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Seed Manual for Ornamental Trees and Shrubs

A G Gordon D C F Rowe



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SEED MANUAL
FOR
ORNAMENTAL TREES
AND SHRUBS

by

A. G. Gordon, B.Sc., Agric., Ph.D.

and D. C. F. Rowe, B.Sc.

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Introduction

The Forestry Commission has, until recently, restricted its broadleaved tree seed research to a very small number of species important to the commercial forestry industry. However two factors have brought about a change, firstly a shift in Commission policy towards more amenity and environmental planting and secondly a desire in many trade nurseries to improve on the poor production record from seed for many ornamental tree species.

The British nursery stock industry has traditionally relied heavily upon vegetative propagation. To a considerable extent this has been due to the unreliability of production from seed. Vegetative propagation is the only method of ensuring complete trueness to type, but there are many situations where the natural variation inherent in plants raised from seed will be acceptable, if not actually beneficial.

There is a paucity of published British work on the problems of propagating broadleaved species from seed. Nurserymen have therefore had to rely mainly upon foreign material much of which is outdated, contradictory and unreliable. This has often resulted in seeds being sown on an entirely unplanned and uneconomical basis. Although the cost of the seed itself is perhaps relatively small, a great deal of time and money can be wasted on preparing and maintaining seed-beds for seeds which will never germinate.

The aims of this manual are two-fold. Firstly it presents the practical plant propagator with all the relevant information he needs to ensure reliable production from seed of the more commonly grown ornamental broadleaved species. It includes the latest results of the Forestry Commission's own work and summarises existing information gleaned from experienced nurserymen and the literature. This publication, therefore, updates those parts of Chapters 6 and 7 of Forestry Commission Bulletin 43 (Aldhous, 1972) relating to broadleaved species and replaces Forestry Commission Research Branch Paper 10 (Gray, 1953). It does not attempt to discuss establishment, management and financing of nurseries. These topics are adequately covered in Bulletin 43 or rather more fully in *Hardy Woody Plants from Seed* (McMillan Browse, 1979). For the benefit of the practitioner the recommendations are summarised in appendices 5, 6 and 7 at the end of the manual.

It was felt that a manual of this sort would be incomplete without some recommendation as to where the species covered should be planted. Accordingly a summary of the recommendations made by Alan Mitchell and John Jobling in the book entitled *Decorative Trees for Town and Country* soon to be published by HMSO has been included. For tree species and shrubs not covered by these authors, recommendations were drawn from Brown (1972), Hilliers Manual (1971) and Notcutts Catalogue (1980). The recommendations are given in Appendix 1 along with a full list of the botanical names, synonyms, common names and origins of the species covered by the manual.

The second aim of this manual is to provide the student and interested amateur with a complete scientific background to the subject of raising trees and shrubs from seed, and to act as a reference volume should they wish to pursue their interest more deeply. It will also act as a handbook for anyone involved in seed collection, seed testing and storage. The manual therefore seeks to fill an obvious and important gap in the current British literature on the subject of raising trees and shrubs from seeds.

This manual is divided into two parts: the first part describes general principles of seed biology and seed handling, while the second consists of tables giving detailed information on many aspects of seed origin, production, quality and treatment for individual genera and species. For some species data and experience are sparse and positive recommendations to ensure germination cannot be made. However, these are the only results available and although improved information is likely to be available later, present knowledge has been included for guidance, and as a reference point for further research.

Throughout the chapters of the manual frequent references have been made to individual genera and species. These have been included by page number in Appendix 1 to serve as a specific index. A subject index is included in its own right at the end of the manual.

Sessile, Pedunculate and Red oak and beech are grown as widely for ornamental purposes as they are for commercial forestry. They are the only species included in this manual that are subject to legis-

lation. They will be covered fully in a companion to this, a seed manual of commercial and conifer species, in a Forestry Commission Bulletin but for the sake of completeness they are also included here.

Students should note that throughout most of the manual the term 'seed' is used in its broadest sense to describe any prime dispersal unit of the species here considered comprising a food storage area, a latent growth axis and a restrictive covering. The exception is Chapter 3 where such lax terminology is unsuitable for the topic under discussion and where the term 'seed' is used literally to describe a matured ovule containing an embryo and nutritive tissue enclosed in a coat (testa) or coats (tegmen and testa) derived from the integument(s).

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PART I: SEED BIOLOGY

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Chapter 1

SEED SOURCE-COLLECTION OR PURCHASE?

Once it has been decided to grow stock from seed rather than by purchasing it from home or foreign nurseries, the first decision to be made is on the source of seed. There are two alternatives, either the seed can be collected locally or it can be purchased from one of the commercial seed houses. Each has merits and demerits which deserve close consideration.

Local collections

The local collection of seed has much to recommend it and certainly, since becoming more interested in ornamental broadleaves, the Forestry Commission has encouraged nurserymen to collect their own seed, so long as this can be done legally. (see Chapter 2). Positive identification of at least one of the prospective parents is thus possible and the likelihood of cross-pollination from other species can be assessed. These are both important factors for the nurseryman to consider, which are not always considered by seed merchants. Species often develop their own geographical races which are particularly adapted to their own local conditions, resulting in plants grown from seed collected from one natural environment being unable to fulfil their true potential when grown in another. Similarly, knowledge of how plants, raised from a particular seed source, have grown in local conditions can be of permanent importance. If a specimen or stand of an introduced species has been able to grow well and produce mature seed, then seed collected from that source has a better chance of producing seedlings suited to the local conditions than seed collected at random from the species' natural range. There are other benefits to be gained by a nurseryman making his own collection, such as being able to time collection to avoid deep dormancy (Vincent, 1968) and having seed available when wanted instead of when the seed merchant can supply.

A nurseryman who decides to start making his own collections should begin keeping records from the outset. He should first of all identify good healthy specimens of the species in which he is interested and then make notes of their flowering and fruiting habits, as well as the yield of processed seed. Before any individual collection is made, it is

important to see that the fruit does in fact contain some fertile seed. A lot of time and expense can be wasted if a collection is subsequently found to contain nothing but empty seeds. The greater the set of seeds in each fruit, the more seed will be produced, but it is only by making personal records that knowledge of what constitutes an economical collection will be built up, although the tables in Part II will help.

It is often tempting to collect seed from individual specimen trees in an arboretum or garden because of ease of access. It should be clearly realised that there are dangers associated with this practice. Self pollination almost invariably leads to a poor set of viable seed. The seed produced may be less vigorous and more susceptible to disease. Most importantly if the plant in question is a particular cultivar any progeny raised will not necessarily be true to type. Great care should therefore be taken before giving it the name of the parent (mother) cultivar. On occasions plants raised from such seed can produce interesting new types but such seed should only be used if all the risks are appreciated. For these reasons, seed described by cultivar in seed merchants catalogues should be avoided. When trees of closely related species are grown near together, some hybridisation may take place. Although this may also produce interesting new forms, progeny raised should not be described by the name of the mother species. An example of this is found frequently in the hybridisation that occurs between common *Tilia* species. Imported seeds often produce a whole range of different seedling types. Before making collections it is therefore important to assess the likelihood of cross fertilisation by other species and the number of acceptable pollinating trees in the locality. For most species there should be a minimum of 20 trees within the nearest square kilometre.

Often the advantages associated with local collection are outweighed by the disadvantages. Many of the species required by a nurseryman will not grow in his area and, even if they do, they may well fail to set seed successfully every year or present problems during harvesting and processing which require an unjustifiable expenditure of time and labour. Ultimately the propagator must rely on the commercial seed houses for at least a portion of his supply.

Seed purchases

A nurseryman might decide he cannot undertake all or even part of his seed collections himself and will have to turn to commercial sources of seed. In Britain there are only a few seed merchants offering a complete range of ornamental seed, and nearly all of the seed on offer is from foreign sources. Nurserymen have therefore been forced to rely heavily upon foreign seed sources. The Seed Branch of the Forestry Commission has in recent years offered a limited range of broadleaved species for forestry and ornamental use, but most of this seed has also been imported. From now on the Forestry Commission will only be offering seed of commercial forestry importance. Nurserymen wishing to purchase seed from the Forestry Commission should obtain a catalogue from the Seed Store, Alice Holt Lodge, Wrecclesham, Farnham, Surrey. (Telephone No. Bentley (0420) 22255. Telex 858623).

Commercial seed houses are able to offer extensive ranges of species almost every year because they are able to afford to gather together collections from widely scattered sources and to store them from year to year using facilities normally unavailable to nurseries. However, few seed merchants are able to control strictly the genetic quality of the material they sell. Some operate their own collection teams and thus can control the actual trees from which the seeds are collected, but by far the larger proportion of seed is collected under contract by casual workers for whom economic and not genetic constraints apply. Another source of cheap seed to continental seed merchants is Eastern Europe. Here collections are often made by itinerant workers who are not selective of the localities they collect in and certainly do not avoid collecting from unhealthy or poor quality trees if the trees are fruiting heavily.

The optimum handling and storage conditions have not been investigated scientifically for many ornamental species, and some imported seed lots have not received the individual storage treatment they need and so seed viability has suffered. It is therefore important that when seed is obtained commercially the purchaser should try to ensure that it is covered by a current germination or viability test certificate. (Fuller details of reasons for and methods of seed testing are given in Chapters 2 and 6).

Information on the number of live seed bought is relevant to the price paid for the seed, but is also important for deciding on appropriate sowing density in the nursery.

All seed supplied by the Seed Branch of the Forestry Commission is covered by a Seed Suppliers Certificate giving current details of tests carried out on that seed lot.

Seed origins

Very little work has been done in Britain to identify the best origins of broadleaved species. What little has been done has been devoted to the more commercial species, such as oak, beech and more recently *Nothofagus* and *Eucalyptus*. Little specific advice can be given therefore on choice of origin if home collected seed is not available. Even home collected seed may actually come from foreign origins, as so much foreign ornamental planting stock has been introduced into Britain in the last quarter century. The very variable flushing dates in any one area in the thorn hedges in Britain is good evidence of this. If trees of foreign origin set seed regularly it is a good indication that they are well adapted to British conditions and are therefore acceptable sources.

Although there are some important exceptions, the general principles that apply for those commercial broadleaved species investigated, could justifiably be expected to apply to ornamental broadleaved species. Thus, in general seed from a maritime climate of similar latitude can be expected to yield more suitable plants than seed from a continental climate or very different latitude. If given a choice, nurserymen should choose seed from North West European sources, such as Northern France, Belgium, Holland, Denmark and Germany rather than East or South European sources (Hungary, Romania or Italy). Cost alone should not determine the choice of origin.

REFERENCE

- Vincent, G. (1968) Double dormancy and germination on the example of *Tilia* and *Carpinus* seeds. *International Symposium on Seed Physiology of Woody Plants* (Kornick), p 121-126.

Chapter 2

FOREST SEED LEGISLATION

As a consequence of joining the European Economic Community legislation was introduced into British law laying down genetic standards for and controlling the marketing of seeds and plants of 13 species and one genus of forest trees. (Statutory Instrument 1973, No. 944, *Seeds*, The Forest Reproductive Material Regulations, 1973). Following amendment to the EEC Directives, a revised Statutory Instrument of the same name was issued (1977, No. 891).

Genetic standards

The Forest Reproductive Material Regulations apply to seed and plants for forestry purposes but do not apply to plants and parts of plants (eg poplar cuttings) intended for purposes other than the production of wood (Regulation 3(1)(a)). Thus plants grown for amenity planting are excluded. The only broadleaves covered by the Regulations are all poplars, Pedunculate, Red and Sessile oak and beech.

It is important that nurserymen understand the implications of these Regulations. If they are growing nursery stock of these oaks or beech for ornamental use the genetic standard of the seed they use is not legally controlled. Therefore the seed does not need to come from registered sources (stands specially selected as growing significantly better for forestry purposes than the average). If the stock is to be sold for commercial forestry purposes, the seeds must come from registered sources anywhere in the EEC (or exceptionally, when there is a shortage of seed from registered sources, from special seed lots collected or imported under a licence obtainable on application to the Forestry Commission Headquarters). Where nurserymen are not sure of the ultimate use of their oak or beech planting stock, they would be well advised to use seed from registered stands for all sowings. For other species there are no legally enforceable genetic standards whether or not the seed is destined to produce plants for commercial forestry, although it is to the nurseryman's advantage to see that, where possible, collections are made from good quality healthy trees.

Physical standards

The 1973 FRM Regulations revoked the Seeds Regulations of 1961 (Statutory Instrument 1961 Nos. 212

& 274). The latter required seed test certificates to be issued for all seed sold in Great Britain of 37 tree species (including 15 broadleaved species) as well as many agricultural and horticultural seeds. The FRM Regulations reintroduced seed testing requirements for the 13 species and one genus covered by the Regulations but did not reintroduce the same requirement for the other species previously covered. The difference between the regulations for physical standard and those for genetical standards, is that they apply to all seed sales of the 13 species and one genus whatever the ultimate destination of the planting stock. This means that any seed of Pedunculate, Red, Sessile oak and beech and any species of poplar that is sold in Great Britain for ornamental as well as forestry use must be covered by a current seed test certificate. If any of these seeds have been stored for a significant time in Britain or if they have been harvested in Britain, the test certificate must be issued by the Official Testing Station for forest seed at Alice Holt Lodge. On the other hand if the seed is bought direct from a foreign supplier, or if it has recently been imported but immediately remarketed by a British supplier, then the test certificate presented to the Customs is acceptable. In all cases the information given on the test certificate is required to be passed on to the purchaser by furnishing a Seed Suppliers Certificate at time of delivery of the seed.

Seeds of no other broadleaved species are covered by seed testing requirements and at present there are no intentions of introducing legislation to cover those species that were covered prior to 1973. However, sales of seed fall within the normal consumer protection legislation and merchants selling falsely identified or dead seed are legally responsible for their actions. Retrospective claims never completely compensate a nurseryman for lost planting stock, so he should always insist that a current test certificate is available for any seed he buys. He would also be well advised to establish minimum purity and germination or viability standards, or alternatively minimum numbers of germinable or viable seeds per kilogram before a purchase is confirmed. It is also in a seed merchant's own interest, in the event of a claim, to be able to prove by means of a current test certificate that the seed he has sold is of a certain standard. Even a quick information test carried out

on a small sample will provide some security as well as acting as a guide for sowing density calculation (see Chapter 6).

Although the FRM Regulations specify that seed of the 13 species and one genus imported and marketed must be covered by a seed test certificate, for acorns and, to a lesser extent, beech nuts this poses a very real practical problem. These species cannot be stored for long at harvest moisture contents without losing their quality. It is therefore uneconomical to delay marketing such seed until the seed test certificate is available as this may take up to 4 weeks for oak. Even for beech, where a quick viability test is performed, because the germination test may take up to 26 weeks, a delay of a week may be critical. This difficulty has been recognised by the Forest Authority and the Customs and Excise have been advised. In practice the requirement to present a test certificate on importation, and to supply a Suppliers Certificate at time of marketing the seed has not been strictly enforced.

Seed health standards

Over the years the British authorities have taken the

view that seeds of forest species, unlike several important agricultural crops, are relatively unlikely to introduce new pests and diseases into Britain and should therefore be allowed free entry. This position was based upon the lack of any positive evidence for any tree species, that diseases were transmitted from one generation to another by way of seeds. Seeds of tree species imported into Britain have therefore not required phytosanitary clearance. This is in marked contrast to many foreign countries where phytosanitary certificates are an absolute necessity before tree seed can be allowed in. In some countries disinfection and/or fumigation are an added requirement. This does not apply in Britain, even though some countries insist upon seed for export to Britain being treated in this way.

In 1980 the EEC Plant Health Directive was put into force in Britain by means of four Statutory Instruments (Nos. 420, 449, 450 and 499, 1980). Currently there are no regulations in force in Britain prohibiting the import of seed of tree or shrub species on plant health grounds, nor are phytosanitary certificates required when such seed is imported.

Chapter 3

SEED FORMATION

Some woody plants naturally multiply by vegetative means but almost all trees produce seeds as their principal means of perpetuation and dispersal. The processes by which these seeds are formed are complex and differ greatly between species. They are very susceptible to environmental factors which can either increase or diminish the quality and quantity of seeds finally produced in any year. Through an understanding of these processes it is possible to make an early assessment of potential seed crops, enabling foreseen shortfalls to be covered by prompt orders to one of the commercial seed houses. Details of height, seed-bearing age and seed crop frequency are found in Appendix 2 and of phenology of flowering in Appendix 3.

Flowering

Broadleaved trees, in common with all woody plants, pass through a juvenile or vegetative period during which they are physiologically incapable of flowering or fruiting. The length of this phase varies from species to species: Amur maple (*Acer ginnala*) reaches minimum seed-bearing age after only five years while Sessile oak (*Quercus petraea*) can start producing viable seed only after forty years or more of vegetative growth.

In addition to the variation between species, there is also within species variation concerning the actual age when an individual commences production of seed, due to physiological and environmental conditions. It is normal for each individual tree to devote available resources to overcoming the competition of surrounding plants before it devotes them to reproductive purposes, although sudden acute stresses can stimulate a self-perpetuation response. A tree usually has a very long fecund life span in which to produce the one viable offspring necessary for its eventual replacement, so that seedling can be postponed for some time without risk.

Open-grown trees and those on the edges of stands receive sunlight on a larger portion of their crowns, and flower at an earlier age than those in closed stands and dense shade. (Baldwin, 1942) Trees grown specifically for fruit or seed production are widely spaced within their orchards, thus encouraging maximum seed production at the youngest seed-bearing age possible.

Once a tree attains the ability to flower and fruit naturally, it will normally continue doing so at regular intervals throughout the rest of its life. There will usually be a particularly fruitful period just after rapid vegetative growth has slowed, during middle age (Matthews, 1963) but with the advent of over-maturity flowering will eventually decline.

The exact processes which lead to a change from vegetative growth to flower initiation and development are still largely unknown. The vegetative meristematic tissues suddenly change to produce initials which will form reproductive structures. Among temperate species this change normally occurs in the late growing season preceding the floral bud break although the flower initials can be formed any time up to a year before the buds develop and open. The precise times of flower initiation and opening vary by as much as one month from year to year, even for an individual, depending on climatic conditions, with low temperatures markedly delaying and prolonging the time taken for buds to open.

Broadleaved trees are angiosperms and produce flowers consisting of all or some of the following parts: a *peduncle* (stalk), a *receptacle* (the swollen end of the peduncle to which other parts are attached), a *calyx* (sepals), a *corolla* (petals), *stamens* (composed of anthers and filaments) and one or more pistils each having a stigma, style and ovary (see Figure 1). A flower exhibiting all these parts is said to be *complete* while the lack or non-functioning of any one of these parts results in an *incomplete* flower. Though lacking the *accessory* parts (calyx and corolla) a flower is *perfect* when it has both stamens and pistil but *imperfect* when either functioning stamens or functioning pistils are absent. Imperfect flowers are also termed *unisexual* while perfect flowers may be called either *bisexual* or *hermaphrodite*. If the only functioning sex organs present are the stamens then the imperfect flower is staminate (often called male) while if the pistil is the only active organ then the flower is *pistillate* (or female).

Staminate and pistillate flowers may be borne on the same tree, as in alders (*Alnus*) and birches (*Betula*) which are called *monoecious* species; or on separate trees, as in some maple (*Acer*) or holly (*Ilex*) species, which are called *dioecious* species. In some instances both perfect and unisexual flowers occur on the

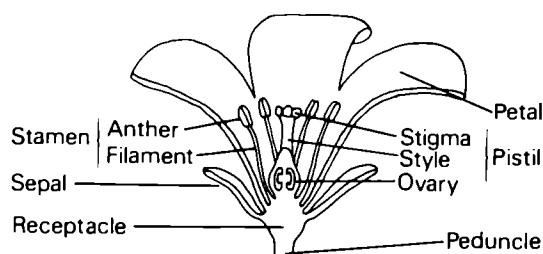


Figure 1 Diagrammatic representation of a typical complete flower.

same plant. When selecting possible parent plants for seed collection it should be remembered that

only plants bearing pistillate or perfect flowers can produce seed.

Pollination and Fertilisation

Pollination is the transfer, by some means, of the pollen grains from stamens to pistils, while fertilisation is the actual union of the male pollen grain nuclei with the female nuclei of the ovules. To ensure fertilisation, pollen dispersal and stigma receptivity must more or less overlap within any species, although even when the individual is monoecious or bears perfect flowers fertilisation may not take place. This separation of male and female flowering benefits most tree species because the timing differences reduce the chances of self-pollination.

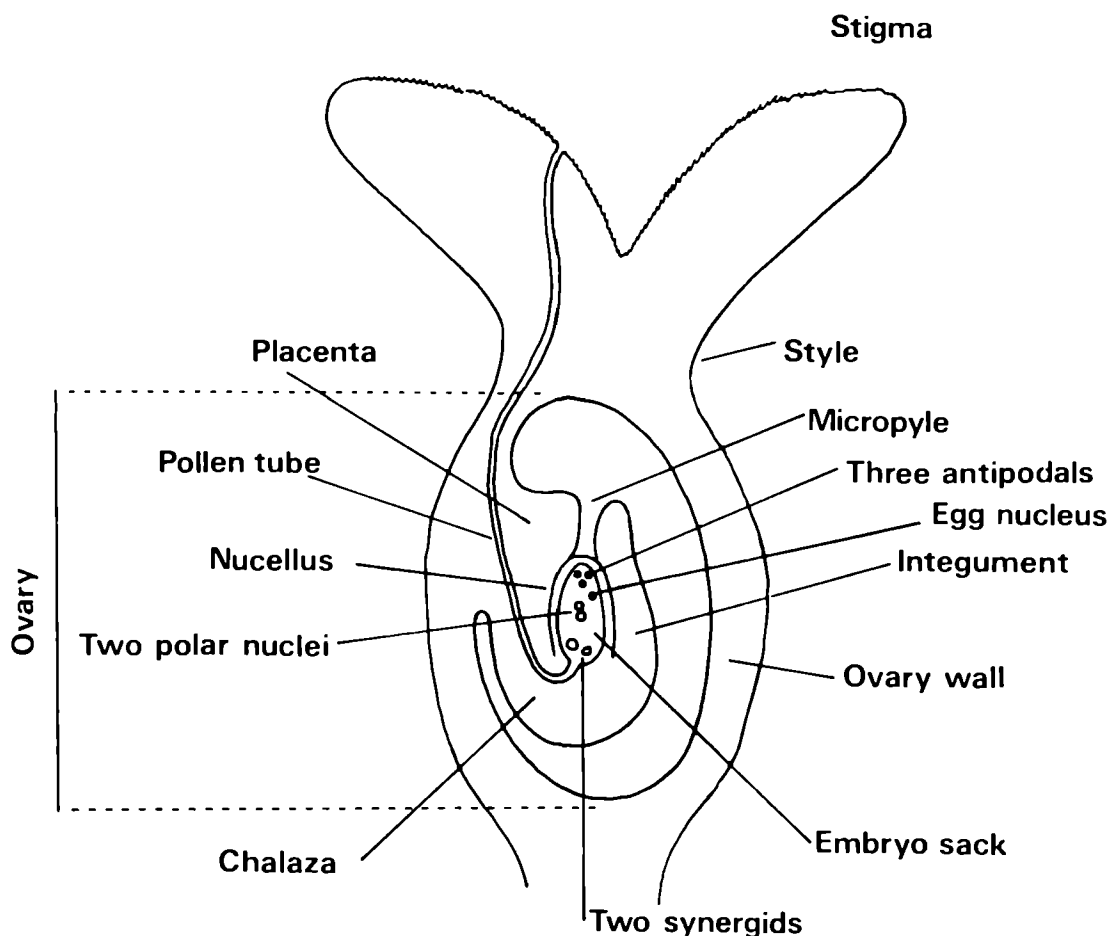


Figure 2 Diagrammatic representation of female flower shortly before fertilisation.

nation which can result in embryo abortion and empty seed production or in progeny less vigorous than those resulting from cross-pollination. In many other members of the plant kingdom eg cereals, self-fertilisation is the norm. There are two main methods by which angiosperm tree and shrub species achieve pollination; these are wind and insects.

Wind pollinated flowers often open before the leaves as in poplar (*Populus*) or concurrently with the unfolding of leaves as in walnut (*Juglans*) but this is not always the case. Beech (*Fagus*) flowers just after the foliage has emerged. A common feature of wind pollinated flowers is the lack of accessory floral parts resulting in rather inconspicuous flowers like those of elms (*Ulmus*) and ash (*Fraxinus*) but the most common feature of many wind-pollinated species is their production of catkins, eg birches (*Betula*) and oaks (*Quercus*). Conversely insect pollination normally occurs in those species with brightly coloured or scented flowers, eg apple (*Malus*) and cherries (*Prunus*). Sometimes other agents, eg birds, also affect pollination.

Development, release and dispersal of pollen from the anthers are all dependent on the weather, so adverse conditions can lead to a reduction in the amount of seed that is set. Low temperatures and heavy rainfall curtail insect activity and prevent shedding and dispersal of windborne pollen, while excessively dry winds can also cause damage by encouraging premature pollen shedding with subsequent dessication of the released pollen grains. Even under conditions ideal for dispersal the pollen grains must reach a receptive stigma comparatively quickly as the pollen loses its viability in a matter of days, hours or even just minutes, depending on the species (Maheshwari, 1950).

The receptive period of an individual stigma also varies greatly between species but usually lasts a matter of days. The stigma tip is endowed with hairs, sticky secretions or specialised surfaces to facilitate pollen retention. Viable pollen grains which are compatible with the stigma soon germinate to form a pollen tube which grows down between the cells of the stigma and style towards an ovule. Each ovule is usually penetrated by one pollen tube only. This discharges two pollen nuclei into an embryo-sac which generally contains eight cells. During fertilisation one of these cells, the egg cell, unites with one of the pollen nuclei to form a zygote which develops into an embryo. The other pollen nucleus unites with what are termed the two polar cell nuclei (see Figure 2) and the resulting fused nucleus develops into the endosperm. The remaining five embryo-sac nuclei disintegrate as the embryo and endosperm begin to divide and develop. Sometimes plants, especially hybrids, may develop seed without

any fertilisation taking place (apomixis). Examples include many of the hybrid *Cotoneaster* species (eg *C. splendens*). The genus *Sorbus* is more or less completely apomictic. Seed collected from an apomictic species will develop into progeny resembling the mother plant.

Development and Structure of Fruit and Seeds

A fruit is generally described as a matured ovary, although in some fruits various accessory parts such as the receptacle, involucre (husk), calyx and style are also included.

The life history of a fruit starts with the formation within the flower bud of the ovary containing the ovule or ovules. Development then ceases until pollination, and usually fertilisation, of at least one ovule has occurred. Post-fertilisation growth is mostly by cell enlargement in the fruit and by cell multiplication in the seed. Fertilisation does not guarantee fruit formation as the process can be halted, by adverse conditions, at almost any time up to full maturity, with consequent seed abortion and fruit drop.

Fruit growth and development is normally regulated by growth substances produced by the developing ovules although in a few species fruits are set and mature without seed development and without fertilisation of an ovule. Such fruits, called *parthenocarpic fruits*, are well known, and often desirable in cultivated species but parthenocarpy also occurs in several genera of forest trees including some species of *Acer*, *Betula*, *Carpinus*, *Fraxinus* and *Ulmus*. As the fruit ripens, metabolic rates continually rise towards a climax and carbohydrates, organic acids and nitrogenous compounds are produced. Water also plays a dynamic part. Diurnal variations in water content due to transpiration are followed by a marked decrease associated with maturation in fruits which are dry, or by large increases in fruits which are fleshy when ripe eg berries. Several other metabolic changes are involved as the fruits of different species mature, including the loss of chlorophyll, the development, or uncovering, of colours (anthocyanins), softening of fleshy fruits, development of flavour and odour, differential desiccation of some dry fruits, and increases, decreases or alterations in various chemical constituents (Kozłowski, 1971).

Botanists have long classified tree fruits according to their development and structure. If their origin can be traced to a single pistil, they are known as simple fruits, but when two or more pistils are involved in their formation, they are said to be *compound*. Both types of fruit may be dry or fleshy. Dry fruits may be papery, leathery or woody. When

mature, some may split along definite lines of suture to release their seeds, while others, usually one-seeded, are separated from the plant without releasing their seeds. A fruit which releases its seed by splitting open is said to be *dehiscent*, while one lacking sutures is *indehiscent*. The following, commonly used classification scheme of fruits is given to aid persons collecting their own seed. Each class requires different collection and processing methods as described in Chapter 4.

I SIMPLE FRUITS

A. *Dry Indehiscent Fruits*—pericarp dry but not splitting open when ripe; seeds not separable from the pericarp.

1. *Achene*—a small, hard one-seeded, unwinged but often plumose fruit as are the individual units which form the multiple fruits of *Platanus*. (*Daphne*, *Elaeagnus*, *Hippophae* and *Rosa* produce achenes surrounded by a more or less fleshy structure and should be handled as if they were drupes (c.f.). The fruits of the first three genera are termed 'Drupaceous achenes' whereas *Rosa* achenes are aggregated to form a special type of compound fruit known as a 'hip').
2. *Samara*—pericarp modified to form a winged, achene-like fruit as in *Acer*, *Ailanthus*, *Fraxinus*, *Liriodendron* and *Ulmus*.
3. *Nut*—usually one-seeded fruit with a bony, woody leathery or papery pericarp; usually partially or wholly enclosed in a husk (involucre). Examples include fruits of *Carpinus*, *Carya*, *Castanea*, *Corylus*, *Fagus*, *Nothofagus*, *Ostrya*, *Pterocarya*, *Quercus*, *Tilia* and *Zelkova*. *Alnus* and *Betula* nutlets are borne in multiple fruits known as 'strobiles'.

B. *Dry Dehiscent Fruits*—pericarp dry and splitting open when ripe to release the enclosed seeds.

1. *Follicle*—the product of a simple pistil splitting along one suture. In *Magnolia* the follicles are aggregated to form a compound fruit.
2. *Legume* (Pod)—the product of a simple pistil splitting along two lines of suture as in *Cercis*, *Cytisus*, *Gleditsia*, *Laburnum*, *Lupinus*, *Robinia*, *Sophora* and *Ulex*.
3. *Capsule*—the product of a compound pistil that splits at maturity along two or more sutures as in *Aesculus*, *Euonymus*, *Hamamelis* and *Liquidambar*. In *Liquidambar* the capsules are aggregated to form a compound fruit.

C. *Fleshy Fruits*

1. *Pome*—a fruit characteristic of a sub family of Rosaceae consisting of an enlarged fleshy receptacle surrounding the pericarp as in *Amelanchier*, *Chaenomeles*, *Cotoneaster*, *Crataegus*, *Cydonia*, *Malus*, *Pyrus* and *Sorbus*.

2. *Drupe*—a usually one-seeded fleshy fruit, usually the product of a simple pistil; the outer wall fleshy, the inner wall bony forming the stone which only breaks open on germination. Examples include *Celtis*, *Cornus*, *Davidia*, *Ilex*, *Juglans*, *Morus*, *Nyssa*, *Prunus*, *Rhamnus*, *Sambucus*, *Symphoricarpos* and *Viburnum*. In *Morus* the drupes are borne in compact clusters to form multiple fruits.

3. *Berry*—a several seeded fruit (rarely one-seeded). The seeds are embedded in a fleshy or pulpy mass, the whole being enclosed by a thin skin. Examples include *Berberis* and *Mahonia*.

II COMPOUND FRUITS

A. *Aggregate Fruit*—a compact cluster of simple fruits traceable to separate pistils of the same flower as in *Liquidambar*, *Liriodendron*, *Magnolia* and *Rosa*.

B. *Multiple Fruit*—a compact cluster of simple fruit traceable to the pistils of separate flowers as in *Alnus*, *Betula*, *Morus* and *Platanus*.

As the fruits develop, many processes occur within the seeds. Following fertilisation, the endosperm forms at a faster rate than the embryo and in some species remains as a large portion of the mature seed's food reserve, eg as in the seeds of Snowberry (*Symphoricarpos*). In other species, such as *Robinia* and Oak (*Quercus*), the endosperm is consumed by later embryo growth so the mature seeds contain comparatively large embryos with most or all of their food reserve in thick, fleshy cotyledons. However, most species form seeds which are intermediate in nature with a more or less well developed endosperm surrounding cotyledons of medium to large size. After germination these cotyledons can form chlorophyll and synthesize food prior to the development of true leaves. In yet other species, notably some maples (*Acer*), the cotyledons contain chlorophyll even before germination, and the endosperm has no storage function, being reduced to a thin, dry, protective membrane.

There is also great variation in the moisture contents of mature seeds. Developing seeds of most broadleaved tree species undergo an initial increase in moisture content after pollination and fertilisation but the percentage moisture content decreases slowly as the embryo gains in dry weight. In some species, the seeds are dispersed naturally with a moisture content which is low enough to permit medium-term storage without adversely affecting seed viability, eg *Betula*, *Nothofagus*, *Robinia*. Seeds of other species can only be stored successfully after drying (*Prunus*,

Sorbus, *Viburnum*). However, the seeds of yet others cannot tolerate excessive desiccation below their naturally high moisture content levels and so cannot be stored successfully. Many large seeded species, *Quercus*, *Castanea*, are included in this group. (Storage problems associated with seed moisture content are discussed in greater detail in Chapter 5).

Changes also occur in levels of growth-regulating substances found within developing seeds. As seeds mature the levels of auxins, gibberellins and cytokinins generally decrease, although they still remain at concentrations which are relatively high when compared to the levels occurring in other plant tissues. It is known that these hormones play a part in the development of the seeds and fruits but the exact processes involved are, as yet, unknown.

Factors affecting seed production

One of the most important and least understood problems associated with tree seed collection involves the irregular and unpredictable production of flowers, fruits and seeds. This varies among species, among trees of the same species and from year to year in the same tree. In order for a tree to have a good seed crop, each of the previously described phases of reproductive development must have been successful, from initiation of flower primordia to seed ripening.

Even after the reproductive stage has been reached, the individuals of most temperate zone tree species do not flower every year. Normally, a heavy flower and fruit crop is followed by a number of years of little, or no flowering. Some species, such as *Betula* spp, produce good crops annually, but others have good seed crops at fairly regular intervals of two or more years. This is the phenomenon known as periodicity.

Towards the end of the last century, Hartig (1889) demonstrated that good mast years in beech (*Fagus sylvatica*), when large seed crops are formed, occurred when stores of carbohydrates in the stems had built up to such a level that a full seed crop could develop. The production of seeds reduced the carbohydrate store drastically and many years of only light seeding were necessary to permit the rebuilding of the stores. It is assumed that similar relationships exist for other species.

Climate can affect seed production in both a positive and negative way. Dry windy weather at pollination will ensure a good seed set. On the other hand late frosts are a principal cause of flower and early fruit mortality, while damp conditions in spring can reduce pollination. Drought or cold at critical periods during development may cause seed abortion and strong winds can destroy flowers and fruits at

any time. Finally, even if climatic conditions have allowed a crop to develop, insects, mammals, birds and diseases can take their toll of developing seeds.

Insects can cause extensive damage throughout all the stages of seed development. For example, the currant galls, which form on the male catkins of oak, and the bizarre knopper galls, which deform the cups and fruits of oak are caused by the cynipid gall wasps *Neuroterus quercus-baccarum* and *Andricus quercus calicis*, respectively. Other insects cause less visible but far more serious problems. The larvae of *Torymus druparum* develop within the seeds of *Sorbus* spp; the weevil, *Curculio mucum* consumes the kernels of hazel nuts; and many larvae consume the embryos of acorns, chestnuts, walnuts etc., leaving only shells full of frass. Such depredations often occur on a large scale and severely reduce seedling emergence (Winter, 1978). Finally, insects which feed on leaves, eg *Tortrix viridana*, the oak leaf roller moth on oak, or on the sap of trees, eg aphids, can reduce the amount of photosynthates available for seed production and hence reduce the size of the seed crop.

In comparison to insects, birds and mammals cause damage of minor importance. Although crops of cherries, rowan berries and other such fleshy fruits can become seriously depleted by birds, this can be avoided, usually if the fruit is collected before it is fully ripened and soft. Unfortunately, there is no such simple solution to the problem of grey squirrels (*Scirus carolinensis*) which start eating chestnuts and beech seeds long before these are suitable for collection. If grey quirrrels do become a serious pest they must be controlled using the methods described by Rowe (1980).

Diseases caused by fungi and bacteria also affect the quantity and quality of seeds produced. The major pathogenic organisms affecting hardwoods are described by Peace (1962) but many less serious diseases affecting flower production have not appeared important enough to warrant careful study of pathologists. Therefore, relatively little is known about the diseases affecting the female catkins and staminate flowers of many trees and shrubs. Although there is no evidence of serious diseases being transmitted from parent to offspring through the seed (including Dutch elm disease and oak wilt) many tree species have been shown to possess resistant strains. Therefore, seed should be collected only from healthy trees in the hope that the resistance may be inherited.

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Chapter 4

COLLECTION AND PROCESSING

Successful production of hardwoods from seed relies, to a great extent, on the maintenance of satisfactory levels of seed viability from the time the seeds are collected until such time as they are required for sowing. This creates few problems with those species with seeds which can be harvested annually, and which are not dormant, as no prolonged storage is required. However, for those species having periodic seeding and which produce seeds capable of storage, it is necessary to store seed produced in good seed years in order to provide a regular supply in the bad seed years. Thus, good harvesting and handling procedures are required to maintain seed quality at the highest possible level, and effective seed testing methods are necessary to enable the accurate monitoring of this quality.

Collection

TIME OF COLLECTION

Seed should be collected during the period between embryo maturation and seed dispersal. For species of many genera, this period is short, (eg *Populus* and *Salix*) but for others the seeds may remain on the tree for months, eg *Fraxinus*. Alternatively, the seeds may lie beneath the tree for some time. This is the situation for many large seeded genera such as *Aesculus* and *Quercus*. Unfortunately, the collection period for the seed of each species cannot be given exactly, as it varies in both timing and duration, from year to year and from tree to tree. However for guidance the periods of ripening and dispersal are given for individual species in Appendix 3. The dates quoted must be interpreted sensibly. An early spring and dry summer will usually bring forward the seed maturation time, and conversely, poor weather may delay flowering to such an extent that the seeds never mature. Similarly, seed can usually be expected to be collected from trees growing in the south of England sooner than it can be collected from trees of the same species growing in the north.

It is normally best to collect at the earliest opportunity after seed maturation as this is the time when maximum amount of seed is available. Any delay may result in the prospective harvest being blown away by the wind or consumed by the local wildlife. Correct timing for leguminous seeds is particularly

critical as the pods ripen rapidly in ideal conditions and can dehisce and scatter their seeds almost overnight. Aspect (north or south facing slope) can vary the optimum collection date considerably, not only for legumes. Experience, observation, record keeping and the weather forecast will determine when a collection trip should be planned.

Fortunately, most fleshy fruits mature sufficiently for collection a week or more before they become attractive to birds, and most dry fruits are mature enough for collection sometime before they are dispersed. For most species, the exact timing of collection involves a subjective assessment using simple indicators such as the attainment of 'ripe' colouration, softness of fleshy fruits, appearance and condition of the seeds, etc. However, most fruits and seeds have a naturally wide variation in colour, size and appearance which collectors can recognise only with experience. When in doubt a physical examination of the contents of the seed should be made. It is almost always safer to collect late, rather than to run the risk of collecting immature seeds which will produce inferior seedlings. Evidence for this has been gathered from detailed experiments on *Acer campestre* which have shown that although early collection greatly reduces the level of dormancy in the seeds, it does result in the seedlings grown from the seed being much smaller and weaker than seedlings grown from fully mature seeds. (See Figure 3) This finding is in marked contrast to recently issued advice on seed collection of *Acer* and other species (see McMillan Browse, 1979).

In order to plan the size of fruit collection necessary to obtain the quantity of seed required, it is useful to know the yield of seed from each individual type of fruit. Unfortunately published data on this are very limited. The information available has been pooled with figures obtained from recent Forestry Commission experience and is presented in Appendix 4. For all the reasons covered in Chapter 3 these yields will vary from season to season and collection to collection. They must therefore only be used as a guideline. Again the best method of judging the quantity of fruit required is by experience, physical examination, full record keeping and use of the same sources when possible. A suggested record sheet is given at Appendix 4b.



Figure 3 *Acer campestre* seedlings produced from seeds which were collected and sown over a period of 14 weeks. Although some of the early collections, on the left, show good germination, the resulting seedlings are very poor in comparison to the large plants on the right of the photograph, which germinated from ripe seeds.

METHODS OF COLLECTION

The cheapest method of seed collection which is used widely throughout the world, is employment of casual labour under supervision with payment based upon the quantity collected. In this way collections can be made outside normal working hours by family units and will not take away high cost labour from other more skilful tasks.

From the ground

Those species which deposit their seeds on the soil are perhaps the easiest from which to make collections as they can simply be picked or swept up. However these seed types are often attractive to animals and collections must not be left too late.

Many a collection team has been horrified by the quantity of seed shifted overnight by the local fauna.

When seed is on the ground there is always a great temptation to sweep it up along with the debris. This is acceptable if the seed is to be used directly by the collector, but presents practical problems if the seed is to be stored or even sold. The amount of debris collected can be reduced by thoroughly cleaning the undergrowth and leaves from the area under the trees on which the seed will fall. Another method is to lay out tarpaulins or hessian sheets. Even these methods will produce seeds with quite a high content of twigs, leaves, cupules etc. It often proves cheaper to insist upon collections of individual clean seeds than to spend a lot of time and effort later thoroughly cleaning seeds from sweepings. Special

equipment based on the principle of a vacuum cleaner has been designed in Germany to help in collection of seeds from the forest floor. The daily drop of seeds of this type can be increased by pulling on ropes tied to strategically placed branches, or on small enough trees by tree shakers designed for fruit picking.

From the tree or shrub

For those species which do not deposit their seed on the forest floor, there is no other way to collect the seed or fruit than by climbing and use of suitable equipment. Any apparatus that brings the collector close enough to the seed to enable him to harvest the seed *in safety* will be usable. This includes, ladders, tripod (fruit pickers) ladders, hydraulic hoists etc.

Although solid walled containers can be used for the actual collection procedure, as soon as possible thereafter the seeds or fruits should be put into loosely woven hessian sacks. During intervals in collecting, these sacks should be placed out of direct sunlight in good ventilation but under shelter from rain. Provided seeds and fruits are well handled afterwards, collection is still possible when they are wet. In these circumstances the seeds must be stored overnight by emptying them onto a dry surface and allowing dry air to circulate over and if possible through them.

Seed Processing

The methods used for processing seeds in order that they can either be stored safely or efficiently pre-treated are closely related to their morphology. Thus, acorns need different treatments from samaras and berries. For this reason the different processing methods will be described by the same fruit classification used in Chapter 3. Full details by species are given in U.S.D.A. Agriculture Handbook No 450 (Schopmeyer, 1974). Where seeds are to be sown or set for treatment immediately after collection, the amount of processing carried out will depend upon the personal views of the nurseryman using the seed.

If the seeds are to be stored for any period they must be dried and cleaned. For short term storage until the next sowing season, the seeds need not be dried as thoroughly as they should be if they are to be stored for a year or longer. However even for short term storage suitable cold conditions are essential if the quality is to be maintained satisfactorily. Full details of drying techniques are given on page 18.

For all types of fruits processing and cleaning is greatly helped if the fruits have been collected free from pedicels, leaves and twigs. These make prob-

lems for the machinery during processing and cause difficulties for random sampling and later during sowing. Collections should not be accepted therefore if they comprise bunches of fruits, which have not been separated from their supporting structures.

PROCESSING OF TRUE ACHENES

Platanus. Seed of this species must be collected before the compound fruits in which they are held disintegrate in the spring. After collection the fruits must be allowed to dry out thoroughly. This can be done by spreading them thinly in a well ventilated and dry place or in a stream of slightly heated air. Disintegration of the fruits can be aided manually or mechanically by any crushing or blending device that does not harm the seeds. The fine hairs detached from the seeds will cause irritating dust problems. Without specially designed equipment the fruit receptacle can only be separated from the seeds manually. The seeds should be thoroughly dried for safe storage.

PROCESSING OF SAMARAS

Acer, *Ailanthus*, *Fraxinus*, *Liriodendron*, *Ulmus*. The seeds of *Liriodendron* are collected by shaking them when dry from the cone-like fruits on the tree. The seeds of all other species in this group are collected when they have matured sufficiently. Although surface dry the seeds will still have a relatively high moisture content (20–40% on a fresh weight basis see page 19). For safe short-term storage they must be allowed to after-ripen and dry out even further. (*Fraxinus* seeds collected in mid-winter will not need further after-ripening). The safe moisture content for long-term storage differs for different *Acer* species (see pages 101–2) but for all other species the seeds should be thoroughly dried. A lot of processing time can be saved if the samaras are collected free from their pedicels and twigs. No machine is available which can do this without harming the seed. Even for local use the samaras must be separated from the twigs by hand to allow even sowing. Normally no attempt is made to remove the wings of samaras. Some blending-type machines can successfully remove the wings of *Liriodendron* and those *Acer* species with thick pericarps. (Bonner, 1978).

PROCESSING OF NUTS

This type of seed can be sub-divided into those that will bear drying out and thus can be stored and those which will not and cannot be stored. This significantly affects their methods of processing.

Storable Nuts

Alnus, *Betula*, *Carpinus*, *Carya*, *Corylus*, *Fagus*, *Juglans*, *Nothofagus*, *Ostrya*, *Tilia* and *Zelkova*. When collected the seeds or fruits of *Betula*, *Carpinus*, *Carya*, *Nothofagus*, *Tilia* and *Zelkova* will have a relatively low moisture content but will still be respiring heavily. They will thus require storage in well ventilated conditions before they can be processed further. They should be turned regularly to ensure even drying. Much time can be saved in processing if the pure seeds are separated from the fruit parts (cupules, stalks etc) during collection. Seeds of *Betula* are not normally separated from the bract-like parts of the catkin. The stalks of the catkins, like flower parts of other species eg *Nothofagus* cupules can be separated from the seeds by normal sieving techniques. For *Tilia* a type of mild blending machine can successfully break off the dry persistent bracts before sieving.

The moisture content of *Corylus* and *Fagus* seeds will be quite high (c. 40%) at time of collection. In *Corylus* this will result from early collection to avoid rodent attack when the involucre first begins to brown. The fruits should be laid out in a thin layer to dry until the nuts can be separated from the involucre. For *Fagus* seeds, the cupules and nuts are similar in size and ordinary sieving is not particularly effective, but a winnowing machine with a strong air blast gives a reasonably good separation. Further processing and drying of *Fagus* seed is closely linked to its future use, that is, if it is to be used immediately, to be stored or put for sale. Full details of the processing of seed of this timber producing species are contained in the companion seed manual.

The fruits of *Juglans* will have been collected when the husks have turned black, that is firm but just beginning to soften. If left too long on the tree or on the ground before collection the husk becomes putrid and cannot be removed completely. Ultimately the husk will dry out completely and will then be impossible to remove. Husks at the correct stage of maturity can be removed successfully by hand or for large quantities by any machine which has a mild blending or macerating action. The husks and empty seeds can then be separated by flotation. Good seeds should be dried slowly in a well ventilated place down to about 15% moisture content.

Seeds of *Alnus* are harvested in cone-like strobiles which must be dried before the seeds themselves can be recovered. Any source of moving air heated up to 40°C can be used to dry the strobiles but it is usual for them to be given a period of storage in the open to allow some of the moisture to be driven off before heat is applied. The seeds will fall from the open strobiles but may require quite vigorous shaking for complete release. They can be separated

from the strobile quite simply by sieving.

For long term storage the seeds of all the species in this group should be dried thoroughly. For details see later in this Chapter.

Non-storable Nuts

Castanea, *Pterocarya*, *Quercus*, *Aesculus*—although the seeds of the last are botanically not nuts, they are non-storable and should be treated in the same way as the others. When collected, seeds of *Quercus* will still show some green colour; in *Aesculus* and *Castanea* the lack of full maturity will be masked by their brown colour. All types will still be respiring strongly. At this time their moisture content is in excess of 50%. The object of the processing is to slow down the respiration which is mainly centred in the testa, while maintaining the moisture content at the required relatively high level of 40–45%.

This is best done by storing the seeds in layers up to 30 cm deep on a wooden floor, in a place where the temperature will not be too high but where the ventilation is good. They should be monitored each day and turned by means of a wooden shovel to keep the drying uniform. Water from sweating should not be allowed to build up as it becomes a focus for fungal attack. When the loss of moisture begins to slow down (this can be gauged by daily weighings of a sample in a loose weave nylon net) the seed will have reached a moisture content of about 40–45%. The respiration will have tailed off and any further significant moisture loss will be at the expense of the embryo and will be potentially dangerous. When the nuts have lost all their green colour, the testae are hard to the finger nail and the embryos still completely fill the cavity. They are then ready for bagging. During the turning and bagging processes it is normally possible to sieve the seeds to remove leaves, twigs and other foreign items. This will also ensure that the seeds are thoroughly mixed, which is often important in these large seeded species where there is the danger that seeds from only one tree will find their way into individual bags.

For smaller collections the same principles apply, but it is normally possible to effect the drying and after-ripening of the seed within the sack, provided it is loosely woven and kept in a cool well-ventilated place. At some time in the drying it will be necessary to mix nuts in order to ensure uniformity.

PROCESSING OF FOLLICLES, LEGUMES (PODS) AND CAPSULES

Magnolia, *Cercis*, *Cytisus*, *Eucalyptus*, *Gleditsia*, *Laburnum*, *Robinia*, *Sophora*, *Ulex*, *Aesculus*, *Euonymus*, *Hamamelis* and *Liquidambar*. All these

fruit types dry out and release their seed by rupturing themselves often explosively. Although the fruit of *Aesculus* and *Euonymus* are botanically capsules, the seeds are not typically dry at time of release and require special treatment. (For *Aesculus* see Non-storable nuts and for *Euonymus* see drupes and berries). In all other species the seeds are themselves more or less dry at time of rupture and the processing is carried out dry. Provided the fruits are picked at the optimum moment, (when they are fully dry, but before they rupture) the rupturing will take place in the collection sack or after very little extra drying. The fruits should be laid out on a dry surface where they can be subjected to warm dry ventilation.

If the fruits have been collected too early they might need a little help to dehisce satisfactorily. This can be provided manually for small quantities or mechanically for large. Blending type apparatuses or end-over-end tumblers have worked satisfactorily but any machine capable of breaking the fruit slightly will also achieve the desired effect. After the seed is released from the fruit, it can be separated readily by sieving or winnowing equipment. All seeds except *Aesculus* should be dried thoroughly before storing for long periods.

PROCESSING OF POMES, BERRIES, DRUPES, HIPS, DRUPACEOUS ACHENES AND FRUITS OF *EUONYMUS* SPECIES *Cornus*, *Cotoneaster*, *Crataegus*, *Elaeagnus*, *Euonymus*, *Hippophae*, *Ilex*, *Mahonia*, *Malus*, *Prunus*, *Pyrus*, *Rhamnus*, *Rosa*, *Sambucus*, *Sorbus*, *Viburnum*. All fruits in these classes are more or less fleshy at time of harvest and require totally different techniques from other fruits for extracting the pure seed. The seeds of *Euonymus* possess pulpy arils which restrict their dispersal from the fruit, so they too are normally handled in the same way. Processing of such fruits may involve nothing more than drying the fruit or it may involve complete separation of the seed from the pulp by maceration in water.

Dry Processing

Fleshy fruits and seeds of *Euonymus* species are occasionally sold simply as dried fruits and require little processing. After collection the fruits are spread thinly on a wooden or other absorbent surface and allowed to dry as quickly as possible by means of normal ventilation. The drying should be initiated before the fruits show any sign of heating or fermentation. If heating occurs during drying they should be spread more thinly. As drying continues, it is possible to supplement the natural ventilation by gentle heat. Eventually a moisture content of approximately 10% should be reached. After such

treatment twigs and leaves can be removed by sieving. After drying *Euonymus* fruits the seeds are easily separable and can be removed from the remnants by sieving and winnowing. The great disadvantage of this method is that the seeds are still enclosed in the fruit parts with all their inhibitory effects, and before they can germinate these will have to be removed. For dried fruit this is more difficult and time consuming than for fresh fruit. If the fruit parts are not removed the pretreatment must be increased greatly, and in any event the effect of pretreatment is much less predictable.

Wet Processing

The great majority of seed of these species sold is as pure seed. The exact methods used to separate seed and fruit vary from species to species and from individual to individual and are often closely guarded secrets. However the principles are all the same. A water soak is used to soften the fruits' walls before they are placed in a machine which loosens the seed from the pulp. Sometimes the softening process is aided by a crushing machine before the seeds are soaked. These are often home made or agricultural turnip shredders specially adapted.

Fleshy fruits are respiring strongly when they are harvested and must be treated carefully so that the viability of the seeds is not impaired. They will often rupture when stored in bulk and the juice will begin to ferment very quickly. If collection is into a hard walled receptacle or non porous sack the quantity in each should be relatively small and the fruits should not be allowed to remain standing without adequate circulation of air for very long. If processing cannot begin at once, or if long distances are involved, the fruits should be stored in hessian or other type of sacks which allow the fruits to breathe despite the inevitable loss of juices. At all times the sacks should be kept as cool as possible.

Processing of the seed should begin as soon as possible after collection. If the fruit is fully ripe, there should be little difficulty in extracting the seeds. If the seed is not fully ripe extraction may be more troublesome. Pomes are normally gently crushed before being soaked in water; other fleshy fruits are normally put straight into a water soak. Hot or cold water can be used depending upon how quickly the processing should proceed, and how hard (immature) the fruits are. Hot water contains less oxygen than cold water so must be changed more frequently. The steeped fruits must not be allowed to ferment excessively or become anaerobic. The water treatment should continue until, by experience, the fruits are soft enough to be handled by the depulping equipment.

The type of equipment used for depulping varies widely from country to country and plant to plant. In America a Dybvig machine, designed on the principle of a food blender, is widely used. This loosens the seeds from the pulp but the separation has to be done with sieves and copious quantities of cold water in a later operation. In Europe a Leonhardt Passiermaschine designed to collect the pulp of fruit is widely used. It works in the reverse mode from the original design; the pulp is discarded, but the fruit remnants and seed are retained and later separated by sieving with water. Clearly the design of apparatus is not critical, and any machine with the same capabilities can probably be suitably adapted.

Seed Cleaning

Most types of seeds will need cleaning after processing. Few machines have been made specially for cleaning seeds of forest species, because of the small scale involved and the great variability in seed structure. If many lots of seed are to be collected, a simple cleaning machine, incorporating a set of reciprocating sieves and a weak winnower, would probably be a good investment. If only a few lots are to be handled, cleaning can normally be carried out quite adequately by hand sieving and winnowing. Seeds of many tree and shrub species contain high proportions of empty seeds, some of which will be removed along with inert matter by ordinary winnowing machines. To reduce the empty seed content to much lower levels special aspiration equipment must be used.

Seed Drying

Seed must be dried either because it is too wet at harvest or because during processing it has been rewetted. Whatever the type of seeds that have to be dried, the principles that apply are the same. Recent research has shown that the relationships that exist between storage temperature, storage moisture content and longevity also apply during seed drying. Thus the higher the moisture content of the seeds and the higher the temperature to which they are raised, the more damage will be done to them. The temperature to which the seeds are raised depends not only upon the air temperature used, but also upon the amount and humidity of the air being used. However the greater the air flow at a given temperature the lower will be the temperature that the seeds reach because of the cooling effect of the latent heat of evaporation.

It is not always possible to ensure that seeds are completely dry at time of collection. Before they can

be cleaned efficiently they must therefore be dried. For *Fraxinus*, *Ailanthus* and some *Acer spp* this can be done by spreading them out on a non-sweating surface (wood) in a well ventilated place and turning them regularly. For most other broadleaved species a more effective way is to place them in a suitably constructed apparatus in which warm air is blown through the seeds. Normally a temperature not exceeding 30°C is used, but provided the air flow is large enough a much higher temperature can be used safely. Drying can proceed until the desired moisture content for storage is reached or it can be terminated when the seeds are dry enough to permit cleaning. The latter is better practice since the inert matter in the seeds will influence the measured moisture content and further drying may be necessary after cleaning. Some driers are static, with several boxes allowing different lots to be dried at the same time; some are revolving drums capable of drying only one seed lot at a time. Both have been found to be equally efficient for drying surface dry seed, except that very light seed such as *Betula* species can blow out of open-ended box kilns when they have dried fully. Even drum kilns require special dust traps before they can be used for light seeds.

The methods used for drying non-storable nuts of *Aesculus*, *Castanea* and *Quercus* have been described in the section dealing with their processing.

During the processing of fleshy fruits the seeds come in contact with a lot of water and must be dried before they can be stored safely for long periods. Such seeds are normally small and have been cleaned of inert matter during the processing. These seeds are very wet and all the surface water must be removed before they can be handled by ordinary driers. This is done by laying the seeds in a thin layer in a large flat tray and allowing unheated air to move over them, either naturally or artificially. The seeds should be mixed and turned regularly. As soon as they are surface dry they can be dried down completely by the ordinary seed driers.

Provided the initial moisture content and weight of seed to be dried are known, it is a simple matter to calculate how much water should be driven off to reach a given moisture content. The calculation is based on the dry weights as these are the invariables in the system. Thus—

The final weight to which the seed lot must be dried is equal to the initial dry matter percentage of the seed lot divided by the desired dry matter percentage. For example if it is desired to dry 50 kg of seed with an initial moisture content of 25% down to a moisture content of 10% then the final weight of the seed lot must be reduced to:

$$50 \times \frac{75}{90} = 41.67 \text{ kg}$$

Measurement of seed moisture content

The classical method of calculating the moisture content of seeds is to measure the weight lost when the seeds are heated at 105°C for at least 16 hours. However this procedure also drives off any essential oils and resins in seeds and can give an imprecise result. Accordingly the International Seed Testing Rules (ISTA, 1976) prescribed the toluene distillation method for such species including *Fagus*. This is a very laborious method and was seldom used in practice. It was therefore deleted from the Rules with effect from July 1st 1981. Provided it is understood that some seeds contain oils and that the reported moisture percentage for these seeds will be slightly inflated, a moisture content obtained by the oven method can be used quite satisfactorily in practice.

To perform the oven method accurately either a sensitive measuring device and a small sample or an insensitive device and a large sample can be used. Neither of these alternatives is really practical in nurseries or processing plant, nor is an oven capable of control at 105°C a normal apparatus to find there. For these reasons other cheaper quicker methods of moisture content determination have been developed.

The most widely used quick method is based on an infra-red lamp. It works on the principle that a

weighed standard sample is subjected to heat from an infra-red lamp with such an intensity that it loses all its moisture, without being burnt, in about 20 minutes. When the loss of weight ceases the new weight is measured and the percentage loss calculated. Specially made apparatuses contain a balance and are calibrated directly. However it is quite possible to construct a simple apparatus using an ordinary infra-red lamp and balance arm, which is cheap to construct and able to measure the moisture content of seed samples sufficiently accurately for them to be used for practical purposes.

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Chapter 5

SEED STORAGE

The storage of seeds of commercial forest species has received considerable attention over the years, but there is relatively little published information on storage of seeds of ornamental species. In the last decade a very considerable amount of work has been done on seed storage of economically important food and raw material producing (eg rubber) plants. In all this work seeds have been found to fall clearly into two main groups, so-called orthodox and recalcitrant species. (Roberts, 1973). Orthodox seeds are those which can be stored successfully for long periods at low moisture contents and temperatures. The lower the temperature and the lower the moisture content, the longer the period of viability. Recalcitrant seeds are those which do not follow these rules, and which are killed if their moisture content is reduced below some relatively high value. For some (mainly tropical), low temperatures *per se* are also detrimental to viability.

From all the work done on tree seeds, nothing has yet been found to suggest that they do not also fit into this scheme. Reports of anomalies, referred to in text books, have often been found to be unsubstantiated when examined critically. For example *Populus* and *Salix* spp (Zasada and Densmore, 1980). Many have been shown to be caused by poor handling of the seed between tree and the start of the storage treatment.

The Forestry Commission's Seed Branch has many years of experience of storage of seed of oak, beech and other commercial broadleaved species but rather fewer of storage of seed of the more ornamental broadleaved species. However, whenever seeds of the latter have been stored, they have been dried to approximately 10% moisture content, stored at a low temperature and treated like any other orthodox seed type. Subsequent seed tests have revealed that the quality has been maintained at the initial level within experimental limits. From this experience and, where lacking, from the literature that is available, a classification of storage types has been derived for the species covered in this manual. (See Appendix 5). These data have been used to prepare recommendations for seed storage. So far only one exception to the general rule that species within the same genus behave similarly, ie all are orthodox or all are recalcitrant, has been identified (*Acer*). It is suggested that this principle be applied when con-

sidering storage of species not covered in this manual. Appendix 5 also contains lists, derived from the literature and from very limited research evidence, predicting the behaviour of species covered in this manual, and for which no conclusive first hand evidence is available. One species listed (*Fagus sylvatica*) requires special care and additional comments are given.

Many books have been written on the subject of seed storage. For this reason no further details of the principles will be given here. Readers wishing further amplification are referred to the literature list cited at the end of the chapter.

Orthodox Seeds

For long term storage, seeds of this group should be dried down to near 10% moisture content and held at near 0°C. The nearer to 5% the moisture content is lowered, and the nearer to -18°C the seed is held the longer the viability will be maintained. For practical storage for up to 5 years, it is difficult in most cases to justify using a temperature much lower than 3-5°C. The temperature of transplant cold stores is ideal. To maintain the moisture content, the seeds should be placed in sealed containers. These can be glass or plastic bottles or plastic bags tied tightly by twisting the necks and sealing with wire. Plastic of 4-500 gauge (10-13 microns) should be used. Thinner material allows appreciable exchange of moisture, thicker material inhibits gas exchange. (Bonner, 1978).

Another method widely advocated for maintenance of seed moisture is by controlling the humidities of the storage environment. This enables seed stored in open containers to come to equilibrium moisture content with the humidity in the atmosphere. Normally a relative humidity of about 40% will produce an equilibrium moisture content of approximately 12%. However the equilibrium moisture content varies with the morphology of and tissues in the seeds. This variation may be unacceptable where moisture levels are critical. Another disadvantage of this system of controlling the moisture content is the expensive equipment required to control the humidity as well as the temperature of a store. Also in countries where the ambient humidity fluctuates widely, the stores must be constructed with air locks.

Although from the evidence available at Alice Holt it appears that *Corylus* spp and *Juglans* spp are orthodox species, the literature suggests that they, along with *Carya* species, can be stored successfully for 1 to 5 years with higher moisture contents. This was effected either by storage at high ambient humidities at 1–3°C, sealed storage at 20 to 40% moisture content at 3°C or under stratification conditions outdoors. However, because of their large size it is not normal to store large quantities of these species for long periods. The most practical storage method for these species, whether for six months or for one or more years, would seem to be under stratification conditions. (See Chapter 7).

Recalcitrant seeds

It is impossible to store seeds of these species for long periods without loss of viability. Indeed only by careful control of the conditions can they be stored without loss of viability until required for sowing in the spring following collection. The best method of 'storage' is thus to sow them with adequate protection against vermin in the nursery beds in which they are to be grown. Freshly harvested seeds of many recalcitrant species possess dormancy, and the natural conditions in the seedbed over winter not only overcome this, but provide the best conditions available for maintaining the viability. One worker has found that the deeper the dormancy of some oak species, the more successfully they can be stored for long periods. This may explain why *Q. rubra* has been reported to store for up to four years whereas *Q. robur*, which is often collected with radicles already emerging, will not store for more than one year under the same conditions. The best conditions for artificial storage of recalcitrant species are thus as near as possible those found in the nursery bed without actually allowing germination to proceed (or at most to proceed too far), eg in moist peat.

For *Quercus* species these can be provided either by digging a pit and covering the acorns with soil while leaving somewhere for them to obtain a little air, or by mixing the acorns with a damp peat medium and placing them in containers which retain the moisture but allow ventilation. Another method is to place them at 40–45% moisture content in a cold store at or near 0°C in lightly tied polythene bags. On a small scale these latter conditions have not succeeded very well for *Aesculus* and *Castanea* and it is unlikely that pit storage would work well either. In contrast *Juglans* and *Carya* are reported to store well under both systems. (See previous section).

Without very special facilities the only practical method of storing large quantities of recalcitrant seeds is in sacks. These must be made of loose enough material to allow breathing, but must not be so loose that the moisture content continues to fall too fast. In order to monitor the loss of moisture from stored sacks, several, chosen at random from the bulk, should be weighed at regular intervals. If the initial moisture content is known, the gradual change in moisture content can be followed quite accurately. Most moisture will be lost from the outside seeds in the sacks and these will dry out to near critical levels before the overall moisture falls very much. To keep the loss of moisture as low as possible, the sacks should be stacked in a cool place where there is little circulation of air. They should be placed in stacks two sacks wide and three or four deep, so that at least some part of each sack is exposed to the atmosphere. If the moisture loss becomes excessive the sacks should be lightly sprayed with water until the weight of the checked sacks rise to the desired level. On very windy days loss of moisture can be reduced effectively by covering the sacks in hessian sheeting and keeping this wet. If at any time during storage there is any evidence that the seeds are heating up, the sacks should be re-stacked separately or if excessive the contents spread out and reprocessed. During subsequent transportation the sacks should be covered to stop excessive moisture loss.

For many other recalcitrant species, storage can be carried out for quite long periods using the conditions needed for overcoming dormancy, for example by placing moist seed in sealed plastic bags at just above freezing. The exact moisture content for the longest storage varies with species and seems to depend to some extent on the morphology of the seed eg relative size of wing and embryo in *Acer*s. If seed is stored in a more or less fully imbibed condition, the treatment will be equivalent to pre-chilling, and at the end of six months the dormancy will have been removed almost completely. However, if the seed is stored only slightly above the critical moisture content little pretreatment will take place. When seed is stored in an imbibed state the amount of oxygen required will increase due to the greater metabolism of the seeds. Under these conditions the containers should be opened regularly and the seed gently mixed. Oxygen can become even more limiting if the stored seed is removed from the cold store for even short periods before sowing. Imbibed seed should not be posted in sealed containers. The recommended moisture contents for the longest possible storage of recalcitrant species are given in Appendix 5.

For some tropical species the temperature itself is

critical and seeds will die, despite a satisfactory moisture content when subject to low temperature eg *Monstera delicosa*.

Problem species—*Fagus sylvatica*

Although beech seed has been shown quite clearly to behave in an orthodox manner, the relationship has been difficult to confirm because of the interaction between the moisture content of the seed, the dormancy of the seeds, the loss of dormancy by moist cool storage and the difficulties experienced in laboratory assessments of the germination and viability percentages. The different storage methods used for beech in different countries of Europe have further complicated the interpretation.

The main reason for the difficulties lies in the fact that the Tetrazolium test as currently carried out does not give an immediate indication of seed damage so that seed lots treated badly will show a relatively high viability for some time after they have actually lost the ability to germinate. However as this latter characteristic is measured by a test lasting up to 26 weeks in cool moist conditions, during which the damaged seed deteriorates completely, the exact moment of loss of germinability is impossible to identify. Nevertheless French experience shows quite clearly that newly harvested seed handled carefully and dried slowly in moving air at 20°C from 50–55% moisture content at harvest, to 20–25% during handling and cleaning and finally down to 8% can be stored for many years without significant loss of viability. The lower the temperature the better but for practical nursery storage this should not be more than 2°C and less than –5°C. For seeds which are to be sown the spring following harvest it is not necessary to dry the seeds to this low moisture content. They can be safely stored at 20–25% moisture content at 3–5°C until time to begin such pretreatment prior to sowing. For similar reasons an excellent method of preserving the viability of beech seed is to sow them with adequate

protection in the nursery beds where they are to be grown. This sometimes gives problems when late frosts catch the early germinating seedlings.

In most years the seed available in Britain is of continental origin. By the time it has reached Britain its quality may already have deteriorated, and will depend to a very large extent on the treatment to which it has been subjected. Even though it may have a test certificate showing a high figure this may be meaningless as it may only reflect the quality shortly after harvest when the sample was taken. Seldom will the certificate give a moisture content. During transit, seed of low moisture content will probably suffer little whereas seed at 20–25% moisture content may suffer significantly from the relatively high temperatures experienced. Unless the exact history and current quality of imported seed lots are known, long-term storage is not advised. Fuller details of the different methods of storing/treating beech seed are to be found in the companion Seed Manual, (in preparation).

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Chapter 6

SEED TESTING AND SOWING DENSITY

The legal reasons for testing seed of ornamental species have been described in Chapter 2. The practical reasons for testing seeds and calculating sowing densities are covered more fully here, and descriptions of the testing methods used and the types of certificates available are given. Seed quality data are presented in Appendix 6a. Moisture content tests have been described in Chapter 4.

Seed Testing

REASONS WHY SEED TEST CERTIFICATES SHOULD BE REQUESTED

Before time and effort is put into sowing or treating a seed lot, a nurseryman should be reasonably certain that the seed he is using is alive. If he has collected the seed himself, he will hopefully have checked the quality throughout collection and processing (See Chapter 4). For purchased seed the need for test certificates is greater.

Experience has shown that imported seed is not always of good quality. Much of the seed is still produced by traditional means with very limited quality control. Some continental seed merchants do not even bother to get their seed tested. Others test their seed when it first arrives but not subsequently. As has been described in the previous section, storage conditions can alter the quality significantly over quite short periods. The fact that many broad-leaved species are deeply dormant, requiring many months pretreatment, often hides the fact that the seed is dead or of low quality on arrival in Britain. A great deal of labour and material can therefore be wasted if dead or poor quality seed is sown. Crop failures also involve a nurseryman in a lot of effort to find replacement stock. The answer is for nurserymen to insist that all seed lots purchased are covered by a current seed test certificate. The currency of test certificates is normally taken as twelve months, but in practice this should be determined more by the species and conditions of storage. Only a recently issued certificate can be taken as genuine evidence of seed quality, unless the moisture content and conditions of storage are also quoted and guaranteed.

TYPES OF CERTIFICATE

For imported seed the most reliable certificates available are the three types of International seed lot certificate which are issued by accredited laboratories of the International Seed Testing Association according to prescriptions laid down in its International Rules for seed testing (ISTA, 1976), on samples drawn privately or officially. The colour of the certificate (orange, blue or green) is determined by who draws the seed sample, and in which country the tests are performed.

ISTA certificates are normally used for large consignments of seed or where the value of the seed is particularly high. They refer to the actual quantity of seed sampled, and strictly speaking are not valid for smaller parts of the seed lot. Provided the seed lot is homogeneous at sampling (and a request to sample should be refused if the seed lot appears heterogeneous) there is little danger from accepting certificates representing larger bulks, and this is commonly done in practice.

For seed lots which are going to be sold in a seed merchant's own country it is normal for the seed merchant to obtain certificates issued by the official seed testing laboratory in his country. This laboratory may or may not be accredited to ISTA, and it may or may not test according to ISTA prescriptions. Such certificates, which may be offered if some of the seed is exported, are quite acceptable provided they are current. Less acceptable for obvious reasons are certificates issued by private seed laboratories. International certificates and many other official certificates normally report the results only in terms of the germination (or viability) and purity percentages. These data do not give any indication of the quality on a weight basis, and from them sowing densities cannot be calculated. If nurserymen wish to use certificates for calculation of sowing densities, they should ensure that a 1000 pure seed weight test result is given additionally. Details of the calculation are given later in this chapter.

All seed sold in Britain by the Forestry Commission is covered by Seed Suppliers Certificates, which give the results of valid tests carried out on each seed lot. Since the seed is stored at carefully monitored moisture contents and at low temperature, the results are valid for the full twelve months period. All certificates quote the quality in weight

terms from which sowing densities can be easily calculated.

The official testing station for tree seed in Great Britain is located at Alice Holt Lodge, Wrecclesham, Farnham, Surrey. Anyone wishing an official test to be performed on a seed lot he is going to sell or sow, should send a sample by first class post in a thick paper envelope to the officer in charge at the above address. Although this envelope may cause some change in the moisture content it will allow the seeds to breathe and should not affect the viability significantly if there are no postal delays. Samples for moisture content determination should of course be sent in sealed containers. The cost of such tests varies with species but for 1980-81 seed testing year prices ranged from £2.00 for moisture content determination to £15.20 per sample. Tests take anything from two weeks to nine weeks to perform depending upon species. All certificates include a calculation based on unit weight.

As a last resort a nurseryman can himself check the quality of seed he has bought, stored over winter or collected for himself. The details in the next section are given to help him do this. However, not all nurserymen have the time and facilities available. In recognition of this the Alice Holt Laboratory introduced a quick, cheap information test. For as little as £3 (1980-81) an estimate of quality per unit weight is given (within 10 days of receipt) based upon reduced test samples. Samples submitted for this test should also be sent in thick paper envelopes to the officer in charge clearly marked Quick Information Tests.

SAMPLING

The accuracy of an estimate of seed quality is directly dependent upon the accuracy of the sampling. If a submitted sample is not representative of the bulk of seed, there is little possibility that the test data will accurately reflect the quality of the seed lot. For sampling to be carried out satisfactorily some training is required but untrained personnel can perform reasonably well if they know the principles involved. Rules for taking of samples are given in Part II of Schedule 7 of the Forest Reproductive Material Regulations (1977). They apply to all seed species not just those covered by the Regulations.

The first thing for a sampler to do is to ensure that the seed to be sampled is homogeneous. If the seed is in more than one container the sampler must ensure that the seed in all containers appears the same. He should study the seed at several levels in a container as it is possible to hide heterogeneity by a thin layer of homogeneous seed on the top of all

containers. If there is any evidence of heterogeneity, the seed should be remixed before a sample is drawn. This is essential for seed covered by the Forest Reproductive Material Regulations, but is strongly recommended for any seed to be sold for which an official seed test is requested.

The number of containers to be sampled varies with the number of containers in which the seed is stored as follows:

<i>Number of containers</i>	<i>Minimum number of containers to be sampled</i>
1-5 (inclusive)	Each container, portions being taken from at least 5 positions.
6-14 (inclusive)	Not less than 5 containers.
15-30 (inclusive)	At least one container in 3.
31-49 (inclusive)	Not less than 10 containers.
50 or more	At least one container in 5.

If the seed is stored in bulk sampling should be done with a stick sampler from at least the number of positions indicated in the table below.

<i>Size of bulk</i>	<i>Number of positions to be sampled</i>
Not exceeding 50 kg	Not less than 3
<i>Exceeding</i>	<i>Not exceeding</i>
50 kg	1,500 kg
1,500 kg	3,000 kg
3,000 kg	5,000 kg
5,000 kg	20,000 kg
	Not less than 5
	At least 1 for each 300 kg
	Not less than 10
	At least 1 for each 500 kg

There are special pieces of apparatus available for sampling of which the most common is the stick sampler. If no stick sampler is available, or if it is impractical to sample seeds in bulk or container, portions may be taken by hand, care being taken to keep the fingers tightly closed about the seeds so that none may escape as the hand is withdrawn. If necessary, in order to reach the lower levels, part of the contents shall be emptied into another sack or container.

After the so-called primary samples are taken, they are mixed and randomly reduced to the required submitted sample size. The weights of the latter vary with species. For beech the size laid down by the Forest Reproductive Materials Regulations is 1 kilo-

gram, but for oaks, because of their varying and large size, the limit is based on seed number (500). No other species are listed in Regulations, but the limits normally followed are those prescribed by the ISTA, which are usually based on the weights required to produce 5,000 pure seeds. If in doubt or if no prescription is available for a particular species, this should be the rule of thumb.

The shape of seeds determines to a large extent the ease with which it can be homogenised. Smooth round seed mix easily eg *Robinia*, *Crataegus*, seeds with wings (*Acer*, *Fraxinus*) or other appendages (*Platanus*, *Populus*) do not. For similar reasons the random taking of samples is difficult. Winged seeds do not normally lend themselves to stick samplers, so sampling must be done by hand. For these species, as well as very large seeded species, such as *Quercus*, *Castanea* and *Aesculus*, it is particularly important to part-empty sacks or containers in order to sample properly the lower levels.

ASSESSMENT OF SEED QUALITY

The number of potentially useful seeds in a given weight of seed is determined by three main factors, the purity, the seed size (weight) and the percentage of seeds that germinate or are capable of germinating. These characteristics are the basis of separate tests that are made on samples submitted to seed laboratories for testing. However, a nurseryman, using the same principles but on a reduced scale can make an estimate of seed quality, which, although not as accurate as official tests, will nevertheless give a satisfactory assessment of the seed lot's potential and which he can use for calculation of sowing density.

Purity Test

In theory the practical significance of all purity tests is to enable a purchaser to know that the seed he is buying is of the species he ordered (or if not of the species he ordered to know what in fact it is) and how much of what he has bought is true seed and not dirt and other useless material. This information is provided by the seed analyst, separating the seed of the main species from seed of other species and from inert matter. There are agreed definitions of what constitutes pure seed for each species, and how half seeds and parts of seeds (eg appendages) should be classed. By weighing the constituent parts, the proportion of pure seed is calculated as a percentage. All the seeds are identified as far as possible. The analysis is carried out on one half of the submitted sample for most tree species.

The purity analysis is of great significance in agricultural crops where much legislation in all countries includes minimum purity standards. Seed

is bought and sold on the basis of what are often even higher purities than are legally enforceable and the price of seed is altered accordingly. In the marketing of tree seed the situation is somewhat different. In nearly every country there are no minimum purity standards at all, but in EEC countries there is an absolute standard imposed for the 13 species and one genus covered in the Regulations and this is for the amount of seed of other forest species that are allowed. Purity standards have less direct significance in forestry than in agriculture, because the seeds of many species contain inert matter which is difficult or even impossible to separate out on a commercial scale. Also the ultimate purchaser of tree seed, the nurseryman, is almost always more interested in the quality per unit weight (eg the number of germinable seeds of the desired species per kg) than he is in the absolute purity level, although this latter characteristic is needed to make the calculation.

The Seed Weight

The size and hence the weight of seed of a species can vary greatly for many reasons. Unlike agricultural crops, the size of tree seeds have not been subjected to selection pressures and the world population still shows all its natural variability, due to geography and individuality. The climate will also affect seed size directly and indirectly. In a long dry summer seeds will weigh less than in a warm moist summer. Poor conditions at pollination will lead to relatively high empty seed levels although the effect of this on seed weight will be determined also by the efficiency of the processing. It is by no means unusual to find weight differences of 100% in full seed samples of the same species.

The test used by analysts to determine the weight of seed is the 1000 pure seed weight test. From the pure seed separated out in the purity analysis, eight replicates of 100 seeds are selected at random. These are weighed accurately. If a simple statistical test confirms that the variability of the eight replicates is no greater than would be expected by random sampling, the average weight of the replicates is taken and multiplied by ten. One thousand pure seed weights are normally expressed in grams.

This statistic enables the analyst to calculate the number of pure seeds in a kilogramme of pure seed, and, by multiplying by the purity percentage, to calculate the number of pure seed in a kilogram of the original sample and, by implication, the original seed lot.

Germination and Viability Tests

The tests that are made to assess the ability of a seed lot actually to produce plants are directly related to the level of dormancy in the seed of the species

in question. If seeds are deeply dormant (see Chapter 7) requiring very lengthy periods of pretreatment, then a germination test in the normal way is impractical. Instead a viability test is carried out. If seeds show no dormancy or possess a shallow dormancy which can be overcome easily and in a short time (no more than four weeks), then a germination test is normally given.

It is important for the nurseryman to appreciate the difference between viability and germination. *Viability* is the possession in a seed of those processes essential for the seed to germinate. *Germination* is the successful implementation of those processes, leading to the production of a seedling capable of establishment in the nursery. If the conditions given to overcome dormancy (and the conditions during the germination test) are perfect then the germination percentage will match exactly the viability percentage. If on the other hand the pretreatment conditions have been less than perfect, then there will be a discrepancy between the two. In practice it is seldom possible to achieve perfection in treatment conditions, and the weaker seeds (those possessing less nutrients, less maturity, more processing damage etc) will degenerate. The worse the conditions the greater the degeneration and the larger the discrepancy between the original viability figure and the germination achieved. For deeply dormant seed lots it is therefore advisable, if a really accurate sowing density is desired, to test the germination percentage at the end of the pretreatment period. Better still the response of the seed lot to the pretreatment can be monitored during the pretreatment period so that the best moment to end the pretreatment can be identified. These post-treatment germination tests are identical in principle to ordinary germination tests and will be discussed together.

The prescriptions for assessing the germination or viability of tree seeds in the International Rules for seed testing have been based on the above principles. Where a germination test can be carried out in a suitably short time (less than 8 weeks) it has been preferred to the viability test. Quite clearly viability tests can be and often are given to non-dormant or shallowly dormant seed lots. The most commonly used viability test (by Tetrazolium) is a subjective test, depending much on the experience of the analyst for its accuracy. In theory there should be almost total agreement between results from a viability test of a non-dormant seed lot and from the germination test. In practice this is by no means always the case. Tetrazolium tests are greatly favoured in Germany, the country of development of the test, and test certificates are frequently issued by that country's official stations based on it, whereas most other countries would use germination

tests. The reason given for this practice is that the seed merchant can get his results quicker. As the Tetrazolium results almost always exceed the germination results, the quality is over-estimated and the seed merchant never complains. When interpreting certificates supplied with different German seed lots it is therefore important to appreciate the significance of the results quoted.

Of the species covered by the Forest Reproductive Materials Regulations the germination tests of oaks can be completed without difficulty in four weeks and a Tetrazolium test is therefore not prescribed by ISTA. However, from experience, some official stations do use the latter test method. Acorns contain chemicals which inhibit the correct reaction with Tetrazolium, and Tetrazolium tests tend therefore to under-estimate the actual germination percentage. In contrast Tetrazolium tests of beech seeds tend to over-estimate greatly the actual germination achieved, even after very careful seed treatment.

The prescribed ISTA germination test for beech lasts up to 26 weeks, which is totally impractical, but it seems that a correct interpretation of the Tetrazolium test is only consistently made by very experienced seed analysts and on newly collected and vigorous seed lots. As soon as the seed is dried, processed or stored difficulties in interpretation begin to manifest themselves. (See Chapter 5).

Germination Tests

The principle behind the germination prescriptions in the International Rules is the provision of standard conditions so that tests of seed quality made by two different people (for example the seed seller and seed purchaser) can be justifiably compared. Temperature and light conditions are relatively easy to standardise, but moisture availability is not. This is achieved for the great majority of tree seeds by using an inert filter paper medium. The properties of the medium are carefully defined so that it can be copied exactly in different countries. This medium is used for all seed types up to the size of *Robinia*. For larger seed, (*Quercus*, *Aesculus*, *Castanea*) especially those possessing hard seed coverings (*Acer*, *Prunus*) the more usual medium is moist sand. Although the size and texture of this is also defined, it is less easy to obtain identical samples in different countries and results can vary somewhat. The most non-standard medium that can be used is soil, but it is only recommended for seeds which have shown themselves to be badly infested with microflora, and whose germination is obviously inhibited by them.

For the majority of tree seeds the prescribed germination temperature and light regimes are 16 hours incubation in the dark at 20°C with 8 hours

incubation at 30°C in light (artificial or natural with 250 lux at the germination surface). For a large minority, again tending to be the larger seeds incubated in sand, the germination temperature is lower, usually a constant 20°C. (See Appendix 6b). Experience has shown that these temperatures are not very critical but that sometimes a particular seed lot of a given species does need a lower temperature to achieve maximum germination, eg *Cytisus scoparius*.

The normal procedure when carrying out a germination test is to select at random four replicates of 100 seeds from the pure seed fraction of seed obtained during the purity test (or if a 1000 pure seed weight test has been performed from the eight replicates prepared for that test). These are set up separately on four areas of the germination medium. The size of the seed determines the size of the filter paper or amount of sand that has to be used and may necessitate reducing the number tested to eight replicates of 50 seeds. Each seed should be separated from each other by at least the width of the seed, to reduce the chance of cross contamination by microflora. Some species of seed react best if totally covered in sand, others if incubated on the surface.

Before the seeds of dormant species are set out, they require some form of pretreatment. Sometimes this is very lengthy. (It has been pointed out already that the length of the treatment renders the germination test impractical for issuing official certificates on deeply dormant seed lots, although the International Rules do carry such prescriptions). More often the treatment lasts for a shorter period. It may be a prechilling, which involves setting up the seeds in the moisture condition in which they are to germinate, but at a temperature of 3–5°C for three or four weeks. For leguminous seeds the treatment lasts even shorter. Because of their high proportion of hard seeds, all four replicates of one hundred seeds must be scarified in some way. This may be done by physical means (filing, chipping or piercing) or by chemical means (sulphuric acid). The large seeded species, oak, beech, chestnut, must also be prepared by soaking overnight and either cutting a portion of the seed away or peeling off the pericarp.

After the replicates have been treated and set out, they must be placed like seeds requiring no treatment in some sort of apparatus that controls the temperature, supply of water and light. There are many ways of achieving this, from walk-in room incubators to special cabinet incubators and, the most commonly used in Europe, Jacobson apparatus (an open tank with the seed suspended above the water surface on glass or metal plates). With incubators the moisture may be controlled by maintaining the whole atmosphere at saturation point, by providing moisture to each individual replicate by means of a

wick from a reservoir, or by periodically adding more water to the moist sand. With the Jacobson apparatus (also called the Copenhagen tank) the water which itself controls the temperature is supplied direct from the tank by means of filter paper or cotton wicks.

For all broadleaved seeds except beech the incubation period is from 21 to 28 days. After seven days the number of seedlings which have developed well enough to convince the analyst that they would have grown into healthy plants in the field are identified, removed and counted. This is repeated weekly until the end of the test. These so-called normal seedlings are differentiated from abnormal seedlings (those deemed to be unable to develop into healthy plants in the field) which are also counted. To aid analysts in the interpretation both normal and abnormal seedlings are defined by species or genus in the International Rules. Further amplification is given in a Seedling Evaluation Handbook. (Bekendam and Grob, 1980). (The Forest Tree Seed Committee of the ISTA will be publishing a Handbook dealing exclusively with tree species within the next three years).

When the period of incubation is complete, the ungerminated seeds should be cut open to see if any are still fresh and healthy looking. These are the seeds which are still alive, but which have not reacted to the treatment conditions by germinating. They are still in a dormant condition. They can be distinguished more certainly by using the Tetrazolium test (see below). Other ungerminated seeds will be dead and will have decayed to varying degrees during the course of the test. Others will be empty or nearly empty. The percentage of these is a useful characteristic for a seed merchant to know, as it gives him some indication of how well the seed has been processed. This characteristic may be reported upon request on ISTA certificates. The empty seeds counted at the end of a germination test will include a proportion which have become so because of the decomposition of their contents during the course of the test. A more accurate assessment of empty seed can be made therefore on a separate sample before the start of the test. Another alternative method, recently included in International Rules is to assess the proportion of empty seed non-destructively by X-raying the replicates to be germinated before the start of the germination test.

The number of normal and abnormal seedlings and dead, empty and fresh seeds are added up for each replicate and should equal one hundred. If the variability between the number of normal germinants for the four replicates, is not too great (special tables are available in the International Rules to test this) the average of the four results is taken as an

expression of the quality of the seed lot. If the variability is excessive it indicates it has been caused by something other than the differences that could be expected by random sampling. For official or international tests which exceed the tolerance limit, it is necessary to repeat the whole test procedure.

Viability Tests

There are two main types of viability tests, the staining tests and the excised embryo tests. In the former the viability of the seeds is assessed by their ability to change the colour of liquid (Tetrazolium, Indigo Carmine). The assessment of staining tests is subjective and for this reason the excised embryo test which is a form of growth test is sometimes preferred. This involves the incubation of embryos, carefully removed from their seed coverings. Both the Tetrazolium test and the excised embryo test are described in detail in the International Seed Testing Rules.

When official tests are performed, sampling should be carried out in exactly the same way as for germination tests. However preparing and assessing four replicates of 100 seeds for either of these viability tests is extremely time-consuming and laborious, and for unofficial tests the number of seeds treated is often reduced to four replicates of 50. The same tolerance limits are used for the full Tetrazolium and excised embryo tests as for germination tests.

Tetrazolium Tests. The principle on which the Tetrazolium test is based is that active dehydrogenase enzymes in the seed react with the colourless solution of tetrazolium bromide or chloride to turn it bright red. The distribution of the insoluble red pigment in the important structures of the embryo and endosperm, gives an indication if the seed is viable. Detailed instructions are given in the International Rules as to how the 1% buffered tetrazolium solution and the seeds should be prepared and how the embryos should be evaluated. The cost of the salt at 1981 prices is £3.45 per 10 g.

The aim of the seed preparation is to expose the embryo and endosperm to the Tetrazolium during staining without damaging them in critical places. The exact method of preparation varies from species to species, but normally involves soaking the seeds in water after rupturing the covering layers to allow entry. Sometimes the seeds are then placed in Tetrazolium and the embryos carefully dissected out for assessment. Otherwise the embryos are carefully excised before being placed in the Tetrazolium solution. The seeds are incubated in the Tetrazolium solution for 18–48 hours, depending upon species, at a temperature of 30°C in complete darkness (the solution changes colour in light). At the end of this

period the solution is decanted, and after the seeds are washed in water, each one is assessed as viable or non-viable. During the assessment the embryos should be kept moist. The acceptable staining pattern for each species is given in the Rules, but in essence, the vital areas where the cell divisions take place (the root tip and the plumule) and where the cotyledons are attached to the main axis should be fully stained. For seeds with endosperm, this tissue must also be well enough stained to provide nutrient for satisfactory seedling growth. In most species this means full staining.

In order to carry out reproducible tests the ISTA prescriptions must be followed, but for quick information tests the methods of preparation and test conditions used (concentration, temperature and time) may be varied greatly without affecting the results significantly. A major variation which reduces the preparation time significantly is that used widely in America. Seeds are sliced longitudinally through the embryo (and endosperm) and placed in solution of lower concentration 0.1 to 0.5% for shorter periods. By examining the staining pattern under a binocular microscope an estimate of the viability can be made which has been shown to agree closely with the classical method. When used in this way Tetrazolium testing can be a very useful and versatile tool of the greatest possible help in monitoring the quality of seed during processing. However, being a very subjective test, it requires considerable experience to ensure meaningful evaluation. This can only be gained by practice. Unfortunately the current (1976) ISTA prescriptions have been found to be inadequate and have not given uniform results between laboratories. They are being completely rewritten and the new version should be available in 1984.

The Tetrazolium test gives an estimate of the viability of the seed at the time of the test. For species with little or no dormancy this will agree quite closely with the actual germination test results. However, for very dormant species the relationship will be much less close. This is because the number that germinate will be determined by the pretreatment and germination conditions to which the seed is subjected. If these are perfect then most if not all the seeds assessed as viable will actually germinate. If the conditions are unfavourable then weaker seeds, eg those with damaged parts, will not germinate. For these deeply dormant species it is necessary to classify only those seeds stained perfectly if any meaningful estimate of the future germination quality is to be made.

Other Staining Tests. Many other chemicals possess the ability to react to dehydrogenase enzyme systems. A large number have been tried in the past.

The only other compound still used widely is indigo carmine. Test certificates issued in Eastern European countries may well report this test. It differs fundamentally from Tetrazolium in that live tissues remain unstained, while dead tissues turn blue. In this test only the embryos are examined. Correlations have been obtained with germination that are comparable with those of Tetrazolium tests. The chemical is much cheaper, more uniform between manufacturers products and less toxic to operators than Tetrazolium, and with experience can give very satisfactory results. (Rostovtsev and Lyubich, 1978).

The Excised Embryo Test. The principle on which the excised embryo test is based is that viable embryos dissected from seeds will remain healthy and often begin to grow during a period of incubation, whereas dead, dying and even some weak embryos will decay during the same incubation period.

Detailed suggestions for preparation of the seeds are given in Appendix C of the International Rules. They were introduced in 1976 on a provisional (non-prescription) basis. They vary from species to species and differ in some important respects from the seed preparation prescriptions for the Tetrazolium test of the same species. Most include a period of soaking often following a treatment to allow the water to penetrate. All methods are designed to expose the embryo with as little damage as possible.

After dissection the embryos are placed on a moist filter paper surface and incubated for up to 14 days at 20°C, as described for ordinary germination tests. During the incubation period some embryos will begin to turn green and will start to grow. Often the greening is first observed on the lower cotyledon next to the surface and away from the light. This is due to leaching of inhibitors. Greening and growth are clear indications of viability. Seeds that remain fresh with no sign of greening are also regarded as viable. These are more difficult to assess and often require gentle pressure from a mounted needle to be certain. This must be done with care as it may lead to damage and later assessment difficulties. Any embryos known to be damaged during dissection should be replaced or set aside on one side of the test. Often embryos are damaged unknowingly and on these the damage shows up as straight lines of necrosis or very circumscribed areas.

Embryos which visibly decay, often with associated fungi are clearly non-viable. Embryos which decay by bacterial decomposition are less easy to detect. For these gentle pressure with a mounted needle helps with the assessment. If the embryo shows any tendency to liquify and to lose its integrity it is assessed as non-viable.

Although embryos of many of the species tested will show growth and greening thus rendering the assessment objective, there will remain an element of subjectivity when assessing the non-viable component. The most difficult feature is to decide at what point it is possible to clearly differentiate between viable and non-viable embryos of weak seed lots. Because of contamination from nearby dead embryos, the proportion of dead slowly increases. It is important to maintain as clean conditions as possible at all times. Instruments should be sterilised between handling of individual seeds.

One clear advantage of the excised embryo test over staining tests, is that it allows the level of dormancy in the embryo to be observed. If the test is performed on newly collected seeds the embryo may show no growth at all and possibly even no greening. Later as normal storage proceeds, the embryo may show more and more growth earlier and earlier in the test period, due to a reduction in the level of embryo dormancy (eg *Acer*, *Fraxinus* spp). This feature of the test makes it particularly useful for studying the effect of special seed treatments aimed at speeding up the loss of dormancy. It may also give a more accurate estimate of germination quality than staining methods for non-endospermic seeds. For endospermic seeds it may be less accurate as the embryos are separated from the endosperm before incubation and the latter is not considered in the evaluation.

Accurate Calculation of Seed Quality

From the three tests performed the following characteristics are obtained:

the percentage purity = P.

the weight of 1000 pure seeds = W in grams

the germination or viability percentage = G (or V).

The number of germinable or viable seeds in a kilogram of the bulk is calculated thus:

$$\frac{1000 \times 1000}{W} \times G \text{ (or V)} \times P$$

example for *Carpinus betulus* Purity = 96%
1000 psw = 48.22g
Viability = 37%

$$\frac{1000 \times 1000}{48.22} \times \frac{37}{100} \times \frac{96}{100} = 7366$$

This is normally expressed to the nearest ten ie 7370 viable seeds/kg.

ASSESSMENT OF SEED QUALITY IN THE NURSERY

The principles of testing the viability and germination of seed of ornamental tree species have been given above in some detail in order that nurserymen will know the principles involved if it is necessary

for them to carry out their own tests. However, during the collection, processing, storage and treatment of seeds the nurseryman should want to monitor the quality of his seed. Even though he can get a quick information test carried out at Alice Holt Lodge this will take at least a week to perform and may well not be quick enough. A suggested format for recording assessments made in the nursery is given at Appendix 6c.

It is not essential for the test conditions employed for these quality control tests in the nursery to be identical and comparable with those employed in the laboratory. A quick assessment of the purity could be made simply by eye. For very pure seed lots the greater accuracy achieved by an analysis is probably not justified. For impure seed lots (greater than 10% impurity) the actual percentage may be masked by the impurities and an analysis by weighing is probably justifiable. For germination tests carried out in the nursery to assess the effectiveness of seed treatment, there is some advantage to be gained by using conditions more similar to those that will prevail in the nursery bed at time of sowing. Thus the medium used for the germination test could usefully be the nursery soil and the temperature employed nearer 15°C than the 20–30°C normally prescribed. This level of temperature can be found in some building in most nurseries. The temperature prevailing in air-heated greenhouses in early spring fluctuate much more than naturally and if this environment is used it will be better to ensure that the seed is not in direct sunlight, which can easily induce secondary dormancy. Plastic food containers are readily available and make excellent germination boxes, but they should be punctured to allow drainage of excess moisture. They should be filled with soil or other medium at a moisture level that just allows a drop to be squeezed between the fingers of a clenched fist and should be covered in plastic or glass to conserve moisture, until the seedlings rise above the surface. Simple germination tests can be carried out by placing two sheets of blotting paper, which has been soaked in water and allowed to drain for five minutes, in the bottom of a covered plastic container. This will provide sufficient moisture to allow the seeds to germinate.

Similarly the conditions employed in a nursery Tetrazolium test need not be very exact. As mentioned earlier with experience perfectly satisfactory estimates of viability can be made by using non-standard conditions. Unbuffered solutions of Tetrazolium of more or less any strength may be used; nor is the time and temperature of incubation important. These factors are closely related and by manipulating time, very quick results can be achieved, for example within two hours at 50°C.

During assessment a hand lens is invaluable. For seed lots with high infection of microflora, which will themselves reduce the Tetrazolium solution, addition of a small amount of fungicide eg Thiram will reduce the interference. Tetrazolium is available through most chemical supply firms. The dust from the salt should not be inhaled when preparing the solution.

Assessment of quality before collection

Before any time and effort is spent in making a seed collection, it is important to ensure that the seed is worth collecting. This normally will be a simple question of whether the seed contains an embryo and endosperm or not, that is whether the seed is empty or full. It is extremely rare to find full seeds on a tree that are actually dead unless they have been attacked by insects. A cutting test is thus a very satisfactory practical test to use before beginning collections. A sample of seeds or fruits fully representative of the proposed collection should be taken and the seeds extracted by hand if necessary. Cutting through the seed with a sharp instrument, will clearly show if the seed is full, empty or insect damaged. Although not essential, if time permits the full cut seeds can be placed direct into a 0.1% Tetrazolium solution. Overnight they should stain a deep crimson colour, although the cut surface may appear white, due to the remnants of the cut cell walls.

Assessment of quality during processing

Although the recommendations for handling of seed and fruit given above should ensure the quality of seed is maintained successfully, it may not always be possible to follow them out. Berried fruit may begin to ferment, apparently dry fruits do heat up. Before more time and effort is devoted to further processing, it may be desirable to monitor the current quality. Carrying out a cutting test alone at this time will not tell a nurseryman very much. Almost certainly he will be unable to say if the full seeds are dead or alive. The quick practical test is the Tetrazolium test. During the initial stages of processing the seeds will still have a high moisture content and no soaking will be necessary. A fully representative sample should be taken. Cutting them in two with a sharp instrument (after carefully exposing them in the case of stone fruits) and placing them in tetrazolium solution overnight will enable their viability to be assessed adequately for practical purposes.

Assessment of quality after processing and just before seed treatment

At the end of processing, especially if the seed has been dried, it is advisable for the nurseryman to

check the quality of the final product. At this time he will want to know not only if the seed is alive, but for non-dormant and slightly dormant species, possibly also if it will germinate. For all seed types he will want to know the number of viable or germinable seeds per kilogramme in order to see if he has collected enough of his own for his requirements or if he will have to purchase more.

A sample fully representative of the bulk should be taken. From this a sub-sample should be taken big enough to give an estimated four hundred individual seed units. The surplus can be returned to the bulk. If greater accuracy is required the sub-sample should be increased to an estimated 1000 seed unit sample. The sub-sample chosen should be weighed and sorted into pure seed and inert matter. From the pure seed four replicates of 10, 25, 50 or 100 seeds should be counted at random, depending upon the accuracy of the estimate desired and set up to germinate or soaked in preparation for Tetrazolium testing. The number of seeds not used for the germination or viability test should be accurately counted. At the end of the test the percentage of germinated or viable seeds should be used to calculate the quality of the seed lot. (See later section).

Assessment of quality during storage and during seed treatment

It may be necessary to store seed from one season to the next for a variety of reasons, eg excess was collected, the seed arrived too late to be used or miscalculation of requirements. Recommendations for storage conditions have already been described. Nevertheless it may not be possible to give optimum conditions and it may be advisable to monitor the quality at intervals during storage. Stored seed should certainly be tested before it is finally used for sowing. It may also be desirable to monitor the effect of conditions during treatment to overcome deep dormancy, especially with a new species and when using a new technique.

Provided a truly representative sample is taken, it is usually necessary only to assess a total of 100 seeds. For most species the Tetrazolium test will have to be used. It helps to judge the deterioration of quality, if it can be compared with the results of a test performed at the start of storage. Provided again a truly representative sample is taken, the deterioration can usually be judged using rather fewer than 400 or even 200 seeds. It is suggested instead that a sliding scale be used. The test should be set up in replicates of 25 seeds. If the first replicate shows a high number of well stained seeds, it is probably not necessary to assess further replicates. If it shows about half well stained, a second replicate should be examined. The lower the number

of well stained seeds, the more replicates should be examined in detail. Notes should be kept of the staining patterns in order to compare with any later tests. For non dormant seed types which germinate readily the best method to use is obviously the germination test.

Assessment of quality after seed treatment ends

In order that the effectiveness of seed treatments to overcome deep dormancy can be judged, thus enabling more meaningful sowing densities to be calculated, it is strongly advised that tests be made. Tetrazolium tests made at this time will give an indication whether the treatment conditions have been harmful to the less vigorous seeds, but will give no indication if the treatment has been effective in inducing germination. Germination tests alone can do this. These should be conducted on representative samples of the treated seed. If the seed has been treated in several different containers, each container should be sampled. If the containers are big, samples should be taken from different levels in each. Wherever there is a suspicion that the seed lot has not been given uniform treatment throughout, for some unexpected reason, separate tests should be performed.

The number of seeds set to germinate will depend upon the number of containers and the size of the lot treated. Provided previous tests or inspections have given no hint of heterogeneity of treatment, as few as 100 seeds (25 seeds for large seeded species) will be enough to give an indication of whether the treatment has gone on for long enough. These should be set up as described earlier. For calculating the sowing density accurately, a rather larger sample should be taken.

Monitoring of the quality should begin a few weeks before the expected finishing date of the treatment. Seed lots vary greatly in their specific requirements and field emergence can be badly affected if seed is given too long a treatment before sowing. If this happens the treatment should be terminated as described in Chapter 7.

Another method of monitoring seed, which can be used when the seed lot is available well in advance of treatment initiation, is to set up under identical conditions about one month ahead of the main bulk, a suitably sized sample. By regularly assessing the germination potential of carefully taken sub-samples the optimum time for sowing the bulk can be quite accurately estimated.

Quick calculation of seed quality

The following quick calculation of seed quality can be made at all stages of seed processing and treatment, provided the individual terms in the equation

are all available. The worked example relates to a fairly complete estimate of seed quality at the end of processing.

four replicates pure seeds = a (number)
 germination (viability) = G(V) (per cent)
 remaining pure seeds = b (number)
 weight of original sample = x (grams)

The number of germinable (viable) seeds per kg of bulk

$$= \frac{V \times \left\{ \frac{\text{No of pure seeds in } x}{= a + b} \right\} \times 1000}{x}$$

For example: Taking a 25 g sample of *Carpinus betulus*

four replicates of 50 seeds

∴ a = 200

Number of viables 30 + 33 + 28 + 29 = 120

∴ $V = \frac{120}{200} = 60\%$

remaining seeds = 380 seeds

∴ b = 380

weight of original sample = 25 g

∴ x = 25g

∴ number of viable *Carpinus betulus* seeds per kg of bulk

$$= \frac{60}{100} \times \frac{(200 + 380)}{25} \times \frac{1000}{25} = 13,920$$

Sowing density

RECOMMENDATIONS

Whether by means of test certificates from official laboratories or as a result of tests carried out by himself, the nurseryman should have some idea before sowing of the number of germinable or viable seeds in a given quantity of seeds. Most statements of quality are now based on kilograms but American certificates are still often expressed in imperial units. Armed with the quality, the nurseryman must calculate the density at which he wishes to sow the seed. This will depend upon several interacting factors but the most important is the production strategy—whether seedlings will be sown for transplanting or whether they will be grown on in the seedbed.

With the increase in broadleaved plant production from seed in the United Kingdom there has been a relative increase in the proportion of plants produced as 2+0 undercut stock as opposed to 1+1 transplants. This is due mainly to the problems of transplanting subjects with vigorous tap roots. For production of undercut stock, the sowing density generally used aims at producing from 200 to 300 usable plants per square metre. For small not very

vigorous species the rate is nearer 300 but for vigorous species the aimed stocking may be even lower than 200 usable seedlings per metre.

The alternative system of producing plants by sowing densely in seedbeds and transplanting seedlings at the end of the first growing season, has been used quite widely by the Forestry Commission, but little detailed experimental work has been carried out on the sowing densities involved. Aldhous (1972) in Table 24 lists in the Nursery Practice Bulletin the suggested sowing densities for 42 species in terms of the number of viable seeds per square metre, but these were derived from work carried out in the 1950–60s. It also lists the number of square metres into which an average or standard kilogram of seed should be sown as well as the average yield of seedlings per kilogram of seed. Unfortunately the figures are based on average results and have not made any allowance for the very large variation in quality of individual lots of the same species. From the table it is possible to derive the average number of seedlings produced in a metre which, by implication, is the recommended stocking at the end of the season. It is also possible to derive the germination survival factor. The stocking figure at the end of the season varies from 27 to 660 per square metre and the survival factor from 10 to 95%. Clearly these results do not accord with current nursery practice or with survival figures obtained in the authors' experimental trials. This is probably due to the fact that the tests carried out were in many cases based upon cutting tests and only at the end of the seed treatment. When sowing to produce 1+0 seedlings the best advice therefore that can be given is that the final stocking should be between three and four times that of seedlings destined for undercutting. The exact number per metre will be determined by the size and vigour of the species.

In order to achieve a desired stocking at the end of a season it is necessary to sow more than that number of germinable seeds per metre. This is in order to allow for the failure of some seeds and for deaths of less vigorous seedlings. In addition, extra seed has to be sown to allow for culling of poor quality seedlings, so that the desired number of usable seedlings will be available.

The adjustment made to the sowing rate is now widely known as the Field Factor. This term was originally coined in horticulture. It is exactly the same as the term germination survival factor used in the Nursery Practice Bulletin. It is a measure of all those factors which together influence negatively the successful establishment of seedlings.

From a knowledge of the conditions that exist in his nursery a nurseryman produces this figure which is used to correct the number of germinable seeds

sown in order to end up with the desired number of usable seedlings. Factors such as soil type, seedbed conditions, availability of irrigation, proneness to frost and damping off, season of sowing (autumn or spring) should be considered as well as the particular species, the size of the seed (if abnormally small extra seed should be sown) and if known, the vigour of the seed. This last factor is now widely talked about in agriculture and horticulture but due to inherent difficulties in assessing the germination quality as opposed to viability of ornamental seeds, has received little attention in this field. However, if when testing seed lots after treatment, a nurseryman finds that one lot germinates much faster than another of the same species, he should adjust the sowing rate accordingly. Almost all of the component parts of the Field Factor involve subjective assessments and therefore are very difficult to quantify. Thus the best method of arriving at the Factor is by using previous experience in the nursery. To some extent this can be quantified, by careful record keeping of the number of germinable seeds sown and usable seedlings produced. However even results in the same nursery differ from year to year due to unexpected weather conditions. In 1980 germination throughout Britain was some 25% below expected, probably as a result of the long cool dry spell that followed sowing in most areas. A complete record of weather conditions and other factors should therefore be kept as seed predation, drought, frosting, drying winds, browsing and seedling predation etc. It is never possible to calculate beforehand exactly what the Field Factor should have been and it will be a matter of judgement how much safety margin should be included in the calculations. A suggested nursery record sheet is included at Appendix 6d.

CALCULATION

Once the Field Factor and desired stocking have been decided upon and the germination quality of the actual seeds to be sown is known, the calculation of the sowing density is an easy matter:

$$\begin{array}{lcl} \text{Sowing density} & & \text{Desired population per} \\ \text{in grams/m}^2 & = & \text{metre} \\ & & \hline & & \text{Number of} \\ & & \text{germinable} \\ & & \text{seeds in a} \quad \times \text{field factor} \\ & & \text{kilogram of} \\ & & \text{seed sown} \end{array}$$

This can be derived from first principles for any seed lot as the following example shows:

Desired population per metre = 200 seedlings
Germinable seeds per kg of seed as sown = 4000
Field Factor (Germination Survival Factor) = 0.6
(= 60%)

There are 4000 germinable seeds in 1000 grams
∴ 200 germinable seeds are contained in

$$\frac{1000}{4000} \times 200 \text{ grams}$$

But only 60% of germinable seeds survive to produce seedlings

Therefore to produce 200 seedlings

$$\frac{1000}{4000} \times \frac{200}{0.6} = 83.3 \text{ grams} \quad \text{seeds must be sown in each square metre.}$$

To produce 1000 usable seedlings $\frac{5 \times 83.3 \times 105}{100}$
= 437 grams of seed must be sown allowing for a culling rate of 5% or $\frac{5 \times 83.3 \times 110}{100}$ = 458 grams of seeds at 10% culling rate should be sown at a rate of 83.3 g/100 sq metre of seedbed area.

Seedling yields

In order to calculate the quantity of seeds to purchase a nurseryman must know how many seedlings he can expect to obtain from a given weight of seeds. For seeds which germinate readily such as *Betula*, *Eucalyptus* species etc it is relatively easy to calculate the germination survival factor. For deeply dormant species the germination survival factor in the field will depend not only upon the accuracy of the original assessment of viability but also upon the efficiency of treatment of the seed. Present methods of assessment used in Tetrazolium testing record the number of seeds that are viable at the time the tests are performed, and do not take into account what will happen in the nursery because this will depend so much upon the conditions to which the seeds are subjected. It is therefore unwise to attempt to estimate too accurately the germination survival factor from the figures of seed quality quoted in Appendix 6a. This is best done by building up records over the years. However, it is possible, assuming that all viability tests are equally accurate, and that all seed lots are of average quality, to put forward a rule of thumb which will at least allow some sort of estimate to be made of the quantity of seed to buy. (The task is very much easier if the quality of the seed lot on offer is known beforehand). In general the proportion of viable seeds still alive at the end of treatment will be related inversely to the length of time the seeds are treated, and to the type of treatment, warm and/or cold, given. Seeds subjected to lengthy warm periods will survive less well than seeds given only a couple of months of cold treatment. Thus as a guide seeds given 8–12 weeks of cold treatment alone should germinate 50–75% of the number of viable seeds at the start of pretreatment. Seeds subjected to 12–26 weeks of pretreatment should germinate

40–50% of the number of viable seeds and seeds given warm treatment before cold should germinate from 25–40% of viable seeds treated. If the warm treatment lasts for a month the germination will be nearer 40% and if it lasts several months it will be nearer 25%. To be more accurate than this will necessitate a much more rigorous interpretation of the staining patterns in the Tetrazolium tests (see page 28).

For all the above reasons the actual data available from recent Forestry Commission experience is very inconclusive. Some data are also available from much earlier work and are quoted by Aldhous (1972), but these are also unreliable because they were not based on actual qualities of individual seed lots sown. Despite these uncertainties an estimated germination survival factor has been proposed for each species/genus and has been included in Appendix 6a.

In order to ensure that enough seedlings are produced it is suggested that nurserymen should purchase enough seed to produce their desired quantity of seedlings assuming the worst survival factor,

that it should be pretreated where necessary as suggested in Appendix 7 and that the final quantity sown and the sowing rate used should be determined after carrying out germination tests at the end of pretreatment.

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Chapter 7

SEED DORMANCY AND PRETREATMENT

Mature seeds of most woody plant species from the temperature zones will not germinate promptly when placed under conditions which are normally regarded as suitable for germination. Such seeds are said to be dormant.

Seed dormancy aids the survival of wild plant populations by preventing out of season emergence, and by spreading the germination over many weeks or even years, thereby increasing the opportunities for successful seedling establishment. In contrast, the same phenomenon presents a problem to the nursery operator who is attempting to produce large, uniform crops of seedlings as rapidly as possible. However, the problem is not insurmountable and dormant seeds can be induced to germinate within a reasonable time if certain predetermined conditions are satisfied. (See below and Appendix 7).

Causes, Occurrence and Classification

The mechanisms which restrict germination vary widely, so dormancy is a rather vague and relative term. It describes a condition which results both from inherited properties and from conditions imposed by the environment. It may vary in degree within a species depending on differences between individuals (Rowe, unpublished data on *Acer campestre*), location (Wang, 1980 on *Acer saccharinum*), climatic conditions or times of collection (ie degree of maturity) (Gassner, 1938 on *Robinia pseudoacacia*), and it is certainly modified by the nature and duration of storage. Any common properties and inter-relationships are thus obscured.

Attempts have been made to put the subject into some kind of order, starting with the relatively simple classification scheme proposed by Crocker (1916). Crocker described dormancy as resulting from: i) embryo immaturity, ii) impermeability of the seed covers to water, iii) mechanical resistance of the covers impeding embryo growth, iv) low permeability of the seed covers to gases, v) a metabolic block within the embryo requiring for its removal, a) light, or b) chilling; vi) combinations of the above, and vii) secondary dormancy. This scheme proved extremely useful and served, with only slight re-arrangements, as the basis for much exploratory work and several major works on seed dormancy, including those by Amen (1968) and

Villiers (1972; 1975). However as more information became available, Crocker's system was considered inadequate and a new, more natural, classification was proposed by Nikolaeva (1967; 1977). This new classification was designed specifically with trees in mind and it is therefore the one described in detail below.

The types of dormancy are divided into three groups: exogenous, endogenous and combined, depending on the relationship between the factors preventing germination and the conditions required to remove the block. Table 1 shows a simplified version which adequately describes most dormancy types exhibited by temperate broadleaved tree and shrub seeds.

EXOGENOUS DORMANCY (A)

Exogenous dormancy types are those caused by physical or chemical properties of the outer seed coverings which can be overcome by various physical means.

Physical dormancy (Aph) or hardseededness is the most commonly recognised type. Seeds exhibiting this condition have hard seedcoats which contain cutinised layers preventing the passage of water to the embryo. The control is extremely effective. Most woody legumes exhibit this type of dormancy, and in most, eg *Cytisus*, *Laburnum*, *Robinia*, it is the only factor preventing seed germination. However, amongst many non-leguminous species the hard-seeded condition merely exacerbates other dormancy imposing mechanisms, eg *Tilia*, in which the hard seedcoat is impermeable to water and gases (Aph) and the embryo possesses deep physiological dormancy (C₃).

Chemical dormancy (Ach) of dry indehiscent fruits is caused by the presence of inhibitors in their pericarps. It is seldom the sole factor preventing seed germination although there is some evidence that in certain East Asiatic *Fraxinus* species it may be. Chemical dormancy may occur regularly in combination with other dormancy mechanisms, but the presence of inhibitors usually goes unnoticed since they are leached or neutralised during the lengthy treatments used to overcome the other, stronger dormancy controls.

Table 1 Classification of broadleaved tree seed dormancy (modified from Nikolaeva, 1977)

<i>Types of dormancy</i>	<i>Factors causing dormancy</i>	<i>Conditions breaking dormancy</i>	<i>Example</i>
A—Types of exogenous dormancy			
Physical (A _{ph})	Impermeability of seed coat to water	Scarification	<i>Robinia pseudoacacia</i>
Chemical (A _{ch})	Inhibitors in pericarp	Removal of pericarp or leaching	<i>Fraxinus chinensis</i> var. <i>rhynchophylla</i>
Mechanical (A _m)	Mechanical resistance of covers to embryo growth	Various methods for destroying the covers	<i>Elaeagnus angustifolia</i>
B and C—types of endogenous dormancy			
Morphological (B)	Underdevelopment of embryo (UE)	Warm, moist treatment	(Occurs only in combination with other factors)
Physiological (C)	Physiological inhibiting mechanism (PIM) of germination		
Shallow (C ₁)	PIM weak	Short chilling treatment, growth stimulators, dry storage	<i>Betula pubescens</i>
Intermediate (C ₂)	PIM intermediate	Long chilling treatment and several other influences such as GAs	<i>Nothofagus obliqua</i>
Deep (C ₃)	PIM strong	Long chilling treatment only	<i>Sorbus aucuparia</i>
B-C Morpho-physiological			
	Combination of UE and PIM		
Deep (B-C ₃)	Combination of UE and strong PIM of germination	First warm, then cold treatment	<i>Fraxinus excelsior</i>
Deep, epicotyl (B-Ce ₃)	Combination of UE and strong PIM of epicotyl growth	Same	<i>Viburnum opulus</i>

In the vast majority of cases, seeds show combined dormancy, which represents various combinations of the types of endogenous and exogenous dormancy. For example, in the seeds of *Tilia cordata*, the physiological dormancy (C₃) is associated with a hard-seeded condition (A_{ph}).

Mechanical dormancy (A_m) is similarly most often exhibited in combination with other mechanisms but, unlike the chemical dormancy, it cannot be masked. It is attributable to the presence of a tough outer seed cover which acts as a mechanical obstacle to embryo growth. This tough obstacle is much more difficult to overcome than the hard-seeded condition and its removal takes far more time. Some examples are *Crataegus* and *Carpinus*. Others will be found with the descriptions of combined dormancy.

ENDOGENOUS DORMANCY (B, C)

Endogenous dormancy exists in many forms and is extremely difficult to remove. It is caused primarily

by conditions of the embryo itself, separated by Nikolaeva into three main sub-groups—**morphological dormancy (B)**, **physiological dormancy (C)** and **morpho-physiological dormancy (B-C)**. These endogenous dormancy types can only be broken by the application of those factors, such as light, chilling treatments and growth stimulators, which bring about physiological changes.

Seeds with **morphological dormancy (B)** are dispersed with underdeveloped embryos which must complete their growth and development before the seeds can germinate, eg *Fraxinus excelsior*, *Magnolia* spp. However, in the majority of cases the seeds remain dormant, even after embryo growth because

the morphological dormancy is associated with physiological dormancy. Further examples are given with the description of morpho-physiological dormancy.

Physiological dormancy of seeds (C) is due to reduced embryo activity which, together with the restriction to gas exchange imposed by all seed covers, produces what Nikolaeva designates as the physiological inhibiting mechanism (PIM). The term PIM probably covers a whole range of different dormancy control mechanisms. Certainly several types and strengths of PIM can be recognised, although the borderlines between them are often rather vague. The recognised divisions are—shallow (C₁), intermediate (C₂) and deep (C₃) physiological dormancy.

Shallow dormancy (C₁) is typical of freshly collected seeds of many species from the temperate zones, eg *Betula* spp. The condition can disappear gradually in the course of after-ripening during dry storage of the seeds, but can be removed more quickly when the seeds are moist by any one of a range of different treatments. Changes in the temperature or, more commonly, the illumination conditions can restore germination in the laboratory as can increasing the partial oxygen pressure, or damaging the seed covers. However, the most practical nursery treatments rely on the efficacy of a short moist prechilling treatment (2–4 weeks) (eg some seed lots of *Betula* spp.) or an application of growth stimulators, gibberellins being the most successful.

Intermediate dormancy (C₂) is more complex. The entire seeds normally require a longer moist prechilling treatment (4–12 weeks) before they can germinate, although gibberellin application is sometimes a successful substitute treatment. However, embryos excised from their covers will usually germinate normally if placed under ideal conditions, especially if the seeds have been subjected to dry storage for some time.

In contrast embryos excised from seeds exhibiting *deep physiological dormancy* (C₃) cannot germinate properly. They grow into retarded, abnormal 'physiologically stunted' seedlings, even under the most favourable conditions. A protracted moist chilling treatment (more than 12 weeks) is necessary to break the dormancy and no other treatment is successful. This deep physiological dormancy is especially common among rosaceous general. (*Sorbus*, *Malus*, *Chaenomeles*).

As mentioned previously the physiological dormancy is associated, in some instances, with morphological dormancy. Of the several complex forms recognised by Nikolaeva, only two are of importance to woody plant propagators, morpho-physiological

hypocotyl dormancy and morpho-physiological epicotyl dormancy. *Fraxinus excelsior* seeds exhibit the former type (B-C₁). The seed is dispersed with an under-developed embryo which must grow to fill the seed during a period of moist warm treatment. The seed then requires a protracted moist chilling treatment to overcome the physiological dormancy. Morpho-physiological epicotyl dormancy (B-Ce₁) is removed by the same warm-plus-cold treatment but in this case the radicle emerges during the warm period and the epicotyl or shoot-bud only outgrows after the seedling (with a sufficiently developed root system) has been subjected to a chilling treatment. *Viburnum opulus* seed remains dormant unless treated in this manner.

The vast majority of tree species produce seeds exhibiting combined dormancy, characterised by various combinations of the exogenous and endogenous dormancy types. *Rhamnus frangula*, *Tilia* spp. and some *Rhus* species all produce seeds showing physiological dormancy combined with hardseededness and until water penetrates to the embryos, the changes which take place during prechilling cannot occur. The physiological dormancy can also appear in combination with chemical dormancy (*Fraxinus mandschurica* seed) but is more frequently combined with mechanical dormancy, eg *Cornus*, *Cotoneaster*, *Crataegus*. All these dormancy combinations are removed during the multiple pretreatment regimes which are explained in detail in the next section.

It must be stressed that the classification scheme, outlined above, does tend to over-simplify the dormancy problems. It is because the dormancy of individual seed lots of given species vary so much that the seed pretreatment recommendations given in Appendix 7 are unavoidably broad in some cases. However individual nurserymen can remove much of the guesswork concerning the pretreatment of their own seeds if they collect it, where possible, from the same sources each year and keep detailed records about its treatment and subsequent germination.

Breaking Dormancy by Seed Pretreatment

OVERCOMING EXOGENOUS DORMANCY

The physical and mechanical constraints are the only *exogenous* dormancy mechanisms which will trouble the nurseryman. They are sometimes grouped together as both causing hardseededness but this term is more appropriately used to describe those seeds exhibiting physical, not mechanical, dormancy. The seed pretreatments for the two types differ in important details.

Under natural conditions *physical dormancy*, or *true hardseededness*, is removed gradually, mainly by

the action of biological decay. The process may take many years to reach completion and germination will be sporadic. To obtain rapid and synchronous germination artificially, the seeds must be subjected to some physical or chemical treatment which will quickly destroy the integrity of the impermeable cover and so permit the imbibition of the embryo. The most commonly recommended procedures involve: (i) treatment with sulphuric acid (acid scarification), (ii) immersion in hot or even boiling water, and (iii) mechanical injury of the impermeable cover by chipping or abrasion (mechanical scarification). These are all violent treatments and, when their use is contemplated, it must be remembered that the proportion of hard seeds in different seed lots will vary considerably depending on the species, the degree of maturity, the storage time, and most especially on the air humidity during ripening. (Gassner, 1938). The proportion of hard seeds may vary during storage due to less than optimum storage conditions. Hence the duration of the treatment must be determined experimentally for each seed lot just before each treatment operation.

Physical dormancy is maintained only by a relatively thin, brittle layer which becomes ineffective as soon as it is breached by even the smallest injury. On the other hand seeds showing *mechanical dormancy* have a tough, leathery or fibrous outer-covering which is both thick and permeable. The permeability makes concentrated sulphuric acid treatment a risky procedure to use since any trace of moisture will allow the acid to penetrate the outer cover and destroy the embryo. Furthermore, the thick seedcoat presents difficulties in determining the optimum treatment period because it becomes transformed into a layer of charred material impeding the continued digestive action of the acid. These problems do not mean that concentrated sulphuric acid treatment cannot be used on mechanically dormant seeds, but its use does require even more expertise than is necessary for treating seeds exhibiting true hard-seededness. Certainly Blundell (1973) has demonstrated the successful removal of mechanical dormancy from rose seeds using a concentrated acid soak.

Mechanical scarification is even less satisfactory than acid scarification for most mechanically dormant seeds, and hot water treatment is totally useless. The best method for overcoming mechanical dormancy is based upon the natural process which takes place during the warm, moist conditions of late summer, autumn and spring, namely biological decomposition. This process can be speeded up by controlling the environment of the seed, ensuring optimum warmth, moisture and aeration during the pretreatment period. The methods used to ensure

these conditions are described on page 41. Some species with very thick seed covers such as *Crataegus monogyna* require several months of warm treatment but most *Prunus* spp. will respond to only two weeks. (See Figure 4)

OVERCOMING ENDOGENOUS DORMANCY

A period of exposure to warm moist conditions is also necessary for those seeds exhibiting some form of *morphological dormancy*. The warmth permits the embryo to develop to a stage which is receptive of cold treatment. This warmth requirement can be satisfied either by mid to late summer sowing, or by summer stratification in a pit but, as in the case of the treatment for mechanical dormancy, pretreatment is accomplished more rapidly under controlled conditions. (See page 41)

Physiologically dormant seeds require, as their pretreatment, a period of exposure to cold temperatures (usually between 1°C and 5°C) fully imbibed and adequately aerated. The length of the treatment necessary depends upon the depth of the dormancy, and it may not be satisfied during the course of one winter. Hence, germination is more reliable if the seeds are pretreated under controlled conditions. The practical details of cold and warm temperature treatments are dealt with on page 46.

The physiological effect of the prechill period is far from being properly understood, although it appears to influence the balance of growth regulators and allows time for the mobilisation of storage products (Lewak and Rudnicki, 1977). If the dormancy is not too deep, and the seed covers are permeable then it is possible to stimulate germination of the seeds directly by treating them with growth-stimulating substances such as gibberellins (Bonner, 1976). Apparently, in such instances, only the balance of growth regulators needs to be controlled for the storage products to be rapidly mobilised. *Nothofagus obliqua* seed samples, for instance, will germinate more fully after a twenty-four hour soak in 50 ppm Ga_{4/7} solution (a mixture of gibberellins A₄ and A₇) than after even six weeks of prechilling (Rowe and Gordon, 1981). (See Figure 5). Unfortunately, the technique is of limited value to the nurseryman because so far it has only been found to give a positive response on such a small range of species (eg *Liquidambar styraciflua*, *Nothofagus* spp., *Betula* spp.) Pretreatments for the removal of physiological dormancy will always remain a time-consuming operation, especially since, in most cases, the physiological dormancy is combined with exogenous constraints.

OVERCOMING MULTIPLE DORMANCY

Combined multiple dormancy types are removed by combinations of the relevant pretreatment practices.

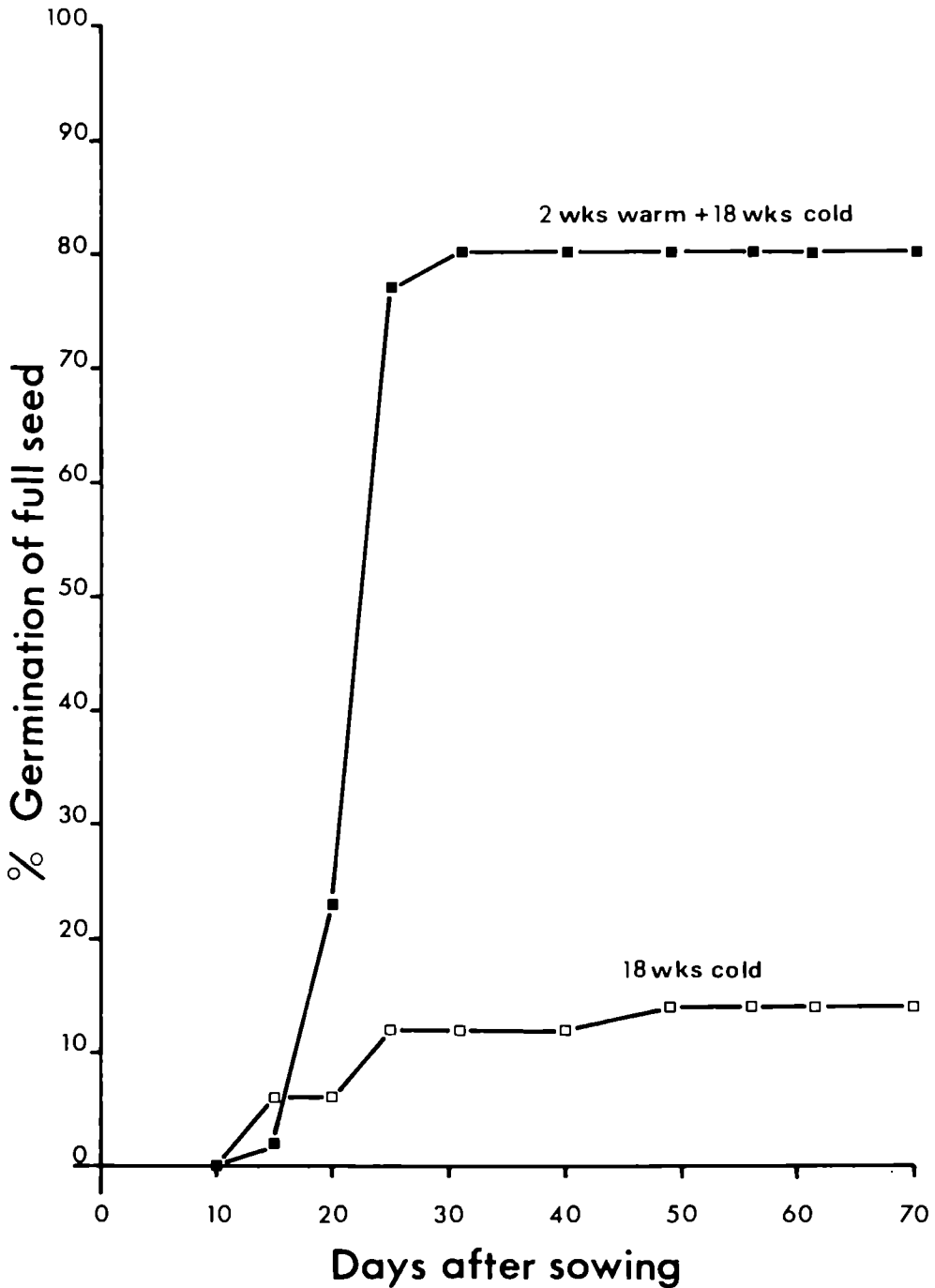


Figure 4 The seeds of Rosaceous species contain deeply dormant embryos requiring a lengthy prechill to promote germination. However, most of them also derive benefit from a warm, moist pretreatment prior to prechilling. For seeds having tough outer covers, such as those of *Prunus spinosa*, the warm period facilitates stone splitting.

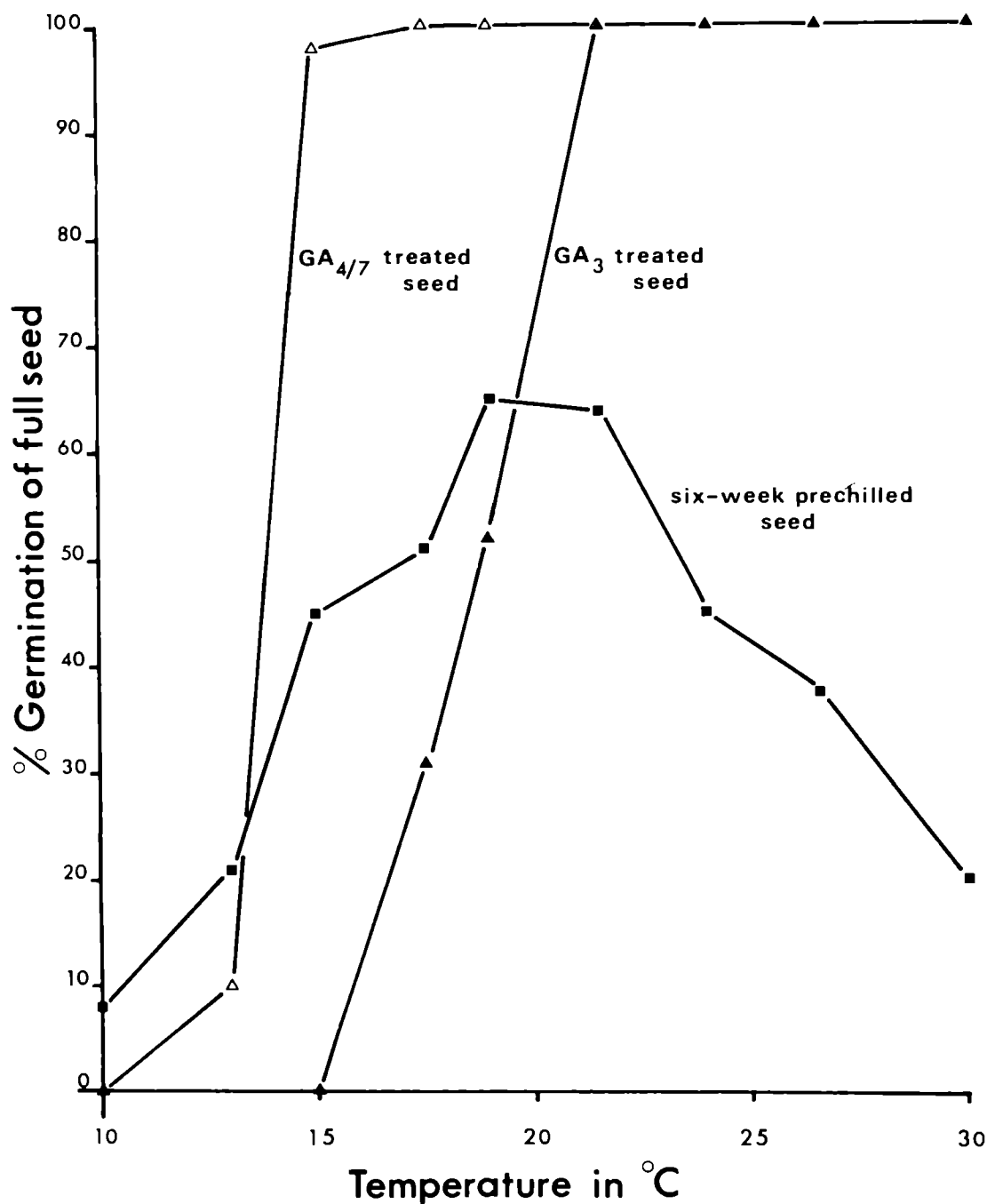


Figure 5 The effect of various pretreatments on the subsequent germination of *N. obliqua* seeds over a range of constant temperatures. GA_{4/7} is probably more effective than GA₃ at breaking *Nothofagus* seed dormancy out in the nursery because it continues stimulating germination at a lower temperature.

For example, *Crataegus monogyna* seeds have a tough seedcoat condition combined with deep physiological dormancy. Eight weeks of warm treatment (or a short concentrated sulphuric acid soak plus four weeks of warmth) weakens the seedcoat, and a subsequent eight to twelve weeks of cold treatment overcomes the embryo dormancy. *Fraxinus excelsior* seeds have only a very weak mechanical dormancy but they require a long warm treatment (eight to twelve weeks) for maturation of the embryo, which then requires a further eight to twelve weeks of conventional cold treatment to break the deep physiological dormancy.

In some genera (eg *Chaenomeles*, *Malus*, *Sorbus*) the seed becomes more dormant if it is allowed to dry out during extraction. For example the seeds of *Sorbus aucuparia* will germinate totally after only ten to twelve weeks of cold treatment, if put into the cold conditions direct from extraction (or directly autumn sown) but if the seed is dried, then at least sixteen weeks of cold treatment plus for some lots, a prior two weeks of warm is necessary. This is caused by the addition of a mechanical constraint, a hard, dried seedcoat, to the already physiologically dormant embryo.

WARM AND COLD TEMPERATURE REQUIREMENTS

Stratification pits were widely used in the past to overcome the dormancy of broadleaved tree seeds but their use has many drawbacks. They are costly to construct properly (see Aldhous, 1972 page 55) and it is difficult to monitor the progress of dormancy-breaking within a pit. When germination does take place development is rapid and cannot be retarded.

Another method still used to satisfy warm and cold temperature requirements is to sow the seed without treatment in the seedbeds in the autumn. Although this can prove successful, it often produces unreliable results. In a cold autumn the necessary warm temperature requirement may not be satisfied. The seeds may be subject to predation by birds and rodents. Very wet conditions for long periods may asphyxiate the seeds. An early warm period in spring may cause germination to begin which could be badly affected by a sharp late frost. (The best known example of this is *Fagus sylvatica*). Autumn sown crops also have other disadvantages. They keep land locked up for much longer than spring-sown crops, and the techniques can therefore only be used where enough fallow land is available. Also seedbeds will require weeding throughout the autumn and winter months. Finally the cost of preventing predation may be very high.

If maximum release of seed dormancy is to be achieved with minimum loss of seed and money, then the best method is clearly to pretreat the seeds arti-

ficially under controlled conditions. In this publication the terms prechilling or cold pretreatment, and warm pretreatment are used to describe the treatments carried out under controlled conditions. Controlled seed pretreatment not only allows known temperatures to be applied for definite periods but allows seed development to be monitored by simple inspection.

Plants have become adapted to their own particular environments and their seeds have different warm and cold requirements for synchronising germination with the most auspicious times for seedling growth. Subjects from the warmer areas of the temperate zones are usually stimulated by only a few weeks at temperatures below 10°C (eg *Fraxinus angustifolia*) whereas those from colder climes may respond only to a protracted cold treatment at temperatures of 1–3°C (eg *Fraxinus excelsior*). Furthermore those species with extensive natural ranges may respond differentially depending on the origin of their immediate parents (eg *Liriodendron tulipifera*, see Barnett and Farmer, 1978). It would be beneficial, therefore, if the controlled conditions provided the exact requirements of each seed lot. However, this is impossible to achieve as so little is known about exact species requirements let alone exact provenance requirements.

In practice it is sufficient if the warm temperature alternates from 30°C to 20°C, or is more or less constant within the range 20°C to 25°C, while the cold is within a range from 1°C to 5°C. Such broad limits have proved suitable for treating the comprehensive range of species listed in the tables of Part 2, and they are certainly very simple to provide. The warm temperatures are those of a propagating case (or airing cupboard), while the required cold temperature range is that of a standard nursery cold store (or main compartment of a domestic refrigerator).

During their temperature treatments the seeds must be kept both moist and adequately aerated, but problems of desiccation can arise, especially during a warm pretreatment. The necessity of providing good aeration conditions is often not understood, but effective treatment induces considerable respiratory activity within the seed. If this activity is hampered by waterlogging and subsequent lack of oxygen the efficiency of the treatment will definitely be impaired, and the seeds may even die.

The seeds of *Alnus*, *Betula* and *Nothofagus* species, and other species with similarly shallow to intermediate physiological dormancy, can be pretreated very successfully in a 'naked' condition (ie without a pretreatment medium) because they only require chilling for from four to six weeks. Seeds requiring longer durations of prechill (or a warm pretreatment of any duration) benefit if they are mixed

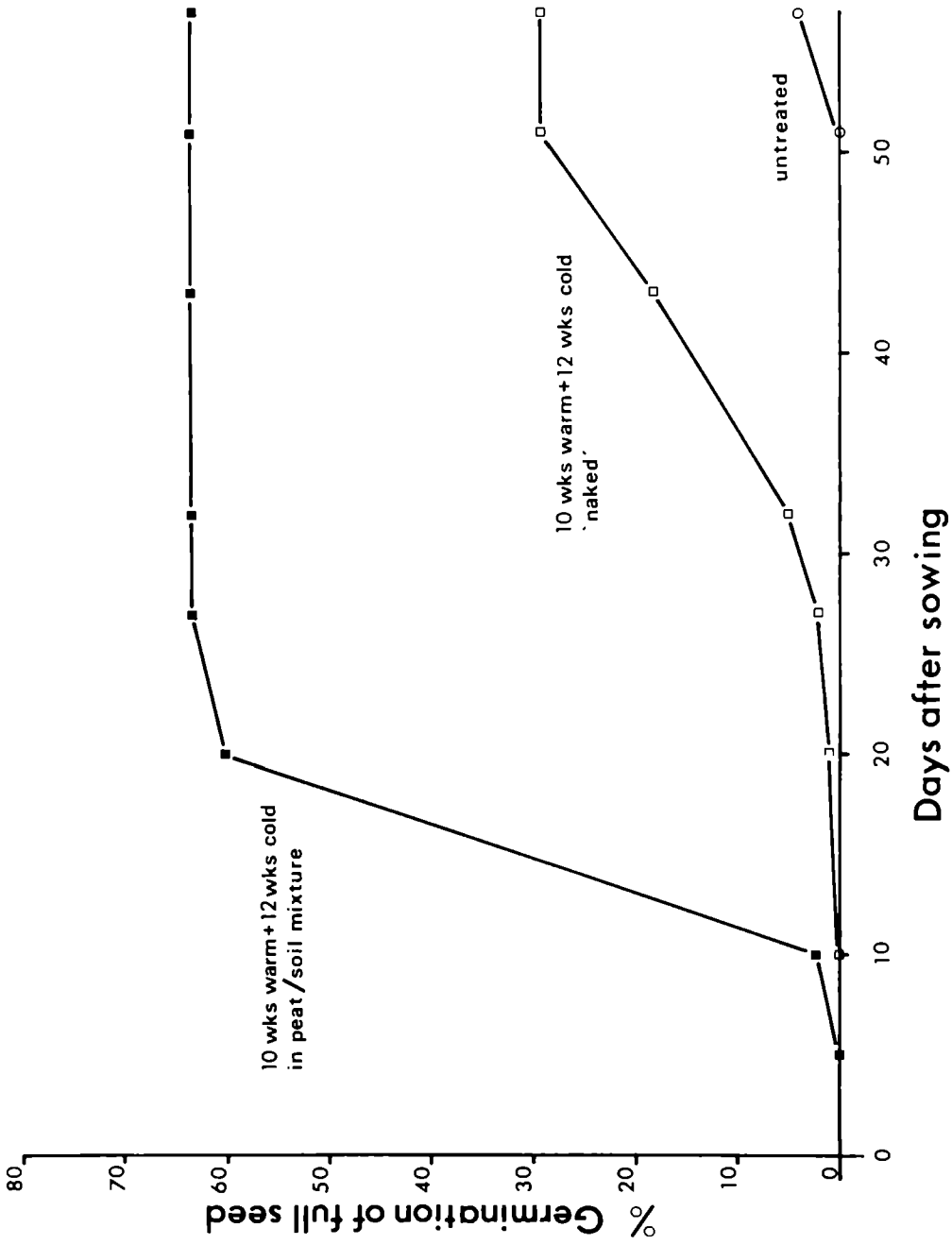


Figure 6 Although it is possible to prechill seeds in a 'naked' condition it is better to mix them with some kind of imbibing medium if the seeds are being given a warm pretreatment prior to their prechill. The effectiveness of this procedure is evident in the figure above which compares the rapid and synchronous germination of *Sambucus racemosa* seeds pretreated in a peat/soil mixture with the poor germination of seeds which were either pretreated 'naked' or sown untreated.

previously with two to four times their own volume of a moistened, water retaining medium. (See Figure 6).

Recent trials have suggested that a moist compost mixture (sieved sandy soil plus sieved sphagnum peat) is superior to moist sand especially when a warm treatment is being given, probably because the peat reduces the degree of compaction and increases both the moisture and oxygen retaining qualities of the medium. (See Table 2) However sand alone is sometimes a most useful medium to work with as it is easily removed from the seeds at the end of the pre-treatment period, simply by sieving the mixture under water. Such a procedure is necessary in experimental work when an exact chitting count is required. Other substances, such as peat or vermiculite, are more difficult to remove, and although they can be sown along with the seeds, their presence can make it difficult to achieve uniform sowing rates. When using a sand/peat mixture or peat alone, these difficulties are reduced if the sand and peat are sieved before mixing and moistening. A further advantage of using sieved material is that the medium so formed is more homogeneous, and less liable to clumping and waterlogging. Whichever medium is chosen it is important to make a note of its exact composition for future reference. A standard technique can then be employed which reduces the effects of varying moisture contents and seed/medium ratios, and thus enables useful experience to be built up on the basis of reproducible results. Experience

has shown that a useful rule of thumb method for obtaining the correct moisture/air content is to carefully add water to the medium until a consistency is reached that will just produce a drop of water when a handful of it is squeezed tightly in the fist.

Little properly controlled experimental evidence is available on the effect of sowing date in the spring on broadleaved species, mainly due to the unpredictable seed supply and uncertain seed pretreatment techniques used in the past. However circumstantial evidence shows that, in the main, the principles that have been established for conifers by the Forestry Commission apply equally to broadleaves. Seed sown into a cold and wet seedbed will germinate sporadically. Seed sown in the second half of May will need exceptional growing conditions, supplemented by irrigation, if it is to produce normal sized seedlings at the end of the season. The optimum sowing period to achieve maximum growth which will vary around the country, should be established from local weather records. This should be when the soil temperature rises to about 10°C, eg end of March to end of April in Hampshire, two weeks earlier in South West England, mid April to mid May in Scotland etc. Seed sown to produce 2 + 0 seedlings may not need to be sown quite so early as seed destined to produce seedlings for transplanting. Similarly very fast growing species like *Betula* and *Nothofagus* may need to be sown later than slower growing species like *Berberis* and *Liriodendron*, if they are not to be too large at the end of the season. However, later sowings should only be contemplated if irrigation is available. Recent experiments have shown the disastrous effect of a sustained period of drought following sowing on the germination of *Betula* and *Nothofagus*, with non-prechilled seed being particularly badly affected.

Excessively high seedbed temperatures at the time of sowing may induce secondary dormancy, especially in Rosaceous subjects like *Prunus* and *Sorbus*, so it is advisable to organise the treatment so that it ends approximately two weeks after the earliest practical sowing date. (Such a timetable allows for variations in optimum treatment times). Also, it is useful to organise the sowing dates so that genera such as *Alnus*, *Betula* and *Nothofagus*, which are known to be immune to thermo-induced secondary dormancy, are the last to complete their presowing treatments. Germination can be retarded in some instances by transferring the seeds to temperatures at or just below 0°C. This procedure has been successfully demonstrated by the authors on chitted seeds of *Acer platanoides* and *Prunus avium*. It is probable that the chitted seeds of some other species could also be held back in this way, but this certainly does not apply to all species.

Table 2 Effect of various seed pretreatments on the pre-germination during treatment and the final seedling production of *Sorbus intermedia* in the nursery.

Seed Pretreatment	Pre-germination %	Seedling production %
None	0	6
16 wks at 3°C in soil	61	13
16 wks at 3°C in sand	33	7
20 wks at 3°C in soil	61	9
20 wks at 3°C in sand	49	6
4 wks at 20/30°C and 16 wks at 3°C in sand	0	63

The pretreatment recommendations shown in Appendix 3 are only guidelines because, as explained earlier, each seed lot will have a different optimum treatment period. Every seed lot therefore requires individual monitoring to determine exactly when its optimum prechilling period has been reached. The required duration of warm treatment cannot be assessed experimentally without a following period of prechilling, so estimates must be made on the basis of past experience.

Many subjects, especially *Acers* and Roseaceous species possess seeds with a very broad range of prechilling requirements, and this is the case even within batches of seed collected from a single tree. The seeds are also capable of germinating at temperatures within the prechilling range. Thus chitting of the individuals with the shortest chilling requirements occurs before those seeds needing the longest chilling treatment have been satisfied. If radicle emergence continues they may be damaged at sowing time, or the chitted seeds may develop into crooked and unsaleable seedlings. It is therefore necessary to decide on a compromise sowing date so that the greatest proportion of seeds can grow into usable seedlings. Although such a balance between early chitting and insufficient chilling is certainly necessary for *Acers*, Forestry Commission experiments suggest that premature chitting may be eliminated altogether in *Sorbus* species, by the use of a warm treatment before the prechilling. Two to four weeks of warm treatment in moist compost have proved suitable for all *Sorbus* species and seed lots tested. See Table 2.

Methods of Seed Pretreatment

MECHANICAL SCARIFICATION

Mechanical scarification of the seed is achieved by agitating it with an abrasive substance or by passing it through rollers covered with abrasive material. Recent studies at Alice Holt Lodge have shown that a reliable treatment can be effected by shaking seeds of some of the larger seeded legumes (*Lathyrus*, *Lupinus*, *Robinia*) in an end over end shaker together with marble sized carborundum chips. Smaller seeded species such as *Cytisus* have not reacted so positively. Mechanical scarification is used on a large scale for the seed treatment of certain agricultural species, but it is seldom recommended for the treatment of tree and shrub seeds since more effective alternatives exist. Similarly, individual chipping by hand can only be recommended for those seeds which are either large enough to handle easily or too valuable to risk in a bulk treatment.

In contrast to the above mechanical procedures, acid scarification and treatment with hot water are the most useful, although unpredictable, techniques

available for the rapid removal of physical dormancy from large quantities of seed. These two treatments are described in detail in the next two sections.

HOT-WATER TREATMENT

A simple hot-water soak is often the best presowing treatment for leguminous seeds, particularly *Acacia* species and its efficacy should always be tested before resorting to more extreme treatments such as the use of concentrated sulphuric acid.

A 100-seed sample is taken from the seed lot bulk and soaked in water at room temperature. After twenty-four hours the seeds are examined to assess whether any have taken up water and become swollen. Boiling water will kill these *soft* seeds, so if they form a significant proportion of the sample, they must be removed from the bulk before it is subjected to the hot water. However, if very few of the seeds have become imbibed during the cold water soak, it is unnecessary to give the bulk of seed this preliminary cold water stage of the treatment.

The remaining hard seeds of the sample are placed in a heat-proof plastic container, and about three times their own volume of boiling water (or 100 ml, whichever is the greater amount) is poured over them. They are left to soak in the cooling water for twenty-four hours. If a significant proportion of hard seeds remain then they can be treated again after they have been separated from any that have swollen. Continued failure of hot water on the sample will signify that the bulk requires more drastic treatment, such as the use of abrasives or concentrated acid. If the boiling water treatment does prove to be effective then the bulk can be treated in a similar manner simply by increasing the scale of the operation. The imbibed seeds must not be allowed to dry out but they should be sown immediately. Separating the swollen from the still hard seeds is the most tiresome part of the hot-water treatment. Fortunately, this is rarely necessary but when it cannot be avoided the job is accomplished with least trouble by gently sieving the seeds under water using a sieve of appropriate aperture size.

Dried *Tilia* seeds present a seedcoat problem which cannot be overcome using the conventional hot-water treatment described above. They have a tough, fibrous pericarp covering in addition to their hard seedcoat condition, and the pericarp covering can be removed only with extreme difficulty. The most practical treatment involves plunging the seeds into six times their own volume of very warm (70°C) water and leaving them to soak as the water cools down. The dry seeds float initially, but some will sink as they take up water and these can be removed. The treatment is repeated on the 'floaters' a further four times, removing the seeds which sink on each

occasion. Any seeds still floating after five treatments are probably empty and can be discarded. The 'sinkers' are mixed with moist sand or compost, then subjected to four weeks of warm treatment to ensure complete imbibition of the embryos, and to allow partial decomposition of the pericarp. After the warm treatment the seeds are transferred to prechill conditions to permit removal of their deep physiological dormancy.

CONCENTRATED ACID TREATMENT

Acid scarification using concentrated sulphuric acid is one of the most effective methods available for overcoming true hardseededness (physical dormancy). It has also proved useful for the reduction of certain forms of mechanical dormancy although more problems are encountered when using it for the latter purpose. Even greater problems exist if the hard seeds are surrounded by a tough pericarp which is difficult to remove (the fruits of *Tilia platyphyllos* for example). Some authorities (MacMillan Browse, 1979; Heit, 1977) have recommended the Spaeth Method (a procedure which involves the use of concentrated nitric acid) for removing the pericarp prior to the concentrated sulphuric acid soak. However, the addition of yet another dangerous substance to the nursery is unnecessary; nitric acid is recommended for a very limited number of species, all of which can be treated successfully by other, less hazardous methods. If a hard seed is surrounded by a tough layer then it should be considered unsuitable for acid treatments and a warm treatment used instead.

The reduction of seedcoat conditions using concentrated acid is a potentially dangerous technique both for the seeds and more importantly, for the operator. To avoid personal injury, it is imperative that the following safety precautions are adhered to throughout the pretreatment procedure.

1. **Always wear suitable clothing, thick rubber gloves and some form of eye protection.**
2. **Do not allow water to splash into the acid.**
3. **Ensure that all utensils and reaction vessels are made of acid resistant materials.**

(Seamed metal containers are unsuitable as the seams can become weakened and eventually they may split open. Heavy gauge, acid resistant plastic containers are ideal).

The acid used is commercial grade concentrated sulphuric acid (Specific Gravity 1.84). Fresh acid is always used because if the acid has been saved from a previous treatment it will be partially degraded and will be less effective. Two volumes of acid per one volume of cleaned seeds should be used, and not more than 10 kg of seeds should be treated at one time.

The optimum duration of the pretreatment varies according to the species, according to the 'hardness' of the particular seed-lot, and according to the conditions under which the pretreatment is carried out. Most species require from 15 minutes to 60 minutes for the action to be complete, but some unusual seed lots may react very differently (eg one *Acacia* seed lot would not soften in hot water and resisted a 24 hour soak in sulphuric acid). It is better therefore that the operator should assess each seed-lot individually himself. This is accomplished by treating small samples for different known periods and then soaking the seeds in water at room temperature for twenty-four hours. The optimum treatment duration is the one which yields the greatest proportion of swollen seeds without causing damage to the embryos. All treatments are undertaken at a standard temperature between 18°C and 20°C using a standard proportion of two volumes acid to one of seeds, because changes in either will influence the rate of the acid scarification.

In order to ensure even seedcoat reduction, the mixture of acid and seeds is stirred regularly and gently to prevent any localised variations in temperature and reaction rate. Vigorous stirring must be avoided as this aerates the mixture and can cause an uncontrollable temperature build-up. Similar sharp rises in temperature will occur if there is any moisture adhering to the seedcoats at the start of the treatment. Such moisture will almost certainly develop if seeds are exposed to the air directly after their removal from a cold store. For this reason, it is important to ensure that the seeds, which are to be treated, are kept in a closed plastic bag until they have warmed to ambient temperature.

To terminate the treatment, the acid is decanted off and the seeds are plunged into a large volume of cold water, which has been made slightly alkaline by the addition of a small quantity of washing soda (Sodium carbonate). Finally, the seeds are rinsed in running water. The sample is then ready for sowing or further pretreatment, or it can be dried and then stored for a short period if such action is necessary.

The procedure, described above, is most effective for reducing the hard seedcoat condition of truly hardseeded subjects, because such seeds are uniformly dry and impermeable. However immersion in concentrated sulphuric acid is sometimes suggested for the seed treatment of Rosaceous plants such as *Cotoneaster*, *Crataegus* and *Rosa*, which have thick permeable seed coverings containing large amounts of water when fresh. This water permits the passage of acid through to the living seed tissues and damages the embryo. For this reason, the fresh seeds of Rosaceous subjects require thorough drying prior to acid treatment. However, even when dry, the thick seedcoat still presents problems. Instead of a gradual

etching process the acid tends to char the seed covering, forming a barrier which disrupts uniform acid digestion and obscures any attempt to monitor the progress of the treatment. Thus the complete removal of mechanical dormancy using concentrated acid is not attempted in practice. Instead the greater proportion of the hard material is reduced using acid, and then the process is finished off by a period of warm, moist treatment so that damage to the soft tissues is avoided (Blundell & Jackson, 1971). Such acid treatment effectively cuts in half the time required for warm treatment alone.

WARM AND COLD PRETREATMENTS

A logical and reproducible sequence of warm and cold pretreatments enhances the probability of producing the greatest number of good quality seedlings from a given seed lot. A useful summary of directions is given below. In order to be able to plan sowing dates ahead of time it is often a good idea to begin to treat a pilot batch three to four weeks ahead of the bulk.

1. Divide up the bulk into lots corresponding to particular seedbed areas in order that the seed can be later sown at the correct sowing density.
2. Place these lots into suitable containers—thick polythene bags up to 500 gauge are ideal—and add several times their volume of cold water. Keep at approximately 3–5°C for 48 hours making sure that the seed does not float and remains dry. Label the containers clearly with species, identity number if available, dry weight of seed and relevant dates and details concerning the pretreatment regime.
3. Drain the seeds of water and then
 - a) if the seeds are to be prechilled 'naked', leave in similar lightly tied polythene bags in refrigeration at approximately 3–5°C.
 - b) if the seeds are to receive a warm treatment or a prolonged cold treatment, mix with the pretreatment medium and place the mixture plus a label in a suitable container (large plastic bag or plastic dustbin), which is clearly labelled on the outside. Place the container at the pretreatment temperature. (See above)
4. Once per week open the containers, mix the seeds and remoisten with a water spray if the surfaces show signs of drying out.
5. At the end of the pretreatment period remove the pretreatment medium (if possible and if applicable). Spread the seeds (still in lots for sowing) thinly on trays and allow to surface dry without artificial heat in a cool, shaded and well-ventilated

area. [This last procedure is not always necessary but it usually makes sowing more easy because the seeds can flow without sticking together in lumps, resulting in more even seedling densities.] *Chitted seed must not be dried at all* and if seed has chitted during 'naked' prechilling then moist sand should be added to protect the radicles during sowing.

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PART II: TABLES OF DATA AND RECOMMENDATIONS

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Notes on presentation of data and recommendations

As far as possible the data presented in the following tables have been drawn from actual results and experience gained by the Forestry Commission Seed Branch from its routine seed processing and testing activities and more recently from a four year period of intensive research into ornamental tree and shrub seeds. Where no direct data were available, published data have been cited. The sources of data in the Appendices are shown in one composite list at the end of the part. Most of the data in Appendices 4, 5 and 6 have been obtained at first-hand; exceptions are indicated in each case.

Data for all characteristics listed in the Appendices are not available for all species. As many data as available have been included as an interim measure, for the benefit of people planning their own seed collections.

APPENDIX 1

Classification, nomenclature, natural distribution, characteristics and recommendations for planting ornamental tree and shrub species.

Details of the nomenclature and natural distribution have been obtained from data sources 3, 4, 5, 6, 7, 8, 10, 11, 12, 14, 16, 17, 19, 20 and 21. For further information on the distribution within Britain of native (indigenous) and naturalised trees and shrubs reference should be made to *Atlas of the British Flora*, edited by F.H. Perring and S.M. Walters, Nelson and Sons, London, 1976, 1–432.

Recommendations for planting and uses. Where available, details of the uses and most appropriate sites to plant the tree species listed have been drawn from the final typescript of a new book entitled *Decorative Trees for Town*

and *Country* by Alan Mitchell and John Jobling (former colleagues of the authors at the Forest Research Station, Alice Holt Lodge, Farnham, Surrey) to be published by HMSO. Where such information was not available for tree species, and for all shrub species listed frequent reference was made to the following publications.

The Pruning of trees, shrubs and conifers by George E. Brown, Faber Paperbacks, Faber and Faber, London.

Hillier's Manual of Trees and Shrubs, Edition 2, Hillier and Sons, Winchester.

Notcutts Catalogue, 1980 Edition, Notcutts Nurseries Ltd, Woodbridge, Suffolk.

Genus and family	Scientific names and synonyms	Common names
ACER Aceraceae— Maple family	<i>A. campestre</i> L.	Field maple, Hedge maple, Common maple
	<i>A. cappadocicum</i> Gleditsch. <i>A. laetum</i> C.A. Mey <i>A. pictum colchicum</i> Hort.	Cappadocian maple
	<i>A. palmatum</i> Thunb. <i>A. polymorphum</i> Sieb. & Zucc.	Japanese maple
	<i>A. platanoides</i> L.	Norway maple
	<i>A. pseudoplatanus</i> L.	Sycamore, Great maple, Sycamore maple.
	<i>A. rubrum</i> L.	Red maple, Scarlet maple, Soft maple
	<i>A. saccharinum</i> L. <i>A. dasycarpum</i> Ehrh. <i>A. eriocarpum</i> Michx.	Silver maple, River maple, Soft maple

Notes for Appendix 1: 1. Native to Britain. 2. Naturalised in Britain.

Although the appendix lists the sites in which the individual subjects will grow best, it is true to say that provided the person planting the species is prepared to spend some extra effort in giving the plant the conditions it needs, eg liming, fertilising, mulching, protecting from frosts and winds etc, almost any species listed is capable of growing in any garden soil anywhere in the United Kingdom. The more nearly the desired conditions are available naturally the better the subject will grow and the more likely it is to flower and fruit. The choice of species to plant thus becomes a matter of how much effort an

individual is prepared to put into its cultivation over what may sometimes be quite a long period of time.

Index As a means of helping readers to find their way quickly to the references to individual species, an index has been included for the main text and appendices. Where a particular species has not been included, it is safe to conclude, in the greater majority of cases, that its characteristics are very similar to those of another species in the genus. The page numbers are given for the main text and the Appendix number only for the Appendices.

<i>Natural range</i>	<i>Recommended planting position and use</i>	<i>Index</i>
Europe ¹ to N. Persia and N. Africa (Not native in Scotland and Ireland).	Wide range of habitats, especially good on shallow soils over chalk. Resistant to exposure, gold in autumn.	<i>Acer</i> spp. 7, 9, 10, 13, 15, 18, 21, 25 – 26, 29, 44 <i>Acer campestre</i> 13, 35 <i>Acer ginnala</i> 7 <i>Acer platanoides</i> 43 <i>Acer saccharinum</i> 35
Caucasus and W. Asia to China.	Good colour on chalky soils.	
Japan, China and Korea	Small trees and shrubs. Plant singly sheltered from cold winds. Damaged by late frosts. Brilliant colour.	
Continental Europe ² from Norway southwards.	Medium to large tree. Wide range of habitats especially good on chalk and acid stands. Gold to orange in autumn. Decorative all year but soon grows large. Cultivars available.	
Central and Southern Europe ² .	Medium to large trees. Not very attractive, fast growing, aggressive. Suitable for wide range of habitats, extremely tough and exposure resistant. Poor autumn colour. Cultivars available.	
Eastern N. America	Strong neat growth when young. Better on damp soils. Poor growth and colour on chalk. Yellow to scarlet to red in autumn. Unattractive when old and in winter.	
Eastern N. America	Very fast early growth. Forming tall trees. Suitable for wide range of habits, especially over chalk and limestone. Silvery summer appearance, autumn colours yellow and pinks. Not good in exposed sites. Cultivars available.	

Genus and family	Scientific names and synonyms	Common names
ACER (continued)	<i>A. saccharum</i> Marsh. <i>A. saccharinum</i> Wengenh. <i>A. saccharophorum</i> K. Koch.	Sugar maple, Rock maple, Hard maple.
AESCULUS Hippocastanaceae— Horse chestnut family	<i>A. hippocastanum</i> L.	Horse chestnut
	<i>A. indica</i> (Camb.) Hook.	Indian horse chestnut
AILANTHUS Simaroubaceae— Ailanthus family	<i>A. altissima</i> (Mill.) Swingle <i>Toxicodendron altissimum</i> Mill. <i>A. glandulosa</i> Desf.	Ailanthus, Tree-of-Heaven
ALNUS Betulaceae— Birch family	<i>A. cordata</i> Desf.	Italian alder
	<i>A. glutinosa</i> (L.) Gaertn. <i>A. rotundifolia</i> Mill. <i>A. alnus</i> (L.) Britton	Common alder, Black alder
	<i>A. incana</i> (L.) Moench	Grey alder, Speckled alder.
	<i>A. rubra</i> Bong. <i>A. oregona</i> Nutt.	Red alder, Oregon alder, Western alder.
AMELANCHIER Rosaceae— Rose family	<i>A. laevis</i> Wieg.	Snowy mespil, June berry.
BERBERIS Berberidaceae— Barberry family	<i>B. darwinii</i> Hook	
	<i>B. julianae</i> Schneid.	

Notes for Appendix 1: 1. Native to Britain. 2. Naturalised in Britain.

<i>Natural range</i>	<i>Recommended planting position and use</i>	<i>Index</i>
Eastern N. America	Medium to large tree growing well on variety of sites and climates. Attractive foliage. Short-lived scarlet and gold in autumn. Needs full light and a lot of space.	
Balkans and Caucasus	Large handsome tree suitable for a wide range of sites; good in built-up areas. Regular flowering, golden colour in autumn. Prone to damage by school boys after conkers and to losing heavy branches suddenly. No fruiting cultivar available.	<i>Aesculus</i> spp. 10 – 11, 13, 16, 18, 21, 25 – 26
Himalayas	Large handsome tree but can show poor shape at maturity. Suitable for wide range of site. Early and late foliage attractive; late flowering; conkers not sought after.	
China	Large tree with very vigorous growth in south; slow and uncertain in north. Withstands dry conditions exceptionally well. Seeds of scarlet in autumn. No autumn leaf colour. Late into leaf, early to shed.	<i>Ailanthus</i> spp. 10, 15, 18
S. Italy and Corsica	Large vigorous tree with good shape. Prefers moist soils but grows in most sites. Good pioneer due to nitrogen fixing characteristic. No autumn colour.	<i>Alnus</i> spp. 7, 10, 16, 41, 43
Europe ¹ , N. Africa and Asia	Small to medium tree with reasonable shape. Very rapid early growth. Useful for very wet sites where they can be vigorous throughout their life. Nitrogen fixing. Does not like dry conditions. No autumn colour. Like other alders can be used as windbreak in apple orchards.	
Europe ² , Caucasus Mts.	Vigorous growth but short-lived. Attractive foliage. Most tolerant alder of dry sites. Nitrogen fixing. No autumn colour. Cultivars available.	
Pacific coast of N. America.	Very vigorous early growth in damp soil but never grows very large. Nitrogen fixing. No autumn colour.	
Eastern N. America	Small tree growing well in moist well-drained sites. Very hardy. White fragrant flowers in May. Good autumn colour.	<i>Amelanchier</i> spp. 10
Chile	Evergreen, early flowering, shade tolerant. Prefers moist soils. Cultivars available.	<i>Berberis</i> spp. 10, 43 } Shrubs which will grow in more or less any garden soils or situations
China	Evergreen, robust shrub, excellent for hedging. Leaves red in autumn.	

<i>Genus and family</i>	<i>Scientific names and synonyms</i>	<i>Common names</i>
BERBERIS (continued)	<i>B. thunbergii</i> D.C. <i>B. sinensis</i> K. Koch. <i>B. japonica</i> Hort.	Japanese barberry
	<i>B. vulgaris</i> L.	European barberry, Common barberry
BETULA Betulaceae— Birch family	<i>B. pendula</i> Roth <i>B. verrucosa</i> Earh. <i>B. alba</i> L. in part	Silver birch, White birch.
	<i>B. pubescens</i> Ehrh. <i>B. odorata</i> Bechst. <i>B. alba</i> L. in part	Downybirch, Hairy birch, White birch.
CARPINUS Betulaceae— Birch family	<i>C. betulus</i> L.	Hornbeam, European hornbeam.
	<i>C. caroliniana</i> Walt. <i>C. americana</i> Michx. <i>C. virginiana</i> Michx.	American hornbeam, Blue beech, Water beech.
CARYA Juglandaceae— Walnut family	<i>C. cordiformis</i> K. Koch.	Bitternut, Bitternut hickory.
CASTANEA Fagaceae— Beech family	<i>C. sativa</i> Mill.	Sweet chestnut, Spanish chestnut, European chestnut
CELTIS Ulmaceae— Elm family	<i>C. occidentalis</i> L. <i>C. crassifolia</i> (Lamb)	Nettle-tree, Hackberry
CERCIS Leguminosae— Pea family	<i>C. canadensis</i> L.	Eastern redbud
	<i>C. siliquastrum</i> L.	Judas tree

Notes for Appendix 1: 1. Native to Britain. 2. Naturalised in Britain.

<i>Natural range</i>	<i>Recommended planting position and use</i>	<i>Index</i>
Japan	Deciduous compact shrub with autumn foliage and fruit colour. Cultivars available.	} Shrubs which will grow in more or less any garden soils or situations
Europe ¹	Deciduous medium size shrub with oblong red fruits. Cultivars available.	
Europe ¹ and Asia Minor	Graceful tall tree, pendulous from early age. White bark develops within eight to ten years. Tolerates moist well drained soils and grows well on dry sandy soils. Good autumn colour. Good for bird life. Cultivars available.	<i>Betula</i> spp. 7, 9 – 11, 16, 18, 33, 37 – 38, 41 – 43 <i>Betula pubescens</i> 36
Europe ¹ and N. Asia	The best birch for poorly drained soils but has twisted non-pendulous shoots and therefore poor form.	
Europe ¹ to Iran	Broad handsome tree with good foliage and keyed fruits. Normally found in hedges but good for heavy clay soils. Good long autumn colour, silvery bark. Casts deep shade. Cultivars available.	<i>Carbinus</i> spp. 9 – 10, 16, 32, 36
N. America and mountains of central America.	Beautiful small tree growing well on clay or chalky soils. Branches spreading, leaves tinted only in autumn.	
Eastern N. America	Tall slender tree with attractive foliage, golden in autumn. Hardy but needs warmth. Should be confined to south and east in sheltered site and good soil.	<i>Carya</i> spp. 10, 16, 21
Southern Europe ² , Asia Minor and N. Africa	Vigorous, handsome tree. Grows anywhere on light soil. Yellow and russet in autumn. Not suited to confined spaces.	<i>Castanea</i> spp. 10 – 11, 16, 18, 21, 25 – 26
Eastern N. America	Fast growing, medium sized tree. Must have good well drained soil. Black fruits in autumn.	<i>Celtis</i> spp. 10
S.E. Canada, eastern USA	Small not very free flowering tree. Must have full sun and good drainage.	<i>Cercis</i> spp. 10, 16
S. Europe, W. Asia	Hardy small tree but too slow growing and non-flowering in north. Grows well on dry sandy and chalky soils in full sun. Spectacular but irregular flowering.	

<i>Genus and family</i>	<i>Scientific names and synonyms</i>	<i>Common names</i>
CHAENOMELES Rosaceae— Rose family	<i>C. japonica</i> (Thunb.) Spach <i>Pyrus japonica</i> Thunb. <i>Cydonia japonica</i> (Thunb.) Pers. <i>Cydonia maulei</i> T. Moore	Japanese quince
CORNUS Cornaceae— Dogwood family	<i>C. alba</i> L. <i>C. tatarica</i> Mill.	Red-barked dogwood
	<i>C. controversa</i> Hemsl.	Table dogwood
	<i>C. drummondii</i> C.A. Mey. <i>C. priceae</i> Small	Roughleaf dogwood
	<i>C. florida</i> L. <i>Benthamidia florida</i> (L) Spach.	Flowering dogwood
	<i>C. kousa</i> Hance <i>C. Benthamidia japonica</i> Sieb. & Zucc. <i>japonica</i> Koehne	Japanese dogwood, Kousa dogwood
	<i>C. mas</i> L. <i>C. mascula</i> Hort.	Cornelian cherry
	<i>C. nuttallii</i> Audub. <i>Benthamidia nuttallii</i> (Audub. Moldenke)	Pacific dogwood, Mountain dogwood, Nuttall's dogwood
	<i>C. sanguinea</i> L.	Common dogwood
CORYLUS Betulaceae— Hazel family	<i>C. avellana</i> L.	Hazel, filbert

<i>Natural range</i>	<i>Recommended planting position and use</i>	<i>Index</i>
Japan	Small shrub will grow well in border or against south facing wall.	<i>Chaenomeles</i> spp. 10, 37, 41
Siberia to Manchuria, N. Korea	Dense mass of stems, rich red in winter. Cultivars available.	<i>Cornus</i> spp. 10, 17, 37 These shrubs or small trees will grow in more or less any garden soils or situations.
Japan, China	Tree-like with good flowering in May. Foliage rich purple-red in autumn.	
Eastern and Central USA	Large shrub with red-brown stems, fruits white.	
Eastern N. America	Large shrub growing best in rich loamy, well drained soils. Large petal-like bracts in May. Good autumn colour. Does not like shallow chalk soils. May suffer from spring frosts. Cultivars available.	
Japan and Korea	Large shrub growing best in rich well drained soils. Large petal-like bracts. Leaves bronze crimson in autumn.	
Central and Southern Europe and Western Asia	Large shrub eventually small tree grown for flowers in February. Grows anywhere. Fruits bright red. Leaves red to purple in autumn. Cultivars available.	
Western N. America	Tree like, not for growing on poor shallow chalky soils. Large petal-like bracts. Yellow foliage in autumn.	
Europe ¹	Grows more or less anywhere. Prominent stems in winter. Rich purple foliage in autumn.	
Europe ¹	Large shrub or small many stemmed tree. Useful for screening. Attractive flowers in February. Prefers moister conditions. Cultivars available.	<i>Corylus</i> spp. 10, 16, 21

<i>Genus and family</i>	<i>Scientific names and synonyms</i>	<i>Common names</i>
COTONEASTER Rosaceae— Rose family	<i>C. bullatus</i> Bois. <i>C. franchetii</i> Bois. <i>C. salicifolius</i> Franch.	
CRATAEGUS Rosaceae— Rose family	<i>C. crus-galli</i> L. <i>C. intricata</i> Lange <i>C. coccinea</i> L. in part <i>C. x media</i> Bechst. (<i>monogyna</i> x <i>oxycantha</i>) <i>C. mollis</i> Scheele. <i>C. monogyna</i> Jacq. <i>C. oxycantha</i> L. <i>C. oxycanthoides</i> Thuillier <i>C. pedicellata</i> Sarg. <i>C. coccinea</i> L. in part <i>C. x prunifolia</i> (Poir.) Pers.	Cockspur thorn Often incorrectly listed as Midland hawthorn. Red haw, Downy thorn Common hawthorn, quickthorn, may Midland hawthorn Scarlet haw Broad-leafed cockspur thorn
CYDONIA Rosaceae— Rose family	<i>C. oblonga</i> Mill. <i>Pyrus cydonia</i> L. <i>C. vulgaris</i> Pers.	Common quince
CYTISUS Leguminosae— Pea family	<i>C. scoparius</i> Link. Sarthothamnus scoparius (L) K. Koch	Common broom, Scotch broom

Notes for Appendix 1: 1. Native to Britain. 2. Naturalised in Britain.

<i>Natural range</i>	<i>Recommended planting position and use</i>	<i>Index</i>
W. China	Large shrubs, rich autumn colouring to leaves. Early bright red fruits.	<i>Cotoneaster</i> spp. 10, 17, 37, 45 These shrubs will grow in more or less any garden soil or situation. Cultivars available.
China	Semi-evergreen, medium sized shrub. Orange to scarlet fruits.	
China	Evergreen shrub. Profusion of small bright red fruits.	
Eastern and Central N. America	Small tree, growing well on chalk. Pale orange autumn foliage. Persistent red fruits.	<i>Crataegus</i> spp. 10, 17, 25, 36–37, 45 <i>Crataegus monogyna</i> 38, 41 Among hardiest and most adaptable trees growing well in industrial areas and exposed sites. When mature tolerate both dry and wet conditions.
Eastern N. America	Large shrub. Reddish brown fruits.	
Europe ¹	Intermediate between parents.	
Central N. America	Large tree. Showy cherry-like fruits.	
Europe ¹ to	Normally only large untidy bush. Rarely a tree. Occasional autumn colour. Cultivars available.	
N.W. and Central Europe ¹	Large bush with very showy flowers. Many cultivars available.	
N. eastern N. America	Small tree with large bunches of showy fruits, normally good autumn colour.	
	Small tree with outstanding October colour. Dark red fruit not persistent grows well on chalk.	
N. Persia and Turkestan	Small tree growing in most southern soils. Golden yellow fruit. Rich yellow leaves in autumn.	<i>Cydonia</i> spp. 10
Europe ¹	Hardy shrub not growing on poor shallow chalky or very acid soils. Sun loving. Cultivars available.	<i>Cytisus</i> spp. 10, 16, 27, 33, 44

<i>Genus and family</i>	<i>Scientific names and synonyms</i>	<i>Common names</i>
DAPHNE Thymelaeaceae— Daphne family	<i>D. mezereum</i> L.	Mezereon
DAVIDIA Davidiaceae— Davidia family	<i>Davidia involucrata</i> Baill	Dove tree, Ghost tree, Pocket-handkerchief tree
ELAEAGNUS Elaeagnaceae— Oleaster family	<i>E. angustifolia</i> L.	Russian-olive, oleaster
	<i>E. commutata</i> Bernh. <i>E. argentea</i> Pursh, not Moench.	Silver berry, wolf-berry
	<i>E. umbellata</i> Thunb. <i>E. crispa</i> Thunb.	Autumn olive
EUCALYPTUS Myrtaceae— Myrtle family	<i>E. dalrympleana</i> Maiden	Mountain gum
	<i>E. gunnii</i> Hook.f.	Cider gum
	<i>E. niphophila</i> Maiden et Blakely	Snow gum
EUONYMUS Celastraceae— Spindle tree family	<i>E. europaeus</i> L.	European spindle-tree
FAGUS Fagaceae—	<i>F. sylvatica</i> L.	Beech, European beech, Common beech

<i>Natural range</i>	<i>Recommended planting position and use</i>	<i>Index</i>
Europe ¹ , Asia Minor and Siberia	Thrives in chalky soils but will grow in most gardens. Sweet scented copious flowers in February and March. Cultivars available.	<i>Daphne</i> spp. 10
Central and Western China	Medium sized tree growing well on any good loamy soil but not in polluted air or thin poor soils. Showy petal-like bracts only form on mature trees. Attractive foliage but no autumn colour. Not tolerant of exposure.	<i>Davidia</i> spp. 10
Temperate Asia	Spiny shrub with silver-amber prominent fruits.	<i>Elaeagnus</i> spp. 10, 17 <i>Elaeagnus angustifolia</i> 36 Large shrubs or small trees with prominent silvery effect from foliage. Very exposure and drought resistant. Do not like shallow chalky soils.
N. America	Medium sized shrub, fragrant flowers, fruits small.	
China, Korea, Japan	Large vigorous shrub, fragrant flowers, orange fruit striking in autumn.	
N.S.W., Victoria, Tasmania	Medium sized, attractive bark becomes white.	<i>Eucalyptus</i> spp. 4, 16, 33 Fast growing evergreen trees. All are hardy in all but severest British winters. Will grow in great variety of soils and sites. Not very happy on chalks and clays.
Tasmania	Exceedingly fast growing, tolerant of very poor soil. Needs light, susceptible to windthrow when young.	
N.S.W. & Victoria	No juvenile foliage but young foliage and blue-white bark striking.	
Europe ¹ to W. Asia	Vigorous shrub growing almost anywhere, good on chalk. Persistent scarlet fruits.	<i>Euonymus</i> spp. 10, 16, 17
Europe	Handsome tree growing well on chalky soils, gravels, light loams and acid sands. Much used for hedging due to persistent leaves. Trees cast dense shade and are unsuited for near buildings. On shallow and poorly drained soils it is unstable. Prone to unsuspected fungal attacks which cause sudden loss of limbs. Cultivars available.	<i>Fagus</i> spp. 1, 4-6, 9-11, 16, 19, 20, 22, 27, 41

<i>Genus and family</i>	<i>Scientific names and synonyms</i>	<i>Common names</i>
FRAXINUS Oleaceae— Olive family	<i>F. angustifolia</i> Vahl.	Narrow leaved ash
	<i>F. excelsior</i> L.	Ash, European ash, Common ash
	<i>F. ornus</i> L. <i>F. floribunda</i> Hort. Wall. <i>Ornus europaea</i> Pers	Flowering ash, Manna ash
GLEDITSIA Leguminosae— Pea family	<i>Gleditsia triacanthos</i> L.	Honey locust
HAMAMELIS Hamamelidaceae— Witch-hazel family	<i>H. mollis</i> Oliv.	Chinese witch-hazel
	<i>H. virginiana</i> L.	Virginian witch-hazel
HIPPOPHAE Elaeagnaceae— Oleaster family	<i>H. rhamnoides</i> L.	Common seabuckthorn
ILEX Aquifoliaceae— Holly family	<i>I. aquifolium</i> L.	Holly, English holly
JUGLANS Juglandaceae— Walnut family	<i>J. nigra</i> L.	Black walnut
	<i>J. regia</i> L.	Common walnut, English walnut, Persian walnut

<i>Natural range</i>	<i>Recommended planting position and use</i>	<i>Index</i>
S. Europe, N. Africa, W. Asia	Large tree with attractive foliage. Suitable only for southern situations.	<i>Fraxinus</i> spp. 9 – 10, 13, 15, 18, 25, 29, 35 <i>Fraxinus angustifolia</i> 41 <i>Fraxinus excelsior</i> 36, 41
Europe ¹ and Asia Minor	Large tree capable of rapid early growth on best soils and of reasonable growth even in far north, by the sea and in cities.	
Southern Europe and Western Asia	Moderate in size. Luxuriant foliage tinted purple in autumn. Scented white-cream flowers in May. Thrives by roads and in cities but prefers good soils with some shelter.	
Mid-western USA	Grows into a large tree in hot, dry inner city sites but in open only in south-east. Vigorous but short season in leaf. Bright autumn colour.	<i>Gleditsia</i> spp. 10, 16
China	Large shrub with large yellow flowers in December to March. Yellow leaves in autumn.	<i>Hamamelis</i> spp. 10, 16 Grows in most garden soils but best with ample humus.
Eastern N. America	Large shrub/small tree with good yellow autumn tints. Medium sized flowers in September to November.	
North-western Europe ¹	Tall shrub, growing in almost any soil but very tolerant of wind, salt and arid conditions. Orange to yellow persistent berries.	<i>Hippophae</i> spp. 10, 17
Western, central and southern Europe ¹ and Mediterranean.	Small tree tolerant to most sites but growing well on dry sandy soil. Only females produce berries but not in shaded positions. Many cultivars available.	<i>Ilex</i> spp. 7, 10, 17
Eastern USA from Massachusetts to Texas	Handsome vigorous tree on deep rich soils in hotter areas. Bright gold foliage in autumn. Does not thrive in western Britain or exposed and dry sites.	<i>Juglans</i> spp. 9 – 11, 16, 21
South-eastern Europe to China	Attractive but not so vigorous tree. Needs space and rich deep light soils.	

<i>Genus and family</i>	<i>Scientific names and synonyms</i>	<i>Common names</i>
LABURNUM Leguminosae— Pea family	<i>L. anagyroides</i> Med. <i>L. vulgare</i> Bercht & Presl.	Common laburnum, goldenchain
LIQUIDAMBAR Hamamelidaceae— Witch-hazel family	<i>L. styraciflua</i> L.	Sweet gum, Red gum
LIRIODENDRON Magnoliaceae— Magnolia family	<i>L. tulipifera</i> L.	Tulip tree, tulip-poplar, yellow-poplar
MAHONIA Berberidaceae— Barberry family	<i>M. aquifolium</i> Nutt. <i>Berberis aquifolium</i> Pursh.	Oregon grape
MALUS Rosaceae— Rose family	<i>M. baccata</i> (L.) Borkh. <i>Pyrus baccata</i> L.	Siberian crab-apple
	<i>M. sylvestris</i> Mill. <i>Pyrus malus</i> var <i>sylvestris</i> L. <i>M. acerba</i> Merat.	Common crab-apple, Wild crab
MORUS Moraceae— Mulberry family	<i>M. alba</i> L.	White mulberry, Silkworm mulberry
	<i>M. nigra</i> L.	Black mulberry, Common mulberry
NOTHOFAGUS Fagaceae— Beech family	<i>N. alessandrii</i> Espinosa	Ruil
	<i>N. antarctica</i> (Forst.f.) Oerst.	Antarctic beech, Nirre
	<i>N. betuloides</i> (Mirb.) Bl.	Coigue de Magellanes
	<i>N. cunninghamii</i> (Hook) Oerst.	Myrtle beech

Notes for Appendix 1: 1. Native to Britain. 2. Naturalised in Britain.

<i>Natural range</i>	<i>Recommended planting position and use</i>	<i>Index</i>	
Central and southern Europe	Suitable for all types of soils. Attractive small tree for small gardens but all parts are poisonous especially the seeds.	<i>Laburnum</i> spp. 10, 16, 35	
Eastern and southern USA	Capable of becoming large but requires deep and fertile soil with adequate moisture. Will not grow well in northern parts of Britain. Needs full sunlight. Good autumn colour if planted where cold air flows to them but not in frost hollows.	<i>Liquidambar</i> spp. 10, 16, 38	
South-eastern and mid-western USA.	Vigorous large attractive tree in south but slow growing and making only moderate size in Scotland. Hardy and grows in towns but prefers a deep well drained fertile soil but can grow on warm sandy soil with mulching. Good autumn colour.	<i>Liriodendron</i> spp. 10, 15, 41, 43	
Western N. America	A shrub growing in most well-drained and even chalky and poor soils. Shade tolerant. Attractive yellow flowers and blue-black berries.	<i>Mahonia</i> spp. 10, 17	
Asia	Small rounded tree. White fragrant flowers, small yellow or red fruits.	Small trees thriving in all fertile including heavy soils. Useful for small gardens. Spring flowers and decorative fruit in autumn.	<i>Malus</i> spp. 9 – 10, 17, 37, 41
Europe ¹ and south-western Asia	Small tree often with spurs. Flowers white-pink, fruit yellow-green or red flushed.		
China	Fruits white changing to pink to red. Edible.	Small decorative trees growing better in well drained, enriched soils but good for towns and coastal gardens.	<i>Morus</i> spp. 10
Western Asia	Fruits black-red, agreeable taste.		
Chile	Potential size not yet known. Most European beech-like Southern beech. Susceptible to late spring frosts.	<i>Nothofagus</i> spp. 4, 10, 16, 38, 40 – 43 <i>Nothofagus obliqua</i> 36, 38, 40	
Chile and Argentina	Loose multi-stemmed feathery leaved bush, occasionally growing to attractively barked small trees. Hardy. Tolerates poor soils and exposed sites.		
Chile and Argentina	Similar to <i>N. dombeyi</i> . More tolerant of cold.		
Tasmania	Small, tiny-leaved evergreen tree for mild gardens.		

<i>Genus and family</i>	<i>Scientific names and synonyms</i>	<i>Common names</i>
NOTHOFAGUS (continued)	<i>N. dombeyi</i> (Mirb.) Bl.	Coigue, Dombey's southern beech
	<i>N. fusca</i> (Hook.f.) Oerst.	Red beech
	<i>N. menziesii</i> (Hook.f.) Oerst.	Silver beech
	<i>N. nitida</i> (Phil.) Krass.	Coigue de Chiloe
	<i>N. obliqua</i> (Mirb.) Bl.	Roble beech, pelli
	<i>N. procera</i> (Poepp. & Endl.) Oerst	Rauli beech, raoul
	<i>N. pumilio</i> (Poepp. & Endl.) Krass	Lenga
	<i>N. solandri</i> (Hook.f.) Oerst.	Black beech
NYSSA Cornaceae— Dogwood family	<i>N. aquatica</i> L.	Water tupelo
	<i>N. sylvatica</i> L.	Tupelo, Black gum
OSTRYA Betulaceae— Birch family	<i>O. carpinifolia</i> Scop.	European hop-hornbeam
	<i>O. virginiana</i> (Mill.) K. Koch	Eastern hop-hornbeam

Natural range	Recommended planting position and use	Index
Chile and Argentina	Evergreen handsome tree. Can grow vigorously in most parts of Britain. Small dark green leaves which turn yellow-orange before finally shedding.	
New Zealand	Normally small but in favoured position can grow tall. Attractive evergreen, tender when young but hardy later.	
New Zealand	Small to medium evergreen tree, hardy in south in favoured position.	
Chile	Similar to <i>N. dombeyi</i> but probably better suited to wetter maritime positions.	
Chile	Very fast growing even on poor dry acid soils. Attractive tree with smallish, lobed leaves. Deciduous with some autumn colour.	May suffer from late spring and early autumn frosts. Grow well on soils varying from deep sands to heavy clay. Do not thrive on shallow soils over chalk.
Chile	Very fast growing but prefers damper richer sites. Normally better form than <i>N. obliqua</i> with larger leaves. Deciduous, some autumn colour.	
Chile and Argentina	Leaves like <i>N. antarctica</i> but capable of growing into handsome attractive barked trees on better and sheltered sites.	
New Zealand	Medium sized slender tree with fan-like branches. Tiny leaves. Evergreen.	
South-eastern coastal plains of N. America	Small tree.	<i>Nyssa</i> spp. 10 Trees with insignificant flowers and fruits but rich in autumn colours. Prefers deep rich lime-free soil and warmth.
Eastern N. America	Medium sized tree, handsome even in summer.	
S. Europe, Asia Minor	Medium sized round-headed tree with yellow autumn tints. Attractive catkins in spring.	<i>Ostrya</i> spp. 10, 16 Deciduous trees resembling Hornbeams with hoplike fruits in autumn.
Eastern N. America	Small tree with rich warm yellow autumn fruits.	

<i>Genus and family</i>	<i>Scientific names and synonyms</i>	<i>Common names</i>
PLATANUS Platanaceae— Plane family	<i>P. orientalis</i> L. <i>P. vulgaris</i> Spach.	Oriental plane tree, Chennar tree
PRUNUS Rosaceae— Rose family	<i>P. armeniaca</i> L. <i>Armeniaca vulgaris</i> Lam.	Apricot
	<i>P. avium</i> L.	Gean, Wild cherry mazzard
	<i>P. cerasifera</i> Ehrh. <i>P. domestica</i> var <i>myrobalana</i> L. <i>P. myrobalana</i> Loisel.	Myrobalan plum, Cherry plum
	<i>P. cerasus</i> L.	Sour cherry
	<i>P. dulcis</i> D.A. Webb. <i>P. amygdalus</i> Batsch.	Almond
	<i>P. laurocerasus</i> L.	Cherry laurel, Common laurel
	<i>P. lusitanica</i> L.	Portugal laurel
	<i>P. padus</i> L. <i>P. racemosa</i> Lam. <i>Padus racemosa</i> Schneid. <i>Cerasus padus</i> DC.	Bird cherry
	<i>P. persica</i> Batsch. <i>Amygdalus persica</i> L. <i>Persica vulgaris</i> Mill.	Peach, Common peach

<i>Natural range</i>	<i>Recommended planting position and use</i>	<i>Index</i>
South-eastern Europe, Asia Minor, India	Large tree but needs even more warmth than London plane for good growth, hence does not thrive in northern Britain. Needs space. Unusual autumn colour.	<i>Platanus</i> spp. 10, 15, 25
Central Asia, China	Wild species. Small round-headed tree, white flowers, yellow fruits.	<i>Prunus</i> spp. 9 – 11, 17, 26, 38, 43 <i>Prunus avium</i> 43 <i>Prunus spinosa</i> 39 Very attractive trees in spring. Easy to grow on any well-drained well prepared garden soil. Happy on chalky soils. Prefers open sunny positions. Many cultivars available.
Europe ¹ , N. Africa W. Asia	Vigorous shapely tree of medium to large size. White flowers. Fruits attract birds. Prefers some lime or good loam. Short lived on dry sandy soils. Shallow rooting. Suckers.	
W. Asia	Excellent dense hedging shrub. Small white flowers in March. Mature trees may bear fruits.	
S.E. Europe, S.W. Asia	Small bushy tree flowering in May. Red or black fruits sour to the taste.	
W. Asia, N. Africa	Small tree, short-lived with poor shape. Very early pink flowers, prefers some lime in soil. Suffers from leaf curl disease.	
S.E. Europe ² , Asia Minor	Vigorous wide-spreading evergreen shrub. Large dark leaves with small white flowers in April, fruits red then black. Not at best on shallow chalky soils.	
Spain, Portugal	Evergreen shrub or small tree. Flower and fruits small. Hedging plant and grows even on chalk soils.	
Europe ¹ , N. Asia	Small tree growing on alkaline soils but tolerant of more acid sandy soils. Late flowering, white scented flowers. Fruit attractive to birds. Some autumn colours. Host for cereal virus vector.	
China	Small bushy tree, slightly later pink flowers than almond. Fleshy fruits.	

<i>Genus and family</i>	<i>Scientific names and synonyms</i>	<i>Common names</i>
PRUNUS (continued)	<i>P. sargentii</i> Rehd.	Sargents cherry
	<i>P. serotina</i> Ehrh.	Black cherry
	<i>P. spinosa</i> L.	Sloe, blackthorn
	<i>P. virginiana</i> L.	Choke cherry
PTEROCARYA Juglandaceae— Walnut family	<i>P. fraxinifolia</i> Spach.	Caucasian wing-nut
PYRUS Rosaceae— Rose family	<i>P. communis</i> L.	Common pear
QUERCUS Fagaceae— Beech family	<i>Q. cerris</i> L.	Turkey oak
	<i>Q. ilex</i> L.	Holm oak, Evergreen oak.
	<i>Q. palustris</i> Muenchh.	Pin oak, Spanish oak
	<i>Q. petraea</i> (Mattuschka) Lieblein <i>Q. sessiliflora</i> Salisb. <i>Q. robur</i> Mill., not L.	Sessile oak, Durmast oak.

Natural range	Recommended planting position and use	Index
Japan, Sakhalin	Medium sized all purpose tree for towns and gardens. Early flowering and early autumn colour. Vigorous grower therefore needs space.	Very attractive trees in spring. Easy to grow on any well-drained well prepared garden soil. Happy on chalky soils. Prefers open sunny positions. Many cultivars available.
Eastern N. and Central America	Small to medium sized tree. Glossy laurel like leaves. White flowers in May/June.	
Europe ¹ , N. Africa, W. Asia	Large dense shrub or small tree. Profuse small white flowers. Damson-like attractive fruits.	
Eastern N. America	Small tree, glossy leaves. Dense small white flowers in May. Dark red fruits.	
Caucasus to N. Persia	Large vigorous handsome tree requiring a lot of space. Suckers profusely. Good moist soil and sun for best growth.	<i>Pterocarya</i> spp. 10, 16
Europe ¹ , W. Asia	Medium sized tree with autumn tints. Profuse blossom in April. Grows anywhere even in streets. Many cultivars available.	<i>Pyrus</i> spp. 10, 17
Southern Europe to Western Asia	Very fast grower, good in chalky soil near coast and in cities. Deciduous.	<i>Quercus</i> spp. 4, 6, 9–11, 13, 15–16, 18, 20–21, 25–26 <i>Quercus petraea</i> 1, 5, 7 <i>Quercus robur</i> 1, 5, 21 <i>Quercus rubra</i> 1, 5, 21 Tall stately trees requiring space. Deep rooted, growing in any soil or position. Most are lime tolerant provided soil is deep.
S.W. Europe	Broadly domed, dense evergreen tree growing anywhere except in cold poorly drained sites. Excellent for tall permanent shelter against sea winds. Slow growth, dense shademaker.	
S.E. Canada, Eastern USA	Shapely crown, growing well on poorly drained site. Needs warmth, hence not for Scottish conditions. Good autumn colour.	
Europe ¹ and Western Asia	More rapid early growth than <i>Q. robur</i> a handsome domed tree unsuited to heavy clays. Needs good drainage but adequate moisture and space also.	

<i>Genus and family</i>	<i>Scientific names and synonyms</i>	<i>Common names</i>
QUERCUS (continued)	<i>Q. robur</i> L. <i>Q. pedunculata</i> Ehrh.	English oak, Pedunculate oak
	<i>Q. rubra</i> L. Sec. Du Roi <i>Q. borealis</i> Michx.f.	Red oak
	<i>Q. suber</i> L.	Cork oak
RHAMNUS Rhamnaceae— Buckthorn family	<i>R. cathartica</i> L.	Common buckthorn
	<i>R. frangula</i> L.	Alder buckthorn, Glossy buckthorn
ROBINIA Leguminosae— Pea family	<i>R. pseudoacacia</i> L.	Black locust, False acacia, Common acacia.
ROSA Rosaceae— Rose family	<i>R. canina</i> L.	Dog rose
	<i>R. rugosa</i> Thunb.	Ramanas Rose
SAMBUCUS Caprifoliaceae— Honeysuckle family	<i>S. glauca</i> Nutt.	Blueberry elder
	<i>S. nigra</i> L.	Common elder
	<i>S. racemosa</i> L.	Red-berried elder

Notes for Appendix I: 1. Native to Britain. 2. Naturalised in Britain.

<i>Natural range</i>	<i>Recommended planting position and use</i>	<i>Index</i>
Europe ¹ , N. Africa Western Africa	Irregular growth leads to many-domed canopy. Will grow on heavy clays but must have plenty of space especially near buildings on heavy clays.	Tall stately trees requiring space. Deep rooted, growing in any soil or position. Most are lime tolerant provided soil is deep.
Eastern N. America	Rapid early growth on variety of soils. Grows in moderate exposure but needs good drainage. Will even grow on acid sands or peat. Needs space. Autumn colour good when young.	
S. Europe, N. Africa	Medium sized wide-spreading tree. Low frost resistant, will not grow well in north.	
Europe ¹	Grows well on chalk, black fruit makes it attractive in autumn.	Large bush or small tree, growing on all types of soil.
Europe ¹	Grows well on damp and peaty soils. Turns yellow in autumn with red then black fruits.	
Eastern USA	Large tree suitable for any soil, but thrives in cities on industrial waste, on nitrogen poor soils and dry sands in southern Britain. No autumn colour. Suckers profusely.	<i>Rhamnus</i> spp. 10, 17 <i>Rhamnus frangula</i> 37
Europe ¹ , N. Africa	Medium to large shrub. Very variable. Grows anywhere. Many cultivars.	<i>Robinia</i> spp. 10, 16, 25 – 26, 35 – 36, 44
N.E. Asia	Strong growing dense shrub, making many suckers. Ideal for hedging. Grows anywhere. Many cultivars.	<i>Rosa</i> spp. 10, 17, 45
Western N. America	Large shrub, excellent for wildlife. Blue-black fruits. Good autumn colour.	Hardy shrubs, quick growing, tolerant of almost all soils.
Europe ¹ , N. Africa, W. Asia	Large shrub or small trees. Useful for extremely chalky sites. Flowers in June, black fruit.	
Europe, W. Asia	Medium to large shrub. Flowers in April, scarlet fruits in summer.	

Sambucus spp.
10, 17
Sambucus racemosa
42

<i>Genus and family</i>	<i>Scientific names and synonyms</i>	<i>Common names</i>
SOPHORA Leguminosae— Pea family	<i>S. japonica</i> L.	Japanese pagoda tree
	<i>S. macrocarpa</i> Sm.	Large-seeded sophora
	<i>S. macrophylla</i>	Small-leaved sophora
SORBUS Rosaceae— Rose family	<i>S. aria</i> (L.) Crantz	Whitebeam
	<i>S. aucuparia</i> L.	Mountain ash, rowan
	<i>S. intermedia</i> (Ehrh.) Pers.	Swedish whitebeam
	<i>S. torminalis</i> (L.) Crantz	Wild service-tree
SYMPHORICARPOS Caprifoliaceae— Honeysuckle family	<i>S. rivularis</i> Suksd. <i>S. albus</i> (L.) Blake var. <i>laevigatus</i> (Fern) Blake	Snowberry, Garden snowberry
TILIA Tiliaceae— Linden family	<i>T. cordata</i> Mill. <i>T. parvifolia</i> Ehrh.	Little-leaved linden Small-leaved lime
	<i>T. x europaea</i> L. (<i>platyphyllos</i> x <i>cordata</i>) <i>T. vulgaris</i> Hayne	Common lime
	<i>T. platyphyllos</i> Scop.	Large-leaved linden, Broadleaved lime

Notes for Appendix 1: 1. Native to Britain. 2. Naturalised in Britain.

<i>Natural range</i>	<i>Recommended planting position and use</i>	<i>Index</i>
China	Medium to large tree growing best on well drained soil in full sun. Flowers white in September only on mature trees.	<i>Sophora</i> spp. 10, 16
Chile	Evergreen shrub with compound leaves. Large rich yellow flowers.	
New Zealand, Chile	Large shrub, dense and wiry when young. Small yellow flowers.	
Europe ¹	Small to medium compact round tree, tolerant of acid sands, thin chalky soils and of paving over roots. Scarlet fruit. Brief autumn colour. Many cultivars available.	<i>Sorbus</i> spp. 9 – 11, 17, 37, 41, 43 – 44 <i>Sorbus aucuparia</i> 11, 36, 41 <i>Sorbus intermedia</i> 42 Hardy, medium to small trees, easily grown in any well-drained fertile soil.
Europe ¹	Small tree growing well on chalky soils or acid peats. Extremely hardy and resistant to exposure. Small erect crowns. Early scarlet fruit and good autumn colour in far north. Many cultivars available.	
N.W. Europe	Sturdy broad-domed tree, growing reasonably well on all but wet soils. Scarlet fruits. Cultivars available.	
Europe ¹ , Asia Minor, N. Africa	Grows to a large tree on most soils including chalk but prefers good, deep moist conditions. Fruit brown, good autumn colour.	
Western N. Africa	Shrubs growing well even in poor soils or shaded corners. Large marbled sized white fruits in autumn.	<i>Symphoricarpos</i> spp. 10
Europe ¹	Vigorous early growth with suckers. Thrives in hottest cities. Mature trees need space. Little autumn colour.	<i>Tilia</i> spp. 3, 10, 16, 35, 37 <i>Tilia cordata</i> 36 <i>Tilia phatyphyllos</i> 45 Large handsome trees, tolerant of heavy pruning and thus widely used for roadside planting. Will grow in all types of fertile soils and situations.
Occasionally occurs in wild with parents.	Large, vigorous tree, densely suckering.	
Central and southern Europe ² . Possibly native.	Large vigorous tree with rounded crown and very few suckers. Grows in cities and streets. Needs space. No autumn colour. Aphid and honeydew a problem.	

<i>Genus and family</i>	<i>Scientific names and synonyms</i>	<i>Common names</i>
ULEX Leguminosae— Pea family	<i>U. europaeus</i> L.	Common gorse
ULMUS Ulmaceae— Elm family	<i>U. glabra</i> Huds. <i>U. montana</i> With. <i>U. campestre</i> L. in part	Wych elm, Scotch elm.
VIBURNUM Caprifoliaceae— Honeysuckle family	<i>V. lantana</i> L.	Wayfaring tree
	<i>V. lentago</i> L.	Sheepberry, blackhaw
	<i>V. opulus</i> L.	Guelder rose, Water elder
	<i>V. trilobum</i> Marsh <i>V. opulus</i> L. var. <i>americanum</i> Ait.	American cranberry-bush
ZELKOVA Ulmaceae— Elm family	<i>Z. carpinifolia</i> (Pall.) K. L. Koch. <i>Z. crenata</i> Spach	Caucasian elm
	<i>Z. serrata</i> (Thunb.) Mak. <i>Z. acuminata</i> Planch.	Keaki

<i>Natural range</i>	<i>Recommended planting position and use</i>	<i>Index</i>
Western Europe ¹	Shrub growing almost anywhere and best in poor, dry, acid soils. Does not relish shallow chalky soils. Cultivars available.	<i>Ulex</i> spp. 10, 16
Europe ¹ , N. and W. Asia	Broadly domed spreading tree needing a lot of space. Needs damp but well-drained soils. Moderately tolerant of exposure and urban situations.	<i>Ulmus</i> spp. 9 – 11, 15
Europe ¹ and W. Asia	Large bush, growing well on chalky soils. Oblong black fruits.	<i>Viburnum</i> spp. 10 – 11, 17 <i>Viburnum opulus</i> 36 Easily cultivated shrubs with white flowers and attractive fruits.
Eastern N. America	Large, strong growing shrub with rich autumn colours. Fruits black-blue.	
Europe ¹ , N. and W. Asia, N. Asia	Large vigorous shrub showing rich autumn colours. Translucent red persistent fruits.	
Northern N. America	Large shrub, very similar to <i>V. opulus</i> .	
Caucasus, N. Iran	Initially slow growing with a dense upright ovoid-shaped crown. Russet in autumn. Suckers profusely.	<i>Zelkova</i> spp. 10, 16 Medium to large trees thriving in deep moist loamy soils; tolerant of shade.
Japan	Normal domed tree, thriving even in most polluted cities. May not like exposure or acid peats. Good autumn colour.	

APPENDIX 2

Height, seed bearing age and seed crop frequency of ornamental tree and shrub species.

<i>Species</i>	<i>Height at maturity (metres)</i>	<i>Minimum seed-bearing age (years)</i>	<i>Interval between large seed crops (years)</i>	<i>Data source</i>
ACER				
<i>campestre</i>	4.5 – 18	10	1	19, 20
<i>cappadocicum</i>	9 – 14	—	—	19
<i>palmatum</i>	6 – 10	—	—	19
<i>platanoides</i>	18 – 21	25 – 30	1 – 3	1, 19, 21
<i>pseudoplatanus</i>	18 – 30	25 – 30	1 – 3	1, 19, 21
<i>rubrum</i>	28 – 36	(4)*	(1)*	19, 21
<i>saccharinum</i>	27 – 36	(11)*	(1)*	19, 21
<i>saccharum</i>	30 – 36	(30)*	(3 – 7)*	19, 21
AESCULUS				
<i>hippocastanum</i>	30 – 38	20	1 – 2	1, 17, 18
<i>indica</i>	30	—	—	19
AILANTHUS altissima	26 – 30	(15 – 20)*	—	17, 19, 21
ALNUS				
<i>cordata</i>	up to 15 – 16	—	—	17
<i>glutinosa</i>	up to 26	15 – 20	2 – 3	1, 17
<i>incana</i>	up to 25	—	—	17
<i>rubra</i>	12 – 20	(under 10)	(4)*	17, 19, 21
AMELANCHIER laevis	up to 12	—	—	19
BERBERIS				
<i>darwinii</i>	up to 4	—	—	4
<i>julianae</i>	up to 3	—	—	4
<i>thunbergii</i>	up to 2.5	—	—	4
<i>vulgaris</i>	up to 2	—	—	4
BETULA				
<i>pendula</i>	12 – 18	15	1 – 3	1, 15, 19
<i>pubescens</i>	up to 21	15	1 – 3	1, 19, 27
CARPINUS				
<i>betulus</i>	up to 19	10 – 30	2 – 4	1, 19, 21
<i>caroliniana</i>	10 – 12	(15)*	(3 – 5)*	19, 21

Legend * – These data are based on North American experience and may not be completely applicable to British conditions.

<i>Species</i>	<i>Height at maturity (metres)</i>	<i>Minimum seed-bearing age (years)</i>	<i>Interval between large seed crops (years)</i>	<i>Data source</i>
<i>CARYA cordiformis</i>	15 – 30	(30)*	(3 – 5)*	19, 21
<i>CASTANEA sativa</i>	30	30 – 40	1 – 4	1, 19
<i>CELTIS occidentalis</i>	10 – 12	–	–	17, 19
<i>CERCIS canadensis</i>	4·5 – 9	(5)*	Fruits only after hot summers	10, 21
<i>siliquastrum</i>	6 – 12	–		4, 19, 21
<i>CHAENOMELES japonica</i>	1	–	–	4
<i>CORNUS alba</i>	3	–	–	4
<i>controversa</i>	9 – 15	–	–	
<i>drummondii</i>	3 – 9	–	–	10
<i>florida</i>	3 – 6	–	–	4
<i>kousa</i>	7	–	–	4
<i>mas</i>	14	–	–	19
<i>nuttallii</i>	7 – 16	–	–	4
<i>sanguinea</i>	2 – 4	–	–	4
<i>CORYLUS avellana</i>	4 – 6	–	2 – 3	19, 21
<i>COTONEASTER bullatus</i>	3 – 4	–	–	4
<i>franchetii</i>	2·5 – 3	–	–	4
<i>salicifolius</i>	up to 7·5	–	–	4
<i>CRATAEGUS crus-galli</i>	up to 7·5	–	–	19
<i>intricata</i>	1 – 4	–	–	4
<i>x media</i>	3 – 9	10	1 – 2	1, 10, 16
<i>mollis</i>	9 – 12	–	–	19
<i>monogyna</i>	up to 10·5	10	1 – 2	1, 19
<i>oxycantha</i>	4·5 – 6	10	1 – 2	1, 19
<i>pedicellata</i>	up to 9	–	–	10
<i>x prunifolia</i>	up to 6	–	–	19
<i>CYDONIA oblonga</i>	4·5 – 6	–	–	19
<i>CYTISUS scoparius</i>	1 – 2	3	1 – 2	1, 4, 12
<i>DAPHNE mezereum</i>	1 – 1·5	–	–	5

<i>Species</i>	<i>Height at maturity (metres)</i>	<i>Minimum seed-bearing age (years)</i>	<i>Interval between large seed crops (years)</i>	<i>Data source</i>
<i>DAVIDIA involucrata</i>	12 – 19	–	–	19
<i>ELAEAGNUS</i>				
<i>angustifolia</i>	up to 12	(3 – 5)*	(1)*	5, 19, 21
<i>commutata</i>	2 – 4	(1 – 2)*	–	5, 21
<i>umbellata</i>	1 – 5	–	–	5, 21
<i>EUCALYPTUS</i>				
<i>dalrympleana</i>	20 – 30	c. 10	–	25, 26
<i>gunnii</i>	20 – 30	5	1 – 2	25, 26
<i>niphophila</i>	10	c. 10	–	25, 26
<i>EUONYMUS europaeus</i>	3 – 7.5	15	2 – 4	1, 5, 17
<i>FAGUS sylvatica</i>	19 – 30	50 – 60	5 – 10	1, 19
<i>FRAXINUS</i>				
<i>angustifolia</i>	18 – 25	–	–	19
<i>excelsior</i>	30 – 42	25 – 30	3 – 5	1, 19
<i>ornus</i>	up to 20	(20)*	–	19, 20
<i>GLEDITSIA triacanthos</i>	up to 23	–	fruits only after hot seasons	17
<i>HAMAMELIS</i>				
<i>mollis</i>	3 – 4.5	–	1	10, 13
<i>virginiana</i>	6 – 9	–	1	5
<i>HIPPOPHAE rhamnoides</i>	1 – 3 Rarely to 12	–	1	5
<i>ILEX aquifolium</i>	up to 25	20	2 – 4	1, 19
<i>JUGLANS</i>				
<i>nigra</i>	25 – 30	–	–	19
<i>regia</i>	up to 30	–	fruits only form after hot summer	17, 19
<i>LABURNUM anagyroides</i>	up to 9	–	–	19
<i>LIQUIDAMBAR styraciflua</i>	up to 22	–	(3)*	5, 21

<i>Species</i>	<i>Height at maturity (metres)</i>	<i>Minimum seed-bearing age (years)</i>	<i>Interval between large seed crops (years)</i>	<i>Data source</i>
<i>LIRIODENDRON tulipifera</i>	up to 30	—	prolific only after hot summers	5, 17
<i>MAHONIA aquifolium</i>	0.5–2.5	—	1	5
<i>MALUS baccata</i>	6–15	—	(2–4)*	19, 21
<i>sylvestris</i>	up to 9	—	(2–4)*	19, 21
<i>MORUS alba</i>	up to 16	—	—	5, 17
<i>nigra</i>	up to 9	—	—	19
<i>NOTHOFAGUS alessandrii</i>	—	—	—	—
<i>antarctica</i>	3–12.5	—	viable seeds very infrequent	6, 24
<i>betuloides</i>	15	—	viable seeds very infrequent	6, 24
<i>cunninghamii</i>	7–16	—	—	6
<i>dombeyi</i>	12–21.5	—	viable seeds very infrequent	6, 24
<i>fusca</i>	8–21	—	—	6
<i>menziesii</i>	9–19	—	—	6
<i>nitida</i>	—	—	—	6
<i>obliqua</i>	up to 25	—	prolific only after hot summers	6, 24, 25
<i>procera</i>	up to 25	—	prolific only after hot summers	6, 24, 25
<i>pumilio</i>	—	—	—	—
<i>solandri</i>	11–17.5	—	—	—
<i>NYSSA aquatica</i>	4.5–9	—	—	10
<i>sylvatica</i>	14–24	—	irregular	6, 30
<i>OSTRYA carpinifolia</i>	15–18	—	—	19
<i>virginiana</i>	9–18	(25)*	—	19, 21
<i>PLATANUS orientalis</i>	up to 30	—	infrequent	6

<i>Species</i>	<i>Height at maturity (metres)</i>	<i>Minimum seed-bearing age (years)</i>	<i>Interval between large seed crops (years)</i>	<i>Data source</i>
PRUNUS				
<i>armeniaca</i>	6–9	—	infrequent	6
<i>avium</i>	up to 18	—	1–3	1, 19, 25
<i>cerasifera</i>	up to 9	—	never produces large crops	6, 19, 25
<i>cerasus</i>	10–15	—	1	21
<i>dulcis</i>	up to 9	—	infrequent	6, 19
<i>laurocerasus</i>	over 6	—	—	19
<i>lusitanica</i>	up to 6	—	—	19
<i>padus</i>	9–15	—	1–3	1, 6, 19
<i>persica</i>	up to 6	—	infrequent	6, 19
<i>sargentii</i>	grafted plants to 10	—	—	17
<i>serotina</i>	9–15	—	—	
<i>spinosa</i>	4·5–6	—	1–2	19, 25
<i>virginiana</i>	up to 4·5	—	never produces large crops	6, 19
PTEROCARYA fraxinifolia	up to 25	—	fruits form after hot summers	6, 17
PYRUS communis	up to 12	—	—	19
QUERCUS				
<i>cerris</i>	up to 40	—	—	19
<i>ilex</i>	up to 21–27	—	Fruit matures only in hot, dry seasons	6, 19
<i>palustris</i>	21–30	—	infrequent	6
<i>petraea</i>	up to 30	40–50	2–4	1, 19
<i>robur</i>	18–30	40–50	3–5	1, 6, 19
<i>rubra</i>	18–24	30–40	2–4	1, 6, 19
<i>suber</i>	up to 18	—	—	1, 6
RHAMNUS				
<i>cathartica</i>	1·5–6	—	—	6, 14
<i>frangula</i>	up to 5·5	—	—	6
ROBINIA pseudoacacia	up to 25	—	—	19
ROSA				
<i>canina</i>	0·5–3	—	—	3, 21
<i>rugosa</i>	1–2	—	—	3, 21
SAMBUCUS				
<i>glauca</i>	1·5–3	—	—	3
<i>nigra</i>	up to 10	—	1	19
<i>racemosa</i>	2·5–3·5	—	infrequent	3

<i>Species</i>	<i>Height at maturity (metres)</i>	<i>Minimum seed-bearing age (years)</i>	<i>Interval between large seed crops (years)</i>	<i>Data source</i>
SOPHORA				
<i>japonica</i>	15 – 24	30	fruit very rarely set	3, 17
<i>macrocarpa</i>	6 – 12	—	fruit occasionally set	3
<i>microphylla</i>	3 – 9	—	fruit occasionally set	3, 10
SORBUS				
<i>aria</i>	9 – 24	—	—	3, 19
<i>aucuparia</i>	9 – 18	10	2 – 3	1, 3
<i>intermedia</i>	6 – 12	—	—	3
<i>torrinalis</i>	9 – 21	—	—	3
SYMPHORICARPOS <i>rivularis</i>	up to 3	—	—	10
TILIA				
<i>cordata</i>	up to 30	20 – 30	2 – 3	1, 19
<i>x europaea</i>	up to 30	20 – 30	2 – 3	1, 3, 19
<i>platyphyllos</i>	up to 31	20 – 30	2 – 3	1, 17
ULEX <i>europaeus</i>	0.5 – 2	—	—	3
ULMUS <i>glabra</i>	up to 38	30 – 40	1 – 2	1, 17
VIBURNUM				
<i>lantana</i>	3.5 – 4.5	—	—	3
<i>lentago</i>	up to 6 – 9	(8)*	does not fruit freely	3, 21
<i>opulus</i>	6 – 9	(3 – 5)*	1	3, 21
<i>trilobum</i>	—		—	21
ZELKOVA				
<i>carpinifolia</i>	up to 35	—	uncommon in this country	17, 19
<i>serrata</i>	up to 20	—	—	19

APPENDIX 3

Phenology of flowering, seeding and collection information for ornamental tree and shrub species

<i>Species</i>	<i>Flowering habit</i>	<i>Flowering dates</i>	¹ <i>Seed collection/ dispersal dates</i>
ACER			
<i>campestre</i>	Monoecious	late Apr. – mid May	Oct. – Jan.
<i>cappadocicum</i>	Polygamous	mid – late May	Sept. – Nov.
<i>palmatum</i>	Polygamous	early April	Aug. – Nov.
<i>platanoides</i>	Monoecious	late Mar. – mid Apr.	Oct. – Feb.
<i>pseudoplatanus</i>	Monoecious	mid April	Sept. – Oct.
<i>rubrum</i>	Polygamous	late Mar. – early Apr.	Apr. – June
<i>saccharinum</i>	Polygamo-dioecious	March	Apr. – June
<i>saccharum</i>	Polygamous	Apr. – May	(Oct. – Dec.) ²
AESCULUS			
<i>hippocastanum</i>	Polygamous	Apr. – May	Sept. – Oct.
<i>indica</i>	Polygamous	June – July	–
AILANTHUS altissima	Dioecious (occasionally monoecious)	July	Sept. – Nov.
ALNUS			
<i>cordata</i>	Monoecious	Feb. – Apr.	Sept. – Jan.
<i>glutinosa</i>	Monoecious	early Mar. – late Apr.	Sept. – early spring
<i>incana</i>	Monoecious	late Feb. – May	Sept. – Dec.
<i>rubra</i>	Monoecious	April	Fall
AMELANCHIER laevis	Perfect	late Apr. – early May	July – Aug.
BERBERIS			
<i>darwinii</i>	Perfect	Apr. – May	Sept. onwards
<i>julianae</i>	Perfect	–	–
<i>thunbergii</i>	Perfect	(May – June) Germany	Sept. onwards
<i>vulgaris</i>	Perfect	May – June	Sept. onwards

Legend

1. Many of the seed collection and dispersal dates are based upon the authors' observations in Southern England.

2. These data are based on North American experience and may not be completely applicable in Britain.

3. Fruits take two seasons to mature.

The notes on seed collection are based mainly upon the authors observations and data source 21.

<i>Data source</i>	<i>Notes for seed collection</i>		
	<i>Collect from</i>	<i>Collect when/as soon as</i>	<i>Collect by</i>
2, 11, 17	trees	seeds brown	ladders, climbing
17, 20	"	"	"
19, 20	"	"	"
8, 17, 19	"	"	"
8, 19	"	"	"
19, 21, 30	"	"	"
19, 30	"	"	"
19, 21, 30	"	"	"
1, 8, 17, 19	ground	"	tree shaking
19, 20	"	"	"
4, 17, 19	trees	pericarp papery	stripping or flailing tree
4, 19	trees	strobiles start opening	ladders, climbing
1, 16, 17, 19	"	"	"
4, 17, 18, 19	"	"	"
4, 19	"	"	"
17, 19, 20	trees	as soon as fruits black	ladders, climbing
4	bushes	as soon as fruits ripe	hand, flailing bushes
4	"	"	"
4, 12	"	"	"
4, 14	"	"	"

<i>Species</i>	<i>Flowering habit</i>	<i>Flowering dates</i>	¹ <i>Seed collection/ dispersal dates</i>
<i>BETULA</i> <i>pendula</i> <i>pubescens</i>	Monoecious Monoecious	late Mar. – Apr. April	Aug. – winter Aug. – winter
<i>CARPINUS</i> <i>betulus</i> <i>caroliniana</i>	Monoecious Monoecious	March April	Nov. – spring October
<i>CARYA cordiformis</i>	Monoecious	late May – early June	late fall
<i>CASTANEA sativa</i>	Monoecious	late June – July	Oct. – November
<i>CELTIS occidentalis</i>	Polygamomonoecious	May	October
<i>CERCIS</i> <i>canadensis</i> <i>siliquastrum</i>	Perfect Perfect	May – June mid-May	– Sept. onwards
<i>CHAENOMELES japonica</i>	Perfect	Apr. – June	early winter
<i>CORNUS</i> <i>alba</i> <i>controversa</i> <i>drummondii</i> <i>florida</i> <i>kousa</i> <i>mas</i> <i>nuttallii</i> <i>sanguinea</i>	Perfect Perfect Perfect Perfect Perfect Perfect Perfect Perfect	June June – July – May May – June Feb. – Mar. May June	– October late fall (November) ² – September (Sept. – Oct.) ² –
<i>CORYLUS avellana</i>	Monoecious	Feb. – Apr.	October
<i>COTONEASTER</i> <i>bullatus</i> <i>franchettii</i> <i>salicifolius</i>	Perfect Perfect Perfect	– May –	Sept. onwards October fall

<i>Data source</i>	<i>Notes for seed collection</i>		
	<i>Collect from</i>	<i>Collect when/as soon as</i>	<i>Collect by</i>
1, 4, 19 1, 4, 19	trees, felled trees	strobiles still intact ,,	stripping strobiles ,,
1, 4, 17, 19 4, 19	trees ,,	fruits slightly green ,,	climbing, ladders, flailing trees ,,
4, 19	ground, trees	husks dry, (brown/black)	shaking, flailing trees
1, 4, 19	ground	involucre begins to split	tree shaking
4, 19, 30	tree	after leaves have fallen	hand or flailing
4, 10 10, 19	trees ,,	as soon as pods ripe ,,	hand or flailing ,,
4	bush	pomes turn or yellow	hand
21 4, 19 21 4, 21 4 4, 19, 21 4, 21 4, 18	ground, bushes ,, ,, ,, ,, ,, ,, ,,	as soon as fruit white ,, white ,, white ,, dark red ,, rose red ,, scarlet ,, orange ,, black	stripping, shaking from branches ,, ,, ,, ,, ,, ,, ,,
1, 8, 19	tree	involucre begins to turn brown	hand picking
4 4 4, 10	shrub ,, ,,	as soon as fruit bright red ,, orange scarlet ,, red	hand ,, ,,

<i>Species</i>	<i>Flowering habit</i>	<i>Flowering dates</i>	<i>¹Seed collection/ dispersal dates</i>
<i>CRATAEGUS</i>			
<i>crus-galli</i>	Perfect	late May – June	October onwards
<i>intricata</i>	Perfect	–	fall
<i>x media</i>	Perfect	May	Sept. – Nov.
<i>mollis</i>	Perfect	June	September
<i>monogyna</i>	Perfect	mid May	Sept. – Nov.
<i>oxycantha</i>	Perfect	May	Sept. – Nov.
<i>pedicellata</i>	Perfect	May – June	September
<i>x prunifolia</i>	Perfect	June	September
<i>CYDONIA oblonga</i>	Perfect	May	late fall
<i>CYTISUS scoparius</i>	Perfect	May	Sept. – Nov.
<i>DAPHNE mezereum</i>	Perfect	Feb. – Mar.	fall
<i>DAVIDIA involucrata</i>	Monoecious	late May	October
<i>ELAEAGNUS</i>			
<i>angustifolia</i>	Perfect	early June	October onwards
<i>commutata</i>	Perfect	May	September
<i>umbellata</i>	Perfect	May – June	(Sept. – Nov.) ²
<i>EUCALYPTUS</i>			
<i>dalrympleana</i>	Perfect	May – October	Any time
<i>gunnii</i>	Perfect	May – October	Any time
<i>niphophila</i>	Perfect	May – October	Any time
<i>EUONYMUS europaea</i>	Perfect (occasionally polygamous)	May – June	Sept. – Nov.
<i>FAGUS sylvatica</i>	Monoecious	May	Sept. – Nov.
<i>FRAXINUS</i>			
<i>angustifolia</i>	Polygamous	May	September
<i>excelsior</i>	Perfect, Imperfect or polygamous	April	Aug. – Jan. (see text)
<i>ornus</i>	Polygamous	May	late Sept. – Dec.
<i>GLEDITSIA triacanthos</i>	Monoecious or Polygamous	June	Sept. onwards

<i>Data source</i>	<i>Notes for seed collection</i>		
	<i>Collect from</i>	<i>Collect when/as soon as</i>	<i>Collect by</i>
4, 17, 19	tree	as soon as fruit red	hand picking
4	"	" reddish brown	"
1	"	" red	"
4, 19	"	when fruit is red	"
1, 4, 19	"	as soon as fruit red	"
1, 4, 19	"	" red	"
4, 19	"	" scarlet	"
4, 19	"	" red	"
4, 19	bushes	as soon as fruit golden yellow	hand picking
1, 4	shrub	before pods dehisce	hand, flailing
5, 8	bush	as soon as fruit scarlet	hand
5, 17, 19	tree	as soon as fruit reddish brown	hand
5, 19	tree	as soon as fruit silvery white	hand, flailing tree
5	"	" silver	"
5, 21	"	" red-pink	"
25	tree	capsules green/brown	hand picking
25	"	" greenish brown	"
25	"	" "	"
1, 8, 18	shrub	aril orange	hand, shaking tree
1, 5, 19	ground		hand, vacuum, shaking tree
5, 19	tree	fruit has turned brown	stripping clusters, shaking by hand
1, 17, 19	ground	"	"
5, 19, 21	"	"	"
5, 19, 30	tree ground	pods ripe red-brown	Shaking tree

<i>Species</i>	<i>Flowering habit</i>	<i>Flowering dates</i>	¹ <i>Seed collection/ dispersal dates</i>
<i>HAMAMELIS</i> <i>mollis</i> <i>virginiana</i>	Perfect Perfect	Dec. – Feb. Sept. – Nov.	Aug. – Sept. Aug. – Sept.
<i>HIPPOPHAE rhamnoides</i>	Dioecious	Mar. – Apr.	Sept. – Feb.
<i>ILEX aquifolium</i>	Dioecious (rarely polygamous)	May	Nov. – Feb.
<i>JUGLANS</i> <i>nigra</i> <i>regia</i>	Monoecious Monoecious	May – early June mid May – early June	October fall
<i>LABURNUM anagyroides</i>	Perfect	mid-May – early June	Sept. – Oct.
<i>LIQUIDAMBAR styraciflua</i>	Monoecious	May	(November) ²
<i>LIRIODENDRON tulipifera</i>	Perfect	mid-June	October onwards
<i>MAHONIA aquifolium</i>	Perfect	Feb. – May	August
<i>MALUS</i> <i>baccata</i> <i>sylvestris</i>	Perfect Perfect	Apr. – May late May	fall Sept. – Oct.
<i>MORUS</i> <i>alba</i> <i>nigra</i>	Dioecious and monoecious Dioecious and monoecious	May –	July – Aug. July – Aug.
<i>NOTHOFAGUS</i> <i>alessandrii</i> <i>antarctica</i> <i>betuloides</i> <i>cunninghamii</i> <i>dombeyi</i> <i>fusca</i> <i>menziesii</i> <i>nitida</i> <i>obliqua</i> <i>procera</i> <i>pumilio</i> <i>solandri</i>	– Monoecious Monoecious – Monoecious – – – – Monoecious Monoecious – –	– Apr. – May May – late May – – – – May May – –	– Sept. – Oct. Sept. – Oct. – Sept. – Oct. – – – – Aug. – Sept. Aug. – Sept. – –

<i>Data source</i>	<i>Notes for seed collection</i>		
	<i>Collect from</i>	<i>Collect when/as soon as</i>	<i>Collect by</i>
5, 15, 20	tree	before fruits split	hand
5, 15, 20	„	„	„
5	tree	fruits orange-yellow	hand
1, 8, 17	tree	fruits red	stripping, ladders
5, 19	ground	as soon as husk turns black	shaking tree
5, 17	„	„	„
17, 18	tree	Pods dry	hand, ladders
19, 21	tree	before fruits split open	hand, ladders
17, 21	tree, ground	fruits turn brown	picking, shaking
5	bush	fruits turn blue-black	stripping, hand
17, 19, 21	tree	fruits turn red or yellow	hand
17, 19, 21	ground	„ yellow-orange	shaking
5, 21	trees, ground	most fruits ripe	hand, flailing
17	„	„	„
19, 23	ground	first seed often empty, cupules begin	tree shaking, ladders, hand
23	„	to open	„
19	felled trees	„	„
	„	„	„
	„	„	„
	„	„	„
19, 25	„	„	„
19, 25	„	„	„
	„	„	„
	„	„	„

<i>Species</i>	<i>Flowering habit</i>	<i>Flowering dates</i>	¹ <i>Seed collection/ dispersal dates</i>
<i>NYSSA</i> <i>aquatica</i> <i>sylvatica</i>	— Polygamo-dioecious	— June	— October
<i>OSTRYA</i> <i>carpinifolia</i> <i>virginiana</i>	Monoecious Monoecious	April April	Sept. – Oct. fall
<i>PLATANUS orientalis</i>	Monoecious	May	—
<i>PRUNUS</i> <i>armeniaca</i> <i>avium</i> <i>cerasifera</i> <i>cerasus</i> <i>dulcis</i> <i>laurocerasus</i> <i>lusitanica</i> <i>padus</i> <i>persica</i> <i>sargentii</i> <i>serotina</i> <i>spinosa</i> <i>virginiana</i>	Perfect Perfect Perfect Perfect Perfect Perfect Perfect Perfect Perfect Perfect Perfect Perfect Perfect Perfect	March – early April early April – mid May early March mid-May Mar. – Apr. April June late May early April early – mid April May – June Mar. – early Apr. late May	July July Aug. – Sept. July Sept. – Oct. September October July – Aug. July – Aug. August September September (August) ²
<i>PTEROCARYA fraxinifolia</i>	Monoecious	late Apr. – May	fall
<i>PYRUS communis</i>	Perfect	late Apr. – early May	fall
<i>QUERCUS</i> <i>cerris</i> <i>ilex</i> <i>palustris</i> <i>petraea</i> <i>robur</i> <i>rubra</i> <i>suber</i>	Monoecious Monoecious Monoecious Monoecious Monoecious Monoecious Monoecious	May June early May May May May late May – early June	October ³ October fall ³ Sept. – Nov. Sept. – Nov. Sept. – Oct. October
<i>RHAMNUS</i> <i>cathartica</i> <i>frangula</i>	Dioecious Perfect	May – July May	October fall
<i>ROBINIA pseudoacacia</i>	Perfect	mid – late June	throughout winter

<i>Data source</i>	<i>Notes for seed collection</i>		
	<i>Collect from</i>	<i>Collect when/as soon as</i>	<i>Collect by</i>
19	ground tree, felled tree	fruits—dark purple, blue black ,,	hand, ladders ,,
19 29, 21	tree ,,	strobiles pale green-brown ,,	hand, ladders ,,
19, 21	tree	fruits turn brown, after leaf fall	hand, ladders
6	tree	as soon as fruit yellowish	hand stripping, tree shaking
6, 19	,,	,, yellowish-red	,,
6, 17, 19	,,	,, red	,,
17	,,	,, light-dark red	,,
6	,,	,, husk splits open	,,
19	,,	,, black	,,
19	,,	,, dark purple	,,
19	,,	,, black	,,
6	,,	,, yellow-red	,,
19	,,	,, —	,,
6, 19	,,	,, black	,,
19, 25	,,	,, blue-black	,,
19, 21	,,	,, purple	,,
	tree	fruits begin to turn brown	hand stripping
	tree, ground	fruits ripe (seed brown)	hand, ladders, shaking
19	ground	after first frost	laying tarpaulins, hand
6, 19	,,	,,	,,
6	,,	,,	,,
1, 19	,,	,,	,,
1, 19	,,	,,	,,
1, 19	,,	,,	,,
19	,,	,,	,,
7, 14	tree	2 weeks before fully ripe, ie fruit black	hand, ladders
14	,,	,,	,,
17	tree	before pods burst	hand, felling tree

<i>Species</i>	<i>Flowering habit</i>	<i>Flowering dates</i>	¹ <i>Seed collection/ dispersal dates</i>
<i>ROSA</i> <i>canina</i> <i>rugosa</i>	Perfect Perfect	June – July May throughout summer	October onwards fall (see text)
<i>SAMBUCUS</i> <i>glauca</i> <i>nigra</i> <i>racemosa</i>	Perfect Perfect Perfect	June June April	(Aug. – Oct.) ² Aug. – Sept. June – July
<i>SOPHORA</i> <i>japonica</i> <i>macrocarpa</i> <i>microphylla</i>	Perfect Perfect Perfect	Aug. – Sept. May –	– – –
<i>SORBUS</i> <i>aria</i> <i>aucuparia</i> <i>intermedia</i> <i>torminalis</i>	Perfect Perfect Perfect Perfect	late May May – June late May May – June	September July – Sept. September September
<i>SYMPHORICARPUS rivularis</i>	Perfect	June – July	October onwards
<i>TILIA</i> <i>cordata</i> <i>x europaea</i> <i>platyphyllos</i>	Perfect Perfect Perfect	early July early July late June	October October October
<i>ULEX europaeus</i>	Perfect	Apr. – May	May – July
<i>ULMUS glabra</i>	Perfect	early March	June – July
<i>VIBURNUM</i> <i>lantana</i> <i>lentago</i> <i>opulus</i> <i>trilobum</i>	Perfect Perfect Perfect plus sterile Perfect (plus sterile?)	May – June May – June early June – July –	July onwards – September onwards July onwards
<i>ZELKOVA</i> <i>carpinifolia</i> <i>serrata</i>	Monoecious Monoecious	April April – May	September September

<i>Data source</i>	<i>Notes for seed collection</i>		
	<i>Collect from</i>	<i>Collect when/as soon as</i>	<i>Collect by</i>
7, 21	bush	fruits turn red	hand
3, 21	„	„	„
3, 21	tree	fruits—blue black	stripping
19	„	black	cutting
3	„	scarlet	clusters
17	tree	before pods burst	hand
10	ground	„	flailing
	„	„	„
3, 17, 19, 21	tree	fruits turn crimson	stripping, cutting clusters
1, 7, 17, 19	„	„ bright red	„
19	„	„ orange red	„
7, 17, 19	„	„ brown	„
3, 21	shrub	fruits turn white	stripping clusters, flailing
1, 17	tree	bracts have turned brown after frosts	hand, ladders, tree shaking
1, 3, 17	„	„	„
17	ground	„	„
3, 17, 18	shrub	before pods burst	hand picking
1, 17, 21	tree	wing begins to turn brown	stripping, tree shaking
3, 7	bush	fruits turn black	hand, stripping
3	„	„ black	„
3, 7	„	„ red and soft	„
10	„	„ red	„
3, 19, 30	tree	green fruit	hand, ladders
3, 19, 30	„	seed mature	„

APPENDIX 4A

Seed Yield Data

Very limited data have been published on the quantity of cleaned seed that may be expected from a given quantity of fruit. The yields obtained will vary widely depending upon many factors as described in Chapter 3. The following table has been compiled mainly from the Forestry Commission's recent experience (data sources 25 & 26) but it also incorporates any figures available from data source 4.

The data are presented as ranges or sometimes, where taken from the literature, as a single figure. In the latter case the yield quoted should be regarded as an average for fruit with an average set of full seeds. It should be adjusted by at least 50% up or down if the seed set is above or below average. Where a range has been given, it represents the lowest and highest yields recorded, after empty seeds and inert matter have been removed. A figure intermediate between the highest and lowest should be used to estimate the yield for fruit with an average set of

full seeds. Estimates of yields should be adjusted according to the proportion of seeds in a sample that are filled. Some of the yields have been based on rather few seeds lots. The number of samples used have been given in parenthesis after the yield of cleaned seeds per kilogram. Data based on only a few samples should be used with some discretion, but have been included as a rough guideline by which would-be collectors can attempt to evaluate the cost effectiveness of their collections. No data are given for species where the fruit or seed collected is effectively the same as that marketed, eg *Acer* species, *Aesculus hippocastanum*, *Fagus sylvatica* etc. For these species the seed quality data should be used to give some idea of the yield of seeds per kilogram.

A suggested format for a record sheet that could be used from collection to processing is also given at Appendix 4b.

Species	Wt of 1 litre fruit (kg)	Yield of cleaned seed (g)	
		per 1 kg fruit	per 1 litre fruit
<i>Acer</i> spp.	SEE APPENDIX 6		
<i>Aesculus</i> spp.	SEE APPENDIX 6		
<i>Ailanthus altissima</i>		300 – 900	
<i>Alnus cordata</i>		c. 100 (1)	
<i>glutinosa</i>		30 – 260 (7)	14 – 100
<i>incana</i>	1.0 – 1.4	30 – 110 (3)	
<i>rubra</i>	0.4	c. 90 (1)	67
<i>Betula pendula</i>	0.07 – 0.20	410 – 650 (9)	
<i>pubescens</i>	0.37 – 0.49	c. 150	
<i>Carpinus betulus</i>	SEE APPENDIX 6		
<i>Castanea sativa</i>	SEE APPENDIX 6		
<i>Celtis occidentalis</i>		400 – 750	
<i>Cercis canadensis</i>		200 – 250	
<i>Cornus</i>			
<i>drummondii</i>		180 – 270	
<i>florida</i>		190 – 460	
<i>mas</i>		c. 150	
<i>nuttallii</i>	2.0	c. 121	244
<i>sanguinea</i>	0.75	172 – 317 (3)	184
<i>Corylus avellana</i>		600	2,016 – 2,383
<i>Cotoneaster bullatus</i>		81 (1)	
<i>Crataegus</i>			
<i>monogyna</i>	0.25 – 0.71	150 – 443 (11)	40 – 230
<i>oxycantha</i>		172 (1)	
<i>pedicellata</i>	0.5	123 (1)	64
x <i>prunifolia</i>	0.5	154 (1)	73

Species	Wt of 1 litre fruit (kg)	Yield of cleaned seed (g)	
		per 1 kg fruit	per 1 litre fruit
<i>Cytisus scoparius</i>	0.1	160 – 220 (4)	18
<i>Elaeagnus</i>			
<i>angustifolia</i>		150 – 600	
<i>umbellata</i>		50 – 100	
<i>Eucalyptus</i>			
<i>coccifera</i>	0.44 (1)	2 (1)	8 (1) (uncleaned seed)
<i>nitens</i>	—	8 (1)	— " "
<i>pauciflora</i>	0.43	72 (1)	31 (1) " "
<i>Euonymus europaea</i>	0.4	156 (1)	55
<i>Fagus sylvatica</i>	SEE APPENDIX 6		
<i>Fraxinus excelsior</i>	SEE APPENDIX 6		
<i>Gleditsia triacanthos</i>		200 – 350	
<i>Hippophae rhamnoides</i>		100 – 300	
<i>Ilex aquifolia</i>	0.5	220 (2)	104
<i>Juglans nigra</i>	—	300 – 650	—
<i>Laburnum anagyroides</i>	—	250	—
<i>Liquidambar styraciflua</i>	0.5	30	50
<i>Mahonia aquifolia</i>	2.1	80 (1)	185
<i>Malus baccata</i>	—	25	—
<i>Ostrya virginiana</i>	0.6	200	120
<i>Prunus avium</i>	0.35 – 1.1	100 – 530 (8)	90 – 460
<i>cerasifera</i>	—	100	—
<i>cerasus</i>	—	200	—
<i>lusitanica</i>	—	78	—
<i>padus</i>	0.70 – 1.1	190 – 220 (4)	100 – 400
<i>spinosa</i>	0.60 – 1.0	100 – 160 (5)	80 – 120
<i>Pyrus communis</i>	—	10 – 50	—
<i>Quercus</i> spp.	SEE APPENDIX 6		
<i>Rhamnus cathartica</i>	—	180 – 200	—
<i>frangula</i>	0.6	90 – 105 (1)	170
<i>Robinia pseudoacacia</i>	—	150 – 330	—
<i>Rosa canina</i>	—	200 – 320	—
<i>Sambucus nigra</i>	0.6	35 – 110 (6)	25 – 60
<i>racemosa</i>	—	30	—
<i>Sorbus aria</i>	0.6	26 – 30 (2)	—
<i>aucuparia</i>	0.30 – 0.90	7 – 80 (21)	5 – 60
<i>intermedia</i>	—	9 (2)	—
<i>torminalis</i>	0.35 – 0.55	25 – 65 (4)	15 – 25
<i>Tilia</i> spp.	SEE APPENDIX 6		
<i>Viburnum lantana</i>	30 – 40	390 – 645 (2)	160 – 183
<i>opulus</i>	52 – 88	60 – 82 (5)	30 – 70

Seed/Fruit Collection and Processing Sheet

<i>Location of collection</i>	<i>Grid reference</i>	<i>Species</i>
Details of site etc. <i>Details of collection</i> Initial assessment of quality % (cutting/TZ/germn.) date Number of trees		Identity or Lot Number
		Native/Introduced
		Origin if Introduced
		Unregistered or Registered
Method of collection: ground/hessian/climbing/ladder/shaking hyd.plat./scaffold		Conservancy notified 28 days before collection begins. Registered species only (date) Conservancy notified (Registered species only)
Quantities collected		
kg	Date	
kg	Date	
etc.		
Total quantity collected		

Date Condition on arrival

SEED PROCESSING**Remarks****Dry**

Initial cleaning/Not Date

Initial moisture content % Date

Weight after cleaning

Initial weight of sample 1 Date

„ „ „ „ 2 Date

„ „ „ „ 3 Date

1st day weight of sample 1 Date

„ „ „ „ „ 2 Date

„ „ „ „ „ 3 Date

2nd day weight of sample 1 Date

„ „ „ „ „ 2 Date

„ „ „ „ „ 3 Date

Desired weight of sample to reach % m.c.

Recleaning/Not Date

Final weight of bulk

(notified to Conservancy registered seed only)

Moisture content of recleaned seed % Date

Final purity % Final Germination/viability %

Final 1000 p.s.w. g Dates

Subsequent storage method Date

Subsequent treatments Dates

Wet

Volume/weight of fruits litres/kg

Initial cleaning/Not Date

Soaking regime (Dates)

Depulped (Date)

Seed dried/Not (Date)

Seed cleaned/Not (Date)

Final weight of seed kg

Final moisture content % (Date)

Final purity %

Final germination/viability

Final 1000 p.s.w. g

Storage method Date to store

Subsequent treatments Dates

APPENDIX 5

Storage recommendations based upon routine quality control test evidence and some trials made at Alice Holt

Note: All moisture contents quoted are on wet weight basis

<i>Orthodox</i>		<i>Recalcitrant</i>	
<i>Species</i>	<i>Recommended storage conditions</i>	<i>Species</i>	<i>Recommended storage conditions</i>
<i>Acer campestre</i> <i>platanoides</i>	Dry to at least 15% Dry to at least 15%	<i>Acer pseudoplatanus</i> <i>Aesculus hippocastanum</i>	Do not dry below 35% Do not dry below 45%
<i>Alnus cordata</i> <i>glutinosa</i> <i>incana</i> <i>rubra</i>	} Dry to below 10%		
<i>Berberis thunbergii</i>	Dry to below 12%		
<i>Betula pendula</i> <i>pubescens</i>	} Dry to below 10%		
<i>Carpinus betulus</i>	Dry to below 12%	<i>Castanea sativa</i>	Do not dry below 50%
<i>Cornus mas</i> <i>sanguinea</i>	} Dry to below 12%		
<i>Corylus avellana</i>	Dry to below 15%		
<i>Cotoneaster franchetii</i>	Dry to below 10%		
<i>Cytisus scoparius</i>	Dry to below 10%		
<i>Elaeagnus angustifolia</i>	Dry to below 15%		
<i>Fagus sylvatica</i>	Contradictory evidence (See Text page 22)		
<i>Fraxinus americana</i> <i>excelsior</i>	} Dry to below 12%		
<i>Gleditsia triacanthos</i>	Dry to below 12%		
<i>Hippophae rhamnoides</i>	Dry to below 12%		
<i>Ilex aquifolia</i>	Dry to below 12%		
<i>Juglans regia</i>	Dry to below 15%		
<i>Laburnum anagyroides</i>	Dry to below 10%		
<i>Liquidambar styraciflua</i>	Dry to below 10%		
<i>Liriodendron tulipifera</i>	Dry to below 10%		
<i>Mahonia aquifolia</i>	Dry to below 10%		
<i>Malus sylvestris</i>	Dry to below 10%		
<i>Nothofagus obliqua</i> <i>procera</i>	} Dry to below 10%		
<i>Prunus avium</i> <i>padus</i> <i>spinosa</i>	} Dry to about 12%		
		<i>Quercus cerris</i> <i>ilex</i> <i>palustris</i>	} Do not dry below 45%
		<i>Quercus petraea</i> <i>robur</i>	} Do not dry below 50%
		<i>Quercus rubra</i>	Do not dry below 45%

<i>Orthodox</i>		<i>Recalcitrant</i>	
<i>Species</i>	<i>Recommended storage conditions</i>	<i>Species</i>	<i>Recommended storage conditions</i>
<i>Rhamnus cathartica</i>	Dry to below 10%		
<i>Robinia pseudoacacia</i>	Dry to below 10%		
<i>Sambucus nigra</i>	} Dry to below 10%		
<i>racemosa</i>			
<i>Sorbus aria</i>	} Dry to below 12%		
<i>aucuparia</i>			
<i>intermedia</i>			
<i>torminalis</i>			
<i>Tilia cordata</i>	} Dry to below 15%		
<i>platyphyllos</i>			
<i>Viburnum lantana</i>	} Dry to below 15%		
<i>opulus</i>			

For the following species no conclusive evidence as to the conditions in which their seeds should be stored is available. From literature and from limited Forestry Commission evidence the species have been classified into Orthodox and Recalcitrant species. It is suggested that the former be stored dry (below 15%) at low temperatures and the latter at high moisture contents at low temperatures until the effect of desiccation be properly established.

<i>Orthodox</i>		<i>Recalcitrant</i>	
<i>Firm evidence from literature</i>	<i>Limited evidence from Forestry Commission and literature</i>	<i>Evidence</i>	<i>Limited evidence from Forestry Commission</i>
<i>Acacia</i> spp.	<i>Acer argutum</i>	<i>Acer saccharinum</i>	<i>Acer cappadocicum</i>
<i>Acer rubrum</i>	<i>Acer buergerianum</i>	<i>Pterocarya fraxinifolia</i>	<i>Acer sieboldianum</i>
<i>Acer saccharum</i>	<i>Acer crataegifolium</i>		
<i>Carya</i> spp.	<i>Acer forrestii</i>		
<i>Celtis occidentalis</i>	<i>Acer ginnala</i>		
<i>Eucalyptus</i> spp.	<i>Acer griseum</i>		
<i>Euonymus</i> spp.	<i>Acer grosseri</i>		
<i>Hamamelis</i> spp.	<i>Acer japonicum</i>		
<i>Morus</i> spp.	<i>Acer miyabei</i>		
<i>Platanus</i> spp.	<i>Acer mono</i>		
<i>Pyrus</i> spp.	<i>Acer rufinerve</i>		
<i>Rosa</i> spp.	<i>Acer spicatum</i>		
<i>Zelkova</i> spp.	<i>Ailanthus altissima</i>		
	<i>Chaenomeles japonica</i>		
	<i>Cydonia oblongata</i>		
	<i>Daphne mezereum</i>		
	<i>Davidia involucrata</i>		
	<i>Juglans nigra</i>		
	<i>Nothofagus</i> spp. (except <i>N. obliqua</i> and <i>N. procera</i>)		
	<i>Nyssa</i> spp.		
	<i>Ostrya</i> spp.		
	<i>Sophora</i> spp.		
	<i>Symphoricarpos rivularis</i>		
	<i>Ulex europaeus</i>		
	<i>Ulmus</i> spp.		

APPENDIX 6A

Seed quality data

The data in this table have been prepared from results of tests carried out by the Seed Laboratory of the Forestry Commission and from information published by Data sources 21 and 23. The data on germinable seeds per kg for *Eucalyptus* species have been obtained from Data source 21 and unpublished data from CSIRO, Canberra, Australia. Some of the data are based on very few test results but they have been included as an orientation figure. Where the range of a small number of viability or germination results is very wide no average has been given. The seed weight data and the viability and germination data are based on different numbers of test results; the respective sample numbers are given. Where viability and germination data are given, the sample

number refers to the viability data. The germination data are invariably based upon fewer samples.

Notes:

$$1. \text{ The percentage purity} = \frac{\text{Weight of pure seed}}{\text{Total weight of sample containing pure seed}} \times 100$$

$$2. \text{ The percentage viability} = \frac{\text{Number of viable seeds by Tetrazolium, Excised embryo or cutting tests}}{\text{Total number of pure seeds tested}} \times 100$$

Seed quality data

Species	Cleaned seeds per kg		Seed Weight Samples (Number)	Average Purity ¹ %	Average Viability ² %
	Range (Thousands)	Average (Thousands)			
ACER					
campestre	8.6 – 15.0	13.5	11	92	72
palmatum	21.0 – 43.0	29.0	3	92	50
platanoides	2.8 – 10.3	6.5	40	86	70
pseudoplatanus	5.4 – 15.8	9.4	40	90	60
rubrum	27.9 – 84.0	50.3	18	— ⁵	—
saccharinum	2.0 – 7.0	4.0	10	— ⁵	—
saccharum	7.0 – 20.0	15.5	19	— ⁵	—
AESCULUS					
hippocastanum	0.051 – 0.314	0.107	23	100	83
indica		0.0311	1	—	—
AILANTHUS altissima					
	29.3 – 43.3	36.7	6+	88	—
ALNUS					
cordata	358 – 509	412	4	85	—
glutinosa	582 – 1,406	767	93	81	—
incana	961 – 1,980	1,460	126	80	—
rubra	843 – 2,391	1,370	7	75	—
AMELANCHIER laevis					
	—	80.0	1	— ⁵	—

3. The percentage germination = $\frac{\text{Number of seeds which germinate under laboratory conditions after the appropriate pretreatment (if necessary)}}{\text{Total number of pure seeds tested}} \times 100$
4. The average number of germinable or viable seeds per kilogram seed as supplied = $\frac{\text{Average cleaned seeds per kg} \times \text{purity \%} \times \text{germination or viability \%}}{\text{}} \times 100$

This statistic has been compiled by combining data based upon different numbers of tests. It will therefore not be as accurate as it might have been. Where

viability and germination percentages are given for the same seed lot, the average number of viable seeds per kilogram is quoted and this is signified by a V after the calculated figure.

5. Where the average purity has not been available a figure of 90% has been assumed for the purity when calculating the average number of germinable or viable seeds per kilogram.

Recommended germination temperatures (Appendix 6b) and suggested formats for recording the quality of seed at all stages from collection to sowing (Appendix 6c) and for recording nursery germination and survival (Appendix 6d) are also given.

<i>Average Germination³ %</i>	<i>Samples (Number)</i>	<i>Average number of germinable (g) or viable (v) seeds per kg⁴</i>
54(v)	105	8,900 (v)
49	26	13,300 (v)
40	127	3,900 (v)
40	201	5,000 (v)
88	23	40,000 ⁵
95	7	3,400 ⁵
95	90	13,000 ⁵

Species	Cleaned seeds per kg		Seed Weight Samples (Number)	Average Purity ¹ %	Average Viability ² %
	Range (Thousands)	Average (Thousands)			
BERBERIS					
<i>darwinii</i>	—	—	—	—	—
<i>julianae</i>	58.0 – 68.0	62.4	5	95	—
<i>thunbergii</i>	54.0 – 81.0	62.3	6	— ⁵	72
<i>vulgaris</i>	74.8 – 90.2	83.6	2	93	91
BETULA					
<i>pendula</i>	1,200 – 2,900	1,900	55	30	—
<i>pubescens</i>	1,650 – 9,900	3,570	60	30	—
CARPINUS					
<i>betulus</i>	16.0 – 30.8	24.2	19	96	65
<i>caroliniana</i>	33.0 – 99.0	66.0	7	— ⁵	—
CARYA cordiformis	0.110 – 0.407	0.276	5	100	80
CASTANEA sativa	0.150 – 0.330*	0.239	10	100	65
CELTIS occidentalis	7.7 – 11.9	9.5	12	— ⁵	—
CERCIS					
<i>canadensis</i>	30.8 – 55.0	39.4	10	99	—
<i>siliquastrum</i>	—	45.0	—	99	—
CHAENOMELES japonica	34.0 – 56.0	45.0	2	—	—
CORNUS					
<i>alba</i>	28.0 – 41.0	33.0	3	80	81
<i>controversa</i>	—	—	—	—	—
<i>drummondii</i>	18.9 – 46.2	34.5	5	—	—
<i>florida</i>	7.3 – 13.6	9.9	12	100	—
<i>kousa</i>	14.3 – 18.3	20.5	4	— ⁵	58
<i>mas</i>	3.5 – 7.5	5.0	25	100	68
<i>nuttallii</i>	8.8 – 13.4	10.4	5	100	—
<i>sanguinea</i>	16.0 – 26.0	20.2	8	97	76
CORYLUS avellana	0.352 – 1.179	0.797	251	100	61
COTONEASTER					
<i>bullatus</i>	—	65.0	1	100	50
<i>franchettii</i>	136 – 161	150	3	99	48
<i>salicifolius</i>	—	—	—	—	—

*Note: Mediterranean sources tend to have seed at the very bottom of the range

<i>Average Germination³ %</i>	<i>Samples (Number)</i>	<i>Average number of germinable (g) or viable (v) seeds per kg⁴</i>
—	—	—
—	1	—
91	147	40,000 ⁵
	2	71,000 (v)
26	291	150,000
30	115	320,000
—	171	14,500
3	2	1,800 ⁵
55	3	2,200 (v)
67 – 93	5	176
47	7	4,000 ⁵
20 – 96	2	8 – 37,000
—	—	—
—	—	—
—	33	21,000
—	—	—
25	3	7,700 ⁵
35	7	3,500
	12	10,700 ⁵
57	120	3,400 (v)
51	4	5,300
—	70	15,000 (v)
70	109	480

Species	Cleaned seeds per kg		Seed Weight Samples (Number)	Average Purity ¹ %	Average Viability ² %
	Range (Thousands)	Average (Thousands)			
<i>CRATAEGUS</i>					
<i>crus-galli</i>	—	15·4	—	— ⁵	34
<i>intricata</i>	—	20·0	—	— ⁵	27
<i>x media</i>	11·5 — 15·0	13·7	4	98	55
<i>mollis</i>	—	—	—	—	47
<i>monogyna</i>	9·5 — 11·5	11·2	10	97	73
<i>oxycantha</i>	—	10·0	—	—	—
<i>pedicellata</i>	—	20·0	2	—	—
<i>x prunifolia</i>	—	13·0	1	99	6
<i>CYDONIA oblonga</i>	—	56·0	1	98	—
<i>CYTISUS scoparius</i>	91·0 — 177	127	16	99	—
<i>DAPHNE mezereum</i>	—	9·8	1	— ⁵	57
<i>DAVIDIA involucrata</i>	0·107 — 0·177	0·142	2	98	—
<i>ELAEAGNUS</i>					
<i>angustifolia</i>	7·4 — 15·4	11·5	17	100	69
<i>commutata</i>	8·1 — 10·1	8·4	5	—	—
<i>umbellata</i>	44·0 — 119	59·7	8	—	—
<i>EUCALYPTUS</i>					
<i>dalrympleana</i>	100 — 250	150	7	Not tested	Not tested
<i>gunnii</i>	300 — 800	500	> 10	„ „	„ „
<i>niphophila</i>	100 — 200	150	5	„ „	„ „
<i>EUONYMUS europaea</i>	18·7 — 35·2	29·0	34	83	80
<i>FAGUS sylvatica</i>	3·4 — 6·4	4·6	35	97	68
<i>FRAXINUS</i>					
<i>angustifolia</i>	13·0 — 14·5	13·8	3	91	65
<i>excelsior</i>	8·6 — 16·0	12·9	21	91	67
<i>ornus</i>	36·2 — 50·0	43·1	2	85	83
<i>GLEDITSIA triacanthos</i>	3·9 — 8·9	6·1	40	100	—
<i>HAMAMELIS</i>					
<i>mollis</i>	—	—	—	—	—
<i>virginiana</i>	18·0 — 23·2	20·6	4	98	—

<i>Average Germination³ %</i>	<i>Samples (Number)</i>	<i>Average number of germinable (g) or viable (v) seeds per kg⁴</i>
73	15	4,700 ⁵
—	30	4,800 ⁵
—	2	7,400
42 – 50	3	—
—	137	7,900
—	—	—
—	—	—
—	1	770
—	1	—
68	221	85,000
—	—	5,000 ⁵
—	1	—
60	44	7,900
93	1	4,500 ⁵
—	—	50,000 ⁵
—	—	19,000 ⁶
90	10	140 – 666,000 ⁶
70	< 5	—
71	195	19,000 (v)
60	195	3,000 (v)
64	3	8,200 (v)
61	67	7,800 (v)
49	1	30,000 (v)
80	3	4,900

Species	Cleaned seeds per kg		Seed Weight Samples (Number)	Average Purity ¹ %	Average Viability ² %
	Range (Thousands)	Average (Thousands)			
<i>HIPPOPHAE rhamnoides</i>	55.0 – 130	90.2	16	99	75
<i>ILEX aquifolium</i>	21.0 – 45.0	35.8	5	99	62
<i>JUGLANS nigra</i>	0.020 – 0.330	0.093	24	94	—
<i>regia</i>	0.030 – 0.197	0.100	16	100	84
<i>LABURNUM anagyroides</i>	33.0 – 39.6	37.6	15	100	—
<i>LIQUIDAMBAR styraciflua</i>	143 – 250	181	43	93	—
<i>LIRIODENDRON tulipifera</i>	9.4 – 76.0	43.3	15	88	8
<i>MAHONIA aquifolium</i>	83.6 – 116	103	6	99	69
<i>MALUS baccata</i>	48.4 – 187	136	6	81	78
<i>sylvestris</i>	42.0 – 80.0	61	2	99	74
<i>MORUS alba</i>	286 – 770	512	19	—	—
<i>nigra</i>	—	460	—	— ⁵	38
<i>NOTHOFAGUS alessandrii</i>	96 – 110	99	3	98	—
<i>antarctica</i>	190 – 364	284	5	50	—
<i>betuloides</i>		350	1	21	—
<i>cunninghamii</i>	136 – 493	371	3	46	—
<i>dombeyi</i>	284 – 291	289	3	46 – 92	—
<i>fusca</i>	110 – 200	155	2	95	—
<i>menziesii</i>	165 – 200	183	2	88	—
<i>nitida</i>	—	734	1	86	—
<i>obliqua</i>	54 – 143	116	32	90	—
<i>procera</i>	31 – 138	92.8	23	89	—
<i>pumilio</i>	34 – 45	39.5	2	95	—
<i>solandri</i>	166 – 193	180	2	99	—
<i>NYSSA aquatica</i>	—	1.0	—	— ⁵	—
<i>sylvatica</i>	4.1 – 10.1	7.8	6	— ⁵	—

<i>Average Germination³ %</i>	<i>Samples (Number)</i>	<i>Average number of germinable (g) or viable (v) seeds per kg⁴</i>
	100	67,000
80	22	22,000
53	16	46
80	6	84
82	87	31,000
85	14	143,000
—	32	3,000
—	199	70,000
—	1	86,000
54	92	45,000
—	—	—
—	10	157,000
2 – 19	4	
32	5	45,000
17	1	18,000
19	3	32,000
1 – 34	3	92,000
11	2	16,000
34	2	54,000
—	1	—
24	32	25,000
25	23	20,500
12	2	4,500
20	2	35,000
79	24	700 ⁵
71	8	5,000 ⁵

Species	Cleaned seeds per kg		Seed Weight Samples (Number)	Average Purity ¹ %	Average Viability ² %
	Range (Thousands)	Average (Thousands)			
OSTRYA					
<i>carpinifolia</i>	—	190	—	—	—
<i>virginiana</i>	55.0 – 77.0	66.0	6	— ⁵	—
PLATANUS orientalis	178 – 356	282	8	— ⁵	—
PRUNUS					
<i>armeniaca</i>	0.440 – 1.232	0.697	10+	— ⁵	—
<i>avium</i>	3.2 – 6.6	5.1	24	99	80
<i>cerusifera</i>	1.7 – 2.9	2.2	9	— ⁵	76
<i>cerasus</i>	3.3 – 8.8	6.4	6+	— ⁵	84
<i>dulcis</i>	0.270 – 0.495	0.398	3+	— ⁵	—
<i>laurocerasus</i>	—	—	—	—	—
<i>lusitanica</i>	—	—	—	—	—
<i>padus</i>	11.8 – 27.1	20.1	11	99	74
<i>persica</i>	0.158 – 0.537	0.343	6+	— ⁵	84
<i>sargentii</i>	—	—	—	—	—
<i>serotina</i>	6.2 – 13.3	9.3	68	— ⁵	64
<i>spinosa</i>	4.3 – 6.7	5.4	10	— ⁵	86
<i>virginiana</i>	6.6 – 18.5	11.0	20	— ⁵	—
PTEROCARYA fraxinifolia	—	14.0	—	—	—
PYRUS communis	26.4 – 52.8	31.5	18	— ⁵	—
QUERCUS					
<i>cerris</i>	0.132 – 0.350	0.245	11	99	78
<i>ilex</i>	0.364 – 0.500	0.435	3	100	—
<i>palustris</i>	0.700 – 1.800	1.087	7	94	50
<i>petraea</i>	0.130 – 0.649	0.316	23	100	86
<i>robur</i>	0.110 – 0.495	0.273	34	99	81
<i>rubra</i>	0.165 – 0.563	0.281	48	99	86
<i>suber</i>	0.110 – 0.360	0.188	15	100	—
RHAMNUS					
<i>cathartica</i>	28.6 – 70.0	48.5	8	98	75
<i>frangula</i>	40.0 – 70.4	57.6	11	— ⁵	67
ROBINIA pseudoacacia	35.2 – 78.0	53.6	9	98	—
ROSA					
<i>canina</i>	40.0 – 119	73.1	21	99	73
<i>rugosa</i>	65.0 – 163	114	3	99	79

<i>Average Germination³ %</i>	<i>Samples (Number)</i>	<i>Average number of germinable (g) or viable (v) seeds per kg⁴</i>
88	2	52,000 ⁵
38	8	96,000 ⁵
95	4	600 ⁵
77	355	4,000 (v)
58	88	1,500 ⁵ (v)
82	1	4,800 ⁵ (v)
90	—	320
—	—	—
—	68	14,700 (v)
82	36	260 ⁵ (v)
—	—	—
—	87	5,400 ⁵
84	91	4,200 ⁵ (v)
77	3	7,600 ⁵
—	—	—
94	2	27,000
33 – 76	3	190 (v)
94	1	400
—	3	510
79	10	270 (v)
81	25	220 (v)
82	11	240 (v)
86	5	160
—	19	35,600
—	43	34,700
70	6	36,800
47	657	53,000
79	60	89,000

Species	Cleaned seeds per kg		Seed Weight Samples (Number)	Average Purity ¹ %	Average Viability ² %
	Range (Thousands)	Average (Thousands)			
SAMBUCUS					
<i>glauca</i>	257 – 570	451	23	89	—
<i>nigra</i>	254 – 435	350	7	99	78
<i>racemosa</i>	345 – 463	387	3	97	72
SOPHORA					
<i>japonica</i>	—	—	—	—	—
<i>macrocarpa</i>	—	4.4	1	98	—
<i>microphylla</i>	11.7 – 14.0	12.7	4	99	—
SORBUS					
<i>aria</i>	36.0 – 73.0	53.2	9	89	65
<i>aucuparia</i>	200 – 432	290	43	96	88
<i>intermedia</i>	40.0 – 71.0	54.8	10	92	67
<i>torminalis</i>	28.0 – 56.0	45.3	4	86	78
SYMPHORICARPOS rivularis	85.8 – 143	122	5 +	—	—
TILIA					
<i>cordata</i>	23.0 – 38.3	30.1	71	94	78
<i>x europaea</i>	9.0 – 9.6	9.3	2	98	69
<i>platyphyllos</i>	7.5 – 11.0	8.8	16	97	76
ULEX europaeus	145 – 269	156	21	97	—
ULMUS glabra	66.0 – 105	89.3	13	95	—
VIBURNUM					
<i>lantana</i>	22.0 – 34.0	29.7	7	99	66
<i>lentago</i>	4.8 – 27.3	12.6	23	—	—
<i>opulus</i>	20.7 – 39.2	29.4	21	99	83
<i>trilobum</i>	20.7 – 39.2	29.0	4	— ⁵	—
ZELKOVA					
<i>carpinifolia</i>	—	—	—	—	—
<i>serrata</i>	—	93.0	—	—	—

<i>Average Germination³ %</i>	<i>Samples (Number)</i>	<i>Average number of germinable (g) or viable (v) seeds per kg⁴</i>
77	4	309,000
46	40	270,000 (v)
64	59	270,000 (v)
—	—	—
44	1	1,900
89	4	11,200
—	7	31,000
70	10	245,000
—	8	33,800
—	3	30,400
—	—	—
70	10	22,000
—	2	6,300
70	14	6,500
75	10	113,000
44	73 +	37,000
—	115	19,400
—	—	—
60	53	24,200
30	6	7,800
—	—	—
—	—	—

APPENDIX 6B

Recommended germination test temperatures

Extracted from the International Rules for Seed Testing, 1976, Seed Science and Technology 4, 1 – 177 and data source 21.

Notes:

1. The suggested temperature only applies after the proper seed treatment has been given.
2. For some species an alternative temperature regime is suggested which may give better results for a particular seed lot.
3. For some species different temperatures have been found to give better results at Alice Holt Lodge.

Alternating temperature:— 20°C for 16 hours and 30°C for 8 hours with light

Acacia spp^{1, 2}
 Aesculus hippocastanum²
 Ailanthus altissima
 Alnus spp
 Betula spp
 Caragana arborescens¹
 Carya spp¹
 Castanea sativa
 Celtis occidentalis¹
 Cercis spp¹
 Cornus spp¹
 Cotoneaster spp^{1, 2}
 Crataegus spp^{1, 2}
 Cytisus scoparius^{1, 3}
 Elaeagnus angustifolia¹
 Euonymus europaea¹
 Fraxinus spp¹
 Hamamelis spp¹
 Hippophae rhamnoides¹
 Juglans spp¹
 Laburnum spp^{1, 3}
 Liquidambar styraciflua
 Liriodendron tulipifera¹
 Morus spp

Nothofagus spp¹
 Nyssa spp¹
 Ostrya spp¹
 Platanus orientalis
 Pyrus communis¹
 Rhamnus spp¹
 Robinia pseudoacacia¹
 Sambucus spp¹
 Sorbus spp^{1, 2}
 Symphoricarpus rivularis¹
 Tilia spp¹
 Ulmus glabra²
 Viburnum spp¹

Alternating temperature:— 10°C for 16 hours and 30°C for 8 hours with light

Rosa multiflora¹ Zelkova serrata¹

Alternating temperature:— 15°C for 16 hours and 25°C for 8 hours with light

Carpinus betulus¹

Alternating temperature:— 10°C for 16 hours and 25°C for 8 hours with light

Berberis thunbergii¹ Cotoneaster spp^{1, 2}

Constant temperature:— 20°C for 24 hours, with 8 hours light.

Acacia spp ^{1, 2}	Gleditsia triacanthos ¹
Acer spp ¹	Laburnum spp ¹
Aesculus hippocastanum	Prunus spp
Carpinus betulus ^{1, 2}	Quercus spp
Corylus spp ¹	Rosa spp (except R. multiflora)
Crataegus spp ^{1, 2}	Sorbus spp ^{1, 2}
Cytisus scoparius ³	Spartium junceum ¹
Eucalyptus delegatensis	Ulex europaeus ¹
glaucescens	
niphophila	
nitens	

APPENDIX 6C

Sheet for Assessment of Seed Quality in the Nursery

Species

Identity or Seed Lot Number

When planning and just before collection

$$\frac{\text{Number of apparently normal seeds ()}}{\text{Number of seeds examined () eg 25 seeds per tree}} \times 100 = (\text{ }) \% \text{ full and viable seeds}$$

At any stage of processing

$$\frac{\text{Number of properly stained seeds ()}}{\text{Number of seeds examined () eg 100 seeds per stage}} \times 100 = (\text{ }) \% \text{ viable seeds}$$

After processing

$$\frac{\text{Original weight ()} - \text{Dry weight ()}}{\text{Original weight of sample ()}} \times 100 = (\text{ }) \% \text{ moisture content}$$

$$\frac{\text{Weight of pure seed from sample ()}}{\text{Weight of original sample ()}} \times 100 = (\text{ }) \% \text{ purity (P)}$$

$$\frac{\text{Weight () of pure seeds}}{\text{Number () of pure seeds}} \times 1000 = (\text{ }) \text{ 1000 pure seed weight}$$

$$\frac{\text{Number of normally germinating seeds ()}}{\text{Number of seeds set to germinate ()}} \times 100 = (\text{ }) \% \text{ germination (G)}$$

$$\frac{\text{Number of properly stained seeds ()}}{\text{Number of seeds examined ()}} \times 100 = (\text{ }) \% \text{ viability (V)}$$

Hence

$$\frac{1000 \times 1000 \times P \times G(V)}{(1000 \text{ p.s.w.})} = \text{Number of germinable or (viable) seeds/kg}$$

During storage and seed treatment

$$\frac{\text{Number of properly stained seeds ()}}{25 \text{ (seeds examined)}} = (\text{ }) \text{ Viability \% (V)}$$

IF V is less than 75% repeat with further 25 seeds
50% repeat with further 50 seeds
25% repeat with further 75 seeds

Hence

$$\frac{\text{Total number of properly stained seeds ()}}{\text{Total number of seeds examined ()}} = \text{Viability \%}$$

As seed treatment ends

This test is to be performed *either* on a sample set up for treatment under identical conditions 1 month before bulk treatment starts

or

from the bulk from four to one week before the scheduled treatment ends.

$$\frac{\text{Number (NG) of seeds germinating under stress conditions ()}}{\text{Number (N) of seeds set to germinate ()}} = \text{potential field germination}$$

Weight (W) of seed and medium containing N seeds () g

To calculate sowing density

W () g of seed and medium contain NG () germinable seeds

Hence

$$\text{there are } \frac{NG(\text{ })}{W(\text{ })} \times 1000 \text{ germinable seeds in 1 kg}$$

but

assuming only 200 seedlings are needed per square metre and germination survival factor is 60%

then

$$200 \text{ germinable seeds are contained in } \frac{200 \times W(\text{ })}{NG(\text{ }) \times 1000} \text{ kg seed and medium}$$

but

only 60% of germinable seedlings survive

therefore

$$\text{to produce 200 seedlings } \frac{200 \times W(\text{ }) \times 100}{NG(\text{ }) \times 1000 \times 60} \text{ kg must be sown in one square metre}$$

or

$$\text{allowing for 10\% culling } \frac{200 \times W(\text{ }) \times 110}{NG(\text{ }) \times 1000 \times 60} \text{ kg must be sown in one square metre.}$$

APPENDIX 6D

Nursery Record Sheet

To calculate germination survival factor (field factor), culling factor and seedling yields

(a) Species	(b) Identity or Lot No	(c) No. of viable seeds/kg at start of pretreatment	(d) No. of germ- inable seeds/kg at sowing	(e) Quantity sown (kg)	(f) No. of germ- inable seeds sown (d) × (e)	(g) No. of 1 + 0 seedlings produced

(h) Germination survival factor (g) – (f)	(i) No. of usable 1 + 0 seedlings produced	(j) Culling factor $\frac{(g - i)}{g}$	(k) No. of 1 + 0 seedlings stood over	(l) No. of 2 + 0 seedlings produced	(m) Overwinter survival factor $\frac{(k - l)}{k}$	(n) No. of usable 2 + 0 seedlings produced	(o) 2nd year culling factor $\frac{(l - m)}{l}$

APPENDIX 7

Recommended seed treatments before sowing

Notes: Some of the recommended treatments involve a range of weeks—for an explanation reference should be made to page 41 *et seq.* of Part 1.

In some specific recommendations, further details are given in Part 1 and the relevant page number is given.

For some species pre-sowing seed treatments may be very similar to conditions recommended for short term storage—(until the spring following harvest) by some authorities. These should not be confused with long term storage recommendations which are given in Appendix 5. For further explanation see p. 20.

The pretreatment medium ensures that the seed

remains both fully imbibed and suitably aerated throughout the pretreatment period.

'Compost' refers to a mixture of sieved peat and moist sand or a mixture of sieved peat and sieved soil. For some seeds moist sand alone is adequate while some seeds do not require a pretreatment medium at all and are pretreated 'naked' (See Chapter 7).

Most of the recommendations are based on work carried out at Alice Holt Lodge. Where possible this has been confirmed by consultation with experienced nursery managers. These are indicated by an asterisk. Other sources quoted are 13, 15, 21, 27, 28 and 29.

Species	General Remarks	Pre-treatment medium	Duration of Treatment	
			Warm (weeks)	Cold (weeks)
<i>ACER</i>				
<i>campestre</i> *	Spring sow after treatment.	compost	4	12 – 24
<i>cappadocicum</i> *	Spring sow after treatment.	compost	0	12 – 16
<i>palmatum</i> *	Fresh seed can be autumn sown immediately after collection. The seedbeds should be protected against frost as the seedlings will emerge in the early spring. Commercial samples will have developed a hard seed coat on being dried and will require treatment before spring sowing.	compost	0	0
<i>platanoides</i> *	Sow immediately after collection or store dry in cool store until the end of February, when pretreat before sowing. Commercial samples vary widely in pre-treatment requirements and germination is often erratic.	compost	4	4 – 12
<i>pseudoplatanus</i> *	Home collections as for <i>A. platanoides</i> except for storage, seed should only be surface dry. Treat commercial samples as indicated before spring sowing.	'naked'	0	12 – 16
<i>rubrum</i>	Sow immediately, although long term storage is possible.		0	6 – 12
	Canadian origins require 8 weeks chilling if sown in spring.		0	0
			0	8

Species	General Remarks	Pre-treatment medium	Duration of Treatment	
			Warm (weeks)	Cold (weeks)
<i>saccharinum</i>	Sow immediately as viability is transient.		0	0
<i>saccharum</i>	Spring sow after treatment.	'naked' or compost	0	6 – 12
AESCULUS*				
<i>hippocastanum*</i> <i>indica*</i> }	Sow immediately after collection or store moist in a cold place before spring sowing. See page 16. The viability of imported seed has often been reduced due to drying. Soak in warm water before sowing in spring.		0	0
<i>AILANTHUS altissima</i>	Spring sow after treatment or sow in late winter.	moist sand	0	8
ALNUS				
<i>cordata*</i> <i>glutinosa*</i> <i>incana*</i> <i>rubra*</i> }	Spring sow after pretreatment; the seeds can be mixed with moist fine sand to make sowing more easy.	'naked'	0	4
<i>AMELANCHIER laevis</i>	Macerate home-collected fruit as soon as possible and sow the extracted seeds immediately, without allowing them to dry out. Keep the seedbed well irrigated throughout the late summer and seedlings will emerge the following spring. Dried seed will need lengthy pretreatment before spring sowing.		0	0
		compost	4	16
BERBERIS				
<i>darwinii*</i> <i>julianae*</i> <i>thunbergii*</i> <i>vulgaris*</i> }	Spring sow after treatment.	compost	0	6 – 13
BETULA				
<i>pendula*</i> <i>pubescens*</i> }	As for <i>Alnus</i> spp.	'naked'	0	4
CARPINUS				
<i>betulus*</i>	Spring sow after treatment.	compost	4	12 – 14
<i>caroliniana</i>	Spring sow after treatment.	compost	8	8
<i>CARYA cordiformis</i>	Either autumn sow with untreated seed or spring sow after treatment.	'naked' or compost	0	13

Species	General Remarks	Pre-treatment medium	Duration of Treatment	
			Warm (weeks)	Cold (weeks)
<i>CASTANEA sativa</i> *	Autumn sow in October/November or store and spring sow in late March. Nuts should be stored cool and kept moist in peat by regularly sprinkling with water. Commercial samples which arrive dry should be soaked for 48 hours in cold water and then, if found to be viable, stored as described. See p. 21.			
<i>CELTIS occidentalis</i>	Spring sow after treatment.	compost	0	8 – 12
<i>CERCIS canadensis</i>	Both scarification and cold treatment are needed on most seed lots before adequate germination will occur.	compost	0	5 – 8 after scarification
<i>siliquastrum</i>	Sow immediately after collection or store dry and then scarify before spring sowing.		0	0
<i>CHAENOMELES japonica</i>	Sow immediately after collection or spring sow after treatment.	compost	2	8 – 16
<i>CORNUS</i>	For most species, best results are obtained when freshly collected and cleaned stones are autumn sown. However, this practice is limited to the few species which will produce seed in the UK. Dry stones require pretreating:			
<i>alba</i>	Spring sow after treatment.	compost	0	12 – 14
<i>controversa</i>	Spring sow after treatment.	compost	8 – 12	8 – 12
<i>drummondii</i>	Spring sow after treatment.	compost	4 – 8	4 – 8
<i>florida</i>	Spring sow after treatment.	compost	0	12 – 14
<i>kousa</i>	Spring sow after treatment.	compost	0	6 – 14
<i>mas</i> *	Spring sow after warm and cold treatments or sow in late November after warm treatment only.	compost	16	4 – 16
<i>nuttallii</i>	Spring sow after treatment.	compost	0	12 – 14
<i>sanguinea</i> *	Spring sow after treatment.	compost	8	8 – 12
<i>CORYLUS avellana</i> *	Autumn sow home-collected nuts in protected beds immediately after cleaning. Commercial seed samples will also germinate most successfully if autumn sown after soaking in cold water for 2 days. May be stored dry, (see p. 21) but spring sowing after treatment is less successful, due to difficulty in drying seed properly.	compost	0	12 – 16

Species	General Remarks	Pre-treatment medium	Duration of Treatment	
			Warm (weeks)	Cold (weeks)
<i>COTONEASTER</i>				
<i>bullatus</i> <i>franchetii</i> <i>salicifolius</i> }	Spring sow after treatment.	compost	12	12
<i>CRATAEGUS</i>				
	All <i>Crataegus</i> species require lengthy pretreatment before spring sowing:—			
<i>crus-galli</i>		compost	12 – 16	16
<i>intricata</i>		compost	8	16 – 24
<i>x media</i>		compost	4 – 8	12 – 16
<i>mollis</i>		compost	4	16 – 24
<i>monogyna</i> *		compost	4 – 8	12 – 16
<i>oxycantha</i> *		compost	4 – 8	12 – 16
<i>pedicellata</i>		compost	8	16 – 24
<i>x prunifolia</i>		compost	12 – 16	16
<i>CYDONIA oblongata</i>	Sow immediately after collection or spring sow after treatment.	compost	2 – 4	16
<i>CYTISUS scoparius</i> *	Store dry until required then treat with boiling water, concentrated sulphuric acid, or mechanically scarify the seed. Sow end March or early April.		0	0
<i>DAPHNE mezereum</i>				
	Collect fruits as soon as they begin to turn colour, extract the seed and sow immediately. Alternatively, spring sow after treatment.			
	The hard seed coat condition associated with dried seed, can be overcome using a concentrated sulphuric acid soak or a protracted warm treatment.	compost	8 – 12	14
<i>DAVIDIA involucrata</i>	Each 'nut' usually contains 3 – 5 embryos. These embryos exhibit epicotyl dormancy. Mix the cleaned nuts with damp compost in June/July and store, undisturbed, in wooden or earthenware containers. Ensure that the compost remains moist and after 12 – 20 weeks the nuts will have split and radicles will have emerged. The chitted nuts can then be autumn sown.	compost	12 – 20	Autumn sow
	Alternatively, the nuts can be sown and treated in flats in June/July and the seedlings transplanted in the spring.	compost	12 – 20	12 – 16

Species	General Remarks	Pre-treatment medium	Duration of Treatment	
			Warm (weeks)	Cold (weeks)
<i>ELAEAGNUS</i>				
<i>angustifolia</i> *	Autumn sow or spring sow after treatment. Some seed lots benefit from a 30 – 60 minute sulphuric acid soak.	compost	0 – 4	8 – 12
<i>commutata</i>	Autumn sow.		0	0
<i>umbellata</i>	Autumn sow or spring sow after treatment.	compost	0	8 – 12
<i>EUCALYPTUS</i> spp				
	Sow in spring after dry storage except following which benefit from cold treatment			
<i>delegatensis</i>		'naked'	0	4
<i>glaucescens</i>		'naked'	0	4
<i>niphophila</i>		'naked'	0	4
<i>nitens</i>		'naked'	0	4
<i>EUONYMUS europaeus</i>	Sow in March after treatment	compost	8 – 12	8 – 16
<i>FAGUS sylvatica</i> *	Autumn sowing is satisfactory if the soil is free draining, the site is not prone to spring frosts and the seed can be protected from predators. Seeds sown in spring require treatment, but this depends upon their method of storage (see page 22) and upon the seed lot. Gradually raise the moisture content to about 30%, (soaking, sprinkling, mixing with moist compost). Cold treat for required time. For long term stored seed this should be determined by small trial beforehand. For seed stored moist from autumn, aim to cold treat for 12 weeks; prolong if no chitting then evident; curtail if chitting begins early. Sow when radicles appear but be prepared to protect against late frosts, particularly when seedlings in vulnerable 'crook' stage.	'naked'	0	4 – 20
<i>FRAXINUS</i>				
<i>angustifolia</i> *	The seed is not dormant but germination is more uniform if the seed is treated before spring sowing.	compost	0	2 – 4
<i>excelsior</i> *	Collect seeds when green in August to early September and sow immediately. Spring sown seed must be pretreated and can give more complete germination.	compost	8 – 12	8 – 12
<i>ornus</i>	Autumn sow, or spring sow after treatment.	compost	2 – 4	12
<i>GLEDITSIA</i>				
<i>triacanthos</i> *	As for <i>Cytisus scoparius</i> .		0	0

Species	General Remarks	Pre-treatment medium	Duration of Treatment	
			Warm (weeks)	Cold (weeks)
<i>HAMAMELIS</i>				
<i>mollis</i> } <i>virginiana</i> }	Satisfactory methods for overcoming dormancy have not been found. Early collection and immediate sowing may be more successful than spring sowing treated seed.	compost	8	16 – 24
<i>HIPPOPHAE</i>				
<i>rhamnoides*</i>	Spring sow after treatment.	moist sand	0	12
<i>ILEX aquifolium</i>	Satisfactory methods for overcoming dormancy have not been found. An extremely protracted warm treatment followed by a long prechill has been suggested as a possible pre-treatment for spring sown seed.	compost	40	24
<i>JUGLANS</i>				
<i>nigra</i>	Remove seeds from their husks and store dry until ready to pretreat or store in cold moist conditions (stratification pit) until sown. After treating, station sow the seeds in the spring and cover with 25 – 50 mm of soil.	moist sand, compost	0	12 – 20
<i>regia</i>	As for <i>J. nigra</i> . See pp 16 & 21			
<i>LABURNUM</i>				
<i>anagyroides</i>	As for <i>Cytisus scoparius</i> .		0	0
<i>LIQUIDAMBAR</i>				
<i>styraciflua</i>	Spring sow after treatment. Some seed lots show almost no dormancy.	'naked'	0	4 – 12
<i>LIRIODENDRON</i>				
<i>tulipifera</i>	Spring sow after treatment.	'naked'	0	7 – 20
<i>MAHONIA</i>				
<i>aquifolium</i>	As for <i>Berberis</i> spp.	compost	0	6 – 13
<i>MALUS</i>				
<i>baccata</i> } <i>sylvestris</i> }	Extract seed from the fruit and sow immediately after collection or dry the seed and store before pretreating for spring sowing. The seed must be ready for sowing before mid-April to avoid inducing secondary dormancy, from high seedbed temperatures.	compost	2	12 – 16
<i>MORUS</i>				
<i>alba</i> } <i>nigra</i> }	Spring sow after treatment.	'naked'	0	4 – 12

Species	General Remarks	Pre-treatment medium	Duration of Treatment	
			Warm (weeks)	Cold (weeks)
<i>NOTHOFAGUS</i>				
	For most species prechilling for quite lengthy periods is beneficial. Where prechilling is effective a soak in 50 ppm GA _{4/7} solution for 12 – 24 hours also enhances germination, sometimes more sometimes less than prechilling but always more than no prechilling, probably due to different levels of dormancy between seed lots. (See Figure 5) After both methods seeds may be surface dried before sowing.			
<i>alessandrii</i> *	Prechilling and GA _{4/7} beneficial.	'naked'	0	4
<i>antarctica</i> *	Prechilling and GA _{4/7} beneficial.	'naked'	0	4
<i>betuloides</i> *	Prechilling and GA _{4/7} beneficial.	'naked'	0	4
<i>cliffortiodes</i> *	Prechilling reported to be beneficial.	'naked'	0	9
<i>cunninghamii</i> *	Prechilling not beneficial.	'naked'	0	0
<i>dombeyi</i> *	Prechilling and GA _{4/7} beneficial.	'naked'	0	4 or more
<i>fusca</i>	Prechilling reported to be necessary.	sand	0	9
<i>menziesii</i>	Prechilling reported to be necessary.			
<i>nitida</i>	Prechill probably beneficial.	'naked'		4 or more
<i>obliqua</i> *	Prechilling and GA _{4/7} beneficial.	'naked'	0	6
<i>procera</i> *	Prechilling and GA _{4/7} beneficial.	'naked'	0	6
<i>pumilio</i> *	Seed usually mouldy and suffers prechill damage. 0.02% Thiram soak before prechill improves response.	'naked'	0	4
<i>solandri</i> *	Prechilling and GA _{4/7} beneficial.	'naked'	0	6 or more
<i>NYSSA</i>				
<i>aquatica</i> } <i>sylvatica</i> }	Spring sow after treatment.	moist sand	0	4 – 16
<i>OSTRYA</i>				
<i>carpinifolia</i> } <i>virginiana</i> }	Spring sow after treatment.	compost	8	16 – 20
<i>PLANTANUS</i>				
<i>orientalis</i>	Spring sow.		0	0
<i>PRUNUS</i>				
	It is desirable to clean the seeds of all pulp and juice as soon after collection as possible. A short warm period before cold treatment can have dramatic effect. (See Figure 4). All treated seed must be sown before mid-April in south to avoid the induction of secondary dormancy, due to high seedbed temperatures.			
<i>armeniaca</i>		compost	2	11 – 18
<i>avium</i> *		compost	2	18
<i>cerasifera</i>		compost	2	18

Species	General Remarks	Pre-treatment medium	Duration of Treatment	
			Warm (weeks)	Cold (weeks)
<i>dulcis</i>		compost	0	9
<i>laurocerasus</i>		compost	0	9
<i>lusitanica</i>		compost	0	9
<i>padus*</i>		compost	2 – 4	18
<i>persica</i>		compost	2	18
<i>sargentii</i>		compost	2 – 4	18
<i>serotina</i>		compost	2 – 4	18
<i>spinosa*</i>		compost	2	18
<i>virginiana</i>		compost	2	18
PTEROCARYA				
<i>fraxinifolia</i>	Sow immediately after collection. Commercial seed samples may have deteriorated due to drying. Soak immediately and sow after prechilling.	moist sand	0	0
			0	8 – 12
<i>PYRUS communis</i>	As for <i>Malus</i> spp.	compost	2	10 – 12
QUERCUS				
	May be sown in the autumn if soil well drained and seeds can be protected against predation. Cover with 75 – 100 mm extra soil and remove this in March. Alternatively spring sow the acorns after cold storage. See p. 16. Some species require a minimum prechilling period before they can germinate.			
<i>cerris*</i>			0	0
<i>ilex*</i>		moist peat	0	4
<i>palustris*</i>		moist peat	0	8
<i>petraea*</i>			0	0
<i>robur*</i>			0	0
<i>rubra*</i>		moist peat	0	4 – 8
<i>suber</i>			0	0
RHAMNUS				
<i>cathartica</i>	Spring sow after treatment.	moist sand	0	2 – 4
<i>frangula</i>	Spring sow after treatment.	moist sand	0	8
ROBINIA				
<i>pseudoacacia*</i>	As for <i>Cytisus scoparius</i>		0	0
ROSA				
<i>canina</i>	Spring sow after treatment.	compost	8	8 – 12
<i>rugosa</i>	Spring sow after treatment. See p. 46 for method using acid.	compost	0	12 – 16

Species	General Remarks	Pre-treatment medium	Duration of Treatment	
			Warm (weeks)	Cold (weeks)
SAMBUCUS				
<i>glauca</i>	Spring sow after treatment.	compost	0	16
<i>nigra*</i> <i>racemosa*</i> }	Spring sow after treatment. (See Figure 6)	compost	10	12
SOPHORA				
<i>japonica*</i> <i>macrocarpa*</i> <i>microphylla*</i> }	Spring sow after chipping and soaking the seeds.		0	0
SORBUS				
<i>aria*</i> <i>aucuparia*</i> <i>intermedia*</i> <i>torminalis*</i> }	As for <i>Malus</i> spp.	compost	2	14 – 16
SYMPHORICARPUS				
<i>rivularis</i>	Autumn sow after a warm treatment only. Alternatively spring sow after giving an additional period of cold treatment.	compost compost	12 – 16 12 – 16	Autumn sow 18 – 26
TILIA				
<i>cordata*</i>	Collect as the fruit changes colour from green to buff and sow immediately. Dried seeds should be spring sown after treatments which overcome the hard seed-coat condition and the embryo dormancy (See p. 44 – 45).	compost	4 – 20	16 – 20
<i>x europaea*</i> <i>platyphyllos*</i> }		compost	4 – 20	20 – 24
<i>ULEX europaeus*</i>	As for <i>Cytisus scoparius</i> .		0	0
<i>ULMUS glabra*</i>	Collect seed in June prior to natural dispersal. Sow immediately after collection, the same day if possible or store dry. Water seed after sowing and before covering to prevent seed jumping. Keep seed-beds well irrigated.		0	0
VIBURNUM				
<i>lantana*</i> <i>lentago</i> <i>opulus*</i> <i>trilobum</i> }	Satisfactory methods for overcoming dormancy have not been found. Suggested treatment is to collect fruit before fully ripe then extract and sow seeds immediately.		Summer sow	
ZELKOVA				
<i>carpinifolia</i> <i>serrata</i> }	Sow immediately after collection in September or store dry. Commercial samples will also have been dried and should be spring sown after treatment.	'naked'	0	2 – 6

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