefore they must be deliberately imbibed before pretreatment (see Appendix 3).

### Storage and/or pretreatment and sowing

The freshly extracted, undried seeds are usually at a low enough moisture content to be treated in any of the following four ways:

- Sow immediately outdoors to pretreat naturally (in line with pretreatment times recommended in Appendix 1); or
- Store in a loosely-tied polythene bag in the main compartment of a refrigerator (approximately +4°C) for no more than one winter; or until imbibed for natural or artificial pretreatment (according to Appendix 1); or
- Mix with moist peat and sand and store in a loosely-tied polythene bag in the main compartment of a refrigerator (approximately +4°C) for no more than one winter, or until fully imbibed for natural or artificial pretreatment (according to Appendix 1); or
- If storage is considered, careful drying to approximately 10–15% moisture content (fresh weight basis) will probably make sub-zero storage possible. Storage at approximately 10–15% moisture content (fresh weight basis) and –5°C to –20°C is more likely to achieve 2–5 years of storage than storage at +4°C.

Then:

- Sow outdoors, to pretreat naturally (in line with Table 1); or
- Pretreat artificially (according to Appendices 1 and 3) and sow the following spring.

## 7. Recalcitrant/deeply dormant species

**Sycamore (*Acer pseudoplatanus*).**

Sycamore (*Acer pseudoplatanus*) is unique in its combination of recalcitrance and deep dormancy. Do not let the fruits dry out or they will die. But at high moisture contents any exposure to the low temperatures (–3°C to +5°C) appropriate to storage will act as a pre-chill temperature and automatically contribute towards dormancy breakage.



## Storage and/or pretreatment and sowing

The freshly collected fruits are usually at a high moisture content and should be sown as soon as possible. If short-term storage is unavoidable, the following guidelines apply:

- Low temperatures (−3°C to +5°C) will slow fungal growth, retard fruit respiration and (at the high moisture content of the freshly collected seed) bring about pretreatment.
- High humidity will retard drying.
- Avoid sealed containers as sufficient gaseous exchange to permit respiration is essential.
- Do not aim to store until any later than the following spring.

Then: sow outdoors as soon as possible.

Use Appendix 1 to identify specific storage/pretreatment methods for sycamore.

## Other things to try with deeply dormant seeds

Since it may take up to two years to overcome the dormancy of some deeply-dormant fruits, you might like to try the following as a possible way of decreasing the time required.

- **Propagating the seeds from some berries without drying**

There is anecdotal evidence that some seeds which exhibit deep dormancy and are extracted from fleshy fruits may not require such a long dormancy breakage pretreatment - so long as seed drying is avoided. It will still be necessary to remove the seed from the fruit, thoroughly wash it (and possibly use a suitable tool to make a small hole in the seed coat to assist water uptake and embryo emergence) - but omitting a drying phase, may reduce pretreatment time significantly.

- **Propagating trees with deeply dormant fruits from 'excised embryos'**

In the 1930s, Florence Flemion developed techniques for carefully removing the embryos from many of the deeply dormant fruits. She found that if she placed the carefully removed embryos under light, warm, moist conditions, then, although some of the embryos decayed and died, and others merely remained firm, fresh and quiescent, within a week or two, a few embryos began to grow, green and even develop into seedlings. The technique has since been used as a method for determining whether deeply dormant fruits are 'dead' or 'alive' - a so-called 'viability' test. But despite 50 years of development as an 'excised embryo' seed test, it has never been properly investigated as a means of propagation. So it is not known whether embryos which start to grow will continue to do so. Perhaps they just slow down and die. Perhaps they become dwarf plants. Perhaps they need to receive the dormancy breakage pretreatment that they missed as seeds whilst they are in miniature plant form. So, try some of your own research. Have a go with species like cherry (use a vice to crack open the stone), or ash (carefully use a sharp knife to surgically remove the embryo). Incubate the embryos on moist kitchen towel, spread them on a seed tray and enclose in a polythene bag (to retain a humid atmosphere). After a week or two, transplant any growing embryos to a pot of peat and sand and see if you can by-pass months or years of stratification (incubation of moist seeds at c. 4°C between layers of sand or soil).

# Vegetative propagation

Propagation is the creation of a new plant from a cutting of a branch taken from the parent plant. Many woody species found in Britain can be propagated from cuttings. Poplars and willows are the best examples and the easiest to propagate, but it is also possible to propagate apple, cherry, dogwood and hazel. However, it is important to remember that vegetatively propagated material can only have the genes of the parent plant, whereas seed material will certainly contain female genes from the mother plant and probably male genes from the pollen of a separate plant. If a wider gene base is important, seed may be the preferred route, or care should be taken to collect cuttings from a varied population or populations.

# Sowing seeds and raising seedlings

The three essential requirements for the germination of any mature, live, non-dormant seed are adequate water, good aeration and a favourable temperature.

Although light is often thought of as a further essential for germination, it is now believed to stimulate germination speed or final germination percentage by acting as a dormancy breakage agent, not as an essential requirement for the germination process itself. Light, of course is essential for the subsequent development of normal, healthy seedlings with green cotyledons (the first leaf to grow from a germinating seed) and leaves.

The three main steps or stages in sowing seeds and raising seedlings are:

1. Take pretreated, non-dormant (occasionally 'chitted' or sprouted) seeds and undertake one of the following:
  - Sow onto or into any moisture-retaining medium of loose particles such as peat, peat alternative, sand, soil, moss, perlite, vermiculite (or any desired mix of these) contained in a plant pot. Gently firm the surface. Cover with a layer of light coloured grit no deeper than 2–3 mm; or
  - Broadcast sow onto suitably cultivated soil. Gently firm into the surface. Cover with a layer of light coloured grit no deeper than 2–3 mm; or
  - Sow in drills prepared to a depth of no more than three times the diameter of the seed. Back fill the drill.
2. Provide a suitable environment for germination either naturally (outdoors) or artificially (e.g. on a shaded window ledge, in a cold-frame, glass house or poly-tunnel). Water, ventilate and shade as necessary.

It is important to remember how significantly temperature influences germination (Figure 9). For example, the seeds of deeply dormant species tend to germinate at higher percentages at lower temperatures of 10–15°C. It is also important to remember that temperatures of 20°C and above inhibit the germination of most deeply dormant seeds, and they can also re-impose a secondary seed dormancy which is just as time consuming to overcome with pretreatment as the primary dormancy. Another thing to bear in mind is that the germination of many deeply- and shallowly- dormant tree seeds also benefits from daily temperature fluctuations. Finally, ensure that the seeds are protected from mice, slugs, snails, and excessive cold, heat and damp.

3. Transplant seedlings to a wider spacing when necessary. This will result in sturdy young plants that are more likely to successfully establish in open ground when they are ultimately transplanted to their final growing position.

### Ungerminated 'failures'

Even when every possible care has been taken to handle tree seeds carefully, store them properly, pretreat them correctly and sow and nurture them optimally, some seeds apparently fail to grow. Don't give up hope – they might still only be dormant. Leave any ungerminated seeds in the ground or put pots back in the corner of the garden, and keep an eye on them for another two or three years. Many of the seeds of deeply dormant species might yet respond to natural conditions and ultimately yield seedlings.

## Transplanting to final growing position

In due course, you will want to transplant your seedlings or saplings to their final growing position. Successful establishment requires as much care and attention as you have spent on pretreating the seeds and growing the seedlings, but the details are beyond the scope of this Guide. A good source of information is given in the Forestry Commission Bulletin 121 *Forest tree seedlings*.

Figure 10

Transplanting a sapling of a native tree to its final growing position. Perthshire, Scotland.



# Further reading

## Forestry Commission publications

Forestry Commission Practice Note 12:

- Handling and storing acorns & chestnuts and sycamore fruits

Forestry Commission Bulletin 121:

- Forest tree seedlings: best practice in supply, treatment and planting
- Forest reproductive materials: regulations controlling seed, cuttings and planting stock for forestry in Great Britain

For ordering information and details of these and other Forestry Commission publications, visit our online publications catalogue at [www.forestry.gov.uk/publications](http://www.forestry.gov.uk/publications)

## Other publications

Agency for the protection of the environment and for technical services (APAT) Roma, Italy

- Seed propagation of Mediterranean trees and shrubs

British Columbia Ministry of Forests

- Native woody plant seed collection guide for British Columbia
- Seed Handling Guidebook

Conservation Volunteers Northern Ireland

- Our trees – A guide to growing Northern Ireland's native trees from seed

Danida Forest Seed Centre.

- Guide to handling of tropical and sub-tropical forest seed

Institute National de la Recherche Agronomique (INRA)

- Seeds of forest broadleaves: from harvest to sowing

The Tree Council

- The good seed guide

## Useful websites

Royal Botanic Gardens, Kew

- Seed Information Database (release 7.0) – [www.kew.org/data/sid](http://www.kew.org/data/sid)

United States Forest Service

- Woody plant seed manual – [www.nsl.fs.fed.us/wpsm](http://www.nsl.fs.fed.us/wpsm)

# Storage and pretreatment summary

Appendix 1 is arranged alphabetically by genus and species and summarises the storage properties, dormancy characteristics and pretreatment durations for over 120 woody species commonly grown in Britain. Use the table to select an individual species and find practical guidance on storability and especially likely pretreatment durations. Then use Appendix 2 to implement the practical methods required to overcome either hard-seededness, deep or shallow dormancy.

Scientific name	Common name	Storage/dormancy characteristics	Storage moisture content and temperatures	Pretreatment weeks warm (c. 15°C)	Pretreatment weeks cold (c. 4°C)	Efficacy of pretreatment/ remarks	Approximate date to initiate pretreatment (for 1 March sowing)
<i>Abies alba</i>	Fir (European silver)	Intermediate <sup>a</sup> /Shallow	9–12% @ < -5°C	0	8 (6–12)	1	4 January
<i>Abies balsamea</i>	Fir (balsam)	Intermediate <sup>a</sup> /Shallow	9–12% @ < -5°C	0	8 (6–12)	1	4 January
<i>Abies concolor</i>	Fir (Colorado white)	Intermediate <sup>a</sup> /Shallow	9–12% @ < -5°C	0	8 (6–12)	1	4 January
<i>Abies fraseri</i>	Fir (Fraser)	Intermediate <sup>a</sup> /Shallow	9–12% @ < -5°C	0	8 (6–12)	1	4 January
<i>Abies grandis</i>	Fir (grand)	Intermediate <sup>a</sup> /Shallow	9–12% @ < -5°C	0	8 (6–12)	1	4 January
<i>Abies nordmanniana</i>	Fir (Caucasian)	Intermediate <sup>a</sup> /Shallow	9–12% @ < -5°C	0	8 (6–12)	1	4 January
<i>Abies procera</i>	Fir (noble)	Intermediate <sup>a</sup> /Shallow	9–12% @ < -5°C	0	8 (6–12)	1	4 January
<i>Acer campestre</i>	Maple (field)	Intermediate <sup>a</sup> /Shallow	10–15% @ < 0°C	8 (4–8)	24 (20–24)	3	19 July
<i>Acer platanoides</i>	Maple (Norway)	Intermediate <sup>a</sup> /Shallow	10–15% @ < 0°C	0	16 (12–20)	2 (dry slowly)	8 November
<i>Acer pseudoplatanus</i>	Sycamore	Recalcitrant/Deep	Store moist @ 4°C	0	12 (8–16)	2	6 December
<i>Aesculus hippocastanum</i>	Horse chestnut	Recalcitrant <sup>b</sup>	Store moist @ 4°C	–	–	–	–
<i>Alnus cordata</i>	Alder (Italian)	Orthodox/Shallow	8–10% @ < 4°C	0	6 (3–9)	1	18 January
<i>Alnus glutinosa</i>	Alder (black or common)	Orthodox/Shallow	8–10% @ < 4°C	0	6 (3–9)	1	18 January
<i>Alnus incana</i>	Alder (grey)	Orthodox/Shallow	8–10% @ < 4°C	0	6 (3–9)	1	18 January
<i>Alnus rubra</i>	Alder (red)	Orthodox/Shallow	8–10% @ < 4°C	0	6 (3–9)	1	18 January
<i>Alnus viridis</i>	Alder (green)	Orthodox/Shallow	8–10% @ < 4°C	0	6 (3–9)	1	18 January
<i>Araucaria araucana</i>	Monkey puzzle	Recalcitrant <sup>b</sup>	Store moist @ 4°C	–	–	–	–
<i>Arbutus unedo</i>	Strawberry tree	Orthodox/Deep	10–12% @ < 0°C	0	12 (8–14)	2	6 December
<i>Betula pendula</i>	Birch (silver)	Orthodox/Shallow	8–10% @ < 4°C	0	6 (3–9)	1 (high % empty)	18 January
<i>Betula pubescens</i>	Birch (downy)	Orthodox/Shallow	8–10% @ < 4°C	0	6 (3–9)	1 (high % empty)	18 January
<i>Calocedrus decurrens</i>	Incense cedar	Intermediate <sup>a</sup> /Shallow	9–12% @ < -5°C	0	4 (4–8)	2	1 February
<i>Carpinus betulus</i>	Hornbeam	Orthodox/Deep	10–12% @ < 0°C	4 (4–8)	24 (16–24)	3	16 August
<i>Castanea sativa</i>	Chestnut (sweet)	Recalcitrant <sup>b</sup>	Store moist @ 4°C	–	–	–	–
<i>Cedrus atlantica</i>	Cedar (Atlas)	Intermediate <sup>a</sup> /Shallow	9–12% @ < -5°C	0	8 (6–12)	1	4 January
<i>Cedrus deodara</i>	Deodar	Intermediate <sup>a</sup> /Shallow	9–12% @ < -5°C	0	8 (6–12)	1	4 January
<i>Cedrus libani</i>	Cedar (Lebanon)	Intermediate <sup>a</sup> /Shallow	9–12% @ < -5°C	0	8 (6–12)	1	4 January
<i>Chamaecyparis lawsoniana</i>	Lawson's cypress	Intermediate <sup>a</sup> /Shallow	9–12% @ < -5°C	0	6 (3–9)	1	18 January
<i>Cornus alba</i>	Dogwood (red-barked)	Orthodox/Deep	10–12% @ < 0°C	0	14 (12–20)	2	22 November
<i>Cornus mas</i>	Cornelian cherry	Orthodox/Deep	10–12% @ < 0°C	16 (12–20)	16 (12–20)	2	19 July
<i>Cornus sanguinea</i>	Dogwood	Orthodox/Deep	10–12% @ < 0°C	8 (8–12)	12 (12–20)	2	11 October
<i>Corylus avellana</i>	Hazel	Orthodox/Deep	10–15% @ < 0°C	0	16 (16–20)	3	8 November
<i>Crataegus laevigata</i>	Hawthorn (Midland)	Orthodox/Deep	10–12% @ < 0°C	8 (4–12)	26 (24–32)	3	5 July
<i>Crataegus monogyna</i>	Hawthorn (common)	Orthodox/Deep	10–12% @ < 0°C	8 (4–12)	26 (24–32)	3	5 July
<i>Cryptomeria japonica</i>	Japanese red cedar	Intermediate <sup>a</sup> /Shallow	9–12% @ < -5°C	0	6 (3–9)	1	18 January
<i>Cytisus scoparius</i>	Broom	Orthodox/Hard	6–8% @ < 4°C	–	–	1	–
<i>Euonymus europaeus</i>	Spindle	Orthodox/Deep	10–15% @ < 0°C	10 (8–12)	16 (8–16)	3	30 August
<i>Fagus sylvatica</i>	Beech	Intermediate <sup>a</sup> /Deep	15% @ < -5°C	0	16 (12–20)	2	8 November
<i>Fraxula alnus</i>	Buckthorn (alder)	Orthodox/Deep	10–15% @ < 0°C	0	8 (8–12)	2	4 January
<i>Fraxinus excelsior</i>	Ash	Orthodox/Deep	10–12% @ < 0°C	16 (8–16)	20 (16–32)	2	21 June
<i>Ginkgo biloba</i>	Maidenhair tree	Orthodox/Deep	10–15% @ < 0°C	4 (4–8)	8 (8–12)	2	6 December
<i>Hamamelis mollis</i>	Wych hazel	Orthodox/Deep	10–15% @ < 0°C	10 (8–16)	16 (12–20)	3	30 August
<i>Hippophae rhamnoides</i>	Buckthorn (sea)	Orthodox/Deep	10–12% @ < 0°C	0	12 (12–16)	2	6 December
<i>Ilex aquifolium</i>	Holly	Orthodox/Deep	10–12% @ < 0°C	40 (28–52)	24 (20–52)	3	6 December (–2 yr)
<i>Juglans nigra</i>	Walnut (black)	Orthodox/Deep	10–15% @ < 0°C	0	20 (16–24)	3	11 October
<i>Juglans regia</i>	Walnut (English)	Orthodox/Deep	10–15% @ < 0°C	0	20 (16–24)	3	11 October
<i>Juniperus communis</i>	Juniper	Orthodox/Deep	10–15% @ < 0°C	40 (12–52)	24 (12–36)	3	6 December (–2 yr)
<i>Laburnum alpinum</i>	Laburnum (Scotch)	Orthodox/Hard	6–8% @ < 4°C	–	–	1	–
<i>Laburnum anagyroides</i>	Laburnum (common)	Orthodox/Hard	6–8% @ < 4°C	–	–	1	–
<i>Larix decidua</i>	Larch (European)	Orthodox/Shallow	6–8% @ < 4°C	0	6 (3–9)	1	18 January
<i>Larix kaempferi</i>	Larch (Japanese)	Orthodox/Shallow	6–8% @ < 4°C	0	6 (3–9)	1	18 January
<i>Larix x eurolepis</i>	Larch (hybrid)	Orthodox/Shallow	6–8% @ < 4°C	0	6 (3–9)	1	18 January
<i>Laurus nobilis</i>	Bay laurel	Intermediate <sup>a</sup> /Deep	10–15% @ < -5°C	0	8 (6–12)	2	4 January
<i>Ligustrum vulgare</i>	Privet	Orthodox/Deep	10–15% @ < 0°C	0	8 (8–12)	2	4 January
<i>Liquidambar styraciflua</i>	Sweet gum	Orthodox/Shallow	c.10% @ < 4°C	0	3 (0–9)	1	8 February
<i>Liriodendron tulipifera</i>	Tulip tree	Orthodox/Deep	c.10% @ < 4°C	0	20 (16–24)	2	11 October
<i>Lupinus arboreus</i>	Tree lupin	Orthodox/Hard	6–8% @ < 4°C	–	–	1	–



# Appendix 1

Scientific name	Common name	Storage/dormancy characteristics	Storage moisture content and temperatures	Pretreatment weeks warm (c. 15°C)	Pretreatment weeks cold (c. 4°C)	Efficacy of pretreatment/ remarks	Approximate date to initiate pretreatment (for 1 March sowing)
<i>Malus sylvestris</i>	Apple (wild/crab)	Orthodox/Deep	10–15% @ < 0°C	2	14 (8–16)	3	8 November
<i>Metasequoia glyptostroboides</i>	Dawn redwood	Intermediate <sup>a</sup> /Shallow	9–12% @ < –5°C	0	6 (3–9)	1	18 January
<i>Morus nigra</i>	Mulberry (black)	Orthodox/Deep	10–15% @ < 0°C	0	8 (8–16)	2	4 January
<i>Nothofagus nervosa</i>	Southern beech (rauli)	Orthodox/Shallow	8–10% @ < 4°C	0	8 (6–12)	1	4 January
<i>Nothofagus obliqua</i>	Southern beech (roble)	Orthodox/Shallow	8–10% @ < 4°C	0	8 (6–12)	1	4 January
<i>Picea abies</i>	Spruce (Norway)	Orthodox/Shallow	6–8% @ < 4°C	0	6 (3–9)	1	18 January
<i>Picea omorika</i>	Spruce (Omorika)	Orthodox/Shallow	6–8% @ < 4°C	0	6 (3–9)	1	18 January
<i>Picea pungens</i>	Spruce (blue)	Orthodox/Shallow	6–8% @ < 4°C	0	6 (3–9)	1	18 January
<i>Picea sitchensis</i>	Spruce (Sitka)	Orthodox/Shallow	6–8% @ < 4°C	0	6 (3–9)	1	18 January
<i>Pinus contorta</i>	Pine (lodgepole)	Orthodox/Shallow	6–8% @ < 4°C	0	6 (3–9)	1	18 January
<i>Pinus muricata</i>	Pine (bishop)	Orthodox/Shallow	6–8% @ < 4°C	0	6 (3–9)	1	18 January
<i>Pinus nigra</i>	Pine (Austrian)	Orthodox/Shallow	6–8% @ < 4°C	0	6 (3–9)	1	18 January
<i>Pinus nigra ssp. laricio</i>	Pine (Corsican)	Orthodox/Shallow	6–8% @ < 4°C	0	6 (3–9)	1	18 January
<i>Pinus peuce</i>	Pine (Macedonian)	Orthodox/Deep	6–8% @ < 4°C	0	30 (20–40)	3	2 August
<i>Pinus pinaster</i>	Pine (maritime)	Orthodox/Shallow	6–8% @ < 4°C	0	6 (3–9)	1	18 January
<i>Pinus radiata</i>	Pine (Monterey)	Orthodox/Shallow	6–8% @ < 4°C	0	6 (3–9)	1	18 January
<i>Pinus sylvestris</i>	Pine (Scots)	Orthodox/Shallow	6–8% @ < 4°C	0	6 (3–9)	1	18 January
<i>Populus canescens</i>	Poplar (grey)	Recalcitrant <sup>c</sup>	Store moist @ 4°C	–	–	–	–
<i>Populus nigra</i>	Poplar (black)	Recalcitrant <sup>c</sup>	Store moist @ 4°C	–	–	–	–
<i>Populus nigra var. betulifolia</i>	Poplar (downy black)	Recalcitrant <sup>c</sup>	Store moist @ 4°C	–	–	–	–
<i>Populus tremula</i>	Poplar (aspen)	Recalcitrant <sup>c</sup>	Store moist @ 4°C	–	–	–	–
<i>Prunus avium</i>	Cherry (wild)	Orthodox/Deep	10–12% @ < 0°C	2 (2–8)	18 (16–24)	3	11 October
<i>Prunus cerasifera</i>	Cherry-plum	Orthodox/Deep	10–12% @ < 0°C	2 (2–8)	30 (20–36)	3	19 July
<i>Prunus padus</i>	Cherry (bird)	Orthodox/Deep	10–12% @ < 0°C	2 (2–8)	18 (16–20)	2	11 October
<i>Prunus spinosa</i>	Sloe	Orthodox/Deep	10–12% @ < 0°C	2 (2–4)	18 (16–20)	2	11 October
<i>Pseudotsuga menziesii</i>	Douglas fir	Orthodox/Shallow	6–8% @ < 4°C	0	6 (3–9)	1	18 January
<i>Quercus cerris</i>	Oak (Turkey)	Recalcitrant <sup>b</sup>	Store moist @ 4°C	–	–	–	–
<i>Quercus ilex</i>	Oak (holm)	Recalcitrant <sup>b</sup>	Store moist @ 4°C	–	–	–	–
<i>Quercus petraea</i>	Oak (sessile)	Recalcitrant <sup>b</sup>	Store moist @ 4°C	–	–	–	–
<i>Quercus robur</i>	Oak (pedunculate)	Recalcitrant <sup>b</sup>	Store moist @ 4°C	–	–	–	–
<i>Quercus rubra</i>	Oak (red)	Recalcitrant <sup>b</sup>	Store moist @ 4°C	–	–	–	–
<i>Rhamnus cathartica</i>	Buckthorn (common)	Orthodox/Deep	ca10% @ < 4°C	0	8 (8–16)	2	4 January
<i>Robinia pseudoacacia</i>	False acacia	Orthodox/Hard	6–8% @ < 4°C	–	–	1	–
<i>Rosa arvensis</i>	Rose (field)	Orthodox/Deep	10–15% @ < 0°C	12 (8–12)	12 (8–12)	2	13 September
<i>Rosa canina</i>	Rose (dog)	Orthodox/Deep	10–15% @ < 0°C	12 (8–12)	12 (8–12)	2	13 September
<i>Rubus fruticosus</i>	Blackberry	Orthodox/Deep	10–15% @ < 0°C	10 (8–12)	12 (12–16)	3	27 September
<i>Ruscus aculeatus</i>	Butchers broom	Orthodox/Deep	10–15% @ < 0°C	8 (8–12)	12 (12–20)	2	11 October
<i>Salix alba</i>	Willow (white)	Recalcitrant <sup>c</sup>	Store moist @ 4°C	–	–	–	–
<i>Salix aurita</i>	Willow (eared)	Recalcitrant <sup>c</sup>	Store moist @ 4°C	–	–	–	–
<i>Salix caprea</i>	Willow (goat)	Recalcitrant <sup>c</sup>	Store moist @ 4°C	–	–	–	–
<i>Salix cinerea</i>	Willow (grey)	Recalcitrant <sup>c</sup>	Store moist @ 4°C	–	–	–	–
<i>Salix fragilis</i>	Willow (crack)	Recalcitrant <sup>c</sup>	Store moist @ 4°C	–	–	–	–
<i>Salix pentandra</i>	Willow (bay)	Recalcitrant <sup>c</sup>	Store moist @ 4°C	–	–	–	–
<i>Salix purpurea</i>	Willow (purple)	Recalcitrant <sup>c</sup>	Store moist @ 4°C	–	–	–	–
<i>Salix triandra</i>	Willow (almond)	Recalcitrant <sup>c</sup>	Store moist @ 4°C	–	–	–	–
<i>Salix viminalis</i>	Willow (osier)	Recalcitrant <sup>c</sup>	Store moist @ 4°C	–	–	–	–
<i>Sambucus nigra</i>	Elder	Orthodox/Deep	c. 10% @ < 4°C	10 (8–12)	12 (12–16)	3	27 September
<i>Sequoia sempervirens</i>	Coast redwood	Intermediate <sup>a</sup> /Shallow	9–12% @ < –5°C	0	6 (3–9)	1	18 January
<i>Sequoiadendron giganteum</i>	Wellingtonia	Intermediate <sup>a</sup> /Shallow	9–12% @ < –5°C	0	6 (3–9)	1	18 January
<i>Sorbus aria</i>	Whitebeam	Orthodox/Deep	10–12% @ < 0°C	2 (2–4)	16 (12–16)	2	25 October
<i>Sorbus aucuparia</i>	Rowan	Orthodox/Deep	10–12% @ < 0°C	2 (2–4)	30 (16–30)	3	19 July
<i>Sorbus intermedia</i>	Whitebeam (Swedish)	Orthodox/Deep	10–12% @ < 0°C	2 (2–4)	16 (12–16)	2	25 October
<i>Sorbus torminalis</i>	Wild service tree	Orthodox/Deep	10–12% @ < 0°C	2 (2–4)	30 (16–30)	2	19 July
<i>Taxodium distichum</i>	Swamp cypress	Orthodox(?) / Deep(?)	10–12% @ < 0°C	0	12 (8–16)	2	6 December
<i>Taxus baccata</i>	Yew	Orthodox/Deep	10–12% @ < 0°C	24 (20–52)	40 (32–52)	3 (toxic)	6 December (–2 yr)
<i>Thuja plicata</i>	Western red-cedar	Intermediate <sup>a</sup> /Shallow	9–12% @ < –5°C	0	6 (3–9)	1	18 January
<i>Tilia cordata</i>	Lime (small-leaved)	Orthodox/Deep	10–15% @ < 0°C	16 (16–20)	16 (16–20)	3	19 July
<i>Tilia platyphyllos</i>	Lime (large-leaved)	Orthodox/Deep	10–15% @ < 0°C	16 (16–20)	16 (16–20)	3	19 July
<i>Tilia x europaea</i>	Lime (common)	Orthodox/Deep	10–15% @ < 0°C	16 (16–20)	16 (16–20)	3	19 July
<i>Tsuga heterophylla</i>	Western hemlock	Intermediate <sup>a</sup> /Shallow	9–12% @ < –5°C	0	6 (3–9)	1	18 January
<i>Ulex europaeus</i>	Gorse	Orthodox/Hard	6–8% @ < 4°C	–	–	1	–
<i>Ulmus glabra</i>	Elm (wych)	Orthodox/Deep	10–15% @ < 0°C	0	8 (8–12)	1 (high % empty)	4 January
<i>Viburnum lantana</i>	Wayfaring tree	Orthodox/Deep	10–15% @ < 0°C	0	10 (8–12)	2	20 December
<i>Viburnum opulus</i>	Guelder rose	Orthodox/Deep	10–15% @ < 0°C	4 (4–8)	8 (8–12)	3	6 December

## General table notes

Bracketed numbers represent commonly observed pretreatment variation between seed lots.

a Maximum advisable storage c. 3 years @ c.10% moisture content –10°C.

b Maximum advisable storage c.18–24 weeks in non-drying conditions @ 0°C.

c Maximum advisable storage c. 4 weeks in non-drying conditions @ 0°C.

## Efficacy of pretreatment column

1 Generally effective: a significant proportion of live seeds should germinate.

2 Generally effective: although pretreatment durations, and numbers of repeat cycles may vary significantly between seedlots.

3 Only partially effective: even with the longest pretreatment durations and/or several pretreatment cycles.

## Pretreatment of hard-seeded species

Seeds of these species possess a thick, impermeable seed coat which prevents germination by significantly retarding water uptake, respiratory gas exchange or both. Pretreatment consists of removing, splitting, puncturing (Figure A2.1), abrading (Figure A2.2), softening (Figure A2.3) or burning (Figure A2.4) the hard seed coat – without damaging the embryo within.

The following species are the only seeds of woody plants which do not need to be moist in order to respond to any pretreatments, but they need subsequent moistening to germinate.

- broom (*Cytisus scoparius*)
- common laburnum (*Laburnum anagyroides*)
- false acacia (*Robinia pseudoacacia*)
- gorse (*Ulex europeaus*)
- Scotch laburnum (*Laburnum alpinum*)
- tree lupin (*Lupinus arboreus*)

**Figure A2.1** Chipping

Hold seed down with an eraser. Use a sharp knife or scalpel to chip away a small section of seed coat without significantly damaging the embryo. Wear safety spectacles.



**Figure A2.3** Softening

Pour 3–10 volumes of boiling/hot water on to 1 volume of seeds. Allow seeds and water to cool for 18–24 hours. This will give time to observe whether the majority of seeds have swollen through imbibition or not.



**Figure A2.2** Abrasion

Use a file or abrasive paper to remove a small section of the seed coat.



**Figure A2.4** Burning

Make a small hole in the seed coat with a soldering iron or a hot instrument from a fire.



# Pretreatment of deeply- and shallowly-dormant seeds

Deeply dormant seeds (whether freshly collected or dry-stored) generally do not germinate under any conditions until pretreated. Pretreatment consists of exposing imbibed seeds to either a relatively long period of cold conditions (approximately 4°C); or warm (approximately 15°C) then cold conditions (4°C) under moist conditions. Deeply dormant species include most broadleaves (e.g. ash, beech, cherry), plus a few conifers (e.g. juniper, yew, Macedonian pine (*Pinus peuce*)).

Shallowly dormant seeds (whether freshly collected or dry-stored) are usually slow to germinate and are only capable of germinating over a narrow range of conditions until pretreated. Under the 'right' conditions, some seeds will germinate without a dormancy breakage pretreatment, but pretreatment will usually stimulate quicker germination of more seeds over a wider range of conditions. Pretreatment consists of incubating imbibed seeds for a relatively short period of time (three to nine weeks) under moist conditions at approximately 4°C (a so-called pre-chill). Shallowly dormant species include most conifers (e.g. cedars, firs, pines, spruces), and a few broadleaves (e.g. alders and birches).

Figures 9b and 9c illustrate the general characteristics of how temperature influences the germination of untreated and pretreated deeply dormant and shallowly dormant seeds. This shows that deeply dormant species have an absolute requirement for a very lengthy pretreatment in order to stimulate any germination at all, and that the germination of shallowly dormant species is only stimulated under some conditions. It is important to recognise that not only do virtually every different tree species possess a different depth of dormancy, but so do different seed lots of the same species, and even individual seeds within a seed lot. Hence, the optimum pretreatment duration for any particular seed lot will always be a compromise.

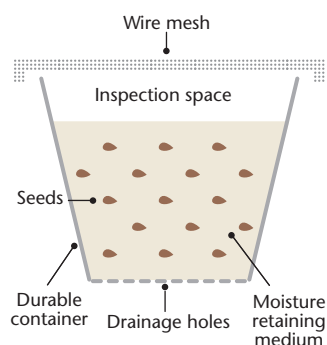
For recommended pretreatment durations for individual species see Appendix 1.

Practical details of 'easy', 'moderate' and 'skilled' pretreatment methods are given below.

## Easy: natural (outdoor) pretreatment/sowing with medium

Figure A3.1

Plant pot covered with rodent-proof wire netting as a suitable pretreatment container.



1. Determine prescribed warm and cold pretreatment durations for individual species from Appendix 1.
2. Prepare a moisture retaining medium by mixing one volume of an organic material (such as peat, decomposed leaf litter, or peat alternative) with one volume of a coarse particle material (such as sand, grit, perlite or vermiculite).
3. Mix one volume of seeds with one volume of the moist medium and distribute seeds uniformly throughout.
4. Place the mixture of seeds and medium in a suitably-sized container which is rodent proof, durable, open to rainwater at the top, and has drainage holes at the base (e.g. a plant pot, transparent plastic bottle or jar; bucket or dustbin). Leave a gap at the top of the container to allow easy inspection, cover with a fine wire mesh (to prevent predation) and label with species, date of collection and start date of pretreatment/sowing.

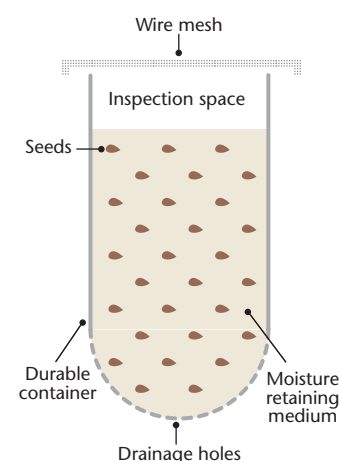
5. Position container outdoors, either against a sheltered, north-facing wall; in a permanently shady position or buried in the ground to receive exposure to seasonal temperature fluctuations, whilst avoiding wide daily temperature changes.
6. Inspect seeds regularly (preferably weekly to fortnightly) for the following:
  - Re-moisten the stratification mix if necessary in dry weather.
  - Remove decaying seeds to prevent the spread of fungal infections.
7. Remove and sow germinating seeds. Or if preferred, when approximately 10% of seeds have begun to split, chit or germinate, sow all of the seeds.

## Moderate: artificial (temperature controlled) pretreatment with medium

1. Determine prescribed warm and cold pretreatment durations for individual species from Appendix 1.
2. Prepare a moisture retaining medium by mixing one volume of an organic material (such as peat, decomposed leaf litter, or peat alternative) with one volume of a coarse particle material (such as sand, grit, perlite or vermiculite).
3. Mix one volume of seeds with one volume of the moist medium and distribute seeds uniformly throughout.
4. Place the mixture of seeds and medium in a suitably sized container (e.g. a plant pot; transparent, plastic bottle or jar; bucket; dustbin or polythene bag). Leave a gap at the top of the container (to allow easy inspection) cover with a fine wire mesh (to prevent predation) and label with species, date of collection and start date of pretreatment.
5. Apply artificial pretreatment regime prescribed in Appendix 1 to break dormancy. Use a 'cool' room (10–15°C) for the warm phase – avoid airing cupboards (too warm) and window ledges (too variable). Use the main compartment of a refrigerator for the chilling phase – avoid the icebox (too cold).
6. Inspect seeds regularly (preferably weekly to fortnightly) for the following:
  - Re-moisten the stratification mix if necessary.
  - Remove decaying seeds to prevent the spread of fungal infections.
7. Undertake one of the following three:
  - apply the prescribed pretreatment durations and sow (with the knowledge that the maximum germination potential of the seed lot may be sacrificed because some seeds may still be dormant); or
  - remove and sow germinating seeds at each inspection; or
  - wait until approximately 10% of seeds have begun to split, chit or germinate and sow whole population.

Figure A3.2

Decapitated plastic bottle covered with drainage holes and rodent-proof wire netting as a suitable pretreatment container.



### Skilled: artificial (temperature controlled) pretreatment without medium

1. Determine prescribed warm and cold pretreatment durations for individual species from Appendix 1.
2. Place seeds in a loosely-tied woven bag in a suitably sized watertight container. Either:
  - wash in cold, running water; or
  - add at least five volumes of cold water, soak at 4°C and change water if it becomes discoloured. Regularly withdraw bag, drain and re-submerge to allow thorough washing and removal of any chemical inhibitors.
3. After 48 hours washing/soaking, drain seeds in a sieve, air- or spin-dry to obtain imbibed, surface dry, free-flowing, easily handled seeds.
4. Transfer imbibed, surface-dry seeds to a polythene bag. Leaving an air gap above the seeds, loosely tie the neck of the polythene bag with a finger sized entrance/exit hole to permit gaseous exchange but retard drying. Apply the artificial pretreatment regime prescribed in Appendix 1 to break dormancy. Use a 'cool' room (10–15°C) for the warm phase – avoid airing cupboards (too warm) and window ledges (too variable). Use the main compartment of a refrigerator for the chilling phase – avoid the icebox (too cold).
5. Inspect seeds regularly (preferably weekly to fortnightly) for the following:
  - Re-moisten if necessary.
  - Remove decaying seeds to prevent the spread of fungal infections.
6. Undertake one of the following three:
  - Apply the prescribed pretreatment durations and sow (with the knowledge that the maximum germination potential of the seed lot may be sacrificed because some seeds may still be dormant); or
  - Remove and sow germinating seeds at each inspection; or
  - Wait until approximately 10% of seeds have begun to split, chit or germinate and sow whole population.

This Practice Guide introduces the principles and practical methods for collecting, storing and propagating from seed a wide range of woody species commonly grown in the British Isles. It is aimed partly at anyone interested in raising a relatively small number of plants, and partly at commercial growers – as a useful reference but without the legal aspects. The Guide begins with information on flowering and fruit development, and recommendations for small-scale collecting, handling and processing. It then provides detailed advice on storage, dormancy and pretreatment methods for over 100 woody species. It gives suggestions of ‘things to try’ to hasten dormancy breakage in the most time consuming and dormant species. The Guide concludes with some tips on sowing seeds and raising seedlings.



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